Technical Assistance Consultant’s Report

Project Number: 41598
July 2010

India: Capacity Development of the National Capital Region Planning Board
(Financed by the TA Special Fund)

Prepared by:
Wilbur Smith Associates, India

For National Capital Region Planning Board

This consultant's report does not necessarily reflect the views of ADB or the Government concerned, and ADB and the Government cannot be held liable for its contents.

Asian Development Bank
FINAL REPORT

Asian Development Bank
National Capital Region Planning Board

Capacity Development of the National Capital Region Planning Board
Package 2 Component B
TA No. 7055-IND

Volume V-D1: Main Report
DPR for Multi-level Parking Facility in Ghaziabad

WilburSmith ASSOCIATES
July 2010
Capacity Development of the National Capital Region Planning Board (NCRPB) – Component B
(TA No. 7055-IND)

FINAL REPORT
Volume V-D1: DPR for Multi-level Parking Facility at Ghaziabad
Main Report

July 2010

WilburSmith
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADB</td>
<td>Asian Development Bank</td>
</tr>
<tr>
<td>BIS</td>
<td>Bureau of Indian Standard</td>
</tr>
<tr>
<td>BOQ</td>
<td>Bill of Quantities</td>
</tr>
<tr>
<td>CBR</td>
<td>California Bearing Ratio</td>
</tr>
<tr>
<td>CMSA</td>
<td>Cumulative number of Million Standard Axles</td>
</tr>
<tr>
<td>DFR</td>
<td>Draft Final Report</td>
</tr>
<tr>
<td>DL</td>
<td>Deal Load</td>
</tr>
<tr>
<td>DPR</td>
<td>Detailed Project Report</td>
</tr>
<tr>
<td>ECS</td>
<td>Equivalent Car Space</td>
</tr>
<tr>
<td>GDA</td>
<td>Ghaziabad Development Authority</td>
</tr>
<tr>
<td>INR</td>
<td>Indian Rupees</td>
</tr>
<tr>
<td>IRC</td>
<td>Indian Road Congress</td>
</tr>
<tr>
<td>IS</td>
<td>Indian Standard</td>
</tr>
<tr>
<td>KMPH</td>
<td>Kilometer per Hour</td>
</tr>
<tr>
<td>LCV</td>
<td>Light Commercial Vehicle</td>
</tr>
<tr>
<td>LL</td>
<td>Live Load</td>
</tr>
<tr>
<td>MAV</td>
<td>Multi-axle Vehicle</td>
</tr>
<tr>
<td>MORT&amp;H</td>
<td>Ministry of Road Transport and Highways</td>
</tr>
<tr>
<td>NCR</td>
<td>National Capital Region</td>
</tr>
<tr>
<td>NCRPB</td>
<td>National Capital Region Planning Board</td>
</tr>
<tr>
<td>NH</td>
<td>National Highway</td>
</tr>
<tr>
<td>RCC</td>
<td>Reinforced Cement Concrete</td>
</tr>
<tr>
<td>ROW</td>
<td>Right of Way</td>
</tr>
<tr>
<td>SP</td>
<td>Standard Procedure</td>
</tr>
<tr>
<td>TA</td>
<td>Technical Assistance</td>
</tr>
<tr>
<td>UP</td>
<td>Uttar Pradesh</td>
</tr>
<tr>
<td>UPSRTC</td>
<td>Uttar Pradesh State Road Transport Corporation</td>
</tr>
</tbody>
</table>
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Compendium Volumes

Besides this Volume V-D1, the DPR Multi-Level Parking in Ghaziabad has following Volumes appended separately.

Volume V-D2: Financial & Economic Analysis
Volume V-D3: Initial Environmental Examination
Volume V-D4: Short Resettlement Plan
1. INTRODUCTION

A. Background

1. The National Capital Region Planning Board, constituted in 1985 under the provisions of NCRPB Act, 1985, is a statutory body functioning under the Ministry of Urban Development, Government of India. NCRPB has a mandate to systematically develop the National Capital Region (NCR) of India. It is one of the functions of the Board to arrange and oversee the financing of selected development projects in the NCR through Central and State Plan funds and other sources of revenue.

2. On Government of India’s request, Asian Development Bank (ADB) has formulated the technical assistance (TA) to enhance the capacities of National Capital Region Planning Board and its associated implementing agencies. The TA has been designed in three components: Component A relates to improving the business processes in NCRPB; Component B relates to improving the capacity of the implementing agencies in project identification, feasibility studies and preparing detailed engineering design; and Component C relates to urban planning and other activities.

3. ADB has appointed M/s Wilbur Smith Associates to perform consultancy services envisaged under Component B. In the context of this contract, the first deliverable – Inception Report, was submitted in October 2008. The second deliverable – Interim Report comprising Master Plan for sewerage in Hapur, Master Plan for Water Supply for Panipat, Master Plan for Drainage for Hapur, Master Plan for Solid Waste management for Ghaziabad, Traffic and Transport analysis for Ghaziabad, Socio-Economic base line survey result in 3 sample project towns and proceedings of workshop 1 was submitted in January 2009. The four Master Plans as stated above are also made available on NCRPB web site for use of the implementing agencies.

4. The third deliverable Draft Final Report (DFR) comprising Detailed Project Report (DPR) for water supply in Panipat, DPR for sewerage in Hapur, DPR for drainage in Hapur, DPR for drainage in Sonipat, DPR for solid waste management in Ghaziabad, DPR for four selected transport components (Flyover, Road widening, Multi-level Parking and Bus Terminal) in Ghaziabad, and a Report on Capacity Building Activities were submitted.

5. Now, this is the Final Report (FR) and is the fourth and final deliverable. The comments/feedback on Draft Final Report received from ADB, NCRPB and respective implementing agencies were duly incorporated and final DPRs for components of Water Supply, Sewerage, Drainage, Solid Waste Management, and Transport are submitted as part of this Final Report. This is the Detailed Project Report for Transport Component of Multi-level Parking in Ghaziabad.
B. Overview of this ADB TA

6. **Objectives.** The objective of this TA is to strengthen the capacity at NCRPB, state-level NCR cells, and other implementing agencies in the area of planning for urban infrastructure and to impart necessary skills to conceive, design, develop, appraise and implement good quality infrastructure projects for planned development of NCR. The increased institutional capacity of the NCRPB and the implementing agencies will lead to effective and time scaling-up of urban infrastructure to (i) improve quality of basic urban services in the NCR; (ii) develop counter magnet towns; (iii) reduce in-migration into Delhi and orderly development of NCR; and (iv) accelerate economic growth in the NCR.

7. The TA – Capacity Development of the NCRPB, Component B focuses on strengthening the capacities of NCRPB and implementing agencies relating to project feasibility studies and preparation, and detailed engineering design in the implementing agencies. Specifically this component B of the TA will support the project preparation efforts of the implementing agencies by preparing demonstration feasibility studies that include all due diligence documentation required for processing of the project in accordance with best practices, including ADB’s policies and guidelines.

8. **Scope of Work.** According to the terms of reference of the TA assignment, the following activities are envisaged in component B of the TA:

   (i) Conduct technical, institutional, economic and financial feasibility analysis of identified subprojects in the six sample implementing agencies;

   (ii) Conduct safeguards due diligence on the subprojects, including environmental assessment report and resettlement plan for all subprojects covered in the sample implementing agencies;

   (iii) Prepare environmental assessment framework and resettlement framework; and

   (iv) Develop a capacity building and policy reform program for the implementing agencies, including governance strengthening, institutional development and financial management.

9. Besides, this component of the TA will also:

   (i) help in assessing the current practices and procedures of project identification and preparation of detailed project reports including technical, financial, economic and social safeguard due diligence;

   (ii) support preparation of standard procedure manuals for project identification and preparation of detailed project reports including technical, financial, economic and social safeguard due diligence;

   (iii) train the implementing agencies in the preparation of detailed project reports by using the sample subprojects, reports on deficiency of current practices and standard protocol manuals; and

   (iv) help in developing a user-friendly web-page where different manuals and guidelines for preparation of DPRs will be made available for the implementing agencies.
C. **About the Final Report**

10. At Interim Report stage of the TA, the Master Plans for Water Supply in Panipat, Sewerage system in Hapur, Drainage for Hapur and Municipal Solid Waste Management for Ghaziabad were prepared. The Master Plans provided 100 percent coverage of population and the area likely to be in planning horizon year 2031/2041. All works required up to planning horizon year were conceptualized, broadly designed and block cost was estimated. The Master Plans also provided phasing of investment such that under phase 1 works required to cover present spread of city were proposed.

