People’s Republic of China: Construction and Demolition Waste Management and Recycling

Prepared by AECOM Asia Company Limited for the PRC Ministry of Housing and Urban-Rural Development and the Asian Development Bank

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Construction and Demolition Waste Management and Recycling

Output 1: Assessment on CDW Management and Recycling in the PRC
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# Table of Content

1 Synthesis .......................................................................................................................... 1

1.1 Background of Technical Assistance Study ..................................................................... 1
1.2 Methodology ..................................................................................................................... 1
1.3 Waste Types and Quantities ............................................................................................ 1
1.4 Laws and Regulations ...................................................................................................... 1
1.5 CDW Management and Recycling Authorities ............................................................... 2
1.6 Stakeholder Analysis ......................................................................................................... 2
1.7 Economic Analysis of the PRC CDW Recycling Market Failure ..................................... 5
1.8 Current Status of Urban Construction Waste Utilization and Management in the PRC ......................... 6

2 Background of the Technical Assistance ............................................................................. 12

2.1 Definition and Classification of CDW in the PRC ............................................................ 12
2.2 CDW Amount in the PRC ............................................................................................... 14
2.3 Current Status of CDW Utilization .................................................................................. 17

3 CDW Management and Recycling Assessment .................................................................. 19

3.1 National and Local Legislation Framework ...................................................................... 19
3.2 Government departments involved in CDW management and utilization ....................... 25
3.3 Stakeholder Analysis ....................................................................................................... 28
3.4 Analysis of Obstacles to Market Promotion of CDW Recycling in the PRC ..................... 33

4 Economic Analysis of the PRC CDW Recycling Market Failure ......................................... 37

4.1 Methods of Economic Analysis ....................................................................................... 37
4.2 Whole Industrial Chain Cost Elements of Construction Waste Recycling Technology .......... 37
4.3 Cost Calculation and Comparative Analysis of Construction Waste Recycling Technology and Landfill Technology .................................................................................................................. 40
4.4 Benefit Analysis of Construction Waste Recycling Technology ......................................... 44

5 Comparison of Performance Criteria between Recycled CDW Products and Conventional Construction Materials ......................................................................................................................... 49

5.1 Types and Technical Requirements of Recycled CDW Products ....................................... 49
5.2 Conventional Construction Material Products Types and Technical Performance Criteria .... 60
5.3 Comparison Analysis ....................................................................................................... 63

6 Current Status of Urban Construction Waste Utilization and Management in the PRC ..................... 64

6.1 Selection of Typical Cities ............................................................................................... 64
6.2 Shenzhen ......................................................................................................................... 64
6.3 Xi’an ............................................................................................................................... 69
6.4 Xuchang ......................................................................................................................... 73
6.5 Wujin District, Changzhou City ...................................................................................... 78
6.6 Beijing ........................................................................................................................... 83
6.7 Comparison of Case Study Cities.................................................................................... 85

Appendix 1 CDW Generation Estimation Methods ..................................................................... 89
Appendix 2 Summary of National Laws, Regulations and Legislation Framework of CDW Management ..................................................................................................................................................... 95
Appendix 4 Existing CDW Recycling Standards in the PRC .................................................. 102
Appendix 5 List of Stakeholders Consulted ............................................................................ 106
References ............................................................................................................................ 118
Abbreviations

ADB  Asian Development Bank
CAUES  Chinese Association of Urban Environmental Sanitation
CCP  Chinese Communist Party
CDW  Construction and Demolition Waste
CNY  China Yuan (also known as Renminbi)
EIA  Environment Impact Assessment
MIIT  Ministry of Industry and Information Technology
MEP  Ministry of Environmental Protection
MOST  Ministry of Science and Technology
MOF  Ministry of Finance
MOHURD  Ministry of Housing, Urban and Rural Development
NDRC  National Development and Reform Commission
PRC  the People’s Republic of China
SAT  State Administration of Taxation
TA  Technical Assistance
1 Synthesis

1.1 Background of Technical Assistance Study

The Government of the People’s Republic of China (the PRC) has requested policy and advisory technical assistance (TA) from the Asian Development Bank (ADB) to enhance the PRC’s policies and practices related to the management and recycling of construction and demolition waste (CDW).

The impact of the TA will be improved CDW management policies and practices in the PRC, and the outcome will be an agreed set of policy recommendations to regulate CDW management and promote CDW recycling.

1.1.1 Scope of Technical Assistance Study

The scope of the study comprises:

- An assessment of CDW management in the PRC. This will be carried out through literature review, questionnaire surveys, and case studies of CDW recycling success stories in the PRC cities, the policies and current practices of CDW management at construction and/or demolition sites, the perceptions in relation to recycled and conventional construction materials, and the barriers to increased application of recycled materials. The assessment will include an economic analysis to identify the probability of a CDW market failure in the PRC.

- A review of international good practice in CDW management and recycling. This will include in-depth case studies to be conducted in selected advanced economies with high CDW recycling rates, as well as a study tour to one of these countries. The international good practice report will document hindering and enabling factors for sustainable CDW management and recycling.

- Development of a set of policy recommendations for the regulation of CDW management and the promotion of CDW recycling in the PRC (including cost–benefit analysis). This will consist of
  i. policy recommendations to regulate CDW supply, including technical guidelines for CDW segregation and processing, and capacity-building needs to improve CDW management at construction or demolition sites; and
  ii. a set of policy instruments to promote demand for, and increase uptake of, recycled CDW in the construction industry. The policy recommendations will be identified and formulated in consultation with relevant ministries and professional associations. A cost–benefit analysis will quantify how much the implementation of these recommendations could benefit the PRC.

- Preparation of a synthesis report, which will be prepared which will summarise and present the outputs of this TA.

1.1.2 Purpose of This Report

This report analyses the current CDW management practices in the PRC and identifies the main obstacles to improvement. It also includes a number of case studies which reflect current best-practice CDW management within the PRC.

1.2 Methodology

This report studies the CDW management policies and current status in the PRC through literature review, questionnaire survey and interviews with key stakeholders, and case studies of five Chinese cities that have made significant improvement in CDW management and recycling; and analyzes the obstacles to application of recycled building materials and the feasibility of market-based solutions for incentivising CDW recycling.

1.3 Waste Types and Quantities

This study focuses on the types of CDW which are the responsibility of Ministry of Housing, Urban and Rural Development (MOHURD), and therefore does not include wastes from road, hydraulic and hydropower structures, railways and tunnels. The main types of CDW are:

- Waste from excavation
Waste from demolition of old buildings
- Waste from construction sites, and
- Waste from building fit-out and decoration.

The types of CDW generated depend on construction methods and the types of buildings being demolished. Modern buildings are primarily constructed from reinforced concrete, whereas buildings currently being demolished in the PRC, dating from the 1960s to 1990s, include a large proportion of bricks.

Among the above CDW components, a mature recycling system has been developed for asphalt blocks, and there is also active recycling and reuse of waste metal, plastics, wood and glass. The remaining large amount of surplus spoil, scrap bricks and tiles, waste mortar and concrete blocks have become the current focus of CDW management and recycling. From environmental protection and disposal safety perspectives, management of surplus spoil is one of the key issues, but there is no mature recycling technology for this material.

Although there are no official statistics of CDW production at the national level, according to several survey results, CDW production shows an upward trend each year, with the annual CDW production currently being over 1.5 billion tons. A recent study\(^1\) estimated that CDW production will reach over 2.5 billion tons per year in 2020.

### 1.4 Laws and Regulations

#### 1.4.1 Laws

At present, the PRC government has not formulated specific laws for CDW management and solid waste management - related provisions are only covered by subordinated laws, including:

- Environmental Protection Law
- Cleaner Production Promotion Law
- Solid Waste Pollution Prevention Law
- Circular Economy Promotion Law
- Building Law

However, the provisions of these laws are expressions of principle, low in operability, and therefore they do not adequately provide guidance or deter illegal behaviour: they can only provide a basis for policy formulation. This study recommends that there should be a series of supporting administrative laws, regulations and systems that can truly provide guidance for CDW management and recycling. CDW are regional materials, and therefore provincial, municipal and county governments should also be able to formulate CDW management methods, but currently only 21.7% of the provinces and cities in the PRC have issued local regulations and policies on CDW management and recycling.

#### 1.4.2 Standards

There are sixteen CDW recycling related standards, including those already issued and those under formulation, and eight local standards that are already issued.

### 1.5 CDW Management and Recycling Authorities

#### 1.5.1 National Level

*The Notice on Roles and Responsibilities for CDW Utilization* issued by the State Commission Office of Public Sector Reform in 2010 (No. [2010] 106) clarifies the responsibilities of central government departments, including the Ministry of Housing and Urban-Rural Development (MOHURD), the National Development and Reform Commission (NDRC), the Ministry of Industry and Information Technology (MIIT), the Ministry of Environmental Protection (MEP), the Ministry of Science and Technology (MOST), the Ministry of Finance (MOF) and the State Administration of Taxation (SAT). MOHURD is the leading authority in CDW management and recycling. The following issues were identified during a survey of CDW management functions of the above ministries:

- Lack of coordination

Although all departments performed their duties specified by State Commission Office of Public Sector Reform, their duties are separated. MOHURD is in charge of the management of source and final use of CDW; whilst MIIT is responsible for management of CDW recycling companies. The evaluation and auditing system is developed by National

\(^1\) Construction Waste Recycling and Reuse Policy Research Report, the Chinese Architecture Design Institute (CADI)
Development and Reform Commission (NDRC). The responsibilities are separated and there is a lack of coordination mechanisms at the ministerial level.

- Enforcement performance varies at the local level.

At the Central Government level MOHURD has been clearly defined as leading unit, but in local governance, the construction department is divided into housing construction bureaus and urban management bureaus (city appearance and environmental sanitation) to perform different duties; but there is lack of effective management and coordination with respect to CDW management.

- Lack of clear positioning of recycling enterprises

CDW recycling enterprises are regarded as “common enterprises” when the State Commission Office of Public Sector Reform defined the responsibilities. According to the “Notice on urban domestic waste treatment charging system and promoting waste treatment industrialization” (NDRC [2002]872), urban solid waste explicitly included CDW and spoil, therefore, construction waste recycling facilities should be regarded as “public utilities”. Referring to the solid waste management, urban infrastructure shall be managed by the centralized construction department, which is conducive to the implementation and enforcement of policies.

### 1.5.2 Local Government Level

The CDW recycling management of local governments involves different government administration departments (including development and reform commission, land resources, housing and construction, planning, municipal administration and landscape, transport, environmental protection, industry and information technology and finance) with their respective administration privileges and responsibilities. Currently in the PRC, the urban management department is the major CDW authority in most cases. At the local government level, the issues are similar to those at national level. The following specific issues were identified during the survey.

- The CDW administration authority and enforcement authority are separate.

The authority of the urban management department has no control over demolition and construction sites. It has the right to approve CDW transportation licenses but does not have right to regulate overloading of vehicles: to do this requires joint law enforcement of 5~6 departments. There is a low level of efficiency in enforcement, which causes difficulties in source control of CDW generation and sorting, and failures in back-end support for promotion and application of recycled products.

- Construction waste management is not linked with existing administrative licensing of construction projects.

The permits and license required for construction projects have no requirement for CDW recycling, therefore CDW recycling is usually ignored for both new construction projects and demolition. Uncontrolled dumping is common.

- Government responsibilities do not match with the construction waste recycling industry supply chain.

Existing functions are based on the management of permits and integrated considerations from upper, middle to downstream industry chain, so as to make it impossible for integrated management. The CDW recycling enterprises are often short of raw materials and find it difficult to sell their products. Policy development is also only for producer or consumer. The policies are difficult to implement.

### 1.6 Stakeholder Analysis

Stakeholders relevant to CDW management including central government bodies, local governments, developers, construction companies, construction waste disposal companies, transportation companies and the general public; this report includes surveys and analysis covering the aspects of CDW recycling awareness, CDW recycling promotion, CDW recycled products application and price, issues in CDW recycling, and suggestions to promote CDW recycling, which are summarized as follows:

#### 1.6.1 Upstream Industry – Sources of CDW

- **Gaps of legal system and lack of supervision of the market**

It is generally believed by stakeholders that CDW is inert material, non-toxic and odorless, and public complaints are minor. The environmental and resource conservation awareness is weak, and impacts on public safety are not considered. For
example, the Building Law and government solid waste announcements don’t consider CDW at all, and there are no provisions on building demolition. The administration and management only care about construction while demolition is overlooked. There is a lack of waste prevention and minimisation concepts. There is no CDW generation statistical system or unified calculation standard. The existing regulations don’t have any quantitative targets on CDW emission, recycling and disposal, or standards and requirements on CDW pollution control, which bring difficulties in the actual management. The existing management is basically following the mode from the era of planned economy, i.e. the CDW administrative units bear the responsibilities of qualification approval and also shoulder the tasks of supervision and law enforcement. This kind of arrangement mixes administration and enforcement and weakens the effectiveness of macro management functions, which has seriously limited development of CDW recycling.

- Lack of appropriate provisions, randomly dumping hard to stop

At present, the PRC’s “Housing construction and decoration quote” does not include construction waste disposal costs but has construction waste removal fees only, which has not changed for many years and is generally low. At the same time, random dumping of construction waste has not been recognized as a serious crime, attracting just simple low fines, and most contractors are more interested in short-term profits. Most CDW is dumped directly despite the fact that the CDW recycling enterprises suffer from a lack of materials.

- Unsorted CDW affects resource treatment costs and product quality

Currently, waste demolition is separated from recycling and reuse: the management of demolition waste is not regulated, and there is lack of evaluation of both construction and demolition waste and detailed management. Specifically, engineering demolition is generally done by a demolition company. Due to the absence of regulation on sorting and storage, (except metals), demolition enterprises will store waste concrete, broken brick, soil, wood, and plastic together, sometimes also with domestic garbage. The CDW recycling enterprises have to sort the wastes. This significantly increases the treatment cost and the quality of recycling products is also affected.

- Stakeholder Analysis

The project owner, construction unit, design institute and government are involved in source generation. The project owner is the major player during demolition and construction; at the source generation stage, the project owner is in the center. The major concerns of design institutes include incorporating their ideas into the building while meeting the requirements of the project owner, completing as many works as possible in the shortest time, and accomplishing work which comply to standards. The construction unit is concerned about how to complete the construction at the fastest rate and with least resources and cost inputs. The government expect less CDW generation. Their expectations, responsibilities and obligations should be properly coordinated.

1.6.2 Midstream Industry - Recycled CDW products

- Management of construction waste transportation industry

The construction waste disposal administrative licensing and other construction licenses are not bound to each other. Approval documents, engineering drawings and other relative materials of construction project shall be submitted to the approval authority, i.e. the Urban Management Administrative and Law Enforcement Bureau for the CDW disposal administrative license. However, the relative procedures and filings have not been done appropriately in compliance with the regulations. Meanwhile, some vehicles are modified in order to save transportation expenses and carry more CDW, which increases the safety risks during the transportation. Uncontrolled dumping of CDW in areas where CDW recycling plants suffer from shortages of material is quite common.

The mutual cooperation and linked enforcement mechanism is insufficient between functional departments. Traffic police, public security, housing construction, urban management and highways departments are all involved in the CDW transportation. Nevertheless, the departments lack mutual cooperation and information sharing, which results in low efficiency.

- Difficulties in land use approval for CDW recycling

At present, CDW land use is not guaranteed. The high cost of CDW transport results in reliance on nearby land. However, the CDW recycling land is not included in the urban construction plan in many cities and the investment for the CDW recycling does not meet the marketization standard. Thus, the land problems hinder the CDW recycling development.

- Environmental assessment approval for CDW recycling project is difficult
The products of CDW recycling enterprises are mainly building materials, belonging to the “construction and processing enterprise” category. Building material processing enterprises are forbidden to build factories in urban area by the environment departments of many local governments in compliance with the laws and regulations, which may add difficulties for the factories to obtain authorization under the EIA process. Meanwhile, to demonstrate the environmental-friendliness of CDW recycling, as well as to facilitate the administrative permit, if the word “waste” remains in the project name, the local residents disagree with the construction of such facilities and the negotiation with the residents is difficult.

- **High costs and investment of CDW recycling**

At present, the CDW recycling industry is still in the primary stage. Due to the diversity and complexity of the raw materials of CDW, the underdevelopment and high cost of relative disposal technologies and equipment, as well as the costly environment investment, recycled CDW products are high price and consequently cannot achieve good sales. Although it may involve the government administrative departments, demolition unit, transport enterprises, construction unit, using unit for the development of CDW recycling, the industrialization for the CDW recycling needs negotiation and coordination among the entire industry chain.

1.6.3 **Downstream Industry - Utilization of Recycled CDW Products**

- **Lack of mandatory regulations for recycled CDW products**

Many provinces and cities require that the infrastructure engineering investment by governments (including roads, landscaping, public toilets, garbage buildings, pavements, river channels and embankments) shall use a certain percentage of recycled CDW products according to the relative proportion of the city. However, the execution of the regulations remains to be improved, in which the recycled CDW products are in excess of demand and products for public infrastructure are unavailable. Meanwhile, the above regulations restrain the application scope of recycling products, which hinders the actual application.

- **Lack of completed standards for recycled CDW products**

Although the production standards are generally complete, the corresponding evaluation and product certification standards for recycled CDW products are incomplete and insufficient, which prevents construction units from judging the current products correctly, resulting in reduced use of recycled CDW products.

- **Lack of price competitiveness for recycled CDW products**

Screening, crushing and other relative treatment processes are needed for the recycled CDW products, which increases the labor and relative processing costs. Also, the promotion costs are rising considering the lack of subsidies, which decreases the price competitiveness of recycled CDW products.

- **Traditional conception hinders the use of recycled CDW products**

Recycled CDW products are mainly recycled aggregate, recycled brick, and recycled concrete, which illustrates the products characteristics well. But this kind of nomenclature is not in accordance with any current standards, which increases the engineering difficulties. Also, developers do not agree to use words like “recycled” and “garbage” when describing construction materials, as it is unacceptable for the public and may influence the sales of houses.

1.6.4 **Obstacles in Promoting Recycled CDW Products**

Based on the above analysis, the obstacle to market promotion of CDW recycling comes from various parts of the industrial chain, involving not only influences of macro-level policies, but also micro-level problems arising in the development of enterprises.

1.7 **Economic Analysis of the PRC CDW Recycling Market Failure**

The economic analysis under this Study is carried out by means of empirical analysis and whole industrial chain comparative analysis. The cost elements of CDW generation and sorting, CDW removal and transportation, CDW digestion and CDW beneficial use are analyzed from the perspective of the whole production process CDW recycling. Cost computation and comparative analysis are conducted by means of standardized processing of data sampled from the individual cases of fixed crushing CDW recycling, mobile crushing CDW recycling and CDW landfill. Costs of different CDW recycling technologies as well as prices of recycling products and common construction material products are compared and analyzed.
The analysis shows that construction waste recycling technology generates marginal economic benefits. Without proper policies and instruments on subsidizing, it is very hard for all types of recycling facilities to be financially viable. Products of fixed treatment technology have better marketing advantage despite their higher investment cost than mobile treatment technology that is limited by process equipment.

The financing costs of different types of enterprises have not been considered in the study, i.e. all the investment is considered made by the enterprises fully with their own capital. If such financing costs are taken into account, the economic benefits of both fixed and mobile technologies are expected to be lower, which is one of the obstacles to market application of construction waste recycling technology.

According to the study, due to the absence of measures for mandatory dumping and transportation of construction wastes, there is not a stable source of materials for construction waste recycling enterprises, resulting in the absence of stability of revenue for enterprises engaged in, for example, fixed construction waste recycling and also bringing certain impacts on their market sustainability.

Sales price in the market is not an obstacle influencing market application of recycled CDW products because there are occasions when their prices are lower than ordinary construction material products. It is more a factor of market acceptance of recycled CDW products. Their narrow application and the absence of a uniform quality certification and accreditation identification system in the sector cause some problems of marketing.

1.8 Current Status of Urban Construction Waste Utilization and Management in the PRC

1.8.1 Selection of Case Study Cities

Typical cities have the following features:

- Adequate CDW source management
- Scaled CDW recycling and sustainable enterprise operations
- Effective marketing of recycled CDW products
- High CDW recycling rate
- Different types of cities which can provide lessons and experience for each other

1.8.2 Cities Selected for Case Studies

Shenzhen — an emerging large city which has an early start in CDW recycling with many recycling enterprises that in sustainable operation. Shenzhen is playing a leading role in CDW recycling among the major cities in the PRC.

Xi’an — a famous historic and cultural city which has established a mature disposal approval system, with adequate source management and large-scale recycling enterprises in sustainable operation.

Xuchang — a small to medium city which has achieved adequate whole process management of CDW recycling, there are scaled recycling enterprises with sustainable operations. Its CDW recycling rate is ahead in the country.

Wujin District of Changzhou City — one district of a medium city, its CDW recycling has a late start but the promotion is strong and effective, there are already scaled recycling enterprises.

Beijing — a megacity of the PRC, even though great importance is attached to CDW recycling, the performance is not satisfactory, a brief introduction is provided in this study for comparison with other cities.

1.8.3 Summary of Successful Experiences

- **Shenzhen**

(1) Laws and regulations of Construction Waste Reduction and Utilization

On October 1st 2009, Shenzhen issued the first legal regulation on construction waste reduction and utilization in the PRC, specifying 9 innovation systems, including the review and record of construction wastes, reduction and disposal proposal, labels of recycled products, emission tariff, disposable residence decoration, mandatory use of the construction waste recycled products, exchange and utilization of construction spoil, on-site classification of the construction waste. The regulation provides clear legal basis to cut down the sources of construction waste.
(2) Government counterpart and strong supervision

Under the supervision of the legal regulations, two record systems namely construction waste reduction and utilization are established. The system of reviewing construction waste content in the designed drawings specifies the requests that the design unit shall have reduction design, the drawing review institute shall report to the administrative competent department after the approval of relevant content for record; The system of construction waste reduction and utilization indicates that reduction design and utilization plan should be prepared in the construction of new projects, demolition of existing architectures, structures and municipal roads. The construction unit shall report to the competent department before the commencement of the project.

(3) Market-driven and industrial upgrading

Shenzhen has developed 5 integrated construction waste utilization enterprises successively and explored the business model of integrated construction waste utilization, namely “site-plant combined mode”, temporary land use mode, on-site disposal mode. The site-plant combined mode is defined that, the recycling treatment facilities and receiving site will be constructed jointly for the purpose of eliminating the stored wastes; Temporary land use mode is defined that, the land use for recycling disposal facilities is used temporarily, mainly eliminating the waste for street demolition; On-site disposal mode is defined that, the recycling facilities are constructed on the demolition site, so as to realize “zero emission” of construction waste and reuse the recycled products in project construction.

(4) Technique support and innovation upgrading

In 2012, the first construction disposal emission technical standards was released in the PRC and clarified the standards of construction waste emission, detailed requirements of waste reduction design and construction reduction. It is very critical to the design institutes in optimizing the construction design, reducing the consumption of building materials, generation of the construction waste, guiding the construction unit to recycle the construction waste.

(5) Promotion and Social Recognition

Shenzhen attaches great importance to the promotion and guidance of construction waste recycling. With various channels such as newspapers and magazines, Shenzhen has special feature report to show the hazards of construction wastes compared with the social and environmental benefits of waste recycling. Also it shows the technique and recycled products to the public. Through promotion and guidance, the construction waste recycled products have achieved social recognition and good market acceptance.

- Xi’an

(1) Serious Governmental Recognition

Leaders of the CCP Municipal Committee and the Municipal Government have conducted field studies and held multiple special meetings. In 2010, a steering group headed by the responsible leader of the Municipal Government and comprising of members from the municipal authorities of city appearance, city administration and traffic police was established; in the meanwhile, 15 joint inspection teams comprising of members from the municipal authorities of city appearance, city administration and traffic police were established for daily inspections and strict strike of various violations in terms of construction waste transportation.

(2) Assurance from Legislative System

Xi’an has set up an integrated and complete construction waste management system consisting of local legislations, government specifications and sector regulations. Construction Waste Management Regulations of Xi’an City defined the responsibilities of the government authorities of city appearance, city administration and traffic police and others involved as well as at the management levels of district, county and community and described in full detail the rights, obligations and responsibilities of government departments and individuals in terms of construction waste generation, transportation, digestion, recycling and legal responsibilities, including specific and strongly operable measures.

“Methods for Appraisal and Evaluation of Construction Waste Transportation Companies in Xi’an City”, “Provisional Requirements on Charges of Construction Waste Disposal in Xi’an City” and “Methods of Accountability Investigation in Construction Waste Management in Xi’an City” were issued in succession, along with series of rules and regulations on daily reporting, site supervision, comprehensive evaluation, market withdrawal, recycling company registration, traffic safety registration, “uniform management in 7 aspects” and joint inspection.
(3) Appropriate Enforcement of Actions and Measures

Xi’an City has been implementing discharge permit and daily reporting in a strict way making sure that producers of construction wastes must apply for and obtain a “Construction Waste Disposal (Discharge) Permit and that the construction waste transportation permit shall not be granted until the procedures of reporting, generation verification and disposal fee payment are fulfilled. In practice, a daily report of the transportation vehicles at night time is required, with the reported information shared by the city administration and traffic police authorities via the Comprehensive Management System of Construction Wastes. The concerned government authorities carry out their respective duties and responsibilities based on the reported information.

Xi’an City has specific requirements on transportation capacity and site scale for the purpose of strictly managing the qualifications and competence of transportation operators. Vehicles transporting construction wastes are managed under the category of special vehicles and the vehicles, drivers and corporate owners are subject to traffic police registration and “uniform” management. Transportation operators are subject to monthly evaluation and year-end appraisal for quantitative rating. Those with poor performance in monthly evaluation will be suspended for improvement while those with unacceptable performance will be disqualified and instructed to withdraw from the construction waste transportation sector, with their Construction Waste Disposal (Transportation) Permit revoked.

Xi’an established a recycling enterprise registration system. Registered enterprises are included in the comprehensive management system of construction wastes and the city appearance authorities of the various districts and development zones, upon approval of construction sites, will assign demolition wastes based on the production needs of the enterprises to support their production activities.

Thanks to the effective implementation of a series of management measures, effective interaction is achieved of the stages of construction waste generation, transportation and disposal to ensure that the construction wastes are transported to the digestion sites or recycling enterprises, destination of construction wastes is effectively controlled and development of construction waste recycling industry is facilitated.

(4) Strengthened Supervision and Appraisal

In order to make sure that the various measures are enforced, the Municipal Joint Inspection Team carries out zone-based and group-based night tours around the City while the City Appearance and Gardening Bureau organizes at least 2 non-notified inspections per week focusing on site control at the entrances and exits of construction sites with waste generation. Transportation permit approval is, in the first instance, suspended for sites with problems discovered in such inspections and then evaluation scores of the respective jurisdiction are deducted, with news published on Xi’an Daily, Xi’an Evening News and other media.

- Xuchang

(1) A special management body is established to facilitate effective management.

Both the Municipal CCP Committee and People’s Government of Xuchang attach consistent and great importance to construction solid wastes management. Early back in 1999, Xuchang City established the Construction Solid Waste Management Office and was then approved in 2014 by the People’s Government of Xuchang City as a permanent government body, which plays an extremely important role in facilitating the management and beneficial use of construction solid wastes in Xuchang.

(2) Powerful supports were provided through policy improvement.

Xuchang City consecutively issued the “Methods for Management of Urban Construction Solid Wastes in Xuchang City”, the “Detailed Rules of Implementation of Urban Solid Waste Management in Xuchang City” and the “Standard on Collection of Urban Solid Waste Treatment Fee in Xuchang City”, the “Methods of Management of Construction Materials and Construction Solid Wastes on Construction Sites” and the “Opinions on Comprehensive Use of Construction Solid Wastes”, specifying the full process of management and beneficial use of construction solid wastes from source declaration, collection, transportation, disposal and promotion and application of regenerated products of construction solid wastes. The adequately detailed and strongly operable requirements included in such policies guaranteed their effective implementation.

(3) Franchised operation model was developed to increase the impetus of industrial development.
As of Year 2008, the People’s Government of Xuchang City initiated “franchised operation” of integrated collection, transportation and beneficial use of construction solid wastes in the urban area. The franchised enterprise has the exclusive right of investing in and constructing, operating and maintaining projects of construction solid waste transportation, disposal and utilization within the scope of franchised operation and collecting construction solid waste transportation tariff according to the tariff standard approved by the People’s Government of Xuchang City. This enterprise undertakes construction projects of construction solid wastes treatment plants to realize recycling and reuse of construction solid wastes and fulfills the public benefit tasks and other obligations assigned by the government. With clearly assigned rights and obligations, the franchised enterprise experienced high-speed development, and the CDW recycling industry in Xuchang has reached a relatively high level.

(4) Joint efforts from multiple government departments contribute to effective supervision.

Xuchang established its joint law enforcement mechanism, under which, the Municipal Government, as the leading organization, is responsible for organizing joint law enforcement participated in by the government departments of city management, public security, housing and urban construction, transportation and highway administration. The key purpose of such joint action is to control and manage construction sites, debris transportation vehicles and commodity concrete transportation vehicles. In addition, improvements were made to the supervision, examination, reward and penalty and accountability mechanisms, accompanied by stronger efforts in inspection and penalty. These actions have effectively addressed the problems of spillage of construction solid wastes and pavement contamination by muddy vehicles. In order for closer partnership between the franchised enterprises and the management authorities, joint management teams were established to increase the frequency of routine inspections and assure that all the construction solid wastes are transported to designated disposal sites.

(5) S&T innovations become a driver of sector development.

The franchised enterprise established Henan’s first engineering and technology research center specialized in R&D of construction solid wastes. Thanks to its all-round efforts of S&T research in classified collection, disposal, key processes and technologies and new product development in terms of construction solid wastes, technological, process, equipment and management models were developed for the sector of beneficial use of construction solid wastes, laying a solid foundation for nationwide duplication of “Xuchang Jinke Model”. The franchised enterprise was certified in 2014 as a national hi-tech enterprise.

(6) Policy and technology supports assured market application.

The Municipal Government provided supports to comprehensive use of construction solid wastes through comprehensive use of public financing, taxation and investment and other economic levers and incorporating regeneration products of construction solid wastes into the scope of government procurement and regarding such incorporation as one of the prerequisites of financial settlement and fund disbursement. Projects failing to use construction solid waste regenerated products according to the design shall not be permitted for final acceptance and registration upon completion. Such policy supports opened the gate to market application of regenerated products. Construction solid wastes regeneration products have already been widely applied in construction projects of urban roads, gardens, plazas, houses, rivers and water conservancy facilities in Xuchang.

- **Wujin District, Changzhou City**

(1) Demonstrative Role in Green Development

Changzhou follows the concept of green development, and has made requirements for CDW recycling enterprises on classified dismantling, regulated transportation, enclosed production, high recycling rate, zero pollution and zero discharge.

(2) Policy supports enabling the formation of a closed industrial chain

Changzhou City has consecutively issued the “Implementation Plan for Special Actions in Controlling and Regulating Construction Wastes in Changzhou City”, the “Announcement on Strengthening Management of Municipal Construction Waste Disposal”, the “Opinions on Implementing the “Municipal Construction Waste Management Regulations”, the “Minutes of Meeting on Further Strengthening Beneficial Use of Construction Wastes” (No. 2013-88) and the “Minutes of Meeting on Coordinating Efforts in Facilitating the Work of Management and Harmless Disposal of Construction Wastes” and integrated the efforts of all concerned departments to set up a comprehensive management system and formed a closed industrial chain integrating the generation, collection, transportation, disposal and recycling and application of construction wastes.
(3) Four development goals achieved through departmental interaction

Changzhou Urban Administration Bureau, in coordination with Wujin District government departments and offices of urban administration, housing, finance, reform and development, taxation, economic and IT, science and technology, collection, transportation, water conservancy and public security, has set up a comprehensive coordination and management mechanism for construction waste recycling. "Admission thresholds" are established for vehicles and enterprises to be engaged in construction waste transportation to regulate the process of construction waste transportation and avoid "spillage and leakage" during transportation. A sound construction waste management system that is led by the government, participated by the social public and managed by the competent industrial department and involves cooperation from all concerned sides shall be set up, and incorporate construction waste recycling into modernized development plan of building industry and truly realize reduction, harmless and beneficial use and industrialization of construction wastes.

(4) Franchised enterprises established using PPP model

In Changzhou Wujin District Green Building Industrial Zone, franchised construction waste enterprises are established using PPP model for the sake of moderate integration of market competition and government regulation. State-owned and private account for 70% and 30%, respectively, for Franchise enterprise, and project land use is unified transfer. Economic benefits are realized simultaneously with social benefits to bring profits to the enterprises.

(5) Green production achieved through technological research and innovation

The franchised enterprise has developed excellent partnership of technological development with a number of scientific research institutes and colleges and universities. In addition, it has set up the Construction Waste Green Recycling Engineering Technology Research Center and Jiangsu Province Graduate Work Station. Advanced process technologies and equipment were imported, and automation and integration of diversified product promotion modules were realized and green production achieved in construction waste recycling.

(6) Recycling product market expanded by diversified means

It is pointed out in the Minutes of Meeting on Coordinating Efforts in Facilitating the Work of Management and Harmless Disposal of Construction Wastes that construction waste recycling products should be included into the catalogs of green construction materials, the catalogs of government procurement and the engineering cost information for preferential promotion and application in construction projects. Construction waste recycling products should be utilized as a top priority in green buildings and the construction project design stage. Construction projects financed with state-owned fund or by the national government must use construction waste recycling products to expand the scope of application of construction waste recycling products. The franchised enterprise has sped up the R&D and promotion of new technologies, new processes, new equipment and new materials, in particular, the development of new regenerated construction materials and raw materials oriented towards the current hot directions of industrial development.

1.8.4 Comparison of Case Study Cities

There are various factors influencing urban CDW management, in terms of the case studies stated above, there are general practices of CDW recycling and reuse among different case study cities and also differences. In general, the key success factor for CDW management and utilization are primarily government policies and promotions, as well as actively participation by enterprises in the local market, secondly tailored measures based on its own features.

Shenzhen is the first city in the nation that has CDW utilization legislation, although some items in Shenzhen Construction Waste Reduction and Utilization Regulations are not in details, it is the first time in the nation that regulations are set out for CDW source reduction and utilization, which is demonstrative action for the legislation of CDW recycling and reuse in the whole nation.

Xi’an Construction Waste Management Regulations are in adequate details and provide legislations for the implementation of urban CDW management, it is highly practical and provides strong support to monitoring of CDW disposal and transportation for Xi’an.

Methods for Management of Urban Construction Solid Wastes in Xuchang City provides legislation condition for establishing franchise mode, Xuchang became the first city that implements CDW recycling and reuse Franchise.

Although there has been no legislation established in Changzhou, regulations for CDW recycling and reuse management are developed through 2 meeting minutes, which set out policy support for CDW disposal and transportation enterprise franchise, and the implementation of disposal and transportation government subsidies.
Advices on promotion of CDW Recycling and Reuse Comprehensive Management in Beijing includes all aspects, however, it is at macro level and not practical.
2  Background of the Technical Assistance

2.1  Definition and Classification of CDW in the PRC

2.1.1  CDW Definition

Currently, there is no unified definition of CDW which applies throughout the world. Researchers and scholars in developed countries have different opinions on the definition of CDW. Domestically, the “Classification of Urban Solid Waste and Emissions” (CJ/tor3030-1996) issued by MOHURD defined that construction wastes generated from construction and decoration are classified as urban solid waste. There are specific explanations in the revised “Regulation on Urban Construction Waste and Spoil” (June, 2003). It classified both construction waste and spoil as construction waste, which is defined as waste debris, waste slag, sludge and other waste generated during construction, demolition, reconstruction and decoration of various types of buildings and building structures by individuals or construction contractors. Regulation 2 item 2 in the “Regulation of Urban Construction Waste” issued by MOHURD (March, 2005) further defined CDW as: waste soil, waste material and other waste generated during construction, reconstruction, expansion works and demolition of various types buildings, building structures and pipe networks by building units and construction contractors. “Regulation of Urban Construction Waste” defined a broader range of CDW to include various waste during construction works.

2.1.2  Classification of CDW

CDW is mainly divided into four categories, according to the source of the waste:

- solid waste from excavation,
- solid waste from demolition of old buildings,
- solid waste from construction site, and
- solid waste from housing decorations.

Excavation waste refers to the waste generated from underground excavation activities required by architectural engineering projects, (e.g. construction of roads, metro and other building and structures): the waste composition varies from region to region. The soil, gravel and rock generated from excavation can be used in the industry for backfilling or processed into aggregate. In recent years, more and more excavated spoil and mud are generated with more large-scale, high-rise and underground engineering structures being constructed; such wastes accumulate in large amounts, causing disposal difficulties.

Old building demolition waste refers to the waste generated during demolition of old buildings or structures and that can’t be reused directly: such waste consists mainly of waste tiles, concrete, waterproof materials, metal, glass, ceramics, plastics and wood.

Engineering construction waste is generated during building construction activities, such as leftover wood and formwork, fallen mortar, waste concrete and bricks, building blocks, surplus rebar and plastics.

Although the above demolition and construction wastes have complex compositions, sorted collection can be achieved through careful demolition processes and proper management during construction.

Housing decoration wastes are wastes generated during engineering decoration: the composition is highly complex, covering virtually all components of CDW.

In conclusion, CDW can be generated from many sources, and its composition is complex, mainly consisting of waste mortar, brick scrap, concrete block, scrap tile, coating material, plastics, wood and packaging.

Among the above CDW categories, housing decoration waste is complex in composition and is often mixed with domestic waste, which doesn’t allow significant recycling at the current stage.
Among the above CDW components, a mature recycling system has been developed for asphalt blocks, and there is also active recycling and reuse of waste metal, plastics, wood and glass, thus the remaining large amount of spoil, scrap bricks and tiles, waste mortar and concrete blocks have become the current focus of efforts to improve management and recycling. From the environmental protection and disposal safety perspectives, spoil is the main target of CDW management, but there is no mature recycling technology for this material, other than re-use as fill material where possible.

Based on the above analysis, the target for improved CDW management is all waste material falling into one of these categories; while the targets for improved CDW recycling are the demolition, construction and excavation wastes (excluding spoil) mainly consisting of scrap bricks and tiles, and waste mortar, concrete blocks and gravel.

Buildings constructed in different periods in the PRC have distinct material composition, for example, buildings constructed before the 1950s are mainly composed of natural materials made by simple processing; during 1960s to 1980s, because of limited economic conditions, residential and office buildings are constructed from multi-layer mixed materials: during this period, construction material for building structures is primarily composed of clay bricks, as well as precast concrete slabs as main components, and windows are composed of both wooden and metal materials. Masonry plaster is primarily composed of cement mortar, cement and lime mortar. As the PRC’s social and economic development has been accelerated, those original buildings have become the main objects of demolition; in late 90s, as the living condition improved, there has been increasing market demand for various architectural buildings, and building materials in the PRC underwent big changes, with generation and application of large number of new building materials and also diversification of the building structures. Therefore, demolition of buildings in different periods generates different types of CDW.

2.1.3 Construction and Demolition Waste (CDW)
As one of the key stakeholders of this study, the Ministry of Housing and Urban-Rural Development of the PRC (MOHURD) has been consulted throughout the study. The concepts and definitions used in this study have been identified mainly based on MOHURD’s usual practices. Hence, for the purposes of this study, Construction and Demolition Waste (CDW), is identified as waste debris from construction, reconstruction, deconstruction and expansion of a building (including decoration), structure and pipe network (excluding road, hydraulic and hydropower structures, railway and tunnel), and unwanted soil from natural hazard).

2.1.4 CDW Recovery
There are many technology and management tools that could be used to turn CDW into useful materials. The process is normally referred to as “recovery”. Figure 2-1 illustrates the CDW recovery process.

![CDW recovery diagram](image)

After separating materials which could be directly reused, the remaining waste debris, such as bricks, concrete and mortars will be processed to produce aggregates and powders, which could be again mixed with cement and other materials to produce construction products. This process transforms CDW to materials which are essential to the construction industry.
2.2 CDW Amount in the PRC

2.2.1 Current Generation of CDW

With the economic development and urbanization in the PRC, the generation of CDW continues to rise caused by increasing demolition of buildings. Prior to 2000, the amount of CDW generated in the PRC was relatively low, and backfilling of mineral extraction sites was sufficient to balance out the generation and disposal; after 2000, CDW has undergone rapid growth due to the large amount of urban construction and old town reconstruction; after 2010, in the cities which are at an advanced stage of development and have limited land availability, disposal of CDW became an issue. Although there are no official statistics of CDW production at the national level, according to several survey results, CDW production showed an upward trend each year, with the annual CDW production reached over 1.5 billion tons. A report estimated that CDW production will reach over 2.5 billion tons per year in 2020.²

![Centralized demolition](image1)

![Old town reconstruction](image2)

![Earthquake](image3)

Figure 2-2 Generation of CDW

At the end of 2015, the Chinese Association of Urban Environmental Sanitation (CAUES) CDW Management and Utilization Committee conducted a survey for the production of CDW in major cities in the PRC. Results of the survey are summarized in Table 2-1.

<table>
<thead>
<tr>
<th>No.</th>
<th>City</th>
<th>Production (million tons)</th>
<th>No.</th>
<th>City</th>
<th>Production (million tons)</th>
<th>No.</th>
<th>City</th>
<th>Production (million tons)</th>
</tr>
</thead>
</table>

Table 2-1 CDW generation of major provinces/districts

---

Source counting is based on the unit production. In this context, the two multipliers will be less, excavated soil has been excluded from the CDW ill data and retrieved from those published on the website of. To how much construction material would be needed by unit area provided in the guidance manual al. Recycling of clean spoil over from the previous year equals to the difference of construction area and completion area of that year (construction) taken over from the previous year from the construction area of this year. (Where the construction area t Statistically, newly constructed area could be roughly calculated by deducting the construction area (area under current practice assumes that the demolition area accounts for 10% of the newly constructed type are 50%, 30% and 20%. Most buildings covered in this study are civil ones. Without concrete mixture, reinforced concrete, and brick–wood mixture. Table 1

<table>
<thead>
<tr>
<th>1</th>
<th>Beijing</th>
<th>39</th>
<th>10</th>
<th>Zhengzhou</th>
<th>100</th>
<th>19</th>
<th>Haikou</th>
<th>6.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Shanghai</td>
<td>144</td>
<td>11</td>
<td>Changsha</td>
<td>25.5</td>
<td>20</td>
<td>Kunming</td>
<td>7.6</td>
</tr>
<tr>
<td>3</td>
<td>Chongqing</td>
<td>40</td>
<td>12</td>
<td>Jining</td>
<td>45</td>
<td>21</td>
<td>Urumqi</td>
<td>8.35</td>
</tr>
<tr>
<td>4</td>
<td>Shijiazhuang</td>
<td>24</td>
<td>13</td>
<td>Guangzhou</td>
<td>36</td>
<td>22</td>
<td>Nanchang</td>
<td>1.50</td>
</tr>
<tr>
<td>5</td>
<td>Taiyuan</td>
<td>15</td>
<td>14</td>
<td>Shenyang</td>
<td>10</td>
<td>23</td>
<td>Xining</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>Xi ' an</td>
<td>55</td>
<td>15</td>
<td>Changchun</td>
<td>4</td>
<td>24</td>
<td>Shenzhen</td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>Nanjing</td>
<td>15</td>
<td>16</td>
<td>Harbin</td>
<td>5.3</td>
<td>25</td>
<td>Fuzhou</td>
<td>23</td>
</tr>
<tr>
<td>8</td>
<td>Xiamen</td>
<td>6</td>
<td>17</td>
<td>Lanzhou</td>
<td>1.5</td>
<td>26</td>
<td>Qingdao</td>
<td>12</td>
</tr>
<tr>
<td>9</td>
<td>Wuhan</td>
<td>20</td>
<td>18</td>
<td>Chengdu</td>
<td>38</td>
<td>27</td>
<td>Yinchuan</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Others: Hubei Province, about 100, Guizhou province, about 90, Fuyang 4.5, Huainan 2.7, Dongguan 3, Yuhang 6, Jiaxing 6, Baotou 1.32, Luoyang 12, Xu Chang 4, and Handan 5

Total: about 1 billion tons

Note: 1. Data refers to CDW production in 2014; due to different survey method in different city, waste soil was not counted in few cities.
2. Survey method for CDW mainly includes counting production at source and counting amount of CDW transported. Source counting is considered as more objective, however accurate reporting of source counting is important; transportation counting method only counts legal transports, illegal transports were unable to be counted.

2.2.2 Estimate of CDW Amounts

The absence of yearly statistics of CDW makes it difficult to estimate how much CDW will be generated based on historical data. Instead, generation of CDW could be estimated by looking back to areas have been constructed and demolished. This estimation and prediction is based on the unit production. In this context, the two multipliers will be construction area (floor area) and area-volume (weight) coefficient where the coefficient would be essential to make a reliable result. Furthermore, data used in this study are yearly data and retrieved from those published on the website of National Bureau of Statistics. In addition, it is almost impossible to estimate excavated soil solely from statistical data of construction area, in the absence of construction drawings. As a result, excavated soil has been excluded from the CDW estimation, and in addition, excavated soil was not one of the materials that could be recovered and hence is not discussed in detail in this study. It is important when considering CDW arising statistics to understand whether or not excavated spoil is included. Excavated spoil, particularly soft material (i.e. soil as opposed to rock) can be recycled as fill material either on the site where it is generated, or other sites, provided it is not contaminated. Recycling of clean spoil does not require processing technology, but the scope of application needs to be specified. Based on the requirements of MOHURD, excavated spoil is not considered as a priority material in this study.

(1) Waste from demolition

The waste generated from demolition could be expressed as the product of demolition area and area-volume coefficient:

\[ V_1 = A_1 \times C_1 \]

Where \( V_1 \) is the quantity of demolition waste; \( A_1 \) is the area has been demolished; and \( C_1 \) is the area-volume coefficient.

Referring to how much construction material would be needed by unit area provided in the guidance manual “Building Construction Handbook”, published by the PRC Architecture & Building Press, the area-volume coefficient could be identified. However, the coefficient differs between types of buildings, as shown in Table 2-2. In the PRC, buildings currently being demolished were mainly built in 1980-1990s, with three main types: brick–concrete mixture, reinforced concrete, and brick–wood mixture. It is assumed that the percentage of buildings in the three type are 50%, 30% and 20%. Most buildings covered in this study are civil ones. Without statistical data on demolition, current practice assumes that the demolition area accounts for 10% of the newly constructed area\(^3\) (Sun J.Y., 2015). Statistically, newly constructed area could be roughly calculated by deducting the construction area (area under construction) taken over from the previous year from the construction area of this year. (Where the construction area taken over from the previous year equals to the difference of construction area and completion area of that year).

Table 2-2 Area-volume coefficient to estimate demolition waste (kg/m\(^2\))

\(^3\) Construction Waste Recycling and Reuse Policy Research Report, the PRC Architecture Design Institute (CADI)
(2) Waste from construction

Similarly, waste generated from construction could be expressed as the product of construction area and area-volume coefficient:

\[ V_2 = A_2 \times C_2 \]

Where \( V_2 \) is the quantity of construction waste; \( A_2 \) is the area has been constructed; and \( C_2 \) is the area-volume coefficient.

Based on construction material losses in prevailing buildings, such as brick-concrete, frame, and cast-in-place structures, the area-volume coefficient in this context could be roughly estimated as 0.05 tons/m\(^2\). Construction area used in this study is from those published in the PRC Statistical Year Book.

(3) Waste from decoration

Again, waste generated from decoration could be expressed as the product of decoration area and the area-volume coefficient:

\[ V_3 = A_3 \times C_3 \]

Where \( V_3 \) is the quantity of waste generated from decoration; \( A_3 \) is decoration area; and \( C_3 \) is the area-volume coefficient.

Assuming decoration area is about 10% of total floor area, 0.1 and 0.2 tons of waste will be generated from per square meter area of residential and public buildings separately, and the percentage of the two types of work account for 60% and 40%.

(4) CDW in total

Apart from the area of construction, reconstruction and rehabilitation, and decoration, there are many other factors could influence the generation of CDW, such as waste generated from producing construction materials, excavation, employment of environmental friendly materials, recovery rate of CDW, enforcement of government policies and strategies, etc. To simplify the estimation of the total CDW, according to the reported accumulated contribution rate of 95.254\%\(^4\), area of construction and demolition has been selected as the two dominant factors impact the total CDW. Hence, the CDW generated each year could be express as:

\[ V = (V_1 + V_2 + V_3) \times 0.95 \]

In addition, in the context of the possibly slower economic growth, other assumptions include the growth of construction industry is slower than that of the overall economy, and in particular the annual growth rate of the construction area is 3\% from 2015 to 2020. Based on sections and assumptions above, estimations of the total CDW generated in year 2013 and 2014 and predictions for 2015-2020 are shown in Table 2-3. Generally, CDW annual generation is expected to be billions of tons per year.

### Table 2-3 Annual CDW Generation in the PRC (2013-2030)

<table>
<thead>
<tr>
<th>Year</th>
<th>Demolition</th>
<th>Construction</th>
<th>Decoration</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>655.605</td>
<td>566.001</td>
<td>423.391</td>
<td>1644.997</td>
</tr>
<tr>
<td>2014</td>
<td>675.148</td>
<td>624.913</td>
<td>475.390</td>
<td>1775.451</td>
</tr>
</tbody>
</table>

\(^4\) Lu Ning, Lu Lu, *Calculation and Prediction Methods of Production of CDW in the PRC Cities [J]*, Journal of Changan University, 2008 (09).
### 2.2.3 Impact of CDW

Currently, most CDW is stockpiled and buried in suburban areas without any treatment, which not only increases the cost of waste cleaning and transferring, occupies a large amount of land but also cause serious environment impact due to waste leakage, dust, sand generated during the stockpiling and transferring. The specific impacts are as follows:

(i) Land occupation. 0.167 ha land is required for 10,000 ton CDW stockpiling with 5m height stockpile (Sun et al, 2015). 356 million ha land will be occupied per year if CDW cannot be properly disposed in the PRC.

(ii) Water pollution. Leachate from CDW dumping sites contains a large amount of calcium silicate hydrate, calcium hydroxide, sulphate and heavy metal ions. Surface and ground water will be polluted if the leachate flows into watercourses and aquifers without proper control.

(iii) Air pollution. The waste plaster of CDW may contains sulphate ions, which could be converted to hydrogen sulphide in anaerobic conditions such as in landfills. In the same conditions, lignin and tannin may be dissolved form waste cardboard and wood and furtherly decomposed to volatile fatty acids (VFA) under anaerobic conditions. These substances could cause air pollution.

(iv) Soil pollution. The hazardous ingredients in CDW and leachate generated will cause soil pollution, including changes of the physical and chemical characteristics of soil, impact on the activities of micro-organisms in soil, and accumulation of hazardous substances in soil. According to research (Sun et al, 2015), it takes decades for stockpiled CDW to be stabilized. Although CDW could be stabilized without generation of harmful gas and leachate, large areas of land are still occupied by a large amount of inorganic substances, which may continue to cause persistent environmental impacts.

The above environmental impacts caused by CDW are still indirect and therefore it has not generated enough attention from the leadership and the public.

The uncontrolled dumping of CDW may also cause serious impacts on traffic safety and water landscape, which has been reported in many cities recently. Especially, the serious “12.20” landslide accident of waste soil which happened in Guangmin New District, Shenzhen, Guangdong at the end of 2015 has sent a strong message on potential impacts of CDW stockpiles in urban areas. About 380,000m² land was affected by the landslide accidents. 33 buildings were buried or damaged. This accident also caused 73 deaths, 4 missing, and 17 injuries. 90 enterprises were affected. Direct financial losses were about CNY880 million.

In the perspective of urban development and people’s livelihood, there is an urgent need to achieve nationwide effective management and recycling for CDW.

### 2.3 Current Status of CDW Utilization

In the 1990s, given that CDW was generated in large quantities from the construction sites, some large-scale construction enterprises, for economic reasons, started spontaneous exploratory research and practice on CDW disposal and recycling. Typical cases include: in 1990, Shanghai Second Construction Engineering Company recycled the ballast, scrap brick, concrete pieces, etc. generated during the structural construction of several high-rise buildings of “Huolan” and “Huating” projects in downtown Shanghai, and reused masonry mortar and plastering mortar: the amount of recycled waste reached approximately 480t. In 1992, Beijing Urban Construction Group First Company successively recycled various kinds of construction wastes generated during the construction of 90,000m² of multi-story and high-rise buildings and used for masonry mortar, interior wall, ceiling plastering, fine aggregate concrete floor and concrete cushion: the application area reached over 30,000m². The target of the CDW recycling at this stage was the (relatively clean) CDW generated and

<table>
<thead>
<tr>
<th>Year</th>
<th>Amount (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>695.402</td>
</tr>
<tr>
<td>2016</td>
<td>716.265</td>
</tr>
<tr>
<td>2017</td>
<td>737.752</td>
</tr>
<tr>
<td>2018</td>
<td>759.885</td>
</tr>
<tr>
<td>2019</td>
<td>782.682</td>
</tr>
<tr>
<td>2020</td>
<td>806.162</td>
</tr>
</tbody>
</table>

Note: Due to the fact that building structures have been developed into larger, taller buildings, as well as the rapid growth of urban subway transportation, large amount of waste soil has been generated from excavation. If waste soil is counted, total amount of CDW will be much higher than the estimates listed in the Table.
collected by the construction enterprises themselves, where the waste was simply processed through primary crushing into recycled aggregate for mixing mortar and concrete.

From 2000 onwards, CDW generation was growing rapidly from urban development and redevelopment while massive engineering constructions presented huge demand for aggregate. CDW accumulation and disposal issues started to arise in some cities, and CDW recycling gradually became a conscious action of some local governments and enterprises. Professional CDW recycling enterprises with over 100 million tons capacity emerged one after another in Beijing, Hebei, Shenzhen, Xuchang and other places, along with some small-scale production lines responding to aggregate demands from construction industry, which marks the start of CDW recycling industry. However, the large-scale enterprises were struggling in operation. Recycled CDW products mainly include recycled aggregate, recycled brick and recycled road base materials. The CDW recycling at this stage was already being practiced by professional enterprises, and CDW was processed by professional manufacturers into recycled aggregates. Processing facilities can be divided into stationary and mobile types: stationary plant normally adopts a two-stage (or more) crushing and screening process while mobile plant normally adopts one-stage crushing and screening; the separation process such as earth removal, magnetic separation and winnowing has become one of the processing links of CDW recycling. Normally small production lines directly provide recycled aggregates to the market; and large-scale enterprises mainly use the recycled aggregate internally for the production of recycled products (e.g. bricks and road materials), and sell the surplus recycled aggregate.

From 2010 onwards, CDW has been causing significant problems for cities with rapid economic development and land use shortage; meanwhile the country has been raising the requirements on resource conservation, energy saving and emission reduction, and has issued several relevant policies. More local governments have started to attach importance to CDW recycling, and more large-scale CDW recycling production lines are being developed. Currently, there are approximately 70 CDW recycling production lines with capacity above 1 million tons/year and several hundreds of enterprises with smaller capacity. Most enterprises are private. The production lines which are in operation only use less than 50% of their available capacity, and operation at a loss or breakeven is common. The recycling rate of CDW is still quite low and there is a huge need in the PRC for such industry. The recycled CDW products at this stage are more diversified, mainly including recycled aggregate, recycled concrete, recycled bricks for floor and wall, recycled building blocks, recycled road base materials, recycled mortar and cement raw material. At this stage, professional suppliers of CDW recycling equipment have emerged, responding to the development needs of CDW recycling technology. High value-added recycled products such as recycled building block, recycled mortar and concrete are the preferred choices of large-scale CDW disposal enterprises.
3 CDW Management and Recycling Assessment

3.1 National and Local Legislation Framework

3.1.1 Relevant National Laws, Regulations and Policies

At present, the PRC government has not formulated specific laws for CDW management, current laws and regulations that related to CDW management are mainly included in energy conservation and environmental protection, circular economy and other relevant laws and regulations. Appendix 2 provides a summary of the current the PRC laws and regulations on CDW. On one hand, some policies do not have direct requirements on CDW, they only suggest that CDW recycling management can be included into the requirements on energy-saving, environmental protection and ecology, without providing specific measures, which makes it impossible to implement; on the other hand, CDW management related policies are mostly encouraging policies. Even though there are some non-compliance punishment measures, the cost of non-compliance is relatively low, and as a result, CDW management policies are not actually being complied with.

(1) Environmental Protection Law

CDW Regulations include:

- The State adopts policies and measures in terms of fiscal assistance, taxation, prices and government procurement to encourage and support the environmental industries such as environmental protection equipment, comprehensive utilization of resources techniques, environmental services etc.

- The State shall encourage and guide citizens, legal persons and other organizations to use environmental-friendly products and recycled products to reduce waste generation. State authorities and other institutions financed by fiscal funds shall give priority to the purchase and use of energy-efficient, water-saving, materials-saving products, equipment and facilities that support environmental protection.

- The people's governments at various levels shall, in a coordinated manner, plan for treatment facilities and supporting pipeline networks for urban and rural construction sewage, environmental and sanitary facilities such as those for the collection, transportation and disposal of solid waste, centralized facilities and sites for hazardous waste disposal, as well as other public facilities for environmental protection, and ensure the normal operations thereof. (CDW recycling facilities are included in the environmental protection public facilities, government shall plan in advance and solve land use issues).

Analysis:

- CDW recycling should be categorized as part of the environmental protection industry, and should not be treated as general building material enterprises; otherwise the development of the industry will face difficulties in approval and EIA issues.

- CDW recycling facilities should be categorized as public environmental protection facilities, for which the government should provide planning, proper layout and land in advance. Currently, they are treated as general building materials enterprises without relevant provision being made for them in the planning process.

- Recycled CDW products should be given preference in engineering application, and the government has the responsibility to facilitate. However currently recycled CDW products are only recommended (and not required) to be used in government projects, resulting in low market recognition of recycled CDW products.

(2) Cleaner Production Promotion Law

CDW Regulations include:
Cleaner production refers to continuous improvement, use of clean energy and raw materials, adoption of advanced technology and equipment, improved management and comprehensive utilization to reduce pollution from the source and improve resource efficiency during product manufacturing and usage.

Local governments at county or above level shall develop circular economy and promote cooperation among enterprises on resources and waste utilization for the purpose of waste recycling and high-efficiency resource usage. People's Governments at all levels should give priority to purchase energy-saving, water conservation, waste reuse, environmental protection and resource conservation products.

The relevant departments under the State Council will approve relevant product labels to establish energy conservation, water conservation, waste reuse, environmental and resource protection product labels according to corresponding standards prescribed by the State.

**Analysis**

CDW reduction should be considered during both design and construction stages. Currently there is a lack of recognition of “source reduction and prevention first” concepts, and there are no supporting regulations.

Currently the promotion and application requirements are limited to energy saving, water saving and waste recycling and reuse, with no pertinent polices and measures provided on CDW.

**(3) Solid Waste Pollution Prevention Law**

**CDW Regulations include:**

- The state shall take economic and technical policies and measures to promote recycle and reuse of solid waste.
- The State encourages and supports centralized solid waste disposal methods to promote development of the solid waste management industry and protect the environment.
- Relevant departments of the State and the local people's Governments at or above the county level and their departments for urban and rural construction, land use, industrial development planning, regional development, should be taken into account to reduce the generation of solid waste and harm, promoting solid and comprehensive utilization of waste disposal.
- The product producers, sellers, importers and users shall afford responsibility for solid waste pollution according to the law.
- The environmental protection administrative departments of large and medium cities shall regularly disclose information on solid waste types, amounts and disposals etc.
- Projects that generate solid waste or projects for solid waste storage, utilization and disposal shall follow the environmental impact assessment procedures.
- Units and individuals that generate solid waste shall take measures to prevent or reduce pollution from solid waste.
- Enterprises and institutions shall take economic and technical feasible measures to reuse the industrial solid waste they generate.
- Project construction units should clean up the construction solid waste generated in the process, and dispose CDW following the requirements from health and environmental protection administrative departments.
- Claim and registration system is applied for industrial waste. The units generating industrial solid waste shall provide information including types, amount, flow direction, storage and disposal of industrial solid waste to the environmental authority of the local government (above county level) according to Ministry of Environmental Protection.
- Construction units not cleaning up solid waste generated in the course of construction and causing environmental pollution shall be punished the fines of between 5,000 yuan and 50,000 yuan.
Construction units that do not comply with requirements from environmental health administration departments on solid waste use or disposal shall be fined between 100,000 yuan and 10,000 yuan.

**Analysis**

- With the increasing importance the country attaches environmental pollution, solid waste management and recycling has been put onto the agenda. However it is not clear from the regulatory standpoint whether CDW belongs to the category of industrial solid waste.
- Since CDW disposal has not been given specific attention, no corresponding statistical system has been established. Although relevant regulations require information disclosure on all aspects of solid waste, CDW has not been included.
- Currently Environment Impact Assessment (EIA) requirements on construction engineering don’t include any specific requirements on CDW.
- Despite provision of punishment measures for non-compliant disposal, the regulations do not clearly define the requirements of recycling. The enforcement performance is poor. The penalties range from 5,000 to 100,000 CNY, which is too low and some cities do not enforce the penalties.

(4) **Circular Economy Promotion Law**

**CDW Regulations include:**

- Architectural, building and construction units should be in accordance with the relevant regulations and standards regarding use of energy, water, land and materials technology and small, lightweight, recycled products on the design and construction of buildings and structures.
- State encourages the use of non-toxic solid waste to produce building materials.
- City people's Government and the owners or users of buildings should take measures to strengthen the maintenance and management of buildings, and extend its service life. To conform to the urban planning and construction standards, buildings should have a reasonable service life and, except where it is in the public interest, demolition should be avoided.
- Construction units should make comprehensive utilization of construction waste; if re-use is not possible, the construction unit shall entrust a qualified company to dispose or recycle CDW.
- The provinces, autonomous regions and municipalities shall charge emission fees of waste according to the administration's economic and social development. Fees charged shall be used in garbage sorting, collection, transportation, storage, use and disposal, and the fees shall not be appropriated for other purposes.
- The government shall implement procurement policies in favor of circular economic development. Procurement using Government funds should give priority to purchase energy, water and materials and environmentally friendly products and recycled products.

**Analysis**

- As there is no implementation guideline for the delivering the measures discussed, this results in obstacles in the promotion and application of recycled products.
- Although relevant demolition management rules are provided, the management is inadequate during implementation as there is a lack of specific implementation method from the authorities.
- Relevant requirements on CDW management and recycling are made for the construction units, however the enforcement is inadequate.
- The CDW tariff system doesn’t have specific implementation rules, the disposal tariff is low and the use of collected fee is not clear: recycling enterprises rarely get subsidies.
Incentive measures lack detailed implementation guidelines, meanwhile, since CDW recycling have not started implementation yet in most areas of the PRC, the application of procurement by using financial funds in CDW recycled products is generally facing difficulties.

(5) Building Law

**CDW Regulations include:**

- Construction enterprises shall comply with the relevant environmental protection and safety provisions of laws and regulations, taking measures to control pollution from construction site dust, waste gas, waste water, solid waste, and noise and vibration.
- Construction units shall ensure safety during demolition and afford relevant responsibility.

**Analysis**

- Principle requirements are made for construction and demolition units, especially on safety management, but there is no requirement on CDW management and recycling, not to mention implementing guideline or corresponding punishment measures. Building construction only takes construction into account, without considering waste management or whole life cycle concept. There is no overall consideration of construction and demolition, which hinders CDW management and recycling.

(6) Evaluation Standard for Green Building

**CDW related management requirements include:**

- The requirements associated with CDW disposal in “Green Building Evaluation Criteria” (GB/ton 50378-2014) include: building materials produced with waste as raw material will be evaluated based on the following criteria with a total score of 5 points:
  - Use one kind of building material produced with waste as raw material: if usage of this material reaches 30% of the total, 3 points are awarded; if it reaches 50%, 5 points are awarded.
  - Use two or more kinds of building material produced with waste as raw material: if usage of this material reaches 30% of the total, 5 points are awarded.

**Analysis**

- The weighting is too low to make a difference. Green building evaluation indicators system include 7 categories of indicators, e.g. land saving and outdoor environment, energy saving and energy utilization, water saving and water resource utilization, material saving and material resource utilization, indoor environmental quality, construction management and operating management. The type of indicator includes control item and scoring item.
- Currently scoring criteria for CDW is only included into the scoring items of “material saving and utilization”, apart from this, the owner has other 13 alternative scoring factors to choose, such as optimal building shape, optimal design of foundation, structural system and structural components, integrated design of civil works and decoration, using reusable partition (wall) for the function-switchable indoor space in public buildings, using integrated and modular design kitchen and bathroom, using local produced building materials, using pre-mixed concrete, using pre-mixed mortar, proper application of high-strength building structural materials, proper application of highly durable building structural materials, using reusable and recyclable materials, and proper application of decoration and furnishing materials that are highly durable and easy to maintain.

3.1.2 Local Regulations and Policies

With growing attention attached to CDW recycling and utilization from relevant governments, many local governments have issued ordinances and administrative management measures, or even laws on CDW utilization in recent years. This shows the government has taken policies into consideration. Local policies and regulations mainly include following aspects:

**Requirements of source control for CDW recycling and utilization:** some local provinces and cities proposed that:
- project Feasibility Study Report or Project Proposals prepared by construction units shall include reduction, classification and recycling of CDW, and also include relevant cost into the investment budget;

- construction units shall prepare CDW recycling plan prior to applying for construction permits for new construction and reconstruction projects;

- for buildings and building structures that are procured by municipal or prefectural government or approved by urban and rural planning departments, procurement agents or the owner of the building or building structures, shall prepare the record keeping for the demolition project at municipal or prefectural urban and rural construction administration departments;

- applicants for the record keeping shall prepare CDW recycling plan prior to the record keeping for demolition projects, and submit to municipal or prefectural urban and rural construction administration departments for approval.

Policies of promotion of CDW recycled products

- some local provinces and cities proposed to set out policies and regulations regarding the promotion of CDW recycling techniques, equipment research and development and recycled CDW labels, to include recycled CDW products into the recommended construction material list, government green procurement list, etc.; construction projects partially use recycled CDW products, for those do not meet the regulated ratio, disposal fee for CDW will be returned based on the actual ratio.

Requirement of information management of CDW recycling

- some local provinces and cities proposed to develop an information monitoring platform for CDW recycling, to upload the information including CDW discharge amount, types, amount of CDW transported, recycling enterprises, as well as amount and types of recorded recycled products and production units.

Requirement of CDW standards management

- recycled CDW products quality standard and application technical specifications shall be improved.

However, until now the central Government has not issued effective guidance or detailed implementation measures. There are only 11 provincial CDW utilization administrative measures or regulations (accounting for 35% of provinces), of which some regulations only laid down principles at macro-level and are not practical. As the key bodies of CDW management, 54% of prefecture level governments have issued regulations on CDW utilization but only a few of these are actively taking measures to promote CDW utilization. The PRC local CDW management policies and regulations are listed in Appendix 3.

### Table 3-1 Provincial, Municipal and Prefectural CDW Management Regulations

<table>
<thead>
<tr>
<th>Category</th>
<th>Total</th>
<th>Regulations</th>
<th>Laws approved by People’s Congress</th>
<th>Clearly Defined CDW Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount</td>
<td>Percentage</td>
<td>Amount</td>
<td>Percentage</td>
</tr>
<tr>
<td>Provincial Level</td>
<td>31</td>
<td>11</td>
<td>35%</td>
<td>———</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19%</td>
</tr>
<tr>
<td>Prefectural Level</td>
<td>334</td>
<td>180</td>
<td>54%</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>78</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23%</td>
</tr>
</tbody>
</table>

### 3.1.3 National and Local Specifications and Standards

Currently, there are 17 standards for the production and application of recycled CDW. Detailed specifications of each standards are listed in Appendix 3, standards are listed in Table 3-2, Table 3-3, and Table 3-4.

### Table 3-2 Existing Standards (Published)

<table>
<thead>
<tr>
<th>No.</th>
<th>Standard</th>
<th>Type of Standard</th>
<th>Standard No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Technical specification for CDW recycling technologies</td>
<td>State Engineering Standard</td>
<td>GB/ton 50473-2012</td>
</tr>
<tr>
<td>2</td>
<td>Concrete with recycled coarse aggregate</td>
<td>State Product Standard</td>
<td>GB/ton 25177-2010</td>
</tr>
<tr>
<td>No.</td>
<td>Standard</td>
<td>Type of Standard</td>
<td>Status</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------------------------------</td>
<td>-----------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>3</td>
<td>Concrete and mortar with recycled fine aggregate</td>
<td>State Product Standard</td>
<td>GB/ton 25176-2010</td>
</tr>
<tr>
<td>4</td>
<td>Technical specification for CDW processing</td>
<td>Sector Engineering Standard</td>
<td>CJJ 134-2009</td>
</tr>
<tr>
<td>5</td>
<td>Technical specification for application of recycled aggregate</td>
<td>Sector Engineering Standard</td>
<td>JGJ/ton 240-2011</td>
</tr>
<tr>
<td>6</td>
<td>Tile and permeable brick with recycled aggregate</td>
<td>Sector Product Standard</td>
<td>CJ/ton 400-2012</td>
</tr>
<tr>
<td>7</td>
<td>Inorganic mixture with recycled CDW aggregate for road construction</td>
<td>Sector Product Standard</td>
<td>JC/ton 2281-2014</td>
</tr>
<tr>
<td>8</td>
<td>Technical specification for control of durability of concrete with recycled aggregate</td>
<td>Association Standard</td>
<td>CECS 385:2014</td>
</tr>
<tr>
<td>9</td>
<td>Standard for Testing the Environmental Protection Safety of Cement Recycled Material</td>
<td>Association Standard</td>
<td>CECS 397:2015</td>
</tr>
</tbody>
</table>

Table 3-3 Existing Standards (Under Preparation)

<table>
<thead>
<tr>
<th>No.</th>
<th>Standard</th>
<th>Type of Standard</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Technical specification for recycled concrete structures</td>
<td>Sector Engineering Standard</td>
<td>2014. need consultation</td>
</tr>
<tr>
<td>2</td>
<td>Technical specification for application of recycled permeable concrete</td>
<td>Sector Engineering Standard</td>
<td>2014. submitted for approval</td>
</tr>
<tr>
<td>3</td>
<td>CDW Recycled Aggregates Solid Bricks Wall Bricks</td>
<td>Sector Product Standard</td>
<td>2014. submitted for approval</td>
</tr>
<tr>
<td>4</td>
<td>Technical specification for CDW processing</td>
<td>Sector Engineering Standard</td>
<td>CJJ134,2015. modified</td>
</tr>
<tr>
<td>5</td>
<td>Technical specification for recycled mixed concrete structures</td>
<td>Sector Engineering Standard</td>
<td>2015. formulated</td>
</tr>
<tr>
<td>6</td>
<td>Code for CDW recycling plant design</td>
<td>State Engineering Standard</td>
<td>2015. formulated</td>
</tr>
<tr>
<td>7</td>
<td>Technical specification for application of Stationary CDW treatment facilities</td>
<td>Sector Engineering Standard</td>
<td>2015. formulated</td>
</tr>
</tbody>
</table>

Table 3-4 Municipal Specifications and Standards

<table>
<thead>
<tr>
<th>No.</th>
<th>Standard</th>
<th>Standard No.</th>
<th>Released by</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Code for structure design using recycled concrete</td>
<td>DB11/ton 803-2011</td>
<td>Beijing Municipal Quality Supervision Bureau</td>
</tr>
<tr>
<td>2</td>
<td>Quality acceptance inspection for urban road with recycled CDW pavement</td>
<td>DB11/ton 999-2013</td>
<td>Beijing Municipal Quality Supervision Bureau</td>
</tr>
<tr>
<td>3</td>
<td>Requirements for CDW transportation vehicle marking, monitoring and closure</td>
<td>DB11/ton 1077-2014</td>
<td>Beijing Municipal Quality Supervision Bureau</td>
</tr>
<tr>
<td>4</td>
<td>Concrete brick made with recycled concrete aggregate from buildings destroyed by earthquake</td>
<td>DB51/ton 863-2008</td>
<td>Sichuan Provincial Quality Supervision Bureau</td>
</tr>
<tr>
<td>6</td>
<td>Technical Specification of CDW Recycled Aggregates Pavement Base Construction</td>
<td>DB13(J)/ton 155-2014</td>
<td>Hebei Provincial Quality Supervision Bureau</td>
</tr>
<tr>
<td>7</td>
<td>Technical Specification of CDW Reduction</td>
<td>SJG21-2011</td>
<td>Shenzhen Municipal Housing and Construction Bureau</td>
</tr>
<tr>
<td>8</td>
<td>Technical Specification of Road Base Filling with CDW</td>
<td>DB41/ton 1193-2016</td>
<td>Henan Provincial Quality Supervision Bureau</td>
</tr>
</tbody>
</table>
3.2 Government departments involved in CDW management and utilization

3.2.1 National Level

The “Notice on Roles and Responsibilities for CDW Utilization issued by State Commission Office of Public Sectors Reform in 2010” (No. [2010] 106) clarifies the responsibilities of central government departments:

- MOHURD is the major authority, in conjunction with relevant departments to i) develop overall plan and policies on CDW utilization; ii) overall coordination of CDW utilization; iii) develop recycling policies and supervise their implementation; iv) organize and coordinate innovation on recycling technology and demonstration projects.

- NDRC is responsible for i) incorporating CDW utilization into plans of circular economy and comprehensive utilization of resources; ii) study on the policies to promote CDW utilization; iii) ensure consistency and balance of various policies; iv) arranging key CDW recycling projects.

- MIIT is responsible for: i) developing policies, standards and specific plans on recycled construction materials; ii) organizing research and study on CDW recycling equipment and technologies; iii) participating in development of industry support policies.

- MOEP is responsible for: i) development of CDW pollution prevention policies, standards and technical specifications; ii) monitoring and supervising the pollutant emissions during CDW recycling process.

- Science and technologies, finance and tax departments carry out related works in their respective duties, such as R&D, financing support and tax policies.

The performance of each department is presented in Table 3-5.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Duties</th>
<th>Works been done</th>
<th>Prepare special plans</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ministry of housing and urban-rural development</td>
<td>i) develop overall plan and policies on CDW utilization; ii) overall coordination of CDW utilization; iii) develop recycling policies and supervise their implementation; iv) organize and coordinate innovation on recycling technology and demonstration projects.</td>
<td>i) develop overall plan and policies on CDW utilization; ii) overall coordination of CDW utilization; iii) develop recycling policies and supervise their implementation; iv) organize and coordinate innovation on recycling technology and demonstration projects.</td>
<td>No, but participating in development of 13th Five Year Plan of the PRC</td>
<td>Working in accordance with functional requirements</td>
</tr>
<tr>
<td>Ministry of industry and information technology</td>
<td>i) developing policies, standards and specific plans on recycled construction materials; ii) organize research and study on CDW recycling equipment and technologies; iii) participating in development of industry support policies.</td>
<td>i) Promote development of CDW recycling industry and encourage colleges, institutes and companies to conduct researches and increase add-values of the recycling products; ii) organize development of sector specification on CDW utilization.</td>
<td>No</td>
<td>Working in accordance with functional requirements</td>
</tr>
<tr>
<td>National Development and Reform Commission</td>
<td>i) incorporating CDW utilization into plans of circular economy and comprehensive utilization of resources; ii) study on the policies to promote CDW utilization; iii) ensure consistency and balance of various policies; iv) arranging key CDW recycling projects.</td>
<td>i) incorporating CDW utilization into plans of circular economy and comprehensive utilization of resources; ii) study on the policies to promote CDW utilization; iii) ensure consistency and balance of various policies; iv) arranging key CDW recycling projects and allocate budgets to support such projects.</td>
<td>Yes, circular economy development strategy and action plan in the short term (Issued by the State Council [2013]5)</td>
<td>Working in accordance with functional requirements</td>
</tr>
</tbody>
</table>
3.2.2 Present Situation of Relevant Administrations at Local Level

The CDW recycling management of local governments involves different government administration departments (including development and reform commission, land resources, housing and construction, planning, municipal administration and landscape, transport, environmental protection, industry and information technology and finance) with their respective administration privileges and responsibilities, in which the management procedures on CDW of the whole construction process are shown in the figure below:

Local governments in terms of CDW management generally adopt the following organizational arrangements:

**Formal system of joint management.** For example, Beijing has clearly defined the joint management system in the “Opinions on promoting integrated management of construction waste recycling activities”. Member units include: the Municipal Development and Reform Commission, the Municipal Supervision Bureau, the Municipal Finance Bureau, the Municipal Environmental Protection Bureau, Municipal Planning Commission, the Municipal Housing, Municipal Urban and Rural Construction Commission, Sanitation Commission, Traffic Commission, the Municipal Quality Supervision Bureau, the Municipal Bureau of Public Security and Traffic Management Bureau, Municipal Urban Management Bureau and the County governments. The Vice Mayor chairs the joint meeting on a regular basis to inform issues and solve problems. However, such system is difficult to establish because the departments involved are at the same administrative level with the leading department. The leading department finds it difficult to lead and other departments did not prioritise CDW management.

**Construction Administrative Department as administrative authority.** For example, the Construction Administrations at Shenzhen (Guangdong Province) City level and District level are the administrative authority for CDW reduction and
reducing. The Urban Management Departments are responsible for CDW transportation and receiving. The Departments of Development and Reform Commission, Trade and Industry, Finance, Land and Housing, Planning, Environmental Protection, and Pricing and other administrative sectors perform their respective duties to assist CDW management. However, the Construction Administrative Department is only in charge of the CDW and recycling on site. The Urban Management Department is responsible for management of transportation and landfill. Poor coordination between the two departments creates gaps in the CDW recycling chain.

**Urban Management Department as administrative authority.** This is the most common practice in the PRC. For example, Xuchang (Henan Province) Urban Management Bureau is the administrative department of CDW management, mainly responsible for i) review and supervision of CDW collection, transportation and disposal; ii) provide supervision and guidance for county level CDW management; and iii) regulate and guide franchise units to ensure they properly implement the franchise agreement.

Handan (Hebei Province) Urban Management Bureau is responsible for i) verifying and approval of CDW disposal; ii) organize and coordinate supervision and inspection of illegal disposal of construction waste.

Xi’an (Shaanxi Province) Urban Management Bureau has set up a CDW Department to i) manage CDW and its utilization; ii) develop CDW disposal site plan and review; iii) verifying CDW amounts; iv) issue transportation license of companies and vehicles; and v) co-ordinate and guide CDW management of each districts and development zone. The County/District Appearance and Environmental Sanitation Administration assume CDW management duties within their administrative areas. This kind of centralized management approach could help promote CDW recycling but did not rise to the level of city government. There are lack of preferential policies relevant to CDW recycling and the progress is slow.

### 3.2.3 Analysis of the CDW Management and Utilization Management Responsibilities of the Government

According to the functions of Central and local governments on construction waste management, the following conclusions can be drawn:

- **Lack of coordination**

Although all departments performed their duties specified by State Commission Office of Public Sectors Reform, their duties are separated. MOHURD is in charge of the management of source and usage of CDW; MIIT is responsible for management of the CDW recycling companies. The evaluation and auditing system is developed by NDRC. The responsibilities are separated from each other and limited to specific sections. There is a lack of coordination mechanism at the ministerial level.

CDW recycling enterprises are regarded as “common enterprises” when the State Commission Office of Public Sectors Reform defined the responsibilities. According to the “Notice on urban domestic waste treatment charging system and promoting waste treatment industrialization” (NDRC [2002]872), the urban solid waste explicitly included CDW and spoil, therefore, construction waste recycling facilities should be regarded as public utilities. Referring to the solid waste management, urban infrastructure shall be managed by the central construction department, which is conducive to the implementation and enforcement of policies.

- **Enforcement performance various at local level.**

At the Central Government level, MOHURD has been clearly defined as leading unit, but in local governance, the construction department is divided into housing construction bureaus and urban management bureaus (city appearance and environmental sanitation) to perform different duties but there is lack of effective management and coordination.

- **The CDW administration authority and enforcement authority are separate.**

For example, the authority of the urban management department is outside of construction sites and has no control of demolition and construction sites. It has the right to approve CDW transportation licenses but does not have the right to regulate overload. This kind of arrangement makes it difficult to control CDW amounts and classification at source and ensure promotion of recycled products.

- **Construction waste management is not linked with existing administrative licensing of construction project.**

The permits and license required for construction projects include site selection approval, land use plan permit and construction project planning permit but there is no requirement for CDW recycling. This is the same situation during
The government responsibilities do not match with construction waste recycling industry chain.

Existing functions are based on the management of permits and integrated considerations from upper, middle to downstream industry chain, so as to make integrated management impossible. The CDW recycling enterprises are often short of raw materials and find it difficult to sell their products. Policy development is also only for producer or consumer. The policies are difficult to implement.

3.3 Stakeholder Analysis

3.3.1 Stakeholder Matrix Analysis

Stakeholder analysis is used to identify all individuals or groups that are likely to affect or be affected, and help the stakeholders to assess impacts from key stakeholders during the formulation of a strategy. Stakeholder analysis often uses a Mendlow Matrix which is the power interest matrix presented by Aubrey Mendelow in 1991, also called stakeholder matrix. The matrix categorizes all stakeholders into four quadrants according to their powers and interests to establish the stakeholder relationships and strategy closely related to the development of the strategy, and analyze the powers and interests of different stakeholders.

![Stakeholder Matrix Analysis Chart](image)

The primary stakeholders in formulating a new strategy are those in the fourth quadrant with the highest powers and interests. The CDW recycling management strategy and policy formulation mainly involves central government, local governments, development enterprises, construction enterprises, disposal enterprises, social groups, public representatives and design & research institutes: the potential influences from fourth quadrant are the focus of the stakeholder analysis.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Power Degree</th>
<th>Power Implications</th>
<th>Interest Degree</th>
<th>Interest Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central government</td>
<td>High</td>
<td>Formulating national level laws, regulations and policies on CDW recycling management</td>
<td>High</td>
<td>Facilitate the country’s CDW recycling management</td>
</tr>
<tr>
<td>Local governments</td>
<td>High</td>
<td>Formulating local level laws, regulations and policies on CDW recycling management</td>
<td>High</td>
<td>Facilitate local CDW recycling management</td>
</tr>
<tr>
<td>Development enterprises</td>
<td>Very high</td>
<td>Decide the disposal of CDW and the use of recycled CDW products</td>
<td>High</td>
<td>Benefit from product value-added by using recycled CDW products</td>
</tr>
<tr>
<td>Construction enterprises</td>
<td>Very high</td>
<td>Decide the disposal of CDW</td>
<td>Low</td>
<td>Mandatory work, no obvious benefit</td>
</tr>
<tr>
<td>Disposal enterprises</td>
<td>Very high</td>
<td>Decide the disposal process and product form of CDW</td>
<td>Very high</td>
<td>Directly benefit from recycled CDW products</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------</td>
<td>-----------------------------------------------</td>
<td>-----------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Social groups</td>
<td>High</td>
<td>Promote CDW recycling in the industry</td>
<td>High</td>
<td>Facilitate industrial development and improve influence of the industry</td>
</tr>
<tr>
<td>Public community representatives</td>
<td>Very high</td>
<td>Choose whether to use recycled CDW products</td>
<td>High</td>
<td>Environmental benefits</td>
</tr>
<tr>
<td>Others</td>
<td>High</td>
<td>Develop new CDW recycling technologies and products, provide design according to relevant standards</td>
<td>High</td>
<td>Benefits from providing technical services</td>
</tr>
</tbody>
</table>

Through the above analysis, it is found that the powers and benefits of relevant stakeholders in CDW recycling are not fully equivalent, which indicates corresponding issues in practice and the need for improvements in policy management, for which further in-depth study was conducted by the research group through survey.

### 3.3.2 Main Stakeholders Involved in CDW Management and Utilization

To identify the relations of various stakeholders and existing issues, the TA team consulted relevant stakeholders during November 2015 to March 2016 through questionnaires, seminars, field visit, interviews, and emails. Stakeholders included central government bodies, local governments, developers, construction companies, construction waste disposal companies, and the consultation focused on the present situation of construction waste disposal and planning, standards, policies and measures, management agencies and promotion of recycled CDW products. A total of 50 questionnaires were distributed and 35 questionnaires were returned. 68 stakeholders were interviewed, which are listed in Appendix 5, questionnaires are included in Appendix 6.

| The Central Government |

The central government bodies views on the issues on promotion of CDW utilization and planned actions are presented in Table 3-7.

#### Table 3-7 Problems in promoting the utilization of CDW and next steps

<table>
<thead>
<tr>
<th>Sector</th>
<th>Existing problems</th>
<th>Next work plan</th>
</tr>
</thead>
</table>
| Ministry of Housing and Urban-Rural Development | (1) Lack of awareness: MOHURD did not pay enough attention to the management and reuse of CDW, lack of national testing standards of construction waste recycling.  
(2) Institutional mechanisms are not perfect: lack of overall planning of the construction waste recycling project; too many departments are involved in CDW management; lack of emission reduction mechanism at source; regional coordinating mechanism has not been established.  
(3) Return mechanism for recycling project is incomplete. | (1) Issue the construction waste recycling industry standards and interim measures for the management of CDW recycling.  
(2) Publish the list of enterprises which comply with the construction waste recycling industry standard.  
(3) Encourage enterprises to develop advanced technology, equipment and innovation; and promote mature construction waste recycling technologies. |
| Ministry of Industry and Information Technology | (1) The lack of specialized industrial guidance policies;  
(2) Related standards are not perfect. MIIT are in charge of the production regulations of CDW recycling, i.e., “Inorganic Mixture for Roads”, and “Disposal of Stationary CDW Technical Procedures” is in preparation. | (1) Issue the construction waste recycling industry standards and interim measures for the management of CDW recycling.  
(2) Publish the list of enterprises which comply with the construction waste recycling industry standard.  
(3) Encourage enterprises to develop advanced technology, equipment and innovation; and promote mature construction waste recycling technologies. |
| National Development and Reform Commission   | (1) Environmental value is not fully reflected;  
(2) The legal system is not perfect;  
(3) Management at source is inadequate;  
(4) There is a need to strengthen disposal and utilization of CDW. | (1) Strengthening planning and reasonable positioning for CDW recycling sector development.  
(2) Strengthening the development of regulatory standards.  
(3) Improve policy mechanisms.  
(4) Promote recycling products.  
(5) Enhance capacity-building for the promotion of CDW recycling.  
(6) Pilot demonstration. |
- **Developers**
  
  - Awareness of the work of CDW recycling: CDW recycling is important. Most CDW is solid waste generated from construction or demolition. CDW recycling could reduce environmental pollution and reduce resource consumption, which is in line with the requirements of sustainable development.
  
  - Promoting CDW recycling: promote awareness of CDW recycling during daily work by explaining to relevant colleagues and support application of recycled CDW products on construction site where there are opportunities.
  
  - Currently the application of recycled CDW products in engineering projects are relatively few, mainly due to the lack of knowledge of recycled CDW products and lack of large scale applications in engineering projects; it is planned to pilot test the products in construction in the near future.
  
  - Price of CDW recycled products: the enterprises consulted accept charging for recycled CDW products provided that the pricing shall not be higher than the sum of current construction waste disposal cost and raw materials cost.
  
  - Problems of CDW recycling: lack of knowledge of resource utilization of CDW; waste separation is inadequate; recycling rate is low; resource recycling technology is backward; government investment is not enough.
  
  - Suggestions to promote CDW recycling: the government issue policies to strengthen CDW disposal supervision on the construction site; construction waste processing; strengthening the CDW recycling-related manufacturing technologies development; improve CDW separation and collection; improve construction worker awareness of the reutilization of CDW; establishing relevant laws and regulations, and provide financial support and preferential policies.

- **Contractor**
  
  - Awareness of CDW recycling: construction enterprises have some knowledge on resource utilization of CDW and will comply with national laws and regulations but lack of efficient and appropriate technology. There is lack of legal and regulatory requirements.
  
  - Promoting CDW recycling: As the end user of CDW recycling technologies, they can promote the development of CDW recycling technologies and the preparation of technical standards through engineering practices.
  
  - CDW recycling on construction site: no measures have been taken at source; sent to suburban or rural, landfill or disposal in open space; it is acceptable to install sorting and collection equipment on sites but hope professional third party company provide funds.
  
  - Application of recycled CDW products: the enterprises consulted did not use any recycled products currently but have plans for future projects.
  
  - Price of CDW recycled products: the enterprises consulted accept charging for CDW recycled products provided that the pricing shall not be higher than the natural materials.
  
  - Problems of CDW recycling: lack of quota for recycled products, quality concerns, project owner cannot mentally accept recycled product.
  
  - Suggestions to promote CDW recycling: carry out waste concrete crushing equipment and technology study; strengthen legal and economic leverage to develop CDW recycling promotion measures and mandatory measures; develop preferential policies and financial support.

- **CDW disposal enterprises**
  
  - The main source of CDW: demolishing old buildings, construction of new buildings and the municipal road works. Purchase of construction waste accounts for 20% of total costs.
  
  - Technologies adopted: there are two major technologies: i) mobile crushing and screening equipment; and ii) fixed sorting and crushing equipment then to produce various products.
• Constraints of CDW recycling: lack of mandatory policy; no guarantee for CDW sources; lack of policies to guarantee application of recycling products; the existing policies are not practical; no coordination during the whole cycle from generation, transportation, disposal to application; lack of awareness on CDW recycling; there is no product directory for recycled products and engineering application is limited; production cost is high.

• Technical issues on application of recycled CDW products: critical technology to improve continuous stability and performance of fixed sorting and crushing production lines; separation of light material; application of recycled aggregate in the "sponge city" concept; certification of recycled products and durability test problem; harmless disposal technologies for decoration garbage; extensive application of spoil earth and separated powders.

• Suggestions to promote CDW recycling: financial policy and tax offers; legal requirements on source control; mandatory requirements on sorting at source and transport to treatment enterprises; establishment of integrated management platform to improve policy enforcement; development of technical standard system; development of specific equipment and manufacture domestically; high added-value products development; quality certification for recycled products quality qualified certification; other policy such as: land allocation, EIA, subsidies and promotion of recycled products.

Detailed interviews were conducted with transportation enterprises closely associated with CDW source management.

• Problems in the industry: Although requiring special permission, enterprises are small and scattered, with affiliated individuals. The shipping cost and billing methods are unchanged for many years. The dumping vehicles are often overloaded and dumped at will. The current standard load of transportation vehicles is relatively small. Unlicensed vehicles are common. The management of affiliated companies is poor. The waste is transported during nighttime so it is difficult to supervise. The regulatory departments involved are too many.

• Suggestions to promote CDW recycling: establishment of transport permission and regulatory systems; regulating the whole transportation process; introduction of "smart sanitation" construction\(^5\); adding road cleaning management, requiring transport unit to be equipped with clean vehicles; a single administration unit or establishment of cross departmental mechanisms to solve the problem of separated administration authority and enforcement authority.

- **Public**\(^6\)

  • The public lack perspectives, attitudes and tolerance toward CDW; due to the indirect and delayed nature of CDW impacts, most people think CDW disposal is not directly associated with their working and living.

  • There is no supervision from public on illegal dumping of CDW: as uncontrolled dumping doesn’t occur within public activity areas, most people think CDW disposal doesn’t really concern them.

  • Public support to CDW recycling and willingness to use recycled products are weak: over 70% of the public think they can accept CDW recycled products to a certain extent if the products have price advantages compared to average building materials.

3.3.3 **Analysis of the Existing Problems**

- **Upstream Industry – Source of CDW**

  • **Gaps of legal system and lack of supervision of the market**

Currently there are no specific laws and regulations on CDW recycling although a number of environment-related laws and regulations have touched on CDW but simply provided for the implementation of cleaner production. There is a lack of specific details and practical regulations rather than substantive requirements. The legal gaps will be filled by departmental regulations or local laws, which to a large extent diminishes the effectiveness and implementation of the law. There are no quantitative indicators in existing rules and regulations relating to CDW emissions, recycling and there are no

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\(^5\)Smart sanitation refers to real time management of the whole sanitation process based on networking technology and mobile internet technology to improve performance and reduce operation cost. All services of smart sanitation are deployed into the smart city cloud and connected to the network of smart city. The cloud based approach can provide services to managers and sanitation workers.

\(^6\)The public interviewed mainly includes students of universities and ordinary public.
environmental pollution control standards for CDW, which makes it difficult to implement. CDW management in the PRC is basically in the planning economy mode. The CDW administrative units bear the responsibilities of qualification approval and also shoulder the tasks of supervision and law enforcement. This kind of arrangement mixes administration and enforcement and obviously weakness the effectiveness of macro-management functions, which has seriously limited development of CDW recycling.

- **Lack of appropriate provisions, randomly dumping hard to stop**

At present, the PRC's “Housing construction and decoration quote” does not include construction waste disposal costs but has construction waste removal fees only, which has not changed for many years and is generally low. At the same time, uncontrolled dumping of construction waste has not been recognized as a serious crime, with just simple low fines, and most contractors are more interested in short-term profits. Most CDW is dumped directly, despite the fact that CDW recycling enterprises lack materials.

- **Unsorted CDW affects resource treatment costs and product quality**

Currently, demolition waste is separated from recycling and reuse, management of demolition waste is not regulated, and there is a lack of evaluation on CDW as well as detailed management. Specifically, engineering demolition is generally done by a demolition company. Due to the lack of regulations on sorting and stacking (except metals), demolition enterprises will stack waste concrete, broken brick, soil, wood, and plastic together, sometimes also with domestic garbage. The CDW recycling enterprises have to sort the wastes. This significantly increases the treatment cost and the quality of recycling products is also affected.

Meanwhile source management also covers whole life cycle management of buildings with the objective of CDW reduction. Issues include inadequate CDW generation statistical system and lack of statistical channels and unified calculation standard.

- **Midstream Industry – Recycled CDW Products**

  - **Management of construction waste transportation industry**

The construction waste disposal administrative licensing and other construction licenses are not bound to each other. Approval documents, engineering drawings and other relative materials of construction project shall be submitted to the approval authority, i.e. the Urban Management Administrative and Law Enforcement Bureau for the CDW disposal administrative license. However, the relative procedures and filings have not been done appropriately in compliance with the regulations. Meanwhile, some vehicles are modified in order to save transportation expenses and carry more CDW, which increases the safety risks during the transportation. Uncontrolled dumping of CDW in areas where CDW recycling plants suffer from shortages of material is quite common.

The mutual cooperation and linked enforcement mechanism is insufficient between functional departments. Traffic police, public security, housing construction, urban management and highways departments are all involved in the CDW transportation. Nevertheless, the departments lack mutual cooperation and information sharing, which results in low efficiency.

  - **Difficulties in land use approval for CDW recycling**

At present, CDW land use is not guaranteed. The high cost of CDW transport results in reliance on nearby land. However, the CDW recycling land is not included in the urban construction plan in many cities and the investment for the CDW recycling does not meet the marketization standard. Thus, the land problems hinder the CDW recycling development.

  - **Environmental assessment approval for CDW recycling project is difficult**

The products of CDW recycling enterprises are mainly building materials, belonging to the “construction and processing enterprise” category. Building material processing enterprises are forbidden to build factories in urban area by the environment departments of many local governments in compliance with the laws and regulations, which may add difficulties for the factories to obtain authorization under the EIA process. Meanwhile, to demonstrate the environmental-friendliness of CDW recycling, as well as to facilitate the administrative permit, if the word “waste” remains in the project name, the local residents disagree with the construction of such facilities and the negotiation with the residents is difficult.

  - **High costs and investment of CDW recycling**
At present, the CDW recycling industry is still in the primary stage. Due to the diversity and complexity of the raw materials of CDW, the underdevelopment and high cost of relative disposal technologies and equipment, as well as the costly environment investment, recycled CDW products are high price and consequently cannot achieve good sales. Although it may involve the government administrative departments, demolition unit, transport enterprises, construction unit, using unit for the development of CDW recycling, the industrialization for the CDW recycling needs negotiation and coordination among the entire industry chain.

- **Downstream Industry - Utilization of Recycled CDW Products**

  - **Lack of mandatory regulations for recycled CDW products**

    Many provinces and cities require that the infrastructure engineering investment by governments (including roads, landscaping, public toilets, garbage buildings, pavements, river channels and embankments) shall use a certain percentage of recycled CDW products according to the relative proportion of the city. However, the execution of the regulations remains to be improved, in which the recycled CDW products are in excess of demand and products for public infrastructure are unavailable. Meanwhile, the above regulations restrain the application scope of recycling products, which hinders the actual application.

  - **Lack of completed standards for recycled CDW products**

    Although the production standards are generally complete, the corresponding evaluation and product certification standards for recycled CDW products are incomplete and insufficient, which prevents construction units from judging the current products correctly, resulting in reduced use of recycled CDW products.

  - **Lack of price competitiveness for recycled CDW products**

    Screening, crushing and other relative treatment processes are needed for the recycled CDW products, which increases the labor and relative processing costs. Also, the promotion costs are rising considering the lack of subsidies, which decreases the price competitiveness of recycled CDW products.

  - **Traditional conception hinders the use of recycled CDW products**

    Recycled CDW products are mainly recycled aggregate, recycled brick, and recycled concrete, which illustrates the products characteristics well. But this kind of nomenclature is not in accordance with any current standards, which increases the engineering difficulties. Also, developers do not agree to use words like “recycled” and “garbage” when describing construction materials, as it is unacceptable for the public and may influence the sales of houses.

3.4 **Analysis of Obstacles to Market Promotion of CDW Recycling in the PRC**

Based on the above analysis, the obstacle to market promotion of CDW recycling comes from various parts of the industrial chain, involving not only influences of macro-level policies, but also micro-level problems arising in the development of enterprises. In such a context, the following analysis of market obstacles reviews the elements of the industrial chain and analyzes obstacles of market promotion existing therein from the perspective of the whole industrial chain of CDW recycling.
3.4.1 Source Generation of Construction Wastes

There is no effective legal regulation on collection of construction wastes. The existing laws and regulations in the PRC have not taken account of the issue of construction waste collection and recovery and only contain principles and general requirements on energy conservation, environment protection, low carbon or some general requirements on collection, transportation or recycling of construction wastes. Due to absence of punishment measures, the cost of illegal dumping of construction wastes is very low, not only producing negative impacts on the enthusiasm of government officials, developers and clients toward construction waste recycling, but also unable to provide effective assurance of material supply for construction waste recycling enterprises.

There are no official statistical data of construction waste production. The PRC has set up periodical statistics reporting system for urban domestic wastes and statistical data in this regard is available even from the national statistical yearbooks. However, calculation of construction waste volume still relies on formula. Construction wastes generated from new buildings are estimated based on building area, but there is no way to obtain the statistical data of construction wastes from demolition of existing buildings and decoration and repair. Absence of such data leads to the absence of a comprehensive planning and development strategy at the national, provincial and even municipal level to drive the development of construction waste recycling as a sector and further leads to the absence of effective data support to the corresponding supporting policies.

There is no corresponding tariff system and surveillance system for construction wastes. According to the Stipulations on Management of Urban Construction Wastes in the PRC, construction waste disposal shall follow the tariff regime and the tariff standard should be based on respective national stipulations. In actual implementation, there is no specific tariff determination guidance and standards and the local governments do not have a uniform standard to implement. In addition, since these are not mandatory requirements, they are not enforced in many places. In contrast, such regimes are available overseas in countries known for high rate of construction waste recycling. In Denmark, for example, a landfill tax of CNY 473 / ton and six other taxes, including carbon tax and waste heat tax, with a total tax amount of CNY 1200 / ton, are levied; the UK levies differential landfill taxes of GBP 2.65/ton (inactive waste) and GBP 84.4/ton (active waste). Without a corresponding solid waste tariff system and price regulation system, the enterprises have to determine their own prices not subject to a sector-wide price regulation and management. As a result, the market is in chaos, obviously not favourable to the development of construction waste recycling enterprises with economic benefits.

3.4.2 Classification and Collection of Construction Wastes

There are no management methods and supervisory mechanism for construction waste classification. According to the Stipulations on Management of Urban Construction Wastes in the PRC, residents should separately collect and stockpile at designated sites the construction wastes generated in the course of house decoration and repair and domestic solid wastes; the construction companies should remove and transport construction wastes generated during construction out of the site in a timely manner. No specific requirement is included in the Stipulations on classification of demolition wastes. In actual operation, without specific rules of implementation, construction wastes are usually stockpiled in an uncontrolled manner and even transported to and dumped at places without supervision at night. Due to the absence of
effective classification, construction waste recycling enterprises have no access to fully assured supplies of materials, some of which need multiple screening and classification, implying increase of cost for the recycling enterprises.

The PRC still needs further efforts in research and development of construction waste classification technology and equipment. Workers engaged in construction waste classification and sorting in the PRC are under qualified and using relatively primitive technology with poor awareness of environmental protection. As a result, classification operation does not meet the respective requirements, increasing cost of production and processing in the later stage; and on the other hand, due to the limited development of technology in the PRC, most of the sorting equipment relies on import or joint venture, representing, to a certain extent, an increase of cost for construction waste recycling enterprises.

3.4.3 Transportation and Treatment of Construction Wastes

There is no market-oriented pricing mechanism for the transportation cost. On one hand, the reality is that most of the transportation operators are SMEs, which, for the sake of self-interest, takes a random pricing attitude and the low and unfair prices can easily lead to malign market competition and uncontrolled dumping; on the other hand, transportation prices in a great majority of the places have not been changed and adjusted for decades along with market changes and, as a result, the transportation enterprises, often in a state of margin profit or deficit, resulting in uncontrolled dumping at the nearest location for greater economic return.

There is no a sound construction waste transportation management mechanism. In the PRC, at the local level, construction waste transportation management is undertaken by multiple government authorities, resulting in ambiguous management boundary and prevarication among concerned authorities and poor management efficiency and unclearly defined responsibilities. In particular, no effective surveillance and management can be achieved over the illegal transportation vehicles in existence. In Japan, for example, there is a voucher system with a septuplicate voucher. The industrial waste discharger keeps Page A after the necessary information is registered while Page B1, B2, C1, C2, D and E are given to the collection and transportation operators. The collection and transportation operators keep Page B1 and hand over the wastes and Page C1, C2, D and E to the treatment operator while Page B2 is returned to the waste discharger within 10 days after the transportation is completed. The treatment operator keeps Page C1 and returns Page C2 to the collection and transportation operators and Page D to the discharger within 10 days after the treatment is completed. If final treatment is implemented, Page E of the voucher will also be returned to the discharger.

3.4.4 Construction Waste Recycling and Treatment

Supportive effect of the financial incentive system is not obvious. In order to reduce cost for construction waste recycling enterprises, the Chinese government formulated a series of preferential policies on value-added tax, business tax and income tax levied on construction waste recycling enterprises. However, the reality now is that few enterprises benefit from these preferential policies.

The reasons that few enterprises benefit from the preferential VAT policy are that, first, it is hard to define, in actual operation, the percentage of materials of a recycled products and there are no corresponding operation methods and instructions to follow in the actual operation; and, secondly, VAT deduction becomes unlikely since most of the acquirers or buyers of construction waste materials are local government management bodies or the respective public institutions that are unable to produce VAT invoices.

The reason that few enterprises benefit from the preferential policies on income tax and business tax is that a relatively high threshold is set for assessment of enterprises enjoying the income tax and business tax preferential policy. It is a mandatory requirement that such enterprises must own patents and inventions with independent intellectual property right and need to assure yearly input in continuous R&D issues. Few enterprises in an emerging sector of construction waste recycling can satisfy such requirements, thus few finally benefiting from these policies.

(1) Preferential VAT Policy

It is stipulated in the Notice by MOF and SAT on Printing and Issuing the “Catalog of Products and Labor Services of Comprehensive Resource Utilization Entitled to Preferential VAT Policy” (MOF Tax Document No. [2015]78) that:

- Solid wastes (including construction wastes): Bricks and tiles (excluding fired common bricks), building blocks, ceramicite, wall panels, tubes (tubular piles), concrete, mortar, road well lids, road guardrails, fireproof materials, refractory materials (excluding magnesite-chrome bricks), heat-insulating materials, mineral (rock) wools, glass ceramic, U-shaped glass may enjoy the VAT refund-upon-levy policy at a refund rate of 70% if more than 70% of the product materials originate from the above-listed resources.

- Building (structure) wastes, construction sand and aggregates: Products with more than 90% of their materials originating from the listed resources and the products made of building (structure) wastes and complying with
the technical requirements specified in “Recycled Coarse Aggregates for Concrete” (GB/t25177-2010) or “Recycled Fine Aggregates for Concrete and Mortar” (GB/t25176-2010) may enjoy the VAT refund-upon-levy policy at a refund rate of 50%.

- Solid waste treatment and disposal service may enjoy the VAR refund-upon-levy policy at a refund rate of 70%.

(2) Income Tax and Business Tax Preferential Policy

It is stipulated in the Notice by MOF, SAT and MOST on Revising and Issuing the “Management Methods for Assessment of High and New Technology Enterprises” (MOST Fahuo Doc. No. [2016]32) that enterprises complying with the conditions for assessment of high and new technology enterprises may enjoy the following preferential tax policies:

- Small low-profit enterprises complying with the specified conditions shall enjoy tax reduction and pay enterprise income tax at a tax rate of 20%.

- Hi-tech enterprises included in the national program of focused supports shall enjoy tax reduction and pay enterprise income tax at a tax rate of 15%.

- Weighted deduction of R&D expenses means that 50% of the R&D expenses incurred by enterprises from development of new technologies, new products and new processes may be subject to weighted reduction provided that no intangible assets are formed and included in the current period profit and loss and such expenses are deducted according to the respective stipulations; if intangible assets are formed, such expenses shall be amortized at 150% of the intangible assets.

- Technology development, technology transfer and technological consulting contracts that have been registered by an enterprise as technological contracts may be exempted from business tax.

The construction waste recycling sector has not been assigned in a reasonable position. The construction waste recycling sector is currently included under the “construction material” industry. However, considered as a part of the high energy-consumption and polluting industry during the planning and land approval process, the sector is faced with obstacles in the process of project land approval, EIA and project approval, resulting in relatively high cost of early-stage siting and review and approval. In addition, the absence of effective data support for calculation of the comprehensive benefits and quantitative assessment of the environmental and social benefits of the construction waste recycling sector also makes it unlikely to precisely determine the position of this sector.

Construction waste recycling enterprises are managed in a rather extensive manner. Construction waste recycling enterprises in the PRC are mostly transformed from former transportation companies, solid waste landfill enterprises and do not have the management concepts and regimes of a modern enterprise. The extensive enterprise management practices do not only make product cost control difficult, but also affect, to a certain degree, sales of products.

3.4.5 Utilization of Recycled CDW Products

Recycled CDW products do not have competitive market prices. As analysed above, although the prices of some recycled CDW products are lower than ordinary construction material products, the price of most such products are higher than ordinary products. As a result, many construction waste recycling enterprises have to rely on governmental subsidy to survive and have not found a path of market-oriented development. Promoting the market price of recycled CDW products should be considered from the perspective of the full process and whole industrial chain of construction waste recycling. In addition, the cost of recycled CDW products can also be reduced to a certain extent through regulating the management and tariff collection system of all the stages.

The recycled CDW products do not enjoy high level of market acceptance. In order to drive the application of recycled CDW products, many provinces and municipalities in the PRC launched incentive measures to expand the application of such products, including the establishment of the recycled CDW product identification system and the inclusion of such products into the catalogue of recommended construction materials, the catalogue of green government procurement products as well as government-financed public infrastructure construction projects (including road, gardening and landscaping, public toilet, garbage building, footpath and river slope protection projects). However, since these measures are incentives, in order to avoid engineering risks, many clients and developers still choose conventional construction materials. Furthermore, without corresponding testing standards and demonstrative projects of extensive application, recycled CDW products encounter obstacles in the process of extension and low level of market acceptance.
4 Economic Analysis of the PRC CDW Recycling Market Failure

4.1 Methods of Economic Analysis

The economic analysis under this Study is carried out by means of empirical analysis and whole industrial chain comparative analysis.

Empirical analysis is one of the methods of social science research that conducts theoretical reasoning and explanations based on current social or academic reality and using examples and experiences. This Study, having taken account of the status quo of the construction waste market in the PRC where there is a shortage of basic sector data, conducts an empirical analysis of individual cases of fixed crushing construction waste recycling technology, mobile crushing construction waste recycling technology and construction waste recycling technology and processing and analysis of the empirical data considering the characteristics of the construction waste recycling sector in order to identify the economic law of development as well as the fields of market failure of the construction waste recycling market in the PRC.

Whole industrial chain comparative analysis studies the influence of exogenous variables on endogenous variables and analyzes and compares different economic values on the basis of development and change of the whole industrial chain as a feature of technology. This Study compares the economic indices of various construction waste recycling treatment technologies, construction waste recycling utilization technologies and general landfill technologies from the perspective of the whole industrial chain to analyze and judge the general economic value of different technologies in the whole life cycle.

Economic analysis is carried out in the following steps:

1. Analysis of cost elements of construction waste recycling technology: the cost elements of construction waste generation and sorting, construction waste removal and transportation, construction waste digestion and construction waste beneficial use are analyzed from the perspective of the whole production process construction waste recycling.

2. Analysis of costs of different construction waste recycling technologies and CDW landfill: costs are calculated by means of standardized processing of data sampled from the individual cases of fixed crushing construction waste recycling, mobile crushing construction waste recycling and construction waste landfill.

3. Cost benefit analysis: benefits of different construction waste recycling technologies as well as CDW landfill are calculated by assuming the prices of recycling products and conventional construction material products. The environmental benefits and social benefits of construction waste recycling from the sector perspective are analyzed.

4.2 Whole Industrial Chain Cost Elements of Construction Waste Recycling Technology

Costs of recycled CDW products are closely linked with the recycling production processes. Rooted in the processes of the whole industrial chain of construction waste recycling, this Study analyzes the cost elements of products of various stages of the process of construction waste generation and sorting, construction waste removal and transportation, construction waste digestion and construction waste recycling.

4.2.1 Costs of Construction Waste Sorting

Based on the sources of generation, construction wastes are classified into five groups, namely, land excavation wastes, road excavation wastes, old building demolition wastes, building construction wastes and construction material production wastes and mainly comprise of debris, crushed stone, waste mortar, crushed bricks and tiles, concrete blocks, asphalt blocks, waste plastics, waste metal and waste bamboo and wood. Therefore, it is necessary to improve sorting of the various types of construction wastes in the course of construction waste generation so as to cut the costs of future treatment of construction wastes.

Construction waste sorting costs consist of cost of labor, cost of sorting equipment and, in some cases, cost of utilization of localized crushed construction wastes. Such costs are usually borne by the recycled CDW product manufacturers and may be included if the recycled products manufacturers need to purchase sorted construction waste as raw materials.
4.2.2 **Cost of Construction Waste Removal and Transportation**

Construction waste removal and transportation is achieved by three means, namely: removal and transportation by the construction waste producer, removal and transportation by specialized transportation companies and door-to-door collection and transportation by construction waste recycling enterprises. Transportation cost is the major component of the cost of removal and transportation by the construction waste producer, but in the case of removal and transportation by specialized transportation companies and door-to-door collection and transportation by construction waste recycling companies, cost of construction waste removal is also included, apart from transportation cost.

Price of construction waste transportation is determined by enterprises engaged in construction waste removal and transportation and the cost of construction waste transportation comprises of kilometer cost, time cost and direct transportation cost. Here shown in the table below are the transportation cost data of construction waste transportation vehicles of Beijing Yunanda Transportation Company involved in the study (the transportation time is 23:00 – 6:00 and the average speed of the whole transportation process is 50km/hour):

<table>
<thead>
<tr>
<th>Load capacity</th>
<th>Average number of trips per night</th>
<th>Average kilometer per trip</th>
<th>Transportation cost per kilometer</th>
<th>Transportation cost per hour</th>
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<tr>
<td>25t</td>
<td>8</td>
<td>20</td>
<td>9.1</td>
<td>0.12</td>
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<td></td>
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<td>Fuel cost</td>
<td>Vehicle maintenance cost</td>
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<td></td>
<td>Driver salary</td>
<td>Depreciation</td>
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<td>34</td>
<td>40</td>
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<td>Overhead</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Source: study data from Beijing Yunanda Transportation Company</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on the table above, assuming that the aforesaid conditions are met, i.e., the vehicle has a load capacity of 25 tons, conducts 8 trips per night on average with a single trip distance of 20km, achieves a transportation distance of 160km in an 8-hour working time, the transportation cost of construction waste per ton is calculated as follows:

<table>
<thead>
<tr>
<th>Fuel cost</th>
<th>Vehicle maintenance cost</th>
<th>Driver salary</th>
<th>Depreciation</th>
<th>Overhead</th>
<th>Total cost</th>
<th>Cost per kilometer per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>1456</td>
<td>19.2</td>
<td>272</td>
<td>320</td>
<td>32</td>
<td>2099.2</td>
<td>0.5248</td>
</tr>
</tbody>
</table>

Currently there is no universal pricing standard and tariff requirement on construction waste removal and transportation and the construction waste tariff contents, standards and regimes of the various provinces and cities are largely different. Here shown as follows are data collected from the study of the concerned provinces and cities:

<table>
<thead>
<tr>
<th>Beijing</th>
<th>Shanghai</th>
<th>Rizhao</th>
<th>Qingdao</th>
<th>Kunming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of construction waste transportation is CNY 6.00/ton with a haulage of less than 6km and CNY 1.00/ton with a haulage of more than 6km.</td>
<td>The base price of construction debris transportation is CNY 0.90/ton, with a fluctuation of ±10%.</td>
<td>Cost of transportation is CNY 8.00/ton with a haulage of less than 5km (including 5 km), CNY 11.00/ton with a haulage of 5km to 10km (including 10km) and CNY 13.00/ton with a haulage of more than 10km.</td>
<td>Cost of transportation is CNY 23.03/ton with a haulage of less than 10km and increases by CNY 0.95/ton per km when the haulage is greater than 10km.</td>
<td>The cost of transportation of construction wastes (debris, waste materials and other wastes generated from reconstruction and expansion activities by organizations and residents) is CNY 150/ton.</td>
</tr>
</tbody>
</table>
Data source: The data source for Beijing is the "Table of Solid Waste and Debris Removal, Transportation and Digestion Tariff in Beijing" while that for Shanghai is the "Stipulations on Transportation of Debris in Various Districts of Shanghai". The data sources for Rizhao, Qingdao and Kunming are respectively the Request for Adjustment or Extension of the Tariff Standard of Urban Construction Waste Disposal", the "Notice by Qingdao Municipal Price Bureau, Finance Bureau and Gardening and Sanitation Bureau on Adjusting the Solid Waste Removal and Transportation Tariff Policies" and the "Notice on Adjusting the Domestic Solid Waste Treatment Tariff Standard in Kunming City".

In addition, the PRC usually adopts fixed rate tariff system for removal and transportation of residential decoration and construction wastes, meaning that such tariff is collected from individual households based on flat rate determined by the government. Here shown as follows are the survey data of the concerned provinces and cities:

### Table 4-4 Survey of Residential Decoration and Construction Waste Transportation Cost in the PRC

<table>
<thead>
<tr>
<th></th>
<th>Beijing</th>
<th>Shanghai</th>
<th>Changzhou</th>
<th>Lijiang</th>
</tr>
</thead>
<tbody>
<tr>
<td>The cost of decoration waste transportation is CNY 200 per household with a decoration area of less than 100m² and CNY 300 per household with a decoration area of 100m² to 150m².</td>
<td>Construction waste removal and transportation fee for residences with a unit area of less than 55m² (inclusive) is charged against the unit area with a ceiling price of CNY 300 for first decoration and CNY 360 for non-first decoration. For residences with a unit area of more than 55m², an additional removal and transportation fee will be charged based on the additional area.</td>
<td>Tariff for construction waste generated from residential decoration is charged at a rate of CNY 3 per ton while that for street shops is charged at a rate of CNY 5 per ton.</td>
<td>Tariff for residential construction waste dumped by the residents on their own is charged at a rate of CNY 20 per ton while that for construction waste dumped by sanitation authorities on behalf is charged at a rate of CNY 40 per ton.</td>
<td></td>
</tr>
</tbody>
</table>

Data source: Data for Beijing is sourced from the survey data provided by the Municipal Administration and City Image Committee; data for Shanghai is sourced from the "Notice on Regulating Tariff of Removal and Transportation of Non-domestic Waste Generated by Residents"; data for Changzhou is sourced from the survey data provided by the Housing and Urban-rural Construction Bureau; data for Lijiang is sourced from the "Notice on Regulating the Standard for Tariff of Construction Waste Digestion and Disposal in the Old City".

### 4.2.3 Cost of Construction Waste Management Sites

The construction cost of construction waste management sites consists of fixed asset investment and current fund. The fixed asset investment mainly covers land cost of construction waste processing sites, cost of plant area facilities and leveling, cost of comprehensive construction, cost of office equipment purchase, cost of purchase of equipment for beneficial treatment of construction wastes and contingencies of site construction.

### 4.2.4 Cost of Beneficial Management of Construction Wastes

There exists considerable difference in the disposal costs of different construction waste treatment technologies and, based on the complexity of material availability, some may need sorting and crushing, screening in the early stage while some others allow direct production of the recycled products. Technologies in common use nowadays include fixed treatment and mobile treatment. Fixed treatment refers to the treatment method at fixed sites and using fixed workshops, fixed plants and relatively fixed equipment for construction waste recycling; mobile treatment refers to localized treatment of construction wastes at the treatment site and using mobile equipment. Costs in the crushing process include cost of material procurement, cost of equipment, cost of fuel and power, cost of labour and cost of equipment maintenance.
After crushing, depending on different production processes, regenerated aggregates, regenerated concrete products, regenerated bricks among many other products may be produced from construction wastes and the costs involved therein include cost of production process equipment, cost of fuel and power, cost of labor and cost of equipment maintenance, etc., plus the cost of additional raw materials (e.g. cement) required to make products such as concrete.

4.3 Cost Calculation and Comparative Analysis of Construction Waste Recycling Technology and Landfill Technology

4.3.1 Notes on Restrictive Conditions of Cost Calculation

Construction waste recycling technologies are by large manifested in specific construction projects. Therefore, in this part of the analysis, in order to take data availability into account, the cost elements of traditional construction projects are selected, i.e. fixed asset cost and operational cost (fixed cost and variable cost). Fixed asset cost includes workshop construction cost, land cost, equipment cost, while operational cost includes labour cost, fuel and power cost, material procurement cost, asset and equipment depreciation cost and other expenses (risk cost, sales cost, overhead and other material expenses, etc.). In fact, the above cost elements are the same as the whole industrial chain cost elements described in Section 4.2 and the only difference is the categorization method. This Study attempts to identify existing obstacles from the perspective of whole industrial chain of construction waste recycling through project analysis.

Since the construction waste recycling technology projects subject to analysis are located in different cities and different regions and use different treatment technologies and equipment purchased from different channels, there exists relatively large difference in the cost of these technologies. In addition, the construction waste recycling sector does not have a data base for cost analysis and economic analysis. In this Study, the empirical analysis method is adopted to analyse fixed crushing construction waste recycling manufacturers in Shaanxi Province and mobile crushing construction waste recycling manufacturers in Yunnan Province and also a number of specific case studies of construction waste landfills in Shenzhen. In order to increase the data comparability of different regions, in this Study, the two elements influencing cost due to regional difference are normalized, specifically including:

- Land price: At present, the PRC requires all construction waste recycling enterprises and construction waste landfills to be located on industrial land. Based on the “National Standard for Lowest Transfer Price of Industrial Land”, industrial land in the PRC is divided into five grades, with different lowest price standards specified for different grades as shown in the table below in detail. The land price under this Study is Grade VIII average price in the middle, i.e. CNY 252.

<table>
<thead>
<tr>
<th>Land grade</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest price standard</td>
<td>840</td>
<td>720</td>
<td>600</td>
<td>480</td>
<td>384</td>
<td>336</td>
<td>288</td>
<td>252</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Land grade</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
<th>XIII</th>
<th>XIV</th>
<th>XV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest price standard</td>
<td>204</td>
<td>168</td>
<td>144</td>
<td>120</td>
<td>96</td>
<td>84</td>
<td>60</td>
</tr>
</tbody>
</table>

- Labour cost: There exists remarkable difference in the employee salary costs of the construction waste recycling enterprises and construction waste landfills in different regions in the PRC. In this Study, the average labour cost of the construction sector of the PRC is used as the base of calculation. According to the Statistical Yearbook of 2015 of the PRC, the yearly average salary of employees of urban organizations in the construction sector of the PRC for Year 2014 is CNY 45,804. CNY 60,000/year/person was used in this Study considering the increase of labour cost with time.

4.3.2 Cost Calculation of Construction Waste Recycling Technology

Since no financial data are available for the construction waste recycling sector in the PRC, in this Study, a survey has been carried out of the cost of a fixed crushing construction waste recycling manufacturer in Shaanxi Province and a mobile crushing construction waste recycling manufacturers in Yunnan Province. The assumptions are compared and processed to reflect, to a certain extent, the cost element characteristics of the sector as a whole.
### Table 4-6 Cost Assumption Analysis of Construction Waste Recycling Products

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Fixed crushing technology</th>
<th>Mobile crushing technology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic assumptions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDW treatment capacity</td>
<td>2 million ton / year</td>
<td>1 million ton / year</td>
</tr>
<tr>
<td>Working time</td>
<td>300 days/year, 8 hours/day</td>
<td>220 days/year, 8 hours/day</td>
</tr>
<tr>
<td>Service life</td>
<td>15 years</td>
<td>15 years</td>
</tr>
<tr>
<td>Product mix</td>
<td>32% recycled aggregates, 15% pre-mixed recycled concrete, 45% recycled bricks, 8% residuals (disposal in landfills)</td>
<td>95% recycled aggregates, 0.0024% recovered metals, 5% residuals (disposal in landfills)</td>
</tr>
<tr>
<td><strong>Fixed assets cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workshop construction cost</td>
<td>Involving a workshop construction cost of approximately CNY 3000/m² and a construction area of 3000 m²</td>
<td>Involving no construction of workshops.</td>
</tr>
<tr>
<td>Land cost</td>
<td>Involving a total land occupation of 150mu, with 55 mu for buildings and structures, 15mu for finished product stockpiling site, 15mu for material stockpiling and 65mu for other purposes.</td>
<td>Involve no land cost.</td>
</tr>
<tr>
<td>Equipment cost</td>
<td>Feeder machine, crushing machine, sieving machine, loading machine, washing machine, etc.</td>
<td>Feeder machine, crushing machine, sieving machine, loading machine, washing machine, diesel generator</td>
</tr>
<tr>
<td><strong>Fixed costs per year</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset and equipment</td>
<td>Cost of fixed asset depreciation, such as houses and equipment</td>
<td>Cost of fixed asset depreciation, such as houses and equipment</td>
</tr>
<tr>
<td>depreciation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor cost</td>
<td>Involving 100 permanent staffs, including factory manager, electrician, loader driver, operator, etc.</td>
<td>Involving 20 permanent staffs, including factory manager, electrician, loader driver, operator, etc.</td>
</tr>
<tr>
<td>Fuel and power cost</td>
<td>Electricity consumption, loader fuel consumption, water consumption, etc.</td>
<td>Fuel consumption for diesel generator and loader, water consumption, etc.</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>Cost of operation and maintenance</td>
<td>Cost of operation and maintenance</td>
</tr>
<tr>
<td>Others</td>
<td>Risk cost, marketing cost, overhead and other material costs</td>
<td>Risk cost, marketing cost, overhead and other material costs</td>
</tr>
<tr>
<td><strong>Variable costs per year</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material purchase costs</td>
<td>Including materials costs (consumables) for CDW sorting, transportation, recycling and sending to landfills, and the cost of materials used for manufacturing recycled CDW products (e.g. cement).</td>
<td>Including materials costs (consumables) for CDW sorting, recycling and sending to landfills.</td>
</tr>
</tbody>
</table>

Based on the cost assumptions and analysis conditions in Table 4-6, the total annual cost and unit cost for fixed crushing process and movable crushing process are analysed in Table 4-7 below.

### Table 4-7 Cost Estimation of Construction Waste Recycled Products

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Fixed Crushing Technology</th>
<th>Mobile Crushing Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed investment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workshop construction cost</td>
<td>CNY 55.2 million, including CNY 38 million for building construction, CNY 6.4 million for other construction works and CNY 10.8 million for physical contingency</td>
<td>0</td>
</tr>
</tbody>
</table>
### Table 4-8 Cost Assumptions Analysis of Construction Waste Landfill Disposal Technology

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Cost Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic assumptions</td>
<td>Landfilling capacity 2 million tons/year</td>
</tr>
<tr>
<td></td>
<td>Working time 300 days/year, 8 hours/day</td>
</tr>
<tr>
<td></td>
<td>Service life 15 years</td>
</tr>
<tr>
<td>Fixed investment</td>
<td>Workshop cost Office building with an area of approximately 1000m²</td>
</tr>
<tr>
<td></td>
<td>Plant infrastructure construction Cost of pit excavation and infrastructure treatment in plant area</td>
</tr>
<tr>
<td></td>
<td>Land cost With a land occupation area of 860,000m² allocated by government involving no land cost</td>
</tr>
<tr>
<td></td>
<td>Equipment cost Bulldozer, roller, excavator, water truck and road cleaner</td>
</tr>
<tr>
<td>Fixed costs per year</td>
<td>Annual depreciation and maintenance of assets and equipment Depreciation of fixed assets such as buildings, equipment</td>
</tr>
<tr>
<td></td>
<td>Labor cost 20 persons</td>
</tr>
<tr>
<td></td>
<td>Energy consumption cost Electricity consumption, water consumption, fuel consumption, etc.</td>
</tr>
<tr>
<td></td>
<td>Maintenance cost Cost of operation and maintenance</td>
</tr>
<tr>
<td></td>
<td>Others Risk cost, marketing expenses, overhead and other material costs</td>
</tr>
<tr>
<td>Variable costs per year</td>
<td>Material purchase costs Transportation cost (CNY 0/ton),</td>
</tr>
</tbody>
</table>

#### 4.3.3 Cost Calculation of Construction Waste Landfill Disposal

Since no financial data available for the sector of construction waste landfill disposal in the PRC, in this Study, a survey is carried out of the cost of a construction waste landfill site in Shenzhen and the assumptions are made correspondingly to reflect, to a certain extent, the cost element characteristics of the sector as a whole.
Based on the cost assumptions and analysis conditions in Table 4-9, where the average prices currently in force in the PRC for land and labor cost are adopted and the actual data of the study samples of Shenzhen are adopted for the other cost items. The technological costs are calculated using both the static and dynamic methods, both of which take account of the total cost and per ton treatment cost within the 15-year service life of the technology. Calculation details are shown in the table below:

Table 4-9 Cost Estimation of Construction Waste Landfill Disposal Technology

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Cost Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed investment</td>
<td></td>
</tr>
<tr>
<td>Workshop cost</td>
<td>CNY 0.3 million</td>
</tr>
<tr>
<td>Plant infrastructure construction</td>
<td>CNY 1.20 million</td>
</tr>
<tr>
<td>Land cost</td>
<td>CNY 0 million</td>
</tr>
<tr>
<td>Equipment cost</td>
<td>CNY 10.0 million</td>
</tr>
<tr>
<td>Fixed costs per year</td>
<td></td>
</tr>
<tr>
<td>Annual depreciation cost of assets and equipment</td>
<td>CNY 0.77 million</td>
</tr>
<tr>
<td>Labor cost</td>
<td>CNY 1.2 million</td>
</tr>
<tr>
<td>Energy consumption cost</td>
<td>CNY 0.50 million</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>CNY 0.03 million</td>
</tr>
<tr>
<td>Other costs</td>
<td>CNY 1.80 million</td>
</tr>
<tr>
<td>Variable costs per year</td>
<td></td>
</tr>
<tr>
<td>Material purchase costs</td>
<td>CNY 0</td>
</tr>
<tr>
<td>Total on annual basis</td>
<td></td>
</tr>
<tr>
<td>Subtotal of total cost (excluding fixed investment)</td>
<td>CNY 3.53 million</td>
</tr>
<tr>
<td>Subtotal of total cost (including fixed investment)</td>
<td>CNY 4.30 million</td>
</tr>
<tr>
<td>Cost per ton of final product (excluding fixed investment)</td>
<td>CNY 1.77/ton</td>
</tr>
<tr>
<td>Cost per ton of final product (including fixed investment)</td>
<td>CNY 2.15/ton</td>
</tr>
</tbody>
</table>

4.3.4 Comparative Analysis of Costs of Construction Waste Recycling Technology and Landfill Disposal Technology

Based on above analysis, total costs and unit costs of construction waste recycling technology and landfill disposal technology are shown in table below.

Table 4-10 Comparative Analysis of Costs of Construction Waste Recycling Technology and Landfill Disposal Technology

<table>
<thead>
<tr>
<th>Contents</th>
<th>Construction waste recycling technology</th>
<th>Construction waste landfill disposal technology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fixed (2 million ton/year)</td>
<td>Mobile (1 million ton/year)</td>
</tr>
<tr>
<td>Total cost per year (without depreciation)</td>
<td>CNY 237.8 million</td>
<td>CNY 4.74 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CNY 3.53 million</td>
</tr>
<tr>
<td>Total cost per year (including depreciation)</td>
<td>CNY 248.8 million</td>
<td>CNY 5.64 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CNY 4.30 million</td>
</tr>
<tr>
<td>Cost per ton CDW (without depreciation)</td>
<td>CNY 118.9/ton</td>
<td>CNY 4.74/ton</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CNY 1.77/ton</td>
</tr>
<tr>
<td>Cost per ton CDW (with depreciation)</td>
<td>CNY 124.4/ton</td>
<td>CNY 5.64/ton</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CNY 2.15/ton</td>
</tr>
</tbody>
</table>

We may find from the table above that:

(1) The construction waste landfill disposal technology enjoys better cost advantage than the construction waste recycling technology. It can be seen from the comparative analysis in Table 5-10 that, thanks to the presence of such price advantage, a remarkable number of construction waste generation clients and some local governments are willing to select landfill disposal technology that is simple in terms of both technology and work procedure for treatment of construction wastes so as to avoid the large investment at the initial stage.
Table 4-11 Comparative Analysis of Costs of Construction Waste Recycling Technology and Landfill Disposal Technology

<table>
<thead>
<tr>
<th>Cost contents</th>
<th>Construction waste recycling technology</th>
<th>Construction waste landfill disposal technology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fixed</td>
<td>Mobile</td>
</tr>
<tr>
<td>Fixed cost</td>
<td>Workshop construction cost</td>
<td>Remarkably big area and high cost</td>
</tr>
<tr>
<td></td>
<td>Equipment cost</td>
<td>Complicated treatment and production process and high cost</td>
</tr>
<tr>
<td></td>
<td>Material procurement cost</td>
<td>Including sorting, sieving and transportation costs; high cost</td>
</tr>
<tr>
<td></td>
<td>Land cost</td>
<td>Industrial land cost</td>
</tr>
<tr>
<td>Operational cost</td>
<td>Labor cost</td>
<td>Requiring a large staff and high technical qualification requirements; high cost</td>
</tr>
<tr>
<td></td>
<td>Fuel and power cost</td>
<td>Involving a large number of workshop equipment, high cost</td>
</tr>
<tr>
<td></td>
<td>Annual depreciation and maintenance cost of assets and equipment</td>
<td>A large number of equipment; high cost</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>High level of management complexity; high cost</td>
</tr>
</tbody>
</table>

(2) The construction waste recycling technology enjoys better advantages on economic benefits than the ordinary landfill technology. In fact, compared with the construction waste landfill technology, the construction waste recycling technology involves corresponding added value generated from the additional land cost and equipment cost, etc., meaning that different types of recycled products, including recycled aggregates, recycled concrete products and recycled tiles, can be produced and the recycled products can achieve their economic benefits through marketing, which, however, is not what the construction waste landfill disposal technology can achieve.

4.4 Benefit Analysis of Construction Waste Recycling Technology

4.4.1 Analysis of Economic Benefits of the Construction Waste Recycling Technology

(1) Revenue Calculation of Construction Waste Recycling Technology

It is indicated in the study of the Shaanxi-based construction waste recycling manufacturer adopting fixed crushing technology (2 million ton/day) and the Yunnan-based construction waste recycling manufacturer adopting mobile crushing technology (1 million ton/day) that the final products of construction waste recycling of these manufacturers include recycled aggregates, pre-mixed recycled concrete, recycled concrete products. The recycled concrete products include wall bricks, building blocks, and road bricks, curb bricks, vegetated bricks of recycled concrete. Yearly revenue is shown in the table below:
Table 4-12 Revenue Analysis of Construction Waste Recycling Technology Products
(Fixed crushing equipment with 2 million ton/day capacity)

<table>
<thead>
<tr>
<th>Recycled product</th>
<th>Unit rate</th>
<th>Yearly production</th>
<th>Yearly sales revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled aggregates</td>
<td>CNY 25/ton (different size averaged)</td>
<td>640,000 ton</td>
<td>CNY 16 million</td>
</tr>
<tr>
<td>Pre-mixed recycled concrete</td>
<td>CNY 180/m³</td>
<td>300,000 m³</td>
<td>CNY 4 million</td>
</tr>
<tr>
<td>Recycled concrete product</td>
<td>CNY 168/m³ (averaged)</td>
<td>900,000 m³</td>
<td>CNY 151.2 million</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>CNY 221.2 million</td>
</tr>
<tr>
<td><strong>Revenue/ton CDW</strong></td>
<td></td>
<td></td>
<td>CNY 110.6/ton</td>
</tr>
</tbody>
</table>

Thanks to the easy mobility of the mobile production lines, the operations are usually implemented on sites of construction waste stockpiling and generation. Restricted by the components of construction wastes, great difficulty exists in controlling the performance of recycled aggregates. Therefore, recycled aggregates produced by mobile crushing lines are usually used for backfilling and fabrication of non-bearing bricks.

Table 4-13 Revenue Analysis of Construction Waste Recycling Technology Products
(Mobile Crushing Equipment with 1 million ton/day capacity)

<table>
<thead>
<tr>
<th>Recycled product</th>
<th>Unit rate</th>
<th>Yearly production</th>
<th>Yearly sales revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled aggregates</td>
<td>CNY 8/ton</td>
<td>950,000 ton</td>
<td>CNY 7.6 million</td>
</tr>
<tr>
<td>Scrap broken bar</td>
<td>CNY 1500/ton</td>
<td>24 ton</td>
<td>CNY 36,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>CNY 7.64 million</strong></td>
</tr>
<tr>
<td><strong>Revenue/ton CDW</strong></td>
<td></td>
<td></td>
<td><strong>CNY 7.64/ton</strong></td>
</tr>
</tbody>
</table>

(2) Cost/Benefit Analysis of Construction Waste Recycling Technology

Cost and benefit analysis of construction waste recycling technology are shown in the table below:

Table 4-14 Cost and Benefit Analysis of Construction Waste Recycling Technologies

<table>
<thead>
<tr>
<th></th>
<th>Construction Waste Recycling Technology</th>
<th>Fixed equipment</th>
<th>Mobile equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost (without depreciation)</td>
<td>CNY 118.9/ton</td>
<td>CNY 4.74/ton</td>
<td></td>
</tr>
<tr>
<td>Revenue</td>
<td>CNY 110.6/ton</td>
<td>CNY 7.64/ton</td>
<td></td>
</tr>
<tr>
<td>Net profit</td>
<td>CNY – 8.3/ton</td>
<td>CNY 2.9/ton</td>
<td></td>
</tr>
</tbody>
</table>

It can be seen that without subsidies and economic incentives, it is hard for fixed-type of CDW recycling facilities to make profit. And as a result, enterprises invested in fixed facilities will not be able to survive in the market. Meanwhile, mobile-type facilities could maintain certain economic benefits. However, due to the difficulties in land taking and limited type of final products, it is still very challenging to have achieve financial viability for mobile processing facilities.

(3) Comparative Analysis of Sales Prices of Construction Waste Recycled Products and Ordinary Products

Since the sector lacks data concerning construction waste recycled products, the analysis under the Study is conducted taking recycled concrete applied in a Beijing-based project as example. Prices in 2014 in Beijing are respectively CNY 45 / ton for natural sand, CNY 35 / ton for natural stone, CNY 50 / ton for recycled aggregates, CNY 440 / ton for cement and CNY 2.4 / kg for water reducer (liquid).
Table 4-15 Comparison of Sales Price and Cost of Recycled Concrete and Non-recycled Concrete

<table>
<thead>
<tr>
<th>Dosage Category</th>
<th>Water (kg)</th>
<th>Cement (kg)</th>
<th>Sand (kg)</th>
<th>Stone (kg)</th>
<th>Additive (kg)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original mix design at the mixing plant</td>
<td>170</td>
<td>325</td>
<td>688 (natural)</td>
<td>1031 (natural)</td>
<td>12.3</td>
<td>/</td>
</tr>
<tr>
<td>Mix design of recycled concrete</td>
<td>181</td>
<td>353</td>
<td>677(1/3 natural)</td>
<td>564 (natural) + 451 (recycled)</td>
<td>13.17</td>
<td>/</td>
</tr>
<tr>
<td>Cost of original mix design at the mixing plant (CNY)</td>
<td>0</td>
<td>143</td>
<td>31</td>
<td>36.1</td>
<td>29.5</td>
<td>239.6</td>
</tr>
<tr>
<td>Cost of mix design of recycled concrete (CNY)</td>
<td>0</td>
<td>155.3</td>
<td>19.2</td>
<td>42.29</td>
<td>31.6</td>
<td>248.39</td>
</tr>
<tr>
<td>Increase of sales price and cost (CNY)</td>
<td>0</td>
<td>12.3</td>
<td>-11.8</td>
<td>6.19</td>
<td>2.1</td>
<td>8.79</td>
</tr>
</tbody>
</table>

It can be concluded from the above analysis that recycled concrete involves a higher cost than ordinary concrete and the price is higher by CNY 8.79, accounting for 3.5% of the total sales price. However, cases may be different in different areas. For example, based on the latest data of June 2016 included in the Cost Information of Construction Projects in Beijing, the price of premixed concrete is CNY 320 / m³. While the price of pre-mixed recycled concrete, the product of the fixed construction waste recycling manufacturer in Shaanxi, is CNY 180/m³. Therefore, so far as the market is concerned, most of the recycled CDW products have higher prices than conventional construction material products, but some products in some regions do have lower prices than conventional construction materials, making premature to judge that the higher cost of recycled CDW products has become an obstacle to their market application.

(4) Analysis of Economic Benefits of Construction Waste Recycling Technology

- The above analysis shows that construction waste recycling technology generates marginal economic benefits. Without proper policies and instruments on subsidizing, it is very hard for all types of recycling facilities to be financially viable. Products of fixed treatment technology have better marketing advantage despite their higher investment cost than mobile treatment technology that is limited by process equipment.

- The financing costs of different types of enterprises have not been considered in the study, i.e. all the investment is considered made by the enterprises fully with their own capital. If such financing costs are taken into account, the economic benefits of both fixed and mobile technologies are expected to be lower, which is one of the obstacles to market application of construction waste recycling technology.

- According to the study, due to the absence of measures for mandatory dumping and transportation of construction wastes, there is not a stable source of materials for construction waste recycling enterprises, resulting in the absence of stability of revenue for enterprises engaged in, for example, fixed construction waste recycling and also bringing certain impacts on their market sustainability.

- Sales price in the market is not an obstacle influencing market application of recycled CDW products because there are occasions when their prices are lower than ordinary construction material products. It is more a factor of market acceptance of recycled CDW products. Their narrow application and the absence of a uniform quality certification and accreditation identification system in the sector cause some problems of marketing.

4.4.2 Analysis of Social and Environmental Benefits of Construction Waste Recycling Technology

Construction waste recycling technology enjoys relatively strong “economic externality” and very strong “positive externality”, i.e. the activities of a certain economic behavior benefits other individuals or society at no cost of any kind to the beneficiary. Such externality is reflected in the relatively strong environmental benefits and social benefits of construction waste recycling technology.
(1) Environmental Benefits

Nowadays, the PRC lacks analysis of the impacts of environmental emissions of individual construction waste recycling technology. However, macroscopic analysis still reveals the excellent environmental benefits of such technology. Stockpiling in open air or landfilling construction wastes in suburban areas without any prior treatment will not only generate high cost of solid waste removal and transportation and occupy a large area of land, but will also cause environmental pollution due to spillage, dust and ash and sand in the course of transportation and stockpiling. Corresponding recycling actions may alleviate environmental hazards and the specific environmental benefits include:

- Land occupation will be reduced. Calculated on the basis of a yearly construction waste generation of 3 billion tons in the PRC, each day, approximately 8.22 million tons of construction wastes are generated, with 2.2 ton per capita (based on a population of 1.368 billion), and each city produces approximately 4.56 million tons of construction wastes (based on a total number of cities of 657); assuming that the construction wastes are stockpiled in nature without corresponding actions and calculated on a stockpiling height of 5m, stockpiling 10,000 tons of construction wastes would require a land occupation of 2.5 mu, meaning that 750,000 mu, i.e. 500km², will be occupied each year and, on the assumption of a 100-year building life, the total urban area in the PRC will be fully covered by construction wastes in 300 years.

- Water pollution will be reduced. Leachate containing heavy load of water and calcium silicate, calcium hydroxide, sulfate ion and heavy metal ion will be generated from construction wastes leached by rain water on stockpile sites. Such leachate, if not controlled and flowing into rivers or permeated into the ground, will cause pollution to both surface water and ground water.

- Air pollution will be reduced. Waste gypsum in the construction wastes contains heavy load of sulfate ion, which is converted to hydrogen sulfide in anaerobic conditions while the waste paper boards and waste wood generate lignin and tannin in anaerobic conditions and are decomposed into volatile organic acid. Such hazardous gases will pollute the atmosphere.

- Soil pollution will be reduced. Hazardous substances contained in the construction wastes and their leachate cause pollution to soil, including changing physical structure and chemical properties of soil, influencing activity of microorganisms in soil and causing accumulation of hazardous substances in soil. Research shows that it takes decades for construction wastes in stockpiles to become stable and, even if the construction wastes are stabilized and no longer release hazardous gases and leachates no longer pollute environment, large area of land is still occupied by the massive inorganic substances, continuing generating permanent environmental problems.

- Comprehensive environmental benefits: if corresponding recycling measures are taken to the construction wastes, from 100 million tons of construction wastes, 36 million tons of mixtures and 10 million tons of recycled concrete aggregates can be produced, 15000 mu land for brick making and 2.7 million tons of coal can be saved and 1.3 million tons of CO2 can be reduced.

(2) Social Benefits

The social benefits of the construction waste recycling sector will emerge only when enterprises engaged in construction waste recycling grow and agglomeration and group effects arise in the sector. The PRC at present does not have a method for quantitative measurement of the social benefits and contribution by a certain enterprise, but what can be judged is that the growth of an enterprise is bound to lead to the progress of a sector and development of the national economy.

- Development of upstream and downstream industries of the construction sector will be facilitated.

Construction waste recycling is present in the full life cycle of a construction project from project initiation and approval, planning and design, construction, operational management, demolition, transportation and product application. Recycling does not only facilitate the whole industrial chain to carry out the production and construction activities according to the low carbon, environment-friendly and energy-saving requirements, but also drives full chain development of the construction industry.
• More jobs will be provided.

Construction waste recycling raises energy-saving and environment-friendliness requirements on each part of the full life cycle of a building and also incurs more needs for technological promotion and lean management, thus inevitably driving the industrial development of labour services, technological research and development, equipment manufacturing, product distribution linked with the early-stage sorting, crushing, transportation and recycling processes of construction wastes and, therefore, generating more jobs. According to a survey in the U.S., in the course of construction waste recycling, 168 additional jobs can be generated from each 100 work activities. Similarly, driving construction waste recycling will also bring more jobs in the PRC.

In summary, construction waste recycling enjoys outstanding comprehensive benefits and the government should develop corresponding policies and mechanisms to fix the market failure in this respect concerning the environmental and social benefits which, although likely to be large, cannot be accurately quantified at this stage.

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7 Sun L.X., Chen J.L., CDW Recycling and Reuse Existing Status and Benefit Analysis for Europe, Construction Technology, 2012, 43(7), 598-600
5 Comparison of Performance Criteria between Recycled CDW Products and Conventional Construction Materials

Currently, recycled CDW products in the PRC are mainly divided into 3 categories. One is recycled aggregate. Recycled aggregates can be used as raw material for concrete and mortar, and raw material for other various types of reuse products. Second is the environmental-friendly construction material. Both technology and market of using CDW materials for environmental-friendly construction materials are under rapid growth, the technique of producing recycled brick using CDW materials has become quite mature in the PRC. The third is road pavement material. According to the current reuse technologies and market demand for construction materials, using CDW materials for recycled aggregates, recycled concrete, recycled mortar, recycled brick and masonries is considered as more effective for resource utilization, and with higher added value to the renewable products, as well as economic benefits and environmental benefits. However, compared with natural construction material, recycled aggregate has certain performance criteria restrictions that limit its full replacement of natural material, as well as the promotion and development of reuse products, although the characteristics of its reuse products are generally the same as natural products. This section will describe recycled CDW products and evaluation of their economic benefits in following aspects.

5.1 Types and Technical Requirements of Recycled CDW Products

5.1.1 Recycled Concrete Aggregate

(1) Technical requirements of recycled aggregate for concrete

![Figure 5-1: Diameters of Different Size of Recycled Aggregates](image_url)
Recycled aggregates and Recycled Concrete Aggregate (RCA) shall be accordance with:

- Class I recycled coarse aggregate can be used to produce concrete with various level of strength; Class II recycled coarse aggregate is applicable for producing concrete with strength level lower than C40; Class III recycled coarse aggregate can be used to produce concrete with strength level of C25 and below, it is not applicable to produce concrete with frost resistance requirement. Compared with natural coarse aggregate, recycled coarse aggregate has clearly defined applications for each class, as well as the maximum concrete strength level for each class.

- Class I recycled fine aggregate can be used to produce concrete with strength level of C40 and below; Class II recycled fine aggregate is applicable for producing concrete with strength level lower than C25; Class III recycled fine aggregate is not applicable to produce concrete. Compared with natural fine aggregate, recycled fine aggregate has clear defined applications for each class, as well as the maximum concrete strength level for each class.

- Recycled concrete can be used for building construction or production of concrete structures.

- Besides requirements for recycled aggregate, requirements for raw materials characteristics are similar for recycled concrete and conventional concrete, raw materials for recycled concrete shall be accordance with following regulations:
  
  - Cement shall be accordance with regulations set out in current national standard General Portland Cement (GB 1745); if other types of cement is used, criteria shall meet with its corresponding standards. Different cement shall not be mixed together.
  
  - Recycled coarse aggregate and recycled fine aggregate shall be accordance with 4.1 and 4.2 in this regulation; if particle size distribution cannot meet requirement, natural aggregate shall be added to meet requirement.
  
  - Natural coarse aggregate shall be accordance with current national standard Pebble and Crushed Stone for Building (GB14685), natural fine aggregate shall be accordance with current national standard Sand for Construction (GB14684).
  
  - Mixing water shall be accordance with Water Standard for Concrete (JGJ63).
  
  - Mineral admixtures including fly ash, slag, silica fume and zeolite powder, etc. shall be accordance with current national standard or sector standard Fly Ash for Cement and Concrete (GB 1596), Granulated Blast Furnace Slag for Cement and Concrete (GB 18046), Natural Zeolite for Concrete and Mortar (JG/ton 3048) or Mineral Admixtures for High Strength and High Performance Concrete (GB 18736).
  
  - Admixtures shall meet with current national standard or sector standard Admixtures for Concrete GB 8076, Pumping Aid for Concrete (JC 473), Waterproof Additive for Mortar and Concrete (JC 474), Frost Resistant Additive for Concrete (JC 475) and Expansive Additives for Concrete (GB 23439).

- Durability design of RCA shall be accordance with current national standard Code for Design of Concrete Structures (GB 50010) and Code for Durability Design of Concrete Structures (GB 50476). If RCA is used for concrete structure with design period of 50 years, durability shall be accordance with Table 5-1. Compared with natural concrete material, the durability requirements for RCA is more stringent.

<table>
<thead>
<tr>
<th>Environment Category</th>
<th>Maximum Water-cement Ratio</th>
<th>Minimum Strength Level</th>
<th>(% Maximum Chloride Content)</th>
<th>Maximum Alkali Content (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.55</td>
<td>C25</td>
<td>0.20</td>
<td>3.0</td>
</tr>
<tr>
<td>II a</td>
<td>0.50 (0.55)</td>
<td>C30 (C25)</td>
<td>0.15</td>
<td>3.0</td>
</tr>
<tr>
<td>II b</td>
<td>0.45 (0.50)</td>
<td>C35 (C30)</td>
<td>0.15</td>
<td>3.0</td>
</tr>
<tr>
<td>III a</td>
<td>0.40</td>
<td>C40</td>
<td>0.10</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Note:
1. Chloride Content means the percentage of chloride with cementing material;
2. Water-cement ratio and minimum strength level of plain concrete structures are not restricted;
3. If engineering experience is reliable, minimum concrete strength level can be lowered by 1 level for category II environment;
4. Air entraining agent or air entraining additive can be used for concrete in for category II b and III an environment in frost and cold area, criteria in parenthesis can be used.
5. If inactive aggregate is used, alkali content in concrete is not restricted.

- Allowable content of Sulfur trioxide in RCA shall be accordance with current national standard Code for Durability Design of Concrete Structures (GB 50476).
- If recycled coarse aggregate or recycled fine aggregate are not accordance with current national standard Recycled Coarse Aggregate for Concrete (GB 25177) or Recycled Fine Aggregate for Mortar and Concrete (GB 25176), however, experiment show that recycled aggregates meet requirement for use, they can be used for non-structural concrete.
- Compared with natural aggregate and natural aggregate concreted, due to the specific characteristics of recycled aggregate and RCA, the applications of recycled aggregate and RCA are restricted with clearly defined strength level. Meanwhile, on the basis of compliance of quality and strength requirements, by restricting the application of recycled aggregate and RCA, safety and durability can be ensured for recycled concrete structure: e.g. Recycled aggregate shall not be used to produce Pre-stressed Concrete, recycled aggregate is not applicable for producing Pre-stressed Concrete and Ultra Long Concrete Structure; recycled aggregate is not applicable for producing concrete structure with design period equal or longer than 100 years.

(2) Recycled aggregate concrete products

Currently the engineering application of recycled concrete products in the country mainly includes pre-mixed recycled aggregate concrete and prefabricated recycled aggregate concrete elements.

- Pre-mixed recycled aggregate concrete is concrete mixture produced at a mixing plant according to certain dosage of the components including cement, recycled aggregate, water, additive and mineral admixtures, and sold and delivered by truck to the using site within a certain timeframe.
- Prefabricated recycled aggregate concrete elements: prefabricated recycled concrete element is the basis for prefabrication of main structures. Such product: has good structural performance; plant production can ensure structural mechanics and low discreteness; allows rapid construction; good product quality; high surface smoothness which can achieve the decoration performance of bare concrete; coordination between structure and building; industrialized production can saving energy and contribute to environmental protection, and reduce construction noise on site; good fireproof performance, but the overall performance of its structure is weak, not suitable for buildings with high seismic requirement. Currently the prefabricated recycled concrete elements applied in engineering constructions mainly include:

- Prefabricated recycled concrete beam;
- Prefabricated recycled concrete slab;
- Prefabricated recycled concrete column

![Figure 5-2 Current Application of Commercial Recycled Concrete](image-url)
(3) Limitations in promotion of recycled aggregate concrete products

- The recycled aggregate comes in complex sources, and quality control is difficult, which thereby affects the quality guarantee rate of commercial recycled concrete products.

- Since the overall performance of recycled aggregate is weak, often it needs to be mixed with cement to ensure required concrete strength, which causes increase in production cost, therefore low economic efficiency limits the application of commercial recycled concrete products.

- Due to safety and durability concerns, the current specifications and standards often set limitations (e.g. strength, application environment and service life) on the application scope of commercial recycled concrete products, which is also one of the factors limiting its more intensive promotion.

- Absence of design standard and construction & acceptance specification on recycled aggregate and recycled concrete is the main constraint for the application of recycled concrete; meanwhile pre-mixed recycled concrete, prefabricated recycled concrete, recycled concrete brick and building blocks still follow the specifications and standards for average concrete and products, there is no mature standard system established for recycled concrete, which further hinders the application of recycled concrete products.

- Design personnel have inadequate understanding in the performance of recycled aggregate and recycled aggregate concrete, and little knowledge on relevant CDW recycling theories.

- Government attitude toward the promotion of recycled concrete is not clear, and there are no strong and effective policies or incentives supporting the promotion of recycled concrete.

- Absence of dissemination and public education of knowledge on recycled concrete also limits the application and promotion of recycled concrete.

- Currently the commercial recycled concretes applied in engineering construction are usually low in strength (such as C30, C25 and C20); the application of commercial recycled concrete is still at its initial stage compared to the variety of strength degrees and application forms of average commercial concrete. Absence of production of high value-added commercial recycled concrete (e.g. high-performance recycled concrete, self-compaction recycled concrete and bare concrete) limits the application degree of commercial recycled concrete. Meanwhile, the R&D of new recycled concrete products cannot keep pace with the development of commercial concrete and its products, which further hinders the application and promotion of commercial recycled concrete.

5.1.2 Recycled Mortar

(1) Recycled Mortar Technical Specifications

- Recycled fine aggregates can be used for masonry mortar, plastering mortar and ground mortar. Recycled aggregate base mortar shall not be used for bottom layer.

- Recycled aggregate masonry mortar and plastering mortar shall use general Portland cement or masonry cement; recycled aggregate ground mortar shall use general Portland cement, and Portland cement or ordinary Portland cement. Except cement and recycled fine aggregates, other raw materials for recycled aggregate mortar shall be accordance with national standard Ready-mixed Mortar (GB 25181) and Technical Specification of Plastering Mortar (JGJ220).

- Class I recycled fine aggregates can be used to produce mortar with various strength level, Class II recycled fine aggregates can be used to produce mortar with strength level equal to or below M15, Class III recycled fine aggregates is proper to be used to produce mortar with strength level equal or below M10.

- Recycled aggregate plastering mortar shall be accordance with current sector standard Technical Specification of Plastering Mortar (JGJ220); when mechanical spraying plaster is used in construction, recycled aggregate plastering mortar shall be accordance with current sector standard Specification of Mechanical Spraying Plaster Construction (JGJ105).

- If using recycled aggregate mortar for building masonry structures, it shall be accordance with current national standard Technical Specification of Masonry Structure (GB 50003).
- Performance criteria of ready-mixed mortar produced by recycled aggregates shall be accordance with current national standard Ready-mixed Mortar (GB 25181).

- Performance criteria of on-site mixed recycled aggregate mortar shall be accordance with regulations listed in Table 5-2. Compared with natural aggregate mortar, requirements for the water content and 14d tensile adhesive strength are different; requirements for frost resistance are basically the same.

**Table 5-2 Performance Criteria Requirement for On-site Mixed Recycled Aggregates Mortar**

<table>
<thead>
<tr>
<th>Types of Mortar</th>
<th>Strength Level</th>
<th>Consistency (mm)</th>
<th>Water Content (%)</th>
<th>14d Tensile Adhesive Strength (MPa)</th>
<th>Frost Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled Aggregate Masonry Mortar</td>
<td>M2.5, M5, M7.5, M10, M15</td>
<td>50~90</td>
<td>≥82</td>
<td>—</td>
<td>≤25</td>
</tr>
<tr>
<td>Recycled Aggregate Plastering Mortar</td>
<td>M5, M10, M15</td>
<td>70~100</td>
<td>≥82</td>
<td>≥0.15</td>
<td>≤25</td>
</tr>
<tr>
<td>Recycled Aggregate Ground Mortar</td>
<td>M15</td>
<td></td>
<td>≥82</td>
<td>—</td>
<td>≤25</td>
</tr>
</tbody>
</table>

Notes: if frost-resistance is needed, frost-resistance test shall be conducted. Number of freeze-melt cycles shall be 15 for areas with hot summer and warm winter, 25 for areas with hot summer and cold winter, 35 for cold area, 50 for extremely cold areas.

- Recycled aggregate performance test methods shall be accordance with current sector standard Standards of Building Mortar Performance Test Method (JGJ 70).

(2) Limitations in promotion of recycled mortar

Recycled mortar is still in its initial stage of application in the RPC, the products mainly include masonry mortar, plastering mortar and floor mortar. Its promotion has the following limitations:

- Recycled mortar is often produced with recycled fine aggregate, its main component is cement mortar whose overall performance is weak compared to traditional natural fine aggregate (river sand), therefore the produced recycled mortar is low in strength and overall performance.

- The existence of recycled fine aggregate will increase the water absorption during preparation. Compared to traditionally prepared mortar, the recycled mortar requires large amount of water, more factors need to be taken into consideration during the mixing process, thereby increasing the cost in engineering application and limiting its production and promotion.

- Normally recycled mortar has higher drying shrinkage than average mortar, the appearance of recycled mortar products in engineering application is less attractive than average mortar; in addition, its abrasion performance is poor.
5.1.3 Recycled Concrete Block

(1) Recycled Concrete Block Technical Requirements

Recycled aggregate blocks are classified into 6 classes according to the compressive strength: MU3.5, MU5, MU7.5, MU10, MU15 and MU20.

Raw materials used for recycled aggregate blocks shall be accordance with the following regulations:

- Nominal Maximum Aggregate Size (NMPS) shall not be larger than 10mm;
- Performance criteria of recycled coarse aggregate and fine aggregate shall be accordance with regulations listed in Table 5-3 and Table 5-4;
- If gravel is used for aggregates, proportion of gravel with particle size smaller than 0.15mm shall not be larger than 20%.

### Table 5-3 Performance Criteria Requirement for Recycled Coarse Aggregate for Blocks and Bricks

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Absorption (counted in mass, %)</td>
<td>&lt;10.0</td>
</tr>
<tr>
<td>Other content (counted in mass, %)</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td>Soil content, hazardous material content, stiffness, crushing index, alkali-aggregate reaction performance</td>
<td>Recycled Coarse Aggregate for Concrete (GB 25177) shall be complied</td>
</tr>
</tbody>
</table>

### Table 5-4 Performance Criteria Requirement for Recycled Fine Aggregate for Blocks and Bricks

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine powder content (Counted in mass, %)</td>
<td>MB &lt;1.40 or qualified</td>
</tr>
<tr>
<td></td>
<td>&lt;12.0</td>
</tr>
<tr>
<td></td>
<td>MB ≥1.40 or unqualified</td>
</tr>
<tr>
<td></td>
<td>&lt;6.0</td>
</tr>
<tr>
<td>Soil content, hazardous material content, stiffness, crushing index, alkali-aggregate reaction performance</td>
<td>Recycled Fine Aggregate for Concrete (GB 25177) shall be complied</td>
</tr>
</tbody>
</table>

- Allowable deviation of size and appearance quality of recycled aggregate block shall be accordance with regulations in Table 5-5.

### Table 5-5 Recycled Aggregate Block Size Allowable Deviation and Appearance Quality

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Requirement</th>
</tr>
</thead>
</table>
Size allowable deviation

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>(mm)</td>
<td>±2</td>
<td>±2</td>
<td>±2</td>
</tr>
</tbody>
</table>

Minimum External Wall Thickness

<table>
<thead>
<tr>
<th></th>
<th>Bearing wall</th>
<th>Non-bearing wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>(mm)</td>
<td>≥30</td>
<td>≥16</td>
</tr>
</tbody>
</table>

Rib Thickness

<table>
<thead>
<tr>
<th></th>
<th>Bearing wall</th>
<th>Non-bearing wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>(mm)</td>
<td>≥25</td>
<td>≥15</td>
</tr>
</tbody>
</table>

Missing edges and angles

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>Minimum three direction projection (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤2</td>
<td>≦20</td>
</tr>
</tbody>
</table>

Fracture propagation projection accumulation size (mm)

|          | ≤20          |

Bend (mm)

|          | 2            |

Compressive strength of recycled aggregate blocks shall be accordance with Table 5-6. Compared with compressive strength of natural aggregate blocks, requirements are generally the same for recycled aggregate blocks, which indicates that the design criteria for recycled blocks products for compressive strength has no significant difference with natural block products.

### Table 5-6 Recycled Aggregate Block Compressive Strength

<table>
<thead>
<tr>
<th>Class of Strength</th>
<th>Compressive Strength (MPa)</th>
<th>Average</th>
<th>Minimum value for single brick</th>
</tr>
</thead>
<tbody>
<tr>
<td>MU3.5</td>
<td>≥3.5</td>
<td>≥2.8</td>
<td></td>
</tr>
<tr>
<td>MU5</td>
<td>≥5.0</td>
<td>≥4.0</td>
<td></td>
</tr>
<tr>
<td>MU7.5</td>
<td>≥7.5</td>
<td>≥6.0</td>
<td></td>
</tr>
<tr>
<td>MU10</td>
<td>≥10.0</td>
<td>≥8.0</td>
<td></td>
</tr>
<tr>
<td>MU15</td>
<td>≥15.0</td>
<td>≥12.0</td>
<td></td>
</tr>
<tr>
<td>MU20</td>
<td>≥20.0</td>
<td>≥16.0</td>
<td></td>
</tr>
</tbody>
</table>

Recycled aggregate block drying shrinkage shall not be larger than 0.060%; relative moisture content shall be accordance with Table 5-7; frost-resistance shall be accordance with Table 5-8; carbonation coefficient and softening coefficient shall not be smaller than 0.80. Compared with natural aggregate block, requirements of frost-resistance are generally the same for recycled blocks and natural blocks.