11. At draft final report stage of the TA the Detailed Project Reports (DPRs) were prepared for Phase 1 works as suggested in the Master Plans. For preparation of DPRs, engineering surveys and investigations were conducted and various possible and feasible alternatives evaluated. Finally for the selected options the DPRs prepared with detailed designs, item wise detailed cost estimate, work specifications, implementation process and proposed implementation arrangements. Further, according to ADB procedures these DPRs in addition to technical analysis included institutional, financial and economic feasibility analysis and environmental and social safeguards due diligence – environmental assessment and resettlement plans.

12. The DPR's submitted as part of Draft Final Report was reviewed by the implementing agencies, NCRPB and the ADB. Now this Final Report comprising DPR's modified in light of comments of IA's is being submitted. The draft DPR for water supply in Panipat was reviewed by PHED Haryana. Detailed discussions were held with Superintending Engineer (Urban), Executive Engineer (Urban), Superintending Engineer (Karnal) and Executive Engineer Panipat. The comments made by PHED have been suitably incorporated in this Final Report.

13. These DPRs are proposed to be made available to the ULBs and other implementing agencies of the state governments as model DPRs so that they may replicate the methodology/approach in the future DPRs prepared by them for obtaining finances from the NCRPB.

14. **Organization of this Final Report.** The Final Report of the TA Component B is organized in following Seven Volumes:

- **Volume I**: Detailed Project Report for Water Supply System in Panipat
- **Volume II**: Detailed Project Report for Rehabilitation and Augmentation of Sewerage System in Hapur
- **Volume III**: Detailed Project Report for Rehabilitation of Major Drains in Hapur
- **Volume IV**: Detailed Project Report for Improvement of Solid Waste Management System in Ghaziabad
- **Volume V**: Detailed Project Reports for Four Transport Components in Ghaziabad
- **Volume VI**: Capacity Building Activities
Volume VII: Detailed Project Reports Rehabilitation of Drainage in Sonipat

D. Structure of Volume V Report

15. The DPRs for all four transport components are compiled in Volume V. This is Volume V is presented four volumes:

   (i) Volume V-A: DPR for Mohan Nagar Flyover  
   (ii) Volume V-B: DPR for Road Widening  
   (iii) Volume V-C: DPR for Bus Terminal  
   (iv) Volume V-D: DPR for Multi-level Parking

1. Structure of this Volume V-D Report

16. This DPR for Multi-level Parking Facility in Ghaziabad is compiled in following four sub-volumes (Volumes V-D1 to V-D4) including this Main Report:

   Volume V-D1: Main Report:
   
   - Section 1 Introduction  
   - Section 2 presents parking demand analysis  
   - Section 3 presents planning and design of the proposed parking facility  
   - Section 4 presents cost estimates

   Volume V-D2: Financial & Economic Analysis  
   Volume V-D3: Initial Environmental Examination  
   Volume V-D4: Short Resettlement Plan
2. PARKING DEMAND ANALYSIS

A. Overview

17. The unprecedented growth of personalized vehicles and the unplanned road infrastructure have made the provision for parking an important aspect of transportation planning. As part of Traffic Study conducted as part of this ADB TA, a parking study was also conducted at important locations in Ghaziabad. The area surrounding the old Bus Stand at Navyug Market is major centre and is CBD of Ghaziabad. This centre is busy with various activities; a number of commercial establishments, markets, government offices (Ghaziabad Nagar Nigam and Ghaziabad Development Authority) and the bus stand are situated here. Since most of these places are frequented by public and busy with floating population, the demand for parking is very high.

17. On-street parking is observed on all the roads surrounding Old Bus Stand and Navyug Market. Many cars and two wheelers are seen parked on either side of the roads. Both angular as well as parallel type of parking was noticed on almost all the stretches of the roads. This has reduced the capacity of the carriageway and endangering pedestrians and motorists alike. The frontage of almost all the roads in this area has been converted into commercial land use without taking into account the demand for parking of the vehicles. There is no planned parking space available.

18. Following sections assess the parking situation in the CBD area, its demand and the supply analysis.

B. Existing Parking Scenario

19. At present, the vicinity of the old bus stand has developed into a business and commercial hub along with government offices and restaurants. Thus, the demand for the parking has increased leading to parking irregularities. On-street parking is observed on all the roads surrounding Old Bus Stand and Navyug Market which is adjacent to Ghaziabad Development Authority. Many cars and two wheelers are seen parked on either side of the roads. Both angular as well as parallel type of parking can be noticed on almost all the stretches of the roads. Consequently, almost one lane of the carriageway is taken up, in turn creating traffic chaos.

20. Following Photographs show the on-street parking scenario in CBD Area near GDA office and Figure 2-1 show the location of existing parking places.
Photographs: On-Street Parking near GDA Office
Figure 2-1: On-street and Off-street Parking in the Study Area
C. Parking Demand Analysis

21. The following steps are involved in the parking study for Ghaziabad CBD area:

- Site reconnaissance
- Conduct of Parking and Traffic Surveys
- Estimation of current parking supply and demand
- Future demand forecast
- Development of conceptual parking facility layout

22. The following sections illustrate the approach and methodology, which have been followed to undertake the study. Before the betterment of parking problems, it is necessary to analyze the existing parking characteristics at various locations. Parking surveys are intended to provide all the information needed for assessment of the parking demand and supply for the study area. All the survey formats are included in Annexure I.

23. Site Reconnaissance Survey. In order to understand the study, a site reconnaissance survey is essential. This survey was done for the study area, to capture the road characteristics like available ROW and carriageway width. Land use in the site vicinity was also ascertained. Major establishments and traffic generators were identified. Traffic circulation and accessibility to the site were also assessed. Based on the above surveys, major issues in the area were identified.

24. Parking Surveys. The following surveys were conducted for understanding the parking characteristics, estimation of demand and supply for parking and for projecting the future parking demand.

- On-street parking surveys to study the parking characteristics and demand along the roadside.
- Opinion surveys (willingness to pay surveys) elicited opinion of the users about the facilities available for parking and their willingness to pay the fee for using the facility. The opinion survey also revealed the extent of suppressed parking demand.
- Inventory surveys were conducted to collect the potential of the existing facility in terms of available space, road characteristics, type of parking, land use of the location, etc.

25. Existing parking demand has been estimated through aggregation of on-street and off-street parking surveys. After the reconnaissance survey, the study area layout map was prepared on which the road stretches and off street parking lots within 500m (walk distance) from the proposed locations were identified for parking surveys. The roads for survey were identified based on the intensity of parking on the selected stretches, and also their connectivity to the proposed site.
1. **On Street Survey**

26. On street parking surveys are intended to collect the extent of usage of parking facilities along the roadside. The survey has been conducted by counting the vehicles parked on the road at regular intervals for a particular duration of the day.

27. The locations for the on-street survey have been identified through reconnaissance survey. The survey was conducted to ascertain the characteristics and magnitude of parking and accumulation on the adjoining streets of the proposed parking. The proposed site and about 500 m around proposed parking were surveyed for on-street parking survey. Registration numbers of the parked vehicles were noted down at half an hour interval in major parking areas. The survey was conducted from 8AM to 10 PM for three weekdays. The data collected include the time, type and registration number of the vehicle. Parking pattern of unregistered vehicles (like cycles, cycle rickshaws, etc.) was also estimated by counting such type of vehicles parked along the selected locations.

28. The data were entered in the format with the codes for each vehicle type. The codes adopted for various vehicle types are given in **Table 2-1**.