### Table 5-7 Relative Moisture Content of Recycled Aggregate Blocks

<table>
<thead>
<tr>
<th>Moisture Level of the Area</th>
<th>Wet</th>
<th>Medium</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Moisture Content (%)</td>
<td>≤40</td>
<td>≤35</td>
<td>≤30</td>
</tr>
</tbody>
</table>

Notes: Wet area indicates area where annual average relative moisture content > 70%; medium area indicates area where annual average relative moisture content between 50% – 75%; dry area indicates area where annual average relative moisture content < 50%.

### Table 5-8 Frost-resistance of Recycled Aggregate Blocks

<table>
<thead>
<tr>
<th>Weather Condition</th>
<th>Frost-resistance Index</th>
<th>Mass Loss (%)</th>
<th>Strength Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area with hot summer and warm winter</td>
<td>D15</td>
<td>≤5</td>
<td>≤25</td>
</tr>
<tr>
<td>Area with hot summer and cold winter</td>
<td>D25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold area</td>
<td>D35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extremely cold area</td>
<td>D50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(2) Other Recycled Concrete Block Products

- Recycled concrete small-size hollow brick: made of cement, sand and recycled aggregate, hollow ratio 25%~50%. The product is suitable for building wall (including for high-rise and long span buildings) and municipal facilities such as enclosing wall, retaining wall, bridge and flower bed. It can also be used for average industrial and civil block buildings, especially for bearing wall of multi-story buildings and filler wall of frame structure buildings.

- Autoclaved aerated recycled concrete block: mainly applicable to inner and outer filler walls above building floor (±0.000) and inner filler wall below building floor. The product shouldn’t be directly laid on building surface or floor. The foot of the walls that are under constant influence of dry-wet alternations (bathroom, balcony and contact between air conditioner supporting plate on outer wall and the masonry) should be pour with C20 plain concrete cushion (width: same as the wall thickness; height: no less than 0.15m); for other walls, a cushion no less than 0.15m high should be made with autoclaved sand-lime brick at the foot. The product cannot be used at the following positions:
  - below the building ±0.000 (apart from indoor filler wall of basement);
  - under soaking or constant influence of dry-wet alternations;
  - under chemical erosion environment, such as strong acid, strong alkali or high CO₂ concentration;
  - masonry surface often under high temperature environment (above 80℃);
  - roofing parapet wall.

(3) Limitations in Promotion of Recycled Concrete Block

Inadequate relevant standards and supporting polices are the main limitation in promotion of recycled concrete block. Currently the technical standards for conventional concrete block are applied to recycled concrete block without consideration of the characteristics of recycled concrete block. Especially there are not standards for different types of recycled concrete blocks, such as recycled concrete hollow blocks, auto caved lightweight recycled concrete block, and light aggregate recycled concrete blocks. Additional limitations include; inadequate understanding and knowledge of the design personnel; absence of government procurement; public publicity and education; lack of government incentives; lack of cost-effective and high value-added products. It should be noted that the coarse aggregate and fine aggregate used to produce recycled concrete blocks in the PRC are mostly poor quality recycled coarse aggregate and fine aggregate mainly comprising mortar, low quality aggregate affects the strength, overall performance and durability of the recycled concrete block. Especially under extreme environment (freeze-thaw damage and chloride ion erosion), its service
life will be significantly reduced. Compared to average concrete block, the uncompetitive preparation cost and shorter service life make it difficult to its engineering application and promotion. Although performance optimization of recycled aggregate can improve the product’s overall performance and durability, but the cost will significantly increase, which makes the approach unacceptable to CDW recycling enterprises.

5.1.4 Recycled Concrete Brick
(1) Technical Requirement for Recycled Concrete Brick

Recycled aggregate can be used to produce porous brick, hollow brick and solid brick, and classified into 6 classes according to the compressive strength: MU7.5, MU10, MU15, MU20, MU25 and MU30. The compressive strength for recycled brick shall be accordance with Table 5-9. Compressive strength test method for recycled solid bricks shall be complied with current national standard Test Methods for Wall Bricks (GB/tou2542). Compared with natural aggregate bricks, requirements for compressive strength are generally the same for both recycled and natural bricks, which indicates that the design criteria for compressive strength for recycled bricks is same as natural bricks.

Table 5-9 Compressive Strength of Recycled Aggregate Bricks

<table>
<thead>
<tr>
<th>Strength Class</th>
<th>Compressive Strength (MPa)</th>
<th>Compressive Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Minimum value for single brick</td>
</tr>
<tr>
<td>MU7.5</td>
<td>≥7.5</td>
<td>≥6.0</td>
</tr>
<tr>
<td>MU10</td>
<td>≥10.0</td>
<td>≥8.0</td>
</tr>
<tr>
<td>MU15</td>
<td>≥15.0</td>
<td>≥12.0</td>
</tr>
<tr>
<td>MU20</td>
<td>≥20.0</td>
<td>≥16.0</td>
</tr>
<tr>
<td>MU25</td>
<td>≥25.0</td>
<td>≥20.0</td>
</tr>
<tr>
<td>MU30</td>
<td>≥30.0</td>
<td>≥24.0</td>
</tr>
</tbody>
</table>

Single brick water absorption rate for recycled solid brick shall not be larger than 18%. Drying shrinkage rate for recycled porous brick shall not be larger than 0.045%, relative water content shall be accordance with Table 5-10. Water absorption rate, drying shrinkage rate and test methods for relative water content shall be accordance with current national standard Test Methods for the Small concrete Hollow Block (GB/tou4111).

Table 5-10 Maximum Relative Water Content of Recycled Porous Brick

<table>
<thead>
<tr>
<th>Drying Shrinkage Rate, %</th>
<th>Maximum Relative Water Content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wet Environment</td>
</tr>
<tr>
<td>&lt;0.03</td>
<td>45</td>
</tr>
<tr>
<td>0.03~0.045</td>
<td>40</td>
</tr>
</tbody>
</table>

Notes: Wet area indicates area where annual average relative moisture content > 70%; medium area indicates area where annual average relative moisture content between 50% ~ 75%; dry area indicates area where annual average relative moisture content < 50%.

Frost-resistance of recycled bricks shall be accordance with Table 5-11, test methods shall be complied with current national standard Test Methods for Small Concrete Hollow Bricks (GB/tou4111). Compared with natural aggregate bricks, frost-resistance requirements for recycled aggregate bricks are the same.

Table 5-11 Recycled Aggregate Bricks Frost-resistance

<table>
<thead>
<tr>
<th>Weather Condition</th>
<th>Frost-resistance Index</th>
<th>Mass Loss%</th>
<th>Strength Loss%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area with hot summer and warm winter</td>
<td>D15</td>
<td>≤5</td>
<td>≤25</td>
</tr>
<tr>
<td>Area with hot summer and cold winter</td>
<td>D25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold area</td>
<td>D35</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(2) Recycled Concrete Brick

- Recycled concrete solid brick: currently the compressive strength for recycled concrete brick is divided into four grades in the RPC, i.e. MU7.5, MU10, MU15 and MU20, the recycled aggregate applied can meet the requirements of the Technical Specification for Application of Recycled Aggregate (JGJ/ton240-2011), the grain size of the recycled aggregate used for preparation of recycled concrete brick should be no larger than 15mm.

- Recycled concrete hollow brick: the product can directly replace sintered clay brick and apply to different building wall structures (including non-bearing type, bearing and insulating and frame filler), presenting broad market prospects. Recycled concrete hollow brick has the characteristics of low production energy consumption, land conservation and waste reduction, easy construction and lightness, high strength, good insulation and durability, little shrinkage strain and neat appearance, making it an ideal alternative for sintered clay brick; meanwhile use of recycled aggregate can reduce consumption of natural aggregate and contribute to environmental protection.

- Recycled concrete pavement brick: produced mainly with cement and recycled aggregate, and through processing, vibration pressure or other forming techniques; mainly used for urban pedestrian road and square. The surface may have a topping layer or not; in natural color or color.

- Recycled concrete permeable brick: compared to average concrete permeable brick, the product has better permeability. The product can address urban surface hardening issue, and help build a high quality natural living environment, maintain urban ecological balance. It has the characteristics of permeability, moisture retention, skid resistance, high strength, cold resistance, weather resistance and noise reduction. The product is a green product as it uses CDW recycled aggregate, slag and waste ceramics as raw materials. Current recycled concrete bricks applied in engineering constructions have the following characteristics:
  - Good permeability and ventilation, allows rapid infiltration of rainwater into ground to complement soil moisture and ground water, and help maintain soil moisture and improve the living environment of urban vegetation and soil microorganism.
  - It can absorb the moisture and heat to adjust local surface temperature and moisture, adjust urban microclimate and mitigate urban heat island effect.
  - Alleviate urban drainage and flood protection pressure, and contribute to public water pollution prevention and wastewater treatment.
  - Avoid water logging after raining and slippage after snow, and contribute to safe travel.
  - Slight concave-convex pattern on the surface can avoid reflection on pavement, absorb traffic noise and improve comfort and safety of travel.
  - Rich-colored, economical and practical, and diversified specs.
(3) Limitations in the Promotion of Recycled Concrete Brick

Similar to recycled concrete, inadequate relevant standard and supporting polices. Additional the limitations include: inadequate understanding and knowledge of the design personnel; absence of government procurement; public publicity and education; lack of government incentives; lack of cost-effective and high value-added products. It should be noted that recycled concrete brick performance indicators mainly include strength, durability, cold resistance, drying shrinkage and permeability (permeable concrete brick), of which, strength is the most important indicator which affects other performance indicators. Unfortunately recycled concrete brick's (especially recycled concrete pavement brick) durability, cold resistance and drying shrinkage performances are not as good as average concrete brick, which limits its extensive application and promotion.

5.1.5 Technical Requirement for Other Types of Recycled Concrete Products

- If CDW is used to produce active renewable powder, its technical parameters shall be accordance with requirements set out for secondary coal ash in Coal Ash for Cement and Concrete (GB 1596), it can be used as the adhesive material for concrete admixture and cement active mix; CDW sources for production of recycled ashes or powders shall be strictly controlled to ensure the recycled ash quality; production equipment and processes shall be optimized for recycled powders, as well as the product inspection work, for recycled powder that cannot meet quality requirement, it is prohibited to be used for recycled products.

- Clay in the construction waste soil can be used to produce recycled vitrified bricks. Quality of the recycled vitrified ordinary bricks shall be accordance with Vitrified Ordinary Brick (GB 5101), quality of recycled vitrified porous bricks shall be accordance with Vitrified Porous Brick (GB 13544); other types of construction waste soil can be used for backfill, artificial mountains and artificial land.

- Broken brick pieces, concrete block pieces, gravels and cement mix in the CDW can be used as raw material for piles, design and construction of piles shall be accordance with Design Specification of Piles (JGJ/ton 135).

5.1.6 Key Concerns from Stakeholders

CDW management mainly involves project owner, construction unit, design institute, transportation enterprises, CDW disposal division, recycling enterprises, end users, research institute, and government foundational departments. These stakeholders are closely related to CDW management, and affects the development of CDW industry, especially for those issues on recycled concrete products generated during CDW recycling process, the main concerns from different stakeholders are different, which are listed below:
Concerns from stakeholders at the recycled concrete source

The major CDW recycled products in the PRC are recycled concrete products, the main stakeholders at the source include the CDW producing unit (construction unit), construction unit decide the disposal for CDW rather than recycled concrete products. Construction unit shall take measures first to reduce the generation of CDW when the construction unit is fulfilling the contract. Moreover, if the construction unit can classify the CDW in advance during construction and demolition, the recycling and disposal cost will be highly reduced at the later stage.

During industrialization promotion, it is essential to control the source, which indicates that when construction unit is demolishing and constructing, it should consider the production process comprehensively by considering the various different types of CDW and their characteristics. For example: during demolition, different phases of demolition and classification can be carried out, doors, windows, glasses and other types of CDW can be demolished first, and then concrete structures can be demolished next, by doing this, higher quality recycled raw materials can be provided, therefore, it guarantees the quality of the recycled CDW products at the source, thereby higher added value can be generated.

Concerns from stakeholders at recycled concrete production

The main stakeholders are CDW recycling enterprises, however, at the current stage, due to the lack of regulations and standards for the CDW recycling, the economic benefit and development for those enterprises are hindered. Based on the current technology, although recycled concrete can be made into products with the same types and same characteristics as conventional concrete products, due to the lack of national level and industrial level standards and technical regulations, quality of those products varies between different enterprises, standardization of CDW recycled concrete products has been greatly limited. Based on the above consideration, enterprises should focus on developing innovations and technologies to product high quality recycled concrete products, and take market-oriented approach to promote recycled concrete products; moreover, CDW recycled enterprises shall push forward the development of enterprise standards and national standards, to accelerate the industrialization process of the standardized recycled products; specifically, good economic benefit is the foundation for normal operation of CDW recycling enterprises, enterprises should change from the extensive recycling production into process of creating products to meet demands from different levels, as well as products with different value, enough attention should be paid to high added-value products.

Concerns from stakeholders in the use of recycled concrete products

Enterprises using CDW recycled concrete products are the key factors in the CDW utilization process, during this process, the market factor is the driving factor, which is also the foundation for CDW recycling promotion, as well as the raw driving force for the production of recycled concrete. The enterprises are mainly construction units, however, due to the traditional concept, the application ratio of recycled products from construction “waste” versus conventional products is low. Even in condition where products quality is low and cost is low, the application of recycled products is still rejected by most construction units, which fundamentally limits the promotion of recycled concrete promotion. In summary, enterprises should change their concept of using recycled products, it is recommended to monitor the recycled products through professional institutes, if the quality of recycled products meet the application standard, the application in engineering projects should be encouraged. By involving more and more construction units into construction units using recycled concrete products, projects using recycled products can be promoted, which is the key factor in CDW recycling.

Concerns from stakeholders in the promotion of CDW recycled products

Government is the key player in the promotion of recycled concrete products, however, due to the lack of CDW recycling documents and policies developed by government, including mandatory policies, there has not been any effective incentives for the promotion of CDW recycling. Therefore, government should utilize its function to provide guidance for various steps in CDW recycling process, meanwhile under the adjustment of market itself, industry structure will be improved. On one hand, leading documents shall be produced to enforce CDW recycling, thereby improve the CDW recycling rate; on the other hand, different local conditions shall be considered based on their own urban planning and CDW characteristics, to provide permission to applicable CDW recycling enterprises, and develop relevant CDW recycling and disposal policy documents, and meanwhile provide government subsidies based on the policies.

5.2 Conventional Construction Material Products Types and Technical Performance Criteria

Technical performance criteria for mixing conventional concrete shall meet the following:

- Water for concrete mix shall meet Standard for Concrete Mixing Water (JGJ6);
- Coarse and fine aggregate for the production of concrete shall be accordance with Quality Standard and Test Methods of Gravels for Ordinary Concrete (JGJ52);
- Cement for concrete mix shall be accordance with General Portland Cement (GB 175);
- Mineral additives for concrete mix shall be accordance with current national standard Coal Ashes for Cement and Concrete (GB 18046), Mineral Admixture for High Strength High Performance Concrete (GB 18736) and Natural Zeolite for Concrete and Mortar (JGJ 3048).
- Additive for concrete mix shall be accordance with current national standard Concrete Admixture (GB 8076) and Technical Specification of Application of Concrete Admixture (GB50119);
- Performance criteria for mixing concrete shall be accordance with Technical Specification for Concrete Structure (GB50010), Technical Specification for Concrete Structure Durability (GB50476) and Test Methods for Ordinary Concrete Long-term Performance and Durability. Basic requirements for structural concrete durability are shown in Table 5-12.

<table>
<thead>
<tr>
<th>Category of Environment</th>
<th>Maximum Water-cement Ratio</th>
<th>Minimum Strength Level</th>
<th>Maximum Chloride Content (%)</th>
<th>Maximum Alkali Content (Kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.60</td>
<td>C20</td>
<td>0.30</td>
<td>No limitation</td>
</tr>
<tr>
<td>II a</td>
<td>0.55</td>
<td>C25</td>
<td>0.20</td>
<td>3.0</td>
</tr>
<tr>
<td>II b</td>
<td>0.50 (0.55)</td>
<td>C30 (C25)</td>
<td>0.15</td>
<td>3.0</td>
</tr>
<tr>
<td>III a</td>
<td>0.45 (0.50)</td>
<td>C35 (C30)</td>
<td>0.15</td>
<td>3.0</td>
</tr>
<tr>
<td>III b</td>
<td>0.40</td>
<td>C40</td>
<td>0.10</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Notes: 1) Chloride Content means the percentage of chloride with cementing material; 2) Maximum Chloride content in pre-stressed concrete is 0.06%; minimum concrete strength level is proper to be raised by two levels according to the table; 3) Water-cement ratio and minimum strength level of plain concrete structures are not restricted; 4) If engineering experience is reliable, minimum concrete strength level can be lowered by 1 level for category II environment; 5) Air entraining agent or air entraining additive can be used for concrete in for category II b and III a environment in frost and cold area, criteria in parenthesis can be used. 6) If inactive aggregate is used, alkali content in concrete is not restricted.

Production of ordinary mortar shall be accordance with Ready-mixed Mortar (GB 25181) and Technical Specification for Plastering Mortar (JGJ 220). Performance criteria for natural aggregate mortar shall meet requirements listed in Table 5-13; compressive strength shall meet requirements listed in Table 5-14.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Masonry Mortar</th>
<th>Plastering Mortar</th>
<th>Ground Mortar</th>
<th>Waterproof Mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Content /%</td>
<td>≥88</td>
<td>≥88</td>
<td>≥88</td>
<td>≥88</td>
</tr>
<tr>
<td>14d Tensile Adhesive Strength /MPa</td>
<td>-</td>
<td>M5: ≥0.15</td>
<td>-</td>
<td>≥0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;M5: ≥0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28d Shrinkage Rate /%</td>
<td>-</td>
<td>≤0.20</td>
<td>-</td>
<td>≤0.15</td>
</tr>
<tr>
<td>Frost-resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength loss /%</td>
<td>≤25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass loss /%</td>
<td>≤5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a If frost-resistance is required, frost-resistance test shall be conducted

<table>
<thead>
<tr>
<th>Strength Level</th>
<th>M5</th>
<th>M7.5</th>
<th>M10</th>
<th>M15</th>
<th>M20</th>
<th>M25</th>
<th>M30</th>
</tr>
</thead>
<tbody>
<tr>
<td>28d Compressive Strength</td>
<td>≥5.0</td>
<td>≥7.5</td>
<td>≥10.0</td>
<td>≥15.0</td>
<td>≥20.0</td>
<td>≥25.0</td>
<td>≥30.0</td>
</tr>
</tbody>
</table>
Performance criteria of natural coarse aggregate and fine aggregate for producing ordinary concrete blocks and bricks shall be accordance with Quality Standards and Test Method of Gravels and Rocks for Ordinary Concrete (JGJ52); performance criteria of different types of concrete blocks and bricks shall meet the following:

- Technical Specification of Masonry Structure (GB50003);
- Standards of Autoclaved Aerated Concrete Masonry (GB11968);
- Vitrified Porous Brick and Porous Masonry (GB13544);
- Quality Acceptance Specification of Masonry Structure Construction (GB 50203);
- Small Concrete Hollow Masonry and Concrete (JC860);
- Small Concrete Hollow Masonry and Grouted Concrete (JCJ861);
- Design Specification of Masonry Mortar Mixing Ratio (JGJ98).

**Table 5-15 Natural Aggregate Masonry Block Size Allowable Deviation and Appearance Quality**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Premium Products (A)</th>
<th>Qualified Products (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size allowable deviation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>±3</td>
<td>±4</td>
</tr>
<tr>
<td>Width</td>
<td>±11</td>
<td>±2</td>
</tr>
<tr>
<td>Height</td>
<td>±</td>
<td>±2</td>
</tr>
<tr>
<td>Missing edges and angles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum size shall not be larger than /mm</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Maximum size shall not be larger than /mm</td>
<td>0</td>
<td>70</td>
</tr>
<tr>
<td>Number of missing edges and angles larger than size indicated above shall not be greater than</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Fracture Length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The fraction of combined total fracture size at the same direction in the fracture surface that fracture length through 2 crossing surfaces shall not be greater than</td>
<td>0</td>
<td>1/3</td>
</tr>
<tr>
<td>The fraction of the fracture size at the same direction that the fracture length on any surface shall not be greater than</td>
<td>0</td>
<td>1/2</td>
</tr>
<tr>
<td>Depth of the burst, sticky mold and damage shall not be greater than /mm</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Bending plane</td>
<td>Not allowed</td>
<td></td>
</tr>
<tr>
<td>Loose surface and layer cracks</td>
<td>Not allowed</td>
<td></td>
</tr>
<tr>
<td>Oil and grease on surface</td>
<td>Not allowed</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5-16 Natural Masonry Block Compressive Strength (Aerated Concrete Masonry Block)**

<table>
<thead>
<tr>
<th>Strength Level</th>
<th>Compressive Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>A1.0</td>
<td>≥1.0</td>
</tr>
<tr>
<td>A2.0</td>
<td>≥2.0</td>
</tr>
<tr>
<td>A2.5</td>
<td>≥2.5</td>
</tr>
<tr>
<td>A3.5</td>
<td>≥3.5</td>
</tr>
<tr>
<td>A5.0</td>
<td>≥5.0</td>
</tr>
<tr>
<td>A7.5</td>
<td>≥7.5</td>
</tr>
<tr>
<td>A10.0A</td>
<td>10.0</td>
</tr>
</tbody>
</table>
### Table 5-17 Natural Porous Brick Compressive Strength

<table>
<thead>
<tr>
<th>Strength Level</th>
<th>Compressive Strength (MPa)</th>
<th>Minimum for Single Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>MU10</td>
<td>≥10.0</td>
<td>≥6.0</td>
</tr>
<tr>
<td>MU15</td>
<td>≥15.0</td>
<td>≥9.0</td>
</tr>
<tr>
<td>MU20</td>
<td>≥20.0</td>
<td>≥12.0</td>
</tr>
<tr>
<td>MU25</td>
<td>≥25.0</td>
<td>≥15.0</td>
</tr>
<tr>
<td>MU30</td>
<td>≥30.0</td>
<td>≥18.0</td>
</tr>
</tbody>
</table>

### Table 5-18 Frost-resistance Criteria of Natural Aggregate Blockage Material

<table>
<thead>
<tr>
<th>Weather Condition</th>
<th>Frost-resistance Index</th>
<th>Mass Loss (%)</th>
<th>Strength Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area with hot summer and warm winter</td>
<td>F15</td>
<td>≤5</td>
<td>≤25</td>
</tr>
<tr>
<td>Area with hot summer and cold winter</td>
<td>F25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold area</td>
<td>F35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extremely cold area</td>
<td>F50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 5.3 Comparison Analysis

Strength level for domestic concrete structures are generally below C30. After proper demolition of concrete waste, large amount of raw shape particles can be obtained from the aggregate surface, the roughness of particle surface are increased, and smaller slag adhered to the rough surfaces create preferable condition for use as aggregates. Due to the external forces existed during demolition and breaking, few particles are broken from the raw blocks, new rough surfaces are created, and thus, edges and angle effect are strengthened. Moreover, after repeated collapse and crushing processes, soft particles are eliminated from the original aggregates, also the shape of the particles are improved.

On the other hand, since the surface of the recycled aggregate are covered with a considerable amount of cement mortar, due to the large porous ratio and corners and angles of cement mortar, compared with natural aggregates, recycled aggregates have disadvantages including low apparent density, low bulk density, high water absorption and high crushing criteria. Moreover, due to difference of strength level, water-cement ratio, service period, service environment, area of use and production processes, etc. or recycled aggregate raw concrete, the characteristics of recycled aggregates often varies.

### Table 5-19 Performance Criteria Comparison of Recycled Aggregates with Natural Aggregates

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Recycled Aggregates</th>
<th>Natural Aggregates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Rough surfaces, more edges and pores</td>
<td>Smooth surface, less edges and pores</td>
</tr>
<tr>
<td>Needle and flake particle content</td>
<td>Similar</td>
<td>Similar</td>
</tr>
<tr>
<td>Apparent density and bulk density</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Water absorption rate</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Crashing parameter values</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Stiffness</td>
<td>Relatively low</td>
<td>Relatively high</td>
</tr>
</tbody>
</table>

When recycled aggregate concrete is compared with conventional concrete with same water-cement ratio design, compressive strength of recycled aggregate concrete is lower than conventional concrete; also, compressive strength of recycled aggregate concrete decreases as the replacement ratio of recycled aggregate increases; when the replacement ratio gets lower than 30%, there is no significant difference between recycled aggregate concrete and conventional concrete, if ratio is adjusted, the above defects can be overcame.
6 Current Status of Urban Construction Waste Utilization and Management in the PRC

6.1 Selection of Typical Cities

Typical cities have the following features:

— adequate CDW source management
— Scaled CDW recycling and sustainable enterprise operations
— Effective marketing of recycled CDW products
— High CDW recycling rate
— Different types of cities which can provide lessons and experience for each other

Typical cities selected for case study include:

Shenzhen — an emerging large city which has an early start in CDW recycling with many recycling enterprises that in sustainable operation. Shenzhen is playing a leading role in CDW recycling among the major cities in the PRC.

Xi’an- a famous historic and cultural city which has established a mature disposal approval system, with adequate source management and large-scale recycling enterprises in sustainable operation.

Xuchang- a small to medium city which has achieved adequate whole process management of CDW recycling, there are scaled recycling enterprises with sustainable operations. Its CDW recycling rate is ahead in the country.

Wujin District of Changzhou City, one district of a medium city, its CDW recycling has a late start but the promotion is strong and effective, there are already scaled recycling enterprises.

Beijing-a megacity of the PRC, even though great importance is attached to CDW recycling, the performance is not satisfactory, a brief introduction is provided in this study for comparison with other cities.

6.2 Shenzhen

| Basic Conditions of the City | Shenzhen is located in the coastal area in the Southern the PRC, the eastern coast of Pearl River estuary and in proximity to Hong Kong across the river. There are 10 districts in Shenzhen, namely 6 administrative districts and 4 functional districts. With an area of 1991.64 km², Shenzhen has reached a permanent population of 10.7789 million by the end of 2014. Also Shenzhen is an important international gateway for the PRC external exchanges. Shenzhen is a key economic city and has ranked among one of the most economic efficient cities in the PRC. In 2015, Shenzhen topped the list of comprehensive competitive cities issued by the Chinese Academy of Social Sciences, and got the award of “Civilized City in the PRC” for the fourth time. Shenzhen is known as the “National Garden City”, “National Hygiene City” and “National Green Model City”. In 2014 the GDP of Shenzhen has reached RMB 1.6 trillion and a year-on-year 8.8% increase over last year when calculating by the comparable prices. The total retail sales of social consumer goods are RMB 4.844 trillion and an increase of 9.3% than the year before. The total exports and imports of the whole year have reached RMB 487.765 billion and an increase of 9.8% than the year before, ranking the top among the cities in the PRC mainland for successively |
three years. In 2014, the local public revenue was RMB 208.2 billion with an increase of 20.3%.

### Generation and Management of Construction Wastes

In 2014, according to the statistic of Shenzhen, the construction waste generated in Shenzhen was nearly 60 million tons and the demolition waste more than 8.6 million tons, including more than 2.6 million tons from the new construction of houses. *Shenzhen Construction Waste Reduction and Utilization Regulation* came into effectiveness in October 2009 and defined that, the construction departments at district and city levels are the administrative departments of construction waste. The urban management department is responsible for supervising and managing the cleaning, transfer and collection of construction waste. Shenzhen was identified as the “demonstration city for construction waste reduction and integrated utilization” by the Ministry of Housing and Urban-Rural Development Department in the PRC in March 2012.

### Policy of Construction Waste Management

Shenzhen initiated construction waste recycling quite early and has made up a series of measures covering many procedures such as waste sources classification, transfer, disposal and reuse of construction wastes. As specified in the *Shenzhen Construction Waste Reduction and Utilization Regulations* issued in October 2009, it set out the goals of waste reduction, utilization upgrading and recycled economic development and proposed the management concepts of waste reduction, reuse and recycling in the PRC for the first time, with clear tariff system for construction waste. In January 2014, *Shenzhen Construction Waste Transfer and Disposal Method* took into effectiveness and made clear provisions on waste transfer, receiving site establishment, construction waste clearance, receiving site management, disposal tariff as well as the legal responsibilities for those actions in violation of the regulation. In 2014, the documents such as *Instructions of Strengthening the Construction Waste Management by Shenzhen Urban Management Bureau* have incorporated construction waste recycling into the scope of governmental assessment. In terms of fiscal subsidies, the municipal government shall establish the special fund on construction efficiency development and allocate fiscal fund to support the development of construction waste technology and demonstration projects as requested by the documents such as *Shenzhen Special Economic Zone Construction Waste Reduction and Utilization Regulation and Shenzhen Special Economic Zone Energy Conservation Regulation*. At the same time, in order to encourage and support the development of construction waste recycling, put forward the incentive policies on the aspects of land rental and taxation.

*Shenzhen Construction Waste Reduction and Utilization Regulation* indicates that,

1. The management of construction wastes shall follow the principles of waste reduction, reuse and recycling. The construction wastes which can be reused or regenerated shall be recycled; those which cannot be reused or regenerated shall be treated in accordance with the relevant laws and regulations. The construction wastes shall be treated under integrated classified management. 2. The construction waste shall adopt the charging system. The competent department shall charge for the construction waste emission based on the classification, amount and tariff standards of construction wastes. All discharging fee will be submitted to the financial department to support construction waste reduction and utilization.

*Shenzhen Urban Management Bureau’s Instructions on further Enhancement of the Construction Wastes Management* indicates that: In the government invested receiving site, it shall adopt the governmental tariff in disposing construction wastes; While in the social invested receiving site, it shall adopt marketing pricing.

*Shenzhen Construction Waste Transfer and Disposal Management Method* indicates that, 1) Establish the joint conference system for construction wastes transfer and disposal and introduce the system of waste checklist management. The checklist will be prepared by the construction department in united form, with the construction unit, the transfer unit, the receiving site, the urban management and construction department has one checklist each; The checklist signatory of the construction unit, transport unit and receiving site is the staff directly responsible for the checklist management. For any actions in violation of the checklist management, the unit and the person in charge shall be both punished.

*Shenzhen Urban Management Bureau’s Instructions on further Strengthening the Construction Waste Management* indicates that, the annual tasks and responsibilities shall be defined in accordance with requirements of the city government on construction and management of receiving sites and integrated utilization plants. The municipal supervision bureau will incorporate it into the scope of performance assessment of
relevant departments, district governments and New Zone Administrative Committee and. Incompliance will be accountability.

Trial Method of Shenzhen Pollution Control and Assessment indicates that, the municipal leading group for pollution control shall be responsible for the specific supervision and establish the supervision team consisting of various departments, integrating reports, site review, rectification and proving documents and evaluating the performance of principle units. The full mark is 100. The assessment level is classified into excellent, eligible or non-eligible.

<table>
<thead>
<tr>
<th>Management of Construction Waste Recycling Procedure</th>
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<tr>
<td>In Shenzhen construction waste source management has proposed the concept of waste reduction and clarified requirements of project proposal, design, construction, demolition. Shenzhen also proposed some pollution control measures. The detailed content is listed into the Shenzhen Construction Waste Reduction and Utilization Regulation issued in October 2009, illustrating the requirement of fixed collection and classification as well as real-time monitoring for construction waste.</td>
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</table>

In response to the possibly illegal dumping of construction waste after levyng tariff, to further manage and control the construction waste flow, to get rid of the existing phenomenon of dumper trucks trying to load more and run faster, Shenzhen has proposed the basic thoughts of checklist management and implemented Shenzhen Construction Waste Transfer and Disposal Management since November 2013, so as to establish the system of construction waste checklist management. In order to enhance management, it is requested that the transfer fee of the spoil and the receiving disposal fee shouldn’t be tendered jointly. In addition, Shenzhen has established dumper trucks safety information platform and publishes the data of receiving site on the internet. It is required that the earthworks unit and construction waste transfer enterprises shall sign on the construction waste management contract for record.

The disposal of construction waste in Shenzhen municipality adopts the permit system and permit for establishing of construction waste receiving plant should be applied from the urban management department. Inside or between the construction sites for earthworks backfill, there is no need to get the construction waste receiving permit and the construction department shall supervise according to relevant standards. It is encouraged to invest the construction waste recycling enterprises. The enterprise engaged in construction waste recycling within the receiving sites should be selected through tendering process by relevant administrative department. The government encourages the R&D of new technology, equipment and waste recycling products and may provide financial support. Regarding to construction of construction waste recycling facilities, the government will specify the requirements in one hand and provide financial support on the other hand.

In addition, Shenzhen makes great efforts on the demonstration and promotion of construction waste on-site recycling projects and encourages the recycling enterprises to mobilize into the construction site using the mobilized processing equipment. The Southern Technology University Construction Waste Project has achieved fruitful results with good social and economic benefits. Announcement of Strengthening Construction Waste Reduction and Utilization indicates that, for projects involve demolition and reconstruction with footprint area over 15,000 m² (including 15,000m²) and a construction waste integrated enterprises should be engaged during the demolition stage to recycle or reuse construction waste on site. Announcement of Promoting Green Construction Standards on the Newly Constructed Structures indicates that, Shenzhen will encourage the city regeneration projects with qualified conditions to adapt to the mode of Southern Technology University for the purpose of “Zero Emission” of construction wastes. Announcement of Shenzhen Construction Project Quality Upgrading Action Plan (2014-2018) proposes to prioritize the utilization mode of South Technology University Project in urban regeneration and governmental project, making the earthwork spoils and residuals “turning from waste into treasure” for on-site utilization, producing recycled aggregate, permeable bricks, square bricks and other recycled building materials.

Since 2009, in order to promote the construction waste recycling products. Shenzhen has issued a series of policies successively which ensures the market share of the construction waste recycling products and promotes the recycling process. In addition, Shenzhen also contributes to the demonstration and propaganda of construction waste on-site recycling. In the Southern Technical University construction waste project, the on-site use of the recycled construction wastes is also an effective channel of promoting recycled products. In conclusion, Shenzhen has been at the forefront in the PRC in terms of integrity of policy.
and effects of promoting recycled products.

In 2009, *Shenzhen Construction Waste Reduction and Utilization Regulation* has made it clear that the construction unit of road works shall prioritize the construction wastes as the roadbed cushion. As for the non-load-bearing structures of new construction, rehabilitation and expansion projects, construction waste recycled products are prioritized if the price is equal and in accordance with the functional requirements.

In 2010, *Announcement of Prioritizing Green Recycled Construction Products in Government Investment Project* indicates that the green recycled construction products shall be prioritized in government investment projects. Also it has specified the project scope, production and technical specifications, quality recognition and marketing price of the green recycled construction products, as well as the responsibilities and obligations of the pilot construction agency and the supervision and security measures of competent department, with “list of projects using the green recycled construction products”

In 2012, *Announcement of the 12th Five Year Plan for Shenzhen Construction Energy Conservation and Green Construction* specified that the green recycled products shall be prioritized in the key municipal projects and affordable housing construction. In the municipal government investment projects, using the green recycled products is a mandatory; In the social investment projects, to use green recycled products is encouraged; *Announcement of Strengthening Construction Waste Reduction and Utilization* indicates that all government investment projects shall use the green recycled construction products and provides the “list of classifications and applicable functions of green recycled construction products”

In 2013, *Shenzhen Green Construction Promotion Method* indicated that, the base cushion, fencing, tube wells, trench, retarding walls and roadbed cushion and other parts shall utilize the green recycled products. The bicycle lane, ground parking shall be paved with permeable green renewable building materials.

In 2014, *Shenzhen Renewable Recycled Aggregate Concrete Products Technical Standards* indicated that, the aggregate replacement rate of the curb products shall be no less than 60%, compared with no less than 80% for other products.

### Management Effects of Construction Waste Recycling

In 2007, Shenzhen initiated the scaled construction waste recycling in the PRC for the first time which is marked by the operation of Tanglangshan Construction Waste Utilization Project. At present, Shenzhen has 5 integrated construction waste utilization facilities, namely Huawei Environmental Building Materials Project, Lvfa Pengcheng, Huili Debang, Yongan Environmental Project and Huaquan Technique Project and reached the annual treatment capacity as high as 5.2 million tons. The integrated utilization rate of the construction waste is more than 50% and tops the PRC. In 2009, *Shenzhen Construction Waste Reduction and Utilization Regulation* came out in Shenzhen. Expect for the construction of Stationary-type construction waste integrated utilization sites, Shenzhen also promote the on-site recycling of construction waste, e.g., Shenzhen explored the first on-site green reutilization in Southern Technique University Project with good effects. More than 1 million construction wastes was reused on site with the recycling rate of more than 90%, saving more than RMB 40 million resulting from the savings of waste transfer and landfill disposal.

### On-site Disposal

![On-site Disposal](image1.jpg)

### Application of recycled products

![Application of recycled products](image2.jpg)
**Summary of Experiences**

(1) **Laws and regulations of Construction Waste Reduction and Utilization**

On October 1st, 2009, Shenzhen issued the first legal regulation on construction waste reduction and utilization in the PRC, specifying 9 innovation systems, including the review and record of construction wastes, reduction and disposal proposal, labels of recycled products, emission tariff, disposable residence decoration, mandatory use of the construction waste recycled products, exchange and utilization of construction spoil, on-site classification of the construction waste. The regulation provides clear legal basis to cut down the sources of construction waste.

(2) **Government counterpart and strong supervision**

Under the supervision of the legal regulations, two record systems namely construction waste reduction and utilization are established. The system of reviewing construction waste content in the designed drawings specifies the requests that the design unit shall have reduction design, the drawing review institute shall report to the administrative competent department after the approval of relevant content for record; The system of construction waste reduction and utilization indicates that reduction design and utilization plan should be prepared in the construction of new projects, demolition of existing architectures, structures and municipal roads. The construction unit shall report to the competent department before the commencement of the project. The record system has played an important role in supervising the source of the construction wastes.

Since 2009, Shenzhen has issued policies on promotion and utilization of recycled products subsequently, especially the green recycled products, specifying that the green recycled building materials shouldn’t be used in the government investment projects if there is no label. There are 14 government investment projects using green recycled building materials such as Shenzhen Airport T3 Terminal, Universiade venues and reconstruction project, North Ring reconstruction project, Shenzhen University Xili Campus, etc. All affordable houses in Longhua Longyue Mansion have adopted green recycled building materials. With the gradual completion of the promotion policies, it will lay a solid foundation for the promotion of Shenzhen construction waste recycled products.

In terms of incentive mechanism, Shenzhen provide financial supports on construction waste reduction and utilization, such as “zero premium”, free of added value and “three exemptions and three half-charged” for the income tax. In addition, subsidies are provided through recycled economy and energy conservation special funds, municipal environmental protection special funds, municipal energy conservation development fund, etc.

(3) **Market-driven and industrial upgrading**

Shenzhen has developed 5 integrated construction waste utilization enterprises successively and explored the business model of integrated construction waste utilization, namely “site-plant combined mode”, temporary land use mode, on-site disposal mode. The site-plant combined mode is defined that, the recycling treatment facilities and receiving site will be constructed jointly for the purpose of eliminating the stored wastes; Temporary land use mode is defined that, the land use for recycling disposal facilities is used temporarily, mainly eliminating the waste for street demolition; On-site disposal mode is defined that, the recycling facilities are constructed on the demolition site, so as to realize “zero emission” of construction waste and reuse the recycled products in project construction.

(4) **Technique support and innovation upgrading**

In 2012, the first construction disposal emission technical standards was released in the PRC and clarified the standards of construction waste emission, detailed requirements of waste reduction design and construction reduction. It is very critical to the design institutes in optimizing the construction design, reducing the consumption of building materials, generation of the construction waste, guiding the construction unit to recycle the construction waste.

Shenzhen prepared and released the legal regulation named *Shenzhen Recycled Concrete Products Technical Standards*. It is applicable to the production and application of Shenzhen recycled aggregate concrete products, as the basis of using products in specific projects with the processing procedure of “detection, appraisal and identification”.

Shenzhen has established the construction waste integrated technique development center
around the major, critical and prospective projects and participated into the preparation of national, industrial and provincial technique standards. Organize and balance the resources integration, study industrial development dynamics, promote to apply scientific outcomes and advices for the development of products and technique upgrading, cultivate highly qualified talents for the industry.

(5) Promotion and Social Recognition

Shenzhen attaches great importance to the promotion and guidance of construction waste recycling. With various channels such as newspapers and magazines, Shenzhen has special feature report to show the hazards of construction wastes compared with the social and environmental benefits of waste recycling. Also it shows the technique and recycled products to the public. Since the international green construction conference, Shenzhen has been committed to the urban development concept of “constructing green city and building up beautiful Shenzhen” and construction waste reduction and recycling is considered as one critical aspect accordingly. Through promotion and guidance, the construction waste recycled products have achieved social recognition and good market acceptance.

6.3 Xi’an

| Basic Conditions of the City | Located in the middle of Guanzhong Plain, Xi’an City, the capital of Shaanxi Province known as Chang’an in the ancient times, is an important city center in West the PRC and one of the world’s famous historical and cultural cities. Governing 10 districts and 6 counties. Xi’an has a total land area of 10,108km², a planned urban area of 865km², a built urban area of 449km² and a resident population of 8,627,500. Xi’an has been honored as the PRC National Hygienic City, National Garden City and Best Performance City in National Civilization City Construction, Internationally Famous Tourist Destination City, Top 10 Chinese Cities of Harmony and Sustainability and National Water-saving City. In 2015, the City as a whole achieved a GDP of CNY 581.003 billion, a local public fiscal budget revenue of CNY 65.091 billion and a total financial revenue of up to CNY 111.498 billion. |
| Generation and Management of Construction Wastes | Xi’an is currently in an important stage of extensive city construction with the suburban development zones as the focus of city-wide development and construction while the urban center having to carry out the important construction tasks of old city reconstruction and industrial enterprise relocation. According to a preliminary estimation, the City as a whole generates annually more than 55 million tons of construction wastes, among which 11million tons are demolition waste. Over the recent years, Xi’an Municipal Government has been actively promoting recycling of construction wastes. Xi’an City Administration Bureau is the government authority responsible for management of construction wastes, with its subordinate body, Construction Waste Administration Division, responsible for management and recycling of construction wastes, planning and approval and registration of construction waste digestion sites, review and approval of quantity of construction waste for removal and review of transportation company qualification and licensing and admission qualification of vehicles, guidance and coordination of construction waste management activities of the various districts and development zones. The district and county city appearance and environment and sanitation administration authorities are responsible for management of construction wastes under their jurisdiction. |
| Policy of Construction Waste Management | Xi’an Construction Waste Management Regulations promulgated in August 2012 specifies the competent authority, established the principles of reduction, harmless disposal, reuse, recycling and producer-responsible-for-disposal and requires the Municipal Government to enact preferential policies for, support and develop projects of and strengthen R&D and transformation and application of comprehensive utilization of construction wastes so as to promote the level of comprehensive utilization of construction wastes. It is also stipulated that the accountability system will be implemented in management of construction wastes where the responsibilities of different functional departments will be defined and both the relevant functional departments and their staff will be held accountable. Under the leadership of the Municipal Government, the accountability system will be initiated by the Office of the Municipal Steering Group of Comprehensive Management of Construction Waste Removal and Transportation Market (hereinafter referred to as the "Comprehensive Management Office") and organized and implemented by the supervision authority. Thanks to the implementation of the accountability system, the awareness of responsibility of the |
construction waste management authority is effectively increased.

It is required in the “Notice on Issuing the Accountability Investigation Methods for Construction Waste Management in Xi’an” that: (1) the District Governments and the Development Zone Administration Committee are responsible for management of construction wastes and comprehensive management of the market order of construction waste transportation to realize interactive law enforcement by the authorities of city appearance and environmental sanitation, public security and traffic management, organizing and implementing construction plans of construction waste digestion sites and assuring, as a top priority, land for construction of construction waste digestion sites; (2) the City Appearance and Gardening Bureau (now a part of the City Administration Bureau) is responsible for licensing of construction waste transportation and providing guidance to the district-level city appearance and gardening bureaus, the city administration and law enforcement bureaus of Chang’ an District and Baoqiao District as well as the construction waste management authorities of the development zones in the routine activities of construction waste management; (3) the Municipal City Administration and Law Enforcement Bureau is responsible for supervising, guiding and coordinating the district-level city administration and law enforcement bureaus and the sub-bureaus, which are responsible for investigating into and handling uncontrolled dumping, spillage and leakage of construction wastes among other illegal and non-compliant activities of removal and transportation of construction wastes, investigating into and handling unlicensed discharge, transportation and digestion of construction wastes and vehicles and companies transporting unapproved construction wastes and assisting the concerned authorities in interactive law enforcement; (4) the Municipal Traffic Police Detachment is responsible for traffic safety register of companies, vehicles and drivers engaged in construction waste transportation and supervising and providing guidance to the traffic police brigades of the various districts and development zones in handling traffic law violations by transportation vehicles; (5) the Municipal Construction Committee (and the Construction Bureau of the districts and developments) are responsible for managing disposal of construction wastes by the construction companies as a part of the construction enterprise credit evaluation system and register illegal disposal of construction wastes in the enterprise credit records according to the specified procedure; (6) the Municipal Planning Bureau (as well as the Planning Bureau of the districts and development zones) are responsible for developing, together with the administrative authority, construction plans of construction waste digestion sites; (7) the accountability system covers both the accountability of the concerned functional departments and their staff. Methods for pursuing accountability of the functional departments include: instructing rectification by a required deadline, circulating a notice of criticism, disqualifying law enforcement, suspending work for further investigation, resigning to assume responsibility, resigning as ordered and dismissal. The person held accountable is disqualified to participate in the annual appraisal of employee with outstanding and excellent performance in the respective year.

Management of Construction Waste Recycling Procedure

It is specified in the “Construction Waste Management Methods of Xi’an City” put into force in March 2003 that implementation and construction companies and individuals generating construction wastes shall submit a construction waste disposal plan to the city appearance and environmental sanitation management authority of the respective district and sign the letter of responsibility of city appearance and environmental sanitation prior to commencement of the construction works. In the “Detailed Rules of Implementation of the Construction Waste Management Methods”, further detailed requirements are included on how to submit such plans. In practice, through issuance of transportation permits and strict en route inspection among many other measures, it is assured that construction wastes from different sources are reported to the competent authority before generated so that they are fully incorporated in the scope of supervision and the discharge fee is collected in time. In addition, during implementation of source management, Xi’an worked out a scientific method for calculation of construction waste generation and third party calculation mechanism is introduced in practical management to provide basis for fee collection at source and management of transportation process.

In Xi’an, transportation of construction wastes is subject to the licensing system which requires companies engaged in transportation of construction wastes apply for a construction waste transportation license from the Municipal City Appearance and Environmental Sanitation Authority. Specific requirements are included in the “Methods for Management of Construction Waste Transportation Companies in Xi’an” on necessary conditions, procedure for qualification application and management of qualification, management of transportation enterprises and withdrawal of transportation enterprises. In practice, a daily reporting and registering system was established for construction waste
transportation. Since 2013, a mechanism has been in place for construction waste transportation enterprises to withdraw from market mandatorily requiring enterprises with a score of less than 60 points in year-end appraisal to withdraw from the market of construction waste transportation.

Xi’an includes projects of comprehensive utilization of construction wastes in its science and technology development plan and hi-tech industry development plan and construction land is allocated with top priority while construction waste digestion sites are included into its national economy and social development plan. Through strict control of the sources of generation of construction wastes, Xi’an is able to make reasonable arrangement of the destination of recycling and disposal of construction wastes based on different quantities of generation and types. In addition, the construction waste recycling and disposal charging system (5.0CNY/ton CDW) has been well implemented. Over the recent years, funded by the government, scientific research institutes and manufacturing enterprises have carried studies in technologies of construction waste recycling. Some enterprises carried out independent and effective study and application of production technologies and made excellent achievements in wet treatment of construction wastes and direct reuse of waste concrete.

Xi’an Municipal Government also issued relevant policies on extensive application of construction waste recycling products. It is required in “Xi’an Construction Waste Management Regulations” that projects of municipal environmental sanitation facilities, municipal engineering facilities, gardening and landscaping facilities constructed with public finance shall use construction waste recycling products as a priority; road construction companies are encouraged to use construction wastes for subgrade cushion as a top priority provided that the operation functions are satisfied; construction, renovation and expansion projects are encouraged to use construction waste recycling products as a top priority provided that construction quality is assured; according to the national policies, enterprises using or producing technologies, processes, equipment or products included in the catalog of construction waste recycling technology, process, equipment or products included in the catalog of construction waste recycling technology, process, equipment or products for encouraged use are entitled to preferential taxation.

Management Effectiveness of Construction Waste Recycling

There are dozens of enterprises engaged in construction waste disposal in Xi’an. However, so far, there is only one enterprise achieving high level of scaled production and ability of continuous production. This enterprise has an annual disposal capacity of 1 million tons and produces products (recycled aggregates and bricks) of relatively good quality. The innovative model of concrete recycling featuring in “integral cutting and staged utilization” proposed by a company in Xi’an effectively increased the added value of waste concrete recycling in reducing environmental pollution and represent an extremely characteristic model of construction waste recycling.

Recycled aggregates

Application of recycled products

Summary of Experiences

(1) Serious Governmental Recognition

Leaders of the CCP Municipal Committee and the Municipal Government have conducted field studies and held multiple special meetings to highlight the importance of supervision and management of practitioners, transportation companies and vehicles, actually perform the responsibilities of localized management and sector supervision and establish a long-term effect mechanism of management of construction waste transportation. In 2010, a steering group headed by the responsible leader of the Municipal Government and comprising of members from the municipal authorities of city appearance, city administration and traffic police to carry out the comprehensive management activities for a
continuous period of time for the purpose of continuous regulation of the market order of construction waste transportation. In the meanwhile, 15 joint inspection teams comprising of members from the municipal authorities of city appearance, city administration and traffic police were established for daily inspections and strict strike of various violations in terms of construction waste transportation. In 2012, regulation of the order of construction waste operation was even included into the list of Top 10 Public Benefit Activities for Routine and Unremitted Implementation.

(2) Assurance from Legislative System

Xi’an has set up an integrated and complete construction waste management system consisting of local legislations, government specifications and sector regulations.

In 2003, Xi’an Municipal Government promulgated the Construction Waste Management Methods, which stipulates that construction waste transportation vehicles shall be subject to qualification-based management and qualified fleets shall be established to reform the “disorganized individual vehicles” into “organized transportation fleets” marking the era of corporate operation of construction waste transportation. Thanks to the efforts of nearly a decade, Xi’an witnessed doubled increase of both generation and vehicles of construction wastes and also significant changes of the transportation sector as well as its scenario of development, leading to timely promulgation of the Construction Waste Management Regulations of Xi’an City.

In 2012, on the basis of full and adequate study, the Municipal People’s Congress promulgated the local legislation of Xi’an, namely the Construction Waste Management Regulations of Xi’an City, which defined the responsibilities of the government authorities of city appearance, city administration and traffic police and others involved as well as at the management levels of district, county and community and described in full detail the rights, obligations and responsibilities of government departments and individuals in terms of construction waste generation, transportation, digestion, recycling and legal responsibilities, including specific and strongly operable measures.

After the Regulations were promulgated, the Municipal Government and the concerned authorities developed, on the basis of the Regulations, “Methods for Appraisal and Evaluation of Construction Waste Transportation Companies in Xi’an City”, “Provisional Requirements on Charges of Construction Waste Disposal in Xi’an City” and “Methods of Accountability Investigation in Construction Waste Management in Xi’an City” and a series of rules and regulations on daily reporting, site supervision, comprehensive evaluation, market withdrawal, recycling company registration, traffic safety registration, “uniform management in 7 aspects” and joint inspection.

(3) Appropriate Enforcement of Actions and Measures

Xi’an City has been implementing discharge permit and daily reporting in a strict way making sure that producers of construction wastes must apply for and obtain a “Construction Waste Disposal (Discharge) Permit and that the construction waste transportation permit shall not be granted until the procedures of reporting, generation verification and disposal fee payment are fulfilled. In practice, a daily report of the transportation vehicles at night time is required, with the reported information shared by the city administration and traffic police authorities via the Comprehensive Management System of Construction Wastes. The concerned government authorities carry out their respective duties and responsibilities based on the reported information.

Xi’an City has specific requirements on transportation capacity and site scale for the purpose of strictly managing the qualifications and competence of transportation operators. Vehicles transporting construction wastes are managed under the category of special vehicles and the vehicles, drivers and corporate owners are subject to traffic police registration and “uniform” management. Transportation operators are subject to monthly evaluation and year-end appraisal for quantitative rating. Those with poor performance in monthly evaluation will be suspended for improvement while those with unacceptable performance will be disqualified and instructed to withdraw from the construction waste transportation sector, with their Construction Waste Disposal (Transportation) Permit revoked.

In Xi’an, a recycling enterprise registration system is in place for the sake of acquiring full information of the level of construction waste recycling of the City as a whole and providing convenience to business operation of such enterprises. Registered enterprises are
included in the comprehensive management system of construction wastes and the city appearance authorities of the various districts and development zones, upon approval of construction sites, will assign demolition wastes based on the production needs of the enterprises to support their production activities. In addition, meetings are held or field visits to enterprises are organized on an irregular basis to learn about their operation status, needs and problems and provide more preferential policies to encourage and support their development.

Thanks to the effective implementation of a series of management measures, effective interaction is achieved of the stages of construction waste generation, transportation and disposal to ensure that the construction wastes are transported to the digestion sites or recycling enterprises, destination of construction wastes is effectively controlled and development of construction waste recycling industry is facilitated.

(4) Strengthened Supervision and Appraisal

In order to make sure that the various measures are enforced, the Municipal Joint Inspection Team carries out zone-based and group-based night tours around the City while the City Appearance and Gardening Bureau organizes at least 2 non-notified inspections per week focusing on site control at the entrances and exits of construction sites with waste generation. Transportation permit approval is, in the first instance, suspended for sites with problems discovered in such inspections and then evaluation scores of the respective jurisdiction are deducted, with news published on Xi’an Daily, Xi’an Evening News and other media. Where the circumstance is serious, an Order for Supervised Action will be issued and greater score deduction expected. In addition to effective implementation of the various requirements, the construction waste management authorities of the districts and development zones have developed innovative and tailored management mechanisms and reinforced management measures based on their local conditions.

6.4 Xuchang

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<th>Basic Conditions of the City</th>
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<td>Located in the middle of Henan Province as one of the core cities of the City Cluster of Central Henan Province, Xuchang City governs 6 counties (cities or districts) and 3 government agencies, including 1 urban-rural integration demonstration zone of the deputy-departmental level, 1 national economic and technological development zone and 102 townships (towns and offices). Xuchang has a total land area of 4,996km² and a total population of 4,871,000 at the end of 2014. Proud of its long history and splendid culture and advanced transportation and geographical location, Xuchang enjoys excellent natural environment, with a built urban area green space ratio of up to 34.3%, a greenery coverage percentage of 39.15% and a per capita park green space of 10.4m². Xuchang has been honored as the PRC’s Top Tourist City, National Garden City, National Forest City, National Landscaping Model City, National Hygienic City, National Water-saving City and National Civilization City. In 2014, the City as a whole achieved a GDP of CNY 210.80 billion, up by 9.3%, a local public fiscal budget revenue of CNY 12.5 billion, up by 15.4%, an added value of industry above designated size of CNY 210.80 billion, up by 9.3%, a public local fiscal budget revenue of CNY 12.5 billion, up by 15.4%, a value added of industry above designated size of CNY 120.10 billion, up by 11.9%, and a fixed asset investment of CNY 163.70 billion, up by 19.4%, representing the stability and health of economy and society in Xuchang.</td>
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<th>Generation and Management of Construction Wastes</th>
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<td>High-speed urban construction in Xuchang is accompanied by the massive generation of construction solid wastes. In the years of 2011 to 2013, more than 15 million tons of urban construction solid wastes were generated in Xuchang, with 4 million tons in Year 2011, 5.2 million tons in Year 2012 and 5.8 million tons in Year 2013. Currently, more than 5 million tons of construction solid wastes are generated a year. There are approximately 1 million tons of demolition waste generated in recent 2 years.</td>
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As the government authority responsible for management of urban construction solid wastes, Xuchang City Administration Bureau is mainly responsible for centralized review and approval, ratification and supervision of the collection, transportation and disposal of construction solid wastes generated in the construction processes in the planned urban area, sector supervision of and operational guidance to the government authorities of construction solid waste management at the county (city or district) level, and supervising and guiding the franchised operators to fully perform the franchise agreement. In 1999, Xuchang City established its special body for construction solid wastes management named Construction Solid Waste Management Office as a temporary standing body under Xuchang City Management Bureau, responsible for enforcing laws and regulations on
construction solid wastes management, collecting construction solid waste disposal fee in the planned urban area and strengthening routine management of urban construction solid wastes and promoting the beneficial use of construction solid wastes. This organization was approved in 2014 by the People’s Government of Xuchang City as a permanent government body. The Municipal Housing and Urban Development Bureau, the Public Security and Traffic Police Bureau and the Road Traffic Management Authority are responsible for collaborating and performing their own duties and responsibilities in terms of construction solid waste management. However, before 2008, construction solid wastes in Xuchang City had been large in a state of uncontrolled disposal, represented by serious problems of uncontrolled stockpiling, overloading and spillage during transportation. In such a context, the People’s Government of Xuchang City embarked on the franchised and integrated operation of the collection, transportation and beneficial use of construction solid wastes by means of public bidding, opening the gate of franchised operation of beneficial use of construction solid wastes in Xuchang City.

**Policy of Construction Waste Management**

Xuchang City attaches great importance to construction solid wastes management and regards beneficial use of construction solid wastes as the fundamental way-out for disposal of urban construction solid wastes. The “Methods for Management of Urban Construction Solid Wastes in Xuchang City” (Xuchang Government Document No. [1999]57) published back in 1999 specified the centralized management of urban construction solid wastes; later on, the “Detailed Rules of Implementation of Urban Solid Waste Management in Xuchang City” (Xuchang Government Office Doc. No. [2011]26) and the “Standard on Collection of Urban Solid Waste Treatment Fee in Xuchang City” provided more detailed and explicit requirements on the implementation of the Methods of Management. In the Methods of Management and Detailed Rules of Implementation, very specific requirements are included on penalties of behaviors violating the Methods of Management of Construction Solid Wastes. It is explicitly required that professional organizations and individuals providing business services of transportation and treatment of construction solid wastes must have the respective qualifications and participate in public tendering. In addition, prices of collection and transportation of construction solid wastes and principal responsibilities and specifications on collection, transportation and disposal of construction solid wastes are specified; Xuchang City also published its “Methods of Management of Construction Materials and Construction Solid Wastes on Construction Sites” (Xuchang Government Office Doc. No. [2013]6), specifying the management responsibilities, breaking down the tasks and including improvements to the working mechanism; in order to increase supports to comprehensive use of regenerated products of construction solid wastes, Xuchang City issued its “Opinions on Comprehensive Use of Construction Solid Wastes” (Xuchang Government Office Doc. [2013]70). The issuance of a series of policy documents symbolizes that Xuchang City is marching step by step towards the standardization and long-term effectiveness of management and beneficial use of construction solid wastes.

Requirements included in the “Methods for Management of Urban Construction Solid Wastes in Xuchang City” include: 1) disposal of construction solid wastes shall follow the principles of reduction, reuse and recycle (3R); comprehensive use of construction of solid wastes is encouraged and the project implementation units and construction units are encouraged to use, as a top priority, products of comprehensive use of construction solid wastes; 2) a tariff system shall be implemented on collection, transportation and disposal of construction solid wastes, with the tariff standard developed based on the standards reviewed and approved by the price authority of Xuchang City, allowing no unauthorized reduction and exemption by any organizations and individuals; 3) a permit system shall be implemented for collection, transportation and disposal of construction solid wastes, requiring organizations and individuals generating and engaged in disposal of construction solid wastes to launch an application to the construction solid waste administration authority 5 days in advance and submit their plans and programs of disposal of construction solid wastes, sign the Statement of Responsibility of Sanitation and obtain the Permit for Disposal of Construction Solid Wastes before the construction activities may commence and make sure the construction solid wastes are transported at designated hours and along designated routes. Lending, transfer, alteration and falsification of the Permit for Disposal of Construction Solid Wastes are not permitted.

Requirements in the Opinions on Comprehensive Use of Construction Solid Wastes in Xuchang City include: 1) Stronger efforts shall be made in planning guidance. The urban management authority, in collaboration with the concerned government authorities, shall develop a scientific medium and long-term plan for management and comprehensive use of construction solid wastes taking account of the inventory and
growth projections of regional construction solid wastes and following the principle of proximity in terms of resource utilization, adhere to the system of franchised collection and transportation of construction solid wastes, encourage private investment to enter the market of construction solid waste regeneration products, support and develop enterprises of comprehensive use of construction solid wastes and assure smooth implementation of comprehensive use of construction solid wastes in the city as whole; 2) Preferential policies shall be provided. Supports, in forms of public financing, taxation, investment among other economic levers, shall be provided to comprehensive use of construction solid wastes and enterprises shall be encouraged to participate in construction projects of comprehensive use of construction solid wastes by means of direct investment. Government departments of development and reform, land and resources, urban and rural planning and environmental protection shall give priority to projects of comprehensive use of construction solid wastes in the processes of project identification, land approval, planning and EIA while the government departments of public finance, taxation shall play an active role in helping the enterprises benefit from the national preferential policies of comprehensive use of resources and increase the competitiveness of enterprises engaged in comprehensive utilization of construction solid wastes.

Management of Construction Waste Recycling Procedure

In order to assure that construction solid wastes are subject to orderly transportation and adequate disposal, Xuchang City requires centralized management of construction solid wastes in four aspects, namely, centralized approval, centralized tariff collection, centralized transportation and centralized utilization. Units and individuals generating construction solid wastes shall submit applications to the city management authority to obtain permits for transportation and disposal of construction solid wastes, which shall be transported by permitted transportation enterprises in a centralized way to designated sites for centralized disposal. Collection, transportation and beneficial use of construction solid wastes shall be undertaken by franchised operators. Management shall be integrated with and supported by advertisement. Before construction starts on site, the construction companies shall be contacted so that they are informed of the relevant policies and laws and regulations of construction solid waste management as well as the hazards of uncontrolled dumping of construction solid wastes, tariff of construction solid wastes disposal and use of such revenue; in addition, businesses and communities shall be visited for public popularization of the concepts of reduction and beneficial use of construction solid wastes so as to increase public awareness and enterprise participation of management and beneficial use of construction solid wastes.

For the transportation stage, specific requirements on transportation vehicles and process are included in the Methods of Management of Construction Materials and Construction Solid Wastes on Construction Sites in Xuchang City while specific penalties are specified in the Detailed Rules of Implementation of Management of Urban Construction Solid Wastes in Xuchang City regarding transportation spillage and uncontrolled dumping. For example, 1) the construction solid wastes administration authority may impose a fine of CNY 30/ton or CNY 10/m³ on leakage or spillage of liquids or bulk cargoes in transportation without proper sealing packaging or covering actions, but the actual fine shall not exceed CNY 10,000 per case; 2) the construction solid wastes administration authority may issue an instruction for correction by a specified deadline, give warning or impose a fine ranging from CNY 5,000 to CNY 50,000 on dumping or spillage during transportation of construction solid wastes by organizations engaged in disposal of construction solid wastes. A joint law enforcement mechanism shall be implemented in terms of transportation supervision, with the Municipal Government, as the leading organization, responsible for organizing joint law enforcement participated in by the government departments of city management, public security, housing and urban construction, transportation and highway administration. In addition, improvements shall be made to the supervision, examination, reward and penalty and accountability mechanisms, accompanied by stronger efforts in inspection and penalty. Vehicle washing facilities shall be provided on construction sites and access roads at the entrances and exits shall be paved; construction waste transportation companies shall be required to implement enclosed transportation and GPS surveillance and speed limit systems. 24-hour inspection and duty shift system shall be implemented as a specific management approach so that the key areas are subject to strict surveillance through integration of daytime inspection and nighttime supervision and rewarded reporting and account management and illegal conducts such as unauthorized transportation, overheight and overloading, open transportation and spillage and contamination by construction solid wastes transportation vehicles are subject to strict examination by law. According to the government policy, cost of authorized third party transportation of construction solid wastes shall be borne by organizations or individuals generating such construction solid wastes at a rate of CNY...
10/ton (excluding loading) or CNY 15/ton (including loading).

For the stage of disposal and beneficial use, R&D of technologies of disposal and beneficial use will mainly rely on franchised enterprises. The Municipal Government of Xuchang encourages technological innovation and encourages efforts by colleges and universities, scientific research institutes and enterprises in R&D of new technologies, new processes and new equipment and efforts in importing advanced and proven technologies and equipment for comprehensive use of construction solid wastes so as to continuously enhance the level of technology and industrialization of comprehensive use of construction solid wastes. As a part of the management requirements, the franchised enterprises of construction solid wastes operation are required to respond actively to market demand, increase input in product R&D and equipment renovation and expand the types and specifications of new construction materials manufactured from construction solid wastes. It is required in the “Detailed Rules of Implementation of Urban Construction Solid Waste Management in Xuchang City” that a tariff system shall be implemented for disposal of construction solid wastes at a standard rate of CNY 3.00/ton.

For the stage of promotion and application of regenerated products, it is proposed in the Opinions on Proper Implementation of Comprehensive Use of Construction Solid Wastes that supports shall be provided to comprehensive use of construction solid wastes through comprehensive use of public financing, taxation and investment and other economic levers. Regeneration products of construction solid wastes shall be incorporated into the scope of government procurement and all projects invested and developed by governments must assure the use of construction solid waste regenerated products, which shall be regarded as one of the prerequisites of financial settlement and fund disbursement. Projects failing to use construction solid waste regenerated products according to the design shall not be permitted for final acceptance and registration upon completion.

Xuchang City has one franchised enterprise at present having the exclusive right of investing in and constructing, operating and maintaining projects of construction solid waste transportation, disposal and utilization within the scope of franchised operation and collecting construction solid waste transportation tariff according to the tariff standard approved by the People’s Government of Xuchang City. This enterprise undertakes construction projects of construction solid wastes treatment plants to realize recycling and reuse of construction solid wastes and fulfills the public benefit tasks and other obligations assigned by the government. This enterprise has the qualifications for production of regenerated aggregates, regenerated wall materials, regenerated floor tiles and outdoor floor tiles, regenerated hydraulic products, regenerated pre-mixed mortar, regenerated concrete, regenerated bitumen and other regenerated products and an annual capacity of more than 4 million tons in disposal of construction solid wastes and an annual output value of more than CNY 320 million. Construction solid wastes regeneration products have already been widely applied in construction projects of urban roads, gardens, plazas, houses, rivers and water conservancy facilities in Xuchang. In 2015, in particular, in the construction of the urban water system of Xuchang, such products were extensively used, winning consistent consent and positive comments by both the government and the public.

Thanks to the joint efforts of government authorities and enterprises in Xuchang, up to 95% of urban construction solid wastes have achieved beneficial use in Xuchang, far much higher than the other Chinese cities and even some leading countries in terms of beneficial use of construction solid wastes. Issues that used to be difficult to address, such as urban center besieged by and environmental pollution and ecological damages caused by construction solid wastes, have been effectively settled. Recycling and beneficial use of construction solid wastes are realized, becoming a powerful driver to development of circular economy in Xuchang. Beneficial reuse of construction solid wastes in Xuchang has been covered in news by a number of public media, including CCTV Light of Technology and Half-hour Economy and the newspaper of the PRC Construction. Xuchang Construction Solid Waste Management and Beneficial Use Project won the PRC Habitat Scroll of Honor Award, generating social impacts over the entire country and significant outcomes.
Xuchang made outstanding accomplishments in construction solid wastes management and became the leader of beneficial use of construction solid wastes. Its key experiences of success are summarized as follows:

(1) A special management body is established to facilitate effective management.

Both the Municipal CCP Committee and People’s Government of Xuchang attach consistent and great importance to construction solid wastes management. Early back in 1999, Xuchang City established the Construction Solid Waste Management Office as a temporary standing body under Xuchang City Management Bureau and was then approved in 2014 by the People’s Government of Xuchang City as a permanent government body. Taking the actual demand of Xuchang City as the basis, the Construction Solid Waste Management Office has been, ever since its establishment, pushing the development and implementation of the respective policies and played an extremely important role in facilitating the management and beneficial use of construction solid wastes in Xuchang.

(2) Powerful supports were provided through policy improvement.

Xuchang City consecutively issued the “Methods for Management of Urban Construction Solid Wastes in Xuchang City”, the “Detailed Rules of Implementation of Urban Solid Waste Management in Xuchang City” and the “Standard on Collection of Urban Solid Waste Treatment Fee in Xuchang City”, the “Methods of Management of Construction Materials and Construction Solid Wastes on Construction Sites” and the “Opinions on Comprehensive Use of Construction Solid Wastes”, specifying the full process of management and beneficial use of construction solid wastes from source declaration, collection, transportation, disposal and promotion and application of regenerated products of construction solid wastes. The adequately detailed and strongly operable requirements included in such policies guaranteed their effective implementation.

(3) Franchised operation model was developed to increase the impetus of industrial development.

As of Year 2008, the People’s Government of Xuchang City initiated “franchised operation” of integrated collection, transportation and beneficial use of construction solid wastes in the urban area by means of open tendering and formed and established its model of franchised operation of construction solid wastes. The franchised enterprise has the exclusive right of investing in and constructing, operating and maintaining projects of construction solid waste transportation, disposal and utilization within the scope of franchised operation and collecting construction solid waste transportation tariff according to the tariff standard approved by the People’s Government of Xuchang City. This enterprise undertakes construction projects of construction solid wastes treatment plants to realize recycling and reuse of construction solid wastes and fulfills the public benefit tasks and other obligations assigned by the government. With clearly assigned rights and obligations, the franchised enterprise experienced high-speed development and increasing capacity of disposal; with products of rich diversity and reliable quality, the market space has been expanding continuously, bringing the industry of beneficial use of construction solid wastes in Xuchang to a relatively high level.

(4) Joint efforts from multiple government departments contribute to effective supervision.
Xuchang established its joint law enforcement mechanism, under which, the Municipal Government, as the leading organization, is responsible for organizing joint law enforcement participated in by the government departments of city management, public security, housing and urban construction, transportation and highway administration. The key purpose of such joint action is to control and manage construction sites, debris transportation vehicles and commodity concrete transportation vehicles. In addition, improvements were made to the supervision, examination, reward and penalty and accountability mechanisms, accompanied by stronger efforts in inspection and penalty. These actions have effectively addressed the problems of spillage of construction solid wastes and pavement contamination by muddy vehicles. In order for closer partnership between the franchised enterprises and the management authorities, joint management teams were established to increase the frequency of routine inspections and assure that all the construction solid wastes are transported to designated disposal sites. Flow of construction solid wastes in Xuchang are subject to effective control in the true sense thanks to such interdepartmental and even government-enterprise interactions and the city appearance and environmental sanitation in Xuchang are maintained to the expected level thanks to regulated transportation and source management.

(5) S&T innovations become a driver of sector development.

The franchised enterprise established Henan’s first engineering and technology research center specialized in R&D of construction solid wastes. Thanks to its all-round efforts of S&T research in classified collection, disposal, key processes and technologies and new product development in terms of construction solid wastes, technological, process, equipment and management models were developed for the sector of beneficial use of construction solid wastes, laying a solid foundation for nationwide duplication of “Xuchang Jinke Model”. The franchised enterprise was certified in 2014 as a national hi-tech enterprise. Furthermore, as a result of the additional efforts in domestic and overseas cooperation and exchange and R&D under key technology projects of Henan Province, a large number of difficult technological issues were addressed. So far, 192 patent applications have been submitted and accepted and 33 patents awarded. The franchised enterprise is also a participant in the ministerial activities of compiling the respective national and industrial standards of beneficial use of construction solid wastes. Regeneration products already developed and manufactured by Xuchang Jinke Corporation are divided into 8 categories including more than 50 types and achieve a 100% ex-factory quality acceptance percentage. Such regeneration products have been certified by Henan Provincial Department of Housing and Urban-rural Development as “New Wall Materials” and by Henan Provincial Development and Reform Committee as “Products of Comprehensive Reuse of Wastes”.

(6) Policy and technology supports assured market application.

The Municipal Government provided support to comprehensive use of construction solid wastes through comprehensive use of public financing, taxation and investment and other economic levers and incorporating regeneration products of construction solid wastes into the scope of government procurement and regarding such incorporation as one of the prerequisites of financial settlement and fund disbursement. Projects failing to use construction solid waste regenerated products according to the design shall not be permitted for final acceptance and registration upon completion. Such policy supports opened the gate to market application of regenerated products. In addition, the technological advantages of the franchised enterprise contribute to the successful development of regenerated products fitting the needs of local construction projects and extensive public recognition of the quality assurance and environment-friendliness of such products. Thanks to dual guarantee of policy and technology, construction solid wastes regeneration products have already been widely applied in construction projects of urban roads, gardens, plazas, houses, rivers and water conservancy facilities in Xuchang.

6.5 Wujin District, Changzhou City

| Basic Conditions of the City | Changzhou, a city of southern Jiangsu Province at the center of the Yangtze River Delta and geographically playing an important role in regions south of the Yangtze River, is located on the southern bank of the Yangtze River and northern bank of Lake Tai and looks out to the East the PRC Sea with equal distance from Shanghai, Nanjing and Hangzhou. By Year 2015, Changzhou has, under its administration, five districts and one county-level city, 21 street offices, 37 towns, 807 administrative villages, 323 resident committees and a total area of 4,385km² and a registered population of 3,686,000. A famous Chinese |
historical and cultural city dated back to more than 3,200 years ago, Changzhou has been honored consecutively as the Top 50 Chinese Cities with Comprehensive Strength, the Top 40 Chinese Cities with Best Investment Environment, National Hygiene City, National Garden City and National Ecological City, National Civilization City and Top 10 Cities of Harmonious and Sustainable Development and won the prizes of the PRC Human Habitat Model, Gold Prize of International Garden City. In 2015, Changzhou accomplished a gross regional product of CNY 527.32 billion, an ordinary public budgetary income of CNY 46.63 billion and a tax income of CNY 37.33 billion, respectively up by 9.2%, 7.5% and 7.3% than the previous year.

<table>
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<tr>
<th>Generation and Management of Construction Wastes</th>
<th>Rapid urban construction has been accompanied by year-on-year growth of construction wastes in Changzhou. Over the years of 2012 to 2014, totally 17.6 million tons of construction wastes and decoration wastes were generated in Changzhou. In 2015, 6.79 million tons of construction wastes and decoration wastes were generated. By Year 2020, the urban area will be expecting an annual average production of 7 million tons of CDW. Currently, demolition waste each year is about 2.5 million tons, decoration waste is about 0.5 million tons.</th>
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Thanks to the high recognition by the CCP Committee and People’s Government of Changzhou City, Changzhou Urban Administration Bureau is assigned, as the competent government department, with the responsibility for administering construction wastes. Construction sites are incorporated into the scope of such administration, which adopts the method of source management; the duties and functions of the construction debris administration body are specified and a standardized procedure of declaration is set up to increase efficiency; an admission system is introduced to the construction waste removal and transportation market for the purpose of qualification approval of transportation companies; stronger efforts are made in supervision and inspection of project implementation and construction units and transportation and treatment service providers; active efforts are made to set up a management network for controlling and punishing non-compliant construction debris handling operations through the multi-party interaction of urban administration, public security and traffic police and gradually realize the standardization of construction debris transportation via digital urban administration.

MOHURD (Wujin) Green Building Industrial Cluster Demonstration Zone is mainly responsible for implementing construction waste integrated utilization demonstration project with urban reconstruction projects as the principal component. Wujin District Government conducted studies in the status of generation, disposal and management as well as reduction and recycling of construction wastes, identified better actions as well as a market-based operation mechanism of harmless and beneficial treatment of construction wastes, enacted special laws and regulations and incentives on beneficial and comprehensive utilization of construction wastes and clearly and mandatorily requires urban reconstruction projects to enforce the respective requirements on comprehensive utilization of construction wastes. In order to strengthen beneficial use of construction wastes, Wujin District Government issued the “Minutes of Meeting on Further Strengthening Beneficial Use of Construction Wastes” to implement on a pilot basis construction waste beneficial use project within the Green Building Demo Zone.

| Policy of Construction Waste Management | In the “Implementation Plan for Special Actions in Controlling and Regulating Construction Wastes in Changzhou City” (Changzhou Government Office Doc. No. [2005]73) and the “Announcement on Strengthening Management of Municipal Construction Waste Disposal” (Changzhou Government Office Doc. No. [2005]137) issued in 2005, duties and responsibilities of the various management departments are specified following the principles of “stronger management, strict law enforcement, integrated control and regulation and long-term implementation” for the purposes of strengthening the management of various construction sites, regulating the procedure of approval of construction waste disposal and strictly reviewing the qualifications of units providing service of construction waste transportation. In addition, the “Opinions on Implementing the ‘Municipal Construction Waste Management Regulations’ (Changzhou Urban Administration Doc. No. [2005]25) were also issued to fully regulate the procedure of review and approval, strengthen source management and enhance the level of and strictly punish various violations during construction waste disposal. As the pilot and demonstration of Wujin District of Changzhou City in beneficial use of construction wastes, the “Minutes of Meeting on Further Strengthening Beneficial Use of Construction Wastes” (No. 2013-88) and the “Minutes of Meeting on Coordinating Efforts in Facilitating the Work of Management and Harmless Disposal of Construction Wastes” (No. 2015-72) were consecutively issued to respectively establish a system of full-process |
supervision management of and development guaranteeing policies on beneficial use of construction wastes and establish a government-led system for comprehensive management of construction wastes so as to strictly manage discharge, removal and transportation and disposal of construction wastes, strengthen efforts in promotion and application of construction waste regenerated products and set up a mechanism for sharing of costs of construction waste disposal.

It is required in the "Minutes of Meeting on Further Strengthening Beneficial Use of Construction Wastes" that (1) construction wastes shall be classified at source and discharged in order; (2) uncontrolled dumping and stockpiling of construction wastes is strictly banned following the “producer-responsible-for-disposal” principle. Inert construction wastes generated in the process of removal are state-owned assets and shall not be for unapproved buy and sell by any parties; (3) transporters of construction wastes shall obtain licenses issued by regional urban administration department and transportation vehicles shall be uniformly labeled and carry and use electronic devices containing information such as registered route, time and destination of delivery; (5) the licensed operation system shall be implemented for production and transportation activities of enterprises engaged in construction waste recycling and the district government shall provide sites of production for such enterprises; (6) haulage-based subsidization shall be implemented for construction waste transportation and private enterprises shall pay transportation subsidy according to the respective standards if recycling is required for the construction wastes such enterprises generate; (7) the district science and technology authority shall include construction waste recycling projects into the list of Key S&T and Investment Projects; (8) the district DRC, housing and urban-rural development, transportation, environmental protection, land and resources, planning and resettlement management authorities shall make active efforts in promoting construction waste regeneration products complying with the requirements of marketing.

It is required in the "Minutes of Meeting on Coordinating Efforts in Facilitating the Work of Management and Harmless Disposal of Construction Wastes" that: (1) a sound construction waste management system that is led by the government, participated by the social public and managed by the competent industrial department and involves cooperation from all concerned sides shall be set up to truly realize reduction, harmless and beneficial use and industrialization of construction wastes. (2) Discharge, removal and transportation and disposal of construction wastes shall be managed strictly and a review system shall be established for discharge of construction wastes. Contractors of construction and removal works shall set up sites for classification and collection of construction wastes in the construction areas to realize classified dismantling and stockpiling. Temporary sites of collection shall be provided in areas (communities) where decoration and fitting wastes are generated, with the property management service providers or community offices responsible for routine management. Construction wastes shall be directly delivered by transportation companies approved by the urban administration authority to designated sites (or plants) of disposal for harmless disposal; (3) stronger effort shall be made in promoting the application of construction wastes regenerated products. (4) the district government shall provide appropriate subsidy on transportation and disposal of construction wastes while the district DRC, finance and taxation authorities shall provide supports to enterprises engaged in recycling and disposal of construction wastes; (5) the district urban administration bureau, land acquisition office, housing and urban-rural development, transportation, water conservancy and public security departments shall fulfill their management responsibilities to set up a comprehensive coordination and management mechanism for disposal of construction wastes.

Management of Construction Waste Recycling Procedure

The local government establishes its management system oriented towards harmless disposal and beneficial use of construction wastes to encourage whole society participation while the enterprises realize standardized disposal and production and develop a closed recycling industry chain integrating the processes of generation, collection, transportation, disposal, regeneration and application. Following the principle of "producer-responsible-for-disposal", sites for classified collection of construction wastes are set up in construction areas to achieve classified dismantling and stockpiling. Construction wastes are directly delivered by transportation companies approved by the urban administration authority to designated sites (or plants) of disposal for harmless disposal. Based on the volume and distribution of construction wastes generated in the district, terminals for beneficial use and disposal of construction wastes are reasonably planned so that both Stationary and mobile facilities are adopted to achieve recycling of more than 90% of the dismantling and
construction wastes and more than 60% of the decoration and fitting wastes.

In the transportation stage, all vehicles engaged in transportation of construction wastes must follow the "7-uniform and 1-must" management regulation, i.e. uniform enclosure device, uniform roof lamp, uniform company logo, uniform appearance and color, uniform enlarged license plate, uniform safety warning signs and uniform GPS system. "One-must" means that construction waste transportation vehicles must be subject to uniform management by the local government. Transportation vehicles must be retrofitted according to the specified enclosure standard and checked and accepted by the concerned authorities before the vehicle owners are granted with the "Construction Waste Enclosed Transportation Pass Certificate" and "Construction Waste Enclosed Transportation Registration Document" so that a Road Transportation Permit and a Construction Waste Transportation Permit can be further obtained from Changzhou authorities of transportation and urban administration. With all four certificates in hand, the municipal administration authority will issue a Transportation Qualification Approval to the qualified construction waste transportation units and made public on its website. The local financial department provides the transport enterprises a subsidy of CNY 1.50/ton for transportation of construction wastes.

In the stage of disposal and recycling, active efforts are made by enterprises implementing demonstration projects of construction waste recycling to deepen cooperation with research institutes and colleges and universities following the requirements of standardization, scale and industrialization. State-of-the-art processes and technical equipment are introduced from both home and abroad to continuously promote the level of technical equipment and innovation and enhance rate of harmless disposal. For example, Wujin Luhe Environmental Protection and Construction Material Science and Technology Limited Company cooperate with Beijing University of Civil Engineering and Architecture, the PRC Academy of Building Research, etc. According to the Minutes of Meeting on Coordinating Efforts in Facilitating the Work of Management and Harmless Disposal of Construction Wastes", the subsidy on disposal of dismantling and construction wastes is determined at a rate of 50% of the cost of harmless disposal while that for decoration and fitting wastes at 80% of the cost of harmless disposals.

In the stage of promotion and application of recycling products, enterprises implementing demonstration projects of construction waste recycling make active efforts in technological research of production and application of recycling products and supports are provided to jointly set up R&D centers with research institutes and colleges and universities so as to promote the technological and quality level of construction waste recycling products, expand the scope of application and increase the added value of recycling products and enable such products to comply with national, industrial and local standards. New products should be granted with the corresponding certificates of product promotion and construction waste recycling products should be included into the catalogs of green construction materials, the catalogs of government procurement and the engineering cost information for preferential promotion and application in construction projects. Construction waste recycling products should be utilized as a top priority in green buildings and the construction project design stage. Construction projects financed with state-owned fund or by the national government must use construction waste recycling products. For example, recycled permeable concrete and bricks were used for the road surface in Wujin Green Building Exhibition Park. Recycled permeable bricks and blind track bricks are used for sidewalk of Jintan Kejiao Road and Lanhui Niuxi Road in Wujin District.

Management of Construction Wastes

Jiangsu Wujin Lvhe Environmental Construction Material Technology Co., Ltd., is the franchised construction waste recycling company of Wujin District of Changzhou City. As a state-owned shareholding enterprise established according to the PPP model by MOHURD (Wujin) Green Building Industry Cluster Demonstration Zone, the company has 1 No. 60,000ton/year imported mobile crushing and screening equipment, 1 No. 1,000,000 ton/year fixed classification and grading production line, 1 No. 300,000ton/year pre-mixed mortar production line, 1 No. 800,000ton/year inorganic mixture production line and 3 Nos. 100,000m3/year cement product production line and achieves an annual treatment capacity of 1,600,000 tons of construction wastes and a recycling rate of more than 90%, representing a yearly land saving of 375mu and coal saving of 27,000 tons and a yearly CO2 reduction of 13,000 tons and an annual sales income of CNY 180 million.

Officially commissioned in May 2015, the company has treated nearly 62,500 cubic meters of standard mortar bricks, 94,000 tons of pre-mixed mortar, 125,000 cubic meters of cement-stabilized macadam and 125,000 tons of regenerated aggregates.
Recycled product plant

Typical case: Expo

Construction waste recycling products have been widely applied in construction projects of municipal engineering, transportation, gardening and water conservancy in Changzhou and the surrounding cities, generating benign social impacts and recognized highly by the industry. Successful applications of such products include Jiangsu Green Building Exposition Park, CAS Changzhou Green Technology Industrial Park and the slope protection works of water conservancy projects in Wujin District where the ecological hydro-engineering retaining wall bricks are used in large volume.

Changzhou Construction Waste Recycling Project has been reported on Xinhua Daily, the PRC Environment Newspaper among many other media and was listed as one of the key projects of energy saving and circular economy in the Central Government Budgetary Investment Plan of Year 2015; the technological renovation of the Project won the 2nd prize of scientific research achievements of Jiangsu Department of Housing and urban-rural Development and the Project was included into the Collection of Tentative and Innovative Practices of Jiangsu Province.

Experience Summary

(1) Demonstrative Role in Green Development

Changzhou achieved classified dismantling, regulated transportation, enclosed production, low energy consumption and high efficiency, 100% disposal, high recycling rate, zero pollution and zero discharge in construction waste recycling, not only closely following the national strategy of sustainable development, but also playing a demonstrative role in promoting ecological civilization construction and circular economy development.

(2) Policy supports enabling the formation of a closed industrial chain

Changzhou City has consecutively issued the “Implementation Plan for Special Actions in Controlling and Regulating Construction Wastes in Changzhou City”, the “Announcement on Strengthening Management of Municipal Construction Waste Disposal”, the “Opinions on Implementing the “Municipal Construction Waste Management Regulations”, the “Minutes of Meeting on Further Strengthening Beneficial Use of Construction Wastes” (No. 2013-88) and the “Minutes of Meeting on Coordinating Efforts in Facilitating the Work of Management and Harmless Disposal of Construction Wastes” and integrated the efforts of all concerned departments to set up a comprehensive management system and formed a closed industrial chain integrating the generation, collection, transportation, disposal and recycling and application of construction wastes.

(3) Four development goals achieved through departmental interaction

Changzhou Urban Administration Bureau, in coordination with Wujin District government departments and offices of urban administration, housing, finance, reform and development, taxation, economic and IT, science and technology, collection, transportation, water conservancy and public security, has set up a comprehensive coordination and management mechanism for construction waste recycling. "Admission thresholds" are established for vehicles and enterprises to be engaged in construction waste transportation to regulate the process of construction waste transportation and avoid “spillage and leakage” during transportation. A sound construction waste management system that is led by the government, participated by the social public and managed by the competent industrial department and involves cooperation from all concerned sides shall be set up, demonstrative enterprises with standard management, state-of-the-art technologies and high operational efficiency shall be cultivated and a sound industrial chain developed to incorporate construction waste recycling into modernized development plan of building industry and truly realize reduction, harmless and beneficial use and industrialization of
construction wastes.

(4) Franchised enterprises established using PPP model

In Changzhou Wujin District Green Building Industrial Zone, franchised construction waste enterprises are established using PPP model for the sake of moderate integration of market competition and government regulation and enterprise development under government leadership and supports to not only encourage private investment in public services and expand the development space for private enterprises, but also alleviate pressure of governmental financial expenditures and increase investment efficiency. State-owned and private account for 70% and 30%, respectively, for Franchise enterprise, and project land use is unified transfer. Economic benefits are realized simultaneously with social benefits to bring profits to the enterprises.

(5) Green production achieved through technological research and innovation

The franchised enterprise has developed excellent partnership of technological development with a number of scientific research institutes and colleges and universities including the PRC Academy of Architectural Science, Hunan University, Nanjing University of Technology, and WCCT World Center of Concrete Technology. In addition, it has set up the Construction Waste Green Recycling Engineering Technology Research Center and Jiangsu Province Graduate Work Station and deepened its cooperation with domestic industry and leading enterprises. Advanced process technologies and equipment were imported and multiple technological gaps filled. Its research achievements successfully accredited by Jiangsu Province Department of Housing and Urban-Rural Development and automation and integration of diversified product promotion modules were realized and green production achieved in construction waste recycling.

(6) Recycling product market expanded by diversified means

It is pointed out in the Minutes of Meeting on Coordinating Efforts in Facilitating the Work of Management and Harmless Disposal of Construction Wastes” that construction waste recycling products should be included into the catalogs of green construction materials, the catalogs of government procurement and the engineering cost information for preferential promotion and application in construction projects. Construction waste recycling products should be utilized as a top priority in green buildings and the construction project design stage. Construction projects financed with state-owned fund or by the national government must use construction waste recycling products to expand the scope of application of construction waste recycling products. The franchised enterprise has sped up the R&D and promotion of new technologies, new processes, new equipment and new materials, in particular, the development of new regenerated construction materials and raw materials oriented towards the current hot directions of industrial development, such as "green construction material", "sponge city", so as to increase channels of recycling and added value of recycling products.

6.6 Beijing

The amount of annual CDW generated is approximately 40 million tons, in which there are about one quarter of total amount can be recycled. In the 12th Five-Year Plan, Beijing government proposed to strengthen the promotion of the construction of integrated CDW recycling projects in the north part, south part and the other places in Beijing to achieve the goal of increasing recycling rate up to 80%.

Beijing government paid attention to CDW recycling and reuse, and announced policies to promote the CDW recycling. The major policies are listed as follows:

“Opinions on Promoting Integrated Management of CDW Recycling Activities” was announced and implemented in July, 2011. The “Opinions” clarified the goal, major tasks and safeguard for CDW recycling.

“Green Beijing Development Construction Planning in the 12th Five-Year Plan” was enacted in 2011 to strengthen the promotion of the integrated recycling projects for CDW. It re-indicated that the CDW recycling rate shall meet 80% at the end of the 12th Five-Year Plan.

“Guideline for the Stationary CDW Recycling and Disposal Facilities” (on a trial base) was
announced in November 2011, which regulated the provisions for the scale and structure of disposal facilities, site selection, process and equipment, auxiliary production and supporting facilities, environmental protection and safety and health, and the main technical requirements.

Begin from March 1st 2012, based on “CDW Management Linked Approaches”, construction units, transportation units, disposal sites, and management department implement “Four-Links” system.

In October 2012, Beijing Municipal Commission of Housing and Urban-rural Development (BMCHUD) announced “Opinions on strengthening the application of CDW recycled product” Jingjianfa (2012) No.328 to address that city-government invested public infrastructure construction project (including roads, landscaping, public toilets, garbage buildings, pedestrian space, river, the river channel revetment engineering) should follow the alternative usage ratio announced by BMCHUD to apply CDW recycled product.

“Examination and evaluation methods for comprehensive management of CDW in Beijing” was implemented in January 2013. The condition of district construction waste recycling work was included into the evaluation results of capital city’s environmental construction.

“Three-Year Implementation plan of the construction of municipal solid waste treatment facility in Beijing” (2013-2015) was announced in June 2013, which indicates that the government will provide 30% of the investment subsidies for the construction of CDW recycling facilities.

“Beijing Green Building Action Plan” was announced in July 2013, which involved the comprehensive utilization of CDW into the circular economy development plan.

In December 2013, the “Notice on adjusting the fees for non-resident garbage disposal in the city” regulated: the clean and transport fee for construction waste is 6 yuan/ton within 6 kilometers, and 1 yuan/ton for a distance that is more than 6 kilometers. The treatment fee for construction waste changed to 30 yuan/ton.

In 2013, integrated management and recycling information sharing platform of CDW was established. This platform compromised the source (muck consumptive license), transport enterprises, disposal sites (CDW disposal enterprises), preparation permit, etc.

The entire process of CDW management in Beijing is concluded as follows:

At the source, CDW in construction sites is simply classified and can be centralized collection. In addition, video monitoring and other facilities will be installed in excavated (demolition) sites to guarantee the management effect of CDW sources. Besides, it is required that clean and transportation contracts need to be signed before the start of demolition projects.

In transportation stage, special transportation vehicles need to be normalized, and these vehicles must comply with relevant standards and environmental requirements; in the other words, these vehicles should have closed containers, lifting positioning, speed restrictions, and other functions. In addition, the access and exit mechanism of CDW transportation market will be built, and the management system of transport vehicles will be strengthened. Besides, normal law enforcement mechanism and linkage system of punishment will be built as well.

In disposal stage, the combination of planning and regulation was done under the building of CDW recycling disposal facilities. The Municipal Department unified planned and rationally distributed the CDW recycling projects. Based on the “Guideline”, the construction of recycling facilities was regulated. Several municipal science and technology planning projects related to CDW recycling were approved in Beijing.

In the promotion and application stage of recycling products, based on “Opinions on strengthening the application of CDW recycled product”, the application of CDW recycled products was promoted. However, the application range for the recycled products was too narrow in the “Opinions”, and it also limited the actual use of these products.

Overall, Beijing had clear objectives in CDW recycling aspect. A series of comprehensive policies were set out for accomplishing the goal. Relative monitoring platform was built as well. However, there was still a big gap between the management effect and set goals. In the original plan, six CDW recycling facilities would be built in Daxing, Chaoyang, Fangshan, Shunyi, Haidian, Shijingshan, Fengtai, and other districts and counties by 2015. Recently, only the project in Shijingshan is completely reformed, but the actual energy
production is low; the operation of the company is difficult. The project in Daxing District is still under construction stage. There is no substantial progress in the four projects in Fengtai, Chaoyang, Haidian, and Fangshan. Therefore, Beijing does not actually form large-scale CDW recycling and disposal capacity, and the recycling rate is low.

6.7 Comparison of Case Study Cities

There are various factors influencing urban CDW management, in terms of the case studies stated above, there are general practices of CDW recycling and reuse among different case study cities and also differences. In general, the key success factor for CDW management and utilization are primarily government policies and promotions, as well as actively participation by enterprises in the local market, secondly differentiated work based on its own characteristics.

Comprehensive comparison is conducted on the CDW management and utilization successful experiences between different cities, in order to provide references to those cities with similar condition as the case study cities.

6.7.1 General Practices

The most important CDW management and utilization practices in common between those case study cities on the government focus, government insurance, policies and regulations for steps including CDW production, transportation, disposal and applications of recycled products. In those typical cities, government has paid attention to the CDW utilization, all cities have CDW management department other than Beijing and Changzhou City Wujin district. Also, all cities have local legislation for CDW utilization, the key legislation of the case study cities are summaries in Table 6-1.

<table>
<thead>
<tr>
<th>City</th>
<th>Regulations</th>
<th>Implementation</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shenzhen</td>
<td><em>Shenzhen Construction Waste Reduction and Utilization Regulations</em></td>
<td>2009</td>
<td>Regulate the CDW discharge reduction in design, construction, shop drawing review, construction industrialization, one-time decoration, demolition and approvals, as well as classified collection, transportation, discharge cost, disposal technologies and application of recycled products, provide the system of construction waste checklist management.</td>
</tr>
<tr>
<td>Xi’an</td>
<td><em>Xi’an Construction Waste Management Regulations</em></td>
<td>2012</td>
<td>Provide regulations in terms of CDW emission, transportation, elimination, comprehensively utilization, disposal management and monitoring, as well as legal responsibilities, the main content is streamlined in CDW recycling and reuse process, content include the declaration in CDW disposal, identification of monitoring management and legal responsibilities of ensuring CDW recycling and reuse, especially the regulations on the violation of those ordinances.</td>
</tr>
<tr>
<td>Xuchang</td>
<td><em>Methods for Management of Urban Construction Solid Wastes in Xuchang City</em></td>
<td>2010</td>
<td>Regulate the collection, transportation and disposal of CDW, specify the implementation of franchising for CDW collection, transportation and disposal in the planned area, as well as the regulations for the responsibilities of CDW management relevant government department.</td>
</tr>
<tr>
<td>Changzhou City</td>
<td><em>Minutes of Meeting on Further Strengthening Beneficial Use of</em></td>
<td>2013</td>
<td>Regulate the collection, transportation and disposal of CDW, specify the franchising regulations for the production and transportation of CDW recycling and reuse enterprises, government provides sites for the production for the CDW recycling and reuse enterprises; subsidy for</td>
</tr>
</tbody>
</table>
Shenzhen is the first city in the nation that has CDW utilization legislation, although some items in *Shenzhen Construction Waste Reduction and Utilization Regulations* are not in details, it is the first time in the nation that regulations are set out for CDW source reduction and utilization, which is demonstrative action for the legislation of CDW recycling and reuse in the whole nation.

*Xi'an Construction Waste Management Regulations* are in adequate details and provide legislations for the implementation of urban CDW management, it is highly practical and provides strong support to monitoring of CDW disposal and transportation for Xi'an.

*Methods for Management of Urban Construction Solid Wastes in Xuchang City* provides legislation condition for establishing franchise mode, Xuchang became the first city that implements CDW recycling and reuse franchise.

Although there has been no legislation established in Changzhou, regulations for CDW recycling and reuse management are developed through 2 meeting minutes, which set out policy support for CDW disposal and transportation enterprise franchise, and the implementation of disposal and transportation government subsidies.

*Advices on promotion of CDW Recycling and Reuse Comprehensive Management* in Beijing includes all aspects, however, it is at macro level and not practical.

### 6.7.2 Differentiation Analysis of Successful Experiences

The differentiation analysis of successful experiences among different case study cities are listed in Table 6-2.

<table>
<thead>
<tr>
<th>City</th>
<th>Differential Successful Experiences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shenzhen</td>
<td>Exploration of various types of business mode promotes CDW industry upgrading and development. The improvement of recycled product promotion policies, especially developing identification for green recycled CDW products, and restriction of using non-identified green CDW recycled projects in government investment projects, strongly promotes the CDW recycling markets in Shenzhen, ensures the continuous operation of the CDW recycling and reuse enterprises and increases the recycling rate of CDW.</td>
</tr>
<tr>
<td>Location</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>Technology innovation, relying on the enterprises, establishment of the CDW comprehensive utilization technical research centre, work is developed focusing on the development of key projects and industrialization, to improve the CDW recycling and reuse technologies in Shenzhen, and ensure the quality of CDW recycled products.</td>
<td></td>
</tr>
<tr>
<td>Xi’an</td>
<td>Refined the CDW source declaration through establishment of policies and regulations, declaration processes are clear and practical, emission fee collections are in place.</td>
</tr>
<tr>
<td>Issuing transportation permits and roads inspection are strictly monitored, which ensures the declaration of CDW generation and CDW production is well monitored.</td>
<td></td>
</tr>
<tr>
<td>Specified calculation and checking methods for CDW production, introduce third party checking calculation mechanism, provided basis for source charge and transportation management.</td>
<td></td>
</tr>
<tr>
<td>CDW management responsibility recognition are strengthened through exams, measures for investigation of responsibilities, to ensure supervision and monitoring.</td>
<td></td>
</tr>
<tr>
<td>Xuchang</td>
<td>“Franchise” is implemented for integrated CDW collection, transportation and utilization, franchise enterprises have production chain that covers the key processes of CDW recycling and reuse, the high cost of disposal are paid through the income of other processes, enterprises development is highly promoted.</td>
</tr>
<tr>
<td>Legislation opens the pathway for the CDW recycled projects application, products can be included in the government procurement list, and also can be the basis for the settlement and disbursement of funds, for the projects using products that are not accordance with design requirement, construction completion acceptance is not allowed.</td>
<td></td>
</tr>
<tr>
<td>Franchise enterprise rely on the technology improvement, develop CDW recycled projects that applicable for local needs, products are in various types, quality is ensured. Policy and technology provide double insurance to ensure that the CDW recycled products in Xuchang can be widely used in engineering projects.</td>
<td></td>
</tr>
<tr>
<td>Changzhou City Wujin District</td>
<td>Establish public-private partnership to develop franchise enterprises, this is to combine the market completion with government regulations, government controls and promotes the development of the enterprises, CDW recycling and reuse projects are built in high levels.</td>
</tr>
<tr>
<td>Establish efficient mechanism, strongly support the development of enterprises that manages the entire CDW recycling process.</td>
<td></td>
</tr>
<tr>
<td>Government subsidies for CDW recycling and disposal are in place, operation of disposal enterprises are ensured.</td>
<td></td>
</tr>
<tr>
<td>CDW recycled products are applicable for local needs, policies ensured the primary promotion in engineering project.</td>
<td></td>
</tr>
<tr>
<td>Beijing</td>
<td>Although there are complete policies, links between polices are lacking, policies are difficult to be implemented so that it is difficult to promote CDW recycling and reuse.</td>
</tr>
</tbody>
</table>
Appendix 1 CDW Generation Estimation Methods

CDW generation estimation is basic reference data for the formulation of CDW management and recycling policies. A clear understanding of the urban CDW generation trends is a precondition to its recycling and management.

(1) Per Capita Multiplier Method

This method makes estimations based on urban per capita generation of CDW. CDW quantification using this method has been mentioned in many relevant researches. The method will follow several steps: firstly surveys will be conducted to collect the in and out waste volumes from a public landfill of a certain area for a certain period of time, and calculate the total landfill at the area for the period; then calculate the total population of the area basing on local population statistics, and work out the per capita waste generation of the area for the period; lastly predict future CDW generation based on population projections of the area for a future period of time. As the calculation is over simple with a few influence factors, the prediction often has large difference with the actual figure. In fact population is not the only factor concerned with CDW generation; other closely related factors include construction activities, economic and technological development.

(2) Site Survey

There are two ways of on-site observation: a. direct measurement, which directly measures the total CDW volume from all the drop-off points; b. indirect measurement, which works out the total volume basing on calculations on waste-related equipment such as transport vehicles.

Although direct measurement is convenient and can produce more accurate results, it's very limited in terms of application, especially for large scale investigations, such as the CDW generation of the whole the PRC, it requires large amount of labor and financial inputs, and the results could come in too late. As for indirect measurement, no detailed records of the indirect measurement factors were found available for many construction sites visited by the study group, which serious affects the implementation and promotion of this method.

(3) Generation Rate per Unit Calculation

Based on the existing literature, this method is most widely used, and is applicable to the estimation of CDW generation of different periods; its application can be divided into many forms which mainly include:

1) Generation rate per unit calculation based on the financial value of building permit

Yost and Halstead introduced a methodology that bases CWD estimate on the financial value of building permit, which provides theoretical basis for the site selection of waste recycling enterprises. This method is described in detail in a case study estimating gypsum wallboard waste generation: 1. Systematic survey conducted on interrelated items, and preliminary calculation on generation volume and area of gypsum wallboard, then estimate its generation rate using mathematical method; 2. Calculate unit area price basing on financial value and floor area, then calculate the total value for all constructions in the area. 3. Lastly, based on the corresponding relation, the total gypsum wallboard waste generation is estimated. This method uses the financial value as the coefficient of CDW generation while takes into account of other factors; the results are more accurate and closer to the actual amount. Certainly, a better understanding of the accuracy of relevant government data is the basis of the estimation. As the building structure and materials applied in the study has big difference with that of the PRC, the method is not of high applicability.

2) Generation rate per unit calculation based on statistical data

The precondition to apply this method is to acquire accurate and detailed data from relevant sector and the government, more relevant information will contribute to more convenient and accurate estimates on CDW. In a study conducted in 2011, 3 variables including Beijing's GDP, area of commercial housing sales and building construction area are selected to develop multiple regression equation using SPSS, so as to estimate the CDW generation in Beijing during the 12th FYP period for the development of proper layout of CDW disposal facilities. This method reflects the importance of complete data support to CDW quantification and management.

3) Generation rate per unit calculation based on classification system

Due to the complex composition and variety of CDW, how to conduct sound CDW quantification has been a very difficult
task. In 2011, Wu Zezhou and Liu Wengui conducted a detailed and in-depth review on the literature published home and abroad on CDW quantification, different methods are concluded into area and project levels estimation, and reviewed in detail to develop a set of systematic and comprehensive quantification methods, so as to provide reference for CDW quantification needs on different levels. Solis-Guzman et al. introduced a CDW classification system based on the data produced during the construction activity. Based on Spain’s construction activity estimate system, he developed a standard for CDW classification which provides sound classification of the wastes generated at each division of the construction chain, every division, called chapter, is distinguished from each other and expressed by number; a sub-chapter refers to a small link of the construction activity, expressed by letter. After the classification system is determined, the next step is to calculate the quantity of wastes from all kinds of materials.

Generation rate per unit calculation method has a wide coverage, and can be used to quantify every division of the construction activity, mostly importantly the waste generation, and thereby determine the waste generation from each division, and finally work out the total waste generation from the construction activity.

(4) Material Flow Analysis Method

Material flow analysis approach was presented by Cochran and Townsend for estimating CDW generation on a regional level. The approach studies the overall construction activity, and classifies the divisions that play different roles in the construction activity. The consumptions include: the purchased building materials (W) are not necessarily all in kind, some materials will not be used during the construction, and expected to convert to construction waste, the remaining materials will constitute the gross building body, and will be terminated along with the building’s service life, then all become wastes from construction activity (RW) upon reconstruction, i.e. RW=W-CM.

Assuming the building's service life is 50 years, the estimation of waste generation for such buildings within a certain period (T) can use the equation as follows:

\[
CM(T)=W(T)\times wc
\]

\[
RW(T)=W(T-50)-CM(T-50)
\]

Note: wc stands for average waste ratio of the building materials at construction sites, normally relevant data can be found to backup. The demolition waste generation in year T equals to the total volume of building materials used to construct the building 50 years ago. Two equations added together will be the total CDW generation in Year T.

Similarly, Prof. Li Ying from Beijing University of Civil Engineering and Architecture started with the construction material cost and total cost and the relationship between the actual construction material consumption with theoretically planned quantity, and found that CDW generation is closely related to total purchased materials for construction, thereby a ratio to the total purchased material is used to reflect CDW generation. However depending on construction management practice, the ratios of all waste streams to the total material amount are dispersed, resulting in errors in the CDW generation estimate. The results derived from this method are higher than the actual amount, this is because the actual construction will recycle more or less the waste.

Material flow analysis method has its strength in estimating the total regional CDW generation. However a lack of relevant data has restricted its wide application. Moreover, the current studies usually focus on common building types, with fewer studies on such buildings.

(5) System Modeling Method

As accurate and meticulous quantification is very important in the process, how to achieve accurate and meticulous work has become more needed. Modeling is an effective approach for prediction of CDW generation. This approach considers CDW quantification as a complex system, and examines in detail of every link in the building model, hereby its accuracy is very appreciable.

Wimalasena et.al presented the idea of “activity based quantification” which accumulates the waste from each of the activities, and developed into a complete system. This approach predicts the CDW generation from a systematic point of view which can ensure the accuracy of the whole construction process by detailing every construction activity. Among the factors, some are artificial while some are not. Some primitive and simple methods are adopted to calculate the waste generation from every construction link, hereby accurately determine under different circumstances to what extent these basic links can influence the total CDW generation. Bergsdal and Bohne conducted the practice of tracing the use of construction material in Norway, and then Monte Carlo Model is used to predict CDW generation in the next few years, so as to allow better CDW management. In 2007, Prof. Li Ying and Chen Jialong from Beijing University of Civil Engineering and Architecture used grey forecasting model and generalized regression neural network model to establish gray-generalized regression neural network model of CDW generation in Beijing. In 2008, Lu Ning established a system of indicators affecting urban annual CDW generation, using principal component analysis method and in consideration of the
accumulated contribution rate of indicators’ characteristic roots, a framework for Calculation and Prediction Method for CDW Generation is proposed. In 2008, Niu Jia and Yan Wenzhou used the quantification methods from extemnics and statistics theories for the systematic analysis on CDW and its recycling towards industrialization, and proposed the strategy for its industrialization. In 2011, Katz, A and Baum, H developed a model for estimating CDW generation from newly constructed residential buildings, which approved effective by the survey data and analysis. Jia Shun and Liao Qiyun conducted a study on the CDW generation from the main urban area of Chongqing Municipality, and established a CDW generation indicator system, through questionnaire and principal component analysis, the influence indicators of urban CDW are concluded, then GM model is used to predict the CDW generation from the main urban area of Chongqing in the next 5 years, the study also refers to the good practices of developed countries in urban CDW generation. The study provides basis for Chongqing to formulate its CDW management regulation and solutions.

(6) Domestic Estimation Method is Use

1) Estimation of CDW generation in Luoyang

Luoyang CDW Generation Calculation Standard (the Standard) covers the estimation of CDW generation from demolition, building construction, roads and pipe trench, landscaping and decoration works. The Standard become effective in May 30th, 2008. The estimation formulas are as follows:

1-1) Demolition-house demolition:

CDW generation from house demolition=floor area × CDW generation per unit area

Floor area is based on the data from relevant departments on the building, re-measurement will be needed if lack of such data; same method also applies to the floor area of already demolished houses.

CDW generation per unit area: civil buildings 1.3ton/m2; when recycling is involved, calculation will be based on structure types: wood and brick structure 0.8 ton/m2, brick and concrete structure 0.9 ton/m2, reinforce concrete 1 ton/m2, steel structure 0.2 ton/m2; industrial workshops and storage workshop with more than 9m span: steer structure 0.2 ton/m2, other structures under this category will be calculated as 40-60% of the CDW generation per unit area of similarly structured civil buildings.

1-2) Demolition-structures demolition:

CDW generation from demolition of structure will be calculated by its actual volume, i.e. 1 m3 equals to 1.9 tons of waste.

1-3) Building Construction-spoil generation from foundation construction

Spoil=(excavation-backfill) × spoil per unit volume

Foundation spoil—planned foundation spoil can be calculated basing on the construction drawings; or original drawings if construction drawing estimate is not available.

Spoil per unit volume is calculated by 1.6 tons/m3 of clay.

1-4) Building construction-CDW generation from main structures construction:

CDW generation=floor area × CDW per unit area

Floor area-Construction area calculation

Unit area CDW-brick and concrete structure 0.05ton/m2; reinforced concrete structure 0.03ton/m2

1-5) Spoil from roads and pipe trench construction:

Spoil=(excavation-backfill) × spoil per unit volume

Foundation spoil—planned spoil amount from road and pipe trench construction can be calculated based on the construction drawing; if construction drawing budget is not available, relevant agencies should provide.

Spoil per unit volume- calculated by 1.6 tons/m3
1-6) Landscaping spoil:
Spoil = replacement filling × spoil per unit volume

Foundation spoil—planned spoil amount should be estimated based on the actual construction plan, if relevant data is not available, relevant department should be consulted for data support;

Unit volume spoil—calculated by 1.6 tons/m³

1-7) CDW generation from decoration works

CDW from public infrastructure = total cost estimate × CDW per unit cost
CDW from residential building = floor area × CDW per unit area

Total cost (10,000 yuan) is based on the valid contract (only account for decoration works, excluding equipment cost); CDW per unit cost—office building 2 tons/10,000 yuan; entertainment club 3 tons/10,000 yuan; CDW per unit area—residential buildings of 160 m² and below 0.1 ton/m²; 161 m² and above 0.15 ton/m²

2) CDW generation estimation of Shenzhen

The Technical Specification for Construction Waste Reduction in Shenzhen specifies the estimation method for CDW generation, in which construction wastes are divided into waste from new constructions and from demolition.

The calculation formula:

2-1) Estimation of construction waste from new projects:

Wₙ = Aₓ × qₓ + A₁ × h₁ × ρ₁ + V₂ × ρ₂

Wₙ = construction waste generation from new project (kg)
Aₓ = total area of the new project (m²)
qₓ = indicator for waste generation from new project (kg/m²)
A₁ = hardened area (m²)
h₁ = hardening thickness (m)
ρ₁ = concrete density (2200 kg/m³)
V₂ = surplus soil volume (m³), this can be estimated based on the excavation and backfill plan
ρ₂ = surplus soil density (1900 kg/m³)

<table>
<thead>
<tr>
<th>Types</th>
<th>Waste generation indicator (kg/m²)</th>
<th>Sub-indicator (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential building</td>
<td>37</td>
<td>0101 Concrete</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0102 Brick and blocks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0103 Mortar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0201 Metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0202 Wood</td>
</tr>
<tr>
<td>Commercial Building</td>
<td>34</td>
<td>0101 Concrete</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0102 Brick and blocks</td>
</tr>
</tbody>
</table>
2-2) Estimation of waste generation from demolition:

\[ W_c = A_c \times q_c \]

\( W_c \) = waste generation from demolition (kg)

\( A_c \) = total floor area of the demolished building (m\(^2\))

\( q_c \) = Demolition waste generation indicator (kg/m\(^2\))

<table>
<thead>
<tr>
<th>Types</th>
<th>Waste generation indicator (kg/m(^2))</th>
<th>Sub-indicators (kg/m(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential building</td>
<td>1450</td>
<td>0101 Concrete 880</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0102 Brick and blocks 180</td>
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<tr>
<td></td>
<td></td>
<td>0103 Mortar 200</td>
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<tr>
<td></td>
<td></td>
<td>0201 Metal 65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0105 Glass 3</td>
</tr>
<tr>
<td>Commercial Building</td>
<td>1380</td>
<td>0101 Concrete 880</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0102 Brick and blocks 150</td>
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Table 2 Demolition Waste Generation Indicator \( q_c \) (kg/m\(^2\))
Both formulas not only provide estimation for total CDW generation, but also provide classified estimation for the waste generation from new construction projects basing on the waste generation indicators ($q_r$ and $q_c$). As for other waste mixtures (excluding surplus soil) in addition to the provided indicator, its generation can be estimated by 10% of the construction waste generation.

On the overall, the main estimation approach in *Luoyang CDW Generation Calculation Standard* is “work quantity x waste generation per unit”, then estimate the waste generation from different types of works based on the corresponding unit generation conversion ratio. The Standard provides a prospective classified estimation method for CDW generation with clear and comprehensive classification of works, however the Standard still needs improvements, for example, the unit waste generation conversion ratios for different types of works are subject to question, for example the unit spoil generation conversion ratios of building construction, road and pipe trench construction and landscaping works are the same, and the conversion ratios for other types of construction works are single choices, which do not allow proper classified estimation, therefore it is suggested to review and optimize the conversion ratios based on relevant national standards.

In comparison, the Shenzhen Standard has more detailed and sound waste generation indicators; the formula not only allows proper estimation of total CDW generation, but also classified estimation. However the current waste collection and transportation is not classified, the surplus soil estimation can be solely based on excavation and backfill plan without subdivisions, because a large amount of recyclable wastes generated from the construction are concrete, bricks, blocks and wood, this way is more convenient and saves statistical costs.

Moreover, there is no separated method for estimation of construction excavation waste, except for the estimation method of spoil from road and trenches excavation in some cities such as Luoyang.

<table>
<thead>
<tr>
<th>No.</th>
<th>Category</th>
<th>Name</th>
<th>Order</th>
<th>Effective Date</th>
<th>Issued bodies</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>Law</td>
<td>Environmental Protection Law</td>
<td>Order of President 9</td>
<td>2015.01.01</td>
<td>National People’s Congress</td>
</tr>
<tr>
<td>2</td>
<td>Building Law</td>
<td></td>
<td>Order of President 91</td>
<td>2007.07.01</td>
<td>National People’s Congress</td>
</tr>
<tr>
<td>3</td>
<td>Cleaner Production Promotion Law</td>
<td></td>
<td>Order of President 54</td>
<td>2012.07.01</td>
<td>National People’s Congress</td>
</tr>
<tr>
<td>4</td>
<td>Law on Prevention of Environmental Pollution by Solid Waste</td>
<td></td>
<td>Order of President 31</td>
<td>2005.04.01</td>
<td>National People’s Congress</td>
</tr>
<tr>
<td>5</td>
<td>Enterprise Income Tax Law</td>
<td></td>
<td>Order of President 63</td>
<td>2008.01.01</td>
<td>National People’s Congress</td>
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<tr>
<td>6</td>
<td>Energy Conservation Law</td>
<td></td>
<td>Order of President 77</td>
<td>2008.04.01</td>
<td>National People’s Congress</td>
</tr>
<tr>
<td>7</td>
<td>Circular Economy Promotion Law</td>
<td></td>
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<td>2009.01.01</td>
<td>National People’s Congress</td>
</tr>
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<td>8</td>
<td>Renewable Energy Law</td>
<td></td>
<td>Order of President 23</td>
<td>2010.04.01</td>
<td>National People’s Congress</td>
</tr>
<tr>
<td>9</td>
<td>Administrative Regulations</td>
<td>City Appearance and Environmental Sanitation Administration</td>
<td>Order of State Council 101</td>
<td>1992.08.01</td>
<td>State Council</td>
</tr>
<tr>
<td>10</td>
<td>Regulations on Environmental Protection of Construction Projects</td>
<td></td>
<td>Order of State Council 253</td>
<td>1998.11.29</td>
<td>State Council</td>
</tr>
<tr>
<td>11</td>
<td>Regulations on Work Safety of Construction Projects</td>
<td></td>
<td>Order of State Council 393</td>
<td>2004.02.01</td>
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<tr>
<td>12</td>
<td>Houses on State-owned Land Expropriation and Compensation</td>
<td></td>
<td>Order of State Council 590</td>
<td>2011.01.21</td>
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</tr>
<tr>
<td>14</td>
<td>Green Building Action Programme</td>
<td></td>
<td>State Office (2013) 1</td>
<td>2013.01.01</td>
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<tr>
<td>16</td>
<td>Provisions on Administration of Urban Construction Solid Waste</td>
<td>Order of MOH 139</td>
<td>2005.06.01</td>
<td>Ministry of Housing</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Regulation of Provisions of the 15 Administrative Licensing to be Decided by State Council</td>
<td>Order of MOH 135</td>
<td>2004.12.01</td>
<td>Ministry of Housing</td>
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<td>Programme of Action to Promote Green Building Material Production and Application</td>
<td>MiIT Lianyuan (2015) 309</td>
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<td>23</td>
<td>“Twelfth-Five” Green Building Science and Technology Development Planning</td>
<td>Guokefaji [2012]692</td>
<td>2012.05.24</td>
<td>Ministry of Science and technology</td>
<td></td>
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<tr>
<td>24</td>
<td>Notice on Declaration of Resource-saving and Environmental Protection as 2015 Annual Central Budget Investment Stand-by Projects</td>
<td>Fagaihuanzi [2015]831</td>
<td>2015.03.18</td>
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</table>
### Major Provincial and Municipal Level Laws and Regulations

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Doc. No.</th>
<th>Effective Date</th>
<th>Issued Bodies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Regulation on construction waste and spoil soil management in Tianjin</td>
<td>Jinzheng [1993] 27</td>
<td>1993.06.01</td>
<td>Tianjin Government</td>
</tr>
<tr>
<td>2</td>
<td>Provisions of Beijing City Government on Strengthening Spoil Soil</td>
<td>Beijing No. 16 Order 200</td>
<td>1994.08.17</td>
<td>Beijing Government</td>
</tr>
<tr>
<td>3</td>
<td>Ordinance on promoting CDW management and recycling</td>
<td>Beijing [2009]14</td>
<td>2011.06.08</td>
<td>Beijing Government</td>
</tr>
<tr>
<td>4</td>
<td>Regulation on pollution prevention from solid waste of Hebei Province</td>
<td>-</td>
<td>2015.06.01</td>
<td>Hebei provincial government</td>
</tr>
<tr>
<td>5</td>
<td>Ordinance on further promoting comprehensive utilization of CDW</td>
<td>Jilin [2013]41</td>
<td>2013.10.11</td>
<td>General Office of Jilin Provincial Government</td>
</tr>
<tr>
<td>6</td>
<td>Regulation on CDW management of Shanghai</td>
<td>-</td>
<td>2006.03</td>
<td>Shanghai Commission of Construction and Urban-rural Development</td>
</tr>
<tr>
<td>7</td>
<td>Provisions of CDW and spoil soil disposal administration of Shanghai</td>
<td>Order of people's government No.50</td>
<td>2011.01.01</td>
<td>Shanghai City Government</td>
</tr>
<tr>
<td>8</td>
<td>Provisions of CDW management of Shandong Province</td>
<td>Lujianfaban [1998]49</td>
<td>1998.06.18</td>
<td>Shandong provincial construction commission</td>
</tr>
<tr>
<td>9</td>
<td>Ordinance on comprehensive utilization of CDW of Shandong Province</td>
<td>Luzhengfaban [2010]11</td>
<td>2010.03.04</td>
<td>Shandong Provincial Government</td>
</tr>
<tr>
<td>10</td>
<td>Ordinance on strengthening CDW management and promoting CDW utilization of Henan Province</td>
<td>Yuzhengban [2015]39</td>
<td>2015.7.10</td>
<td>Henan Provincial Government</td>
</tr>
<tr>
<td>11</td>
<td>Regulation on solid waste pollution prevention and control of Sichuan Province</td>
<td>Sichuan Provincial People’s Congress Committee No.6</td>
<td>2014.1.1</td>
<td>Sichuan Provincial People’s Congress</td>
</tr>
<tr>
<td>12</td>
<td>Provisions of CDW management of Chongqing</td>
<td>Yushizhengwei [2014]90</td>
<td>2014.09.01</td>
<td>Chongqing Municipal Committee</td>
</tr>
<tr>
<td>16</td>
<td>Regulation on CDW reduction and utilization of Shenzhen</td>
<td>Municipal People’s Congress Committee No.104</td>
<td>2009.10.01</td>
<td>Shenzhen City Government</td>
</tr>
<tr>
<td>17</td>
<td>Administrative measures on CDW transportation and disposal in Shenzhen</td>
<td>Municipal People’s Government No. 260</td>
<td>2014.01.01</td>
<td>Shenzhen City Government</td>
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### Major Laws, Regulations and Policies in Capital Cities

<table>
<thead>
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<th>No.</th>
<th>Name</th>
<th>Doc. No.</th>
<th>Effective Date</th>
<th>Issued Bodies</th>
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<tr>
<td>1</td>
<td>Implementing rules for CDW administration measures in Xi’an</td>
<td>Municipal Government Office [2006]229</td>
<td>2006.11.08</td>
<td>Xi’an Government</td>
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<td>Order of Lanzhou City Government No. 4</td>
<td>2008.10.01</td>
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</tr>
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<td>3</td>
<td>CDW administrative measures in Changchun City</td>
<td>Order of Changchun City Government No. 26</td>
<td>2011.07.19</td>
<td>Changchun City</td>
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<td>4</td>
<td>Provisions on administration of CDW transportation in Changchun City</td>
<td>Order of Changchun City Government No. 61</td>
<td>1997.9.1</td>
<td>Changchun City</td>
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<td>5</td>
<td>Administrative measures on urban CDW in Kunming City</td>
<td>Kunzhengfa [2011]88</td>
<td>2011.8.1</td>
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<td>6</td>
<td>Programme on CDW utilization in Kunming City</td>
<td>Kunzhengfa [2010]139</td>
<td>2010.07.05</td>
<td>Kunming Government</td>
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<td>7</td>
<td>Urban CDW management in Urumqi City</td>
<td>Order of Urumqi City Government No. 48</td>
<td>2002.12.5</td>
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<td>8</td>
<td>Administrative measures on urban CDW in Qingdao City</td>
<td>Order of Qingdao City Government No. 147</td>
<td>2003.01</td>
<td>Qingdao City</td>
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<td>9</td>
<td>Ordinance on CDW utilization in Qingdao City</td>
<td>-</td>
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<td>Qingdao People's Congress</td>
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<td>10</td>
<td>Administrative measures on CDW in Xi’an City</td>
<td>Order of Xi’an City Government No. 15</td>
<td>2003.05.20</td>
<td>Xi’an Government</td>
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<td>Administrative measures on CDW in Hefei</td>
<td>Order of Hefei City Government No. 149</td>
<td>2009.10.13</td>
<td>Hefei Government</td>
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<td>Administrative measures on CDW transportation in Chengdu City</td>
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<td>2010.06.15</td>
<td>Chengdu Government</td>
</tr>
<tr>
<td>13</td>
<td>Ordinance on CDW disposal in Chengdu City</td>
<td>-</td>
<td>2014.1.1</td>
<td>Chengdu Government</td>
</tr>
<tr>
<td>14</td>
<td>Implementation rules for ordinance on CDW disposal in Chengdu City</td>
<td>Order of Chendu City Government No. 182</td>
<td>2014.3.1</td>
<td>Chengdu Government</td>
</tr>
<tr>
<td>15</td>
<td>Administrative measures on CDW and spoil soil disposal in Fuzhou City</td>
<td>Order of Fuzhou City Government No. 37</td>
<td>2007.10.01</td>
<td>Fuzhou Government</td>
</tr>
<tr>
<td>16</td>
<td>Administrative measures on urban CDW in Hohhot City</td>
<td>Order of Hohhot City Government No.</td>
<td>2009.10.15</td>
<td>Hohhot City</td>
</tr>
<tr>
<td>17</td>
<td>Administrative measures on urban CDW in Nanning City</td>
<td>-</td>
<td>2012.5.1</td>
<td>Nanning People's Congress</td>
</tr>
<tr>
<td>18</td>
<td>Ordinance on CDW management in Guangzhou City</td>
<td>Guangzhou City Congress Committee</td>
<td>2012.6.1</td>
<td>Guangzhou City</td>
</tr>
<tr>
<td>19</td>
<td>Programme on CDW recycling in Guangzhou City</td>
<td>-</td>
<td>2014.06.24</td>
<td>Guangzhou City</td>
</tr>
<tr>
<td>20</td>
<td>Administrative measures on urban CDW in Shijiangzhuang City</td>
<td>Shizhengfa [2011]29</td>
<td>2011.12.29</td>
<td>Shijiangzhuang City</td>
</tr>
<tr>
<td>21</td>
<td>Ordinance on CDW management in Yinchuang City</td>
<td>Approved by NPC Standing Committee Conference</td>
<td>2013.10.1</td>
<td>Yinchuang City</td>
</tr>
<tr>
<td>23</td>
<td>Ordinance on CDW management in Nanchang City</td>
<td>Standing Committee 25th Meeting</td>
<td>2015.0201</td>
<td>Nanchang City</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Doc. No.</td>
<td>Effective Date</td>
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<td>---------------------</td>
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<tr>
<td>1</td>
<td>Administrative measures on CDW and spoil soil management in Xuzhou City</td>
<td>XCG No. 88</td>
<td>2003.7.1</td>
<td>Xuzhou Government</td>
</tr>
<tr>
<td>3</td>
<td>Rules on CDW and spoil soil disposal in Beihai City</td>
<td>Beizhengfa [2004]23</td>
<td>2004.5.1</td>
<td>Beihai Government</td>
</tr>
<tr>
<td>4</td>
<td>Administrative measures on CDW and spoil soil management in Xining</td>
<td>Order of XCG No.62</td>
<td>2004.6.1</td>
<td>Xining Government</td>
</tr>
<tr>
<td>6</td>
<td>Administrative measures on urban CDW management in Yangzhou City</td>
<td>Order of YCG No. 81</td>
<td>2012.03.01</td>
<td>Yangzhou Government</td>
</tr>
<tr>
<td>8</td>
<td>Interim administrative measures on CDW and spoil soil management in Shaoquanguang City</td>
<td>Order of SCG No. 2</td>
<td>2005.5.1</td>
<td>Shaoquanguang City</td>
</tr>
<tr>
<td>9</td>
<td>Administrative measures on Urban CDW management in Datong City (amendment)</td>
<td>Order of DCG No. 54</td>
<td>2005.10.10</td>
<td>Datong Government</td>
</tr>
<tr>
<td>10</td>
<td>Implementation rules on urban CDW management in Xiangfan City</td>
<td>Order of XCG No. 21</td>
<td>2005.10.19</td>
<td>Xiangyang Government</td>
</tr>
<tr>
<td>11</td>
<td>Administrative measures on Urban CDW management in Shaoxing City</td>
<td>Shaozhengbanfa [2005]142</td>
<td>2005.11.03</td>
<td>Shaoxing Government</td>
</tr>
<tr>
<td>12</td>
<td>Administrative measures on Urban CDW management in Kaifeng City</td>
<td>Kaizheng [2005]87</td>
<td>2006.1.1</td>
<td>Kaifeng Government</td>
</tr>
<tr>
<td>13</td>
<td>Administrative measures on Urban CDW management in Suzhou City</td>
<td>Order of SCG No. 87</td>
<td>2006.02.01</td>
<td>Suzhou Government</td>
</tr>
<tr>
<td>14</td>
<td>Administrative measures on Urban CDW management in Sanya City</td>
<td>Sanfu [2006]54</td>
<td>2006.04.27</td>
<td>Sanyan Government</td>
</tr>
<tr>
<td>15</td>
<td>Administrative measures on Urban CDW management in Xuancheng City</td>
<td>XCG No.18</td>
<td>2006.5.1</td>
<td>Xuancheng Government</td>
</tr>
<tr>
<td>16</td>
<td>Administrative measures on Urban CDW management in Jiujiang City</td>
<td>Jiu zhengfa [2006]15</td>
<td>2006.5.23</td>
<td>Jiujiang Government</td>
</tr>
<tr>
<td>17</td>
<td>Administrative measures on Urban CDW management in Jilin City</td>
<td>Order of JCG No. 186</td>
<td>2007.10.01</td>
<td>Jilin Government</td>
</tr>
<tr>
<td>18</td>
<td>Administrative measures on Urban CDW management in Huizhou City</td>
<td>Huifu [2009]43</td>
<td>2009.4.1</td>
<td>Huizhou Government</td>
</tr>
<tr>
<td>20</td>
<td>Administrative measures on Urban CDW management in Shiyan City</td>
<td>Shizhenggui [2010]1</td>
<td>2010.03.01</td>
<td>Shiyan Government</td>
</tr>
<tr>
<td>21</td>
<td>Administrative measures on Urban CDW management in Weihai City</td>
<td>Weizhengfa [2010]27</td>
<td>2010.06.01</td>
<td>Weihai Government</td>
</tr>
<tr>
<td>22</td>
<td>Administrative measures on Urban CDW management in Huangshi City</td>
<td>Huangshi zhenggui [2010]22</td>
<td>2011.01.01</td>
<td>Huangshi Government</td>
</tr>
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<td>No.</td>
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</tr>
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<td>23</td>
<td>Administrative measures on Urban CDW management in Zaozhuang City</td>
<td>Order of ZCG No. 126</td>
<td>2011.03.01</td>
<td>Zaozhuang City Government</td>
</tr>
<tr>
<td>24</td>
<td>Administrative measures on Urban CDW management in Xinyang City</td>
<td>Xinzengwen [2011]15</td>
<td>2011.03.01</td>
<td>Xinyang Government</td>
</tr>
<tr>
<td>25</td>
<td>Implementation rules on urban CDW management in Xuchang City</td>
<td>Order of XCG [2011]8</td>
<td>2011.06.28</td>
<td>Xintai Government</td>
</tr>
<tr>
<td>26</td>
<td>Ordinance on CDW disposal in Xintai City</td>
<td>Order of NCG No. 186</td>
<td>2011.09.01</td>
<td>Ningbo Government</td>
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<tr>
<td>27</td>
<td>Administrative measures on Urban CDW management in Ningbo City</td>
<td>Order of ICN No. 190</td>
<td>2011.09.01</td>
<td>Ningbo Government</td>
</tr>
<tr>
<td>28</td>
<td>Administrative measures on Urban CDW management in Xuchang City</td>
<td>Order of XCG No. 126</td>
<td>2012.01</td>
<td>Xuchang Government</td>
</tr>
<tr>
<td>29</td>
<td>Administrative measures on Urban CDW management in Fangchenggan City</td>
<td>Fangzhengbanfa [2012]29</td>
<td>2012.03.01</td>
<td>Fangchenggan City Government</td>
</tr>
<tr>
<td>30</td>
<td>Ordinance on CDW disposal in Handan City</td>
<td>Order of ZCG No. 126</td>
<td>2012.05</td>
<td>Handan People’s Congress</td>
</tr>
<tr>
<td>31</td>
<td>Administrative measures on Urban CDW management in Xinnixang City</td>
<td>Xinzengfa [2012]85</td>
<td>2012.06.12</td>
<td>Xinnixang Government</td>
</tr>
<tr>
<td>32</td>
<td>Administrative measures on Urban CDW management in Tianmen City</td>
<td>Tianzhenggui [2013]4</td>
<td>2013.06.01</td>
<td>Tianmen Government</td>
</tr>
<tr>
<td>33</td>
<td>Collection of CDW disposal and utilization fees in Qingdao City</td>
<td>Qingzhenbanfa [2013]12</td>
<td>2013.06.05</td>
<td>Qingdao Government</td>
</tr>
<tr>
<td>34</td>
<td>CDW and raw construction materials transportation management in Xiangtan City</td>
<td>Tanzhengfa [2003]29</td>
<td>2013.06.05</td>
<td>Xiangtan City Government</td>
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<tr>
<td>35</td>
<td>Administrative measures on Urban CDW management in Anqing City</td>
<td>Yizhengfa [2013]14</td>
<td>2013.08.01</td>
<td>Anqing City Government</td>
</tr>
<tr>
<td>36</td>
<td>Administrative Measures on Construction Dust Pollution Control in Anhui Province</td>
<td>Jianshi[2014]28</td>
<td>2014.01.30</td>
<td>Anhui Province Housing and Urban-rural Construction Department</td>
</tr>
<tr>
<td>37</td>
<td>Ordinance on urban CDW management in Jiangyou City</td>
<td>Jiangfubanhan [2014]33</td>
<td>2014.04.22</td>
<td>Jiangyou City Government</td>
</tr>
<tr>
<td>38</td>
<td>Administrative measures on Urban CDW management and disposal in Zibo City</td>
<td>Xinzengfa [2012]15</td>
<td>2014.05.01</td>
<td>Zibo City General Office</td>
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<td>39</td>
<td>Administrative measures on Urban CDW management in Guangyuan main urban area</td>
<td>Guangfubanhan[2014]16</td>
<td>2014.05.01</td>
<td>Guangyuan City Government</td>
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<tr>
<td>40</td>
<td>Ordinance on Urban Waste Soil Source and Transport Monitoring</td>
<td>Rongzhengban [2014]76</td>
<td>2014.05.08</td>
<td>Fuzhou Government</td>
</tr>
<tr>
<td>41</td>
<td>Interim measures on urban CDW disposal and management in Bazhong City</td>
<td>Baifubanfa [2014]15</td>
<td>2014.07.01</td>
<td>Bazhong Government</td>
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<tr>
<td>42</td>
<td>Ordinance on Urban CDW Management in Rugao City</td>
<td>Draft Doc. for consultation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Ordinance on Urban CDW Management in Nanchang City</td>
<td>Revised draft doc. for consultation</td>
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<td></td>
</tr>
<tr>
<td>44</td>
<td>Notice on strengthening CDW and spoil soil management in Xuzhou City</td>
<td>Xuzhengfa [2005]11</td>
<td>2005.02.02</td>
<td>Xuzhou Government</td>
</tr>
<tr>
<td>45</td>
<td>Ordinance on Urban CDW Management in Harbin City</td>
<td>Order of City Government No. 223</td>
<td>2010.10.20</td>
<td>Harbin Government</td>
</tr>
<tr>
<td>46</td>
<td>Notice on strengthening CDW transportation management in Harbin City</td>
<td>Hazhengsfazi (2005) 18</td>
<td>2005.06.16</td>
<td>Harbin Government</td>
</tr>
<tr>
<td>47</td>
<td>Notice on strengthening construction materials, CDW and spoil soil management in Qiqihaer City</td>
<td>Qizhengfa [2005]32</td>
<td>2005.07.18</td>
<td>Qiqihaer Government</td>
</tr>
<tr>
<td>48</td>
<td>Special implementation program on CDW management in Changzhou City</td>
<td>Qizhengbanfa [2005]73</td>
<td>2005.07.25</td>
<td>Changzhou General Office</td>
</tr>
<tr>
<td>49</td>
<td>Administrative measures on Urban CDW management in Changzhou City</td>
<td>Changzhengfa [2002] 193</td>
<td>2002.12.01</td>
<td>Changzhou City Government</td>
</tr>
<tr>
<td>50</td>
<td>Notice on further strengthening CDW comprehensive utilization</td>
<td>Luzhengbanfa [2010]11</td>
<td>2010.03.04</td>
<td>Shandong City Government Office</td>
</tr>
<tr>
<td>51</td>
<td>Interim measures on CDW and spoil soil management in Jinjiang City</td>
<td>Jizhengwen [2012]67</td>
<td>2012.4.1</td>
<td>Jinjiang City Government</td>
</tr>
<tr>
<td>52</td>
<td>CDW and sand &amp; rocks transportation and disposal management measures in Zhangzhou City</td>
<td>Zhangzhengzong [2013]146</td>
<td>2013.12.1</td>
<td>Zhangzhou City Government</td>
</tr>
<tr>
<td>53</td>
<td>Notice on strengthening CDW and raw construction materials transportation management in central urban area of Weifang City</td>
<td></td>
<td>2014.03.19</td>
<td>Weifang City Government</td>
</tr>
<tr>
<td>54</td>
<td>Notice on strengthening spoil soil vehicles management in central urban area in Qiqihaer City</td>
<td></td>
<td>2014.03.24</td>
<td>Spoil soil management office of Qiqihaer</td>
</tr>
<tr>
<td>55</td>
<td>Administrative measures on Urban CDW management in Puyang City (trial)</td>
<td></td>
<td>2013.04.03</td>
<td>Puyang City Government</td>
</tr>
<tr>
<td>56</td>
<td>Provisions on strengthening CDW utilization in Handan City</td>
<td></td>
<td>2013.04.10</td>
<td>Handan City Government</td>
</tr>
<tr>
<td>57</td>
<td>Administrative measures on Urban CDW disposal in Anqing City</td>
<td></td>
<td>2013.08. 01</td>
<td>Anqig City Government</td>
</tr>
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<td>58</td>
<td>Administrative measures on Urban CDW management in Rugao City</td>
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</tr>
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<td>Administrative measures on Urban CDW management in Jiangmen City</td>
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<td>2014.02.07</td>
<td>Jiangmen City Government</td>
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<td>60</td>
<td>Administrative measures on Urban CDW management in Luohe City</td>
<td></td>
<td>2014.05.01</td>
<td>Luohe City government</td>
</tr>
</tbody>
</table>

Bazhong, Xinzhou, Lianyungang, Jinghong, Guigang, Huaibei, Xingyi, Chuzhou, Chuxiong, Zigong, Huangshan, Wuzhou, Yangquan, Langfang, Baoding, Hengshui, Changzhi, Jicheng, Shuozhou, Xinzhou, Yuncheng, Dandong, Dalian, Anshan, Panjin, Huludao, Siping, Jiamusi, Jixi, Qitaie, Nantong, Huaian, Yancheng, Zhenjiang, Taizhou, Suqian, Wenzhou, Jiaxing, Huzhou, Quzhou, Taizhou, Lishui, Hanzhou, Suzhou, Bengbu, Fuyang, Huainan, Luan, Maanshan, Chizhou, Sanming,.....
Appendix 4 Existing CDW Recycling Standards in the PRC


This code is formulated to implement the country’s technical and economic policies of resource conservation and environmental protection, promote CDW recycling, and to achieve proper technology application, safe and applicable, economic and sound practice and ensure construction quality.

This code is applicable to the management, disposal and recycling of wastes from construction activities; not applicable to the recycling of polluted or corroded construction waste.

This code stipulates the basic technical requirements for CDW recycling.

The disposal, recycle and reuse of CDW should be conducted in accordance with the Code as well as relevant national standards.

(2) Recycled Coarse Aggregate for Concrete (GB/ton 25177-2010)

This code stipulates the definition, classification and specification, requirements, test method, test code, signage, storage and transportation for recycled coarse aggregate for concrete.

This code is applicable to the recycled coarse aggregate used for the preparation of concrete.

(3) Recycled Fine Aggregate for Concrete and Mortar (GB/ton 25176-2010)

This code stipulates the definition, classification and specification, requirements, test method, test code, signage, storage and transportation for recycled coarse aggregate for concrete.

This code is applicable to the recycled fine aggregate used for the preparation of concrete and mortar.

(4) Code for CDW Treatment (CJJ 134-2009)

This code is formulated to implement the country’s laws and regulations and technical policies on CDW treatment, promote unified CDW management, centralized treatment and integrated utilization, improve CDW reduction, recycling and safety, ensure regulation of the entire CDW treatment process.

This code is applicable to the planning, design and management of CDW collection, transportation, transfer, utilization, backfill and landfill.

This code stipulates the basic technical requirements on CDW treatment, if the code is in conflict with national laws and regulations, the later shall prevail.

CDW treatment shall comply with this code as well as relevant national standards.

(5) Technical Specification for Application of Recycle Aggregate (JGJ/ton 240-2011)

This specification is formulated to implement the country’s technical and economic policies on resource conservation and environmental protection, ensure proper application of recycled aggregate in construction, and to achieve proper technology application, safe and applicable, economic and sound practice and ensure construction quality.

This specification is applicable to the application of recycled aggregate in construction.

The application of recycled aggregate in construction should comply with this specification as well as relevant national standards.

(6) Ground Brick and Water Permeable Brick Prepared by Recycled Aggregate (CJ/ton 400-2012)
This code stipulates the definitions, abbreviations, classification, raw material, requirements, test method, test code, manufacturer's certificate, packaging, transportation and storage of ground brick and water permeable brick prepared by recycled aggregate.

This code is applicable to the production and examination of ground brick and water permeable brick prepared by recycled aggregate.

(7) Recycled Aggregate Inorganic Mixture for Roads (JC/ton 2281-2014)

This code stipulates the scope, terms and symbols, classification, raw material, technical requirement, proportioning design, preparation, test method, examination rules and order & delivery for recycled inorganic mixture from CDW.

This code is applicable to the use of recycled inorganic mixture in base course and subbase course of urban roads, and can be referred by all grades of highway construction.

(8) Technical Specification for Durability Control of Recycled Aggregate Concrete (CECS 385:2014)

This specification is formulated to regulate durability control of recycled aggregate concrete, meet design and construction requirements, ensure construction quality.

This specification is applicable to the durability control of recycled aggregate concrete.

The durability control of recycled aggregate concrete shall comply with this specification as well as relevant national standards.

(9) Standard for Environmental Safety Examination of Cement-based Recycled Material (CECS 397:2015)

This standard is formulated to promote and regulate the recycling of solid waste for construction use, ensure the environmental safety of cement-based recycled material.

This standard is applicable to the environmental safety examination for the use and construction application of cement-based materials recycled from CDW, sludge and industrial solid waste.

The environmental safety examination for cement-based recycled material shall comply with this standard as well as relevant national standards.

(10) Beijing’s Technical Code for the Structural Design of Recycled Concrete (DB11/ton 803-2011)

This code is formulated to protect the eco-environment, achieve recycling and reuse of CDW, promote the sustainable development of construction industry, facilitate the application of recycled aggregate concrete in construction and to be technologically advanced, safe, applicable, economic and durable, and ensure quality.

This code is applicable to the ground structure design of reinforced concrete buildings.

The recycled concrete here refers to the concrete mixed only with recycled aggregate during the preparation.

This code specifies the basic requirements on the structural design of recycled concrete. The design should comply with this code as well as the requirements of relevant national standards, industrial standards and local standards.

(11) Beijing’s Code for Construction and Acceptance of Recycled Construction Waste for Urban Road Base Course

This code is formulated to provide guidance to the use of recycled aggregate in construction of urban road base course and unify quality inspection standard.

This code is applicable to the subbase courses of newly constructed or upgraded urban roads, and base courses of trunk road, secondary trunk road, branch road, expressway's side road and non-motorized lane in the administrative area of Beijing.

The construction and acceptance of recycled construction waste for urban road base course should comply with this code as well as requirements of relevant national and local standards and regulations.
(12) **Beijing’s Technical Requirements for the Identification, Monitoring and Enclosure of CDW Transport Vehicles (DB11/ton 1077-2014)**

This standard stipulates the technical requirements for the identification, monitoring system, truck bed structure and enclosure, as well as the test and examination methods.

This standard is applicable to the freight vehicles transporting CDW, earthwork and aggregates.


This guidance is formulated to strengthen the scientific construction of CDW recycling facility, regulate its construction, promote resources recycling and improve investment benefits.

This guidance is applicable to the construction and upgrade of stationary CDW recycling facilities.

This guidance will be the basis for the preparation of project proposal, feasibility study report, preliminary design estimate, project application report and monitoring and inspection.

The construction of CDW recycling facilities should comply with this guidance as well as relevant national and Beijing standards and regulations.


This technical code is formulated to protect the eco-environment, achieve efficient recycling and reuse of waste concrete, promote the sustainable development of construction industry, facilitate the application of recycled concrete in civil engineering, and reach the goal of advanced technology, safety, applicability, economy, soundness and quality.

This code is applicable to the production of recycled concrete and its products, as well as design and construction of recycled concrete for multi-story buildings and roads.

Concrete that are prepared with recycled aggregate in partial or full replacement of natural aggregate is called recycled concrete. This code mainly refers to the concrete prepared with recycled coarse aggregate, in which the ratio of replacement by recycled coarse aggregate in the preparation of recycled concrete for building structures and roads should be 30% or below. Hollow block has no limitation in terms of ratio of replacement by recycled coarse aggregate, and can be mixed with recycled fine aggregate.

The application of recycled concrete should comply with this code as well as relevant national and Shanghai’s standards.

(15) **Hebei Province’s Technical Specification for the Construction of Pavement Base Course Using CDW Recycled Aggregate (DB13 (J)/ton 155-2014)**

This specification is formulated to provide guidance for the application of recycled aggregate in road construction, regulate construction requirements, and unify quality inspection and acceptance standard.

This specification is applicable to the construction and quality inspection and acceptance of pavement base course and subbase course of urban roads, highway, square and parking lot.

The construction and quality acceptance of pavement base course or subbase course using recycled aggregate should comply with this specification as well as relevant national standards and regulations.

(16) **Shenzhen’s Technical Specification for CDW Reduction (SJG21-2011)**

This specification is formulated to strengthen the CDW management in Shenzhen, reduce CDW emission and improve CDW recycling.

This specification is prepared based on Circular Economy Promotion Ordinance for Shenzhen Special Economic Zone, Shenzhen’s Ordinance on CDW Reduction and Utilization, and the actual situation in Shenzhen.
This specification is applicable to the reduction, recycling and supervision of CDW generated from the construction activities, including the ongoing construction, upgrade, expansion and demolition of buildings, structures, pipeline network, and demolitions.

CDW reduction, recycling and subversion should comply with this specification as well as relevant national laws, regulations and technical standards.

(17) Shen’s Technical Specification for Recycled Aggregate Concrete Products (Trial) N0.174, 2013

This specification is formulated to implement the country’s technical and economic policies of resource conservation and environmental protection, promote CDW recycling in Shenzhen, ensure the quality of recycled aggregate and its concrete products, and to follow the principle of safety, environmental-friendly and sound application.

This specification is applicable to the production control and application of recycled aggregate concrete products, including hollow brick, solid brick, perforated brick, curb, paver, water permeable brick, grass-planting brick.

Recycled aggregate concrete product should comply with this specification as well as the requirements of relevant national and local standards.
# Appendix 5 List of Stakeholders Consulted

<table>
<thead>
<tr>
<th>No.</th>
<th>Stakeholders</th>
<th>Specific units</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Central Government</td>
<td>National People's congresses (1), the Jiu San society (1), Chinese Kuomintang (1), MOHURD (1), MITT (1), NDRC (1)</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Local Government</td>
<td>Shenzhen (1), Xuchang (1), Xi'an (1), Wujin district (1)</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Developers</td>
<td>the PRC Wanke company limited (2); the PRC property group limited (2); Beijing capital land limited etc (2).</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Construction Enterprise</td>
<td>water supply and environmental protection company under the PRC State construction engineering limited company (2); the PRC's construction and development company (2); No.1 Construction Bureau of the PRC Construction; Beijing construction engineering group (1); Cangzhou municipal engineering company limited (1); Beijing Zhongguancun development and construction Corporation (1); No.4 construction company of Jiangxi province (1)</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>CDW Recycling enterprises</td>
<td>Xuchangjinke resources recycling limited company (4), Beijing Shougang company resources comprehensive utilization technology company (4); Shaanxi Jianxin Environmental Protection Technology Company (4), Shenzhen Huawei environmental protection building materials Ltd (4), Changzhou green and environmental protection etc (2).</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>Social Associations</td>
<td>Zhonghuan Associated Construction Waste Utilization Work Committee (2).</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Other</td>
<td>the PRC Architectural Design Institute limited (2), the PRC Academy of building research (2), Beijing Architectural University (2), Beijing architectural design Institute Ltd (2), East the PRC Architectural Design Institute limited (1), Tsinghua University architecture design Institute limited (1)</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>Public Representatives</td>
<td>Such as who?</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>Total</td>
<td></td>
<td>68</td>
</tr>
</tbody>
</table>
Questionnaire (Central Government)

Basic Information:

Name:

Company:

Job Title:

Survey Date and Time:

Survey Location:

Survey Methods: Face-to-face interview/phone interview/email

Questions:

1. What is the responsibility for CDW management?

2. Is there any specific planning for CDW disposal or is it included in any of the planning?
   - □ No.
   - □ Yes. Name of the Plan, Objectives

3. Has any policies and regulations been issued for CDW utilization? (Laws, regulations, ordinances or standards.)

4. What are the current issues or difficulties for CDW utilization in the PRC?

5. Are there any future plans for CDW utilization?
Questionnaires (Local Government)

Basic Information:

Name:

Company:

Job Title:

Survey Date and Time:

Survey Location:

Survey Methods: Face-to-face interview/ phone interview/ email

Questions:

I. Basic Status

1. Unit in charge of construction waste in the region: ________ Bureau ________ Division or other ________.

2. Basic conditions of the region: total population ________, urban area _______ (Square kilometers).

3. Area of new buildings, demolished buildings and municipal infrastructure quantities in recent 3 years.

<table>
<thead>
<tr>
<th>Year</th>
<th>New Building Area (m2)</th>
<th>Area of Building Demolition (m2)</th>
<th>Infrastructure (km)</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Roads</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Subways</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pipe Network</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2013</td>
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</tr>
<tr>
<td>2014</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: use "None" if no infrastructure or other project constructed.

4. CDW production in the region in the last three years (in 10 thousand tons):
   Total amount in 2012 ___________ , including construction waste ___________, demolition waste ___________;
   Total amount in 2013 ___________ , including construction waste ___________, demolition waste ___________;
   Total amount in 2014 ___________ , including construction waste ___________, demolition waste ___________.

Note: construction waste indicates construction waste generated from new construction, reconstruction and expansion works.

5. Please describe the data source in the above question (please tick):

   Estimate: the estimation is based on ___________________________
   Statistics: _______① construction area ② demolition area; ③ transportation amount; ④ demolition amount reported; ⑤ actual amount audited ⑥ others_________.

6. Final disposal of the CDW in the region:
Stacking ______% Landfill ______% ; Backfill ______% Resource utilization ________%

Note: Stacking refers to direct dumping; landfill refers to transportation to a specific approved sites; backfill refers to engineering backfill including artificial mountain, landscaping greening and backfill utilizations; resource utilization refers to reuse of the processed aggregates or products in construction.

7. There are construction waste recycling companies in the region, of which

- _____ with annual processing capacity of less than 0.5 million tons;
- _____ with capacity of 5-1.0 million tons;
- _____ with capacity more than 1 million tons.

The main products are:

- aggregate __________ (in 10,000 tons);
- products ____________ (equivalent to standard brick block); and
- others______________.

II. Planning and Objectives

8. Is there any construction waste management planning in the region?

□ No

□ Yes, is there any clear target for CDW recycling rate: No; Yes, please give the specific objective

9. Has any policies and regulations been issued in this region for CDW utilization? (Laws, regulations, ordinances or standards.)

III. Management Arrangement

10. Is there any CDW administrative department?

□ No.

□ Yes. Name, arrangement and leading office

11. Is there any CDW recycling management department?

□ No.

□ Yes. Name, arrangement and leading office

12. What is the management department for CDW transportation company for this region?

13. Is there any specific administrative department for CDW recycling companies?

□ No.

□ Yes. Name

14. Which sector is CDW recycling regarded as?

□ Construction materials □ Environmental protection □ Other sectors
IV. Administration

15. Does demolition need to be recorded?
   □ No.
   □ Yes. Recorded at _____ (department name)

16. Does the quantities of demolition need to be recorded prior to demolition?
   □ No.
   □ Yes. Recorded at _____ (department name)

17. Are the CDW required to be separated during collection and transportation?
   □ No.
   □ Yes. Classifications__________

18. Is there any control measures on the final destination of CDW?
   □ No.
   □ Yes. □ Landfill (%) , □ Backfill (%), □ Handover to enterprises/plants (%).

19. Is there any qualification management for CDW transportation?
   □ No.
   □ Yes. quantities_________; equipment requirement:_____________; regulations: ____________.

20. What is the fee standard for CDW transportation? how is it calculated?

What is the fee collection method for CDW disposal (landfill and recycling)?

Is there any subsidies for CDW recycling?

21. Is there any mandatory measures for CDW recycling?
   □ No.
   □ Yes, in particular___________

22. What is the mode of CDW recycling management
   □ Marketization
   □ Franchise, applied in: □ Transport □ Disposal
   □ Others

V. Issues and suggestions

23. The major reasons constraint CDW recycling in the regions are:
   □ Lack of mandatory policy
   □ Policy is not practical
24. Suggestions of national level policies for CDW recycling
Questionnaires (Enterprises)

Basic Information:

Name:
Company:
Job Title:
Survey Date and Time:
Survey Location:
Survey Methods: Face-to-face interview/phone interview/email

Questions:

1. What is the understanding of CDW recycling?

2. What is the responsibility in CDW recycling?

3. Did the company ever used recycled CDW product?
   □ No.
   □ Yes. Typical case_______ scale and service period.

4. Is there any future plan to use recycled CDW products?
   □ No.
   □ Yes. Planned applications________

5. Can you accept the fee for CDW recycling? What is the fee standard? _______(RMB/m²)

6. What are the current issues in CDW recycling?

7. What are the suggestions for the promotion of CDW recycling?
Questionnaires (Contractors)

Basic Information:

Name:
Company:
Job Title:
Survey Date and Time:
Survey Location:
Survey Methods: Face-to-face interview/phone interview/email

Questions:

1. What is the understanding of CDW recycling?
2. What is the responsibility in CDW recycling?
3. Did the company ever used recycled CDW product?
   □ No.
   □ Yes. Typical case_______ scale and service period.
4. Is there any future plan to use recycled CDW products?
   □ No.
   □ Yes. Planned applications________
5. Can you accept the fee for CDW recycling? What is the fee standard? ______(RMB/m²)
6. What are the management rules/regulations for CDW in construction site? how are they implemented? How well is the implementation?
7. Can you accept the classification of the CDW sources? How to classify?
8. What are the measures for CDW source classifications, reduction and recycling in the past projects? (e.g. source classification measures: types________________measures_____________)
9. Do you accept to use CDW separation collection equipment in existing construction sites? How to solve the fund source? (pay by yourself? Or funded by professional third party?)
10. How to clean and transport the CDW in existing construction projects? Cost?
11. What are the technologies for CDW reduction, reuse and recycling applied in existing construction projects?
12. Can you accept recycled CDW products? Applications______quantities_______objectives_______?
13. Are there any obstacles for application of recycled CDW products?
14. Are there any suggestions for the promotion of CDW recycling?
Questionnaires (Disposal Enterprises)

Basic Information:

Name:

Company:

Job Title:

Survey Date and Time:

Survey Location:

Survey Methods: Face-to-face interview/phone interview/email

Survey:

1. Basic status of the enterprise
   a. Company existing staff___people, including the R&D personnel___people,
      ___people with senior title, ___people with intermediate title, ___people with primary title
   b. Establishing time, area___mu, registered capital___yuan, fixed assets___yuan;
   c. Existing line of CDW recycled aggregate production,
      Designed treatment capacity___t/year, including coarse aggregate___t/year, fine aggregate___t/year
      CDW recycled concrete and its production:
      □ the production line of recycled concrete, designed treatment capacity___t/year,
      □ the production line of standard brick, designed treatment capacity___t/year,
      □ the production line of applying inorganic combined material in the base of roads, designed treatment capacity t/year,
      □ the production line of building blocks, designed treatment capacity___t/year,
      □ the production line of floor tile, designed treatment capacity___t/year,
      □ the production line of wallboard, designed treatment capacity___t/year,
      □ other_______, design capacity
   d. The business model of enterprises (the relationship between the government and the market)

2. Land use of enterprises
   □ Free government transfers, the probation period
   □ Purchase___yuan/mu
   □ Rent___yuan/mu
   □ Other

3. If the governments have subsidies for enterprises (in the aspects of production, disposal, products, fixed investment, and the others)
   □ No
   □ Yes, subsidy standard_______, subsidy form

4. Environmental impact assessment of enterprises
   The time when the enterprise passed the environmental impact assessment______(MM/DD/YY)
   EIA reference standards
   Index control: factory bounded noise; dust; wastewater

5. Enterprise production cost
   a. The management of CDW uses
      □ Fixed broken line, the average cost of recycled aggregate is___yuan/ton
      □ Moving broken line, the average cost of recycled aggregate is___yuan/ton
      Ordinary aggregate sale price in the region is___yuan/ton
   b. The sale price of recycled building blocks is___yuan/m³, same-type common aggregate block sale price is
c. The sale price of recycled C30 concrete is ___ yuan/m³, same-type common aggregate concrete sale price is ___ yuan/m³.
d. The sale price of inorganic combined material for road base is ___ yuan/m³, the sale price of same-type common inorganic combined material for road base is ___ yuan/m³.

6. Major source of CDW
☐ demolition of old buildings  ☐ construction of new buildings
☐ municipal road project  ☐ other

7. Whether it is necessary to purchase CDW materials
☐ No, CDW is transported to the enterprise
☐ No, but enterprise have to pay for the transportation fee of CDW
☐ Yes, acquisition expenses ___ yuan/ton

8. Whether the source of CDW is classified
☐ No, the components of CDW is complex
☐ Yes, major categories
☐ Most of the CDW is not classified

9. Whether the construction waste raw materials are selectively received
☐ No, all the CDW is received
☐ No, CDW that is relatively clear is received
☐ Yes, only CDW under brick and concrete class is received, no waste residue is received

10. Does the enterprise apply the technology of CDW recycling? (include applying advanced technologies, process equipment, and own technologies)

11. The actual amount of production in 2015
☐ processing ___ tons of CDW
☐ recycled aggregate ___ tons
☐ recycled concrete ___ tons
☐ ___ standard brisk
☐ ___ m³ building blocks
☐ ___ m² floor tiles
☐ ___ m² wall board
☐ other

12. Whether the government effectively implement the protection guarantee for recycled production application
☐ No
☐ Yes, the specific measures and the actual effect

13. The recent three-year market condition
The sales of CDW products is ___ yuan in 2013, ___ yuan in 2014, ___ yuan in 2015.
The actual profit is ___ yuan in 2013, ___ yuan in 2014, ___ yuan in 2015.

14. The major causes that limit the promotion of CDW recycling
☐ lack of enforcing policies, and the source of CDW is not guaranteed.
☐ no political guarantee for CDW recycled products
☐ political operability is weak
☐ no connection between CDW production, transportation, management, and application
☐ the public awareness of CDW recycling is low
☐ recycled products is not in the list of building materials, which limit their applications in projects
☐ the cost for recycling management is high
☐ the charge of recycling management is low or none

15. From enterprise’s point of view, which problem do you think need to be solve to promote the application of CDW recycling?
16. From enterprise’s point of view, what kind of policies and suggestions need to be proposed to promote the application of CDW recycling?

- Fiscal policy disposal fee, tax, etc.
- Legal protection for source control, which helps to accomplish the classification in the source and transport to CDW disposal enterprise
- Systematic management and construction of the comprehensive CDW management platform, which helps to achieve close-loop management in every stage and high quality of recycling products
- Technologies provide guarantee for standard system, equipment’s research and development, high value-added products’ research and development, and the qualification of recycled product quality
- Other policies: land transfer, environment evaluation, construction subsidies, recycled product promotion
Questionnaires (Disposal Enterprises)

Basic Information:
Name:
Company:
Job Title:
Survey Date and Time:
Survey Location:
Survey Methods: Face-to-face interview/phone interview/email

Survey:
1. What are the existing problems for promoting CDW recycling? (policies, technologies, systems and mechanisms, the popularization and application, etc.)