**Table 2-1**: Codes adopted for various types

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Vehicle Category</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Big Car</td>
<td>bc</td>
</tr>
<tr>
<td>2</td>
<td>Small Car</td>
<td>sc</td>
</tr>
<tr>
<td>3</td>
<td>Two Wheelers</td>
<td>tw</td>
</tr>
<tr>
<td>4</td>
<td>Van</td>
<td>v</td>
</tr>
<tr>
<td>5</td>
<td>Jeep</td>
<td>j</td>
</tr>
<tr>
<td>6</td>
<td>Bus</td>
<td>b</td>
</tr>
<tr>
<td>7</td>
<td>Trucks</td>
<td>t</td>
</tr>
<tr>
<td>8</td>
<td>MAV</td>
<td>mAV</td>
</tr>
<tr>
<td>9</td>
<td>LCV</td>
<td>LCV</td>
</tr>
<tr>
<td>10</td>
<td>Auto Rickshaw</td>
<td>aR</td>
</tr>
</tbody>
</table>

29. The data has been analyzed and the results are presented in terms of accumulation graphs and duration diagrams. Different Equivalent Car Spaces (ECS) values were adopted for different vehicle types and are given in **Table 2-2**. The ECS values were arrived based on the size of various vehicles and compared with that of passenger cars. The duration of vehicles parked was classified into three categories and is given in **Table 2-3**.
Table 2-2: ECS Values adopted for Various Vehicle Types

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Vehicle Category</th>
<th>ECS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Car</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>Two Wheelers</td>
<td>0.25*</td>
</tr>
<tr>
<td>3</td>
<td>Bus</td>
<td>2.5</td>
</tr>
<tr>
<td>4</td>
<td>Trucks</td>
<td>2.5</td>
</tr>
<tr>
<td>5</td>
<td>LCV</td>
<td>1.75</td>
</tr>
<tr>
<td>6</td>
<td>Auto</td>
<td>0.5</td>
</tr>
<tr>
<td>7</td>
<td>Cycles</td>
<td>0.1</td>
</tr>
<tr>
<td>8</td>
<td>Cycle Rickshaw</td>
<td>0.8</td>
</tr>
<tr>
<td>9</td>
<td>Carts</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Source: Parking Requirements in CMA, 2003, Wilbur Smith Pvt Ltd
*Source: Module 4-Guidelines for Parking Measures-Policy and Options, MOUD and PADECO Co. Ltd

Table 2-3: Classification of Duration of Parking

<table>
<thead>
<tr>
<th>SL. No.</th>
<th>Duration of Parking</th>
<th>Designation of Parking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 1 Hr</td>
<td>Very Short Duration</td>
</tr>
<tr>
<td>2</td>
<td>1-2 Hours</td>
<td>Short Duration</td>
</tr>
<tr>
<td>3</td>
<td>2-5 Hours</td>
<td>Medium Duration</td>
</tr>
<tr>
<td>4</td>
<td>5-10 Hours</td>
<td>Long Duration</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 10 Hours</td>
<td>Long Term Parking</td>
</tr>
</tbody>
</table>

30. Some important terms associated with parking are explained below:

(i) Parking Accumulation- Total number of vehicles parked in an area at a particular time period.
(ii) Parking Duration- Length of time a vehicle spent in a parking space
(iii) Parking Occupancy- Number of spaces occupied as a percent of total available spaces.
(iv) Parking Turnover- It is usually calculated as the number of time a parking space is been used during the day. Since there are no parking space demarcated in the study areas, and observed parking does not follow any parking norms, the parking turnover for the study is calculated per zone per ECS.

31. Outcome of the surveys include estimates of on-street parking volume, duration and accumulation along each designated roadway stretch.
2. **Willingness to Pay Survey**

32. Opinion surveys were conducted to elicit the opinion of the parkers about the facilities available for parking and about their willingness to pay the fee for using the proposed facility. The survey was done on a random sample basis during peak and off-peak periods. Users of the parking lot were interviewed and responses elicited include problems in existing parking facility, origin, destination, distance traveled, frequency of the visit, purpose of the visit, parking duration, occupancy, opinion about the existing parking rate with respect to existing facility, opinion about the parking fee system and willingness to pay. This survey was conducted on both weekdays and weekends.

33. A total of 522 samples were collected which comprised of 260 samples from Car users and 262 samples from non car users. Outcome of the survey includes identification of influence area of the market, frequency of the visit, purpose of the visit, problems with existing parking facility, occupancy rate opinion about the existing parking rate and about the future parking charge system with improved parking facility.

3. **Survey Schedule**

34. Parking surveys are conducted in the third and fourth weeks of August 2009. Detailed schedule of all surveys is presented in the following **Table 2-4**.

<table>
<thead>
<tr>
<th>Type</th>
<th>Schedule</th>
<th>Day</th>
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<tbody>
<tr>
<td>Junction Volume Count</td>
<td>17-08-09</td>
<td>Monday</td>
</tr>
<tr>
<td>Junction Volume Count</td>
<td>18-08-09</td>
<td>Tuesday</td>
</tr>
<tr>
<td>Junction Volume Count</td>
<td>19-10-08</td>
<td>Wednesday</td>
</tr>
<tr>
<td>Parking Accumulation Survey</td>
<td>20-08-09</td>
<td>Thursday</td>
</tr>
<tr>
<td>Parking Accumulation Survey</td>
<td>21-08-09</td>
<td>Friday</td>
</tr>
<tr>
<td>Parking Accumulation Survey</td>
<td>24-08-09</td>
<td>Monday</td>
</tr>
<tr>
<td>Parking Accumulation Survey</td>
<td>25-08-09</td>
<td>Tuesday</td>
</tr>
<tr>
<td>Parking Accumulation Survey</td>
<td>26-08-09</td>
<td>Wednesday</td>
</tr>
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<td>27-08-09</td>
<td>Thursday</td>
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<td>Parking Accumulation Survey</td>
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<td>Friday</td>
</tr>
<tr>
<td>Opinion Survey</td>
<td>24-08-09</td>
<td>Monday</td>
</tr>
</tbody>
</table>
D. Parking Analysis and Findings

1. Roadway Inventory (Carriageway and ROW) and Issues at the proposed site for parking.

35. The roadway details near the site are as follows:

- Dr Ambedkar Marg, the section leading the main entry to the site, is a four-lane divided roadway (2 lanes in each direction) with ~21 meter width.
- The right of entry to the site has no issues because the road width is sufficient enough to accommodate the entry –exit ramps.
- The roads covering the site have the width of about 7 meters on service lane of the Hapur Road on the northern side of the old bus stand and about 10 m on the cross road on the southern side of the old Bus Stand Road respectively.
- All the roads at the vicinity of the site are two way roads.

36. Major issues near the site are as follows:

- An existing off street paid parking lot near Ghaziabad Development Authority next to the old bus stand cannot cater to the parking demand in the area.
- Public tend to park on street (parallel parking) on the service lane adjacent to old bus stand near the GDA causing inconvenience to the traffic which takes almost one lane from the existing 7m width of the road.
- Unauthorized parking and vehicle waiting in front of Ghaziabad Development Authority and Nagar Nigam cause a lot of confusion and create bottleneck for the turning vehicles.
- Unauthorized Parking near Ghaziabad Development Authority and Nagar Nigam uses up the capacity of the roadway, thus affecting the flow of traffic. Parking needs to be prohibited in this area.
- Parking of auto rickshaws and cycle rickshaws is haphazard in front of the bus stand, where the entry and exit are at the same point. This causes queuing and traffic bottlenecks in this area.

2. Parking Supply

37. Two types of on street parking - parallel, and angular are prevailing in the study area. On street parking includes vehicles parked on the street. There may be authorized parking stretches, as well as stretches where parking is prohibited, but still parking is observed. Majority of the on-street and off-street are unauthorized free parking. On street supply is estimated based on the number of authorized parking slots on a given stretch by maintaining the present configuration and availability of adequate right of way. Parking
supplied is calculated as per the equivalent car space norms and available width of the right of way. For parallel and perpendicular parking, supply is calculated by dividing the length of the stretch by 7.5 m and 4 m respectively.

38. Total parking supply is calculated for the whole area based on the method mentioned above. Parking Inventory of all the roads surveyed in the study area is given in Annexure II.

39. On-street and off-street parking as shown in Figure 2-1 was used as zoning system for the parking analysis. The parking supply and demand estimations are shown in Table 2-5, Table 2-6, and Table 2-7. The hourly parking accumulations are shown in Figure 2-2 to Figure 2-6.

Table 2-5: Parking Demand for 16 hours –On Street (ECS) Cars and Two wheelers

<table>
<thead>
<tr>
<th>Zones</th>
<th>Day 1 ECS</th>
<th>Day 2 ECS</th>
<th>Day 3 ECS</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>3960</td>
<td>3130</td>
<td>2460</td>
<td>9550</td>
</tr>
<tr>
<td>Zone 2</td>
<td>1260</td>
<td>1250</td>
<td>1220</td>
<td>3730</td>
</tr>
<tr>
<td>Zone 3</td>
<td>840</td>
<td>842</td>
<td>830</td>
<td>2512</td>
</tr>
<tr>
<td>Zone 4</td>
<td>680</td>
<td>675</td>
<td>670</td>
<td>2025</td>
</tr>
<tr>
<td>Ambedkar Road</td>
<td>630</td>
<td>810</td>
<td>740</td>
<td>2180</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7370</strong></td>
<td><strong>6707</strong></td>
<td><strong>5920</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 2-6: Parking Demand for Peak Hour –On Street (ECS) Cars and Two wheelers