2. What are the political suggestions for promoting CDW recycling? (policies, technologies, systems and mechanisms, the popularization and application, etc.)
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Construction and Demolition Waste Management and Recycling

TA-8906 PRC

Output 2 - International Good Practice in CDW Management and Recycling
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# Table of Contents

1 Synthesis .......................................................................................................................... 1  
1.1 Introduction....................................................................................................................... 1  
1.2 Technical Factors .............................................................................................................. 1  
1.3 Regulatory Factors ........................................................................................................... 3  
1.4 Economic Factors ............................................................................................................. 5  
1.5 Conclusions ....................................................................................................................... 7  

2 Introduction ....................................................................................................................... 9  
2.1 Study Background ............................................................................................................. 9  
2.2 Report Objectives ............................................................................................................ 9  
2.3 Methodology .................................................................................................................... 9  

3 United Kingdom .................................................................................................................. 10  
3.1 Background ..................................................................................................................... 10  
3.2 Legislation ...................................................................................................................... 10  
3.3 Economic Instruments ................................................................................................. 13  
3.4 Other Relevant Information ......................................................................................... 13  
3.5 Discussion ....................................................................................................................... 17  

4 Hong Kong .......................................................................................................................... 19  
4.1 Background ..................................................................................................................... 19  
4.2 Legislation ...................................................................................................................... 20  
4.3 Economic Instruments ................................................................................................. 22  
4.4 Other Relevant Factors ............................................................................................... 24  
4.5 Discussion ....................................................................................................................... 27  

5 Germany .............................................................................................................................. 30  
5.1 Background ..................................................................................................................... 30  
5.2 Legislation ...................................................................................................................... 31  
5.3 Economic Instruments ................................................................................................. 34  
5.4 Other Relevant Factors ............................................................................................... 34  
5.5 Discussion ....................................................................................................................... 36  

6 Denmark .............................................................................................................................. 38  
6.1 Background ..................................................................................................................... 38  
6.2 Legislation ...................................................................................................................... 39  
6.3 Economic Instruments ................................................................................................. 42  
6.4 Other Relevant Information ....................................................................................... 44  
6.5 Discussion ....................................................................................................................... 45  

7 Japan .................................................................................................................................. 47  
7.1 Background ..................................................................................................................... 47  
7.2 Legislation ...................................................................................................................... 47  
7.3 Economic Instruments ................................................................................................. 51  
7.4 Other Relevant Information ....................................................................................... 51  
7.5 Discussion ....................................................................................................................... 52  

8 References .......................................................................................................................... 53
1 Synthesis

1.1 Introduction

An international good practice study has been carried out, focussing on construction and demolition waste (CDW) management in five case study countries which achieve a high level of CDW diversion from landfill. This synthesis presents an overview of the main technical, regulatory and economic factors which allow these and other countries to achieve good practice in CDW management.

1.2 Technical Factors

1.2.1 Waste Types

Excluding excavated soil\(^1\) and asphalt\(^2\), the main constituents of CDW are:

- Hard inert materials (concrete and brick);
- Wood;
- Mixed waste.

The majority of construction waste in most countries comprises hard inert material, such as concrete and bricks. In terms of improving the amount of CDW that is recycled, this hard inert portion is generally prioritised because:

- This fraction forms the majority of CDW in most countries; and
- Recycling technologies and markets for the smaller fraction of CDW such as plastic and metal are relatively well-established.

Other fractions of CDW which are present in smaller quantities but which have received specific attention include:

- Wood – this can form a significant proportion of CDW, depending on construction methods in specific countries\(^3\);
- Gypsum (e.g. plasterboard/drywall) – landfill disposal is problematic due to its potential to generate toxic hydrogen sulphide;
- Hazardous materials such as asbestos.

In order for CDW waste to be recycled, there must be:

- Supply of recycled material of suitable quality; and
- Demand for the material.

1.2.2 Supply-side Technical Factors

The technical factors affecting the supply-side of CDW recycling can be grouped into two categories:

- Effectiveness of source-separation to produce relatively clean and consistent sources of material which is suitable for processing; and
- Effectiveness of processing to produce recycled material suitable for use.

In some countries, source-separation is mandatory for all but the smallest construction projects (e.g. Japan). In other countries, source-separation is encouraged either by regulators or clients. For instance, public sector clients in the UK often require contractors to prepare and implement Site Waste Management Plans\(^4\), which will normally include provision

---

\(^1\) Excavated soil is often excluded when considering CDW, as its management is relatively straightforward and usually simply a matter of identifying projects requiring fill material which can use the excess cut material from other projects.

\(^2\) MOHURD noted during the inception stage that asphalt recycling is outside the scope of this project.

\(^3\) For example, wood is used extensively in domestic construction in Japan; and bamboo is used for scaffolding in Hong Kong.

\(^4\) Site Waste Management Plans were previously a legal requirement in England: although no longer legally required, they are frequently made a contractual requirement.
for source-separation of the main types of CDW. Hong Kong’s public sector clients also require similar commitments to CDW source-separation.

The primary recycling route for hard inert CDW is back into the construction industry, as a recycled aggregate. Most recycled aggregate is used as general fill or sub-base\(^5\), and the basic procedure for recycling hard inert material is relatively straightforward, consisting of crushing and screening (Hyder Consulting, 2011). More advanced techniques are available, which are intended to produce a higher-quality aggregate which may be used in more demanding applications, such as in concrete.

For instance, a European Union (EU) project investigated waste concrete streams and optimised recycling processes that yield fine cement paste, coarse aggregate and fine binding materials. This was achieved through lab tests, simulations and experiments, as well as through a case study involving industry partners. Tests showed that end-of-life concrete can be recycled with excellent results, although contaminants such as wood or plastic must be removed at an early stage (CORDIS, 2015).

The UK has successfully developed a “Quality Protocol” for recycled aggregates. CDW treatment facilities which accept certain types of waste, and produce recycled aggregate to a recognised specification and following defined quality control procedures are entitled to sell their outputs as a construction product, and it is no longer regulated as a waste. This has helped to build confidence in the market, and reduced regulatory burdens associated with waste legislation (Mineral Products Association, 2011).

In the case of mixed CDW, a UK study into good practice CDW recycling at Materials Recycling Facilities (MRFs) noted that various sorting equipment is available recovering material on the basis of size, mass and other physical and chemical properties, but the level of automation in MRFs varies markedly (WRAP, 2009). Technologies used may include:

- Screening equipment – the most important initial step of a CDW MRF, which uses trommels, vibrating screens or star screens to separate material by size.
- Hand picking – hand separation of mixed waste still remains common in many countries.
- Magnets – to extract ferrous metal.
- Water separation equipment – flotations tanks can be used for separating wood from heavier aggregates.
- Air separation equipment - air- or wind-separation equipment can optimise the quality of aggregate outputs by removing lighter contaminants (such as paper, plastic and wood) from the heavier rubble leaving the picking cabin, or from fines separated out by trommels or vibratory screens.
- Shredders - wood-shredding machines to reduce the space taken up by recovered wood and thus increase transport efficiency, and shredding can also be used for other waste streams.
- Advanced equipment - some highly automated plants used equipment such as ballistic separators (to separate light from heavy fractions), optical sorting technology (applicable to separating several types of materials), and eddy current separators (to remove aluminium).

A study into the potential of Near Infrared (NIR) sorting technology to improve the quality of mixed recycled aggregates carried out tests using samples of mixed recycled aggregates collected in different EU countries (Germany, Sweden, Spain and Italy). Constituents, total sulphur content, acid soluble sulphates, total heavy metals and metal leaching were determined before and after the use of the NIR sorting technology. The results clearly indicate that the problematic fractions (organic material, gypsum and AAC) in the mixed recycled aggregates can be significantly reduced or even eliminated during the NIR sorting treatment, boosting a greater use of recycled aggregates in high grade applications such as concrete manufacturing (Vegasa, Broosb, Nielsen, Lambertz, & Lisbona, 2015).

Although many different technologies are available, the use of specific advanced technologies is not generally identified as a critical factor in achieving a good CDW recycling rate. Provided the necessary regulatory and economic drivers are in place, relatively simple recycling technology should be capable of generating recycled outputs that are suitable for use.

\(^5\) In highway engineering, sub-base is the lowest layer of aggregate, which is placed on top of the soil and which is overlain by the base- and wearing courses of the road.
Source-separation is mandated in many countries and enables higher quality recycled materials to be produced at lower cost. Various well-established technologies can be used for separating mixed CDW, but the emphasis should be on segregation at source.

Although a variety of technologies are available, the basic processes for recycling that largest fraction of construction waste (hard inert material) are relatively simple.

The use of protocols or standards for recycled CDW materials builds confidence in the market by providing a consistent product.

### 1.2.3 Demand-side Technical Factors

Ensuring an adequate supply of source-separated CDW is only half of the problem: if markets are not available, this material cannot find a use. For instance, Hong Kong has been very successful in diverting CDW from landfill, but less successful in finding alternative outlets for this material. Most countries report some difficulties in the acceptance of recycled CDW: often it is perceived as being of low quality. Measures to address this negative perception have included:

- Development of specifications for use of recycled aggregates;
- Publicising case studies which illustrate the technical and economic benefits of using recycled CDW;
- Encouraging or requiring the use of products with a high recycled content;
- Carrying out research into higher value-added CDW recycling.

For example, the Cement & Concrete Association of New Zealand have published a detailed best practice guide for the use of recycled concrete which includes model specifications (Cement and Concrete Association of New Zealand, 2011), and the British Standard for Concrete, BS 8500, applies product-specific, and specification-specific, conditions on the use of recycled aggregates in new concrete construction (Mineral Products Association, 2013). A review of CDW management in Australia concluded that recovery rates are highest in those regions where there is strong market demand for recycled C&D materials, with well-defined and well-publicised specifications supporting the use of recycled products (Hyder Consulting, 2011).

A large amount of research has been carried out into use of recycled CDW, and is published in a wide range of international journals and conferences (for example, the organisation RILEM supports many such events (RILEM, 2011).

**Stimulating demand for recycled CDW products is often challenging. Part of the answer is technical, and can be addressed by research and development of specifications and protocols. Part of the answer relates to perception, and can be addressed by case studies and demonstration projects. Clients can stimulate demand by requiring the use of a certain proportion of recycled material in projects.**

### 1.2.4 Next Steps

Countries which are already achieving relatively high levels of landfill diversion for CDW are increasingly turning their attention to:

- Improving the standard of recycling – i.e. using recycled materials for more value-added applications (such as using recycled aggregate in structural concrete, rather than as general fill); and
- Minimising construction waste at source, for example by designing out waste and better on-site management of materials.

**Countries that have been successful in achieving a high CDW recycling rate are increasingly looking to increase the quality of recycling, and minimize the amount of CDW generated in the first place.**

### 1.3 Regulatory Factors

#### 1.3.1 Waste Regulations and Targets

Some countries have specific regulations relating to CDW, whereas others have broader regulations which apply to all wastes. Successful waste regulations generally require:

6 RILEM (Réunion Internationale des Laboratoires et Experts des Matériaux, systèmes de construction et ouvrages), in English the "International Union of Laboratories and Experts in Construction Materials, Systems and Structures"
Licensing of waste management facilities and waste transport companies;
- Environmental assessment for waste facilities;
- Manifest system to track the transfer of waste between parties; and
- Penalties for illegal dumping of waste.

Measuring the success of CDW recycling policies requires detailed information about the quantities and destinations of CDW. Whilst not straightforward to implement, countries see data collection and management as an important aspect of their overall CDW management programme, and this aspect has been addressed at an EU level (Encord, 2013). In the European Union, over-arching waste policy is set out in a series of Directives which are then passed into law by member countries. CDW is covered by the general requirements for managing waste as set out in the Waste Framework Directive, and there is a specific target that member countries should recycle at least 70% of CDW by 2020 (European Union, 2008). Where problems have been identified, these relate to fragmented and inconsistent approaches. For example, in Germany the lack of a nationwide regulation for secondary building materials, which resulted in many different legislations on state level, is considered as one of the major barriers for sustainable CDW management (Deloitte, 2015).

1.3.2 Controlling Illegal Dumping

In many countries, CDW forms the largest proportion of waste that is illegally dumped. This illustrates the importance of regulating the entire waste “supply chain”, including transportation. Several countries are trialling or have introduced electronic manifests, which allow for wastes to be tracked easily. Even in highly regulated countries, illegal disposal of CDW is not unknown. Measures to reduce the scale of the problem include:

- Publicising cases to act as a deterrent;
- Applying high financial penalties (which may include fines but also exclusion from bidding for Government contracts);
- Enhancing surveillance and counter-measures against known or suspected illegal activities;
- Enforcing liability on the main contractor, to ensure that they are responsible for the actions of their sub-contractors and have a “duty of care” for the waste generated on their site.

Controlling illegal waste dumping is one of the most important elements of sustainable CDW. If waste can be dumped for free and with impunity, this undermines the market for legitimate CDW management. A range of penalties can be applied, but effective surveillance is necessary to ensure that the risk of being caught is high.

1.3.3 Landfill Bans or Mandatory Recycling

Some countries or jurisdictions have introduced either bans on sending certain types of CDW to landfill, or mandatory requirements for recycling.

In Japan, under the Law on Recycling of Construction-Related Materials it is mandatory to recycle most types of construction waste, including concrete, metal, wood and asphalt.

In the US, the city of Seattle has passed regulations meaning that certain CDW must be recycled and may not be put in containers for disposal in landfills. Before receiving a permit from the Seattle Department of Construction & Inspection (SDCI), building permit applicants with projects more than 750 square feet and all demolition projects need to submit a Waste Diversion Report. In addition, a Salvage Assessment is to be filled out for whole building removal projects by a salvage verifier. Once a project is completed, all demolition permits and all new construction and remodeling projects that are $30,000 or more in value need to submit a Waste Diversion Report to SPU. This report documents where construction materials were delivered for reuse, recycling and disposal (Seattle Public Utilities, undated). Seattle is planning to phase in bans on landfilling certain types of CDW (including asphalt paving, bricks, and concrete; metal; cardboard; gypsum; untreated wood; carpet; plastic film; and asphalt shingles).

In the Netherlands there has been a national ban on the disposal of re-useable C&D waste since 1997. As a result only certified C&D crushers and sorters are allowed to dispose of non re-useable C&D waste. Under Dutch law only rubble contaminated with coal tar, asbestos and other forms of chemical contamination are considered non-re-useable (Construction Resources and Waste Platform, 2007).
Landfill bans or mandatory recycling policies have been introduced in several countries and can be effective, but require effective monitoring to ensure compliance.

1.3.4 Non-Statutory Guidelines

Many counties have certification schemes for environmentally friendly construction. Schemes include LEED (USA), BREEAM and CEEQUAL (UK), and HKBEAM (Hong Kong). These schemes typically have a waste management element, and points can be gained from achieving a certain level of landfill diversion or recycling, by separating CDW on site, and by using materials with a high recycled content. Clients may choose to make certification a mandatory requirement, which can drive sustainable CDW management.

Industry- and government-funded bodies issue guidelines to assist contractors with CDW recycling. This includes detailed technical guidelines for designers, but also practical guidelines for site agents, foremen and operatives (Environmental Protection Department, undated). Tools have also been developed to assist designers and contractors both during design and construction, such as the SmartWaste tool developed in the UK (BRE, 2015).

Voluntary measures have a role to play but are unlikely to be sufficient on their own to alter CDW behaviour across the sector.

Technical guidance on how to comply with regulations or best practice is helpful to designers, contractors and site operatives. This guidance should be practical rather than theoretical, and supported by case studies.

1.3.5 Client Requirements

Government or government-owned bodies are the clients for a large proportion of construction projects, particularly in the infrastructure sector. Government can set CDW performance requirements in their construction contracts, and select only contractors who can deliver these requirements. When selecting contractors, Government can show preference to those who can demonstrate achievements in sustainable CDW management. For instance, major contractors in the UK monitor and publicise their CDW recycling performance. For example, Carillion (a large UK-based contractor) has a commitment to sending zero non-hazardous waste to landfill by 2015 and achieved their 2014 target to divert 95% of waste from landfill. Measures included collaborating with the supply chain, designing out waste and strengthening relationships with waste management specialists (Carillion plc, 2015). In Japan, the Kajimi Corporation (a major construction contractor) has adopted a company-wide target for its final disposal rate (i.e. the percentage of total waste material that is not recycled) of under 5% (Kajimi Corporation, undated).

Contractors on major infrastructure projects in the UK are typically required to measure and report their CDW recycling performance to a high level of detail. Project targets for CDW recycling are established at an early stage and continually monitored. For example, on the Crossrail project (Europe’s largest construction project) the Environmental Objectives for 2015-16 include: “Implementing the waste hierarchy by achieving 90% (or greater) reuse or recycling of our construction and demolition waste and 95% (or greater) reuse or recycling of our clean excavated material and achieving at least 15% of the total value of our construction materials from reused or recycled content” (Crossrail, not dated). This is turn is reflected in the contractual requirements of the project.

An Australian study recommended that the wider adoption of sustainable procurement practices, particularly through government agencies, would help increase market demand for recovered C&D materials, and also recommended that Government agencies should favour procurement of material containing recycled C&D content where they meet defined performance criteria / specifications (Hyder Consulting, 2011).

The public sector can act as a role model for sustainable CDW management. Government can require their contractors to prepare CDW management and to provide accurate reporting of CDW management.

1.4 Economic Factors

1.4.1 Background

The economics of recycling CDW (particularly inert material) is faced with two fundamental problems. On one hand, virgin aggregate is widely available and inexpensive; whereas recycled CDW requires relatively costly processing and transport. On the other hand, landfill disposal of CDW is inexpensive even if authorised facilities are used, and even less expensive if dumped illegally.
Some countries have adopted an almost entirely market-based approach to CDW, using economic instruments rather than detailed regulations in order to encourage desired behaviour. The UK provides a good example of this, where environmental taxes are one of the main drivers of improved CDW management. However, economic instruments alone are unlikely to be effective unless illegal disposal is strictly policed, since illegal disposal will always be cheaper than using legitimate facilities.

1.4.2 Raising the Cost of Disposal

Landfill is a relatively low cost operation, requiring land but relatively little plant and equipment. Engineered landfills with gas and leachate collection systems are more costly than inert waste landfills, and the “void space” (i.e. the disposal capacity) at a mixed waste landfill is therefore a more valuable resource than void space at an inert waste landfill. One of the aims of sustainable CDW management is to minimise the amount of waste that is landfilled at all, but also to minimise the amount that needs to be sent to a mixed waste landfill. This means incentivising the separation of CDW into inert and non-inert fractions.

In most developed countries it is usual practice to pay a “gate fee” for the use of a waste treatment or disposal facility. In the absence of specific economic instruments, the gate fee for landfill tends to be relatively low, compared to alternative treatment techniques. Countries use economic instruments to:

a) Increase the cost of landfill disposal, thereby making alternative treatment or recycling more cost-competitive; and

b) Differentiate between the costs of mixed waste and inert waste disposal, thereby incentivising source-separation of waste.

The current rates of UK Landfill Tax (in 2016) are:

- Lower rate (inactive waste): £2.65 per tonne
- Standard rate (active waste): £84.40 per tonne

In Hong Kong, the gate fees for disposing of CDW at various facilities (in 2016) are:

- Public fill reception facilities (inert CDW only): HK$27 per tonne
- Sorting facilities: (> 50% by weight of inert CDW): HK$100
- Landfills (< 50% by weight of inert construction waste): HK$125

Hong Kong recognized the potential for increased illegal disposal when charging for CDW disposal was introduced, and stepped up measures to prevent this and to catch offenders (Advisory Council on the Environment, 2007).

An Australian study also concluded that, where the cost of landfill disposal is sufficiently high, the cost to dispose of mixed waste will be high compared to the cost to reprocess uncontaminated streams of specific C&D waste materials. This provides a strong incentive for high volume and regular generators of C&D waste to source separate materials and allow for easier reprocessing. The study also noted that high landfill disposal costs provide an incentive to process mixed C&D waste in order to recover certain high value and high volume components, and avoid landfill disposal costs (Hyder Consulting, 2011).

### Raising the cost of waste disposal provides a strong incentive for recycling. Differential pricing for inert and non-inert wastes encourages waste producers to segregate at source. However, landfill taxes only work if they can’t be easily avoided by illegal dumping.

1.4.3 Taxation of Virgin Aggregates

The UK has also attempted to address the price differential between recycled and virgin aggregates by means of a tax on virgin aggregates, the "Aggregate Levy". The tax is set at GBP 2.00 (CNY 18) per tonne of aggregate, and recycled aggregates are exempt. The tax forms a significant proportion of UK aggregates cost, which are reported to be approximately GBP 5.00 exclusive of tax (ex quarry). An EU study (European Commission, 2011) concluded that the UK’s Aggregate Levy has encouraged the use of recycling and secondary material, which has led to a decrease of the aggregates output. However, views on the effectiveness of the levy are mixed and critical points mentioned in the literature are the lack of measurement of the impacts on environment externalities, larger transport distances and stockpiling of unsold but locally available lower quality primary aggregates increasing at quarries (European Commission, 2011).
A study in Switzerland concluded that the demand for recycled concrete was found to be most sensitive to changes in construction stakeholders’ awareness of the recycling option and price differences between conventional and recycled material. The scenario analysis showed that a combination of extensive information campaigns and small price advantages for recycled materials would lead to a maximal reuse of construction and demolition waste (Knoeri, Nikolic, Althaus, & Binder, 2014).

A study investigated how taxes on virgin raw materials used in construction in Denmark, Sweden and the UK have reduced the use of these resources (Söderholm, 2011). It concluded that in Sweden, a tax on natural gravel (introduced in 1996) to promote the use of crushed rock and recycled materials encouraged substitution with other materials, although the tax is applied uniformly across the country, even in regions where shortages in natural gravel is less of a problem. In Denmark, a tax on extracted raw materials (sand, gravel, stones, peat, clay and limestone) introduced in 1990 in conjunction with a waste tax has produced a greater demand for recycled substitutes: in 1985 only 12% of construction and demolition waste was recycled, compared with 94% in 2004. In the UK, a tax on aggregates (sand, gravel and crushed rock used in construction) was introduced in 2002 and has encouraged a higher recycling rate in the UK.

The UK’s Aggregate Levy has helped recycled aggregate gain market share, but its implementation has not been straightforward.

1.4.4 Subsidising Waste Treatment Facilities

In Europe, facilities for managing CDW are generally run by the private sector without significant subsidies, although Governments have provided financial assistance with research and development, for example the various work in the UK funded by the organisation WRAP.

Outside of Europe, some countries subsidise the cost of CDW treatment. In Hong Kong, CDW recycling and disposal facilities are provided by Government but operated by the private sector under “Design-Build-Operate” contracts. These facilities do not operate on a full cost-recovery basis, and hence there is some element of public subsidy. Japan provides subsidies for recycling industries in certain “Eco Towns” (Ministry of Economy, Trade and Industry, 2008).

Subsidies may be beneficial in stimulating investment and providing facilities. However, if there is no commercial incentive for providing facilities and insufficient market for the products, then the Government may need to provide long-term support and recycled material may end up being stockpiled rather than beneficially reused. To some extent this has happened in Hong Kong: the support of CDW recycling facilities has certainly been effective in diverting waste from landfill, but in the absence of strong local markets for recycled construction materials there have been difficulties in reusing the outputs of these facilities.

Subsidies can support CDW facilities where they would otherwise be uneconomic; but in the absence of sufficient demand for recycled CDW materials they may struggle to find outlets for their products. Direct provision of, or subsidy to, CDW processing facilities is unusual in Europe and the US.

1.5 Conclusions

Based on a review of international practice in CDW recycling, the main conclusions are:

- Source-separation is mandated in many countries and enables higher quality recycled materials to be produced at lower cost. Various well-established technologies can be used for separating mixed CDW, but the emphasis should be on segregation at source.
- Although a variety of technologies are available, the basic processes for recycling that largest fraction of construction waste (hard inert material) are relatively simple.
- The use of protocols or standards for recycled CDW materials builds confidence in the market by providing a consistent product.
- Stimulating demand for recycled CDW products is often challenging. Part of the answer is technical, and can be addressed by research and development of specifications and protocols. Part of the answer relates to perception, and can be addressed by case studies and demonstration projects. Clients can stimulate demand by requiring the use of a certain proportion of recycled material in projects.
- Countries that have been successful in achieving a high CDW recycling rate are increasingly looking to increase the quality of recycling, and minimize the amount of CDW generated in the first place.
- Control measures on CDW should extend from the site of production to the site of treatment/disposal, but should also include those responsible for transportation.
- Controlling illegal waste dumping is one of the most important elements of sustainable CDW. If waste can be dumped for free and with impunity, this undermines the market for legitimate CDW management. A range of penalties can be applied, but effective surveillance is necessary to ensure that the risk of being caught is high.
- Landfill bans or mandatory recycling policies have been introduced in several countries and can be effective, but require effective monitoring to ensure compliance.
- Voluntary measures have a role to play but are unlikely to be sufficient on their own to alter CDW behaviour across the sector.
- Technical guidance on how to comply with regulations or best practice is helpful to designers, contractors and site operatives. This guidance should be practical rather than theoretical, and supported by case studies.
- The public sector can act as a role model for sustainable CDW management. Government can require their contractors to prepare CDW management and to provide accurate reporting of CDW management.
- Raising the cost of waste disposal provides a strong incentive for recycling. Differential pricing for inert and non-inert wastes encourages waste producers to segregate at source. However, landfill taxes only work if they can’t be easily avoided by illegal dumping.
- Taxes on virgin construction material such as the UK’s Aggregate Levy can help recycled aggregate gain market share, but implementation may not be straightforward.
- Subsidies can support CDW facilities where they would otherwise be uneconomic; but in the absence of sufficient demand for recycled CDW materials they may struggle to find outlets for their products. Direct provision of, or subsidy to, CDW processing facilities is unusual in Europe and the US.
2 Introduction

2.1 Study Background

The Government of the People’s Republic of China (PRC) has requested policy and advisory technical assistance (TA) from the Asian Development Bank (ADB) to enhance the PRC’s policies and practices related to the management and recycling of construction and demolition waste (CDW).

The impact of the TA will be:

- Improved CDW management policies and practices in the PRC.

The outcome of the TA will be:

- An agreed set of policy recommendations to regulate CDW management and promote CDW recycling.

2.2 Report Objectives

This report presents the results of a review of international good practice in CDW management and recycling. The objective of the report is to document hindering and enabling factors for sustainable CDW management and recycling. The report includes in-depth case studies conducted in selected advanced economies with high CDW recycling rates.

2.3 Methodology

2.3.1 Selection of Countries

The countries proposed for case studies have one or more of the following characteristics:

- High degree of CDW diversion from landfill.
- Good availability of policy information and associated research data;
- Relevance to the Chinese situation.

The countries selected for International Case Studies are:

- UK – high CDW diversion and good availability of policy information
- Hong Kong - high CDW diversion and relevant to China as a Special Administrative Region of China
- Germany – high CDW diversion and good availability of policy information
- Denmark – high CDW diversion and good availability of policy information
- Japan – high CDW diversion and relevant to China as an Asian country

2.3.2 Collection of Information

Information on CDW recycling has been collected by:

- Literature review of information from the selected countries and which is available in English; and
- The project team’s knowledge of CDW recycling in case study countries and other jurisdictions.
3 United Kingdom

3.1 Background

| Responsibilities | UK construction waste legislation and regulations are generally national in scope, with municipalities responsible only for land use planning and environmental permitting of small-scale facilities. Certain areas of the UK (Scotland and Northern Ireland) have devolved powers for environmental regulation, but in practical terms these generally follow those of England and Wales. This assessment focuses on the situation in England and Wales, which collectively account for 89% of the UK’s population.

Waste policy and legislation in England and Wales is the responsibility of the Department for the Environment, Food and Rural Affairs (DEFRA). The Environment Agency (EA), a non-departmental public body, is responsible for regulating the waste management sector, including construction waste. The EA is responsible for issuing permits for waste management activities, and taking enforcement action against any breaches of waste management law. DEFRA provided funding to the Waste and Resources Action Programme (WRAP) which carried out research and has developed practical guidance and tools for construction waste minimisation and recovery.

| Construction Waste Statistics | In 2012, the UK-wide generation of construction waste was reported to be 100.2 Mt (representing 50% of total waste generation). Approximately 1 Mt of this waste is hazardous. The total generation of non-hazardous construction waste in, excluding excavated soil, in 2012 (the latest year for which statistics are available) was reported to be 44.8 Mt, of which 38.8 Mt was recovered, representing a recovery rate of 86.5% (Department of Food, Environment and Rural Affairs, 2015).

The UK Office for National Statistics reports that the UK’s population in 2013 was 64,100,000 (Office of National Statistics, 2014), giving a per capita CDEW generation rate of 1.56 tonnes/person/year.

According to data provided by the UK Mineral Products Association (Mineral Products Association, 2015), the total production of aggregates in the UK in 2014 was as follows:

Aggregates: 209 million tonnes (Mt) of which:
- Crushed Rock: 94 Mt
- Sand & Gravel - land won: 44 Mt
- Sand & Gravel – marine: 11 Mt
- Recycled: 49 Mt
- Secondary: 11 Mt

Recycled and secondary materials now account for 29% of the GB aggregates market. Recycled materials include construction and demolition waste, asphalt planings and used railway ballast. Secondary materials include iron and steel slag, waste glass, incinerator and furnace bottom ash and waste from extractive activities such as china clay and slate. The share of recycled and secondary materials in the total UK aggregates market is also the highest share in Europe; the European average stands at about 10% (Mineral Products Association, 2015).

3.2 Legislation

| General | There are no current specific pieces of legislation which relate to CDW alone.

As part of the European Union, the UK is required to comply with EU Directives.
Directives relevant to construction waste include:


The objective of the WFD is to provide a framework for moving towards a European recycling society with a high level of resource efficiency. Article 11.2 stipulates that "Member States shall take the necessary measures designed to achieve that by 2020 a minimum of 70% (by weight) of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the List of Wastes shall be prepared for re-use, recycled or undergo other material recovery" (including backfilling operations using waste to substitute other materials).

In England and Wales, the requirements of the Waste Framework Directive are applied by the Waste (England and Wales) Regulations 2011 and subsequent amendments including (in Wales) the Waste (Wales) Measure 2010.

These set out the requirements for waste management plans, waste prevention plans, implementing the waste hierarchy and carrying of waste/duty of care.

Hazardous Waste


European List of Wastes (Decision 2000/532/EC)

The List of Wastes Regulations in England and Wales transpose the European List of Wastes into law. The List of Wastes helps to identify whether a material substance is a waste or hazardous waste and gives a unique 6 digit code to each waste type. This defines the six-digit code for each waste and the respective two-digit and four-digit chapter headings.

Waste producer’s responsibility

The Waste (England and Wales) Regulations 2011 requires businesses to apply the waste management hierarchy, establishes waste prevention programmes and amends other legislation.

Waste Generation

The Site Waste Management Plan Regulations 2008 were in place in England from April 2008 to December 2013. This involved a mandatory requirement for projects over £300,000 to prepare a Site Waste Management Plan (SWMP) before construction work commenced on site, which should include statements regarding waste minimisation, and a forecast of the types and amounts of waste that would be generated on the project with details of how these would be managed.

The SWMP was then implemented throughout a project and the amount and types of waste generated were recorded along with details of their waste management routes (reuse, recycling, recovery, disposal) and Duty of Care information for waste contractors carrying and dealing with the waste.

However, in 2013 Government repealed the SWMP Regulations (Department for Environment, Food and Rural Affairs, 2013). In justifying their decision to repeal the SWMP regulations, Defra noted that the introduction of a mandatory requirement had the aim of embedding the use of SWMPs across the industry. The wider policy objectives of the Site Waste Management Plans Regulations 2008 were to help prevent the illegal disposal of waste by ensuring that those responsible for construction projects knew the intended destination of waste removed from the site, that their waste was being managed by legitimate registered waste carriers and, as far as possible, that their waste was managed responsibly and in line with appropriate waste management controls. The plans also aimed to improve materials resource efficiency within the construction sector by reducing the amount of waste produced and encouraging recovery of as much as
possible of the remainder.

The intended effect of repealing the SWMP regulations is to free up businesses from some of the more onerous parts of the 2008 Regulations, where they are unnecessary. This will allow businesses to use SWMPs as a flexible resource efficiency tool, rather than an inflexible piece of legislation. Defra views landfill tax as a more effective tool to minimise waste to landfill across all waste streams. SWMPs are still recommended when appropriate, and it is likely that they will be retained for larger construction projects, but as a tool rather than an administrative and regulatory burden (Department for Environment, Food and Rural Affairs, 2013).

Waste Facilities

In England & Wales, the Environmental Permitting (England and Wales) Regulations ("EPR") 2010 and subsequent amendments apply the requirements of the EU Landfill Directive (1999/31/EC) and standardise environmental permitting and compliance for waste management operations in England and Wales to protect human health and the environment. They also set out the regulations covering waste management licences, permits, exemptions and carriers for all other types of waste facilities. All facilities managing waste must have an environmental permit, other than those operating under exemptions as described below.

The EPR includes provision for exemptions for certain types of waste management operations. A waste exemption is a waste operation that is exempt from needing an environmental permit. Each exemption has specific limits and conditions and those wishing to operate under a waste exemption must register that exemption with the Environment Agency. Each registration lasts three years. Registering an exemption does not remove the need to apply for other permits or permissions (for example, land use planning permission or water discharge permit). An exemption will typically specify the types and quantities of waste to which it can be applied, and the types of activities that are allowed – these can relate to use, treatment, storage or disposal. Specific exemptions relevant to CDW include:

Exemption U1 (Use of Waste in Construction) allows for activities such as using crushed bricks, concrete, rocks and aggregate to create a noise bund around a new development and then using soil to landscape the area, using road planings and rubble to build a track, path or bridleway, using woodchip to construct a track, path or bridleway, and bringing in soil from somewhere else to use in landscaping at housing developments. Quantity restrictions vary depending on the type of waste and activity planned.

Exemption T7 (Treatment of waste bricks, tiles and concrete by crushing, grinding or reducing in size) allows for the small-scale crushing of inert CDW, but only in quantities less than 20 tonnes per hour and with no more than 200 tonnes of waste stored on site.

Prevention of Dumping

Fly tipping is the illegal deposit of waste on land contrary to Section 33(1)(a) of the Environmental Protection Act 1990. The types of waste fly tipped range from ‘black bag’ waste to large deposits of materials such as industrial waste, tyres, construction material and liquid waste.

Local councils and the Environment Agency (EA) both have a responsibility in respect of illegally deposited waste. Local councils deal with most cases of fly tipping on public land, whilst the EA investigates and enforces against the larger, more serious and organised illegal waste crimes.

Local Authorities


Household waste accounted for 66 per cent, ‘small van load’ size was 31 per cent and 48 per cent of fly-tips were on highways.

There was a 5.6 per cent increase in fly-tipping incidents in England in 2014/15 compared to 2013/14 with upward trends in most incident size categories. Single bag incidents were the only size category not to see an increase in incidents.

The estimated cost of clearance of fly-tipping to local authorities in England in 2014/15...
was nearly £50 million, nearly 11 per cent higher compared to 2013/14.

Approximately 5% of fly-tipping dealt with by local authorities related to construction waste.

Local authorities carried out 1,810 prosecutions for fly-tipping offences in England in 2014/15, down by 9.6% from 2,002 in 2013/14.

Over 98% of fly-tipping prosecutions in England in 2014/15 resulted in a conviction. The vast majority (82%) resulted in a fine. Other outcomes included conditional discharge, community service and 21 instances of custodial sentences.

Environment Agency

The Environment Agency is responsible for dealing with large-scale, serious and organised illegal dumping incidents which pose an immediate threat to human health or the environment.

In 2013/14 the Environment Agency dealt with 151 incidents of large-scale illegal dumping of waste in England; 34 of these involved construction waste (Department for Environment, Food & Rural Affairs, 2015).

### 3.3 Economic Instruments

**Taxes**

The Aggregates Levy is a UK tax on the commercial exploitation of rock, sand and gravel. It was introduced as an environmental tax in 2002 to encourage the recycling of aggregate. The Aggregates Levy is charged at a flat rate of £2 for every tonne of aggregate extracted. Recycled aggregates made from construction waste and certain secondary aggregates made from by-products of industrial processes are exempt from the Aggregates Levy.

A Landfill Tax was introduced in 1996 as a key mechanism in enabling the UK to meet its targets set out in the Landfill Directive for the landfilling of biodegradable waste. The rate of Landfill Tax has gradually been increased over time (HM Revenue & Customs, 2015).

The amount of Landfill Tax levied is calculated according to the weight of the material disposed of and whether it is active or inactive waste. Inactive waste covers most materials used in a buildings fabric as well as earth excavated for foundations. Most forms of concrete, brick, glass, soil, clay and gravel are classified as inactive. Active waste covers all other forms of waste such as wood, ductwork, piping and plastics. The current rates of Landfill Tax (in 2016) are:

- Lower rate (inactive waste): £2.65 per tonne
- Standard rate (active waste): £84.40 per tonne

**Subsidies**

UK Government does not provide subsidies to operators of CDW processing facilities or to users of recycled construction materials.

### 3.4 Other Relevant Information

**Specifications**

UK construction industry clients have promulgated a range of specifications which permit the use of recycled materials in construction. In general, specifications tend to be based on the performance rather than the source of material, and hence do not explicitly require or preclude the use of recycled materials. Examples of specifications which permit the use of recycled materials include the following:

**Specification for Highway Works**

Highways Agency’s Specifications for Highway Works (SHW) sets out the standards required for materials used in constructing and maintaining the UK’s strategic road network. These specifications are also widely adopted by other infrastructure providers (for instance, local authorities and private developers). It is published as Volume 1 of the
Manual of Contract Documents for Highway Works (MCHW). Relevant sections relating to recycled materials include the following:

**Series 500: Drainage and Service Ducts**

The 500 series gives the requirements for pipes of different material types and aggregates used as pipe bedding, haunching and surround, trench backfill and filter drains. The use of recycled aggregate and recycled concrete aggregate is permitted provided that it complies with the requirements of the Specification. This includes the recycled aggregates being produced in accordance with the WRAP Quality Protocol for the production of aggregates from inert waste.

**Series 600: Earthworks**

The 600 Series describes the acceptable materials to be used in earthworks which include recycled and secondary materials and specifies the tests that need to be carried out on them. No more than 1% of contaminants, such as wood, plastic and metal are allowed in recycled materials. Recycled aggregates must be produced in accordance with the WRAP Quality Protocol for the production of aggregates from inert waste.

The 600 Series also sets out the requirements for other techniques that can be used to increase resource efficiency in earthworks, such as stabilisation with lime and/or cement, use of geosynthetics, soil reinforcement, ground improvement and foundation drainage.

**Series 700: Road Pavements - General**

SHW Series 700 sets out the pavement layer thicknesses and tolerances. It also includes the testing methodology for the constituent materials in recycled aggregates.

**Series 800: Road Pavements - Unbound, Cement and Other Hydraulically Bound Mixtures**

SHW Series 800 prescribes the type of material suitable for the sub-base layers and the testing that is required. This includes the types and proportions of recycled and secondary aggregate allowed and covers both unbound and hydraulically bound mixtures (HBM).

Unbound mixtures are classed as Type 1, Type 2, Type 3, Category B and Type 4 unbound mixtures. The SHW states that Type 1 and Type 2 sub-base can have up to 100% recycled and secondary aggregate content. This includes the use of up to 100% of Recycled Asphalt Planings (RAP) in Type 4 and up to 50% recycled asphalt content in Type 1 and Type 2. Up to 25% of glass and 1% content of other materials such as plastic and wood is allowed in Types 1, 2 and 4.

Type 3 sub-base is open-graded and so the use of recycled asphalt is restricted to less than 5%. Not more than 1% of glass and wood is allowed. Type 4 is specifically for mixtures consisting of asphalt arisings.

HBM include cement bound granular mixtures (CBGM), fly ash bound mixtures (FABM), slag bound mixtures (SBM) and hydraulic road binder bound mixtures. Recycled and secondary materials can be used as aggregates and binders in HBMs. HBM allow the production of sub-base with higher stiffness than unbound sub-base mixtures, and this can be taken into account in the pavement design.

**Series 900: Road Pavements - Bituminous Bound Materials**

SHW Series 900 describes the material requirements for bituminous surface, binder and base courses. The SHW allows reclaimed asphalt to be used in the production of bituminous surface course, binder course, regulating course and base. Secondary aggregate produced from china clay production and slate aggregate is allowed and blastfurnace and steel slag are permitted subject to requirements on their soundness. In situ cold recycled bitumen bound material is included in clause 947, ex situ cold recycled bound material in clause 948 and in situ recycling: the repave process in clause 926.

**Series 1000: Road Pavements - Concrete Materials**
SHW Series 1000 describes the requirements for cement bound pavements. Recycled materials which can be used include recycled aggregate, crushed concrete, blast furnace slag and pulverised fuel ash. All materials need to meet the requirements specified and the origin and history of any recycled coarse aggregate or recycled concrete aggregate used needs to be known.

Series 1100: Kerbs, Footways and Paved areas

SHW Series 1100 describes the requirements for kerbs, footways and paved areas. It refers to the relevant clauses for pavement materials.

Concrete Specifications

Recycled aggregate is derived from crushing inert construction and demolition waste. It may be classified as recycled concrete aggregate (RCA) when consisting primarily of crushed concrete or more general recycled aggregate (RA) when it contains substantial quantities of materials other than crushed concrete. Currently, only the use of coarse aggregate derived from construction or demolition waste is recommended for use in new concrete construction in the UK.

RCA is not the same as reclaimed or recovered aggregate, where these materials are obtained from either the fresh or hardened ready-mixed concrete returned to the concrete producer.

The British/European harmonised product standard, BS EN 12620, for Aggregates for concrete, makes no distinction, in terms of properties covered, between natural, manufactured or recycled materials and mixtures of these aggregates. The British Standard for Concrete, BS 8500 (the complementary UK Standard to BS EN 206-1 and in effect a ‘national Code of Practice’ for concrete) applies product-specific and specification-specific conditions on the use of recycled aggregates in new concrete construction.

RCA conforming to the requirements of BS 8500-2 can be used in both Designated and Designed concretes. In Designated concretes RC25 to RC50, a maximum of 20% of the natural coarse aggregate can automatically be replaced by RCA. For Designated GEN concrete or Designed concrete there are no general restrictions in the standard on the proportion of RCA, as long as any aggregate durability criteria (e.g. frost resistance) are satisfied. RCA can be used in concretes of strength classes up to C 40/50 and in most exposure classes, except exposure to salt (XS, XD), severe freeze-thaw (XF2 - XF4) or aggressive ground more severe than DC-1.

As the potential composition of RA is so wide the additional specification requirements should be assessed on a case-by-case basis taking into account the specific composition of the RA.

For highways work, Highways England’s Design Manual for Roads and Bridges (DMRB) includes specific guidance on the use of RCA in structural concrete, in the form of advice note BA92/07 (Highways Agency, 2007). RCA can be considered as a partial replacement for natural resources on larger projects where a large volume of structural concrete is used. The only type of RCA allowed by the DMRB is high quality material comprising of mainly crushed concrete. Only 10% brick by weight and low levels of impurities are allowed. There should be less than 1.5% by weight of other materials such as wood, asphalt, glass, plastics, and metals. Exposed concrete should contain less than 0.5% asphalt, masonry can be up to 9.5% and lightweight material (floating stony materials only) less than 1000 kg/m3 should also be < 0.1%. Any use of RCA and its specification will require submission and approval through the Highways Agency’s departures process, as part of the technical approval process for structures (Highways Agency, 2007).

The UK concrete industry reports that in 2013, recycled and secondary aggregates accounted for 6.9% of total concrete aggregates (Sustainable Concrete Forum, 2014).

| CDW Management Facilities | CDW management facilities are provided entirely by the private sector and are operated on a fully commercial basis.  
A market study has identified around 530 static sites in the country with an aggregates |
recycling plant. Together, these plants produced around 37 million tonnes of recycled aggregates in 2011. Around a quarter of static recycling sites are located in South East England, which also contains many of the higher-volume plants. Nationally, there are 16 plants that produce more than 200,000 tonnes a year. The study identified the top five recycled aggregates companies as Tarmac, Lafarge, Day & Sons, Aggregate Industries and Frimstone. Although these are well established companies in this sector, they represent less than 15% of the market. Taking the top 10 recycled aggregates companies in total, the report estimates that these represent just over 20% of the market. The study has identified around 400 companies in the sector as a whole (Frimstone Ltd, 2016).

**Client Requirements**

**Award Schemes**

There are a number of voluntary assessment schemes which offer incentives for developers and infrastructure providers to recover construction waste. These include:

**BREEAM**

BREEAM is the Building Research Establishment’s Environmental Assessment Method, an environmental assessment method for buildings. It has specific issues related to CDW waste which include requirements to have a waste management plan, set waste reduction targets and divert waste from landfill.

**CEEQUAL**

CEEQUAL is the international evidence-based sustainability assessment, rating and awards scheme for civil engineering, infrastructure, landscaping and works in public spaces. CEEQUAL has a section on physical resources use and management which includes questions covering waste such as: minimising material use and waste; responsible sourcing of materials; using re-used and/or recycled materials; durability and maintenance; future de-construction or disassembly; design for waste minimisation; waste from site preparation; policies and targets for resource efficiency; and onsite waste management.

**SKA rating**

Led and owned by RICS (Royal Institution of Chartered Surveyors), SKA rating is an environmental assessment method, benchmark and standard for commercial fit-outs which assesses fit-out projects against a set of sustainability good-practice measures. Waste is one of the 8 sustainability areas covered by SKA rating and includes measures such as reducing waste sent to landfill, designing out waste, increase recycling of construction & demolition waste, and preparing a Site Waste Management Plan.

**Client Requirements**

Clients frequently set targets for CDW recycling in construction contracts.

Crossrail is a wholly-owned government company responsible for Europe’s largest construction project, a new rail link (much of it in tunnel) across London, with a budget of £14.8 billion. Crossrail’s Environmental Objectives for 2015-16 include: “Implementing the waste hierarchy by achieving 90% (or greater) reuse or recycling of our construction and demolition waste and 95% (or greater) reuse or recycling of our clean excavated material and achieving at least 15% of the total value of our construction materials from reused or recycled content” (Crossrail, not dated).

Heathrow is the largest airport in the UK and one of the largest in the world. Heathrow has a target of recycling 90% of CDW by 2020, which they are already achieving with a recycling rate of 98% in 2013 and 2014 (LHR Airports Ltd, not dated).

**Contractor Targets**

Recognising that improved sustainability performance increases their chance of winning work, UK construction contractors often set their own targets for recycling construction waste and report on their performance. For example:

BAM Construct UK (annual turnover £887M) has set a target to achieve zero non-hazardous waste to landfill. The proportion of all waste diverted away from landfill in 2014...
stands at 91%, compared to 80% in 2010 (Royal BAM Group, not dated).

Costain (annual turnover £1.1 billion) has a target of reducing the amount of waste generated and the amount of waste going to landfill. In 2013 the group generated 20.3 Mt of construction waste, of which 95% was diverted from landfill (Costain Group plc, not dated).

Carillion (annual turnover £4.1 billion) has a commitment to sending zero non-hazardous waste to landfill by 2015 and finding smart ways to reuse or restore materials, extending their lifecycle. In 2014, Carillion achieved their target to divert 95% of waste from landfill. Measures included collaborating with the supply chain, designing out waste and strengthening relationships with waste management specialists (Carillion plc, 2015).

WRAP and the Environment Agency have produced a series of “Quality Protocols”. A Quality Protocol sets out end-of-waste criteria for the production and use of a product from a specific waste type. Compliance with these criteria is considered sufficient to ensure that the fully recovered product may be used without undermining the effectiveness of the Waste Framework Directive and therefore without the need for waste management controls.

A Quality Protocol indicates how compliance should be demonstrated and points to good practice for the storage, transportation and handling of the fully recovered product. The Quality Protocol further aims to provide increased market confidence in the quality of products made from waste and so encourage greater recovery and recycling.

The Quality Protocol for Aggregates from Inert Waste sets out end of waste criteria for the production and use of aggregates from inert waste. If the criteria set out are met, the resulting outputs will normally be regarded as having been fully recovered and to have ceased to be waste (WRAP/Environment Agency, 2013).

The Quality Protocol has four main purposes:

- clarifying the point at which waste management controls are no longer required;
- providing users with confidence that the aggregate they purchase conforms to an approved industry specification defined in accordance with an appropriate European aggregate standard;
- providing users with confidence that the aggregate is suitable for a use within a designated market sector(s) including by conforming with the industry standard; and
- protecting human health and the environment (including soil).

In addition, the Quality Protocol describes acceptable good practice for the transportation, storage and handling of aggregate.

The use of a differential rate of landfill tax has encouraged the separation of inert from non-inert CDW, and the levy on virgin aggregates has incentivised the use of recycled aggregate (Barritt, 2015). The processing of these hard inert CDW into aggregates has
been the key to the UK achieving 90% recovery of CDW and 27% market share of recycled and secondary aggregates (Barritt, 2015). The development of quality protocols and specifications allowing use of recycled aggregates allows these materials to be used with confidence.

The UK construction industry set a voluntary target of achieving “by 2012, a 50% reduction of construction, demolition and exaction (CD&E) waste to landfill compared to 2008”. This target excludes aggregates used for backfilling quarries, site restoration or legitimately spread on exempt sites”. In 2012, the amount of CD&E waste landfilled was 119 tonnes/£ million construction output against the target of 66.5 tonnes of CD&E waste landfilled/£million construction output; in 2011 it was 140 tonnes/£ million construction output. The 2012 target therefore has not been met, largely due to the rise in excavation waste (soils) landfilled. Despite this, achievements over the period included (Green Construction Board, 2014):

- 29% reduction in the amount of C&D waste landfilled
- Proportion of CD&E waste landfilled that is hazardous has decreased to 5%
- Total amount of CD&E waste entering waste facilities (rather than landfills) has increased by 12%
- Amount of mixed C&D waste entering both landfill and waste facilities has decreased substantially
- The amount of CD&E waste landfilled from waste facilities has decreased by 21%

Lessons learnt as part of this voluntary commitment are reported to be (Green Construction Board, 2014):

- Excavation waste – excavation waste should not have been included in the 2012 target and instead considered separately, as there are distinct drivers for its arising and management.
- The importance of data – By developing a robust measurement methodology, there is now greater clarity on what waste is landfilled, the role of waste facilities, the effect of Government policies and which types of waste should be a priority.
- Supply chain focus – a key challenge is the lack of communication and collaboration across the supply chain. However, where there is better dialogue and understanding, improvements can still be made.
- Enlighten clients – When clients are involved, major improvements in material resource efficiency can be achieved. Engagements with clients’ needs to focus on the business case i.e. the savings and efficiencies gained through diverting waste from landfill and reducing the amount of waste produced.
- Design requirements – it is imperative to engage with designers for better material resource efficiency outcomes.
4 Hong Kong

4.1 Background

Responsibilities

Historically, Hong Kong has made use of construction waste as fill material, to reclaim land from the sea for construction. Material used in this way is referred to as “public fill”, and the Public Fill Committee of the Civil Engineering and Development Department (CEDD) is responsible for implementing measures to promote avoidance, minimization, re-use and recycling of construction and demolition material. It also oversees the management of public filling operations and facilities. The Fill Management Division of CEDD is mainly responsible for formulation and management of the overall public fill strategy as well as marine mud disposal and marine fill supply strategy, including management of public fill reception facilities, construction waste sorting facilities and mud disposal facilities (Civil Engineering and Development Department, 2014).

All public works projects are required to implement waste management, with proper presorting on site to separate construction wastes into severable categories for proper disposal to the appropriate disposal facilities and recyclable materials to the recycler for processing.

For public projects, the project office is required to draw up a Construction and Demolition Materials Management Plan at the feasibility study or preliminary design stage for each project, which generates more than 50,000 m$^3$ of C&D material including rock or that requiring imported fill in excess of 50,000 m$^3$. When the public works project goes on to the construction stage, the contractor is required to prepare a Waste Management Plan (WMP). The WMP provides an overall framework for waste management and reduction. It identifies major waste types and defines ways for waste reduction.

Hong Kong’s Environmental Protection Department (EPD) is responsible for implementing environmental policy and for enforcing environmental laws and regulations. EPD administers the Construction Waste Charging Scheme and is responsible for the operation of Hong Kong’s landfills and other waste management facilities (with of construction waste sorting and disposal facilities which are the responsibility of CEDD) (Environmental Protection Department, 2005).

Construction Waste Statistics

Statistics on waste management in Hong Kong are presented in the annual report “Monitoring of Solid Waste in Hong Kong”, the most recent edition of which covers 2014 (Environmental Protection Department, 2015).

The total quantity of CDW generated in 2014 is reported to be 57,547 tonnes per day (tpd), equivalent to 21 Mt per annum, of which 34,400 tpd (60%) was received at public fill reception facilities; 3,942 tpd (7%) was transferred to landfill, and 19,205 tpd (33%) was transferred directly to projects for reuse. This represents a recovery rate of 93%.

The quantities of CDW generated over recent years are as follows (all figures in Mt) (Environmental Protection Department, 2015):

<table>
<thead>
<tr>
<th>Year</th>
<th>Total CEDW Waste</th>
<th>Disposed of at landfills</th>
<th>Received at public fill reception facilities</th>
<th>Transferred to other projects for direct reuse</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>14.2</td>
<td>2.4</td>
<td>8.1</td>
<td>3.7</td>
</tr>
<tr>
<td>2006</td>
<td>10.9</td>
<td>1.5</td>
<td>6.5</td>
<td>2.9</td>
</tr>
<tr>
<td>2007</td>
<td>8.4</td>
<td>1.2</td>
<td>6.5</td>
<td>0.7</td>
</tr>
<tr>
<td>2008</td>
<td>9.0</td>
<td>1.1</td>
<td>7.0</td>
<td>0.9</td>
</tr>
<tr>
<td>2009</td>
<td>15.4</td>
<td>1.1</td>
<td>6.9</td>
<td>7.4</td>
</tr>
</tbody>
</table>
Hong Kong’s Annual Digest of Statistics (Census and Statistics Department, 2015) reports a mid-year population of 7,241,700 million in 2014, giving a per capita CDW generation rate of 2.89 tonnes/person/year.

### 4.2 Legislation

#### General

The primary legislation governing waste management in Hong Kong is the Waste Disposal Ordinance (Cap.354) (Waste Disposal Ordinance, 1997) which provides for the licensing of collection services and disposal facilities for waste, the prohibition of livestock keeping in urban areas, the control on livestock keeping in restriction areas, the control on discharge or deposit of livestock waste in designated control areas, the control scheme on chemical waste, the control on illegal dumping of waste, the control on import and export of waste and for the establishment of a system whereby disposal of specified wastes must be notified to the relevant authority who may give directions as to the method of disposal.

In the case of construction waste, additional subsidiary legislation under the Waste Disposal Ordinance has been enacted under the "Waste Disposal (Charges for Disposal of Construction Waste) Regulation" (Cap. 354N) which sets out the regulations governing the charging scheme for construction waste disposal, and the Disposal (Designated Waste Disposal Facility) (Amendment) Regulation (Cap. 354L) which designates the facilities to be used for construction waste disposal and the procedures for delivering waste to those facilities.

#### Waste Facilities

Under the Environmental Impact Assessment Ordinance (Cap. 499) (EIAO), an Environmental Permit is required for construction waste management facilities:

(a) with a designed capacity of not less than 500 tonnes per day; and

(b) a boundary of which is less than 200 m from an existing or planned:

- residential area;
- place of worship;
- educational institution; or
- health care institution.

The strategic landfills and main processing facilities used for CDW management in Hong Kong are permitted under the EIAO.

#### Prevention of Dumping

In addition to disposal of CDW at waste management facilities, land filling activities often takes places in rural area for purposes of filling up ponds; leveling off uneven ground surfaces; and forming site for development e.g. landscaping, roads, village houses, car parks or recreation facilities. Land filling can be illegal if it takes places on land without proper authorization of the Government authorities or consent from the land owners/occupiers. Fly tipping refers to the uncoordinated illegal deposition of CDW (and other wastes).

In order to minimise environmental impacts caused by the use of CDW for land filling activities in suburban and rural areas of Hong Kong, specific controls on such activities have been introduced.

Deposition of CDW over an area of more than 20m², even for the purposes of landfilling or construction, requires both written consent of the landowner and prior authorisation from EPD (using a dedicated form EPD-238).

EPD has issued guidance to land owners considering using CDW for land filling operations.
advising them as follows:

- Understand clearly the impact of land filling activities to the surrounding environment. In general, land owners and developers are advised to avoid using construction waste for land filling.
- If construction waste is to be deposited and the total deposition area of construction waste within the lot exceeds 20 m², land owners are required to ensure that:
  - All land owners have given written permission on the depositing activity through the form EPD-238;
  - A duly completed and signed notification form EPD-238 has been submitted to the EPD at least 21 calendar days before the commencement of the depositing activity;
  - The acknowledgement from EPD on the notification form EPD-238 has been obtained;
  - A copy of Parts C and D of the acknowledged form has been securely displayed in a conspicuous place on the lot at all time during the depositing activity.

The fill supplier should be required to confirm the quality and source of the fill. Only uncontaminated inert fill materials can be considered for use.

Land owners are advised never to accept fill from unknown or suspicious source, otherwise they may be liable to legal action and potential clean-up costs.

**Offences and Penalties**

EPD Circular Memorandum 01/2009 sets out the framework for controlling deposition of construction and demolition material on public and private lands, and the procedures for enforcement.

Under the Town Planning Ordinance, a person commits an offence if he undertakes an unauthorized development in the rural New Territories within the Development Permission Area. Any filling of land/pond within the conservation and Agriculture zones (even for undertaking a development which is a permitted use) without the planning permission from the Town Planning Board (TPB) would constitute an unauthorized development. Any land owner whose land is involved in the unauthorized filling of land/pond; or any person responsible for such operation may be subject to prosecution. An offender is liable to a fine of $500,000 for the first conviction; and a fine of $1,000,000 for subsequent convictions.

Under the Waste Disposal Ordinance, a person commits an offence if he deposits or causes or permits to be deposited waste in any place except with lawful authority or excuse, or except with the permission of any owner or lawful occupier of the place. If the total deposition area of construction waste within a private lot exceeds 20 m², it is an offence to deposit construction waste on the lot without EPD’s acknowledgement of prior notification on the deposition together with written permission from all owners of the lot. An offender is liable to a fine of $200,000 and imprisonment for 6 months. In addition, the depositor is liable to a fine of $100,000 if he does not display a copy of the EPD’s acknowledgement in a conspicuous place on the lot at all time during the deposition.

Action against illegal land filling and fly tipping may also be taken under a range of other Ordinances, including the:

- Public Health and Municipal Services Ordinance (Cap.132), which has provisions to deal with sanitary nuisance and require removal of litter or waste from any place.
- Public Cleansing and Prevention of Nuisances Regulation (Cap.132BK), under the registered owner or hirer of the specified vehicle at the time when a littering offence is committed shall be guilty of an offence.
- Land (Miscellaneous Provisions) Ordinance (Cap. 28), under which deposition of CDW may be deemed as illegal occupation of land.
- Buildings Ordinance (Cap. 123), since if land filling activities are undertaken for the purpose of or are associated with building construction works, they are regarded as building works requiring prior approval from the Building Authority.
Enforcement

In order to control and curb land filling and fly-tipping activities in Hong Kong, the Environmental Compliance Division of EPD has taken actions in a number of areas:

1) Enforcement Action

Each of the four Regional Offices of the Environmental Compliance Division has maintained a list of land filling sites and fly-tipping black-spots within its own area. Enforcement teams conduct regular patrol and ambush operations at these locations. Any culprit apprehended may be subject to prosecution under the Waste Disposal Ordinance (Waste), Cap 354.

2) Intelligence and Information Gathering

EPD regularly update the list of land filling sites and fly-tipping black-spots through exchange of information with various government departments, such as the District Office, District Lands Office, Police, Food & Environmental Hygiene Department, Housing Department etc. Reports and complaints from the public are also essential sources of information for the enforcement efforts.

3) Publicity and Education

EPD seek assistance from the public via a series of publicity and education campaigns to, firstly not to partake in any land filling and fly-tipping acts; and secondly report any land filling and fly-tipping acts to the authority. EPD has published a number of leaflets and posters to convey these messages to the public.

4) Partnership Programmes

In addition to the publicity campaigns, the Environmental Compliance Division has also launched a Property Management Partnership Programme and a Construction Industry Partnership Programme with the property management sector and the construction industry, a major part of which involves management of construction waste generated at housing estates and construction sites / projects.

5) Demolition and Renovation Waste

EPD has taken a pro-active role in visiting new housing developments and reminding management companies of the potential construction waste disposal problems arising from renovation works.

6) Other Preventive Measures Against Land filling and Fly-tipping of Construction Waste

In cooperation with other government departments, EPD has implemented other preventive measures against land filling and fly-tipping of construction waste at known black-spots and problem areas. This has included CCTV surveillance at serious fly-tipping black spots, such as at remote locations or access roads leading to landfills.

4.3 Economic Instruments

Taxes and Charges

In 2005 Hong Kong Government introduced a charging scheme for the disposal of CDW – prior to this time disposal of waste to either public fill banks or landfill was at no charge to the waste producer. Government levies the following charges for use of designated construction waste management facilities. These facilities are generally Government-owned, but are built and operated by the private sector under contract to Government.

<table>
<thead>
<tr>
<th>Government waste disposal facilities</th>
<th>Type of construction waste accepted</th>
<th>Charge per tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public fill reception facilities</td>
<td>Consisting entirely of inert construction waste**</td>
<td>HK$27</td>
</tr>
</tbody>
</table>
Sorting facilities | Containing more than 50% by weight of inert construction waste** | HK$100

Landfills® | Containing not more than 50% by weight of inert construction waste** | HK$125

Outlying Islands Transfer Facilities® | Containing any percentage of inert construction waste** | HK$125

++ Inert construction waste means rock, rubble, boulder, earth, soil, sand, concrete, asphalt, brick, tile, masonry or used bentonite.

@ If a load of waste contains construction waste and other waste, that load will be regarded as consisting entirely of construction waste for the purpose of calculating the applicable charge.

The main provisions of the construction waste charging scheme are as follows (Environmental Protection Department, 2015):

The Charging Regulation sets the construction waste disposal charges at $125 per tonne at landfills, $100 per tonne at sorting facilities and $27 per tonne at public fill reception facilities in order to fully recover the capital and recurrent costs of the facilities according to the polluter pays principle.

Under the charging scheme, a main contractor who undertakes construction work with a value of $1 million or above is required to make an application within 21 days after being awarded the contract to establish a billing account. Upon the establishment of the billing account, the main contractor is required to use the account to pay any disposal charges payable in respect of the construction waste generated from construction work undertaken under that contract. A billing account established solely for a construction contract with a value of $1 million or above cannot be used to settle charges arising from other contracts. In addition, to lower the administration costs of managing multiple billing accounts by small and medium contractors, under the Regulation, a contractor may establish one billing account to cover several contracts with a value of less than $1 million each.

According to charging scheme, an account-holder is required to pay to all charges payable within 45 days from the day of the notice of demand. If an account-holder fails to make payment as required within 45 days, he is liable to pay a 5% surcharge. If the account-holder fails to pay the unpaid charges and the surcharge within 14 days, Government may suspend the account in question. Upon the suspension of the account, the Government is required to issue a final notice to the account-holder. If the account-holder fails to pay the unpaid charges and the surcharge within 14 days of the final notice, the Government may revoke the account.

When delivering a load of waste to a designated waste disposal facility, the waste hauler appointed by the account-holder is required to produce a valid "chit". The account-holder is required to pay a deposit when he applies to the Government for such chits and the deposit varies according to the amount of usage. To minimize the financial impact on the trade, a two-tier system is adopted. Under this two-tier system, the deposit for the disposal of construction waste generated from a contract with a value of $1 million or above is charged at a minimum of $15,000 for 200 chits. If additional chits are required, additional deposit on a pro-rata basis has to be paid. For a contract with a value of less than $1 million or other general uses, a deposit of $300 for each chit is required. This amount is determined on the most lenient assumption that all vehicle loads contain inert materials to be disposed of at public fill reception facilities charging at $27 per tonne.

In addition, the Government may, on his own initiative or at an account-holder's request, refund the deposit or part of it if the Government is satisfied that the deposit or that part is no longer required. In making such a decision, the DEP shall have regard to the factors that he considers relevant, including the amount of construction waste that the account-holder proposes to dispose of.
The Charging Regulation specifies the type of construction waste that may be accepted at the various designated waste disposal facilities. If the construction waste delivered by a waste hauler to a designated waste disposal facility is not of the type that may be accepted at that facility, that waste hauler will be turned away. Under these circumstances, to facilitate the waste hauler's delivery of the waste to the appropriate facility, the staff at the facility will give the waste hauler an entry refusal note (Rejection Advice), which will specify the reason for refusal and the appropriate designated waste disposal facility for the waste to be delivered to. When the waste hauler delivers the waste to the appropriate waste disposal facility, he will not be turned away again.

For the purpose of enforcing the requirements on inert construction waste content, determination of the inert content of waste is based on using a reference table based on the waste depth, the net weights and permitted gross vehicle weights of different types of vehicles.

According to the charging scheme, if a main contractor who undertakes construction work under a contract with a value of $1 million or above fails to apply to the Government for the establishment of a billing account within 21 days after being awarded the contract, he will commit an offence and is liable to a fine (maximum $50,000) and, in the case of a continuing offence, to a further daily fine of $1,000.

Hong Kong Government is currently reviewing the charging scheme with a view to increasing the extent to which the actual costs of operating the relevant facilities are recovered.

In a paper issued by the Legislative Council Panel on Environmental Affairs in late 2015 (Legislative Council Panel on Environmental Affairs, 2015), it was noted that the current disposal charges do not recover the full cost of operating the facilities, and hence propose to increase the charges to full cost-recovery level for landfill and public fill (HK$200/t and HK$71/t respectively), and 66% of full cost recovery for sorting facilities (HK$175/t). The reason for not targeting full cost recovery for sorting facilities (which would be HK$265/t) is that this would exceed landfill cost, and hence would incentivise landfilling rather than sorting of mixed CDW.

### Subsidies and Financial Support

The development of the EcoPark is one of the Government's initiatives to provide long-term land at affordable rent for the development of the recycling industry in Hong Kong with a view to encouraging investment in advanced technology and value-added recycling processes.

EcoPark comprises the following three parts:

(a) an administration building, roads and marine frontage;

(b) Phase 1 comprising six land lots (Lots 1 to 6) occupying a total area of 3.6 ha which were made available for leasing from December 2006; and

(c) Phase 2 comprising 10 land lots (Lots 7 to 16) occupying a total area of 9.8 ha which were made available for leasing in three stages between 2009 and 2012.

Lot 11 (10,000 m²) is currently let for HK$150,000 per month for construction and demolition materials/glass recycling, and has an annual throughput of approximately 40,000 tpa of CDW and 2,000 tpa of glass.

As noted above, a recent Government paper noted that the current CDW management facilities are effectively subsidised by Government since the charges levied under the construction waste charging scheme do not recover the full costs of providing and operating these facilities, although Government has signalled its intention to increase charges (Legislative Council Panel on Environmental Affairs, 2015).

### 4.4 Other Relevant Factors

**Specifications**

Several specifications have been promulgated to encourage the recycling of CDW, in the form of Works Branch Technical Circulars. These include:
WBTC 24/2004 - Specification Facilitating the Use of Concrete Paving Units Made of Recycled Aggregates

Promulgates a particular specification to facilitate the use of concrete paving units made of recycled aggregates for public works projects. The paving units can be used in road works and construction of pavement.

WBTC 12/2002 – Specifications Facilitating the Use of Recycled Aggregates

Promulgates the particular specifications to facilitate the use of recycled aggregates in concrete production, and construction of road sub-base in public works projects.

CDW Management Facilities

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hong Kong has a range of facilities for the management of CDW. The types of facilities are described below.</td>
<td></td>
</tr>
<tr>
<td>A Public Filling Area is a designated part of a development project that accepts public fill for reclamation purpose. Public fill stockpiling area is newly reclaimed land where public fill is stockpiled as surcharging material to accelerate the settlement process. After they have achieved the required settlement, the public fill will be removed and deposited in other reclamation. These filling areas/stockpiling areas have been depleted either due to public sentiment against reclamation or due to ecological reasons.</td>
<td></td>
</tr>
<tr>
<td>A Fill Bank is an area allocated for temporary stockpile of public fill for later use. There are two fill banks in Hong Kong, located at Tuen Mun Area 38 and Tseung Kwan O Area 137.</td>
<td></td>
</tr>
<tr>
<td>A Public Filling Barging Point is a strategically located public fill reception facility that utilizes barge transportation to transfer public fill. There are four public fill reception facilities in Hong Kong – one at each of the fill banks plus two additional reception facilities.</td>
<td></td>
</tr>
<tr>
<td>C&amp;D Recycling facility processes hard inert materials into recycled aggregates and granular materials for use in construction activities. There is a single government-owned C&amp;D recycling facility in Hong Kong, located at Tseung Kwan O fill bank</td>
<td></td>
</tr>
<tr>
<td>Construction Waste Sorting Facilities (C&amp;DWSF). Mixed construction waste containing more than 50% by weight of inert construction waste can be delivered to the sorting facilities. Public fill recovered will be disposed of at a fill bank while non-inert construction waste will be disposed of at landfills. This arrangement helps waste producers, particularly small construction sites that do not have enough space to carry out on-site sorting. There are two C&amp;DWSF in Hong Kong, located adjacent to the fill banks at Tuen Mun Area 38 and Tseung Kwan O Area 137.</td>
<td></td>
</tr>
<tr>
<td>Landfills. Mixed construction waste containing more than 50% by weight of inert construction waste can be disposed of at one of three strategic landfills.</td>
<td></td>
</tr>
<tr>
<td>Outlying Islands Transfer Facilities. There are seven outlying islands transfer facilities in Mui Wo, Peng Chau, Hei Ling Chau, Cheung Chau, Yung Shue Wan, Sok Kwu Wan and Ma Wan for delivering construction waste to West New Territories Landfill by container vessels.</td>
<td></td>
</tr>
<tr>
<td>The Government is currently using the inert materials from PFRF to produce G200 rocks for public works projects. However, up to the end of April 2013, only about 0.9 million tons of G200 rocks had been produced from the inert materials. A considerable amount of inert material was transported to adjacent cities in China such as Huizhou or Taishan for land reclamation (Lu, 2015).</td>
<td></td>
</tr>
<tr>
<td>The locations of CDW management facilities in Hong Kong are shown in the map below (Environmental Protection Department, 2009).</td>
<td></td>
</tr>
</tbody>
</table>
Client Requirements

Hong Kong Government is the largest construction client in Hong Kong. Requirements for public works projects are prescribed by Hong Kong Government’s Development Bureau, via a system of Technical Circulars. These often include specific provisions for inclusion into public works contracts. Circulars relating to construction waste include:

DEVB TCW 09/2011 - Enhanced Control Measures for Management of Public Fill. Applicable to projects generating more than 300,000m3 of surplus CDW or requiring more than 300,000m3 of imported fill. Project proponents are required to make annual forecasts of material supply and demand to Government, and to account for any significant variations in forecasts from preceding years.

DEVB TCW 02/2011 - Encouraging the Use of Recycled and other Green Materials in Public Works Projects. This sets out a comprehensive framework for the procurement of recycled and other green materials with a view to promoting their use in public works projects. It also streamlines the process for recyclers which manufacture recycled materials to collect construction and demolition (C&D) materials and introduces a recyclers’ list for C&D materials.

DEVB TCW 06/2010 - Trip Ticket System for Disposal of Construction & Demolition Materials. Promulgates the revised trip ticket system for public works contracts and supersedes ETWB TCW 31/2004 for new projects. Requires Public Fill Committee to designate disposal location for inert CDW, and describes arrangements for supervision of trip ticket system and standard clauses for incorporation into public works contracts.

ETWB TCW 19/2005 - Environmental Management on Construction Sites. Sets out the policy and procedures for managing CDW on sites.

ETWB TCW 31/2004 - Trip Ticket System for Disposal of Construction & Demolition Materials. Enhances the trip-ticket system for CDW management as originally set out in WBTC No. 21/2002, in particular requiring approval of the place for disposal is proposed by the Contractor.

WBTC - 04/1998 - Use of Public Fill in Reclamation and Earth Filling Projects. Promulgates policy requiring reclamation or earth filling projects with imported fill requirements of 300,000 m3 or more to consider using public fill (alternatively termed inert construction and demolition (C&D) material) for the Works.

WBTC 4/98A - Use of Public Fill in Reclamation and Earth Filling Projects. Supplements WBTC No. 4/98 to also require the project proponent to consider using public fill for surcharge mounds and utility zones.

WBTC 12/2000 - Fill Management. Sets out the terms of reference and membership composition of the Marine Fill Committee and Public Fill Committee. It also explains how fill
resources, construction and demolition material (C&DM), and dredged/excavated sediment disposal are managed.

CDW Management on Construction Sites

Under ETWB TCW 19/2005, contractors are required to prepare and implement an Environmental Management Plan (EMP) in all public works contracts, which comprises:

- the abatement of environmental nuisances on construction sites including air, noise and wastewater pollution;
- the reduction of construction and demolition (materials to be disposed of during the course of construction.
- Contractors are required to:
- complete an EMP;
- update the EMP periodically as specified;
- introduce an item into the agenda for the Site Safety and Environmental Management Committee (SSEMC) meeting and the Site Safety and Environmental Committee (SSEC) meeting for discussion on environmental issues of the Site;
- arrange and attend weekly environmental walk; and
- expand site-specific induction training and toolbox talks to cover environmental topics.

Contracts include payment for implementing environmental measures, including arranging and conducting on-site sorting of CDW.

As part of the EMP on waste management, the contractor should establish a mechanism to record the quantities of CDW generated each month and report the quantities to the client on a monthly basis, using the "Monthly Summary Waste Flow Table". In addition, the contractor should provide the estimated quantities of CDW that will be generated each year from the site, using the "Yearly Summary Waste Flow Table". The contractor shall also set up a disposal recording system as part of the EMP by adopting the trip-ticket system as stipulated in WBTC No. 31/2004, for ensuring the proper disposal of CDW to designated outlets.

The contractor should develop site-specific induction training and toolbox talks to cover waste management measures in particular on-site sorting of C&D materials to promote awareness of workers in handling, sorting, reuse and recycling of C&D materials.

### Technical Guidance

EPD has published guidance on its website aimed at the construction sector, giving advice on minimization, recycling and responsible management of CDW (Environmental Protection Department, 2009). This includes specific advice on:

- Planning for Waste Reduction
- Low Waste Construction Designs and Technologies
- Raw Material Management
- Waste Management
- Education and Training

The various Technical Circulars referenced above also include supporting technical information to assist contractors and clients in complying with regulations and achieving effective CDW management. CEDD has also issued guidance on selective demolition and on-site sorting of demolition waste (Public Fill Committee, 2004).

### 4.5 Discussion

A questionnaire and survey carried out in 2008 (3 years after introducing the construction waste disposal charging scheme, CWDCS) concluded that 40% of the survey respondents believed that waste reduction is less than 5% after CWDCS has been implemented. The interviewees agreed that the waste reduction rate was not significant. They expressed that some waste generation were unavoidable despite a waste disposal charge has been imposed. In addition, 30% of survey respondents agreed that the cost of CWDCS was not
high enough to raise the awareness on waste management on construction sites (Poon, et al., 2013).

A study to empirically compare construction waste management performance between public and private projects in Hong Kong used “big data” in the form of 2 million waste disposal records generated from around 5700 projects undertaken in Hong Kong during 2011 and 2012. It found that there is a notable performance disparity between the public and private sectors, with contractors performing better in managing both inert and non-inert waste in public projects than they do in private projects. Furthermore, the interviews and case studies conducted as part of the research suggest that transaction costs are not high enough to incentivize contractors to manage waste conscientiously and therefore other institutional arrangements, such as promoting the value of environment protection leadership, are critical for achieving superior performance (Lu, et al., 2016).

Lu and Tam carried out a longitudinal study of CDW management in Hong Kong, reviewing management practices and arisings data over time to see how they vary as the policy environment has changed. The study concluded that the policies which have been introduced have formed a relatively effective policy framework for regulating CDW in Hong Kong, and waste generated from producing every million dollars’ construction work has been significantly reduced to 20 tonne in recent years from 40 - 70 tonne during the period 2000 - 2005. However, despite contributing only around 3% to the GDP, the construction sector accounts for 25% of the waste disposed of to landfill in Hong Kong (Lu & Tam, 2013).

A review of on-site sorting of CDW in Hong Kong found that construction waste management regulations have significantly enhanced on-site CDW management practices. Site space and project stakeholders’ attitudes are still regarded as the most critical factors but labour and cost are no longer of major concerns in undertaking on-site CWS. Instead, a market for recyclables and an awareness of the profound environmental benefits are now perceived as being of major importance in these practices, together with the introduction of the construction waste charging scheme. Rather than designating a particular person to be responsible, all the workers are expected to separate and place generated construction waste appropriately in line with the waste management plan. Instead of being perceived as interrupting the construction process, waste sorting has been increasingly recognized as an integral part of regular construction activities in Hong Kong (Yuan, et al., 2013).

Lu characterises the Hong Kong CDW management system as operating under an inert/non-inert dichotomy, which has been relatively effective to date in reducing CDW disposal to landfill, but which has not stimulated a market in recycled construction materials, most inert material being used simply as bulk fill or stockpiled awaiting use (Lu, 2013).

Hong Kong Government considers that the construction waste charging scheme, which is intended to provide economic incentives for construction waste producers to reduce waste and to practise sorting, has caused the construction industry to adopt various construction waste reduction measures such as selective demolition, on-site sorting and reuse/recycling, modular building design and pre-casting of building components etc. As a result, the disposal of mixed construction waste at the landfills has declined substantially (Legislative Council Panel on Environmental Affairs, 2015).

This is supported by a study into off-site sorting of CDW (at Government’s construction waste sorting facilities), which concluded that the success of the off-site sorting program is mainly attributed to sustaining policy support from the Hong Kong government, good policy execution, encouraging off-site sorting through higher disposal charges and implementation of the trip-ticket system (Lu & Yuan, 2012). This study also noted that the ratio of construction waste disposed of at landfills to the total waste generated has decreased sharply from 0.77 in 1991 to 0.09 in 2010. Particularly, the ratio has decreased from 0.14 in 2006 to 0.09 in 2010. This demonstrates that an increasing proportion of inert materials has been separated from the mixed construction waste and sent to public fill reception facilities, which is partly due to the off-site sorting programme.

In order to reduce fly tipping, Government is exploring the potential of using automatic monitoring technology in construction waste collection vehicles to help track and log their activities. The tracking may also facilitate investigation when fly-tipping does happen. CEDD has launched in October 2015 a pilot trial to examine the technical feasibility and stakeholder acceptance of mandating the use of positioning technology for all construction...
waste collection vehicles (Legislative Council Panel on Environmental Affairs, 2015).

As of 2015, the two fill banks in Hong Kong are close to be fully occupied and will not be able to accept any more public fill starting from mid-2016 without first sparing some of the used stockpiling capacity. Government is aiming to expedite clearance of the stockpiled public fill so as to ensure that there is unused capacity in the fill banks to maintain their daily operation (Legislative Council Panel on Environmental Affairs, 2015).
5 Germany

5.1 Background

Responsibilities

The Federal German Republic is composed of 16 federal states (Bundesland / Länder) states with relatively broad powers and responsibilities over their regions. Three states (Bayern, Sachsen and Thuringern) are considered Freistaaten (Free States) and possess more autonomy. Another three states (Berlin, Hamburg, Bremen) are Stadtstaaten (city states) and combine the identities and responsibilities of a state and a municipality.

Generally, the Federal level of government establishes laws that the state must implement and administer at a local level (Weisleder and Nasseri, 2006). Where no federal legislation exists, each state can develop its own (EIONET, 2009).

At a Federal level, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB)) has responsibilities for protecting the public from environmental toxins and radiation and establishing the efficient use of raw materials. It has also taken actions on climate change and promoted the use of natural resources that conserve biodiversity and secure habitats. Since December 2013, the BMUB has also been responsible for creating the conditions for good housing standards and sustainable cities and with raising the quality of structural engineering, building technology and construction materials in Germany (BMUB, 2016a).

The Federal Environment Agency (Umwelt Bundesamt (UBA)) is Germany’s main environmental protection agency. UBA is responsible for the enforcement of environmental law and is tasked with ensuring that citizens have a healthy environment where they are protected against air, water and other pollutants to the greatest extent possible. UBA’s responsibilities include waste avoidance, waste management, sustainable production and products and climate protection (UBA, 2016a).

BMUB, in cooperation with UBA, is responsible for legislation on construction and demolition (C&D) waste at the national level. Responsibilities include the provision of technical guidance for waste disposal, setting of targets and transposition of European Union Directives (BioIntelligence Service, 2011).

There is no national Waste Management Plan in Germany and responsibility for the production of waste management plans lies with each state. The states can take part in a national waste prevention programme or choose to operate their own programme (Deloitte, 2014).

C&D waste management and recovery is well established in Germany, and many initiatives are in place at both a state and local level.