<table>
<thead>
<tr>
<th>Zones</th>
<th>Day 1 Peak hour ECS</th>
<th>Day 2 Peak hour ECS</th>
<th>Day 3 Peak hour ECS</th>
<th>Total Peak hour ECS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>373</td>
<td>300</td>
<td>190</td>
<td>863</td>
</tr>
<tr>
<td>Zone 2</td>
<td>90</td>
<td>95</td>
<td>90</td>
<td>275</td>
</tr>
<tr>
<td>Zone 3</td>
<td>55</td>
<td>50</td>
<td>53</td>
<td>158</td>
</tr>
<tr>
<td>Zone 4</td>
<td>40</td>
<td>47</td>
<td>45</td>
<td>132</td>
</tr>
<tr>
<td>Ambedkar Road</td>
<td>50</td>
<td>65</td>
<td>70</td>
<td>185</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>608</strong></td>
<td><strong>557</strong></td>
<td><strong>448</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 2-7: Peak hour Parking Demand, Parking Supply and Gap – On Street (ECS) Cars and Two wheelers

<table>
<thead>
<tr>
<th>Zones</th>
<th>Parking Demand (1)</th>
<th>Parking Supply (2)</th>
<th>Gap (1) - (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>373</td>
<td>234</td>
<td>139</td>
</tr>
<tr>
<td>Zone 2</td>
<td>95</td>
<td>44</td>
<td>51</td>
</tr>
<tr>
<td>Zone 3</td>
<td>55</td>
<td>49</td>
<td>6</td>
</tr>
<tr>
<td>Zone 4</td>
<td>47</td>
<td>49</td>
<td>-2</td>
</tr>
<tr>
<td>Ambedkar Road</td>
<td>70</td>
<td>116</td>
<td>-46</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>640</strong></td>
<td><strong>491</strong></td>
<td><strong>149</strong></td>
</tr>
</tbody>
</table>
**Figure 2-2:** Average Hourly variation of parking Accumulation in zone 1

**Figure 2-3:** Average Hourly variation of parking Accumulation in zone 2
Figure 2-4: Average Hourly variation of parking Accumulation in zone 3

Figure 2-5: Average Hourly variation of parking Accumulation in zone 4

Figure 2-6: Average Hourly variation of parking Accumulation at Ambedkar Veedhi
3. **Survey Findings**

40. *Trip Purpose.* Analysis on purpose of trip revealed that work trips are more with 87% (Car users) and 83% (Non-car users) followed by shopping trips about 6% (Car users) and 9% (Non-car users). The details of journey purpose are presented in **Table 2-8.**

<table>
<thead>
<tr>
<th>Trip Purpose</th>
<th>Car Users (%)</th>
<th>Non-Car Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td>87%</td>
<td>83%</td>
</tr>
<tr>
<td>Shopping</td>
<td>2%</td>
<td>6%</td>
</tr>
<tr>
<td>Leisure</td>
<td>6%</td>
<td>9%</td>
</tr>
<tr>
<td>Others</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

41. *Trip Frequency.* Analysis of trip frequency shows that daily trips are more (40% Car users & 22% Non-car users) followed by weekly trips (22% Car users & 35% Non-car users) and occasional trips (23% Car users & 30% Non-car users). Based on the samples collected (about 300 samples) the trip frequency distribution of the survey is presented in **Table 2-9.**

<table>
<thead>
<tr>
<th>Trip Purpose</th>
<th>Car Users (%)</th>
<th>Non-Car Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>89%</td>
<td>86%</td>
</tr>
<tr>
<td>Weekly</td>
<td>0%</td>
<td>12%</td>
</tr>
<tr>
<td>Occasionally</td>
<td>11%</td>
<td>0%</td>
</tr>
<tr>
<td>Others</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

42. *Willingness to Pay.* The survey also included the willingness to pay survey of the likely users. The survey indicates that users are willing to pay a charge in the range of Rs. 10 – 25 for a closed and secured parking.

E. **Parking Demand Forecast**

1. *Parking Demand Forecast*

43. The present Parking demand is projected to 2030. The growth rate considered for projecting the future parking demand is 6% which is taken in with respect to the average vehicular growth in the region. The details are shown in **Table 2-10.**
Table 2-10: Parking demand is projected to 2030

<table>
<thead>
<tr>
<th>Base year 2010</th>
<th>Projected Parking Demand (No. of vehicles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010 – 2020</td>
<td>650</td>
</tr>
<tr>
<td>2020 – 2025</td>
<td>723</td>
</tr>
<tr>
<td>2025 – 2030</td>
<td>896</td>
</tr>
</tbody>
</table>

Notes:

(i) Econometric modeling is used to derive the Growth Factor. To obtain the Growth Factor we consider the data related to Population, Per Capita Income (PCI), Net State Domestic Product (NSDP) and Gross Domestic Product (GDP).

(ii) The influence area of the study includes the state of Uttar Pradesh and Delhi.

(iii) An econometric model measures past relationships among various variables and then tries to forecast how changes in some variables will affect the future course of others.

(iv) Formula Recommended by IRC (108 – 1996) is:

\[ \log_e P = A_0 + A_1 \log_e GDP + A_2 \log_e NSDP + A_3 \log_e Population + A_4 \log_e PCI \]

Where,

- \( P \) = Traffic Volume
- \( A_0 \) = Regression Constant
- \( A_1, A_2, A_3, A_4 \) are the Elasticity Coefficients

(vi) The time series data of traffic at the study area and the corresponding data on GDP, NSDP, Population and PCI are tabulated.

(vii) Multiple Regression Analysis is done to arrive at the following equation

\[ \log_e P = A_0 + A_1 \log_e GDP + A_2 \log_e NSDP + A_3 \log_e Population + A_4 \log_e PCI \]

The values of \( A_1, A_2, A_3, A_4 \) are found

(viii) Growth rate of traffic = (\( A_1 \) * Expected Growth rate of GDP) + (\( A_2 \) * Expected Growth rate of NSDP) + (\( A_3 \) * Expected Growth rate of Population) + (\( A_4 \) * Expected Growth rate of PCI)

The growth of the traffic is projected with the obtained growth factors. The growth rates obtained are

- 6.5 For the period from 2009 to 2020
- 6.0 For the period from 2020 to 2025
- 5.7 For the period from 2025 to 2030

(ix) The reason behind the variation of growth factor periodically is because of the predicted periodic changes in factors considered in the regression equation.

2. **Space Requirement**

44. As per the parking demand forecasted for the year 2030 at 5% nominal increase taken with parallel to the traffic growth in the region, the current parking demand stands at 640 – 650 PCU’s. Based on the present demand, the future parking demand is projected to be around 900 PCU’s.
45. Considering the scenario to be 80% parking for cars and 20% for two wheelers, approximate space required for car parking would be about 9000 square meters and 540 Square meters for two wheeler parking. Besides additional spaces to be provided for drive ways, columns, off sets, stairs, Lifts etc.

F. Recommendations

46. The parking analysis clearly established the need for constructing a multi-level parking lot in the vicinity of GDA in the CBD area. The best option available is to make use of the site that is currently functioning as the old bus stand. Since the Master Plan for Ghaziabad has already identified a new site for the future bus stand, it has been recommended to shift the existing old bus stand to the new location on Loni Road as identified in the Master Plan. In the event of this, the old bus stand can be used for building the multi-storey parking lot. Total area of the site is 10,040 sq m.

G. Description of the proposed parking site (Old Bus Stand)

I. Access roads to site

47. The main access to the site under consideration (Old Bus Stand) is from Dr. Ambedkar Road. There are other cross roads running perpendicular to Dr. Ambedkar Road which also connect the Old Bus Stand. One of the cross roads is the service lane below the flyover on the NH-24/Hapur Road. Dr. Ambedkar road is a four lane divided roadway and the cross road is a two lane undivided roadway as shown in Figure 2-7. The photographs presented below also show the existing scenario in the study area.

Figure 2-7: Road network around the proposed Parking Lot
Photographs

**Photo 1:** Entry/Exit Gate of Bus Stand

**Photo 2:** View of Bus Stand

**Photo 3:** Ambedkar Circle near Gate 1

**Photo 4:** Service Lane near Gate 3
48. *Entry and Exit Details.* At present, the Old Bus Stand has three main entry gates - G1, G2 and G3 as shown in Figure 2-8. The impact of traffic is expected to be more from Dr Ambedkar Road since Gate 1 and Gate 2 are positioned on Dr Ambedkar Road. The major problem that will affect G1 and G3 is that the intersections are close to the gates which may affect the traffic on that particular stretch of road. Gate 3 does not have a problem at present, since it only serves for the entry and exit for the two wheeler parking inside the bus stand.

**Figure 2-8:** Existing Entry and Exist Details at Old Bus Stand
H. Proposed Multistory Parking Facility & Traffic Considerations

49. The proposed multistory parking facility at the old bus stand accommodates for business and commercial center in the ground floor and parking facility for two wheelers; cars and two wheelers on the first floor, and the second and third floors exclusively for car parking only. Depending on the demand, the terrace (fourth level) can also be used for open car parking.