Construction Waste Statistics

C&D waste arising

In 2012, Germany produced approximately 201 million tonnes (Mt) of C&D waste including:

- 113.7 Mt (56%) of soil (including excavated soil from contaminated sites), stones and dredging soil.
- 52.2 Mt (26%) of concrete, bricks, tiles and ceramics.
- 18.1 Mt (36%) of bituminous mixtures, coal tar and tarred products.
- 7.9 Mt (16%) of metals (including their alloys).
- 4.1 Mt (8%) of wood, glass and plastic.
- 3.7 Mt (7%) of other C&D wastes.
- 0.98 Mt (2%) of insulation materials and asbestos-containing construction materials.
- 0.6 Mt (1.2%) of gypsum-based construction material.
- 8 Mt (4%) of C&D waste was classed as hazardous waste (Deloitte, 2014).

In 2009 C&D waste arising per capita was 2.33 tonnes. When compared to other countries (UK 1.66, Netherlands 1.47) this is considered high (BioIntelligence Service, 2011).

In Germany, the collection of waste data is decentralised, therefore the processing of such data is undertaken in cooperation with the states and federal statistical offices (BioIntelligence Service, 2011).

**C&D waste management**

The management of C&D waste in 2012 comprised (Deloitte, 2014):

- 82 Mt of mineral C&D waste (excluding soil and stones), of which 90% was recovered (68% was recycled and 28% underwent other treatment);
- 19.8 Mt of C&D waste (chapter 17 waste) was landfilled, of which
  - 56% was disposed of at inert landfills (Class 0);
  - 23% was disposed of in mineral waste landfills (Class 1);
  - 5% was hazardous waste disposed of at Class 3 landfills; and
  - 14% was municipal waste landfilled at Class 2 landfills.

57.2% (109.8 Mt) of C&D waste was soil and stones, of which 78% was used at opencast mines, 10% was recycled into building products and 12% was landfilled, giving an overall recovery rate of 88%;

27% (51.6 Mt) of C&D waste was demolition waste, of which 78% was recycled, 17% underwent other treatment and 5% was disposed of, giving an overall recovery rate of 95%;

8% (15.4 Mt) of C&D waste was road construction waste, of which 96% was recycled, 3% underwent other treatment and 1% was disposed of, giving an overall recovery rate of 99%.

Of the 58.9 kt of gypsum waste, 52% underwent other treatment and 48% was disposed of, giving an overall recovery rate of 52%;

8% of C&D waste was mixed / other construction waste (52% metal, 20% wood), of which 93% underwent treatment, 2% was recycled and 5% was disposed of giving an overall recovery rate of 95%.

**Recycled and secondary construction materials**

In 2012, Germany produced over 66.2 Mt of recycled aggregate, corresponding to 12% of the 550 million tonnes of demand. The recycled aggregate is produced from construction waste (40.4 Mt), road waste (14.8 Mt), soil and stones (10.7 Mt) and construction site waste (0.3 Mt).

### 5.2 Legislation

#### General

There are no current specific pieces of legislation that relate solely to CDW.

As part of the European Union, waste management in Germany is governed by a number of European regulations and directives, whereby the former automatically apply to each of the member states, while the latter must be separately transposed into national law by each member state. The basis of this legal framework is the Waste Framework Directive (2008/98/EC).


The WFD defines the main waste-related terms, lays down a five-step waste hierarchy, and contains key provisions for German waste disposal law. It provides a framework for moving
Article 4 introduces the five-step waste hierarchy, in which member states ‘shall apply as a priority order in waste prevention and management legislation and policy:

(a) prevention;
(b) preparing for re-use;
(c) recycling;
(d) other recovery, e.g. energy recovery; and
(e) disposal.’

Article 11.2 sets out targets for construction and demolition waste. It stipulates that ‘Member States shall take the necessary measures designed to achieve the following targets:

(b) by 2020, the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70 % by weight.’

In Germany, the WFD has been a key driver for national waste policies.

Germany’s first national waste disposal act was the Abfallbeseitigungsgesetz (AbfG), adopted in 1972.

Today, Germany’s main waste disposal statute is the Waste Management Act (Kreislaufwirtschaftsgesetz (KrWG), which came into force in 2012 and superseded the Kreislaufwirtschafts- und Abfallgesetz Act (KrW-/AbfG). The Waste Management Act (KrWG) implemented the requirements of the WFD and was intended to tighten the regulations on resource, climate and environmental protection (UBA, 2016b). This included:

− Definition of waste;
− Definition of by-product;
− Defining when ‘end of waste’ status has been achieved, and a waste is no longer subject to waste management controls;
− Implementation of the waste hierarchy;
− Requirements for a waste prevention programme;
− Setting a target for C&D waste recovery (of 70% of non-hazardous C&D waste by 2020); and
− Requirements for waste management planning.

Germany has fulfilled the 70% target for C&D waste re-use, recycling and other material recovery in the Waste Framework Directive.

The Commercial Waste Ordinance (Gewerbeabfallverordnung, GewAbfV), includes requirements for the separation and pre-treatment of wastes, including C&D waste. Producers and holders of C&D waste must hold, store, collect, transport and consign to recovery certain waste fractions (glass, plastic, metals, concrete, bricks, tiles), if they are produced separately. Germany also extended its target for recovery of mixed construction and demolition waste to 85%.

The Abfallverzeichnis-Verordnung (AVV) regulation classifies and lists all waste types and defines which types of waste are hazardous and non-hazardous. This classification then affects the way in which the waste should be handled, stored, transported, managed and disposed.

There is currently no nationwide regulation for the use of recycled and secondary building materials and this has resulted in different legislation at state level and a potentially significant barrier to reuse and recovery of C&D wastes. Currently the state based legal

Since 2006, Germany has been developing a national legal framework for groundwater, substitute building materials, landfill and soil protection (Mantelverordnung), which, once finalised, may overcome previous conflicts in the objectives of these four sustainability issues. The draft Mantelverordnung also includes the Substitute Building Materials Ordinance (Ersatzbaustoffverordnung) which, in its draft form, includes consideration of the end-of-waste status of recycled construction materials to achieve the highest quality of material.

There are no national bans on landfilling C&D waste (BioIntelligence Service, 2011), however the backfilling of C&D waste is permitted in some states, but the Substitute Building Materials Ordinance (draft) (Ersatzbaustoffverordnung) may not allow this in the future (Deloitte, 2014).

45 Prod. RC Act: Duty of public authorities to give preference to the use of recycled products, e.g. for use in construction projects.

Transboundary waste shipments

In Germany, transboundary waste shipments are subject to European Union regulations and the Basel Convention. In 2013 Germany exported 420kt of C&D waste, just over half was recovered, and the remainder was landfilled. Germany imported 962kt of C&D waste from Italy and Luxemburg of which just over half was recovered and the remainder was landfilled (Deloitte, 2014).

Waste Generation

In 2002, the German Government made a commitment to sustainability with the National Strategy for Sustainable Development, as the guiding principle behind its policy-making. As part of this Strategy, it resolved to double raw material productivity by 2020 compared with the base year 1994.

Waste Prevention Programme

The WFD reinforces the importance of waste prevention in EU waste legislation and obligates Member States to establish waste prevention programmes by 12 December 2013 (Article 29, para. 1).

In Germany, Article 33 of the Waste Management Act (KrWG) creates the statutory foundations for a waste prevention program as required by the WFD, and states that the Federation shall draw up a waste prevention programme, and the Federal States (Länder) may take part in the preparation thereof. As such, the German Government's Waste Prevention Programme was adopted by the Cabinet on 31 July 2013.

The Waste Prevention Programme sets out a systematic and comprehensive approach for preventing waste in the public sector, by recommending specific instruments and measures. At the same time, the Cabinet's resolution will open up a dialogue on waste prevention between the Federal Government, Länder, municipalities and other stakeholders.

Severing the link between the use of resources and economic growth is an important environmental policy goal. Because waste always originates from former raw materials and products, waste prevention can make a significant contribution to this objective. The aim of waste prevention is to decouple economic growth from the impacts on human health and the environment caused by waste production. The actions apply before a substance, material or product has to become waste and are:

- reducing the quantity of waste (for example by reusing products, designing minimal-waste products, and extending the life span of products);
- reducing the adverse impacts of waste; and
- reducing the content of harmful substances in materials and products.

The Waste Prevention Programme, in conjunction and coordination with the German Government's other existing strategies, will help to ensure the coherent, sustainable
handling of natural resources and raw materials in Germany.

### Waste Facilities

The states are in charge of local enforcement of C&D waste regulations and supervise the operation of waste management facilities. Waste management contractors are required to submit data on the origin, nature and treatment of the waste handled (BioIntelligence Service, 2011).

Companies that collect, transport, deal in, or act as middlemen in connection with waste are required to notify all transport operations involving non-hazardous waste, and obtain a permit for the transport of hazardous waste.

### Prevention of Dumping

It is reported that there are no major loopholes or many illegal practices in Germany. From time to time illegal dumping (e.g. in a forest) can occur, but this is in general seldom the case (Deloitte, 2015).

### 5.3 Economic Instruments

#### Taxes and Charges

Landfill taxes are in place but they differ between States. (Deloitte, 2014).

Typical waste disposal costs are:

- Bricks €8/tonne
- Mixtures of brick, concrete, tiles and ceramics €15 to 60/tonne
- Gypsum based construction materials €80/tonne
- Construction materials containing asbestos €80/tonne
- Mixed construction and demolition wastes €148/tonne

#### Subsidies and Financial Support

There are no subsidies or financial support that allows further promotion of recycled products (Deloitte, 2014).

### 5.4 Other Relevant Factors

#### Voluntary commitments

A voluntary commitment to halve waste to landfill by 2005 (equivalent to reaching 70% recovery) was initiated in 1996 by the German construction industry. The reference year was 1995 when 40% of construction and demolition was reused or recycled. The target was met in 2011 (BioIntelligence Service, 2011).

#### Specifications

Product stewardship is the basis of waste management policy in Germany. Producers and distributors of goods must design their products to ensure waste reduction and ease of recycling and recovery of materials (BioIntelligence Service, 2011).

Mandatory standards on construction materials used in road building and the construction sector (Technical delivery conditions for mineral materials in road construction and DIN standards) exist (BioIntelligence Service, 2011).

German guidelines state that under certain circumstances recycled aggregate can be used for up to 45% of the total aggregate, depending on the exposure class of the concrete (Concrete: DIN EN 206-1 and DIN 1045-2, recycled aggregates: DIN 4226-100)

The voluntary German Sustainable Building Certificate has a section relevant to C&D waste with a focus on waste prevention, design for dismantling and recycling of construction waste (BioIntelligence Service, 2011).

The Recycling Building Materials Guidelines is another voluntary guideline that ensures that recycled products function in the same way as a primary product (BioIntelligence Service, 2011).
The German Quality Assurance Association for Recycled Building Materials (BGRB) is a privately organised association with the goal to enhance the circular economy in the construction sector in Germany through high class and quality controlled material recycling. It introduced the so-called “RAL quality assurance” for different areas such as recycled construction materials and backfilling of quarries.

CDW Management Facilities

CDW management facilities are generally provided by the private sector and are operated on a fully commercial basis.

In 2007 around 250,000 people worked in the German waste management industry (BioIntelligence Service, 2011). Around 37,000 people worked specifically in the C&D waste recycling sector across collection, sorting, treatment and disposal (Deloitte, 2014).

A number of associations, trade unions and alliances for the sector are well established in Germany including:

- The German Building Materials Association (BBS)
- The Federation of the German Waste, Water and Raw Materials Management Industry (BDE)
- The German Quality Assurance Association for Recycled Building Materials (BGRB)
- The Office Federal Union of Recycling Building Materials (BRB) represents the interests of producers of recycled mineral building materials at national level.
- The German Construction Industry (Die Deutsche Bauindustrie) is the major federation of the construction industry in Germany.

Controlled demolition is often used in Germany, where contaminated material is removed before demolition. Other reusable components are removed and the remaining construction waste (bricks, wood, concrete) is sorted on site (BioIntelligence Service, 2011).

C&D plastic waste recycling is well developed. Within Germany, manufacturers of plastic construction products have formed associations to orchestrate recycling of their products. For example, in 1993, manufacturers of PVC floor coverings established the Association for PVC Floor Covering Recycling (AgPR) which provides recycling centres across the country. Post-consumer vinyl floor coverings can be dropped off at any recycling centre free of charge if they are clean and properly sorted. Similar associations have been developed for recycling vinyl windows and thermoplastic roofing membranes. A key factor in the development of any recycling industry is the presence of a steady supply of post-consumer material. To meet this need, the European-wide PVC recycling association RECOVINYL has been established by vinyl manufacturers and converters. RECOVINYL organizes international PVC waste collection efforts through a network of certified recyclers thereby increasing the reliability of the waste supply. Materials collected include pipes, window frames, vinyl siding and shutters (APPRICOD, 2004).

Client Requirements

Many municipalities specify recycled products in their calls for tenders but this is not a standard. Primary raw materials are abundant in Germany and are relatively cheap when compared to recycled products. Price often drives the decision making process (Deloitte, 2014).


Technical Guidance

There is no national legislative instrument governing the requirements for the recycling of mineral waste or for the use of recycled or spare building materials and laws are established at the State level. In most states these laws are based on note 20 of the Regional Working Group on Waste (LAGA M20, 2003), which sets out requirements for recycling of mineral residues/wastes.

The Bundesgütegemeinschaft Recycling-Baustoffe (www.recycling-bau.de) was founded in 1984 with the aim to promote the recycling economy in construction in Germany by implementing high-quality standards for recycled building materials. The RAL-Quality Assurance for recycled construction materials standards include:
− RAL-GZ 501/1 ‘Recycled Construction Materials’ (recycled aggregates)
− RAL-GZ 501/2 ‘Treatment for reuse of contaminated soil, building elements and mineral materials’
− RAL-GZ 501/3 ‘incinerator bottom ash’
− RAL-GZ 501/4 ‘Treatment of soil – not contaminated’
− RAL-GZ 501/5 ‘Recycled Construction Materials – mobile Treatment’
− RAL-GZ 506 ‘Backfilling and re-cultivating of quarries’

Guideline for Sustainable Building

In 2001, the Federal Building Ministry published a Guideline for Sustainable Building. The document was a practical aid for the planning, construction, structural maintenance, operation and utilisation of federally owned properties. This guideline was made obligatory for the Federal Government. The guideline has been revised several times to reflect developments in the market, legislation and sustainability issues. Latter versions of the guidelines also describe the methods and processes to implement the sustainability aspects in civil engineering. The guideline describes the targets which are to be adhered to for the planning of new building projects and building extensions in the regulations of the Federal Building Authority or the “Guidelines for the Realisation of Federal Building Measures”. The addition of “Use and Management” and “Building Inventory” have made the reworked guideline into a complex action manual for sustainable building. The guideline considers the entire life cycle of a building in the sense of DIN EN 15643-2 (Sustainability of Buildings – Evaluation of the Sustainability of Buildings: general conditions for the evaluation of environmental qualities).

The guideline requires the following aspects to be taken into account during all phases of the building’s life cycle:
− Save natural resources;
− Avoid waste;
− Correctly and safely recycle unavoidable waste; and
− Eliminate waste that cannot be recycled commensurate with the public good.

The following building-related resource saving aspects must be examined with a view to their implementation:
− Reuse of building parts or elements installed;
− Examination of the use of recycled building materials;
− Examination of the use of building materials/parts that can be recycled;
− Preference for low-waste structures thanks to the possibility of selective dismantling of materials; and
− Waste avoidance during construction work.

Guidelines for recycling

The federal government’s ‘Guidelines for Recycling’ (www.arbeitshilfen-recycling.de) describe the planning and execution of the measures necessary for handling building materials to be recycled as well as construction and demolition waste.

Kreislaufwirtschaft Bau (Circular Economy in Buildings) initiative (www.kreislaufwirtschaft-bau.de)

5.5 Discussion

The main drivers for sustainable CDW management in Germany are reported to be (Deloitte, 2015):
− Advanced practices and a well-established network: German CDW management practices are among the most advanced in Europe and the “Kreislaufwirtschaft Bau”
The initiative is a well-established network, which was setting waste reduction targets in its early days and is now monitoring and quantifying the overall waste arising and treatment.

- Responsibility of the public sector: public tenders that value recycled materials at least the same way as primary raw materials or even explicitly favour the use of recycled construction materials are an important driver for sustainable CDW management.
- Universally accepted certificates: certification schemes are identified as an important driver for sustainable CDW management.
- Norms: DIN and EN norms do not constitute any barriers for CDW recycling.

The same study also reports the following constraints to further enhancing CDW management in Germany (Deloitte 2015):

- Heterogeneous Legislation: the lack of a nationwide regulation for secondary building materials, which resulted in many different legislations on state level, is considered as one of the major barriers for sustainable CDW management by most of the market actors.
- Lack of economic incentives: primary raw materials are abundant in most of the regions in Germany and therefore relatively cheap when compared to recycled materials. Since no subsidies or other economic incentives exist that could drive the use of secondary materials, the choice to opt for primary materials is mostly price-related.
- Lack of enforcement: according to stakeholders, the human resources allocated to law enforcement, which happens most of the time at the local level, are insufficient. Sanctions are reportedly too low and are rarely applied.
- Lack of knowledge: according to stakeholders, many employees in the public sector do not have the required knowledge about the specific regulations which are relevant for the use of recycled CDW.
6 Denmark

6.1 Background

Responsibilities

Danish construction and demolition waste (CDW) legislation and regulations were previously the sole responsibility of the Ministry of the Environment (Miljøministeriet) and administered by the Danish Environmental Protection Agency (DEPA). Broad scale government reforms in June 2015 split the responsibility of managing wastes between the Ministry of Environment and Agriculture (Miljø- og Fødevareministeriet) and the Ministry of Energy, Utilities and Climate (Energi-, Forsynings- og Klimaministeriet).

The Ministry of Energy, Utilities and Climate was transferred new powers relating mainly to the requirements for the collection and treating of waste. These include the responsibility to oversee requirements for companies that collect waste, requirements for the design of waste registers for companies and waste facilities, authorization of facilities for the treatment of recyclable industrial waste, municipal waste fees, municipal organisations, facilities for waste disposal and facilities for incineration of waste, as well as accounting and benchmarking of incineration and landfill facilities (Danish Ministry of Energy, Utilities and Climate, 2016).

The Ministry of Environment and Agriculture is responsible for ensuring that waste is treated in an environmentally and economically appropriate manner.

DEPA and the Danish Energy Agency (DEA) now share the responsibilities for administering Danish construction waste legislation and regulations in line with their departmental responsibilities as detailed above.

In practical terms, the management of all wastes, including CDW are the responsibility of the 98 municipalities in Denmark.

Construction Waste Statistics

Danish waste statistics have been reported annually by DEPA with the most recent publicly available statistics from 2013. The statistics contain a detailed description of how much waste was generated in Denmark in a year by waste types and treatments.

CDW Generated

The CDW sector accounts for about 1/3 of the waste produced in Denmark with a waste generation in 2013 of approximately 3.6 million tonnes (excluding soil). If soil is included, then the amount is even higher, reaching approximately 9.7 million tons in 2013 (Danish Environmental Protection Authority, 2015).

Waste from construction activities is traditionally very dependent on the economic cycle. Growth in CDW excluding soil is often relative to the economic development of the construction sector. There has been a significant decline in the volume of waste from 2008 to 2011 because of the economic crisis starting in 2008. In the years 2011-2013, there has been some increase in the amount although economic activity has remained virtually unchanged from 2010 to 2013.

The volumes of generated construction and demolition waste combine up to 40 different waste types by European Waste Catalogue (EWC) codes that are strictly related to CDW. Waste asphalt and concrete make up by far the largest proportion with over 20 % of the total weight of CDW for 2013. Iron and steel waste, bricks, ballast from rail tracks, wood waste, asbestos waste and gypsum waste are also present in significant quantities in Danish CDW.

Significant quantities of mixed construction and demolition waste are present, in the form of approximately 300,000 tons of mixed concrete, bricks, tiles and ceramics and 400,000 to 500,000 tons of uncharacterised mixed CDW. Additionally, the construction sector also generates other types of waste than building waste such as household waste.
Construction waste in general may also be accounted for under other waste fractions for example landfill, wood, and plaster. Other waste fractions that include construction wastes are treated wood and PVC wastes.

The 2013 annual waste report identifies a significant decrease in waste generation of hazardous waste from 2011 to 2012. This decline in volumes, mostly seen in combination with recycling, however is mainly due to decrease in hazardous waste related to construction and demolition waste.

**CDW Treated / Recovered**

Traditionally, Denmark has had a high recycling rate of CDW. In the 1990s the percentage was up to 90% and increased further by 2000 to over 95%. There is often contaminated waste mixed in with CDW that is important to remove from the waste stream before it is recycled and reused.

In the last 15 years successive governments have given increased focus on getting hazardous substances out of construction waste, for example, PCBs and other contaminants in concrete. One consequence of the increased focus on removing environmental contaminants from CDW is some reduction in the rate of recycling. That is, the primary goal is to increase the quality of recycling rather than narrowly to increase the quantity. As a consequence, the current target recycling rate of construction and demolition waste recovery, excluding soil is set to at least 70%.

<table>
<thead>
<tr>
<th>Construction and Demolition Waste Treatments</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tons (,000)</td>
<td>%</td>
<td>Tons (,000)</td>
</tr>
<tr>
<td>Recycling</td>
<td>2,805</td>
<td>84%</td>
<td>2,929</td>
</tr>
<tr>
<td>Incineration</td>
<td>306</td>
<td>9%</td>
<td>257</td>
</tr>
<tr>
<td>Landfill</td>
<td>210</td>
<td>6%</td>
<td>228</td>
</tr>
<tr>
<td>Temporary storage</td>
<td>20</td>
<td>1%</td>
<td>6</td>
</tr>
<tr>
<td>Special treatment</td>
<td>3</td>
<td>0%</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>3,345</td>
<td>100%</td>
<td>3,423</td>
</tr>
</tbody>
</table>

The above table shows that the recycling of CDW (excluding soil) between 2011 and 2013 in Denmark was 84-86%, which is at a somewhat lower level than in the 2000's. Incineration and landfill are between approximately 6% to 9%.

A recent study on delivering the circular economy in Denmark estimated 10-15% of materials are wasted on construction sites through incidents such as over-ordering, inadequate storage, theft and poor coordination between stakeholders (Ellen MacArthur Foundation, 2015).

### 6.2 Legislation

#### General

As part of the European Union, Denmark is required to comply with EU Directives. Directives relevant to construction waste include:


The objective of the WFD is to provide a framework for moving towards a European recycling society with a high level of resource efficiency. Article 11.2 stipulates that "Member States shall take the necessary measures designed to achieve that by 2020 a minimum of 70% (by weight) of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the List of Wastes shall be prepared for re-use, recycled or undergo other material recovery" (including backfilling operations using waste to substitute other materials).

In Denmark, the requirements of the Waste Framework Directive are applied by the Waste Regulations 2012 (Affaldsbekendtgørelsen BEK nr 1309 af 18/12/2012) and the Residual
Product Regulations 2015 (Restproduktbekendtgørelsen BEK nr 1414 af 30/11/2015).

Environmental protections related to impacts from anyone who produces, stores, sorts or manages waste to ensure that there are no unhygienic conditions or emissions to air, water or soil are regulated through the Environmental Protection Act 2015 (Miljøbeskyttelsesloven LBK nr 1317 af 19/11/2015), in particular Chapter 6.

The Approvals Regulations 2015 (Godkendelsesbekendtgørelsen BEK nr 1447 af 02/12/2015) establishes the rules for the authorization scheme in the Environmental Protection Act Chapter 5 for listed activities, including the revaluation of listed enterprises.

The aforementioned regulations constitute the regulatory basis for the management of CDW in Denmark.

**Waste Generation**

A waste producer is defined as anyone whose activities produce waste (the original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change of this waste character or composition. (Waste regulations § 3). When related to the demolition or renovation of a building, in the first instance, it is the Developer who is considered as the waste producer. A craftsman or contractor may, under contract, take over responsibility for disposal of the waste generated in connection with the demolition or renovation of a building. In such an agreement, it is the craftsman or contractor that is considered waste producer. Thus the craftsman or contractor takes over the obligations incumbent upon a waste producer. If a tradesman or contractor is the waste producer, the waste is considered industrial waste, whether the waste comes for a private residence or not.

Waste generating companies must source separate their CDW from their operations in accordance with § 64 and § 65 of the Waste Regulations. This applies to natural stone, unglazed tiles and concrete, and mixtures thereof with the exception of mortar and possibly rebar which should be sorted out, including PCB-containing material, which must also be identified and discarded separately.

Double glazed windows must be sorted out and, if possible, reused, prepared for recycling or reuse. Double glazed windows, which are not suitable for re-use or recycling, for example, if they are contaminated by PCBs are to be disposed of or destroyed.

**Municipal Household Waste:**

CDW from private households is required to be sorted in accordance with municipal waste regulations, and delivered to a recycling centre in the municipality. There is no established minimum threshold for when CDW can be said to be sorted. It is the municipalities which determine whether waste can be considered to be sorted (Residual Product Regulation § 15).

**Uncontaminated Construction Waste:**

There is no established minimum threshold for determining when CDW can be considered uncontaminated. It is the DEPA ’s evaluation that it is difficult to immediately see if construction waste contains pollutants, however waste with visible traces of sealant, paint, soot etc. should be sorted out (Danish Environmental Protection Authority, 2016).

It is therefore important that, in connection with the demolition and renovation of buildings, a thorough examination of the building or parts of the building, which is affected by a renovation, is carried out in order to identify and sort out pollutants and materials. In this context, the history of the building and use should be involved as it can provide information on possible contamination sources within the building. It is the municipality, which determines whether the waste can be considered unpolluted (Residual Products Regulations § 15).

**Waste Recovery & Use**

In accordance with the Waste Regulations, companies must source separate waste, so that materials can be used again. This means that the waste must at least be sorted into the following 10 types of waste:

- Natural stone, such as granite and flint;
- Unglazed tiles (brick and roof tiles);
- Concrete;
- Mixtures of materials from natural stone, unglazed tiles and concrete;
- Iron and Metal;
- Plaster;
- Stone wool;
- Soil;
- Asphalt;
- Mixtures of concrete and asphalt.

Any residual waste must be sorted to landfill waste and/or as combustible waste. Municipal Boards are obligated to classify the waste as recyclable if:

- the waste is delivered to a registered recycling facility;
- the waste is delivered to an authorized and registered collection company;
- the waste is recycled in a business that is exempt from registration;
- the waste is taken to an approved and registered municipal recycling plant (The City of Copenhagen, 2016).

A specific permit is required under Chapter 5 of the Environmental Protection Act for the use of construction and demolition waste (CDW) as a substitute for other materials. If a so-called ‘listed enterprise’ wants to use CDW in its production or on its land, an approval is required which will be given in accordance with the stipulations of the Environmental Protection Act, Chapter 5. This applies in cases where the use of CDW is assessed as an activity that is technically and in terms of pollution, related to the other listed operators (Approval regulations § 3). The approval is given in the first instance by Municipalities, but in some cases, is DEPA the approval authority referred (Approval Regulations § 5.)

CDW from natural stone, brick and concrete must be processed before the waste is used as a substitute for primary raw materials. Pursuant to the Residual Product Regulations, sorted uncontaminated CDW after processing can be used without a permit as a substitute for primary raw materials.

The DEPA interprets the processing requirement to the point that the processing must ensure that the construction waste is of a quality that corresponds to the primary raw materials it replaces. The requirement for processing can, depending on the circumstances, be anything from crushing to trimming. It is the municipality that evaluates whether the waste can be considered as processed (Residual Product Regulations § 15). It is the municipality, which determines whether the waste is suitable for material recovery (Waste Regulations § 4).

### Waste Facilities

The waste producer (or sorting facility) is responsible for the waste to be transferred to authorized treatment facilities, where there is a responsibility for sorting the CDW at source (Waste Regulations 2012).

Municipal waste treatment plants may not conduct collection or treatment of source-separated industrial waste for material recovery. A waste treatment plant must have an environmental permit to handle the waste fractions in question. It can for example be approved for sorting or pretreatment. The treatment facility must also be registered in the Danish waste register to receive the waste fractions in question.

Chapter 5 of Appendix 1 in the Approvals Regulations 2015 lists waste management operations requiring a permit and threshold values relating to production or performance of a facility or activity.

Permits are required for waste management operations disposing of or recovering hazardous waste with a capacity exceeding 10 tons/day, and where involving one or more of activities listed in 5.1 of Appendix 1 (Approvals Regulations 2015).

### Prevention of Dumping

The fine for dropping litter depends on the amount, type, location and especially whether the litterer is a consumer or a company. Small quantities of waste - such as picnic waste - incur a fine starting at 1,000 Danish crowns.

Large amounts of waste trigger considerably higher fines. For companies that are caught
dumping large amounts of waste in natural areas, a fine will be issued of at least 8,000 Danish crowns, while a fine of at least 5,000 Danish crowns in cities and similar built up areas. The tariffs apply only if it is a first time offence. Fines are likely to increase for repeat offenders. The ultimate decision of the size of the fine is held by the police or the courts (Keep Denmark Clean, 2016).

In a news article published on the website of the DEPA on November 16, 2015, four people were convicted of organized environmental pollution, in what has been called Denmark's biggest environmental case. The charges related to the illegal dumping of more than 2,277 tons of construction waste in nature and on private property in Sjælland, in Eastern Denmark. All four accused were found guilty of several violations: three received a sentence of imprisonment of up to 6 years. This provision relates to the systematic and organized character of the crime and had not previously been used since its entering into force in 2006.

In addition to conditions in the Environmental Protection Act, dumping offenders can also be fined in accordance with conditions under the Nature Protection Act (Naturbeskyttelsesloven LBK nr 951 af 03/07/2013) (The Danish Nature Agency, 2016).

### 6.3 Economic Instruments

**Taxes**

Tax on waste can be divided into the following:

- Incineration of waste; and
- Landfill.

**Incineration**

Combustible waste is regarded in Denmark as a fuel in the same way as oil, coal or gas. The tax on combustible waste is divided into three taxes:

- Waste heat tax - tax is applied to the amount of heat supplied from the waste incinerator, and the heat generated, that a company itself uses from the facility for space heating and hot water;
- Supplementary levy - additional tax based on the calorific value of the waste, paid per GJ of heat produced. The supplementary tax is calculated, in principle, based on the energy content of the combustible waste, and must be paid regardless of whether the energy is utilized or not.
- Carbon tax on non-biodegradable waste - a fee is paid based on the amount of CO₂-equivalent content in the waste used as fuel.

The waste heat tax applies to heat delivered or unused, where the tax rates change every year, as indicated in the fee table below (PWC, 2016). Under certain conditions, the following waste is exempt from waste heat tax:

- Waste from biomass;
- Meat meal, bone meal and fats derived from processing animal waste;
- Fiber fractions obtained after degassing and separation of animal manure;
- Waste containing no non-biodegradable waste (e.g. plastics, petroleum products, etc.) in whole separate loads.

Companies using heat for process purposes and that enter into an agreement with the heat producer can reclaim waste heat tax and the Supplementary levy under general rules for reimbursement of energy tax on fuels.

The effective tax rate of the Supplementary levy is determined on the basis of the quantity of heat, as indicated in the fee table below. Under certain conditions, the following waste is exempt from supplementary levies:

- Waste from biomass;
- Meat meal, bone meal and fats derived from processing animal waste;
– Fiber fractions obtained after degassing and separation of animal manure;
– Waste containing no non-biodegradable waste (e.g. plastics, petroleum products, etc.) in whole separate loads;
– Pine oil and green waste (eg wood waste, manure, etc.).

The Carbon tax is calculated, in principle, based on the energy content of combustible waste and can vary annually, as indicated in the fee table below. Under certain conditions, the following waste is exempt from the Carbon tax:

– Waste from biomass;
– Meat meal, bone meal and fats derived from processing animal waste;
– Fiber fractions obtained after degassing and separation of animal manure;
– Pine oil and green waste (eg wood waste, manure, etc.).
– Waste with a content by weight of non-biodegradable waste in less than 1%.

A NOx tax and in many cases, sulfur tax must also be calculated on incineration of waste. Energy and waste facilities and industrial plants with a thermal input exceeding 10 MW, which burn nitrogenous products, are required to register for NOx tax in the first instance. Companies need to also measure emissions of NOx to air and pay a NOx tax based on the amount discharged.

Taxes are payable on emissions of sulfur in the form of a sulfur tax on fuels, which by combustion causes sulfur to be emitted into the air. The tax occurs only on fuels with sulfur content greater than 0.05%. This includes the combustion of such products as coal and petroleum products, waste, straw, wood pellets with a sulfur binder and other fuels have sulfur content above 0.05%.

The tax rate depends on the product and can be calculated by product weights, content of sulfur in the fuel or on the amount of sulfur that is actually derived from the combustion of the product.

Landfill

There is also a tax paid for the landfilling of waste. The tax for landfilling of waste applies also to waste that is landfill with the intention of subsequent combustion. The landfill tax rate is indicated in the table below. Companies and facilities that send waste to landfill covered by the municipal council’s authority or a municipal collection must be recorded.

<table>
<thead>
<tr>
<th>Waste Taxes in Denmark</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fee</td>
<td>CO2 Tax</td>
</tr>
<tr>
<td>Waste Heat Tax</td>
<td>kr./GJ</td>
<td>DKK 18.90</td>
</tr>
<tr>
<td>Supplementary tax</td>
<td>kr./GJ</td>
<td>DKK 26.50</td>
</tr>
<tr>
<td>Carbon Tax</td>
<td>kr./ton</td>
<td>-</td>
</tr>
<tr>
<td>Landfill</td>
<td>kr./ton</td>
<td>DKK 475.00</td>
</tr>
<tr>
<td>Hazardous waste</td>
<td>kr./ton</td>
<td>DKK 475.00</td>
</tr>
<tr>
<td>Sulfur tax</td>
<td>kr./ton</td>
<td>DKK 10.40</td>
</tr>
<tr>
<td>NOX tax *</td>
<td>kr./kg</td>
<td>DKK 26.40</td>
</tr>
</tbody>
</table>

*NOX tax 1 Jan 2016 - 30 June 2016 = DKK 26.60. 1 July 2016 - 21 Dec 2016 = DKK 5.00 (Source: PWC, 2016).

Subsidies

The Danish Government does not provide subsidies to operators of CDW processing facilities or to users of recycled construction materials apart from those tax exemptions already
6.4 Other Relevant Information

Specifications

As previously mentioned in legislative requirements for the recovery and use of CDW, a specific permit is required under Chapter 5 of the Environmental Protection Act. CDW must be processed in order to ensure that the construction waste is of a quality that corresponds to the primary raw materials it replaces.

However, several Danish waste industry articles indicate that there appears to be a lack of requirements for CDW to be tested for contamination or a specific quality before use in some of the common use areas such as, fillings for noise barriers or substrates for roads (The Engineer, 2014).

CDW Management Facilities

CDW management facilities are provided by the private and public sector operators under permit from the DEPA. All CDW management facilities are required to register the business in the Danish Waste register. Operations are divided into seven categories defined below:

- Transport / Logistics: Transports all kinds of waste for other operations, assumes no responsibility for the waste;
- Dealer: Purchases waste, Does not take physical possession of the waste, Assumes no responsibility for waste;
- Broker: Intermediary of waste, does not take physical possession of the waste, Assumes no responsibility for the waste;
- Collection Company without pre-treatment: Loads or receives waste, takes responsibility for waste, does not treat waste;
- Collection Company with pre-treatment: Loads or receives waste, takes responsibility for waste, Processing of waste;
- Municipal treatment: Treating waste for material recovery, Takes over responsibility for waste;
- Recycling Plant: Processing waste materials into products, materials or substances, takes over responsibility for waste.

In total there are currently 43 registered Recycling Plant operations in the Danish Waste Register (Danish Waste Register, 2016).

Client Requirements

CDW Management on Construction Sites

Contractors who demolish or renovate a building or a facility must notify the local Municipality when:

- The building or the installation is greater than 10 m², or
- Generate more than 1 tonne of waste

Notifications are submitted through a central online self-service system called ‘Build and Environment’ (Byg og Miljø) that supports the construction application process and required reporting elements such as CDW. Notifications must be submitted to the municipality at least 14 days before work is started. (The City of Copenhagen, 2016b).

Developers are responsible for the delivery of CDW to authorized treatment facilities. Separation of CDW off-site is done only by companies and facilities that are approved for this purpose under the Environmental Protection Act 2015. (Municipality of Silkeborg, 2016).

Environmental Award Schemes

There are a large number of voluntary assessment schemes which offer incentives for developers and construction providers to recover construction waste.

International schemes such as the US LEED and the British BREEAM are well established in Denmark, in addition to two other schemes, the German DGNB and the French HQE. In
addition to these four schemes, there are several other schemes that are either national or linked to regions other than Europe; it applies, for example, the Japanese CASBEE and the Australian Green Star scheme.

The Green Building Council Denmark in May 2012 introduced a system of certification of sustainable buildings to be used in Denmark based on the DGNB scheme, adapted to Danish conditions. (Green Building Council Denmark, 2016).

### Technical Guidance

**CLEAN**

CLEAN is Denmark's green energy and environment cluster. Through projects and collaborations CLEAN intends to create green growth and innovation, both nationally and internationally.

A specific platform for CDW has been developed in order to strengthen the development of new innovative methods for demolition with emphasis on the use of resources found in CDW. So far, CLEAN has received almost 4 million Danish Kronor from the EU Green Conversion Fund, and half a million Danish Kronor in matching finding from Region Sjælland, in eastern Denmark.

CLEAN is the result of a merger between two national cluster organisations, Lean Energy Cluster and Copenhagen Cleantech Cluster, and is Denmark's leading green cluster organisation with more than 170 members from the entire cleantech sector. They are a politically and technologically neutral platform where domestic and foreign companies, knowledge institutions and public authorities exchange knowledge and enter into new partnerships. This happens across industry boundaries as well as across the public and private sectors, called a 'triple helix' cluster organisation (CLEAN, 2016).

### 6.5 Discussion

According to the Environmental Protection Agency's most recent waste statistics, Denmark has a relatively high recycling rate (almost 90%) of construction waste. It is recognised amongst the construction and civil engineering industry in Denmark that up to 75 percent of the climate impact of new buildings comes from building materials. According to a report released by Danish think Tank, Concito, public builders should make more demands on the choice of building materials (Concito, 2014).

According to a case study on Denmark in delivering a circular economy, the Danish construction sector is fragmented, with many small firms, low labour productivity and limited vertical integration along the value chain, leading to significant material waste and limited reuse of building components and materials. (Ellen MacArthur Foundation, 2015).

With the advent of recent political restructuring, new legislation and agencies sharing responsibilities for governing CDW in Denmark, the market is preparing for what could be a dynamic period of optimistic change. A renewed focus on innovation and recognition of the benefits of a circular economy has also put emphasis on developing models and systems for closing the loop on the CDW sector in Denmark.

The Danish Government's resources strategy document “Denmark without Waste” (Danish Government, 2013) includes a chapter focussed on CDW. Noting the high recycling rate, the document expects the strategy to deliver better quality in recycling construction and demolition waste while maintaining a high recycling rate. Specifically this means:

- Restricting unacceptable spread of substances of concern in the environment from construction and demolition waste by improving the quality of the waste used for new purposes (recovered).
- Materials in at least 70% of the total amount of construction and demolition waste will be used for new purposes (recovered).

Initiatives put forward in the strategy include:

- Stipulation of limit values for the content of PCB in building waste.
- Stricter requirements for demolition of buildings to enable a better and more
A comprehensive overview of the materials and substances contained in building waste.

- Enhanced requirements for the qualifications of demolition companies.
- Investigation of the possibilities for better recycling of concrete and investigate the advantages and disadvantages of new treatment requirements for bricks and impregnated wood as well as requirements to separate roofing felt.
- Support for recycling of end-of-life wind-turbine blades and investigation of the advantages and disadvantages of introducing treatment requirements for end-of-life wind-turbine blades. This is of particular relevance given Denmark’s heavy investment in wind energy.
- Investigation of the advantages and disadvantages of introducing treatment requirements for district heating pipes.
7 Japan

7.1 Background

Responsibilities

Japan has a three-tiered system of Government, operating at the national, prefectural and municipal levels. The responsibilities of the various tiers with respect to waste management are as follows:

National Government

- Defining national waste management policy,
- Setting standards for the appropriate waste management,
- Financial and technical support to the local government

Prefectures

- Establishing regional waste management program,
- Ensuring the appropriate management of industrial waste,
- Authorization for industrial waste treatment agents,
- Authorization for waste treatment facilities and landfills.

Municipalities

- Establishing municipal general waste management program,
- Authorization for general waste treatment agents,
- Treatment of municipal solid waste

National policy for CDW is set by the Ministry of the Environment, and largely implemented by prefectural and municipal governments.

Construction Waste Statistics

CDW is categorized in Japan as a type of industrial waste, and accounts for about 20 percent of the industrial waste generated (and for about 80 percent of illegal dumping).

Inert CDW (e.g. concrete and asphalt) accounts for about 90% of construction wastes. As of 2008, the recycling rate of concrete and asphalt achieved the target of 95%, which was regulated for fiscal 2010 by the Construction Material Recycling Act.

In 2008, the recycling rate of concrete and asphalt was 97.3% and 98.4% respectively. The recycling rate of wood from construction is 80.3%.

7.2 Legislation

General

The Law on Recycling of Construction-Related Materials (Construction Material Recycling Law), put into force in May 2002, aims to promote sorting and recycling of waste concrete, asphalt and other materials that are discarded in the process of demolishing buildings.

The Construction Material Recycling Law promotes recycling by making it obligatory that designated construction materials used for constructions of the specified size or larger are sorted and demolished at the construction site and resulting wastes are recycled.

(1) Construction works to be regulated
Constructions that meet the following standards must be sorted and demolished. The client is required to make a notification.

<table>
<thead>
<tr>
<th>Type of construction</th>
<th>Standard size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demolition of a building</td>
<td>80 m² or more (total floor space)</td>
</tr>
<tr>
<td>Construction of a new building or extension</td>
<td>500 m² or more (total floor space)</td>
</tr>
<tr>
<td>Renovation work, etc.</td>
<td>Contracting fee (100 million yen or more)</td>
</tr>
<tr>
<td>Civil engineering work, etc.</td>
<td>Contracting fee (5 million yen or more)</td>
</tr>
</tbody>
</table>

* “Building” refers to those specified in the Building Standards Law.

(2) Designated construction materials that must be sorted, demolished and recycled

<table>
<thead>
<tr>
<th>Designated construction material</th>
<th>Type of industrial waste</th>
<th>Example recycling facilities</th>
<th>Recycling method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>Construction waste</td>
<td>Crushing facilities</td>
<td>Use as a (raw) material</td>
</tr>
<tr>
<td>Construction materials consisting of concrete and iron</td>
<td>Construction waste, scrap metal</td>
<td>Crushing facilities</td>
<td>Use as a (raw) material</td>
</tr>
<tr>
<td>Wood (wood generated in construction)</td>
<td>Scrap wood</td>
<td>Crushing or incineration facilities</td>
<td>*2</td>
</tr>
<tr>
<td>Asphalt concrete</td>
<td>Construction waste</td>
<td>Crushing facilities</td>
<td>Use as a (raw) material</td>
</tr>
</tbody>
</table>

Notes:

*1 Transferring waste to a recycling facility after selection at a facility other than recycling facilities is also permissible.

*2 It is permitted to reduce (incinerate) wood in a proper facility if recycling is difficult, as in cases where the construction site is more than 50 km away from the nearest recycling facility.

Although crushing facilities designed to process wood into a form suitable for thermal recycling are permissible, a higher priority should be given to transportation of wood to a crushing facility intended for using wood as a (raw) material.

*3 Limited to facilities that are capable of crushing asphalt concrete.

*4 Permissible forms of recycling are: [1] Use as a (raw) material and [2] Thermal recycling. The order of priority is [1] and [2].
The diagram below illustrates how the Construction Material Recycling Law operates in practice.

A amendment of the Waste Disposal and Cleaning Law (Law No. 137 of 1970) in May 2010 (Law No. 34 of 2010) makes the original contractors of construction work responsible for proper waste disposal. In many illegal construction waste disposal cases, it has been difficult to determine which particular contractor was responsible for which particular waste under the current rule that only the contractor who generated the waste is responsible. Layers of contractors typically exist in Japanese construction projects. The amendment increases fines on business firms who violate the law from ¥100 million (about US$1.1 million) to ¥300 million (about US$3.3 million) (Law Library of Congress, 2010).

### Waste Generation

In Japan, construction and demolition waste is considered a type of industrial waste. The total quantity of CDW generated in Japan in 2012 was approximately 73 million tonnes, broken down as shown below (Ministry of the Environment, 2015):

- Asphalt, concrete blocks: 25 million tonnes
- Concrete blocks: 31 million tonnes
- Construction sludge: 6.6 million tonnes
- Mixed construction waste: 2.8 million tonnes
- Wood generated from construction: 5 million tonnes
- Others: 1.6 million tonnes

The recycling rates of these construction wastes and their improvement over time are summarised in the table below.

<table>
<thead>
<tr>
<th></th>
<th>All construction waste</th>
<th>Asphalt, concrete blocks</th>
<th>Concrete blocks</th>
<th>Wood generated from construction (excluding incineration)</th>
<th>Wood generated from construction (including incineration)</th>
<th>Construction sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>58</td>
<td>81</td>
<td>65</td>
<td>40</td>
<td>—</td>
<td>14</td>
</tr>
<tr>
<td>2000</td>
<td>85</td>
<td>98</td>
<td>96</td>
<td>38</td>
<td>82</td>
<td>41</td>
</tr>
<tr>
<td>2002</td>
<td>92</td>
<td>99</td>
<td>98</td>
<td>62</td>
<td>90</td>
<td>68</td>
</tr>
<tr>
<td>2005</td>
<td>92</td>
<td>98</td>
<td>98</td>
<td>91</td>
<td>75</td>
<td></td>
</tr>
</tbody>
</table>
An entity that will provide industrial waste handling (collection, transport and disposal) as a business service must be licensed by the governor of the prefecture (or the mayor of the government ordinance designated city) where the entity will conduct the business. However, this license is not required when waste generators dispose of wastes on their own and for other entities designated by ordinance of the Ministry of the Environment. There are four types of licenses, categorized by the waste’s classification as either industrial waste or industrial waste subject to special control, and also by the type of services to be provided, either collection and transport services or disposal services. In principle, this license needs to be renewed every five years. In addition, the license designates the scope of services able to be performed, specifying the disposal processes and the types of industrial wastes able to be handled. This designation is determined based on the contents of the application submitted and the results of a screening (United Nations Environment Programme, 2013).

The law stipulates that prefectoral governors must not grant a license when the applicant’s competence (knowledge, expertise and basic skills in accounting) cannot be confirmed or when the facility used for the business fails to meet the established standards. Furthermore, the applicant must not fall under conditions for disqualification (cases in which the entity was subject to disciplinary action for certain types of unlawful behaviour, regarding this law or any other laws and regulations, cases in which less than five full years have passed since the entity had its license for waste handling revoked, and other such cases).

The licensing requirements for this business have been made stricter in stages in order to remove disposers who engage in illegal dumping or otherwise engage in the improper disposal of waste (United Nations Environment Programme, 2013).

Japan mandates the use of waste manifests to document the transfer of industrial wastes between parties.

The manifest is a collection of slips containing information such as the names of the waste generator and disposal company, the mode of packing the industrial waste and the addresses of the waste generator and the sites for intermediate processing and final disposal. The waste generators provide this manifest while handing over their industrial wastes to collectors, transporters or disposers.

Japan also operates a system of “electronic manifests” in addition to the paper manifest system. This system electronically delivers, returns, and stores manifest information through a single information processing centre. This enables waste generators to understand or check the disposal status quickly and reduce the amount of work associated with manifest management. It has been becoming increasingly popular, with electronic manifests accounting for about 30% of manifests in 2012 (United Nations Environment Programme, 2013).

When disposers illegally dump or improperly dispose of wastes, waste generators are also the subject of administrative orders, either if it commissions disposal in violation of commissioning standards, or if the disposal company is lacking in sufficient funds and the waste generators did not pay a proper disposal charge, or if the waste generator knew that disposal would be conducted improperly.

Provisions for collecting reports, on-site inspections, orders to improve operations, administrative orders and penalties have been established. These provisions stipulate that waste generators are also subject to administrative orders as mentioned above in specific cases. With regard to penalties, they also established rules on corporate exposure. For the most serious infractions of the law, such as in cases of illegal dumping, penalties of up to 300 million yen (approximately US$3 million) are imposed on corporations involved.

The number of cases of illegal waste dumping has declined from 1,027 in 2000 to 159 in 2013 (Ministry of the Environment, 2015). According to a study done by the Ministry of the Environment, in 2008, 48% of illegal waste disposal was done by business owners who...
generated the waste. Construction waste makes up 78% of illegally disposed waste (Law Library of Congress, 2010).

7.3 Economic Instruments

Taxes

Although there is no national landfill tax, many of the local governments are making moves toward the introduction of waste taxes. According to a Ministry of the Environment survey, as of April 2009, ordinances concerning local discretionary taxes for specific purposes related to industrial wastes are enacted in 27 prefectures out of 47 (Ministry of Environment, 2010).

Subsidies

Although disposal of industrial wastes in Japan is the responsibility of the businesses involved, in response to perceived market failure, local governments invest or contribute funds and designate corporations engaging in industrial waste disposal as "waste disposal centres". The Ministry of the Environment subsidizes a portion of such corporations’ expenses (up to one-fourth) for constructing and maintaining disposal facilities (United Nations Environment Programme, 2013).

Other measures to promote the maintenance of such facilities have been introduced, including a low-interest loan system by the Japan Finance Corporation and a debt guarantee system by the Japan Industrial Waste Management Foundation.

There is also a system for providing assistance for the research and development of waste disposal technologies. The Ministry of the Environment has created a competitive research fund called the "comprehensive promotion fund for environmental research". This fund publicly invites research institutions and private companies to submit applications for research and development topics (United Nations Environment Programme, 2013).

7.4 Other Relevant Information

Specifications

Japan has published various specifications to facilitate the use of recycled CDW. For example, with respect to recycled concrete, standards include:

- JIS A 5021 - Recycled aggregate for concrete - Class H
- JIS A 5022 - Recycled concrete using recycled aggregate Class M
- JIS A 5023 - Recycled concrete using recycled aggregate Class L

Where:

- Class H - No limitations are put on the type and segment for concrete and structures with a nominal strength of 45MPa or less
- Class M - Members not subjected to drying or freezing-and-thawing action, such as piles, underground beam, and concrete filled in steel tubes
- Class L - Backfill concrete, blinding concrete, and levelling concrete

CDW Management Facilities

There are a range of waste facilities accepting the different types of CDW in Japan. This includes facilities processing source-separated waste streams, as well as mixed construction waste.

CDW Waste from Natural Disasters

The Tohoku earthquake in 2011 generated over 22 million tonnes of debris, most of it from the destruction of buildings and other infrastructure. In addition, the municipal authorities normally responsible for waste management were either killed or traumatized by the loss of family or friends or the destruction of property.

Japan’s Ministry of the Environment identified dealing with the debris as a major post-disaster challenge and formed a Task Force on Disaster Debris Management. This consisted of more than 100 experts from government agencies, research institutions, academia and industry. Individual technical experts from various offices within the ministry were deployed to back-up and strengthen those prefecture and municipality offices which
were trying to address the disaster debris.

The ministry’s guidelines laid out the key activities to be undertaken in each municipality to deal with the disaster debris. This ensured there was consistency in the overall approach to the clean-up, segregation, offsite transportation and final disposal of debris. The guidelines emphasized the importance of maximizing recycling opportunities. They also requested local governments to ensure efficiency in contract management and the maximization of local employment in disaster debris management.

The main lessons learned from managing disaster debris from the Tohoku earthquake, as identified by a UNEP expert team were as follows (United Nations Environment Programme, 2012):

- The importance of being prepared: Having documented plans for disaster debris allows the government authorities to move swiftly into “emergency mode” after a disaster.
- Swiftness of response: Japan’s Ministry of the Environment came with a clear guideline for the local municipalities on how to deal with the disaster debris. This included a guidance note on segregation, storage and treatment. This enabled the municipalities to have a consistent framework to deal with the debris.
- Technical backstopping: Dealing with disaster debris is a specialized technical task, something which local municipalities, at least the smaller ones, generally lack the technical capability to implement. The Ministry of the Environment deployed staff from the national government to the prefecture and local level to provide technical backstopping to the local experts.
- Central financial support: The disaster produced such vast quantities of debris that the local municipalities would never have been able to handle the clean-up burden on their own. The national government’s decision to fully underwrite the costs associated with the disaster debris management has been the core factor behind the success of the disaster debris management operation in Japan.
- Collective contracting: The scope and scale of contracts needed for disaster debris management was also far beyond the capability of the local municipalities. The prefecture governments assisted the local municipalities by entering into area-based contracting with major Japanese contractors which brought in the required scale of resources and equipment relatively quickly. Local interests were taken care of by joint venture arrangements.
- Health and safety practices: No concessions were permitted when dealing with health and safety considerations on-site in the affected areas, even during the emergency phase.
- Use of local resources: Efforts to maximize the use of local companies to deal with disaster debris ensured that resources were pumped into the local economy at a time of need.

7.5 Discussion

Japan achieves a high recycling rate for CDW, for example recycling 98% of waste concrete. The use of advanced technologies for concrete recycling coupled with clear standards for recycled aggregate helps to optimise recycling performance (Tam, 2009). A comparative review carried out by Tam (2009) identified, through stakeholder interviews, that Japanese construction contractors had clear recycling policies and in-house expertise in concrete recycling, as a result of the need to comply with the Japanese construction material recycling law. The respondents in that study noted that the passing of mandatory requirements had provided the necessary “push” for contractors to invest in recycling, which may not have occurred in the absence of legislation (Tam, 2009).
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Construction and Demolition Waste Management and Recycling

TA-8906 PRC

Output 3–Policy Recommendations for the Regulation of CDW Management and the Promotion of CDW Recycling
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# Table of Contents

1 Introduction ......................................................................................................................... 1
  1.1 Study Background ............................................................................................................. 1

2 Summary of Work Carried Out to Date ................................................................................. 2
  2.1 Review of Current PRC Practice ....................................................................................... 2
  2.2 International Best Practice Review .................................................................................... 9
  2.3 Study Tour ....................................................................................................................... 22

3 Policy Recommendations and Capacity Building ............................................................... 25
  3.1 Awareness Raising ............................................................................................................. 30
  3.2 Improve Legislation and Regulations ............................................................................... 30
  3.3 Management Reform ....................................................................................................... 31
  3.4 Whole Process Management ............................................................................................ 32
  3.5 Application and Promotion ............................................................................................... 33
  3.6 Economic Instruments ...................................................................................................... 36
  3.7 Training and Dissemination ............................................................................................... 36
  3.8 Policy Recommendations ................................................................................................. 37

4 Cost & Benefit Analysis ....................................................................................................... 41
  4.1 Economic Analysis ............................................................................................................ 41
  4.2 Environmental Benefit Analysis ....................................................................................... 43
  4.3 Social Benefit Analysis .................................................................................................... 44
  4.4 Sensitivity Analysis .......................................................................................................... 45

5 Best Available Techniques for CDW Recycling .................................................................. 52
  5.1 Source Reduction ............................................................................................................. 52
  5.2 Sorting and Transportation ............................................................................................... 55
  5.3 Recycling Process ............................................................................................................ 55
  5.4 Reuse ............................................................................................................................... 59

 Appendix A: Calculation Tables for Economic Sensitive Analysis ........................................ 63
  A.1 Computation Tables of Sensitivity Analysis on Mandatory Policies of Technical Standards .................................................................................................................... 63
  A.2 Computation Tables of Sensitivity Analysis on Incentive Policies of Economic Initiative .......................................................... 68
  A.3 Computation Tables of Sensitivity Analysis on Encouraging Policies of Market Promotion .................................................................................................................. 73
1 Introduction

1.1 Study Background

1.1.1 Objectives of Technical Assistance Study

The Government of the People’s Republic of China (PRC) has requested policy and advisory technical assistance (TA) from the Asian Development Bank (ADB) to enhance the PRC’s policies and practices related to the management and recycling of construction and demolition waste (CDW).

The impact of the TA will be improved CDW management policies and practices in the PRC, and the outcome will be an agreed set of policy recommendations to regulate CDW management and promote CDW recycling.

1.1.2 Scope of Technical Assistance Study

The scope of the study comprises:

- An assessment of CDW management in China. This has been carried out through literature review, questionnaire surveys, and case studies of CDW recycling success stories in PRC cities, the policies and current practices of CDW management at construction and/or demolition sites, the perceptions in relation to recycled and conventional construction materials, and the barriers to increased application of recycled materials. The assessment includes an economic analysis to identify the probability of a CDW market failure in the PRC.

- A review of international good practice in CDW management and recycling. This includes in-depth case studies conducted in selected advanced economies with high CDW recycling rates, as well as a study tour to two of these countries. The international good practice report (a separate deliverable under this TA) documents hindering and enabling factors for sustainable CDW management and recycling.

- Development of a set of policy recommendations for the regulation of CDW management and the promotion of CDW recycling in the PRC (including cost–benefit analysis). This consists of

  (i) policy recommendations to regulate CDW supply, including technical guidelines for CDW segregation and processing, and capacity-building needs to improve CDW management at construction or demolition sites; and

  (ii) a set of policy instruments to promote demand for, and increase uptake of, recycled CDW in the construction industry. The policy recommendations have been identified and formulated in consultation with relevant ministries and professional associations. A cost–benefit analysis quantifies how much the implementation of these recommendations could benefit the PRC.

This report comprises the Draft Final Report for the TA, and presents policy recommendations for improved CDW management.
2 Summary of Work Carried Out to Date

The main tasks carried out to date are:

- Review of current PRC practice
- International best practice review
- Study tour

The outputs of these tasks are presented below.

2.1 Review of Current PRC Practice

2.1.1 Methodology

This task studied the CDW management policies and current status in the PRC through literature review, questionnaire survey and interviews with key stakeholders, and case studies of 5 Chinese cities that have made significant improvement in CDW management and recycling; and analysed the obstacles in application of recycled building materials and the infeasibility of merely relying on market for facilitating CDW recycling through comparison between recycled products and average building materials, cost and economic analysis.

2.1.2 Waste Types and Quantities

This task focused on the types of CDW which are the responsibility of MOHURD, and therefore did not include wastes from road, hydraulic and hydropower structures, railways and tunnels. The main types of CDW are:

- Waste from excavation
- Waste from demolition of old buildings
- Waste from construction sites, and
- Waste from building fit-out and decoration

The types of CDW generated depend on construction methods and the types of buildings being demolished. Modern buildings are primarily constructed from reinforced concrete, whereas buildings currently being demolished, dating from the 1960s to 1990s, include a large proportion of bricks.

Among the above CDW components, a mature recycling system has been developed for asphalt blocks, and there is also active recycling and reuse of waste metal, plastics, wood and glass, thus the remaining large amount of spoil, scrap bricks and tiles, waste mortar and concrete blocks have become the current focus of management and recycling. From environmental protection and disposal safety perspectives, spoil is the main target of CDW management, but there is no mature recycling technology.

Although there are no official statistics of CDW production at the national level, according to several survey results, CDW production shows an upward trend each year, with the annual CDW production currently being over 1.5 billion tons. A recent study (Construction Waste Recycling and Reuse Policy Research Report, China Architecture Design Institute (CADI)) estimated that CDW production will reach over 2.5 billion tons per year in 2020.

2.1.3 Laws and Regulations

At present, the PRC government has not formulated specific laws for CDW management; solid waste management related provisions for CDW are only covered by subordination laws, including:

- Environmental Protection Law
- Cleaner Production Promotion Law
- Solid Waste Pollution Prevention Law
- Circular Economy Promotion Law
- Building Law
However, the provisions of these laws are expressions of principle, low in operability, therefore they cannot provide guidance and deterrent force of the law but instead just provide a basis for policy formulation. The study identified a need for a series of supporting administrative laws, regulations and systems that can truly provide guidance for CDW management and recycling. Provincial, municipal and county governments should also be able to formulate CDW management methods, but currently only 21.7% of the provinces and cities in China have issued local regulations and policies on CDW management and recycling.

2.1.4 Standards

There are 16 CDW recycling related standards, including those already issued and those under formulation, and 8 local standards that are already issued.

CDW Management and Recycling Authorities

The “Notice on Roles and Responsibilities for CDW Utilization issued by State Commission Office of Public Sectors Reform” in 2010 (No. [2010] 106) clarifies the responsibilities of central government departments, including Ministry of Housing and Urban-Rural Development (MOHURD), National Development and Reform Commission (NDRC), Ministry of Industry and Information Technology (MIIT), Ministry of Environmental Protection (MEP), Ministry of Science and Technology (MOST), Ministry of Finance (MOF) and State Administration of Taxation (SAT). MOHURD is the leading authority in CDW management and recycling. The following issues have been identified during a survey of CDW management functions of the above ministries:

– Lack of coordination.

Although all departments performed their duties specified by State Commission Office of Public Sectors Reform, their duties are separated. MOHURD is in charge of the management of source and terminal usage of CDW; MIIT is responsible for management of the CDW recycling companies. The evaluation and auditing system is developed by NDRC. The responsibilities are separated and there is a lack of coordination mechanism at the ministerial level.

– Enforcement performance varies at the local level.

At the Central Government level MOHURD has been clearly defined as leading unit, but in local governance, the construction department is divided into housing construction bureaus and urban management bureaus (city appearance and environmental sanitation) to perform different duties; but there is lack of effective management and coordination.

– Lack of Clear Positioning of Recycling Enterprises

CDW recycling enterprises are regarded as “common enterprises” when the State Commission Office of Public Sectors Reform defined the responsibilities. According to the “Notice on urban domestic waste treatment charging system and promoting waste treatment industrialization” (NDRC [2002]872), urban solid waste explicitly included CDW and spoil earth, therefore, construction waste recycling facilities should be regarded as public utilities. Referring to the solid waste management, urban infrastructure shall be managed by the centralized construction department, which is conducive to the implementation and enforcement of policies.

Local Government Level

The CDW recycling management of local governments involves different government administration departments (including development and reform commission, land resources, housing and construction, planning, municipal administration and landscape, transport, environmental protection, industry and information technology and finance) with their respective administration privileges and responsibilities. Currently in China, the urban management department is the major CDW authority in most cases. Major constraints include:

– The CDW administration authority and enforcement authority are separate.

The authority of the urban management department has no control of demolition and construction sites. It has the right to approve CDW transportation license but does not have right to regulate overloading of vehicles, it requires joint law enforcement of 5~6 departments, the enforcement has low efficiency, which causes difficulties in source control of CDW generation and sorting, and failure in back-end support for promotion and application of recycled products.

– Construction waste management is not linked with existing administrative licensing of construction projects.

The permits and license required for construction projects have no requirement for CDW recycling, therefore, CDW recycling is usually ignored no matter whether for new construction projects or demolition. Uncontrolled dumping is common.
Government responsibilities do not match with the construction waste recycling industry supply chain. Existing functions are based on the management of permission settings and integrated considerations from upper, middle to downstream industry chain, so as to make it impossible for integrated management. The CDW recycling enterprises are often short of raw materials and find it difficult to sell their products.

2.1.5 Stakeholder Analysis

Stakeholders relevant to CDW management including central government bodies, local governments, developers, construction companies, construction waste disposal companies, transportation companies and the general public. The views of various stakeholders were analysed and are summarised below.

Upstream (CDW generators)

- Gaps of legal system and lack of supervision of the market
- Lack of appropriate provisions means that uncontrolled dumping is common
- Absence of source segregation of CDW affects resource treatment costs and product quality

Project owner, construct unit, design institute and government are involved in source generation. The project owner is the major player during demolition and construction; at the source generation stage, the project owner is in the centre. The major concerns of design institutes include incorporating their ideas into the building while meeting the requirements of the project owner, completing as many works as possible with less time and accomplishing model works. The construction unit is concerned about how to complete the construction at the fastest rate and with least resources and cost inputs. The government expects less CDW generation. Their expectations, responsibilities and obligations should be properly coordinated.

Midstream (CDW transport and processing)

- Management of construction waste transportation industry is uncoordinated
- Obtaining approval to use land for CDW recycling is difficult
- Difficulties in EIA approval of CDW recycling projects
- High costs and investment required for CDW recycling facilities

The collection and transportation stage involves construction enterprises, transportation enterprises and CDW disposal enterprises. Construction enterprises care about reducing transportation cost, and prefer transportation service providers who offer low prices, but such service providers are usually not under the government supervision range, they often overload or dump illegally to gain maximum profit; CDW disposal enterprises are concerned about maintaining their disposal capacity of the sites by slow landfilling. Some construction enterprises and disposal enterprises may sign fake contracts in order to get CDW disposal linked approvals or gain profits without increasing disposal capacity. CDW is being dumped into the urban-rural fringe area, endangering the public; in the end, the government pays the price.

Downstream (users of CDW recycling products)

- Lack of mandatory regulations for CDW recycling products
- Lack of completed standards for CDW recycling products
- Lack of price competitiveness for CDW recycling products
- Traditional conception of poor quality waste-derived materials hinders the use of CDW recycling products

2.1.6 Current Status of CDW Recycling Products

Currently, recycled CDW products in the PRC are mainly divided into 3 categories: 1) Recycled aggregate: recycled aggregates can be used as raw material for concrete and mortar, and raw material for other various types of reuse products; 2) Environmental-friendly construction material: the technique of producing recycled brick using CDW materials has become quite mature in the PRC; and 3) road pavement material.

Compared with conventional products, recycled product such as recycled concrete, recycled mortar and recycled concrete block has certain performance restrictions that limit its application scope. However through technical measures, recycled products can have quality equal to natural aggregate and its products, and are safe to use in engineering construction. The current obstacles in application are caused by other factors other than technical performance indicators.
2.1.7 Economic Analysis of PRC CDW Recycling Market Failure

The economic analysis under this Study is carried out by means of empirical analysis and whole industrial chain comparative analysis. The cost elements of CDW generation and sorting, CDW removal and transportation, CDW digestion and CDW beneficial use are analyzed from the perspective of the whole production process CDW recycling. Cost computation and comparative analysis are conducted by means of standardized processing of data sampled from the individual cases of fixed crushing CDW recycling, mobile crushing CDW recycling and CDW landfill. Costs of different CDW recycling technologies as well as prices of recycling products and common construction material products are compared and analyzed.

The analysis shows that construction waste recycling technology generates marginal economic benefits. Without proper policies and instruments on subsidizing, it is very hard for all types of recycling facilities to be financially viable. Products of fixed treatment technology have better marketing advantage despite their higher investment cost than mobile treatment technology that is limited by process equipment.

The financing costs of different types of enterprises have not been considered in the study, i.e. all the investment is considered made by the enterprises fully with their own capital. If such financing costs are taken into account, the economic benefits of both fixed and mobile technologies are expected to be lower, which is one of the obstacles to market application of construction waste recycling technology.

According to the study, due to the absence of measures for mandatory dumping and transportation of construction wastes, there is not a stable source of materials for construction waste recycling enterprises, resulting in the absence of stability of revenue for enterprises engaged in, for example, fixed construction waste recycling and also bringing certain impacts on their market sustainability.

Sales price in the market is not an obstacle influencing market application of recycled CDW products because there are occasions when their prices are lower than ordinary construction material products. It is more a factor of market acceptance of recycled CDW products. Their narrow application and the absence of a uniform quality certification and accreditation identification system in the sector cause some problems of marketing.

2.1.8 Chinese Case Study Cities

Four case study cities in China were chosen, each of which displays:

- Adequate CDW source management.
- Scaled CDW recycling and sustainable enterprise operations.
- Effective marketing of CDW recycling products.
- High CDW recycling rate.
- Different types of cities which can provide lessons and experience for each other.

The cities studied were:

- Shenzhen — an emerging large city which has an early start in CDW recycling with many recycling enterprises that in sustainable operation. Shenzhen is playing a leading role in CDW recycling among the major cities in the PRC.
- Xi’an — a famous historic and cultural city which has established a mature disposal approval system, with adequate source management and large-scale recycling enterprises in sustainable operation.
- Xuchang — a small to medium city which has achieved adequate whole process management of CDW recycling, there are scaled recycling enterprises with sustainable operations. Its CDW recycling rate is ahead in the country.
- Wujin District of Changzhou City — one district of a medium city, its CDW recycling has a late start but the promotion is strong and effective, there are already scaled recycling enterprises.

Relevant details for each case study city are summarised in the following paragraphs.

Shenzhen

(1) Laws and regulations of Construction Waste Reduction and Utilization

On October 1st 2009, Shenzhen issued the first legal regulation on construction waste reduction and utilization in the PRC, specifying 9 innovation systems, including the review and record of construction wastes, reduction and disposal proposal, labels of recycled products, emission tariff, disposable residence decoration, mandatory use of the construction waste
recycled products, exchange and utilization of construction spoil, on-site classification of the construction waste. The regulation provides clear legal basis to cut down the sources of construction waste.

(2) Government counterpart and strong supervision

Under the supervision of the legal regulations, two record systems namely construction waste reduction and utilization are established. The system of reviewing construction waste content in the designed drawings specifies the requests that the design unit shall have reduction design, the drawing review institute shall report to the administrative competent department after the approval of relevant content for record; The system of construction waste reduction and utilization indicates that reduction design and utilization plan should be prepared in the construction of new projects, demolition of existing architectures, structures and municipal roads. The construction unit shall report to the competent department before the commencement of the project.

(3) Market-driven and industrial upgrading

Shenzhen has developed 5 integrated construction waste utilization enterprises successively and explored the business model of integrated construction waste utilization, namely “site-plant combined mode”, temporary land use mode, on-site disposal mode. The site-plant combined mode is defined that, the recycling treatment facilities and receiving site will be constructed jointly for the purpose of eliminating the stored wastes; Temporary land use mode is defined that, the land use for recycling disposal facilities is used temporarily, mainly eliminating the waste for street demolition; On-site disposal mode is defined that, the recycling facilities are constructed on the demolition site, so as to realize “zero emission” of construction waste and reuse the recycled products in project construction.

(4) Technique support and innovation upgrading

In 2012, the first construction disposal emission technical standards was released in the PRC and clarified the standards of construction waste emission, detailed requirements of waste reduction design and construction reduction. It is very critical to the design institutes in optimizing the construction design, reducing the consumption of building materials, generation of the construction waste, guiding the construction unit to recycle the construction waste.

(5) Promotion and Social Recognition

Shenzhen attaches great importance to the promotion and guidance of construction waste recycling. With various channels such as newspapers and magazines, Shenzhen has special feature report to show the hazards of construction wastes compared with the social and environmental benefits of waste recycling. Also it shows the technique and recycled products to the public. Through promotion and guidance, the construction waste recycled products have achieved social recognition and good market acceptance.

Xi’an

(1) Serious Governmental Recognition

Leaders of the CCP Municipal Committee and the Municipal Government have conducted field studies and held multiple special meetings. In 2010, a steering group headed by the responsible leader of the Municipal Government and comprising of members from the municipal authorities of city appearance, city administration and traffic police was established; in the meanwhile, 15 joint inspection teams comprising of members from the municipal authorities of city appearance, city administration and traffic police were established for daily inspections and strict strike of various violations in terms of construction waste transportation.

(2) Assurance from Legislative System

Xi’an has set up an integrated and complete construction waste management system consisting of local legislations, government specifications and sector regulations. Construction Waste Management Regulations of Xi’an City defined the responsibilities of the government authorities of city appearance, city administration and traffic police and others involved as well as at the management levels of district, county and community and described in full detail the rights, obligations and responsibilities of government departments and individuals in terms of construction waste generation, transportation, digestion, recycling and legal responsibilities, including specific and strongly operable measures.

"Methods for Appraisal and Evaluation of Construction Waste Transportation Companies in Xi’an City", “Provisional Requirements on Charges of Construction Waste Disposal in Xi’an City” and “Methods of Accountability Investigation in Construction Waste Management in Xi’an City” were issued in succession, along with series of rules and regulations on
daily reporting, site supervision, comprehensive evaluation, market withdrawal, recycling company registration, traffic safety registration, “uniform management in 7 aspects” and joint inspection.

(3) Appropriate Enforcement of Actions and Measures

Xi’an City has been implementing discharge permit and daily reporting in a strict way making sure that producers of construction wastes must apply for and obtain a “Construction Waste Disposal (Discharge) Permit” and that the construction waste transportation permit shall not be granted until the procedures of reporting, generation verification and disposal fee payment are fulfilled. In practice, a daily report of the transportation vehicles at night time is required, with the reported information shared by the city administration and traffic police authorities via the Comprehensive Management System of Construction Wastes. The concerned government authorities carry out their respective duties and responsibilities based on the reported information.

Xi’an City has specific requirements on transportation capacity and site scale for the purpose of strictly managing the qualifications and competence of transportation operators. Vehicles transporting construction wastes are managed under the category of special vehicles and the vehicles, drivers and corporate owners are subject to traffic police registration and “uniform” management. Transportation operators are subject to monthly evaluation and year-end appraisal for quantitative rating. Those with poor performance in monthly evaluation will be suspended for improvement while those with unacceptable performance will be disqualified and instructed to withdraw from the construction waste transportation sector, with their Construction Waste Disposal (Transportation) Permit revoked.

Xi’an established a recycling enterprise registration system. Registered enterprises are included in the comprehensive management system of construction wastes and the city appearance authorities of the various districts and development zones, upon approval of construction sites, will assign demolition wastes based on the production needs of the enterprises to support their production activities. Thanks to the effective implementation of a series of management measures, effective interaction is achieved of the stages of construction waste generation, transportation and disposal to ensure that the construction wastes are transported to the digestion sites or recycling enterprises, destination of construction wastes is effectively controlled and development of construction waste recycling industry is facilitated.

(4) Strengthened Supervision and Appraisal

In order to make sure that the various measures are enforced, the Municipal Joint Inspection Team carries out zone-based and group-based night tours around the City while the City Appearance and Gardening Bureau organizes at least 2 non-notified inspections per week focusing on site control at the entrances and exits of construction sites with waste generation. Transportation permit approval is, in the first instance, suspended for sites with problems discovered in such inspections and then evaluation scores of the respective jurisdiction are deducted, with news published on Xi’an Daily, Xi’an Evening News and other media.

Xuchang

(1) A special management body is established to facilitate effective management.

Both the Municipal CCP Committee and People’s Government of Xuchang attach consistent and great importance to construction solid wastes management. Early back in 1999, Xuchang City established the Construction Solid Waste Management Office and was then approved in 2014 by the People’s Government of Xuchang City as a permanent government body, which plays an extremely important role in facilitating the management and beneficial use of construction solid wastes in Xuchang.

(2) Powerful supports were provided through policy improvement.

Xuchang City consecutively issued the “Methods for Management of Urban Construction Solid Wastes in Xuchang City”, the “Detailed Rules of Implementation of Urban Solid Waste Management in Xuchang City” and the “Standard on Collection of Urban Solid Waste Treatment Fee in Xuchang City”, the “Methods of Management of Construction Materials and Construction Solid Wastes on Construction Sites” and the “Opinions on Comprehensive Use of Construction Solid Wastes”, specifying the full process of management and beneficial use of construction solid wastes from source declaration, collection, transportation, disposal and promotion and application of regenerated products of construction solid wastes. The adequately detailed and strongly operable requirements included in such policies guaranteed their effective implementation.

(3) Franchised operation model was developed to increase the impetus of industrial development.
As of Year 2008, the People’s Government of Xuchang City initiated “franchised operation” of integrated collection, transportation and beneficial use of construction solid wastes in the urban area. The franchised enterprise has the exclusive right of investing in and constructing, operating and maintaining projects of construction solid waste transportation, disposal and utilization within the scope of franchised operation and collecting construction solid waste transportation tariff according to the tariff standard approved by the People’s Government of Xuchang City. This enterprise undertakes construction projects of construction solid wastes treatment plants to realize recycling and reuse of construction solid wastes and fulfills the public benefit tasks and other obligations assigned by the government. With clearly assigned rights and obligations, the franchised enterprise experienced high-speed development, and the CDW recycling industry in Xuchang has reached a relatively high level.

(4) Joint efforts from multiple government departments contribute to effective supervision.

Xuchang established its joint law enforcement mechanism, under which, the Municipal Government, as the leading organization, is responsible for organizing joint law enforcement participated in by the government departments of city management, public security, housing and urban construction, transportation and highway administration. The key purpose of such joint action is to control and manage construction sites, debris transportation vehicles and commodity concrete transportation vehicles. In addition, improvements were made to the supervision, examination, reward and penalty and accountability mechanisms, accompanied by stronger efforts in inspection and penalty. These actions have effectively addressed the problems of spillage of construction solid wastes and pavement contamination by muddy vehicles. In order for closer partnership between the franchised enterprises and the management authorities, joint management teams were established to increase the frequency of routine inspections and assure that all the construction solid wastes are transported to designated disposal sites.

(5) S&T innovations become a driver of sector development.

The franchised enterprise established Henan’s first engineering and technology research center specialized in R&D of construction solid wastes. Thanks to its all-round efforts of S&T research in classified collection, disposal, key processes and technologies and new product development in terms of construction solid wastes, technological, process, equipment and management models were developed for the sector of beneficial use of construction solid wastes, laying a solid foundation for nationwide duplication of “Xuchang Jinke Model”. The franchised enterprise was certified in 2014 as a national hi-tech enterprise.

(6) Policy and technology supports assured market application.

The Municipal Government provided supports to comprehensive use of construction solid wastes through comprehensive use of public financing, taxation and investment and other economic levers and incorporating regeneration products of construction solid wastes into the scope of government procurement and regarding such incorporation as one of the prerequisites of financial settlement and fund disbursement. Projects failing to use construction solid waste regenerated products according to the design shall not be permitted for final acceptance and registration upon completion. Such policy supports opened the gate to market application of regenerated products. Construction solid wastes regeneration products have already been widely applied in construction projects of urban roads, gardens, plazas, houses, rivers and water conservancy facilities in Xuchang.

Wujin District, Changzhou City

(1) Demonstrative Role in Green Development

Changzhou follows the concept of green development, and has made requirements for CDW recycling enterprises on classified dismantling, regulated transportation, enclosed production, high recycling rate, zero pollution and zero discharge.

(2) Policy supports enabling the formation of a closed industrial chain

Changzhou City has consecutively issued the “Implementation Plan for Special Actions in Controlling and Regulating Construction Wastes in Changzhou City”, the “Announcement on Strengthening Management of Municipal Construction Waste Disposal”, the “Opinions on Implementing the “Municipal Construction Waste Management Regulations”, the “Minutes of Meeting on Further Strengthening Beneficial Use of Construction Wastes” (No. 2013-88) and the “Minutes of Meeting on Coordinating Efforts in Facilitating the Work of Management and Harmless Disposal of Construction Wastes” and integrated the efforts of all concerned departments to set up a comprehensive management system and formed a closed industrial chain integrating the generation, collection, transportation, disposal and recycling and application of construction wastes.

(3) Four development goals achieved through departmental interaction
Changzhou Urban Administration Bureau, in coordination with Wujin District government departments and offices of urban administration, housing, finance, reform and development, taxation, economic and IT, science and technology, collection, transportation, water conservancy and public security, has set up a comprehensive coordination and management mechanism for construction waste recycling. “Admission thresholds” are established for vehicles and enterprises to be engaged in construction waste transportation to regulate the process of construction waste transportation and avoid “spillage and leakage” during transportation. A sound construction waste management system that is led by the government, participated by the social public and managed by the competent industrial department and involves cooperation from all concerned sides shall be set up, and incorporate construction waste recycling into modernized development plan of building industry and truly realize reduction, harmless and beneficial use and industrialization of construction wastes.

(4) Franchised enterprises established using PPP model

In Changzhou Wujin District Green Building Industrial Zone, franchised construction waste enterprises are established using PPP model for the sake of moderate integration of market competition and government regulation. State-owned and private account for 70% and 30%, respectively, for Franchise enterprise, and project land use is unified transfer. Economic benefits are realized simultaneously with social benefits to bring profits to the enterprises.

(5) Green production achieved through technological research and innovation

The franchised enterprise has developed excellent partnership of technological development with a number of scientific research institutes and colleges and universities. In addition, it has set up the Construction Waste Green Recycling Engineering Technology Research Center and Jiangsu Province Graduate Work Station. Advanced process technologies and equipment were imported, and automation and integration of diversified product promotion modules were realized and green production achieved in construction waste recycling.

(6) Recycling product market expanded by diversified means

It is pointed out in the Minutes of Meeting on Coordinating Efforts in Facilitating the Work of Management and Harmless Disposal of Construction Wastes* that construction waste recycling products should be included into the catalogs of green construction materials, the catalogs of government procurement and the engineering cost information for preferential promotion and application in construction projects. Construction waste recycling products should be utilized as a top priority in green buildings and the construction project design stage. Construction projects financed with state-owned fund or by the national government must use construction waste recycling products to expand the scope of application of construction waste recycling products. The franchised enterprise has sped up the R&D and promotion of new technologies, new processes, new equipment and new materials, in particular, the development of new regenerated construction materials and raw materials oriented towards the current hot directions of industrial development.

2.2 International Best Practice Review

2.2.1 Methodology

A review of international good practice in CDW management and recycling was carried out, with the objective of identifying hindering and enabling factors for sustainable CDW management and recycling. The best practice review report includes in-depth case studies conducted in selected advanced economies with high CDW recycling rates. The countries proposed for case studies have one or more of the following characteristics:

- High degree of CDW diversion from landfill.
- Good availability of policy information and associated research data;
- Relevance to the Chinese situation.

The countries selected for International Case Studies were:

- UK – high CDW diversion and good availability of policy information
- Hong Kong - high CDW diversion and relevant to China as a Special Administrative Region of China
- Germany – high CDW diversion and good availability of policy information
- Denmark – high CDW diversion and good availability of policy information
- Japan – high CDW diversion and relevant to China as an Asian country

Information on CDW recycling has been collected by:
– Literature review of information from the selected countries and which is available in English; and
– The project team’s knowledge of CDW recycling in case study countries and other jurisdictions.

The findings of the international best practice review are summarized below.

2.2.2 Key Aspects of Successful CDW Management Systems

In order to achieve a high rate of CDW recycling and establish stable and competitive markets for recycled CDW materials, there are a number of critical factors that need to be addressed as a matter of policy. Any stable market requires a balance between supply and demand, and policy measures play an important role in ensuring a supply of recycled CDW materials of adequate quality, and also encouraging and supporting customer demand for these materials, recognising that government itself is often one of the largest customers for recycled CDW materials, in its role as the ultimate client for public infrastructure.

The critical factors are considered under three main headings:

– Technical factors.
– Regulatory factors.
– Economic factors.

In general it is difficult to establish direct quantitative links between specific CDW policy measures and outcomes (e.g. improvements in recycling rates). This is because, in most countries, a package of policy measures have been introduced over a period of time, making it difficult to disentangle the specific impacts of a particular. In addition, the construction industry in most countries is highly cyclical, with construction activity slowing down sharply whenever GDP growth reduces. This in turn affects the amount of CDW arisings and can limit the demand for recycled construction materials. Nevertheless, in some cases it is possible to identify the major policy measures that have been introduced over a given period of time, and quantify the change in recycling rate over the same period, and examples are provided in this report.

Concrete is the largest single component of CDW, and considerable world-wide effort has gone into developing ways of recycling concrete. The Cement Sustainability Initiative, supported by the World Business Council for Sustainable Development, has assessed the global situation for concrete recycling and identified the following key issues as summarised in Table 2-1 below (The Cement Sustainability Initiative, 2009).

Table 2-1: Issues, Barriers and Benefits of Concrete Recycling

<table>
<thead>
<tr>
<th>Issues</th>
<th>Barriers</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material cost vis-à-vis natural aggregate</td>
<td>Low economic cost of virgin aggregate in some countries.</td>
<td>Aggregates levies and transportation costs for natural aggregates can be higher. Overall project costs can be reduced as less landfill taxes/fees are paid on CDW as the material is recovered instead of being landfilled.</td>
</tr>
<tr>
<td>Availability of material</td>
<td>Non-regular supply of CDW.</td>
<td>CDW is usually found in urban areas near construction and development projects. Virgin materials often need to be transported over greater distances.</td>
</tr>
<tr>
<td>Processing infrastructure</td>
<td>CDW on-site waste management plans are needed. CDW may need to be sorted. High-value recovered concrete requires costly processes.</td>
<td>Once infrastructure is established mobile sorting units and dedicated facilities can provide good returns.</td>
</tr>
<tr>
<td>Public attitudes</td>
<td>Misconception that recovered concrete is of lower quality. New materials are perceived as being of better quality.</td>
<td>Increasing environmental concerns leading to increased demand for eco-friendly products and reuse of materials.</td>
</tr>
</tbody>
</table>
### Issues

<table>
<thead>
<tr>
<th>Laws, regulations and industry accepted standards</th>
<th>Barriers</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification of recovered concrete as waste can increase reporting and permit requirements. Extra limitations can be placed on use.</td>
<td>Positive recycling laws, landfill taxes and green procurement policies by large users can all promote recycled concrete use.</td>
<td></td>
</tr>
</tbody>
</table>

### Environmental impacts

<table>
<thead>
<tr>
<th>Processing technology for recovery of concrete should consider possible air and noise pollution impacts as well as energy consumption, although there is little difference to natural aggregates processing.</th>
<th>Within a life cycle analysis, use of recovered concrete can lower overall environmental impact.</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Failing to use recovered materials increases landfill and associated environmental and health costs</td>
<td></td>
</tr>
<tr>
<td>- Failing to use recovered materials means virgin materials are used instead • Recovered concrete is generally inert</td>
<td></td>
</tr>
<tr>
<td>- In some cases, transportation needs for recycled concrete can be lower than virgin materials (often not located in urban development areas) and as such fuel consumption, CO2 emissions and road and vehicle use can be reduced.</td>
<td></td>
</tr>
</tbody>
</table>

### Physical properties

| For specialized applications (e.g. high performance concrete) there are some limitations on fitness for use. Technology can also limit recycling options. | For most uses, recycled concrete performs well. |

### 2.2.3 Technical Factors

#### Waste Types and Classification

Excluding excavated soil\(^1\) and asphalt\(^2\), the main constituents of CDW are:

- Hard inert materials (concrete and brick);
- Wood;
- Mixed waste.

The majority of construction waste in most countries comprises hard inert material, such as concrete and bricks. In terms of improving the amount of CDW that is recycled, this hard inert portion is generally prioritised because:

- This fraction forms the majority of CDW in most countries; and
- Recycling technologies and markets for the smaller fraction of CDW such as plastic and metal are relatively well-established.

Other fractions of CDW which are present in smaller quantities but which have received specific attention include:

- Wood – this can form a significant proportion of CDW, depending on construction methods in specific countries\(^3\);
- Gypsum (e.g. plasterboard/drywall) – landfill disposal is problematic due to its potential to generate toxic hydrogen sulphide;
- Hazardous materials such as asbestos.

In order to assess the effectiveness of CDW policy, it is necessary to measure CDW performance, which requires a robust and consistent framework for data collection. In the European Union, the European List of Wastes presents a clear and

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\(^1\) Excavated soil is often excluded when considering CDW, as its management is relatively straightforward and usually simply a matter of identifying projects requiring fill material which can use the excess cut material from other projects.

\(^2\) MOHURD noted during the inception stage that asphalt recycling is outside the scope of this project.

\(^3\) For example, wood is used extensively in domestic construction in Japan; and bamboo is used for scaffolding in Hong Kong.
consistent framework for classifying different types of construction waste. A European construction industry organization has developed guidance on how to measure and report waste arisings and reuse / recycling / recovery from construction, demolition and excavation activities on construction projects throughout the EU (Encord, 2013), with the objective of ensuring consistency. In many countries, the mandatory use of waste transfer notes enables the regulator to monitor construction waste types and quantities, and therefore to calculate recycling rates (e.g. transfer notes are required as part of Hong Kong’s construction waste charging scheme).

Supply-side Technical Factors

The technical factors affecting the supply-side of CDW recycling can be grouped into two categories:

- Effectiveness of source-separation to produce relatively clean and consistent sources of material which is suitable for processing; and
- Effectiveness of processing to produce recycled material suitable for use.

In some countries, source-separation is mandatory for all but the smallest construction projects (e.g. Japan). In other countries, source-separation is encouraged either by regulators or clients. For instance, public sector clients in the UK often require contractors to prepare and implement Site Waste Management Plans⁴, which will normally include provision for source-separation of the main types of CDW. Hong Kong’s public sector clients also require similar commitments to CDW source-separation.

The primary recycling route for hard inert CDW is back into the construction industry, as a recycled aggregate. Most recycled aggregate is used as general fill or sub-base⁵, and the basic procedure for recycling hard inert material is relatively straightforward, consisting of crushing and screening (Hyder Consulting, 2011). More advanced techniques are available, which are intended to produce a higher-quality aggregate which may be used in more demanding applications, such as in concrete.

For instance, a European Union (EU) project investigated waste concrete streams and optimised recycling processes that yield fine cement paste, coarse aggregate and fine binding materials. This was achieved through lab tests, simulations and experiments, as well as through a case study involving industry partners. Tests showed that end-of-life concrete can be recycled with excellent results, although contaminants such as wood or plastic must be removed at an early stage (CORDIS, 2015).

The UK has successfully developed a “Quality Protocol” for recycled aggregates. CDW treatment facilities which accept certain types of waste, and produce recycled aggregate to a recognised specification and following defined quality control procedures are entitled to sell their outputs as a construction product, and it is no longer regulated as a waste. This has helped to build confidence in the market, and reduced regulatory burdens associated with waste legislation (Mineral Products Association, 2011).

In the case of mixed CDW, a UK study into good practice CDW recycling at Materials Recycling Facilities (MRFs) noted that various sorting equipment is available recovering material on the basis of size, mass and other physical and chemical properties, but the level of automation in MRFs varies markedly (WRAP, 2009). Technologies used may include:

- Screening equipment – the most important initial step of a CDW MRF, which uses trommels, vibrating screens or star screens to separate material by size.
- Hand picking – hand separation of mixed waste still remains common in many countries.
- Magnets – to extract ferrous metal.
- Water separation equipment – flotations tanks can be used for separating wood from heavier aggregates.
- Air separation equipment - air- or wind-separation equipment can optimise the quality of aggregate outputs by removing lighter contaminants (such as paper, plastic and wood) from the heavier rubble leaving the picking cabin, or from fines separated out by trommels or vibratory screens.
- Shredders - wood-shredding machines to reduce the space taken up by recovered wood and thus increase transport efficiency, and shredding can also be used for other waste streams.

⁴ Site Waste Management Plans were previously a legal requirement in England: although no longer legally required, they are frequently made a contractual requirement.
⁵ In highway engineering, sub-base is the lowest layer of aggregate, which is placed on top of the soil and which is overlain by the base- and wearing courses of the road.
− Advanced equipment - some highly automated plants used equipment such as ballistic separators (to separate light from heavy fractions), optical sorting technology (applicable to separating several types of materials), and eddy current separators (to remove aluminium).

A study into the potential of Near Infrared (NIR) sorting technology to improve the quality of mixed recycled aggregates carried out tests using samples of mixed recycled aggregates collected in different EU countries (Germany, Sweden, Spain and Italy). Constituents, total sulphur content, acid soluble sulphates, total heavy metals and metal leaching were determined before and after the use of the NIR sorting technology. The results clearly indicate that the problematic fractions (organic material, gypsum and AAC) in the mixed recycled aggregates can be significantly reduced or even eliminated during the NIR sorting treatment, boosting a greater use of recycled aggregates in high grade applications such as concrete manufacturing (Vegasa, Broosb, Nielsen, Lambertz, & Lisboa, 2015).

Although many different technologies are available, the use of specific advanced technologies is not generally identified as a critical factor in achieving a good CDW recycling rate. Provided the necessary regulatory and economic drivers are in place, relatively simple recycling technology should be capable of generating recycled outputs that are suitable for use.

Demand-side Technical Factors and Client Requirements

Ensuring an adequate supply of source-separated CDW is only part of the solution: if markets are not available, this material cannot find a use. For instance, Hong Kong has been very successful in diverting CDW from landfill, but less successful in finding alternative outlets for this material. Most countries report some difficulties in the acceptance of recycled CDW: often it is perceived as being of low quality. Measures to address this negative perception have included:

− Development of specifications for use of recycled aggregates;
− Publicising case studies which illustrate the technical and economic benefits of using recycled CDW;
− Encouraging or requiring the use of products with a high recycled content;

Carrying out research into higher value-added CDW recycling. For example, the Cement & Concrete Association of New Zealand have published a detailed best practice guide for the use of recycled concrete which includes model specifications (Cement and Concrete Association of New Zealand, 2011), and the British Standard for Concrete, BS 8500, applies product-specific, and specification-specific, conditions on the use of recycled aggregates in new concrete construction (Mineral Products Association, 2013). A review of CDW management in Australia concluded that recovery rates are highest in those regions where there is strong market demand for recycled C&D materials, with well-defined and well-publicised specifications supporting the use of recycled products (Hyder Consulting, 2011).

A large amount of research has been carried out into use of recycled CDW, and is published in a wide range of international journals and conferences (for example, the organisation RILEM supports many such events (RILEM, 2011).

Government or government-owned bodies are the clients for a large proportion of construction projects, particularly in the infrastructure sector. Government can set CDW performance requirements in their construction contracts, and select only contractors who can deliver these requirements. When selecting contractors, Government can show preference to those who can demonstrate achievements in sustainable CDW management. For instance, major contractors in the UK monitor and publicise their CDW recycling performance. For example, Carillion (a large UK-based contractor) has a commitment to sending zero non-hazardous waste to landfill by 2015 and achieved their 2014 target to divert 95% of waste from landfill. Measures included collaborating with the supply chain, designing out waste and strengthening relationships with waste

The public sector can act as a role model for sustainable CDW management. Government can require their contractors to prepare CDW management and to provide accurate reporting of CDW management.

Source-separation is mandated in many countries and enables higher quality recycled materials to be produced at lower cost. Various well-established technologies can be used for separating mixed CDW, but the emphasis should be on segregation at source.

Although a variety of technologies are available, the basic processes for recycling that largest fraction of construction waste (hard inert material) are relatively simple.

The use of protocols or standards for recycled CDW materials builds confidence in the market by providing a consistent product.

AECOM Construction and Demolition Waste Management

Policy Recommendations for the Regulation of CDW Management and the Promotion of CDW Recycling

RILEM (Réunion Internationale des Laboratoires et Experts des Matériaux, systèmes de construction et ouvrages), in English the "International Union of Laboratories and Experts in Construction Materials, Systems and Structures"
management specialists (Carillion plc, 2015). In Japan, the Kajimi Corporation (a major construction contractor) has adopted a company-wide target for its final disposal rate (i.e. the percentage of total waste material that is not recycled) of under 5% (Kajimi Corporation, undated).

Contractors on major infrastructure projects in the UK are typically required to measure and report their CDW recycling performance to a high level of detail. Project targets for CDW recycling are established at an early stage and continually monitored. For example, on the Crossrail project (Europe’s largest construction project) the Environmental Objectives for 2015-16 include: “Implementing the waste hierarchy by achieving 90% (or greater) reuse or recycling of our construction and demolition waste and 95% (or greater) reuse or recycling of our clean excavated material and achieving at least 15% of the total value of our construction materials from reused or recycled content” (Crossrail, not dated). This is turn is reflected in the contractual requirements of the project.

An Australian study recommended that the wider adoption of sustainable procurement practices, particularly through government agencies, would help increase market demand for recovered C&D materials, and also recommended that Government agencies should favour procurement of material containing recycled C&D content where they meet defined performance criteria / specifications (Hyder Consulting, 2011).

CDW Management in the Project Cycle

Countries which are already achieving relatively high levels of landfill diversion for CDW are increasingly turning their attention to:

- Improving the standard of recycling – i.e. using recycled materials for more value-added applications (such as using recycled aggregate in structural concrete, rather than as general fill); and
- Minimising construction waste at source, for example by designing out waste and better on-site management of materials.

For example, in the UK the government-funded organization WRAP carried out an active programme of developing guidance for the construction sector between 2000 and 2015.

Although it is important to provide effective “end-of-pipe” solutions for recycling of CDW, there are measures to reduce the quantities and increase the recycling rate of CDW that can be taken at all stages of the construction cycle. This included issuing practical guidance to the construction industry on how to manage CDW at all stages of the project cycle, following the principles of “reduce-reuse-recycle” (also known as “3R’s”). Advice from WRAP’s publication “Achieving good practice Waste Minimisation and Management” relevant to waste minimization is summarized below (WRAP, n.d.):

Design solutions

- Building form – design building size and space to eliminate unnecessary elements, and to reduce off-cuts resulting from the construction process, and ensure compatibility between market supply and specification.
- Design flexibility – ensure flexibility in design for future building expansion, adaptation and dismantling.
- Design complexity – reduce the complexity of the design to standardize the construction process and reduce the quantity of materials required.
- Specifications – avoid over-specification and minimise variation in components and joints; evaluate the reuse and recycling opportunities for the specified materials before specification.

Demolition

- Avoid the disposal of reusable materials and building elements; maximise the use of reclaimed materials on site.

Logistics

- Logistic Plan – development of a logistic plan at the early stages of the project will ensure that due consideration is given to material requirements through the construction phase of the project, enabling efficient management of the delivery and storage of materials and that the most effective logistic methods are adopted.
‘Just-in-time’ delivery – improving the movement of materials to the site and within the site to alleviate space constraints for storage and site congestion.

Construction Consolidation Centres – these provide effective supply chain management solutions enabling the safe and efficient flow of construction materials and equipment from supplier to site.

Modern Methods of Construction (MMC)

Improvements in the products or processes employed in the construction industry, ranging from innovative components to be used on site through to whole building systems manufactured off-site.

Off-Site Manufacturing – utilise prefabrication, factory assembly, preassembly, off-site assembly/manufacture, panelised or modular volumetric construction where possible, for example, staircases, lift assemblies, architectural steelwork and toilet blocks for hotels, prisons and student accommodation. Waste Minimisation is realised due to the controlled environment and the “production line” type process where there is repeatability in construction.

Materials procurement

Materials ordering – reduce the amount of surplus materials by ordering the correct amount of materials at the right time.

Material storage – material storage areas should be safe, secure and weatherproof to prevent damage and theft.

Supply chain manager – will develop relationships and partnerships with suppliers during construction who can implement waste minimisation at source.

‘Take-back’ schemes – setting up schemes with suppliers to take back surplus materials.

Packaging

Reduce and reuse – engage with the supply chain to supply products and materials that use minimal packaging, and segregate packaging for reuse.

2.2.4 Regulatory Factors

Waste Regulations and Targets

Some countries have specific regulations relating to CDW, whereas others have broader regulations which apply to all wastes. Successful waste regulations generally require:

- Licensing of waste management facilities and waste transport companies;
- Environmental assessment for waste facilities;
- Manifest system to track the transfer of waste between parties; and
- Penalties for illegal dumping of waste.

Measuring the success of CDW recycling policies requires detailed information about the quantities and destinations of CDW. Whilst not straightforward to implement, countries see data collection and management as an important aspect of their overall CDW management programme, and this aspect has been addressed at an EU level (Encord, 2013). In the European Union, over-arching waste policy is set out in a series of Directives which are then passed into law by member countries. CDW is covered by the general requirements for managing waste as set out in the Waste Framework Directive, and there is a specific target that member countries should recycle at least 70% of CDW by 2020 (European Union, 2008). Where problems have been identified, these relate to fragmented and inconsistent approaches. For example, in Germany the lack of a nationwide regulation for secondary building materials, which resulted in many different legislations on state level, is considered as one of the major barriers for sustainable CDW management (Deloitte, 2015).

It is also important that the regulatory roles and responsibilities are clearly defined and understood by all parties. These responsibilities vary between different countries and there is no particular regulatory model that has been adopted globally. It is however important that these responsibilities are coordinated: the regulatory tasks may include:

- Promulgating CDW regulations.
- Licensing and regulating activities of CDW management facilities.
- Regulating activities on construction sites, including controlling environmental emissions from these sites.

Countries that have been successful in achieving a high CDW recycling rate are increasingly looking to increase the quality of recycling, and minimize the amount of CDW generated in the first place.

Effective CDW waste minimization requires early and continued efforts throughout the project cycle, involving clients, designers and contractors.
- Licensing and regulating vehicles transporting CDW.
- Collecting and publishing data and statistics.
- Advising on the practical aspects of good-practice CDW management.
- Researching new ways of managing and recycling CDW.
- Setting standards for building materials made from recycled CDW.

In some countries, industry bodies have developed in order to advise, from an industry perspective, on aspects of CDW management and how to ensure that regulations are clearly and consistently applied (e.g. the UK’s “Green Construction Board”). From a regulatory perspective, bodies with a role to play may include:

- Environmental agencies or departments.
- Construction and building control departments.
- Transport departments.
- Police and traffic control agencies.
- Universities and research agencies.

There is little information in the literature which deals with inter-agency coordination, but the fact that so many agencies are potentially involved leads to the conclusion that there must be consistency and a clear strategy in place, to ensure there are no weaknesses in the regulatory environment; and that policy, implementation and enforcement are well-coordinated.

Control measures should extend from the site of production to the site of treatment/disposal, but should also include those responsible for transportation.

Many agencies are involved in regulating the CDW supply chain, and their activities need to be coordinated to ensure there are no loopholes or weaknesses.

Controlling Illegal Dumping

In many countries, CDW forms the largest proportion of waste that is illegally dumped. This illustrates the importance of regulating the entire waste “supply chain”, including transportation. Several countries are trialling or have introduced electronic manifests, which allow for wastes to be tracked easily. Even in highly regulated countries, illegal disposal of CDW is not unknown. Measures to reduce the scale of the problem include:

- Publicising cases to act as a deterrent;
- Applying high financial penalties (which may include fines but also exclusion from bidding for Government contracts);
- Enhancing surveillance and counter-measures against known or suspected illegal activities;
- Enforcing liability on the main contractor, to ensure that they are responsible for the actions of their sub-contractors and have a “duty of care” for the waste generated on their site.

Landfill Bans or Mandatory Recycling

Some countries or jurisdictions have introduced either bans on sending certain types of CDW to landfill, or mandatory requirements for recycling.

In Japan, the Construction Material Recycling Law was enacted in May 2000, aiming at recycling and reuse of prospected construction materials in view of ensuring efficient use of resources.

The Construction Material Recycling Law promotes recycling by requiring contractors to sort out and recycle wastes generated in construction where one or more of the following criteria are met:

- in case of demolition work of building, the total floor larger than 80 m²;
- in case of construction work or enlargement work, the total floor area is larger than 500 m²;
in case of repair work or remodeling, contract fee exceeds 100 million yen; or
in case of demolition work or construction work other than building, contract fee exceeds five million yen.

The materials that are required to be sorted and recycled are set out in Table 2-2.

**Table 2-2: Mandatory CDW Sorting and Recycling Requirements in Japan**

<table>
<thead>
<tr>
<th>Designated construction material</th>
<th>Example recycling facilities</th>
<th>Recycling method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>Crushing facilities</td>
<td>Use as a (raw) material</td>
</tr>
<tr>
<td>Construction materials consisting of concrete and iron</td>
<td>Crushing facilities</td>
<td>Use as a (raw) material</td>
</tr>
<tr>
<td>Wood (wood generated in construction)</td>
<td>Crushing or incineration facilities</td>
<td>Permissible forms of recycling are: [1] Use as a (raw) material and [2] Thermal recycling, in order of priority</td>
</tr>
<tr>
<td>Asphalt concrete</td>
<td>Crushing facilities</td>
<td>Use as a (raw) material</td>
</tr>
</tbody>
</table>

CDW recycling performance in Japan has improved significantly since this law was passed.

In the US, the city of Seattle has passed regulations meaning that certain CDW must be recycled and may not be put in containers for disposal in landfills. Before receiving a permit from the Seattle Department of Construction & Inspection (SDCI), building permit applicants with projects more than 750 square feet and all demolition projects need to submit a Waste Diversion Report. In addition, a Salvage Assessment is to be filled out for whole building removal projects by a salvage verifier. Once a project is completed, all demolition permits and all new construction and remodeling projects that are $30,000 or more in value need to submit a Waste Diversion Report to SPU. This report documents where construction materials were delivered for reuse, recycling and disposal (Seattle Public Utilities, undated). Seattle is planning to phase in bans on landfilling certain types of CDW (including asphalt paving, bricks, and concrete; metal; cardboard; gypsum; untreated wood; carpet; plastic film; and asphalt shingles).

Landfill bans or mandatory recycling policies have been introduced in several countries and can be effective, but require effective monitoring to ensure compliance.

In the Netherlands there has been a national ban on the disposal of re-useable C&D waste since 1997. As a result only certified C&D crushers and sorters are allowed to dispose of non-reuseable C&D waste. Under Dutch law only rubble contaminated with coal tar, asbestos and other forms of chemical contamination are considered non-re-useable (Construction Resources and Waste Platform, 2007).

Non-Statutory Guidelines

Many counties have certification schemes for environmentally friendly construction. Schemes include LEED (USA), BREEAM and CEEQUAL (UK), and HKBEAM (Hong Kong). These schemes typically have a waste management element, and points can be gained from achieving a certain level of landfill diversion or recycling, by separating CDW on site, and by using materials with a high recycled content. Clients may choose to make certification a mandatory requirement, which can drive sustainable CDW management.

Industry- and government-funded bodies issue guidelines to assist contractors with CDW recycling. This includes detailed technical guidelines for designers, but also practical guidelines for site agents, foremen and operatives (Environmental Protection Department, undated). Tools have also been developed to assist designers and contractors both during design and construction, such as the SmartWaste tool developed in the UK (BRE, 2015). In the UK, the Government funded the Waste Resources Action Programme (WRAP) to develop a wide range of supporting materials, which included practical “how to” guides, technical reports on construction waste recycling plant operations, and best-practice case studies.

Voluntary measures have a role to play but are unlikely to be sufficient on their own to alter CDW behaviour across the sector.

Technical guidance on how to comply with regulations or best practice is helpful to designers, contractors and site operatives. This guidance should be practical rather than theoretical, and supported by case studies.
2.2.5 Economic Factors

Background

The economics of recycling CDW (particularly inert material) is faced with two fundamental problems. On one hand, virgin aggregate is widely available and inexpensive; whereas recycled CDW requires relatively costly processing and transport. On the other hand, landfill disposal of CDW is inexpensive even if authorised facilities are used, and even less expensive if dumped illegally.

Some countries have adopted an almost entirely market-based approach to CDW, using economic instruments rather than detailed regulations in order to encourage desired behaviour. The UK provides a good example of this, where environmental taxes are one of the main drivers of improved CDW management. However, economic instruments alone are unlikely to be effective unless illegal disposal is strictly policed, since illegal disposal will always be cheaper than using legitimate facilities.

Raising the Cost of Disposal

Landfill is a relatively low cost operation, requiring land but relatively little plant and equipment. Engineered landfills with gas and leachate collection systems are more costly than inert waste landfills, and the “void space” (i.e. the disposal capacity) at a mixed waste landfill is therefore a more valuable resource than void space at an inert waste landfill. One of the aims of sustainable CDW management is to minimise the amount of waste that is landfilled at all, but also to minimise the amount that needs to be sent to a mixed waste landfill. This means incentivising the separation of CDW into inert and non-inert fractions.

In most developed countries it is usual practice to pay a “gate fee” for the use of a waste treatment or disposal facility. In the absence of specific economic instruments, the gate fee for landfill tends to be relatively low, compared to alternative treatment techniques. Countries use economic instruments to:

- Increase the cost of landfill disposal, thereby making alternative treatment or recycling more cost-competitive; and
- Differentiate between the costs of mixed waste and inert waste disposal, thereby incentivising source-separation of waste.

The current rates of UK Landfill Tax (in 2016) are:

- Lower rate (inactive waste): £2.65 per tonne
- Standard rate (active waste): £84.40 per tonne

The landfill tax was introduced in the UK in 1996 at a relatively low level (£7/tonne for active waste and £2/tonne for inactive waste), but has been progressively increased at a pre-determined rate (the “landfill tax escalator”). The effects of the landfill tax on the overall waste generation and disposal routes in the UK are shown in Figure 2-1.

In Hong Kong, the gate fees for disposing of CDW at various facilities (in 2016) are:

- Public fill reception facilities (inert CDW only): HK$27 per tonne
- Sorting facilities: (> 50% by weight of inert CDW): HK$100
- Landfills (< 50% by weight of inert construction waste): HK$125

Hong Kong recognized the potential for increased illegal disposal when charging for CDW disposal was introduced, and stepped up measures to prevent this and to catch offenders (Advisory Council on the Raising the cost of waste disposal provides a strong incentive for recycling. Differential pricing for inert and non-inert wastes encourages waste producers to segregate at source. However, landfill taxes only work if they can’t be easily avoided by illegal dumping.
The CDW charging scheme in Hong Kong was introduced in 2005, and a significant reduction in CDW waste sent to landfill was immediately apparent, as shown in Figure 2-1.

An Australian study also concluded that, where the cost of landfill disposal is sufficiently high, the cost to dispose of mixed waste will be high compared to the cost to reprocess uncontaminated streams of specific C&D waste materials. This provides a strong incentive for high volume and regular generators of C&D waste to source separate materials and allow for easier reprocessing. The study also noted that high landfill disposal costs provide an incentive to process mixed C&D waste in order to recover certain high value and high volume components, and avoid landfill disposal costs (Hyder Consulting, 2011).

Taxation of Primary Aggregates

The UK has also attempted to address the price differential between recycled and primary aggregates by means of a tax on primary aggregates, the "Aggregate Levy". The tax is set at GBP 2.00 (CNY 18) per tonne of aggregate, and recycled aggregates are exempt. The tax forms a significant proportion of UK aggregates cost, which are reported to be approximately GBP 5.00 exclusive of tax (ex quarry). An EU study (European Commission, 2011) concluded that the UK’s Aggregate Levy has encouraged the use of recycling and secondary material, which has led to a decrease of the aggregates output. However, views on the effectiveness of the levy are mixed and critical points mentioned in the literature are the lack of measurement of the impacts on environment externalities, larger transport distances and stockpiling of unsold but locally available lower quality primary aggregates increasing at quarries (European Commission, 2011).

A study in Switzerland concluded that the demand for recycled concrete was found to be most sensitive to changes in construction stakeholders’ awareness of the recycling option and price differences between conventional and recycled material. The scenario analysis showed that a combination of extensive information campaigns and small price advantages for recycled materials would lead to a maximal reuse of construction and demolition waste (Knoeri, Nikolic, Althaus, & Binder, 2014).

A study investigated how taxes on primary raw materials used in construction in Denmark, Sweden and the UK have reduced the use of these resources (Söderholm, 2011). It concluded that in Sweden, a tax on natural gravel (introduced in 1996) to promote the use of crushed rock and recycled materials encouraged substitution with other materials, although the tax is applied uniformly across the country, even in regions where shortages in natural gravel is less of a problem. In Denmark, a tax on extracted raw materials (sand, gravel, stones, peat, clay and limestone) introduced in 1990 in conjunction with a waste tax has produced a greater demand for recycled substitutes: in 1985 only 12% of construction and demolition waste was recycled, compared with 94% in 2004. In the UK, a tax on aggregates (sand, gravel and crushed rock used in construction) was introduced in 2002 and has encouraged a higher recycling rate in the UK.

Subsidising Waste Treatment Facilities

In Europe, facilities for managing CDW are generally run by the private sector without significant subsidies, although Governments have provided financial assistance with research and development, for example the various work in the UK funded by the organisation WRAP.

Outside of Europe, some countries subsidise the cost of CDW treatment. In Hong Kong, CDW recycling and disposal facilities are provided by Government but operated by the private sector under “Design-Build-Operate” contracts. These facilities do not operate on a full cost-recovery basis, and hence there is some element of public subsidy. Japan provides subsidies for recycling industries in certain “Eco Towns” (Ministry of Economy, Trade and Industry, 2008). Subsidies may be beneficial in stimulating investment and providing facilities. However, if there is no commercial incentive for providing facilities and insufficient market for the products, then the Government may need to provide long-term support and recycled material may end up being stockpiled rather than beneficially reused. To some extent this has happened in Hong Kong: the support of CDW recycling facilities has certainly been effective in diverting waste from landfill, but in the absence of strong local markets for recycled construction materials there have been difficulties in reusing the outputs of these facilities.
Conclusions

Based on a review of international practice in CDW recycling, the main conclusions are:

- Source-separation is mandated in many countries and enables higher quality recycled materials to be produced at lower cost. Various well-established technologies can be used for separating mixed CDW, but the emphasis should be on segregation at source.
- Although a variety of technologies are available, the basic processes for recycling that largest fraction of construction waste (hard inert material) are relatively simple.
- The use of protocols or standards for recycled CDW materials builds confidence in the market by providing a consistent product.
- Stimulating demand for recycled CDW products is often challenging. Part of the answer is technical, and can be addressed by research and development of specifications and protocols. Part of the answer relates to perception, and can be addressed by case studies and demonstration projects. Clients can stimulate demand by requiring the use of a certain proportion of recycled material in projects.
- Countries that have been successful in achieving a high CDW recycling rate are increasingly looking to increase the quality of recycling, and minimize the amount of CDW generated in the first place.
- Control measures on CDW should extend from the site of production to the site of treatment/disposal, but should also include those responsible for transportation.
- Controlling illegal waste dumping is one of the most important elements of sustainable CDW. If waste can be dumped for free and with impunity, this undermines the market for legitimate CDW management. A range of penalties can be applied, but effective surveillance is necessary to ensure that the risk of being caught is high.
- Landfill bans or mandatory recycling policies have been introduced in several countries and can be effective, but require effective monitoring to ensure compliance.
- Voluntary measures have a role to play but are unlikely to be sufficient on their own to alter CDW behaviour across the sector.
- Technical guidance on how to comply with regulations or best practice is helpful to designers, contractors and site operatives. This guidance should be practical rather than theoretical, and supported by case studies.
- The public sector can act as a role model for sustainable CDW management. Government can require their contractors to prepare CDW management and to provide accurate reporting of CDW management.
- Raising the cost of waste disposal provides a strong incentive for recycling. Differential pricing for inert and non-inert wastes encourages waste producers to segregate at source. However, landfill taxes only work if they can’t be easily avoided by illegal dumping.
- Taxes on primary construction material such as the UK's Aggregate Levy can help recycled aggregate gain market share, but implementation may not be straightforward.
- Subsidies can support CDW facilities where they would otherwise be uneconomic; but in the absence of sufficient demand for recycled CDW materials they may struggle to find outlets for their products. Direct provision of, or subsidy to, CDW processing facilities is unusual in Europe and the US.

Table 2-3 below summarises the key success factors in CDW management that have been identified in this review, and their potential applicability in Asia. International experience suggests that none of these measures on their own will produce an optimal CDW recycling system, but instead there is a need for an integrated approach, using a range of policy tools.

Table 2-3: Summary of Key Success Factors

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Main Features</th>
<th>Example Countries where Applied</th>
<th>Effectiveness in Strengthening CDW Management</th>
<th>Potential Applicability in Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory source-separation of CDW.</td>
<td>Requirement for all CDW to be separated into different fractions at the construction site.</td>
<td>Japan, Seattle (USA)</td>
<td>Effective if properly enforced at the site level, and if suitable management facilities and markets are in place for the</td>
<td>Potentially applicable: requires high level of enforcement and oversight of construction sites and significant changes in</td>
</tr>
<tr>
<td>Instrument</td>
<td>Main Features</td>
<td>Example Countries where Applied</td>
<td>Effectiveness in Strengthening CDW Management</td>
<td>Potential Applicability in Asia</td>
</tr>
<tr>
<td>------------</td>
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<td>-------------------------------</td>
</tr>
<tr>
<td>Landfill bans.</td>
<td>Prohibition on the disposal of certain types of waste (typically unsorted CDW) to landfill.</td>
<td>Netherlands</td>
<td>Effective, but requires a range of behaviours and infrastructure to be established in order to be effective.</td>
<td>Difficult to implement without first establishing a network of CDW recycling facilities as an alternative to landfill.</td>
</tr>
<tr>
<td>Tax on landfill disposal.</td>
<td>Tax or mandatory charging scheme for disposal of waste to landfill, often with different bands for mixed and inert wastes.</td>
<td>UK, Denmark, Hong Kong</td>
<td>Very effective in developing alternatives to landfill, but with risk of increased fly-tipping if enforcement is poor. Likely to stimulate the supply of recycled CDW materials, but may not increase demand if material quality concerns remain.</td>
<td>Potentially applicable: requires strong enforcement against illegal disposal.</td>
</tr>
<tr>
<td>Tax on primary aggregates.</td>
<td>Tax on primary aggregates in order to make recycled aggregates more cost-competitive.</td>
<td>UK, Sweden</td>
<td>Helpful in stimulating the market for recycled aggregates.</td>
<td>Potentially applicable: may be opposed by aggregates and construction sectors as introducing additional costs to the industry.</td>
</tr>
<tr>
<td>Enforcement of prohibitions on illegal dumping.</td>
<td>Active enforcement of penalties on illegal dumping, with fines or other punishments at a level which are a proper deterrent to illegal behaviour.</td>
<td>UK, Hong Kong, Japan, Germany, Denmark and most other developed economies.</td>
<td>Essential in order to allow other economic measures to take effect.</td>
<td>Potentially applicable, but requires strong and transparent law enforcement.</td>
</tr>
<tr>
<td>Licensing of waste hauliers and use of trip tickets/transfer notes/manifests.</td>
<td>CDW can only be transported by licensed hauliers and all consignments of waste must be accompanied by a note (physical or electronic) which describes source, type and quantity of waste.</td>
<td>UK, Hong Kong, Japan, Germany, Denmark and most other developed economies.</td>
<td>Allows for improved data collection, better control of CDW management, and aids enforcement.</td>
<td>Applicable.</td>
</tr>
<tr>
<td>Targets for CDW recycling on Government-funded projects.</td>
<td>Many infrastructure projects are either funded or directly built by Government; this gives Government the opportunity to set targets for CDW recycling and for the use of recycled CDW</td>
<td>UK, Hong Kong, Denmark, Germany.</td>
<td>Helps to kick-start the market for recycled products by providing a secure outlet. Establishes positive behaviours in CDW management that can then be replicated in</td>
<td>Applicable.</td>
</tr>
</tbody>
</table>
## 2.3 Study Tour

The study tour took place between 4th and 11th May 2016, when a delegation from the PRC visited the United Kingdom and Denmark.

The delegation comprised:

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hongyi Yang</td>
<td>Supervisor, Urban Environment Management Division</td>
<td>Ministry of Housing and Urban-Rural Development</td>
</tr>
</tbody>
</table>
The delegation was accompanied by the TA Deputy Team Leader, Dr Chen. The TA Team Leader, Mr Bains, accompanied the delegation during their stay in the UK.

The purpose of the study tour was to allow PRC delegates to meet with those involved in all stages of the CDW recycling supply chain, from regulator to processor, in order to better understand how these aspects are managed in the relevant country. The itinerary is summarised below:

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Individual &amp; Organisation Met</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 4,</td>
<td></td>
<td>Travel – Beijing to London</td>
<td></td>
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<td>Wednesday</td>
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<tr>
<td>May 5,</td>
<td>Morning</td>
<td>BRE Bucknalls Lane Watford</td>
<td>BRE is an independent and impartial, research-based advisory, testing and training organisation, offering expertise in every aspect of the built environment and associated industries. BRE works extensively in the field of CDW and has developed tools including “SMARTWaste” to help manage CDW. BRE staff described the tools commonly used in the UK to manage CDW.</td>
</tr>
<tr>
<td>Thursday</td>
<td>Afternoon</td>
<td>Graham Winter Environment Agency Ergon House Horseferry Road London</td>
<td>The Environment Agency is responsible for regulating waste producers and processors, and provides input to policy-making. The EA's senior advisor on waste provided an overview of UK waste management regulation regarding construction waste.</td>
</tr>
<tr>
<td>May 6,</td>
<td>Morning</td>
<td>Simon Little Powerday Waste &amp; Recycling Centre Crossan House, Old Oak Sidings, Off Scrubs Lane, London</td>
<td>Powerday is a leading UK CDW processing and recycling company. The facility visited manages approximately 1.6 million tonnes per year of CDW from the London area. A site tour was provided, and the company's commercial director provided an overview of the business drivers governing CDW management and recycling in the UK.</td>
</tr>
<tr>
<td>Friday</td>
<td>Afternoon</td>
<td>John Bradshaw-Bullock Mineral Products Association, Gillingham House, 38-44 Gillingham Street, London</td>
<td>The Mineral Products Association is the industry body for producers of both primary and recycled aggregates in the UK. The MPA’s technical lead for recycling provided an overview on the UK market for recycled aggregate.</td>
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<tr>
<td>May 7,</td>
<td>Rest</td>
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</tr>
<tr>
<td>Saturday</td>
<td></td>
<td></td>
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<tr>
<td>May 8,</td>
<td>Travel –</td>
<td></td>
<td></td>
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<tr>
<td>Sunday</td>
<td>London to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 9,</td>
<td>Morning</td>
<td>Visit to Amager Resource Center Visit to Copenhill solid waste incineration plant Contact Person: Camilla Winther Krgelund, (Project Manager)</td>
<td>Resource Center is responsible for the domestic waste disposal and CDW disposal with the principle of source reduction, and prevention first. The Resource Center is neighboring the city center. The Resource</td>
</tr>
<tr>
<td>Monday</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Time</td>
<td>Individual &amp; Organisation Met</td>
<td>Details</td>
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<tr>
<td></td>
<td></td>
<td>Phone: 0045 43265737</td>
<td>Center can dispose 436 thousand ton waste per annual with only 2% waste landfilled, most waste is recycled or fueled for power generation.</td>
</tr>
<tr>
<td></td>
<td>Afternoon</td>
<td>Visit to relevant building construction waste treatment</td>
<td>The EPB of Copenhagen Municipal Government is a sustainably developing and planning department, introducing the waste disposal status of Copenhagen. The government has the obligation to establish policies and planning, implement inspection, and consult residents. The collection of residential waste is responsible by government, while the industrial waste is responsible by enterprises. In 1996, several activities were began to carry out with law issued, including waste classification, data collection and analysis, qualification required for waste disposal, and promotion policies for waste classification and recycling. Currently, 87% of CDW has been recycled and reused.</td>
</tr>
<tr>
<td>May 10, Tuesday</td>
<td>Morning</td>
<td>Visit to Danish building research institute, Aalborg University</td>
<td>In 2006, Danish building research institute was incorporated to Aalborg University to promote the combination of production and research in compliance with governmental requirements. During the visit, Danish building research institute introduced its basic information and major study scope, and the newly identified pollution and treatment of PCB in recent years. In their perspective, PCB could be fully reused after extracting the hazardous ingredients.</td>
</tr>
<tr>
<td></td>
<td>Afternoon</td>
<td>Return flight</td>
<td></td>
</tr>
<tr>
<td>May 11, Wednesday</td>
<td></td>
<td>Arrive in Beijing</td>
<td></td>
</tr>
</tbody>
</table>
3 Policy Recommendations and Capacity Building

Based on the findings of the PRC study, the international best practice review and the overseas study tour, a long-list of potential policy measures was developed. These potential measures are presented in Error! Reference source not found..

The potential applicability of these measures in China is discussed and developed in this Section, and recommended policy measures are presented in Table 3-2.
### Table 3-1: Applicability Analysis of Potential Policy Recommendations in PRC

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Main Features</th>
<th>Example Countries where Applied</th>
<th>Effectiveness in Strengthening CDW Management</th>
<th>Key Issues</th>
<th>Status and Basis</th>
<th>Analysis of Suggested Policy Measures for the PRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legislation and policies</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1. Lack of clear CDW regulations and introducing “duty of care” regulations.</td>
<td>Identifying legal responsibilities and obligations of government, generators and treatment operators.</td>
<td>Japan, Korea</td>
<td>Providing a legal basis for CDW management and recycling</td>
<td>Useful, but involving great difficulty, complicated procedure and long time to enforce.</td>
<td>Not available and having impacts on the management and recycling effect</td>
<td>Introduction of a Law or Regulations specifically focused on CDW and which clearly sets out the objectives and responsibilities for CDW management would be beneficial. Such regulations should clearly set out the responsibilities throughout the supply chain (from designers through to disposal sites) and also the responsibilities of the various government bodies. Local regulations such as the Construction Waste Management Regulations of Xi’an City can be used as a template for national regulations. Generators of CDW (construction clients/project proponents/principal contractors) should have a legal “duty of care” to ensure that CDW from their project is managed in accordance with the law. Penalties should be in place in the event that this duty of care is breached, such that (for example) a principal contractor can be penalized under the law if a subcontractor disposes of CDW illegally, if the principal contractor cannot demonstrate that he took reasonable steps to satisfy himself that the CDW was being managed in a suitable way. All levels will therefore have a common interest in ensuring that the law is followed.</td>
</tr>
<tr>
<td>2. Enforcement of prohibitions on illegal dumping.</td>
<td>Active enforcement of penalties on illegal dumping, with fines or other punishments at a level which are a proper deterrent to illegal behaviour.</td>
<td>UK, Hong Kong, Japan, Germany, Denmark and most other developed economies.</td>
<td>Essential in order to allow other economic measures to take effect.</td>
<td>Potentially applicable, but requires strong and transparent law enforcement.</td>
<td>Due to great difficulty in law enforcement and low cost of law violation, it becomes difficult to control illegal dumping.</td>
<td>Penalties for illegal disposal of CDW should be increased to highlight the environmental damage and hazard to life that can be caused.</td>
</tr>
<tr>
<td>3. Landfill bans for recyclable CDW</td>
<td>Prohibition on the disposal of certain types of waste (typically unsorted CDW) to landfill.</td>
<td>Netherlands</td>
<td>Effective, but requires a range of measures and infrastructure to be established in order to be effective.</td>
<td>Difficult to implement without first establishing a network of CDW recycling facilities as an alternative to landfill.</td>
<td>CDW recycling enterprises having no source of material supply</td>
<td>Landfill bans for unsorted CDW are unlikely to be a realistic policy at the national level in China, due to the lack of CDW recycling facilities; in the absence of these facilities, it is likely to lead to a significant increase in illegal dumping, or existing CDW recycling facilities being overwhelmed with poor quality CDW.</td>
</tr>
<tr>
<td>4. Tax on landfill disposal.</td>
<td>Tax or mandatory charging scheme for disposal of waste to landfill, often with different bands for mixed and inert wastes.</td>
<td>UK, Denmark, Hong Kong</td>
<td>Very effective in developing alternatives to landfill, but with risk of increased fly-tipping if enforcement is poor. Likely to stimulate the supply of recycled CDW</td>
<td>Potentially applicable: requires strong enforcement against illegal disposal.</td>
<td>Tariff revenue is lower than recycling cost, making recycling difficult.</td>
<td>Mandatory tariffs for CDW transport and disposal are a potentially applicable policy solution in China. The use of a tariff system opens the door to a “banded” system such as that used in Hong Kong, where tariffs can be set differently for different materials, thereby incentivizing contractors to sort CDW prior to disposal. A tariff system can be used in conjunction with CDW transport and processing franchises, either exclusive or non-exclusive. Under an exclusive franchise, a franchise holder has the right (and potentially also the obligation) to accept all CDW within the franchise area. Under a non-exclusive franchise, a number of different companies can be effectively licensed to accept CDW. These franchises can either be private enterprises or public-private partnerships (PPP).</td>
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<table>
<thead>
<tr>
<th>Instrument</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Tax on primary aggregates.</td>
<td>Tax on primary aggregates in order to make recycled aggregates more cost-competitive.</td>
<td>UK, Sweden</td>
<td>Helpful in stimulating the market for recycled aggregates.</td>
<td>Potentially applicable; may be opposed by aggregates and construction sectors as introducing additional costs to the industry.</td>
<td>Price of natural aggregates is lower than that of recycled aggregates, resulting in no market for recycled aggregates</td>
<td>Taxes on primary aggregates are likely to be strongly resisted by the quarrying and construction sectors and their benefits in the Chinese context are uncertain, hence are not recommended at present.</td>
</tr>
</tbody>
</table>
| Subsidies to CDW processing facilities. | Provision of subsidy to operators of CDW processing facilities, for example by paying the capital costs of facility establishment or guaranteeing the supply of CDW material or outlets for recycled products. | Hong Kong, Japan (to a limited extent).                   | Can help to establish facilities which are able to recycle CDW as an alternative to landfill disposal, if markets otherwise would not be viable. | Potentially applicable; if markets for recycled materials rely on subsidy, government may be committed to providing on-going subsidies, and there is a risk of producing material for which there is insufficient market demand. | It is difficult for recycling enterprises to sustain without subsidy. | Continue existing tax exemptions. Consider measures to support CDW processing facilities by either:  
a) Providing land allocations at no/low cost  
b) Providing capital to franchised CDW processing facilities via PPP arrangements |
| Targets for CDW recycling on Government-funded projects. | Many infrastructure projects are either funded or directly built by Government; this gives Government the opportunity to set targets for CDW recycling and for the use of recycled CDW materials. | UK, Hong Kong, Denmark, Germany. | Helps to kick-start the market for recycled products by providing a secure outlet. Establishes positive behaviours in CDW management that can then be replicated in the private sector. | Useful, but the slogans are difficult to enforce during project implementation. | Not noticeably effective without mandatory measures. | Targets should be set for the use of recycled CDW products in all Government-funded projects. These targets could be made mandatory. |
| Lack of planning for CDW management by governments, designers, and contractors | CDW facility is one of the urban infrastructures and requires long-term planning and excellent coordination with urban planning and land planning. The same requirement applies to responsible persons of various stages. | Japan, Korea, Singapore, etc. | Very important; subsequent activities can only be assured by well-developed top design and frontend design. | Useful, but lack of concept and respective provisions at the moment. | Due to lack of planning, great difficulty is incurred for layout planning, land use planning and actual implementation | All urban planning policies should include a separate category for CDW recycling facilities (different from construction material manufacturing site), which should be permitted in urban areas subject to necessary environmental impact assessments and land use zoning restrictions. Master planning studies should include suitable provision for CDW management. Construction projects exceeding a minimum size threshold should be required to prepare a Construction Waste Management Plan (CWMP) which will require submission and approval by the relevant Government body prior to construction commencing, and will also be required to submit a Construction Waste Monitoring Report (CWMR) before completion of the work can be certified. The CWMP should include, as a minimum:  
- Estimates of CDW quantities.  
- Roles and responsibilities for CDW management on site during construction.  
- Mitigation measures to minimize waste generation, maximize source-separation, and reduce local nuisance impacts of CDW.  
- Details of facilities to be used for recycling or disposal of CDW.  
- Description of how CDW generation and management will be monitored and reported during the construction process. |
### Management arrangements

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Main Features</th>
<th>Example Countries where Applied</th>
<th>Effectiveness in Strengthening CDW Management</th>
<th>Key Issues</th>
<th>Status and Basis</th>
<th>Analysis of Suggested Policy Measures for the PRC</th>
</tr>
</thead>
</table>
| Division of responsibilities and lack of coordination amongst Government bodies. | A full process and whole industrial chain seamless management should be developed through joint and synthetic efforts. | Japan | Helpful to responsibility allocation, job coordination and efficiency promotion | Useful, but with great difficulty and requiring support from the whole management system | Fragmented management and lack of integration and coordination | Policy measures are required to:  
   a) Define lead agencies for day-to-day CDW management; and  
   b) Ensure inter-agency coordination.  
Following the model of successful case study cities, it is suggested that the Urban Management Department should take the lead role in CDW policy implementation and enforcement at the city level; and should establish formal inter-agency committees or coordinating bodies including other bodies. |

### Standards and Guidance

| Technical guidance, specifications, and best-practice guides. | Production of a suite of guidance documents, aimed at all levels in the construction industry (site operatives, contractors, designers and clients), which explain how to comply with regulations and highlight examples of best practice, and which provide clear specifications for recycled CDW materials. | UK, Hong Kong, Japan, Germany, Denmark and most other developed economies. | Important in ensuring that regulations are translated into practical actions, and in building confidence in the construction industry to use recycled materials. | Useful, but the key is to enforce and provide supports | Lack of full and detailed technical guidance | Working via existing research institutes, produce training/education materials for construction sector – "how-to" guides, case studies etc.  
Research should be carried out to establish a series of benchmarks for CDW application for various types of project. These benchmarks are then used to encourage or require, when letting construction contracts, the contractors to meet or improve on the benchmarked waste application rate. |

| Protocols or standards for recycled CDW materials. | Published standards or protocols which set out the procedures and quality standards for production of recycled materials from CDW and identify the key points of waste management controls. | UK among others | Helps to build confidence in recycled CDW materials and hence develop markets. Helpful to reduction | Applicable: can be integrated with existing standards and specifications for construction materials. | Partly available, but pending further improvement | CDW recycling is a systematic effort requiring specifications and standards of all aspects and unified action to become effective. At present, standards are available for only some products and applications and there are no standards for source design, construction, demolition and transportation. As a result, standards cannot perform fully. Therefore, it is an important task to improve the entire standard system. |

### Whole Process Management

| Construction waste disposal permit | Qualification management to be strengthened, principal responsibility identified and uncontrolled competition avoided. | All countries of high recycling rate | Helpful to task management and responsibility enforcement | Useful, but requiring further efforts of coordination and implementation | Producers of construction wastes should apply for and obtain a "Construction Waste Disposal (Discharge) Permit" which should not be granted until the procedures of reporting, generation verification and disposal fee payment are fulfilled and a valid CWIMP submitted. Regular reporting of the transportation vehicles should be required, with the reported information shared by the city administration and traffic police authorities via the Comprehensive Management System of Construction Wastes. |

<p>| Mandatory source-separation of CDW. | Requirement for all CDW to be separated into different components at the construction site. | Japan, Seattle (USA), Germany, etc. | Effective if properly enforced at the site level, and if suitable separation facilities and markets are in place for the separated materials. | Requires high level of enforcement and oversight of construction sites and significant changes in behaviours. | Significant increase of recycling treatment cost, loss of disposal enterprises, impacts on quality of recycled products | Mandatory source-separation of waste is adopted in some countries (e.g. Japan), but requires a high level of enforcement and may place a considerable operational burden on contractors where space is limited on construction sites. It is also likely to require a high degree of education, training and cultural shift in order to get the construction sector to fully comply. Bearing this in mind, achieving source-separation of CDW is best viewed as a long-term objective which can be supported by other specific policy measures such as differentiated tariffs, rather than as a national mandatory requirement. However, |</p>
<table>
<thead>
<tr>
<th>Instrument</th>
<th>Main Features</th>
<th>Example Countries where Applied</th>
<th>Effectiveness in Strengthening CDW Management</th>
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<th>Status and Basis</th>
<th>Analysis of Suggested Policy Measures for the PRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licensing of waste hauliers and use of trip tickets/transfer notes/manifests.</td>
<td>CDW can only be transported by licensed hauliers and all consignments of waste must be accompanied by a note (physical or electronic) which describes source, type and quantity of waste.</td>
<td>UK, Hong Kong, Japan, Germany, Denmark and most other developed economies.</td>
<td>Improved data collection, better control of CDW management, and aids enforcement.</td>
<td>Useful, but only in restricting the compliant hauliers, with illegal transportation not reported at all.</td>
<td>Already implemented in some cities, but such measures can be effective without source control.</td>
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<td>national policy should support the introduction of mandatory source-separation by city-level governments in those cases where the local government is capable of enforcing these provisions and where there is sufficient reprocessing infrastructure in place.</td>
</tr>
<tr>
<td></td>
<td>Licensing of waste hauliers and use of trip tickets/transfer notes/manifests.</td>
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<td>Mandatory registration of CDW transportation enterprises, conditional on achieving defined minimum standards for vehicles and staff. The registration process should include checks prior to registration, and regular inspections to ensure standards are maintained. The process should include measures to remove registration in the event of failure of inspections or significant/persistent breaches of environmental or safety regulations.</td>
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<td>Mandatory system of &quot;trip tickets&quot;/manifests for all loads of CDW leaving a site. Systems may be paper-based or electronic and should follow a particular load of waste from the point of generation (leaving a construction site) to the point of disposal/recycling. Sites will be required to make regular data returns to the relevant statistical authorities.</td>
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<td></td>
<td>Cities and provinces should be required to prepare annual CDW management reports which include detailed statistical information on the generation and management of CDW</td>
</tr>
</tbody>
</table>
3.1 Awareness Raising

Studies and research on CDW management and recycling try to develop solutions to managing construction and demolition wastes, focusing on the issues at the last stage of building’s life. But to be effective, CDW management needs to take account of the whole lifecycle of a building and consider processes from design and construction, as well as broader areas such as environment and resources, new-type urbanisation and sustainable development. Over the past years, a large number of studies have been done on the planning, project identification, design, construction, structure and materials, energy saving and safety, etc., resulting in a series of procedures and standards to be followed strictly. However, less attention has been paid to the deconstruction or demolition of buildings, and the generation and disposal of CDW. Therefore, there are many problems in the management of CDW, including lack of data, unclear definitions, absence of demolition management, and insufficient awareness and understanding of CDW management leading to the current disordered and illegal dumping that risks public health and safety. Hence, it is critical to raise the awareness and understanding of both authorities and the public on the management and recycling of CDW.

Despite their limited size on the earth’s surface, the development of cities exert immense demands and pressure to the environment. Within the limits of our planet, recyclable and sustainable development is the only solution to urbanisation. The generation and treatment/disposal of CDW should be treated as a necessary part of urbanisation and the treatment and disposal facilities for CDW should be included as one of the components of city infrastructure during the early stage of preparation of the master plan and land use plan of the city.

The management and recycling of CDW should cover the life span of building, and address the whole processes of construction and the full chain of CDW treatment and disposal.

There is no contradiction between the harmless treatment and recovery or recycling of CDW. Harmless treatment is a prerequisite for reusing the recycled or claimed CDW, while CDW recycling provides a pathway to achieve harmless treatment. One supplements another, and none of them prevails. Ideally, all wastes should be recovered and recycled as much as possible, and safe storage and harmless treatment should be done for the rest that cannot be made for resource recovery with current technologies. Principles guiding CDW treatment and disposal include adjusting and tailoring to local environment and conditions, holistic planning and design, inclusive treatment and disposal and achieving a comprehensive solution to all problems.

3.2 Improve Legislation and Regulations

Legislations and regulations provide the legal basis and guidance for practitioners and entities to follow and have deterrent effects. Due to years of neglect of CDW management, there is very little or even no sections about the CDW in relevant legislations in China. In contrast, the management of domestic wastes has been specifically described in relevant legislations, e.g. the “Environmental Protection Law and the Prevention and Control of Environmental Pollution by Solid Waste”. Equal attention should be paid to the management of CDW. Especially, requirements on CDW management should be written into key relevant legislations, for example, to the “Construction Law,” adding ‘prepare holistic CDW treatment and disposal plan and report to relevant authorities for the record’ as another prerequisite of the Ground-breaking Permit, and articles to promote purchase of recycled products from CDW, such as ‘using C&D materials and recycled content products for new construction is encouraged by the national government’. It is recommended that Administrative Regulations on Construction and Demolition Waste Management should be prepared and issued, based on the current Provisions on the Administration of Urban Construction and Demolition Waste, to clearly specify how to implement the principle of ‘producer responsibility’ with details, incorporate or further clarify the ideas of ‘holistic planning, investment in infrastructures, whole process management, recovery and recycling, and buying of recycled product, etc.’, with practical measures, and to increase penalties for non-compliance and violations and improve the legal management of CDW.

In view of the current situation of ‘build it forget the demolition’ and lack of basic data, it is recommended to establish an appraisal and register system for building demolition, set up data collection and processing system, associate the CDW management with the current administrative permit system for construction project, incorporate requirements on CDW management and recycling into the review
criteria those will be reviewed against when issuing ‘one report and two permits’ for construction projects, and to issue ‘expiry certificate’ of buildings based on existing files and records. The lifecycle management of buildings should be promoted to improve the management and recycling of CDW, and to prolong the useful life of building.

In order to better manage CDW from the source, avoid misreporting to sanitation and/or city administration authorities, and collect data on CDW generation and type, a declaration and registration system for CDW management should be set up to enhance the reporting and inspection of CDW streams. Before construction or demolition, entities who produce CDW should be required to report the types, generation, stops and destinations, storage and disposal, etc. to the local responsible authority for CDW disposal above the county level. The governance of authorities on the generation, transportation and disposal of CDW should be strengthened at all levels. The application materials in written form, as required, should be reviewed carefully and approved strictly. When necessary, a third party should be designated to check on site. All activities to be conducted by owners, contractors and entities responsible for CDW transportation and disposal should only be started with approvals. In large to medium size cities, authorities for environmental protection should release information on generation, disposal and other matters about CDW to the public at regular intervals to facilitate supervision and government by the public and related agencies.

The charging system for CDW should be improved, based on principle of ‘producer pays’: costs and fees relating to the collection, transportation and disposal should be paid by the entity that produces the corresponding wastes. Costs of CDW disposal should be included into the “Quote for Budgeting Building Construction and Finishing Project”. With subsidies for cost recovery and allowing for rational profit for the operator, charging rates should be determined by the city government according to local conditions and references as for service suppliers. In this way, subsidies will be not only for the disposal entities, but also benefit entities who purchase used C&D materials and recycled products.

3.3 Management Reform

A uniform appellation and definition should be agreed at the national level. Supported by careful analysis and tradeoffs, the Chinese terminology could be decided as either “C&D waste” (“laji”), “C&D residual material” (“feiqi wu”) or “construction castoff” (“Qiwu”). In Chinese, the name ‘laji’ follows historical practices, although can mislead the audience to treat such materials as useless. C&D ‘Qiwu’ is more objective, indicates they are castoffs and residuals rather than wastes generated during construction, and likely to indicate a better acceptance of recycled products made from them. Formalizing the name or terminology will relate to many issues, such as administration permit and tax exemption, etc., and would require dissemination nationally and at all levels. Roles and responsibilities of each ministry/committee/commission should be further clarified based on sector positioning and from the perspective of the whole chain and overlaps and linkages between agencies should be carefully managed. The current management arrangements were decided by State Commission Office of Public Sectors Reform (SCPPSR) in 2010 based on understandings by that time. According to MIIT’s strategy, CDW recycling enterprises are treated and managed as enterprises producing new building materials. Since CDW arises from city infrastructures, it may be more rational for them to be manged by MOHURD and its departments. Management complications need to be reviewed and balanced. It is therefore essential to set up an effective coordination mechanism at national level.

At the local level, roles and responsibilities for managing and recycling CDW should be clearly identified, led by local government with administrative and technical guidance provided by the provincial HURD. The authority or association of several authorities, normally the city administrative department according to present practices, should be set up or appointed by the government at municipal level. Within the integrated and accountable management system, the full chain from CDW generation to purchase of recycled products will be managed. Public supervision and complaint routes should also be enhanced by sharing information with departments of public security, transportation and others, improving inter-agency cooperation and coordination, strictly implementing designated duties and achieving synergies. This will improve public supervision and grievance redress. Government performance evaluation, such as issuing of city name-cards, should include indicators reflecting the performance of CDW management and recycling. By getting more attentions from the key governors at city level, CDW management and recycling would be facilitated.
3.4 Whole Process Management

3.4.1 Promote Source Reduction

Policies should be introduced to further implement the “Green Building Action Plan” nationwide, promote prefabricated buildings, and identify development targets of the proportion of prefabricated buildings (in percentage terms) in various places. Through concept propaganda, training, and education, project research should be carried out to establish relevant technical standard and other measures. This will encourage design institutes and designers to consider CDW source reduction and include direct reuse measures during the design stage. Construction companies, or contractors, should practice “Green Construction”, include costs for CDW disposal, reduction plan and other relevant costs into their engineering project management. Generation of CDW and the reduction and disposal plan should be included in the project identification, and should be part of the design document and construction plans. At the construction stage, construction companies, consulting firms and design institutes should thoroughly consider the balance of cut and fill, and adopt reusable construction materials with long service life and ease of maintenance. The choice for technique and auxiliary materials for excavation should consider the feasibility of recovery and recycling of CDW, to minimise the potential harm. Government should promote development and construction of a good standard of primary decoration in housing, to reduce the need for secondary fit-out, and at the demolition stage, should regulate the demolition process. Where possible, contractors should use mobile facilities for direct reuse locally or recycling processing of CDW.

3.4.2 Implement Sorting and Separation

Owners and construction companies should classify, store and transport CDW according to approved plans for sorting and recycling, including earth, broken concrete, tiles and bricks, metals, wood, plastics, and others. Mixing of toxic and harmful wastes and domestic wastes with CDW is prohibited, and the CDW should be handed over to entities with relevant qualifications for treatment and disposal. Demolition of buildings and structures of building for manufacture, storage and usage of materials for chemical industry, metallurgy, pesticides, electroplating, and dangerous chemicals should be conducted after the environmental risk appraisal and completion acceptance of environmental protection by local environment department or bureau. For unsorted or poorly-sorted CDW, the receiving entity could increase charging rates based on market prices to recover the costs for sorting them out properly.

3.4.3 Construction Site Management

Construction companies, or contractors, should practice “Green Construction”, and before construction starts, prepare CDW disposal and reduction plans, and budget for associated costs. Generated CDW during construction should be stored separately by type. Mobile facilities could be used to directly reuse as much materials as possible on site, minimizing the CDW transported.

The requirements on separation storage, harmless treatment and on-site reuse should be included in the criteria and indicators for evaluation of “Civilized Construction Site” and other competitions.

3.4.4 Transportation and Disposal

Reasonable dynamic referential prices for transporting CDW should be identified according to local economic development. Source management should be strengthened to avoid illegal trucks being used for CDW transport. Entities providing CDW transportation should make sure all vehicles are installed with proper covering facilities, camcorder, measurement and monitoring facilities and GPS. A regulatory platform should be established, employing tools of internet and manifests, etc., to prevent secondary pollution caused by releases of CDW and dumping on illegal sites, avoiding corresponding social cost. Training of drivers should be enhanced to avoid over-loading, speeding and red-light running. Relevant agencies should collaborate and enhance the implementation of legislation and regulations jointly, and conduct dynamic management of the transportation firms and drivers. Adoption of the new type of smart and environmentally-friendly haulage vehicles should be promoted. Large and professional firms for CDW transportation should be encouraged and supported to achieve integrated operation, dispatching and management.
3.4.5 Disposal Facilities

Due to the properties of CDW (particularly the large quantity and variability of material), the transporting distance should be reasonable; and the long chain of processing requires a large land footprint CDW management facilities. Land use for CDW disposal facilities should be included into urban construction and development plans in order to ensure that suitable land is secured, and land should be provided with preferential rates and conditions when compared to other industrial uses. It is recommended to manage CDW treatment and disposal facilities as an important component of urban infrastructure, speed up the planning and construction and improve the treatment capacity and quality. Studies and preparation of planning for CDW treatment and disposal facilities should be done by local authorities for CDW management together with authorities for construction management to optimize the layout of disposal, landfill and recycling facilities. Locating the disposal and recycling facilities at one site is encouraged. Recycling facilities for CDW should be incorporated into the master plan, land use plan, planning for circular economy and the specialized plan for city aesthetics and sanitation, to make the land use secured. In addition, the establishment of mobiles CDW treatment facilities should be encouraged. The construction and management of CDW disposal sites, no matter whether permanent or temporary, should follow relevant standards and ensure the minimum environmental impacts and safety.

For the EIA process, it is recommended to prepare criteria in favour of CDW recycling firms, and adopt different evaluation methods for fixed and mobile facilities. Current requirements on environmental protection benefiting the environment and eliminating secondary pollution should be maintained, and at the same time, be practical and realistic, and able to differentiate the CDW management facilities from normal manufacturing and processing companies for building materials.

3.4.6 Process Monitoring

Declaration and registration systems for CDW management should be set up to enhance the reporting and inspection of CDW streams. An independent third party should be employed for the inspection. In the inspection documents, information should be clearly written including the total generation of CDW and the types from the project, name of entities for transportation, time and route; name of consignor of transportation and its qualification; the name, location, qualification and the disposal or recycling plans for each type of wastes of the receivers to transfer, disposal site and/or recycling facilities. All activities to be conducted by owners, contractors and entities responsible for CDW transportation and disposal, should only be started with approvals. It is recommended to establish a Management Information System (MIS) for CDW, using information tools to manage manifests from the generation of CDW, to discharging, transportation and disposal to allow for tracking of sources, prediction of destinations, and accountability of responsibilities.

3.5 Application and Promotion

3.5.1 Protocols or Standards for Recycled Materials

Recovery and recycling of CDW is a systematic process, and normally has a broad range from producing, collection, transportation, storage, to sorting, treatment, recycling and reclaiming and marketing, etc., involving many stakeholders along its long processing cycle. The CDW recycling industry in China is in an early stage of development. It is essential to establish a technical standards system covering the entire processes, in order to ensure the quality and effects of the CDW recycling. The system could target three main aspects:

- firstly, clearly identify the relationships between different agencies, procedures and processes;
- secondly, quality control of recycled products and materials; and
- thirdly, the market admittance criteria and applications.

Based on experience and requirements of CDW recycling in China, four key stages could be identified as:

- source,
- collection and transportation,
- processing and recycling, and
recycled products and application.

Source reduction, and standards guiding the engineering design, construction and demolition, etc. for easier recycling will be managed at the first stage of ‘source’. In the second stage, collection and transportation, standards will focus on the sorting and collection of CDW, higher efficiency of recycling and low carbon transportation, etc. to achieve effective management of CDW and lower economic cost of recycling. The third stage of processing and recycling is mainly concerned with designing of the treatment to ensure the quality of products and green production. The last stage focuses on the quality of recycled products and their large scale applications, including standards of the recycled aggregates, powders, intermediate products, and different kind of products made with the intermediate products entirely or partially replacing natural materials, such as concrete, mortar, bricks, and blocks, etc., as well as the technical standards of using the aforementioned materials and products in construction.

Experiences from countries with well-developed CDW recycling systems indicate that standardization contributes to establishing confidence in recycled CDW products, and helps with market exploration and promotion of source reduction. In its early stage of the development of CDW recycling, China has been establishing standards for CDW recycling, although there are only a few standards for some products and their applications, and none for the upstream design, construction, demolition and transportation. The absence of many required standards, and the limited effectiveness of existing ones, has resulted in a slow development of the CDW recycling.

Considering the development potentials of CDW industry and existing standards, future works could be done in the following areas to supplement and complete the standards system:

- based on the 3R principles, preparing Standard for Basic Terminology for CDW Recycling, Technical Specifications for CDW Recycling and Application, and Technical Code for CDW Reduction, etc.;
- in order to match the properties of recycled aggregates and needs for application, revising the existing Recycled Fine Aggregate for Concrete and Mortar, and Recycled Coarse Aggregate for Concrete, etc.;
- preparing more standards to supplement existing ones for recycled products, including standards for products difficult to be included and described in existing standards, such as Recycled Powder from CDW and Flting Materials recycled from CDW, and for those with similar properties with other materials and could be included in existing standards, incorporating sections about the recycled material into existing standards and the indicators could be adjusted slightly, such as standards for recycled blocks and mortar;
- revising the existing Technical Specification for Application of Recycled Aggregate to enhance the requirements by applying recycled aggregates for producing other building materials;
- to meet the diverse demands by application of recycled aggregate, preparing technical standards for application of other main recycled products, such as Technical Specification for Application of Recycled aggregate and Inorganic Mixture, Technical Specification for Application of Recycled Controlled Low Strength Materials, or Technical Specification for Application of CDW in Concrete;
- and preparing certification standards for recycled products to help users selecting from the list and to include recycled products into the recommended list for green building materials, creating enabling environment for engineering design, application during construction and successful completion acceptance.

3.5.2 Pilot and Demonstration Projects

Compared to traditional materials, recycled materials have a few limitations, however, from a technical point of view, the requirements for application in construction could be fully met with feasible design and quality control of recycled materials. In reality, lack of confidence in the quality of recycled materials impedes the application and promotion of recycled materials. Due to educational factors and traditional views on waste materials, sceptical attitudes over material recycled from wastes are prevalent, with recycled materials viewed as being ‘poor quality’. These negative perceptions have limited the reuse of recycled materials in new constructions and slowed development of the whole industry. International experiences has shown that demonstration and piloting is an effective trigger that can stimulate and boost the market for recycled materials.
Selecting pilot regions and constructing pilot projects could both increase understanding and awareness of the public on CDW recycling and enhance public confidence, and also demonstrate relevant technical and economic benefits, and improve the enthusiasm for promoting CDW recycling and technical competence in different areas. Furthermore, pilot construction and dissemination of experiences and lessons, which could be replicable to other places in China, is of important significance to the CDW recycling industry in China.

Administrative methods could be prepared to provide detailed guidance and requirements on source declaration and data collection, sorting and transportation, disposal ratio, technologies and rates for CDW recycling for the pilot and demonstration projects. It is recommended to establish 10 pilot provinces and cities with 20 pilot projects during the period of 13th Five Year Plan (FYP) demonstrating the benefits, and replicate the successful experiences in other places in China, promoting the CDW recycling and application gradually.

### 3.5.3 Contract Requirements

At present, effective, practical implementation measures with sufficient details and policies that encourage CDW recycling and reuse of its products are absent in China. It is still the early stage of CDW recycling in China, where a comprehensive system covering the entire chain from collection, transportation, processing to the quality control and marketing of recycled products is not in place. Although China has included the recycling and reuse of urban solid wastes including CDW into national strategies, effective industrial policies and the holistic management system has not been issued and established so far. From experiences of recycled CDW products in China, it could be seen that effective policy that promotes reuses of recycled materials is lacking, therefore marketing of recycled materials is impeded by the insufficient governance.

Experience overseas indicate that policies can boost the reuse market effectively and ensure the entering, buying and adoption of the recycled products in the market, and in turn enable the scaling up of the recycling facilities. According to the current status of CDW management and construction, promotion of recycled product could be done from the following four areas:

1) Include recycled materials and products into the green category of the government procurement list, and for projects financed by government projects, impose compulsory conditions on using recycled materials during the design and construction stages and identify targets for CDW recycling generated by the project and for using recycled materials, which provides a direct marketing channel and helps with opening the market for recycled materials;

2) Include use rate of recycled materials as one of the criteria for the green building evaluation, to explore the market for private sectors;

3) promote use of recycled products from city administrative aspect, for example, the recycling and reuse targets could be added into the criteria system for competitions on National Garden City, National Civilized City and Nationally Recognized Clean City, etc.;

4) according to local conditions, practical methods for promoting use of recycled materials are to be prepared and issued by local government.

### 3.5.4 Technical Guidance

The most important issue of CDW management and recycling is to achieve promotion and application of the recycled CDW products. Therefore it is necessary to establish a comprehensive system of technical guidance, regulated by corresponding laws and policies. The technical guidance could include basic requirements, recycling and reuse plan, source reduction, demolish, sorting, transportation, recycling, recycled product and its reuse, and information management etc., and will provide introduction about the best practical case nationwide.

Through establishment of the technical guidance, it is possible to provide a full set of executive guidance about each section of the CDW resource management. This guidance, based on clarification of the Laws and policy documents of each section, can define the technical content of each section and provide support on relevant CDW management and recycling work of all aspects of building industry.
(management unit, client, design, construction, recycling contractors etc.). At the same time, presentation of the best practice cases would provide beneficial references for local government management and contractors' project operation.

Good understanding and implementation of the technical guidance from the public will be beneficial to promote integrated management of CDW, centralized disposal, reuse, reduction, harmless treatment and recycling level.

3.6 Economic Instruments

Economic instruments which can be used to improve CDW management in China include:

- Fully using existing funding sources to enhance investments in CDW management and recycling, and use capital from central government for infrastructure and relevant special funds to support the building and operation of CDW recycling facilities.
- Continue to implement preferential taxation policies for imported key components and raw materials for important technical equipment for CDW recycling.
- Support research on CDW recycling technologies and equipment through the national or local technology development plans, including special funds and specific projects.

3.7 Training and Dissemination

Recommended training and dissemination measures include:

- Fully utilize the existing various training regimes and improve on-the-job training of all levels of the regulatory body.
- Increase respective types of work in Occupational Classification of People's Republic of China.
- Carry out professional training program for workers.
- Fully utilize media such as magazines, radio, television, and internet, through student education, various employee training, conference etc. to improve advertisement of the management and recycling of CDW.
- Propagate ideas on reduction of CDW, recycling and harmless disposal.
- Carry out regular monitoring and propagation of the project using recycled materials, in order to obtain understanding, support, and participation of the general public.
- Set up respective disciplines and establish a construction waste engineering technology research centre or experimental base, etc. which could integrate production, learning, research and application all together.
3.8 Policy Recommendations

Policy recommendations for the CDW management are summarized in below Table 3-2, and details are provided in the above sections.