50. Once the parking facility is developed and parking facility is given to accommodate a number of vehicles in the small place, the impact of this parking facility on the adjacent roads needs to be studied. There will change in the existing flow patterns and will affect the existing traffic density and the roadway capacities.

51. To ascertain the impact, turning movement counts (8 hours) were carried out at three intersections of the roads like Ambedkar Road/ GT Road, Dr. Shyam Prasad Mukharjee Road, Maliwara Road/ Dasana Marg - through which the traffic will enter or leave the existing bus terminal. These junctions include:

   (i) Bus Stand Junction (Ambedkar Road / Hapur Road (NH 24) )
   (ii) Maliwara Junction (Ambedkar Road / Dasna Marg )
   (iii) Chowdary Junction (Ambedkar Road / G T Road (NH- 91)

52. From the turning volume counts, the actual PCUs on the stretch of roadways leading to the bus terminal from these junctions are calculated. It is important to note that because of the shifting of the existing bus terminal, no bus traffic will come on these roads in the future, and also, there will be a significant amount of reduction in the other categories of vehicles on the road network in the vicinity. Factoring these in to projecting the future traffic on the roads leading to the proposed parking facility, it can be stated that the new parking lot will not significantly impact the roadway network capacity in the vicinity of GDA.
3. PLANNING & DESIGN OF MULTI-LEVEL PARKING FACILITY

A. General

53. Need and objective of the project has been explained in the Chapter on parking demand of the region. The location selected is the old bus stand next to Ghaziabad Development Authority. A reconnaissance survey was carried out to gather basic information about the site, type of area like commercial or residential, climate etc. from different sources. Primary and secondary data available were also collected for further studies.

B. Surveys & Investigations

54. The following site surveys were carried out for the finalization of the structure:

- Location Survey
- Topographic Survey
- Traffic surveys

55. Due to busy activities in the existing Bus terminal the Consultant was not able to carry out geotechnical investigations at the site. Hence the geotechnical details taken for the proposed Bus Terminal building is considered for the design of Multilevel Car Parking. The lowest value of SBC at a depth of 3m given in the area of Bus Terminal is 225 KN/m2 and this value is considered for design. It is also recommended to take adequate number of confirmatory bore holes during execution. This item is included in the cost estimates.

1. Topographical Survey

56. The basic objective of the topographical survey was to collect the essential ground features of the area using Total Station so as to develop a Digital Terrain Model (DTM), to take care of design requirements. The data collected will result in the final design and is also used for the computation of earthwork and other quantities required.

57. As first step of the field study, satellite imagery maps of the location were collected and examined thoroughly to have first hand information about the area and to decide on the possible improvement options. It also helped out in finalizing the extent of topographical survey.

58. Spot levels were taken along the proposed area at regular intervals to understand the ground variation. The utility services present along the existing area were also plotted. Topographic survey was carried out using Total Station of 5-sec accuracy for detailed mapping and with higher accuracy total station during the traversing (min 3 sec). The
existing features surveyed were directly imported into Computer Aided Software and the details of the same has been plotted and presented for ready reference.

59. In order to prepare the plan of the Multi Level parking building the following technical factors were taken into consideration:

- Land use requirement for various activities
- Planning norms and regulations
- Topographical and geotechnical factors such as ground features and slope, type of soil, ground water level etc.
- Standards for provision of parking requirement
- Traffic growth trend and future demand
- Seismic zone and wind direction
- Safety and security

C. Planning Considerations

60. The site earmarked for the proposed construction of the multi level parking facility is located in a busy area with major very congested roads (NH 24 and Dr. Ambedkar road on two sides and a cross road less hectic on the third side. The site has rectangular shape with an area of 10,040 sq.m. The built-up area comes to 8,569 sq.m leaving the mandatory minimum setback distances specified in the National building code of India. Norms have been followed and safety measures taken in the parking spaces as well as ramps. The building is a four storied framed structure with commercial space in the ground floor and parking facilities in the three floors and roof above. The demand is to park 650 numbers of vehicles in the base year itself which will increase to 900 numbers within the next 20 years. 80% of parking area is provided for cars and 20% for two wheelers. Ramps on slope 1 in 10 are provided for the entry and exit of vehicles to and from different levels. The structure has two lifts and a staircase for the use of customers utilizing the facility, located at the centre of the building. The building shall be covered with walls only in the ground floor. Other floors are provided with 1m high parapets in the outer periphery. Fire fighting system is not proposed as the building is kept open.

61. General Approach. The entry of vehicles to the parking building is proposed through the cross road and exit to NH 24. Unidirectional flow of vehicles is maintained inside the structure. The circulation pattern shall be guided by proper signage system. The movement of vehicles inside the building is channelized through driveways laid down between the parking bays.

62. Separate parking bays are allocated for two and four wheelers. Considering the predominant business surrounding of the area, ground floor is set aside for commercial purpose. Brick walls are proposed along the exterior of the ground floor with partition inside. Typical floor plans are presented in Figure 3-1 and Figure 3-2. Detailed floor plans, sections and elevations are presented in Appendix 1.
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site area</td>
<td>Sq. m</td>
<td>10,040</td>
</tr>
<tr>
<td>2</td>
<td>Area (Ground Floor)</td>
<td>Sq. m</td>
<td>8,323</td>
</tr>
<tr>
<td>3</td>
<td>Area (1&lt;sup&gt;st&lt;/sup&gt;, 2&lt;sup&gt;nd&lt;/sup&gt; and 3&lt;sup&gt;rd&lt;/sup&gt; Floors)</td>
<td>Sq. m</td>
<td>25,833</td>
</tr>
<tr>
<td>4</td>
<td>Commercial/Retail (Ground Floor)</td>
<td>Sq. m</td>
<td>5,000</td>
</tr>
<tr>
<td>5</td>
<td>Parking (Ground Floor) – 2-wheelers</td>
<td>No. s</td>
<td>117</td>
</tr>
<tr>
<td>6</td>
<td>Parking (1&lt;sup&gt;st&lt;/sup&gt; floor ) – 2-wheelers</td>
<td>No. s</td>
<td>213</td>
</tr>
<tr>
<td>6</td>
<td>Parking (1&lt;sup&gt;st&lt;/sup&gt;, 2&lt;sup&gt;nd&lt;/sup&gt; and 3&lt;sup&gt;rd&lt;/sup&gt; Floors) – Cars</td>
<td>No.s</td>
<td>777</td>
</tr>
</tbody>
</table>
**Figure 3-1**: Ground Floor Plan of the Proposed Multilevel Parking
**Figure 3-2**: Typical Floor Plan of the Proposed Multilevel Parking Facility
D. Structural System

63. The proposed building is 80.46m long and 106.5m wide with a plinth area of 8569 sq.m for each floor. The floor height shall be 3.6m. A combination of column beam arrangement is proposed for the building. Large column spacing of 10.8m is adopted along the breadth and 8.4m is given lengthwise to facilitate easy vehicle movement. Considering the larger size of slab panels, grid beam arrangement is proposed for floors and roof. Ordinary beam slab arrangement is adopted for ramps. Mild condition of exposure is considered in design. Isolated, combined and raft foundations are the different types of foundations adopted. The minimum depth of foundation shall generally be 2.5 m below ground.

64. Salient features of the building are:
   - Length 80.46m
   - Breadth 106.50m
   - Column spacing (along the length): varies from 8.4m to 4.96m.
   - Column spacing (along the breadth):10.8m
   - Column spacing for ramp (along the length): 5.345m
   - Column spacing for ramp (along the breadth): varies from 8.36m to 5.46m.
   - Plinth area: 8569 sq.m

65. Design criterion.
   - Exposure Condition - Mild (as per IS 456 – Table Clause 8.2.2.1 & 5.3.2)
   - Grade of Concrete – M30 (as per IS 456 – Table 5 Clause 6.1.2, 8.2.4.1 & 9.1.2)
   - Reinforcing Steel - Fe 415 conforming to IS 1786.
   - Safe Bearing Capacity of the soil considered – 225 KN/m2
   - Depth of foundation – 2.5m below ground

66. Design codes and standards.

67. The structural design is carried out as per the latest versions of Indian Standard codes published by Bureau of Indian Standards. Various design codes and standards referred are:
   - IS 456 for Plain and Reinforced Concrete.
   - IS 875 Part 1,2,3 & 5 for dead load, live load, wind load and combinations
   - SP 34 for detailing of reinforcement

68. Ghaziabad being in seismic zone IV, the earthquake resistant design became mandatory. The codes followed are:
69. **Loads considered.**

(i) Self Weight of members  
(ii) Wall Load  
(iii) Slab Live Load (3kN/m\(^2\) as per IS 875 Part II)  
(iv) Stair/Lift/Ramp Load  
(v) Load due to Wind

70. For wind load the four Cases considered are:

- Wind force acting in X direction  
- Wind acting in -X direction  
- Wind force acting in Z direction  
- Wind acting in -Z direction

71. **Wind Load Analysis.** General load combinations considered in the design are: (as per IS 456 – Table 18 Clause 18.2.3.1, 36.4 & B-4.3)

- 1.5 * (DL+WX)  
- 1.5 * (DL-WX)  
- 1.5 * (DL+WZ)  
- 1.5 * (DL-WZ)  
- 1.2 * (DL+LL+WX)  
- 1.2 * (DL+LL-WX)  
- 1.2 * (DL+LL+WZ)  
- 1.2 * (DL+LL-WZ)  
- 0.9 * DL+ 1.5 * WX  
- 0.9 * DL - 1.5 * WX  
- 0.9 * DL+ 1.5 * WZ  
- 0.9 * DL - 1.5 * WZ

72. **Load due to Earthquake.** The two cases considered are: (i) force acting in X direction, and (ii) force acting in Z direction: Load combinations considered are:

- 1.5 * (DL+LL)  
- 1.5 * (DL+EQX)  
- 1.5 * (DL-EQX)  
- 1.5 * (DL+EQZ)  
- 1.5 * (DL-EQZ)
Following densities and load values are considered for design:

(i) Density of Reinforced concrete: 24 kN/m$^3$
(ii) Density of brick masonry: 18.85 kN/m$^3$
(iii) Density of earth: 18 kN/m$^3$
(iv) Superimposed Live Load: 4 kN/m$^2$
(v) Floor Finishes: 1 kN/m$^2$

Data for wind load design.

(i) Basic wind speed – Ghaziabad 47 m/sec (Appendix A Clause 5.2)
(ii) Wind Intensity – 1.73 kN/m$^2$

Criteria for Earthquake Resistant Design of Structures. (IS 1893-2002) Clause 6.3.1.2

Partial safety factors for limit state design of reinforced concrete and prestressed concrete structures.

In the limit state design of reinforced concrete structures, the following load combinations are to be accounted for:

(i) 1.5(DL+IL)
(ii) 1.2(DL+IL±EL)
(iii) 1.5(DL±EL)
(iv) 0.9DL±1.5EL

Factors Considered for Earth Quake Analysis.

- Ghaziabad is Located in Zone IV
- Zone Factor: 0.24
- Importance Factor: 1.5
- Response Reduction Factor: 3.0
- Rock & Soil Site Factor: 1.0
- Damping Ratio : 0.5
- Suitable increase in SBC is considered as per IS 1893-2002

Ref: [Table1 Percentage of Permissible Increase in Allowable Bearing Pressure or Resistance of Soils (clause6.3.5.2)]
For Medium soil - Percentage of Permissible Increase is 25% for isolated RCC footing without tie beams, or unreinforced strip foundations.

78. **Clear cover to reinforcement.** The following clear cover to the outer reinforcement shall be adopted:

- For Foundation : 50 mm.
- For Beams : 30 mm.
- For Slabs : 20mm.
- For columns : 40 mm.

79. The framed system is analyzed as a 3D structure using STAAD Pro 2007. The member forces and moments from the STAAD output are taken for the design. The beams are designed as singly reinforced as well as doubly reinforced depending upon the requirement. The columns are designed as square or rectangular in shape. The slabs supported by beams and columns are designed using the method specified in Annexure D of IS 456:2000 and the grid slab is designed as normal practice. The various structural elements are designed for the worst combination of loads.

E. **Analysis of the Multilevel Parking**

80. Multilevel Parking has a plinth area 8569 sq.m with length of 80.46 and width of 106.5m. Ramp will have a width of 10.69m with varying length. STAAD Pro 2007 is used for the modeling of the structure. For the accuracy of results the whole structure has been split into number of units & modeled separately such as ramp portion, lift & staircase & also for different panels within the structure.

81. To take care of temperature stresses in slab an expansion joint of 20 mm is provided along the width of the structure. Two expansion joints are provided forming a total of three sections of 35.587m, 32.045m & 37.693m.

82. Based on the axial load following types of footings are designed:

- Raft foundation of 14.5m x 8.5 for lift & staircase portion
- Isolated footings of 6 different sizes.
- Combined Footings of 10 different sizes.

83. Details are given in the structural drawings. All footings shall have a minimum depth of
2.5m from ground level based on the bearing capacity of the soil.

84. Columns were designed for biaxial bending considering axial Load & moments in X & Y directions. There are about 10 different types of columns within the structure considering span & load.

85. Slab of structure is designed for traffic load of 3kN/m² (as per IS 875 Part II) with additional 25% is taken as impact load. Therefore overall super imposed load is taken as 4kN/m² considering overall safety of the structure. The slab is designed as grid slab to give more stability & to enhance serviceability. Whereas the slab in the ramp portion is designed as ordinary slab & beam arrangement to facilitate the slope of the ramp.

86. Seismic Analysis. Static Equivalent Method is used for the seismic analysis utilizing the rules of IS: 1893(part 1) – 2002.

87. Methodology. In seismic load generation using a static equivalent approach, encompassed in code IS 1893, the weights in the structure are specified. There are three methods for specifying the weights: self weight, joint weight and member weight. Weights, which could be treated as being lumped at a node, could be assigned using Joint Weight the same has been used during this analysis.

88. The joint loads at all the nodes are obtained from the initial analysis by assuming pinned supports at all the beam column joints. These loads are applied as weight for the seismic analysis.

89. Analysis of this system for all the loads/load combinations is carried out. Please refer following appendices for detailed structural analysis and drawings.

**Appendix 2**: STAAD Model  
**Appendix 3**: STAAD Input File  
**Appendix 4**: Design of Footing  
**Appendix 5**: Design of Columns  
**Appendix 6**: Design of Beams  
**Appendix 7**: Design of Slab  
**Appendix 8**: Structural Drawings
4. COST ESTIMATES

A. Rate Analysis

90. The unit rates shall be arrived by considering the basic rates, lead distances, man power, machinery, and materials. The unit rate for every individual item is arrived based on Uttar Pradesh Lok Nirman Vibhag (UP Public Works Department), Schedule of Rates for Ghaziabad District 2008 and Central Public Works Department Delhi, Schedule of rates 2007. For items of work with no rates specified in the schedule of rates, market rates are obtained and used.

B. Bill of Quantities & Cost Estimates

91. Total item wise quantities are calculated as per the detailed drawings. Separate heads for all different items of work is included in the BOQ. The major work items considered are:

- Earth work excavation
- Concrete
  - PCC leveling Course
  - Reinforced Cement concrete M30
    - Foundation
    - For walls, columns, beams, slab etc
- Steel
  - Reinforcement
    - Foundation
    - For Walls, columns, beams, slab etc
- Electrical cost
- Miscellaneous Items
  - caution/warning Signs, expansion joints, and etc.,
  - Painting, white washing, finishes and etc.