Table 3-2: Summary of Policy Recommendations

<table>
<thead>
<tr>
<th>Legislation and Policy Recommendations</th>
<th>Reason</th>
<th>Responsibility</th>
<th>Timeline</th>
</tr>
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<tbody>
<tr>
<td><strong>1.</strong> In the “Construction Law”, include ‘prepare holistic CDW treatment and disposal plan and report to relevant authorities for the record’ as another prerequisite of the Ground-breaking Permit, and articles to promote rebuying of recycled products from CDW, such as ‘using C&amp;D materials and recycled content products for new construction is encouraged by the national government’</td>
<td>To provide legal basis to the improvement of source management and utilization of recycled product</td>
<td>MOHURD, NPC</td>
<td>Long term</td>
</tr>
<tr>
<td><strong>2.</strong> Similar with domestic waste, specify sorting, treatment and disposal, and recycling and reuse of CDW in the “Environmental Protection Law”</td>
<td>To provide legal basis to the separation and recycling of CDW</td>
<td>MOHURD, NPC</td>
<td>Long term</td>
</tr>
<tr>
<td><strong>3.</strong> Similar with domestic waste, identify the definition of CDW and describe requirements on preventing pollution by CDW in the act of “Prevention and Control of Environmental Pollution by Solid Waste”</td>
<td>To provide legal basis to the enhancement of CDW management and recycling</td>
<td>MEP, NPC</td>
<td>Long term</td>
</tr>
<tr>
<td><strong>4.</strong> Revise Administration of Urban Construction and Demolition Waste, and prepare “Administrative Regulations on Construction and Demolition Waste Management”, elaborate or further clarify the ideas of ‘holistic planning, investment in infrastructures, whole process management, recovery and recycling, and buying of recycled product, etc.,’ with practical measures.</td>
<td>Update to current situation with better operability</td>
<td>MEP, NPC</td>
<td>Short term</td>
</tr>
<tr>
<td><strong>5.</strong> Issue “Guiding Opinions on the Management and Recycling of CDW” as soon as possible</td>
<td>Urgent to specify</td>
<td>MOHURD</td>
<td>By 2016</td>
</tr>
<tr>
<td><strong>6.</strong> Issue “Regulatory Conditions of the CDW Recycling Industry”</td>
<td>Urgent to specify</td>
<td>MOHURD</td>
<td>By 2016</td>
</tr>
<tr>
<td><strong>7.</strong> Include CDW into the taxable items under the “Environmental Protection Tax”, allowing CDW suitable for landfill and recycling to be taxed at rate of zero.</td>
<td>To stimulate recycling and reuse</td>
<td>MIIT</td>
<td>Short term</td>
</tr>
<tr>
<td><strong>8.</strong> Include rational costs of CDW disposal in the “Quote for Budgeting Building Construction and Finishing Project”</td>
<td>Secure budget for CDW management and recycling</td>
<td>MEP, MOF, SAT</td>
<td>Short term</td>
</tr>
<tr>
<td><strong>9.</strong> Improve the charging system for CDW, such that costs relating to collection, transportation and disposal, etc., should be paid by the waste producer</td>
<td>To enforce the principle of ‘producer responsible’</td>
<td>MOHURD</td>
<td>Short term</td>
</tr>
<tr>
<td><strong>10.</strong> Use capital from central government to support the building and operation of CDW recycling facilities.</td>
<td>To facilitate recycling</td>
<td>Local government</td>
<td>Complete</td>
</tr>
<tr>
<td>No.</td>
<td>Recommendation</td>
<td>Reason</td>
<td>Responsibility</td>
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<tr>
<td>11</td>
<td>Include imported facilities for CDW recycling into the preferential taxation lists for imported key components and raw materials for important technical equipment.</td>
<td>To promote localization of processing facilities</td>
<td>NDRC</td>
</tr>
<tr>
<td>12</td>
<td>Support research on CDW recycling technologies and equipment through the national or local technology development plans</td>
<td>To promote technology innovation and development</td>
<td>MOF, NDRC, MIIT, GAC, SAT, NEA, MOST</td>
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<tr>
<td>13</td>
<td>CDW recycling facilities should be incorporated into the master plan, land use plan, planning for circular economy and the specialized plan for city aesthetics and sanitation, to make the land use secured.</td>
<td>To secure land and infrastructure required by recycling</td>
<td>Local government</td>
</tr>
<tr>
<td>14</td>
<td>Establish appraisal and register system for building demolition, set up data collection and processing system, issue ‘expiry certificate’ of buildings based on existing files and records.</td>
<td>To enhance demolition management and improve data collection toward to fine management</td>
<td>MOHURD, local government</td>
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<tr>
<td>15</td>
<td>Promote concession system, and leverage private capital with PPP mechanism</td>
<td>To establish feasible business model</td>
<td>Relevant agencies</td>
</tr>
<tr>
<td>16</td>
<td>Pilot CDW management and recycling projects in selected provinces and cities, as well as CDW disposal projects.</td>
<td>To learn from</td>
<td>MOHURD, NDRC</td>
</tr>
<tr>
<td>17</td>
<td>Strengthen performance evaluation of local government on CDW management and recycling by introducing related indicators.</td>
<td>To call attention from government on CDW management, to support efforts from line agencies.</td>
<td>Related agencies</td>
</tr>
</tbody>
</table>

**Management Arrangements**

<table>
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<tr>
<th>Recommendation</th>
<th>Reason</th>
<th>Responsibility</th>
<th>Timeline</th>
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<tbody>
<tr>
<td>18. Agree on definition of CDW. Clarify roles and responsibilities of each ministry/committee/commission and manage the overlaps and linkages between agencies. Establish effective coordination mechanism at national level.</td>
<td>To improve management and recycling of CDW all over China</td>
<td>State Council, MOHURD</td>
<td>Short term</td>
</tr>
<tr>
<td>19. Led by the local government, identify the authority(s) for CDW management, establish responsible and accountable integrated management system covering the whole chain from CDW generation and reuse of recycled products.</td>
<td>To specify responsible authority and establish accountability system</td>
<td>Local government</td>
<td>Short term</td>
</tr>
<tr>
<td>20. Share information and work with relevant departments, improving inter-agency cooperation and coordination, strictly implementing designated duties and achieving synergies. Improve public supervision and grievance redress.</td>
<td>To form synthesis</td>
<td>Local government</td>
<td>Short term</td>
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</table>

**Standards**

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<tr>
<th>Recommendation</th>
<th>Why</th>
<th>Responsibility</th>
<th>Timeline</th>
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<tbody>
<tr>
<td>21. Establish the standards system for CDW management and recycling.</td>
<td>To perfect standard system</td>
<td>MOHURD</td>
<td>Short term</td>
</tr>
</tbody>
</table>
23. Set up product standards in documents such as “Recycled Powder from CDW” and “Filtering Materials recycled from CDW”
   - To exploit the application of recycled product
   - MOHURD, MIIT
   - Short term

   - To regulate utilization and ensure quality
   - MOHURD
   - Short / long term

25. Set up certification criteria for recycled products.
   - To supplement relevant policy
   - MOHURD
   - Short term

26. Prepare EIA criteria appropriate for CDW recycling firms.
   - To promote recycling with minimum environmental impacts
   - MEP
   - Short term

27. Revise existing standards including “Technical Specification for Application of Recycled Aggregate”, “Recycled Fine Aggregate for Concrete and Mortar” and “Recycled Coarse Aggregate for Concrete”
   - To match current situation and demands
   - MOHURD
   - Short term

28. Incorporate articles on on-site CDW reduction and reuse in relevant technical standards of construction, such as ‘Code for Quality Acceptance of Concrete Structure Construction’.
   - For better on-site CDW reduction and recycling
   - MOHURD
   - Short term

29. Prepare ‘Technical Code for Building Deconstruction’ specifying compulsory conditions and requirements on demolition procedures and on-site sorting, etc.
   - To facilitate resource management and separation, reduce costs for recycling and ensure quality of recycled product
   - MOHURD
   - Short term

   - To regulate CDW transportation
   - MOHURD
   - Short term

### Whole Process Management

<table>
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<tr>
<th>Recommendation</th>
<th>Why</th>
<th>Responsibility</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>31. Establish declaration and registration system of CDW: local governments should publish information on CDW production and disposal.</td>
<td>Required by laws and regulations, to ensure source reduction, and to raise attention from local government and improve public supervision</td>
<td>MOHURD, MEP, local government</td>
<td>Short term</td>
</tr>
<tr>
<td>32. Add inspection requirements of CDW management and recycling into the construction project management.</td>
<td>By linking with existing administrative permits, to promote CDW management and recycling</td>
<td>MOHURD</td>
<td>Short term</td>
</tr>
<tr>
<td>33. Push forward research on waste minimisation in design and construction.</td>
<td>To promote prevention and reduction</td>
<td>MOHURD</td>
<td>Short term</td>
</tr>
<tr>
<td>34. Enforce CDW separation on site. Include the requirements on separate storage and on-site reuse into the criteria and indicators for evaluation of “Civilized Construction Site” and other competitions. Set up major professional CDW transport company.</td>
<td>To promote source separation and manage sources and outflows</td>
<td>MOHURD</td>
<td>Short term</td>
</tr>
<tr>
<td>35. Implement dynamic qualification management on the transport company, vehicles, and drivers. Promote usage of new vehicles.</td>
<td>To reduce fly-tipping and secure collection.</td>
<td>MOHURD</td>
<td>Short term</td>
</tr>
<tr>
<td>36. Promote construction of CDW disposal infrastructure. Prioritize resource facility</td>
<td>To ensure collection and increase treatment</td>
<td>MOHURD,</td>
<td>Short term</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td><strong>development.</strong></td>
<td><strong>capacity, reduce pressure to landfills.</strong></td>
<td><strong>NDRC, MIIT</strong></td>
<td></td>
</tr>
<tr>
<td>37. Establish CDW information management system, make use of internet and data mining tools to carry out real-time monitoring on CDW production, emission, transport, disposal and application etc.</td>
<td>By making use of advanced tools, to enhance management and secure recycling</td>
<td>MOHURD, MIIT Short term</td>
<td></td>
</tr>
<tr>
<td>38. Establish construction waste engineering technology research centre/experimental base etc.</td>
<td>To boost technology innovation and provide technical supports</td>
<td>NDRC, MOST Short term</td>
<td></td>
</tr>
<tr>
<td>39. Carry out professional training program for employees from various industries. With the help of media, promote propaganda of CDW management and recycling.</td>
<td>To strengthen capacity of professional, increase awareness and understanding of community and mobilize public participation</td>
<td>Relevant agencies Short term</td>
<td></td>
</tr>
</tbody>
</table>
4 Cost & Benefit Analysis

4.1 Economic Analysis

4.1.1 Assumption

The cost-benefit analysis in this section is based on the policy recommendations made in the preceding section, and makes the following assumptions.

(i) Assuming by 2020, the recycling rate of CDW will reach 35%, and 100% harmless disposal rate can be achieved for the remaining unrecycled CDW. Assuming 5% growth rate for CDW recycling during 2016 – 2020, the recycling rate of CDW in 2017, 2018, 2019, will be 20%, 25%, 30% respectively based on an assumed 15% recycling rate in 2016.

(ii) According to the statistics mentioned in Output 1 of this Study, CDW generation in China during 2016 – 2020 is shown in the table below.

Table 4-1: Annual Production of CDW in China (2013 – 2020)

<table>
<thead>
<tr>
<th>Year</th>
<th>Demolition Yield</th>
<th>Construction Yield</th>
<th>Decoration Yield</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>716,265</td>
<td>662,970</td>
<td>504,341</td>
<td>1,883,576</td>
</tr>
<tr>
<td>2017</td>
<td>737,752</td>
<td>682,859</td>
<td>519,471</td>
<td>1,940,083</td>
</tr>
<tr>
<td>2018</td>
<td>759,885</td>
<td>703,345</td>
<td>535,056</td>
<td>1,998,286</td>
</tr>
<tr>
<td>2019</td>
<td>782,682</td>
<td>724,445</td>
<td>551,107</td>
<td>2,058,234</td>
</tr>
<tr>
<td>2020</td>
<td>806,162</td>
<td>746,179</td>
<td>567,641</td>
<td>2,119,981</td>
</tr>
</tbody>
</table>

(iii) The disposal approaches for CDW recycling can be divided into fixed and mobile types. It is assumed in the study that the applied ratio for mobile and stationery approach is 30% and 70% respectively. Costs for mobile and fixed CDW processing and for landfilling of CDW are assumed to be as described in Output 1 of this Study.

(iv) The recycled CDW products will have a promising market after the enforcement of the policy, and 100% sales rate could be reached for all recycled CDW products in the market. Prices for recycled CDW products are assumed to be as described in Output 1 of this Study.

4.1.2 Economic Analysis

(1) Computation of Total Investment Cost

Based on the above assumptions, in order to achieve the targeted recycling rate as well as the harmless disposal rate for CDW in 2016 – 2020, the computation for the annual total investment cost is shown in the table below.

Table 4-2: Total Investment for CDW harmlessness and recycling in China (2016-2020)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Generation</th>
<th>Recycling Rate</th>
<th>Investment Cost of Recycling</th>
<th>Investment Cost of Landfilling</th>
<th>Total Investment Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Recycling Rate</td>
<td>Cost of Stationary Approach</td>
<td>Cost of Mobile Approach</td>
</tr>
<tr>
<td>2016</td>
<td>188,357.60</td>
<td>0.15</td>
<td>2,460,326.97</td>
<td>47,805.16</td>
<td>2,508,132.13</td>
</tr>
</tbody>
</table>
Based on the above assumptions, in order to achieve the targeted recycling rate as well as the harmless disposal rate for CDW in 2016 – 2020, the computation for the total economic benefit per annual is shown in the table below.

### Table 4-3: Total Revenue of Achieving CDW Harmlessness and Recycling in China (2016-2020)

<table>
<thead>
<tr>
<th>Year</th>
<th>Generation</th>
<th>Recycling Rate</th>
<th>Recycled Amount</th>
<th>Recycled Aggregate</th>
<th>Yield</th>
<th>Pre-mixed Recycled Concrete</th>
<th>Recycled Concrete</th>
<th>Revenue</th>
<th>Recycled Aggregate</th>
<th>Pre-mixed Recycled Concrete</th>
<th>Recycled Concrete</th>
<th>Total Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>188,357.60</td>
<td>15%</td>
<td>28,253.64</td>
<td>14,381.10</td>
<td>2,966.63</td>
<td>8,899.90</td>
<td>188,027.97</td>
<td>533,993.80</td>
<td>1,495,182.63</td>
<td>2,217,204.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>194,008.30</td>
<td>20%</td>
<td>38,801.66</td>
<td>19,750.04</td>
<td>4,074.17</td>
<td>12,222.52</td>
<td>258,225.05</td>
<td>733,351.37</td>
<td>3,053,383.85</td>
<td>3,044,960.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>199,828.60</td>
<td>25%</td>
<td>49,957.15</td>
<td>25,428.19</td>
<td>5,245.50</td>
<td>15,736.50</td>
<td>332,464.83</td>
<td>944,190.14</td>
<td>3,267,652.38</td>
<td>3,920,387.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>205,823.40</td>
<td>30%</td>
<td>61,747.02</td>
<td>31,429.23</td>
<td>6,483.44</td>
<td>19,450.31</td>
<td>410,926.42</td>
<td>1,167,018.68</td>
<td>3,926,628.81</td>
<td>4,845,597.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>211,998.10</td>
<td>35%</td>
<td>74,199.34</td>
<td>37,767.46</td>
<td>7,790.93</td>
<td>23,372.79</td>
<td>493,796.57</td>
<td>1,402,367.43</td>
<td>3,926,628.81</td>
<td>5,822,792.81</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(3) Cost Economic Analysis

According to above statistics, economic analysis of the cost of managed disposal and recycling of CDW has been carried out, and the analytic result is shown in the table below.

### Table 4-4: Investment Beneficial Analysis on Achieving CDW Harmlessness and Recycling in China (2016-2020)

<table>
<thead>
<tr>
<th>Year</th>
<th>Amount</th>
<th>Total Investment</th>
<th>Total Revenue</th>
<th>Return</th>
<th>Net Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>188,357.60</td>
<td>2,852,355.64</td>
<td>2,217,204.40</td>
<td>77.73%</td>
<td>-635,151.25</td>
</tr>
<tr>
<td>2017</td>
<td>194,008.30</td>
<td>3,778,195.24</td>
<td>3,044,960.27</td>
<td>80.59%</td>
<td>-733,234.97</td>
</tr>
<tr>
<td>2018</td>
<td>199,828.60</td>
<td>4,757,019.74</td>
<td>3,920,387.35</td>
<td>82.41%</td>
<td>-836,632.39</td>
</tr>
<tr>
<td>2019</td>
<td>205,823.40</td>
<td>5,791,170.68</td>
<td>4,845,597.39</td>
<td>83.67%</td>
<td>-945,573.28</td>
</tr>
<tr>
<td>2020</td>
<td>211,998.10</td>
<td>6,883,090.71</td>
<td>5,822,792.81</td>
<td>84.60%</td>
<td>-1,060,297.90</td>
</tr>
</tbody>
</table>

4.1.3 Summary

Based on the analysis above, under the current situation in China, the CDW market in China will be unprofitable without any policy support, which could be indicated from the indicators of total investment, total revenue, and economic benefit in above 3 tables. Firstly, all return rates of investment are below 100%, which demonstrates no beneficial value of investment could be gained from the project; in addition, all net profit counts of project are below zero, which indicates the CDW enterprises will be in long-term unprofitable situation without any policy support on CDW recycling project, which is the justification for establishing the following policies on promoting the development of market for CDW recycling:
(i) Strengthen and ensure the review policies as well as the price of land use for CDW enterprises. The computation was carried out with the data sourced from the prices in the National Minimum Price Standard for Transfer of the Land of Industrial Use, however in the practical implementation, land use shortage and high product price has become the most critical problem for the cost of many CDW recycling enterprises. The situation for the existence of CDW recycling enterprises will be aggravated without ensured enforcement of above policies.

(ii) Enforce subsidy policies for recycled CDW products. In this study, all types of CDW recycled products have not received subsidies and tax reduction or exemption from government, which will be reflected in the product prices. With the enforcement of the policies, the competitiveness of CDW recycled products will be significantly strengthened in the market, and the achievement of targeted economic benefit can be ensured.

(iii) Strengthen the market promotion policies for CDW recycled products. Assuming 100% sales could be achieved for CDW recycled products in the market, in fact the sales of CDW recycled products is obstructed in the market currently, which needs the mandatory promotion and incentive policies from the government to achieve the estimated sales, hence, the implementation of relative market promotion policies should be strengthened during the policy enforcement.

(iv) Develop a technical standard systems for CDW harmlessness and recycling. Relative technical standard systems should be further improved in China, and the relative technologies and products should become more reliable, besides, the best overseas practice and experiences should be learned to develop the CDW recycling technologies, and to reduce the cost for CDW recycling and landfilling technologies.

(v) Improve the demonstration project of and support for CDW recycling. Currently the CDW recycling rate is still low in China, and the estimated CDW recycling rate in this study was set under the premise of the smooth enforcement of the relative policies, therefore the investment to the demonstration project and program should be increased to ensure the economic benefit of above policies, as well as the achievement of the CDW recycling target.

4.2 Environmental Benefit Analysis

CDW recycling has strong positive impacts on economic externalities, which means economic activities may benefit others or society, but does not provide direct financial benefits to the business making the investment. This kind of externality demonstrates a good promotion to the recycling rate of CDW by the enforcement of relative policies, and significant effect in environmental benefit.

Although the assessment to the environmental impact by single approach on CDW recycling is insufficient currently, we can also identify a good environmental benefit of CDW recycling from the perspective of the enforcement of macro-policies. The exposing and landfilling of untreated CDW may not only cause high cost in cleaning and delivery, but also pollute the environment with the waste leakage, and generation of dust and sand. Relative approaches on CDW recycling can mitigate the impact to environment, and the specific environmental benefits are as follows:

(i) Land occupation. The annual generation of CDW in China is 3 billion tonnes, therefore, there are 8.22 million tonnes CDW generated daily, 22 thousand tonnes CDW per person (count with 1.368 billion population in China), 4.56 million ton (count with 657 cities in China). If the CDW piled without appropriate approaches, 2.5 mu land will be required for 10 thousand ton CDW with 5m piling height, and 750 thousand mu land (500 m2 land) will be required annually, given 100 years building life, existing cities and towns in China will be all covered by CDW after 300 years.

(ii) Water pollution. Leachate which contains a large amount of calcium silicate hydrate, calcium hydroxide, sulphate and heavy metal ion will leach out of CDW piled in dumping site after stormwater immersion, without proper control, the surface and ground water could be polluted if the leachate flows into the river and underground.

(iii) Air pollution. The waste plaster of CDW may contains sulphate ions, which could be converted to hydrogen sulphide in anaerobic conditions, while in the same condition, the waste cardboard and wood
could leach out lignin and tannin, which will be furtherly decomposed to volatile fatty acids (VFA), all of above hazardous gas could cause air pollution.

(iii) Air pollution. The waste plaster of CDW may contain large quantities of sulphate ions, which could be converted to hydrogen sulphide in anaerobic condition, while in the same condition, the waste cardboard and wood could leach out lignin and tannin, which will be furtherly decomposed to VFA, all of above hazardous gas could cause air pollution.

(v) Comprehensively environmental benefit. If relative approaches have been carried out on CDW recycling, 36 million ton recycled mixed products, and 10 million ton recycled aggregates will be generated from 100 million ton CDW, saving 15 thousand mu land for brick manufacture, 2.7 million ton coal, and reducing 1.3 million ton dioxide emission as well.

4.3 Social Benefit Analysis

The enforcement of above policies on CDW recycling will benefit the society by promoting the national macro-economic strategy, developing the sector’s performance, and creating job opportunities generated by the progress of the CDW recycling sector. The social benefits of the sector will gradually emerge with the formation of cluster and group effects, and the development of CDW recycling enterprises as well. Currently, China cannot effectively harness the beneficial contribution of individual enterprises, however the development of individual enterprises will promote the progress of the sector and the development of the national economy as well. Other social benefits include:

(i) Achieving the national goal of energy conservation and emission reduction

In the 13th 5-year national planning strategy, the climate change task has been incorporated in the development of national economy by promoting the ecological and cultural construction, enhancing green and low-carbon development, and persisting in climate change mitigation and adaption. In the International Climate Conference hosted in Paris in Dec 2015, on behalf of Chinese Government, President Xi Jingpin made a commitment that China will achieve peak emission of carbon dioxide by 2030, and strive to realize this target as soon as possible. Besides, by 2030, the carbon dioxide emission will decreased 60% - 65% of the emission in 2005, the ratio of non-fossil energy in primary energy will reduce to 20%, and 4.5 billion m3 forest land will be increased compared with 2005. The enforcement of CDW recycling policies will promote the low-carbon emission of the construction material industry and construction industry, and the reduction of carbon emission will be realized consequently, therefore, the policy enforcement will contribute to realizing the national target of energy conservation.

(ii) Promoting the development of upstream and downstream industry

CDW recycling involves all steps of entire life cycle of construction project, including project permission, planning and design, construction, operation and management, demolition, delivery, and product application. The whole industrial chain of construction, including real estate, architecture, construction material and facility, construction consultancy, relative research on construction can be promoted by the recycling approach, besides, the recycling will become the developing trend for whole industrial chain for construction sector with low-carbon, environmental friendly, energy saving requirements on construction.

(iii) Creating more job opportunities

The requirements on energy saving has been mandated on all steps of the building life cycle by CDW recycling, meanwhile the demands on technical development and management are required to develop all steps of the pre-treatment of CDW recycling, including separation, crushing, delivery, and recycling by improving the labor service, R&D, facility production, product sales. With more requirements on energy conservation having been raised by relative industries (including real estate, architecture, construction material and facility, construction consultancy, construction research), the service scope has been enlarged, and more job opportunities have been created. A research conducted in US showed that 168 additional jobs could be created in every 100 jobs during CDW recycling process.

In general, the comprehensive benefit of CDW recycling is significant, not only in economic aspects, but also in environmental and social aspects.
4.4 Sensitivity Analysis

4.4.1 Assumptions of Sensitivity Analysis

To strengthen the analysis of the influence to the promotion of CDW recycling by different policies, the policies raised in this study can be sorted by 3 types: mandatory policies of technical standards, incentive policies of economic initiative, and encouraging policies of market promotion. To assess the influence to the investment return rate, net profit has been analysed through the sensitivity variations of different policy types.

(i) Mandatory policies of technical standards: assuming that the promotion of this kind of policy will improve the CDW recycling rate, and the flexible variation situations will be analyzed in this study under the scenario of 10% minus, 5% minus, 5% plus, and 10% plus based on the CDW recycling rate described in Section 4.1.

(ii) Incentive policies of economic initiative: given the cost of CDW recycling could be reduce to certain extent by the policy enforcement, the study will analyze the flexible variations in the 4 scenarios of 10% minus, 5% minus, 5% plus, 10% plus on the base of recycling rate described in Sector 4.1.

(iii) Encouraging policies of market promotion: given the price of CDW recycling products can be increased to some extent by the policy enforcement, the study will analyze the flexible variations in the 4 scenarios of 10% minus, 5% minus, 5% plus, 10% plus on the base of recycling rate described in Section 4.1.

4.4.2 Sensitivity Analysis for the Mandatory Policies of Technical Standards

In the scenarios below, the establishment or not of the mandatory policies of technical standards will result in the variations of CDW recycling rate. The computation tables are shown in Appendix A.1, and the specific sensitivity analysis is as follows:

| Analysis on Investment Return Rate under Sensitivity Variations of Recycling Rate |
|---------------------------------|---------------------------------|---------------------------------|-----------------|-----------------|-----------------|
| -10%                            | -5%                             | Baseline Scenario               | 5%              | 10%             |
| 76.53%                          | 77.16%                          | 77.73%                          | 78.26%          | 78.75%          |
| 79.62%                          | 80.13%                          | 80.59%                          | 81.02%          | 81.41%          |
| 81.59%                          | 82.02%                          | 82.41%                          | 82.77%          | 83.09%          |
| 82.97%                          | 83.34%                          | 83.67%                          | 83.98%          | 84.26%          |
| 83.98%                          | 84.30%                          | 84.60%                          | 84.86%          | 85.11%          |

| Analysis on Sensitivity Variations of Investment Return Rate |
|---------------------------------|---------------------------------|---------------------------------|-----------------|-----------------|-----------------|
| -10%                            | -5%                             | Baseline Scenario               | 5%              | 10%             |
| -1.55%                          | -0.74%                          | 100.00%                         | 0.68%           | 1.31%           |
| -1.21%                          | -0.58%                          | 100.00%                         | 0.53%           | 1.01%           |
| -0.99%                          | -0.47%                          | 100.00%                         | 0.43%           | 0.83%           |
| -0.84%                          | -0.40%                          | 100.00%                         | 0.37%           | 0.70%           |
| -0.73%                          | -0.35%                          | 100.00%                         | 0.32%           | 0.61%           |

| Analysis on Net Profit under Sensitivity Variations of Recycling Rate |
|---------------------------------|---------------------------------|---------------------------------|-----------------|-----------------|-----------------|
| -10%                            | -5%                             | Baseline Scenario               | 5%              | 10%             |
| -612133.00                      | -623642.12                      | -635151.25                      | -646660.37      | -658169.49      |
According to the analysis in the table above, the recycling rate of CDW will change with the enforcement of different mandatory policies of technical standards. With the analysis of the variations of CDW recycling rate under the scenarios of 10% minus, 5% minus, 5% plus, 10% plus, conclusions were drawn as follows:

(i) The spans of sensitive influence on investment return rate by mandatory policies of technical standards are ranged from -1.55% to -0.73%, -0.74% to -0.35%, -0.32% to -0.68%, and 0.61% to 1.31% in above 4 scenarios. It is identified that the mandatory policy of technical standards is proportional to the sensitive influence on investment return rate, which means the recycling rate of CDW will increase with more policies established, and the investment return rate will also increase consequently.

(ii) The spans of sensitive influence on net profit by mandatory policies of technical standards are ranged from -5.7% to -3.62%, -2.58% to -1.81%, 1.81% to 2.85%, and 3.62% to 5.7% in above 4 scenarios. It is identified that the mandatory policy of technical standards is proportional to the sensitive influence on net profit, which means the recycling rate of CDW will increase with more policies established, and net profit will also increase consequently.

(iii) In general, variation span of policies is narrower than the variation span of economy, therefore the sensitivity is relatively small in perspective of economic benefit of policies.

### 4.4.3 Incentive Policies of Economic Initiative

In the Scenarios below, the establishment or not of the incentive policies of economic initiative will result in the variations on the cost of CDW recycling. The computation of sensitive analysis is shown in Appendix A.2, and the specific sensitivity analysis is as follows:

**Table 4-6 Sensitivity Analysis on Cost of CDW Recycling – Variation Scope Analysis**

| Analysis on Investment Return Rate under Sensitivity Variations of Recycling Cost |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| -10% | -5% | Baseline Scenario | 5% | 10% |
| 85.23% | 81.31% | 77.73% | 74.46% | 71.45% |
| 88.68% | 84.44% | 80.59% | 77.08% | 73.86% |
| 90.89% | 86.44% | 82.41% | 78.74% | 75.38% |
| 92.42% | 87.83% | 83.67% | 79.89% | 76.44% |
| 93.55% | 88.85% | 117.61% | 80.73% | 77.21% |
According to the analysis in the table above, the cost of CDW recycling will change with the enforcement of different incentive policies of economic initiative. With the analysis of the variations of CDW recycling cost under the scenarios of 10% minus, 5% minus, 5% plus, 10% plus, conclusions were drawn as follows:

(i) The spans of sensitive influence on investment return rate by incentive policies of economic initiative are ranged from -20.46% to 9.64%, -24.26% to 4.60%, -31.36% to 4.21%, and -34.35% to -8.08% in above 4 scenarios. It is identified that the incentive policy of economic initiative is in inverse proportion to the sensitive influence on investment return rate, which means the cost of CDW recycling will decrease with more policies established, and investment return rate will increase consequently.

(ii) The spans of sensitive influence on net profit by incentive policies of economic initiative are ranged from -146.06% to -39.49%, -183.84% to -19.74%, -259.39% to 19.74%, and -297.16% to 39.49% in above 4 scenarios. It is identified that the incentive policy of economic initiative is in proportion to the sensitive influence on net profit, which means the cost of CDW recycling will be decreased with more policies established, and net profit will increase consequently.

(iii) In general, variation span of policies is wider than the influence span to the economy, and the sensitivity will be the strongest in perspective of economic benefit of policies.

4.4.4 Sensitivity Analysis for Incentive Policies of Market Promotion

In the scenarios below, the establishment or not of the incentive policies of market promotion will result in the change on benefit of CDW recycling. The computation of sensitivity analysis is shown in Appendix A.3, and the specific sensitivity analysis is as follows:
Table 4-7 Sensitivity Analysis on Benefit of CDW Recycling – Variation Scope Analysis

| Analysis of Investment Return Rate under Sensitive Variations of Recycling Benefit |
|---------------------------------------------|---------------------------------------------|
| -10%            | -5%            | Baseline Scenario | 5%            | 10%            |
| 69.96%          | 73.85%         | 77.73%            | 81.62%         | 85.51%         |
| 72.53%          | 76.56%         | 80.59%            | 84.62%         | 88.65%         |
| 74.17%          | 78.29%         | 82.41%            | 86.53%         | 90.65%         |
| 75.30%          | 79.49%         | 83.67%            | 87.86%         | 92.04%         |
| 76.14%          | 80.37%         | 84.60%            | 88.83%         | 93.06%         |

Analysis on Sensitivity Variation Scope of Investment Return Rate

<table>
<thead>
<tr>
<th>-10%</th>
<th>-5%</th>
<th>Baseline Scenario</th>
<th>5%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10.00%</td>
<td>-5.00%</td>
<td>100.00%</td>
<td>5.00%</td>
<td>10.00%</td>
</tr>
<tr>
<td>-10.00%</td>
<td>-5.00%</td>
<td>100.00%</td>
<td>5.00%</td>
<td>10.00%</td>
</tr>
<tr>
<td>-10.00%</td>
<td>-5.00%</td>
<td>100.00%</td>
<td>5.00%</td>
<td>10.00%</td>
</tr>
<tr>
<td>-10.00%</td>
<td>-5.00%</td>
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</tbody>
</table>

Analysis on Net Profit under Sensitive Variations of Recycling Benefit

<table>
<thead>
<tr>
<th>-10%</th>
<th>-5%</th>
<th>Baseline Scenario</th>
<th>5%</th>
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</tr>
</thead>
<tbody>
<tr>
<td>-856,871.68</td>
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<td>-635,151.25</td>
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<td>-1,037,731.00</td>
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</table>

Analysis on Sensitivity Variation Scope of Net Profit

<table>
<thead>
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<th>-5%</th>
<th>Baseline Scenario</th>
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<tr>
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<tr>
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<tr>
<td>46.86%</td>
<td>23.43%</td>
<td>100.00%</td>
<td>-23.43%</td>
<td>-46.86%</td>
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<tr>
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<td>27.46%</td>
<td>100.00%</td>
<td>-27.46%</td>
<td>-54.92%</td>
</tr>
</tbody>
</table>

According to the analysis in the table above, the revenue of CDW recycling will change with the enforcement of different encouraging policies of market promotion. With the analysis of the variations of the revenue of CDW recycling under the scenarios of 10% minus, 5% minus, 5% plus, 10% plus, conclusions were drawn as follows:

(i) The spans of sensitive influence on investment return rate by encouraging policies of market promotion are -10%, -5%, 5%, and 10% respectively in above 4 scenarios. It is identified that the encouraging policy of market promotion is proportional to the sensitive influence on investment return rate, which means the revenue of CDW recycling will increase with more policies established, and investment return rate will also increase consequently.
(ii) The spans of sensitive influence on net profit by encouraging policies of market promotion are 34.91% to 54.92%, 17.35% to 27.46%, -27.46% to 17.45%, -54.29% to -34.91%. It is identified that the encouraging policy of market promotion is in inverse proportion to the sensitive influence on net profit, which means the recycling rate of CDW will decrease with more policies established, and net profit will also decrease consequently.

(iii) In general, the variation span of the encouraging policy of market promotion is the closest one to the variation span of economy among the 3 policy types, therefore the sensitivity of encouraging policies of market promotion is relatively significant in perspective of economic benefit.

4.4.5 Summary

According to the analysis above, the sensitivity variation scopes of the 3 different policies are summarized in the tables below:

Table 4-8 Sensitivity Analysis of 3 Different Policies – Summary of Variation Scope

- **Mandatory Policies of Technical Standards**
  
  **Analysis on Sensitivity Variation Scope of Investment Return Rate**

<table>
<thead>
<tr>
<th></th>
<th>-10%</th>
<th>-5%</th>
<th>Baseline Scenario</th>
<th>5%</th>
<th>10%</th>
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</thead>
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<tr>
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<td></td>
<td>0.68%</td>
<td>1.31%</td>
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<tr>
<td>-1.21%</td>
<td>-0.58%</td>
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<td>0.53%</td>
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<td>-0.99%</td>
<td>-0.47%</td>
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<td>0.43%</td>
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<td>0.32%</td>
<td>0.61%</td>
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</table>

**Analysis on Sensitivity Variation of Net Profit**

<table>
<thead>
<tr>
<th></th>
<th>-10%</th>
<th>-5%</th>
<th>Baseline Scenario</th>
<th>5%</th>
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</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>-4.86%</td>
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- **Incentive Policies**
  
  **Analysis of Sensitivity Variation Scope for Investment Return Rate**

<table>
<thead>
<tr>
<th></th>
<th>-10%</th>
<th>-5%</th>
<th>Baseline Scenario</th>
<th>5%</th>
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</thead>
<tbody>
<tr>
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<td>4.60%</td>
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<td>-8.08%</td>
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<td>10.03%</td>
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<tr>
<td>10.28%</td>
<td>4.89%</td>
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<td>-8.53%</td>
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<tr>
<td>10.45%</td>
<td>4.97%</td>
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<tr>
<td>-20.46%</td>
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<td></td>
<td>-31.36%</td>
<td>-34.35%</td>
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**Analysis of Sensitivity Variation Scope for Net Profit**

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<thead>
<tr>
<th></th>
<th>-10%</th>
<th>-5%</th>
<th>Baseline Scenario</th>
<th>5%</th>
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</tr>
</thead>
<tbody>
<tr>
<td>-39.49%</td>
<td>-19.74%</td>
<td>100.00%</td>
<td></td>
<td>19.74%</td>
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<td>100.00%</td>
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<td>23.49%</td>
<td>46.98%</td>
</tr>
</tbody>
</table>
-53.01%  -26.50%  100.00%  26.50%  53.01%
-57.97%  -28.98%  100.00%  28.98%  57.97%
-146.06% -183.84%  100.00%  -259.39%  -297.16%

**Encouraging Policies for Market Promotion**

<table>
<thead>
<tr>
<th>Analysis of Sensitivity Variation Scope for Investment Return Rate</th>
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<tbody>
<tr>
<td><strong>-10%</strong></td>
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<tr>
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<thead>
<tr>
<th>Analysis of Sensitivity Variation Scope for Net Profit</th>
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<tbody>
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<td><strong>-10%</strong></td>
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<tr>
<td>34.91%</td>
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<td>46.86%</td>
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<td>54.92%</td>
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Based on the summarized analysis above, the conclusions could be gained as follows:

(i) Analysis on investment return rate of three policy types

The sensitivity span of investment return rate influenced by mandatory policies of technical standards are ranged from -1.55% to -0.73%, -0.74% to -0.35%, 0.32% to -0.68%, and 0.61% to 1.31%; while the sensitivity span of investment return rate influenced by incentive policies of economic initiative are ranged from -20.46% to 9.64%, -24.46% to 4.6%, -31.36% to 4.21%, and -34.25% to 8.08%; and the sensitivity span of investment return rate influenced by encouraging policies of market promotion are -10%, -5%, 5%, and 10% respectively. Therefore, the priority of significance on sensitivity is incentive policies of economic initiative, encouraging policies of market promotion, and mandatory policies of technical standards.

(ii) Analysis on investment net profit of three policy types

The sensitivity span of investment net profit influenced by mandatory policies of technical standards are ranged from 5.7% to -3.62%, -2.85% to -1.81%, 1.81% to 2.85%, and 3.62% to 5.7%; while the sensitivity span of investment revenue influenced by incentive policies of economic initiative are ranged from -146.06% to -39.49%, -183.84% to 19.74%, -259.34% to -19.74%, and -297.16% to 39.49%; and the sensitivity span of investment revenue influenced by encouraging policies of market promotion are ranged from 34.91% to 54.92%, 17.45% to 27.46%, -27.46% to -17.45%, and -54.92% to -34.91%. Therefore, the priority of significance on sensitivity is incentive policies of economic initiative, encouraging policies of market promotion, and mandatory policies of technical standards.

(iii) Based on the results of sensitivity analysis and in perspective of ensuring the economic effect of the policies, it is recommended that the central government should focus on establishing relative policies on promoting the marketization, increasing the market demand, and developing the market of CDW recycling as well, besides, the issues of economic internality should be solved by reducing the cost
through economic incentives, and policies should be considered in respect of regulating the market environment from the perspective of technical standards.
5 Best Available Techniques for CDW Recycling

5.1 Source Reduction

Construction and demolition waste (CDW) reduction is a comprehensive process to reduce waste production and discharge through management of the volume, mass, type, or toxicity of waste, supporting the efforts to promote clean production. It requires not only to reduce waste volume and mass, but also to minimize its types and reduce harmful substances from waste, and eliminate or reduce impacts to the environment essentially. China’s old practice of waste management focuses on the end - the so called ‘Abatement After Pollution’ – and it induces huge environmental impacts and implies higher treatment costs. While treatment and disposal are important methods to manage waste once waste has already been generated, source reduction prevents waste from being generated in the first place and reduces costs and environmental impacts throughout the whole chain from resource mining, manufacture to transportation. Source reduction of CDW incorporates lifecycle management of building industry, ranging from design, construction to demolition.

Currently, the understanding of China’s construction industry on source reduction of CDW has not yet been deep enough to actively adopt appropriate technologies to promote clean production. Therefore, in order to achieve better reduction management of CDW, proper guidance should be provided by relevant government departments or agencies through policies which promote and support clean production, encourage development of advanced construction technology and equipment, and facilitate sustainable use of raw materials, etc. Sections below show best available technologies for CDW recycling from three aspects of design for source reduction, construction and demolition in detail.

5.1.1 Design

CDW is generated in each process along the life chain, from building construction, maintenance, facility replacement, demolition even to the recycling and reuse of CDW. Therefore, cutting the CDW generation should be incorporated into processes from building design, construction management to demolition, etc. CDW-reduction design is a way of building design applying waste reduction concepts and methods to minimize CDW generation and to reuse CDW already generated during construction. In practice, those design concepts are not commonly adopted by Chinese architects, those concepts include:

Design for adaptability

‘Designing for adaptability’ is considering potential adaptabilities of buildings and reserves flexibilities for possible maintenance and renovation in the design. The building should be designed to local conditions and can reduce waste and extend its useful life, whilst taking other factors into account, such as material durability and risk to damage, etc.

Design for disassembly

Disassembly is a key step towards effective recycling, and will have to be considered in early stage of product design. With focuses on reuse, remanufacture and recycle, ‘designing for disassembly’ is to recycle raw materials for reuse at the minimum costs. It shows that sale of valuable recycled materials can far offset the additional labor costs of building disassembly. Disassembly provides an alternative for building demolition that not only reduces environmental impacts, but also opens new business opportunities for building demolition, recycling and transportation of demolition wastes, and remanufacture and resale of structure component. Designing a building to support disassembly can increase recycling rate of CDW from the current about 20% to 70% and above. Considering 50% of the total CDW are from building demolition and renovation, proper application of disassembly could create huge benefit space.
**Design for green building materials**

China’s building industry heavily relies on traditional and low-performance construction materials, such as concrete, bricks, tiles and mortar, etc., and CDW accounts for 70% of the total municipal wastes in weight. In contrast, green materials use less natural raw materials and as a result of which pollution discharge and energy consumption during its production process are reduced. Adoption of green materials is eco-friendly and without harm to human health. Green materials are easier to be recycled and reused after disassembly, which could further eliminate pollutions to the ecosystem. Therefore, giving priority to green materials in material selection not only serves for CDW source reduction, but also promotes eco-friendly production in the building industry.

**Promote prefabricated structure system design**

Cast-in-situ reinforced concrete structures have been prevailed in the building industry and have become one of the traditional ways of construction. In terms of the structural mechanics, cast-in-situ concrete structures have good structural stability and good seismic performance, however, the CDWs generated with cast-in-situ structure construction are also considerable. As one of the key components in source reduction design, promoting prefabricated structure could heavily reduce CDW generation right from the source.

Currently, prefabricated structures are not commonly used in China and most constructions still adopt traditional techniques. From the perspective of design agencies, the design concept should be adapted to suit pre-fabricated structures and to match technical requirements by assembly-type construction. In terms of construction enterprises and material suppliers, they should increase the professional level of their production and facilitate the standardization of assembly-type components, to meet the needs of industrial development.

**5.1.2 Construction**

Construction processes generate CDWs most directly for various reasons, for example, due to improper management or lacking awareness of conservation by the contractor, material over budgeting resulting in unused or leftover materials; increased CDW due to inappropriate construction techniques or operations taken by workers; and waste of materials due to absence of detailed management of contractor on procurement and its consequences, including ordered materials not meeting design requirements, over-or-under order of material, and poor management on site, etc. Since many activities during construction stage could affect CDW generation directly, strengthening of waste reduction management during construction can’t be overstressed. Based on China’s experience and practice, CDW reduction could be achieved by taking pathways during construction, as described from different angles shown below:

**From management**

The considerable CDWs generated from building construction site are partly due to the unclearly stated and poorly followed management rules and regulations. An inclusive and sound on-site management regulations and its enforcement is essential to reduce CDW effectively. Although the contractor plays an important role in cutting CDWs down, coordination and cooperation between agencies and entities are needed to implement those aforementioned control measures and achieve the goal. On the one hand, government and its department should strive to create enabling environment for setting up system that could reduce CDW. On the other, in addition to follow regulations and systems, to enhance site management and achieve proactive CDW reduction, awareness and understanding of contractors on CDW management should be improved, including management measures of CDW reduction, on-site reuse measures, and awareness on centralized off-site waste treatment and disposal.

**From technologies**

Waste generation from construction has a close relationship with construction and engineering management. Generally, good management could effectively reduce CDW generation. CDW reduction could be achieved by improved management capacities of the contractor.

**From cost management**
To the contractor, CDW reduction or control will fundamentally fall on cost management. Construction and demolition wastes are all construction materials, which cost the largest proportion from the total, normally as much as 70%. Additional costs will be needed for waste treatment and disposal, and procure and process the same amount of building materials to be used for construction, if deconstruction materials are treated as wastes. Therefore, reasonable limitation on costs and budget of contractor would encourage reuse of CDW on site, which will help to reduce CDW generation.

5.1.3 Demolition

After certain serving years, buildings will be demolished. Demolition process closes the old building’s functions and more often opens a new era for new ones. There are two methods used for reducing CDW during demolition: one is to discover and salvage residual values of the old building, preserving existing buildings rather than constructing new ones; another is the eye caught new technology changing the deconstruction from the traditional ‘demolition’ to ‘disassembly’. Based on practical engineering experience, demolition technologies could be improved from two aspects to reduce CDW generation from demolition, as follows:

Promote old building disposal appraisal and preserving

A rational appraisal method has decisive significance to determine a wise disposal plan of the old building and to reduce CDW generated from old building demolition and/or new building construction. Demolition the old building and construction new ones is the common practice in China. Since the current appraisal method rarely, or never considers the potentials of CDW reduction, demolition plan will more often be selected. In order to reduce CDW in the future, it is necessary to incorporate parameters relating to CDW generation into the appraisal matrix.

Comparing to ‘demolition and reconstruction’, refurnishing old building and prolonging its useful life saves energy, building material and resources, also reduces CDW generation. Based on its characteristics, such as historical and cultural features, structure, ambient environment, material, function and space, etc., the residual values and potentials of the old building should be explored for reuse after proper renovation and refurnishing, where careful evaluation, planning, design and construction will be required. Actually, new building construction only takes a small proportion in the building industry in many developed countries, in which renovation and expansion of old buildings prevail. Utilization and reuse of old buildings are advocated. However, demolishing the old building and reconstructing new ones are still normal practice in China, and it’s partly because the absence of a sound method for old building appraisal and the weak awareness on reuse and reclamation. Preserving and reusing old buildings should become one of the targets contributing to the overall goal of CDW reduction.

Optimize demolition or deconstruction with techniques

With the opposite order to construction, selective demolition disconnects and separates components from structures. According to experience on old building demolition, typical sequencing steps include interior stripping and cleaning, separating and deconstructing, cutting down and separating, and transporting. Some of the deconstructed materials should be kept size and shape unchanged, like wood frame and metal components, to make the direct reuse easier. In addition, toxic and hazardous materials should be disassembled before the deconstruction starts to avoid mixture, allowing for the followed up recovery, reuse and processing.

Deconstruction demolition, sometimes called disassembly or dismantlement, similar to selective demolition, also supports dis-connection and separation of building materials. Higher technical requirements and emphasis on direct recovery and reuse of large-sized component makes it different from selective demolition. With deconstruction techniques, higher recovery and reuse rate of material could be expected and the recycling rate of building material could be increased from 20% to 70%. Hence, CDW need treatment and disposal will be significantly reduced.

The non-destructive features of the selective demolition and deconstruction demolition both can be seen clearly. In view of the technical requirements of deconstruction, dissemination and application of deconstruction techniques are significantly limited by current building design methods, which haven’t
considered and are not responding to potential deconstruction practices. In contrast, selective demolition is more commonly used since it’s flexible and can be adjusted to local conditions much easier.

5.2 Sorting and Transportation

Sorting and separation of CDW could be done according to the source building, waste type, and disposal and recovery methods. In order to sort out CDW more efficiently, several bins should be placed on construction and deconstruction site to collect different type of CDW separately. According to waste composition, CDW could be collected separately as concrete and bricks (including tiles), earth and rock, metals and wood. According to sorting experience in China, improvement of sorting and separation of CDW at source would be done by taking measures shown below:

1. Based on waste type and characteristics, the separation collection of CDW should be achieved gradually. The collection method should match with the end disposal and treatment plan of that type.

2. According to their source, type and feature, CDW should keep separate at each stage from piling, deposition, transportation to treatment or disposal. Mixture with domestic waste and toxic or hazardous waste is forbidden in the whole process, from collection to disposal. Unsorted CDW should be treated at disposal site before it flows into the recycling processes.

3. Single-type and clean CDW could be recycled directly without pre-treatment. Mixed or uncleaned CDW will require pre-treatment. Process and facilities used for pre-treatment should be selected based on CDW features: bulk and massive wastes are better sorted mechanically, smaller size and amount of wastes could be sorted manually; to CDW contain mixed constituents, such as earth, wood and plastic, etc., mechanical sorting is recommended where different streams can be separated by vibration, gravity, airflow and screens, etc.

Transportation vehicles for CDW should not transport other types of waste. Especially for type of concrete and bricks & tiles, transportation tank should be covered or closed during operation, to avoid pollution to the environment. In addition, mixing already separated waste streams for transportation is not allowed. Separated CDW should be transported separately.

5.3 Recycling Process

5.3.1 Processing methods

In China, waste treatment started late and many problems exist in the current treatment industry, including the predominant collection of mixed CDW without sorting and separating, poor reuse rate, weak technical capacity for recovery and recycling and low harmless treatment capacity. There are two type of processing methods for CDW before recovery and reuse: fixed and mobile.

Fixed processing plant is generally properly planned with larger footprint and more complete facilities. Compared to mobile types, it takes longer time for the planning and construction of the fixed plant, which is more expensive and capable to deal with bulk CDWs. Fixed processing plant requires large capital investment and resources, but it’s not rare that the plant is running at a loss or closed due to multiple reasons, including incomplete legislation system to govern CDW treatment and weak enforcement of the regulations, insufficient supports from the government, transported CDW are not enough to match the treatment capacity and high level of heterogeneity of CDW, etc.

In contrast, the new type mobile processing features reliable performance, maintenance friendly, light in weight, flexible and adaptable, etc. However, the treatment capacity of mobile facilities, e.g. jaw crusher, impact crusher and cone crusher, are relatively small and not designed for bulk and centralized processing. The pre-treated CDW, which meet the diameter requirements, will be transported to the feeding machine by digger. Small and fine scraps will be filtered out, while large-sized materials will be fed into the impact crusher. Located above the output conveyer, the magnetic iron separator will remove steel bars from the stream and remainder flows into the screening station, from where large-sized materials will be sent back to the impact crusher and small-sized ones be sent to the product stockpiles by conveyers.
After processing, massive CDWs will be separated into different types. Especially, among the CDWs, materials like concrete, sand and stone, bricks and asphalt, etc. could be recycled and reused, reducing pressures to the environment effectively. Recycling and reuse of different materials is introduced in following sections.

(1) Recycling and reuse of concrete

Broken concrete account for 35% of the total CDW and is the major part of urban CDW. Recycling and reuse of broken concrete is of great value. The processed waste concrete could be used for producing reclaimed concrete and cement, and for roadbed and ram pile after mixed with rubble and lime.

(2) Recycling and reuse of bricks

Brickbat, or broken bricks, takes 15 to 20 percentage of the total CDW generated in urban area and is one of the major components of CDW. Experiments show that light blocks and hollow blocks could be made from the mixture of brickbat and mortar. With proper mixing ratio, produced blocks are able to meet all requirements by relevant regulations. In addition, mixture of brickbat and lime could be used for roadbed construction.

(3) Recycling and reuse of asphalt

Mortar accounts for about 2% of the urban CDW and it’s mainly from road rehabilitation and roof removing works. Asphalt could also be recycled. After crushing and screening the asphalt materials collected from roads and roofs, reclaimed asphalt concrete could be made by mixing the processed recycled asphalt with recycling agents, aggregate and fresh asphalt at a proper ratio, and be used for either surface or base of road pavement. Roof asphalt could be recycled and reused for road pavement. In addition, practice shows that mixed asphalt could be used for lower grade road pavement or roadbed after simple treatment, and good performance could be expected.

5.3.2 Process and equipment

Recycling process

The process of reclaiming aggregate from broken concrete is selecting and sequencing different facilities, such as those for cutting and crushing, screening, conveying and impurity removing (in general wasted concrete contains steel bars, wood, plastics, glass and gypsum, etc., inevitably), to process the wasted concrete and produce recycled coarse and fine aggregates that meets relevant quality requirements. Traditional processing procedures are simple, only able to sort out material with limited sizes and have poor performance, resulting in insufficient classification. The crushing processes are also dusty and could have negative impacts to ambient environment. As a result, the gradation of recycled aggregate is bad, limiting product application and hardly being accepted by the market.

Normally, the aggregate production procedures include pre-treatment of wasted concrete, crushing, and post-treatment of aggregate. Pre-treatment procedures include sorting, impurity removing and homogenizing. Multiple levels of crushing and screening are used during crushing. Post-treatment includes physical strengthening and chemical strengthening of aggregate. Performance of aggregate is very important to the quality of product concrete, and the quality, or performance of aggregate is greatly affected by its production processes. The typical processes are shown below:

<table>
<thead>
<tr>
<th>Processes</th>
<th>Brief Introduction</th>
<th>Technical recommendations and process improving measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>With air classification</td>
<td>In the system, fine aggregates with diameter of 0.15-5mm will be separated by air classification facility and vacuum cleaner, which creates opportunity for fine aggregate recycling and reuse.</td>
<td>Based on the status of CDW development in China, following measures could be taken to enhance existing process and improve disposal efficiency, eliminating potential impacts</td>
</tr>
</tbody>
</table>
**With two-step crushing and grinding**
The key of the two-step crushing is the second step of grinding. After heating, dried materials will be grinded, with rubbing and pressing, to remove mortar and soil attached to aggregates and to split already de-structured stones. Grinding could reduce micro-cracks resulting in better quality of reclaimed aggregate.

**With disinfection and de-dusting facilities**
Considering the sources of CDW, sequencing processes could be used to reclaiming aggregates, from upstream to downstream including feeder, disinfection sprinklers installed on the feeder, primary crusher, secondary crusher, screening facility separating fine, medium, coarse and rejected aggregates, de-dusting facilities installed on secondary crusher and screening facility, conveyer taking the rejected material back to secondary crusher, washing system for the medium-sized aggregates, and stock cabins for fine aggregates, coarse aggregates and washed medium-sized aggregates, separately.

**With sufficient impurity removing processes**
The purpose of this process is to remove impurities from the CDW as much as possible, including light matters, iron and other minor impurities, in order to secure the quality of recycled aggregate. According to practice and experience, following measures could be taken to improve removing performance.

1. In view of the relatively low labor cost in China and chunk materials are not easy to be removed mechanically, some compositions, like wood and domestic wastes, could be separately manually.

2. For compositions not easy to separate manually, such as iron and plastic scraps, magnetic separator and working platform will be used to secure quality of recycled aggregates.

3. In short term, main target product reclaiming from CDW will be coarse aggregates, which ranges from 5-40mm in diameter, and more than two crushes of different type could be used to produce coarse aggregates with boarder gradations.

4. Recycled aggregates normally have more impurities attached to the surface than natural ones, such as clay, sediment and fine scraps, etc. It reduces concrete strength made with recycled aggregates and increases mixing water demand. The washing process after screening could further reduce impurities in recycled aggregates.

to the environment.

1. Multiple steps of crushing and screening

After primary crushing, size of large block will be heavily reduced. A secondary crushing could be applied to break them more thoroughly. Magnetic separator could be used to separate steel bars from bricks and concrete blocks. Bricks could be also separated from concrete blocks. Another step – tertiary screening could be used to classify the processed materials into fine, medium-sized and coarse aggregates.

2. Add more de-dusting processes

In order to minimize dust emissions, de-dusting facilities could be adopted in many processes, such as feeding, crushing and aggregate shaping, etc. When using with feeding, sprinkler could be used at the head section, to wet materials before crushing and reduce dust. Micro-sprinkler could be applied in the crushing process. It reduces dust by creating spray, by which micro solid particles will be captured. During the aggregate shaping process, negative pressure created by air supply would help to maintain dust and avoid spreading. Meanwhile, dust collectors could be used to capture micro-particles.

3. Promote aggregate shaping and enhancement technologies

Aggregate enhancement technologies include shaping facilities and gel spray enhancement facilities. Shaping facilities improve strength of aggregates by removing shape edges and corners, as well as old mortar attached to the surface of aggregate with the grind and impact forces between particles created during high speed movement. Gel sprayers enhance strength of aggregate by moistening, washing and drying aggregates and releasing gel to help sealing cracks of aggregate.
(1) Facilities and selection

Table 5-2 : Facilities and selection for CDW Recycling

<table>
<thead>
<tr>
<th>Facility</th>
<th>Brief Introduction</th>
<th>Technical Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushers / Breakers</td>
<td>Pressing type crushers include jaw crusher, gyrator crusher, and cone crusher, etc. Materials, in between with the fixed tooth plate and swing tooth plate, will be broken by the extrusion or compression, chopping and/or bending. Crushers with this kind have been widely used in the CDW recycling industry. It should be noted that pressing crushers break materials in a mixed way and it's very easy to over-break, as well as to produce slab shaped products.</td>
<td>It's hard to get good performance by applying single type of crushers in CDW processing. In practices, two or more types of crushers will be used jointly. Based on practical experiences, following measures could be used to improve the efficiency and accuracy of crushing: (1) Jaw crusher could be used for the primary crushing; (2) Impactor or hammer crusher could be added as the secondary step; (3) If necessary, tertiary crushing with impactor or hammer crusher could be added.</td>
</tr>
<tr>
<td></td>
<td>Impacting type Crushers of this type include impacting crusher and ring hammer crusher, etc. By hitting materials with high speed moving hammers, materials will be 'thrown' to the plate repeatedly. In addition to impact forces, there is also shearing around the hitting hammers and impact plates. This type of crusher is more suitable for smashing, but not for coarse and medium-sized rock materials. Using impacting crushers for soft materials with high brittleness will result in powder and dusts.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shearing type Shearing type of crushers break things by applying shearing, tension, bending, puncturing, and chopping, etc.</td>
<td></td>
</tr>
<tr>
<td>Sorting facilities</td>
<td>Grading screening Vibrating screening is mainly used for separating particles and it consists with screen box, exciter or vibrator, supporting devices and motor, etc. Different amplitudes could be created by adjusting the unevenly spread mass.</td>
<td>(1) In order to remove undersized materials avoiding blockage and improving screening efficiency, grading screening facilities should be placed before and after every crushing stage, as well as to make processed aggregates classified and sent qualified aggregates to material pile directly.</td>
</tr>
<tr>
<td></td>
<td>Air classifier Air classifier separates materials based on working principles as follows: (1) When the density is similar, separation will be achieved since particles with bigger size have higher falling velocity and particles with smaller size have lower falling velocity against upward airflow. The closer the densities of aggregates are, the higher the screening efficient will be. (2) When the size or diameter is similar, particles with higher density have higher falling velocity and particles with lower density have lower velocity. Aggregates have narrower diameter spread and are more uniform, the screening efficiency will be higher.</td>
<td>(2) With air classifier, light materials, like polymer decoration materials with low densities, could be separated. Horizontal air classifier could be used, before the feeder. (3) Materials separating by magnetic force from CDW include steel bar, metal scraps and other small pieces with metal content, and it's been done before crushing or before screening.</td>
</tr>
<tr>
<td></td>
<td>Magnetic separator Magnetic separation is a process in which magnetically susceptible material is extracted from a mixture using a magnetic force. In the solid waste treatment system, this separation is used for recycling 'black metal' or removing materials with iron content. Normal practice for recovery metal scraps from solid waste is collecting before sorting and after crushing, or recovery after crushing and sorting with magnetic separator.</td>
<td>(4) It's especially efficient to recovery of the large-size and light matters, like paper and plastic sheets, meanwhile other matters will also be sorted out, like large-size and weight materials including plastics, rubber, wood and metals. Separator is placed before the feeder.</td>
</tr>
<tr>
<td></td>
<td>Gravity or inertia separation Gravity separation is a separating method using gravity or inertia as the dominant force. By gravity, heavy materials will fall down through the brush made in elastic fibers, while light materials, such as paper and plastics, remain on the top and will be conveyed to another cabin, separately. By choosing fibers with different strength, sometimes jointing several separators, four types of material could be separated including small and heavy, small and light, large and heavy and large and light.</td>
<td></td>
</tr>
</tbody>
</table>
De-dusting Facilities and Selection

| Mechanical dust collector | Mechanical dust collectors separate dust from gas steams using a combination of forces, such as centrifugal, gravitational and inertial. Inertial separators are common, and dust will be separated and collected by centrifugal force created at time of the mixture gas stream hitting the battle plate at high speed or sudden change of its direction. | (1) For the CDW recovering and reclaiming industry, mechanical dust collectors could be used as the primary removal to trap dusts.
(2) When expecting for higher level of removal, fabric filters or other type of collectors could be employed to achieve requirements. |
| Wet dust collectors / scrubbers | Wet dust collectors vary from water bath type, to bubble type and water film type, etc. Dust collectors in spray type are widely used in practice, and they release water droplets and come into contact with a gas steam containing dust particles. Particles will drop and be separated from the gas through contact, interception and agglomeration mechanisms. | |
| Dust filters | Dust filters include fabric filters, commonly knowns as baghouses, and granular dust collectors, etc. Filter bags allows fine particulates to bleed through the bag filter system, as the filtration materials are greater than particle sizes. Therefore, efficient removing can’t be achieved by using filter bags only. | |
| Electrostatic precipitators | The working concept of electrostatic precipitator is that the gas streams will receive a positive charge as they pass through the channel before the main structure of electrostatic precipitator, and these charged particles will then enter into a negatively charged electrode and adhere to it. It removes particles from fume before discharging to the air and is one of the key environmental protection facilities. | |

5.4 Reuse

5.4.1 Recycled aggregates

The main way to recycle and reuse CDW in China is producing recycled aggregates from CDW and making reclaimed concrete. The fact is that concrete strength of most of the concrete structures those have been demolished is less than grade C30. After proper crushing of wasted concrete, massive aggregates which could be recycled, which are separated from the aggregate-mortar interfaces and with the surface roughness significantly improved and similar shape, comparing to the conditions before mixture, which provides good basis for reuse. However, the recycled aggregates are surrounded with certain amount of mortar with high porosity and angularity, comparing to natural aggregates, recycled aggregates are at disadvantages of low apparent density, low bulk density, high water absorption and high crushing value, etc. Furthermore, the properties of recycled aggregates vary a lot with the strength, mixt ratio, age, living environment, producing process and other properties of the old concrete from which recycled aggregates are made. The table below shows basic characteristics of recycled aggregates, as well as some recommendations on using recycled aggregates in construction based on practical experiences.

**Table 5-3 : Basic Characteristics of Recycled Aggregates and Technical Recommendations**

<table>
<thead>
<tr>
<th>Types</th>
<th>Characteristics</th>
<th>Technical Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape and surface texture</td>
<td>Recycled coarse aggregates are more flat and more angular than natural ones, and are shaped in between gravels and pebbles. Those properties have the potentials to reduce the performance of new concrete made with them. The surface of recycled coarse aggregate is normally rough and porous. It can be seen that all recycled coarse aggregates are adhered with mortar, more or less.</td>
<td>In order to produce recycled aggregates with high quality, aggregate shaping and enhancement facilities should be adopted to improve the shape and firmness.</td>
</tr>
<tr>
<td>Percentage of flaky and elongated aggregates</td>
<td>The percentage of flaky and elongated aggregates in the recycled aggregates are similar with that in natural aggregates, sometimes even less than in natural ones. Therefore, from this point of view, recycled aggregates might lead to better performance of the new concrete made with</td>
<td></td>
</tr>
<tr>
<td>Characteristics</td>
<td>Technical Recommendations</td>
<td></td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Firmness</td>
<td>Due to the old mortar, firmness of recycled aggregates is</td>
<td></td>
</tr>
<tr>
<td></td>
<td>lower than that of natural aggregates.</td>
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<tr>
<td>Apparent density and bulk density</td>
<td>The apparent density and bulk density of recycled aggregates</td>
<td></td>
</tr>
<tr>
<td></td>
<td>are 88%-97% and 87%-99% of those of natural aggregates,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>respectively. The lower density of recycled coarse aggregate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>might result in lower density and elasticity of concrete made</td>
<td></td>
</tr>
<tr>
<td></td>
<td>with them.</td>
<td></td>
</tr>
<tr>
<td>Water absorption</td>
<td>Water absorption value in 24 hours of recycled coarse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>aggregates normally is about 2.5%-12%, and it is much higher</td>
<td></td>
</tr>
<tr>
<td></td>
<td>than that of natural ones.</td>
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<tr>
<td>Crushing value</td>
<td>The aggregate crushing value provides a relative measure of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the resistance of an aggregate to crushing under a gradually</td>
<td></td>
</tr>
<tr>
<td></td>
<td>applied compressive load. The crushing value of recycled</td>
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</tr>
<tr>
<td></td>
<td>coarse aggregates is higher than that of natural aggregates</td>
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</tr>
<tr>
<td></td>
<td>and it shows that recycled aggregates have lower strength.</td>
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<tr>
<td></td>
<td>The main reason is that there are lots of mortar adhered to</td>
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</tr>
<tr>
<td></td>
<td>the aggregate and the bond between them is weak, resulting in</td>
<td></td>
</tr>
<tr>
<td></td>
<td>more easily crushed recycled aggregates than natural ones.</td>
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<tr>
<td></td>
<td>To make ready-mixed concrete with recycled aggregates,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>differences with recycled aggregates and primary aggregates</td>
<td></td>
</tr>
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<td></td>
<td>on apparent density and bulk density should be taken into</td>
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<tr>
<td></td>
<td>account when determining the water cement ratio. The lower</td>
<td></td>
</tr>
<tr>
<td></td>
<td>density and lower elastic modulus of recycled concrete</td>
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</tr>
<tr>
<td></td>
<td>should also be noted in the structural design with recycled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>concrete.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recycled aggregate demands more water than primary ones,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>hence with same water mixture, concrete made with recycled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>aggregates will have worse performance than that made with</td>
<td></td>
</tr>
<tr>
<td></td>
<td>primary aggregates. When mixing cement and recycled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>aggregates, the potential impacts of recycled aggregates on</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the concrete performance and water cement ratio should be</td>
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</tr>
<tr>
<td></td>
<td>taken into account. Higher water cement ratio and secondary</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mixing are recommended when mixing cement with recycled</td>
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</tr>
<tr>
<td></td>
<td>aggregates. In order to maintain the quality of concrete,</td>
<td></td>
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<tr>
<td></td>
<td>amount of additive might also need to be adjusted.</td>
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<tr>
<td></td>
<td>In order to remove attached mortar from recycled aggregates,</td>
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</tr>
<tr>
<td></td>
<td>secondary or multi-stage crushing could be used, especially</td>
<td></td>
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<tr>
<td></td>
<td>when adherent mortar remains a lot on the surface of</td>
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</tr>
<tr>
<td></td>
<td>aggregate. Meanwhile, aggregate shaping process could be</td>
<td></td>
</tr>
<tr>
<td></td>
<td>used to reduce the crushing value of recycled aggregate.</td>
<td></td>
</tr>
</tbody>
</table>

### 5.4.2 Recycled concrete

Recycled concrete is that new concrete made with cement, water, other ingredients and aggregates, which are produced from waste concrete and properly grade-mixed after crushing the old concrete, washing and grading, instead of natural aggregates (mainly coarse aggregates), entirely or partially. The combinations could be all with recycled aggregates, coarse recycled aggregates with natural sand, coarse natural gravels or peddles with fine recycled aggregates, or recycled aggregates replacing part of the coarse or fine aggregates. According to experiments and practical experiences, basic properties of reclaimed concrete and application recommendations are listed as follows:

| Table 5-4 : Basic Characteristics of Recycled Concrete and Technical Recommendations |
|---------------------------------|---------------------------------------------------------------|
| Types                           | Characteristics                                                                 | Technical Recommendations                                           |
| Performance                     | The use of recycled aggregates for concrete production usually involves a reduction of the workability as measured by slump. The higher proportion of recycled aggregates is, the more slump loss of the production concrete will be. It's mainly because recycled aggregates have higher absorption than natural aggregates, therefore more free or surface water will be taken by recycled aggregates when mixing. | In view of the lower working performance of recycled concrete, special attention should be given when determining the water cement ratio for ready-mixed concrete. Usage of additive could be adjusted to maintain the performance. |
| Mechanical properties           | It's reported that the compressive strength of concrete will decline with the proportion of recycled aggregates used, almost linearly. Higher replacement ratio will result in lower modulus of elasticity value. | For recycled concrete and traditional concrete with the same design strength, lower water cement ratio or adding more cementing materials could be adopted as the replacement rate rising. |
| Durability                      | Against carbonation: Carbonation depth of reclaim concrete increases with replacement rate and water/cement ratio increasing. The carbonation depth is approximately proportional to the square root of time. | In general, recycled concrete has lower durability than traditional concrete. According to the living environment, it’s recommended to |
5.4.3 Reclaimed mortars

Actually, the usage of mortar is much greater than one expected. It’s reported that quantities of sand used for mortar account for one third of the total usage of sands for construction, and cement used for mortar account for 25%-40% of the total consumption. After CDW crushing and screening, recycled fine aggregates, also called recycled sands could be used to produce mortar replacing natural sands, entirely or partially. It saves natural resources meanwhile eliminates the environmental impacts by solid wastes. Furthermore, using recycled fine aggregates contributes to the green development of the construction industry. According its application, mortars made with recycled fine aggregates could be classified as reclaimed masonry mortar, plastering mortar and screeding mortar. There are numerical experiments and studies conducted on the performance and properties of reclaimed mortars overseas. In terms of the working behavior, experimental results can be concluded as follows:

- The behavior differences between mortars made with recycled aggregates from different sources are small and negligible. It’s suitable to produce recycled mortar from old concrete and bricks.
- Water demands of reclaimed mortar are higher than that of traditional mortar, but with better water holding capacity, the workability of reclaimed mortar is satisfied. In a real world application, more water could be added and secondary mixing method could be adopted when producing recycled mortar.
- The impact on mortar strength is negligible by replacing natural sands with recycled sands in good grading (also called find aggregates).
- The shrinkage of reclaimed mortar is higher than that of traditional mortar, and the shrinkage rate increases as the fine aggregate replacement rate increasing. In practice, surface coverage or water spray curing should be adopted for plastering mortar to minimize the potential impacts of higher shrinkage introduced by reclaimed mortar.

5.4.4 Reclaimed concrete products

Reclaimed concrete products are concrete products made with reclaimed concrete. Table 5-5 lists the basic characteristics of recycled concrete products, as well as recommendations based on practical engineering experiences.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Technical Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reclaimed concrete structures</strong></td>
<td></td>
</tr>
</tbody>
</table>
| **Beam:** Similar with traditional concrete beams, beam made with reclaimed concrete clearly shows different stages of un-cracked elastic deformation, cracking and failure during the loading process. Comparing to traditional concrete beam, the flexural ductility of beam from reclaimed concrete is slightly higher. | By optimizing structure design, reclaimed concrete structures could maintain similar structure mechanical properties and seismic resistance with those of traditional ones. |}
| **Columns:** Columns from reclaimed concrete share similar fracture mechanism with those made from traditional materials. Employment of recycled aggregates has negative impacts to load carrying capacity of concrete columns, where the load carrying capacity declines slightly with the increasing of aggregate replacement ratio. | Choosing of reclaimed concrete should be based on the quality of reclaimed concrete and engineering requirements by the project. Reclaimed concrete with |
Seismic resistance of shear walls made with reclaimed concrete is slightly lower than those made with traditional concrete. With increasing of replacement ratio of recycled aggregates, the seismic performance of concrete shear walls declines.

**Frame structures:**
With low-cycle repeated horizontal loading, frame structures made with recycled concrete show similar fracture mechanism and fracture patterns, which show strong column-weak beam behavior. With increasing of the replacement ratio, the ductility of concrete frames increase.

**Frame-shear wall:**
The performance almost remains the same of structures made with recycled concrete and with traditional concrete. With higher replacement ratio of recycled aggregates, deformation increases whilst the load-carrying capacity almost remains the same. Although the seismic performance of concrete joints, frame structures and frame-shear walls show declining trends with the employment of recycled aggregates, the load-carrying capacity, ductility and energy dissipation still meet the requirements by seismic design.

**Reclaimed concrete bricks**
The reference and design values of the compressive strength of reclaimed concrete are close to those of traditional concrete bricks. Equations to work out the mean value of masonry compressive strength in the current ‘Code for design of masonry structures’ could be used as a reference to derive the compressive strength of reclaimed concrete bricks.

Bricks made from reclaimed concrete have similar compressive performance, as well as similar fracture patterns and processes with traditional concrete bricks.

The Young’s modulus and Poisson’s ratio of reclaimed concrete brick increase with the increasing of strength of mortar

**Reclaimed concrete blocks**
The design value of compressive strength of reclaimed concrete block is slightly lower than that of concrete hollow block defined in the current design code.

Reclaimed concrete blocks have good stiffness and resistance to deformation.

As the strength of block and mortar increasing, working performance of the masonry will also increase.

Reclaimed concrete blocks could meet requirements of earthquake-resistant design of multi-story buildings with masonry structures.
Appendix A: Calculation Tables for Economic Sensitive Analysis

A.1 Computation Tables of Sensitivity Analysis on Mandatory Policies of Technical Standards

Table A-1: Sensitivity Analysis of CDW Recycling Rate – Investment Cost Variations

<table>
<thead>
<tr>
<th>Baseline Scenario</th>
<th>Year</th>
<th>Total Yield</th>
<th>Recycling Approach Cost</th>
<th>Landfilling Approach Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Recycling Rate</td>
<td>Stationery Approach Cost</td>
<td>Mobile Approach Cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>188,357.60</td>
<td>0.15</td>
<td>2,460,326.97</td>
<td>47,805.16</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>194,008.30</td>
<td>0.20</td>
<td>3,378,848.55</td>
<td>65,652.41</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>199,628.60</td>
<td>0.25</td>
<td>4,350,268.62</td>
<td>84,527.50</td>
</tr>
<tr>
<td></td>
<td>2019</td>
<td>205,823.40</td>
<td>0.30</td>
<td>5,376,930.50</td>
<td>104,475.96</td>
</tr>
<tr>
<td></td>
<td>2020</td>
<td>211,998.10</td>
<td>0.35</td>
<td>6,461,278.09</td>
<td>125,545.27</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>-10%</th>
<th>Year</th>
<th>Total Yield</th>
<th>Recycling Approach Cost</th>
<th>Landfilling Approach Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Recycling Rate</td>
<td>Stationery Approach Cost</td>
<td>Mobile Approach Cost</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>188,357.60</td>
<td>0.14</td>
<td>2,214,294.27</td>
<td>43,024.64</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>194,008.30</td>
<td>0.18</td>
<td>3,040,963.70</td>
<td>59,087.17</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>199,628.60</td>
<td>0.23</td>
<td>3,915,241.76</td>
<td>76,074.75</td>
</tr>
<tr>
<td></td>
<td>2019</td>
<td>205,823.40</td>
<td>0.27</td>
<td>4,839,237.45</td>
<td>94,028.36</td>
</tr>
<tr>
<td></td>
<td>2020</td>
<td>211,998.10</td>
<td>0.32</td>
<td>5,815,150.28</td>
<td>112,990.75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>-5%</th>
<th>Year</th>
<th>Total Yield</th>
<th>Recycling Approach Cost</th>
<th>Landfilling Approach Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Recycling Rate</td>
<td>Stationery Approach Cost</td>
<td>Mobile Approach Cost</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>188,357.60</td>
<td>0.14</td>
<td>2,337,310.62</td>
<td>45,414.90</td>
</tr>
<tr>
<td>Year</td>
<td>Total Yield</td>
<td>Recycling Approach Cost</td>
<td>Landfilling Approach Cost</td>
<td>Total Cost</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Recycling Rate</td>
<td>Stationary Approach Cost</td>
<td>Mobile Approach Cost</td>
<td>Recycling Approach Cost</td>
</tr>
<tr>
<td>5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>188,357.60</td>
<td>0.16</td>
<td>2,583,343.32</td>
<td>50,195.42</td>
<td>2,633,538.74</td>
</tr>
<tr>
<td>2017</td>
<td>194,008.30</td>
<td>0.21</td>
<td>3,547,790.98</td>
<td>68,935.03</td>
<td>3,616,726.01</td>
</tr>
<tr>
<td>2018</td>
<td>199,828.60</td>
<td>0.26</td>
<td>4,567,782.05</td>
<td>88,753.87</td>
<td>4,656,535.93</td>
</tr>
<tr>
<td>2019</td>
<td>205,823.40</td>
<td>0.32</td>
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<td></td>
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<td>Recycling Rate</td>
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<td>Mobile Approach Cost</td>
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<td>10%</td>
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<tr>
<td>2016</td>
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## Table A-2: Sensitivity Analysis on CDW Recycling Rate – Revenue Variations

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<th>Recycling Amount</th>
<th>Yield</th>
<th>Recycled Aggregate</th>
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<th>Recycled Concrete Product</th>
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<th>Total Revenue</th>
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<td>6483.44</td>
<td>19450.31</td>
<td>410,926.42</td>
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<td>7790.93</td>
<td>23372.79</td>
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<table>
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<th>Recycling Amount</th>
<th>Yield</th>
<th>Recycled Aggregate</th>
<th>Pre-mixed Recycled Concrete</th>
<th>Recycled Concrete Product</th>
<th>Revenue</th>
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<td>2669.97</td>
<td>8009.91</td>
<td>169,225.18</td>
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<td>34921.49</td>
<td>17775.04</td>
<td>3666.76</td>
<td>11000.27</td>
<td>232,402.54</td>
<td>660016.24</td>
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<td>3528348.61</td>
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<td>4720.95</td>
<td>14162.85</td>
<td>299,218.35</td>
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<td>2379359.14</td>
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<td>4361037.66</td>
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<td>5835.09</td>
<td>17505.28</td>
<td>369,833.78</td>
<td>1050316.81</td>
<td>2940887.07</td>
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<td>5240513.53</td>
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<td>2020</td>
<td>211998.10</td>
<td>32%</td>
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<td>7011.84</td>
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<th>Recycling Amount</th>
<th>Yield</th>
<th>Recycled Aggregate</th>
<th>Pre-mixed Recycled Concrete</th>
<th>Recycled Concrete Product</th>
<th>Revenue</th>
<th>Pre-mixed Recycled Concrete</th>
<th>Recycled Concrete Product</th>
<th>Total Revenue</th>
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<td>14%</td>
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<td>2818.30</td>
<td>8454.90</td>
<td>178,626.58</td>
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<td>3870.47</td>
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### Table A-3: Sensitivity Analysis on CDW Recycling Rate – Investment Benefit Variations

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<th>Year</th>
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<th>Total Investment</th>
<th>Total Economic Benefit</th>
<th>Investment Return Rate</th>
<th>Net Profit</th>
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<td>Baseline Scenario</td>
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<td></td>
</tr>
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</tr>
<tr>
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<td>83.67%</td>
<td>-945,573.28</td>
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<tr>
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<td>6,883,090.71</td>
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<td>84.60%</td>
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<tr>
<td>Year</td>
<td>Yield</td>
<td>Total Investment</td>
<td>Total Economic Benefit</td>
<td>Investment Return Rate</td>
<td>Net Profit</td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
<td>------------------</td>
<td>------------------------</td>
<td>------------------------</td>
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<tr>
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<td>-999,847.70</td>
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</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield</th>
<th>Total Investment</th>
<th>Total Economic Benefit</th>
<th>Investment Return Rate</th>
<th>Net Profit</th>
</tr>
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<tr>
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<td>6,561,725.97</td>
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<td>84.30%</td>
<td>-1,030,072.80</td>
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<table>
<thead>
<tr>
<th>Year</th>
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<th>Total Investment</th>
<th>Total Economic Benefit</th>
<th>Investment Return Rate</th>
<th>Net Profit</th>
</tr>
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<tbody>
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<td>2,974,724.98</td>
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<tr>
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<tr>
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<td>-970,725.93</td>
</tr>
<tr>
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<td>7,204,455.45</td>
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<table>
<thead>
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<th>Year</th>
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<th>Total Economic Benefit</th>
<th>Investment Return Rate</th>
<th>Net Profit</th>
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<td>85.11%</td>
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## A.2 Computation Tables of Sensitivity Analysis on Incentive Policies of Economic Initiative

### Table A-4 Sensitivity Analysis on Cost of CDW Recycling – Investment Cost Variation

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<th>Year</th>
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<th>Total Cost</th>
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<td>Recycling Rate</td>
<td>Stationary Approach Cost</td>
<td>Mobile Approach Cost</td>
</tr>
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<td>2460326.97</td>
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<tr>
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<tr>
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### Baseline Scenario

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</thead>
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<td></td>
<td>Recycling Rate</td>
<td>Stationary Approach Cost</td>
<td>Mobile Approach Cost</td>
</tr>
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<td>2214294.27</td>
<td>43024.64</td>
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<tr>
<td>2017</td>
<td>194008.30</td>
<td>20%</td>
<td>3040963.70</td>
<td>59087.17</td>
</tr>
<tr>
<td>2018</td>
<td>199828.60</td>
<td>25%</td>
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<tr>
<td>2019</td>
<td>205823.40</td>
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<tr>
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</table>

### -10% Variation

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<th>Landfilling Approach Cost</th>
<th>Total Cost</th>
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</thead>
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<td>Recycling Rate</td>
<td>Stationary Approach Cost</td>
<td>Mobile Approach Cost</td>
</tr>
<tr>
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<td>188357.60</td>
<td>15%</td>
<td>2214294.27</td>
<td>43024.64</td>
</tr>
<tr>
<td>2017</td>
<td>194008.30</td>
<td>20%</td>
<td>3040963.70</td>
<td>59087.17</td>
</tr>
<tr>
<td>2018</td>
<td>199828.60</td>
<td>25%</td>
<td>3915241.76</td>
<td>76074.75</td>
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<tr>
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<td>205823.40</td>
<td>30%</td>
<td>4839237.45</td>
<td>94028.36</td>
</tr>
<tr>
<td>2020</td>
<td>211998.10</td>
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<td>112990.75</td>
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### -5% Variation

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<th>Total Cost</th>
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</thead>
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<td></td>
<td>Recycling Rate</td>
<td>Stationary Approach Cost</td>
<td>Mobile Approach Cost</td>
</tr>
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### Table A-5: Sensitivity Analysis on Cost of CDW Recycling – Investment Revenue Rate

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<th>Year</th>
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<th>Total Cost</th>
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<tbody>
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<table>
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<tr>
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<td>20%</td>
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<td>15736.50</td>
<td>332,464.83</td>
</tr>
<tr>
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<tr>
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<th>Total Revenue</th>
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</tr>
<tr>
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<tr>
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<td>23372.79</td>
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### 5%

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<td>8899.90</td>
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<td>1495182.63</td>
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### Table A-6: Sensitivity Analysis on Cost of CDW Recycling – Variations of Investment Benefit

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<th>Year</th>
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<th>Total Economic Benefit</th>
<th>Investment Return Rate</th>
<th>Net Profit</th>
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<tbody>
<tr>
<td>2016</td>
<td>188,357.60</td>
<td>2,852,355.64</td>
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<tr>
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<td>194,008.30</td>
<td>3,778,195.24</td>
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<td>80.59%</td>
<td>-733,234.97</td>
</tr>
<tr>
<td>2018</td>
<td>199,828.60</td>
<td>4,757,019.74</td>
<td>3,920,387.35</td>
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<tr>
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<td>83.67%</td>
<td>-945,573.28</td>
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<tr>
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<td>871,852.79</td>
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#### Baseline Scenario

#### -10%

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<th>Year</th>
<th>Yield</th>
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<th>Total Economic Benefit</th>
<th>Investment Return Rate</th>
<th>Net Profit</th>
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<tbody>
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<td>2016</td>
<td>188,357.60</td>
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<td>Net Profit</td>
</tr>
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<td>------------------------</td>
<td>------------------------</td>
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<table>
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<th>Investment Return Rate</th>
<th>Net Profit</th>
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<table>
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<th>Investment Return Rate</th>
<th>Net Profit</th>
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A.3 Computation Tables of Sensitivity Analysis on Encouraging Policies of Market Promotion

Table A-7 Sensitivity Analysis on the benefit of CDW Recycling – Investment Cost Variations

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<td>Mobile Approach Cost</td>
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<tr>
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</tr>
<tr>
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<th>Landfilling Approach Cost</th>
<th>Total Cost</th>
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<td>Recycling Rate</td>
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<td>Mobile Approach Cost</td>
</tr>
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<td>47,805.16</td>
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<tr>
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<td>84,527.50</td>
</tr>
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<td>15%</td>
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<td>47,805.16</td>
</tr>
<tr>
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73
## Table A-8: Sensitivity Analysis of CDW Recycling Revenue – Investment Revenue Variations

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<th>Recycling Amount</th>
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<th>Recycling Concrete Product</th>
<th>Revenue</th>
<th>Pre-mixed Recycling Aggregate</th>
<th>Recycling Concrete Product</th>
<th>Total Revenue</th>
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<td>23372.79</td>
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## Table A-9: Sensitivity Analysis on Benefit of CDW Recycling – Investment Benefit Variations

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<th>Yield</th>
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<th>Recycling Amount</th>
<th>Yield</th>
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<th>Pre-mixed Recycling Concrete</th>
<th>Recycling Concrete Product</th>
<th>Revenue</th>
<th>Recycling Aggregate</th>
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<td>Yield</td>
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<td>7790.93</td>
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**Baseline Scenario**

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<th>Investment Return Rate</th>
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**-10%**

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<th>Total Investment Benefit</th>
<th>Investment Return Rate</th>
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