92. The total based cost of this Multi-level Parking Project works out to be INR 366.8 million. Bill of quantities and detailed quantities and estimates are presented in Appendix 9.
Appendix 1
STAAD MODEL
Multi Level Car Parking Lift & Stair Portion
Multi Level Car Parking Central Portion with Column Spacing of 10.8 x 8.4
Raft Slab
Multi Level Car Parking Ramp Portion
STAAD INPUT FILE
STAAD INPUT FILE
STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 09-Dec-09
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0.8 0; 2 10.8 0.8 0; 3 21.6 0.8 0; 4 32.4 0.8 0; 5 0 3.3 0; 6 10.8 3.3 0;
7 21.6 3.3 0; 8 32.4 3.3 0; 9 0 0.8 8.4; 10 10.8 0.8 8.4; 11 21.6 0.8 8.4;
12 32.4 0.8 8.4; 13 0 3.3 8.4; 14 10.8 3.3 8.4; 15 21.6 3.3 8.4;
16 32.4 3.3 8.4; 17 0 0.8 16.8; 18 10.8 0.8 16.8; 19 21.6 0.8 16.8;
20 32.4 0.8 16.8; 21 0 3.3 16.8; 22 10.8 3.3 16.8; 23 21.6 3.3 16.8;
24 32.4 3.3 16.8; 25 0 0.8 25.2; 26 10.8 0.8 25.2; 27 21.6 0.8 25.2;
28 32.4 0.8 25.2; 29 0 3.3 25.2; 30 10.8 3.3 25.2; 31 21.6 3.3 25.2;
32 32.4 3.3 25.2; 33 0 6.9 0; 34 10.8 6.9 0; 35 21.6 6.9 0; 36 32.4 6.9 0;
37 0 6.9 8.4; 38 10.8 6.9 8.4; 39 21.6 6.9 8.4; 40 32.4 6.9 8.4; 41 0 6.9 16.8;
42 10.8 6.9 16.8; 43 21.6 6.9 16.8; 44 32.4 6.9 16.8; 45 0 6.9 25.2;
46 10.8 6.9 25.2; 47 21.6 6.9 25.2; 48 32.4 6.9 25.2; 49 1.35 6.9 0;
50 2.7 6.9 0; 51 4.05 6.9 0; 52 5.4 6.9 0; 53 6.75 6.9 0; 54 8.1 6.9 0;
55 9.45 6.9 0; 56 0 6.9 1.4; 57 0 6.9 2.8; 58 0 6.9 4.2; 59 0 6.9 5.6;
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70 25.65 6.9 0; 71 27 6.9 0; 72 28.35 6.9 0; 73 29.7 6.9 0; 74 31.05 6.9 0;
75 0 6.9 9.8; 76 0 6.9 11.2; 77 0 6.9 12.6; 78 0 6.9 14; 79 0 6.9 15.4;
80 0 6.9 18.2; 81 0 6.9 19.6; 82 0 6.9 21; 83 0 6.9 22.4; 84 0 6.9 23.8;
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89 6.75 6.9 8.4; 90 8.1 6.9 8.4; 91 9.45 6.9 8.4; 92 12.15 6.9 8.4;
93 13.5 6.9 8.4; 94 14.85 6.9 8.4; 95 16.2 6.9 8.4; 96 17.55 6.9 8.4;
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241 243 TO 287 963 TO 981 985 989 993 997 TO 1039 1041 1043 1045 1047 1049 - 1051 1053 1055 1057 1059 1061 1063 1065 1067 1069 1071 1073 1075 1077 1079 - 1081 1083 1085 1087 1089 1091 1093 1095 1097 1099 1101 1103 1105 1107 1109 - 1111 1113 1115 1117 1119 1121 1123 1125 1127 1129 1131 1133 1135 1137 1139 - 1141 1143 1145 1147 1149 1151 1153 1155 1157 1159 1161 1163 1165 TO 1209 - 1885 TO 1903 1907 1911 1915 1919 TO 1961 1963 1965 1967 1969 1971 1973 1975 - 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 - 2007 2009 2011 2013 2015 2017 2019 2021 2023 2025 2027 2029 2031 2033 2035 - 2037 2039 2041 2043 2045 2047 2049 2051 2053 2055 2057 2059 2061 2063 2065 - 2067 2069 2071 2073 2075 2077 2079 2081 2083 2085 2087 TO 2131 2807 TO 2825 - 2829 2833 2837 2841 TO 2883 2885 2887 2889 2891 2893 2895 2897 2899 2901 - 2903 2905 2907 2909 2911 2913 2915 2917 2919 2921 2923 2925 2927 2929 2931 - 2933 2935 2937 2939 2941 2943 2945 2947 2949 2951 2953 2955 2957 2959 2961 - 2963 2965 2967 2969 2971 2973 2975 MATERIAL CONCRETE MEMB 2977 2979 2981 2983 2985 2987 2989 2991 2993 2995 2997 - 2999 3001 3003 3005 3007 3009 TO 3053 LOAD 1 LOADTYPE Seismic TITLE EQX 1893 LOAD X 1 LOAD 2 LOADTYPE Seismic TITLE EQZ 1893 LOAD Z 1 LOAD 3 LOADTYPE Wind TITLE WIND X WIND LOAD X 1 TYPE 1 XR 0 32.4 YR 3.3 17.7 OPEN LOAD 4 LOADTYPE Wind TITLE WIND Z WIND LOAD Z 1 TYPE 1 XR 0 32.4 YR 3.3 17.7 25.2 OPEN LOAD 5 LOADTYPE Wind TITLE WIND -X WIND LOAD -X -1 TYPE 1 XR 0 32.4 YR 3.3 17.7 OPEN LOAD 6 LOADTYPE Wind TITLE WIND -Z WIND LOAD -Z -1 TYPE 1 XR 0 32.4 YR 3.3 17.7 ZR 0 25.2 OPEN LOAD 7 LOADTYPE None TITLE SW SELFWEIGHT Y -1 LOAD 8 LOADTYPE Dead TITLE WALL LOAD MEMBER LOAD 1 TO 3 29 TO 40 UNI GY -10.5 LOAD 9 LOADTYPE Dead TITLE FLOOR FINISH FLOOR LOAD YRANGE 6.9 7 FLOAD -1 GY YRANGE 10.5 10.6 FLOAD -1 GY YRANGE 14.1 14.2 FLOAD -1 GY YRANGE 17.7 17.8 FLOAD -1 GY LOAD 10 LOADTYPE Dead TITLE PARAPET LOAD MEMBER LOAD 44 TO 47 51 55 88 TO 92 107 TO 116 201 203 205 207 209 211 213 215 217 219 - 221 223 225 227 229 231 233 235 237 239 241 966 TO 969 973 977 1010 TO 1014 - 1029 TO 1038 1123 1125 1129 1131 1133 1135 1137 1139 1141 1143 1145 - 1147 1149 1151 1153 1155 1157 1159 1161 1163 1888 TO 1891 1895 1899 1932 - 1933 TO 1936 1951 TO 1960 2045 2047 2049 2051 2053 2055 2057 2059 2061 2063 - 2065 2067 2069 2071 2073 2075 2077 2079 2081 2083 2085 2810 TO 2813 2817 - 2821 2854 TO 2858 2873 TO 2882 2967 2969 2971 2973 2975 2977 2979 2981 2983 - 2985 2987 2989 2991 2993 2995 2997 2999 3001 3003 3005 3007 UNI GY -2.85 LOAD 11 LOADTYPE Roof Live REDUCIBLE TITLE LL ON SLAB WITH DISPERSION FLOOR LOAD YRANGE 6.9 7 FLOAD -4 GY YRANGE 10.5 10.6 FLOAD -4 GY YRANGE 14.1 14.2 FLOAD -4 GY YRANGE 17.7 17.8 FLOAD -4 GY LOAD COMB 12 1.5 * (DL+LL) 7 1.5 8 1.5 9 1.5 10 1.5 11 1.5 LOAD COMB 13 1.5 * (DL+EQX) 7 1.5 8 1.5 9 1.5 10 1.5 11 1.5 LOAD COMB 14 1.5 * (DL-EQX) 7 1.5 8 1.5 9 1.5 10 1.5 11 1.5 LOAD COMB 15 1.5 * (DL+EQQ) 7 1.5 8 1.5 9 1.5 10 1.5 2 1.5
LOAD COMB 16 1.5 * (DL-EQZ)
  7 1.5 8 1.5 9 1.5 10 1.5 2 -1.5
LOAD COMB 17 1.2 * (DL+LL+EQX)
  7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 1 1 1 1.2
LOAD COMB 18 1.2 * (DL+LL-EQX)
  7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 1 -1.2
LOAD COMB 19 1.2 * (DL+LL+EQZ)
  7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 2 1 1.2
LOAD COMB 20 1.2 * (DL+LL-EQZ)
  7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 1 -1.2
LOAD COMB 21 0.9 * DL + 1.5 * EQX
  7 0.9 8 0.9 9 0.9 10 0.9 1 1.5
LOAD COMB 22 0.9 * DL - 1.5 * EQX
  7 1.2 8 0.9 9 0.9 10 0.9 1 -1.5
LOAD COMB 23 0.9 * DL+ 1.5 * EQZ
  7 0.9 8 0.9 9 0.9 10 0.9 2 1.5
LOAD COMB 24 0.9 * DL - 1.5 * EQZ
  7 0.9 8 0.9 9 0.9 10 0.9 2 -1.5
LOAD COMB 25 1.5 * (DL+WX)
  7 1.5 8 1.5 9 1.5 10 1.5 3 1.5
LOAD COMB 26 1.5 * (DL-WX)
  7 1.5 8 1.5 9 1.5 10 1.5 5 -1.5
LOAD COMB 27 1.5 * (DL+WZ)
  7 1.5 8 1.5 9 1.5 10 1.5 4 1.5
LOAD COMB 28 1.5 * (DL-WZ)
  7 1.5 8 1.5 9 1.5 10 1.5 6 -1.5
LOAD COMB 29 1.2 * (DL+LL+WX)
  7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 3 1.2
LOAD COMB 30 1.2 * (DL+LL-WX)
  7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 5 -1.2
LOAD COMB 31 1.2 * (DL+LL+WZ)
  7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 4 1.2
LOAD COMB 32 1.2 * (DL+LL-WZ)
  7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 6 -1.2
LOAD COMB 33 0.9 * DL+ 1.5 * WX
  7 0.9 8 0.9 9 0.9 10 0.9 3 1.5
LOAD COMB 34 0.9 * DL - 1.5 * WX
  7 0.9 8 0.9 9 0.9 10 0.9 5 -1.5
LOAD COMB 35 0.9 * DL+ 1.5 * WZ
  7 0.9 8 0.9 9 0.9 10 0.9 4 1.5
LOAD COMB 36 0.9 * DL - 1.5 * WZ
  7 0.9 8 0.9 9 0.9 10 0.9 6 -1.5
PERFORM ANALYSIS PRINT ALL
PRINT MEMBER FORCES ALL
FINISH
STAAD SPACE

END JOB INFORMATION

UNIT METER KN

JOINT COORDINATES
DEFINE MATERIAL ISOTROPIC CONCRETE
E 2.17185e+007
POISSON 0.17
DENSITY 23.5616
ALPHA 1e-005
DAMP 0.05
END DEFINE MATERIAL

MEMBER PROPERTY AMERICAN
27 TO 33 60 61 64 TO 68 177 178 181 TO 185 294 295 298 TO 302 411 412 415 -
416 TO 419 504 TO 509 PRIS YD 0.23 ZD 0.23
2 3 57 69 174 186 291 303 408 420 536 TO 540 568 TO 572 PRIS YD 0.8 ZD 0.8
34 35 58 63 175 180 292 297 409 414 PRIS YD 0.4 ZD 0.7
14 TO 18 20 TO 26 520 522 541 547 549 558 PRIS YD 0.6 ZD 0.3
42 TO 48 56 149 TO 152 159 TO 165 173 266 TO 269 276 TO 282 290 383 TO 386 -
393 TO 399 407 500 TO 503 512 TO 518 PRIS YD 0.4 ZD 0.23
76 78 164 202 202 204 207 209 211 213 215
216 TO 265 310 312 313 315 317 324 326 328 330 332 TO 382 427 429 430 432 -
434 441 443 445 447 449 TO 499 574 576 578 580 582 584 586 588 590 592 594 -
596 598 600 602 604 606 608 610 612 614 616 618 620 622 624 626 628 630 632 -
634 636 638 640 642 644 646 648 650 652 655 TO 668 670 672 674 676 680 -
682 684 697 TO 700 702 704 706 708 710 712 714 716 738 740 742 744 746 748 -
750 752 754 756 760 762 764 766 768 770 772 774 776 TO 1076 1098 1100 -
1102 1104 1106 1108 1110 1112 1114 1116 1118 1120 1122 1124 1126 1128 1130 -
1132 1134 1136 TO 1436 PRIS YD 0.55 ZD 1.4 YB 0.43 ZB 0.3
20 TO 41 49 TO 55 70 TO 75 77 80 82 84 TO 89 91 93 95 97 153 TO 158 -
166 TO 172 187 192 194 197 199 201 TO 206 208 210 212 214 270 TO 275 283 -
284 TO 289 304 TO 309 311 314 316 318 TO 323 325 327 329 331 387 TO 392 400 -
401 TO 406 421 TO 426 428 431 433 435 TO 440 442 444 446 448 523 TO 530 542 -
543 TO 545 550 TO 557 559 TO 562 573 575 577 579 581 583 585 587 589 591 593 -
595 597 599 601 603 605 607 609 611 613 615 617 619 621 623 625 627 629 631 -
633 635 637 639 641 643 645 647 649 651 653 TO 664 669 671 673 675 677 679 -
681 683 685 TO 696 701 703 705 707 709 711 713 715 717 TO 737 739 741 743 -
745 747 749 751 753 755 757 759 761 763 765 767 769 771 773 775 1077 TO 1097 -
1099 1101 1103 1105 1107 1109 1111 1113 1115 1117 1119 1121 1123 1125 1127 -
1129 1131 1133 TO 1436 PRIS AX 0.435 IX 0.0164 IY 0.0001 IZ 0.0316
MEMBER PROPERTY AMERICAN
5 6 59 62 176 179 293 296 410 413 531 TO 535 563 TO 567 PRIS YD 0.55 ZD 0.85
CONSTANTS
MATERIAL CONCRETE ALL
SUPPORTS
1 2 5 6 20 TO 28 279 281 291 293 FIXED
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EXP 1 JOINT 292 294 TO 322 343 TO 354
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4 WEIGHT 234.033
5 WEIGHT 20.653
6 WEIGHT 20.653
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8 WEIGHT 174.457
9 WEIGHT 67.366
10 WEIGHT 67.366
11 WEIGHT 46.1
12 WEIGHT 46.1
13 WEIGHT 17.39
14 WEIGHT 46.1
15 WEIGHT 192.94
16 WEIGHT 192.94
17 WEIGHT 132.958
18 WEIGHT 132.958
19 WEIGHT 2.337
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37 WEIGHT 312.17
38 WEIGHT -108.533
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40 WEIGHT 1170.56
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44 WEIGHT 52.316
45 WEIGHT 10.994
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47 WEIGHT 306.482
48 WEIGHT -101.018
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50 WEIGHT 1154.33
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54 WEIGHT 289.386
55 WEIGHT 289.386
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57 WEIGHT 52.549
58 WEIGHT 11.869
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60 WEIGHT 303.566
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LOAD 2 LOADTYPE Seismic  TITLE EQZ
LOAD 3 LOADTYPE Wind  TITLE WIND X
LOAD 4 LOADTYPE Wind  TITLE WIND Z
LOAD 5 LOADTYPE Wind  TITLE WIND -X
LOAD 6 LOADTYPE Wind  TITLE WIND -Z
LOAD 7 LOADTYPE None  TITLE SW
LOAD 8 LOADTYPE None  TITLE WL
MEMBER LOAD
LOAD 9 LOADTYPE None  TITLE SLAB DL + FLOOR FINISH
FLOOR LOAD
YRANGE 4.6 4.7 FLOAD -3.5 XRANGE 0 1.4 ZRANGE 7.65 9.25 GY
YRANGE 4.6 4.7 FLOAD -3.5 XRANGE 7 8.4 ZRANGE 7.65 9.25 GY
YRANGE 8.2 8.3 FLOAD -3.5 XRANGE 7 8.4 ZRANGE 7.65 9.25 GY
YRANGE 11.8 11.9 FLOAD -3.5 XRANGE 0 1.4 ZRANGE 7.65 9.25 GY
YRANGE 11.8 11.9 FLOAD -3.5 XRANGE 7 8.4 ZRANGE 7.65 9.25 GY
YRANGE 15.4 15.5 FLOAD -3.5 XRANGE 0 1.4 ZRANGE 7.65 9.25 GY
YRANGE 15.4 15.5 FLOAD -3.5 XRANGE 7 8.4 ZRANGE 7.65 9.25 GY
YRANGE 17.9 18 FLOAD -4 XRANGE 2.35 6.05 ZRANGE 7.65 9.25 GY
LOAD 10 LOADTYPE None  TITLE STAIR LOAD
MEMBER LOAD
LOAD 11 LOADTYPE None  TITLE SLAB LL
FLOOR LOAD
YRANGE 4.6 4.7 FLOAD -3 XRANGE -8.4 16.8 ZRANGE 0 10.8 GY
YRANGE 8.2 8.3 FLOAD -3 XRANGE -8.4 16.8 ZRANGE 0 10.8 GY
YRANGE 11.8 11.9 FLOAD -3 XRANGE -8.4 16.8 ZRANGE 0 10.8 GY
YRANGE 15.4 15.5 FLOAD -3 XRANGE -8.4 16.8 ZRANGE 0 10.8 GY
YRANGE 17.9 18.1 FLOAD -1.5 GY
LOAD COMB 12 1.5 * (DL+LL)
7 1.5 8 1.5 9 1.5 10 1.5 11 1.5
LOAD COMB 13 1.5 * (DL+EQX)
7 1.5 8 1.5 9 1.5 10 1.5 1 1.5
LOAD COMB 14 1.5 * (DL-EQX)
7 1.5 8 1.5 9 1.5 10 1.5 1 1.5
LOAD COMB 15 1.5 * (DL+EQZ)
7 1.5 8 1.5 9 1.5 10 1.5 2 1.5
LOAD COMB 16 1.5 * (DL-EQZ)
7 1.5 8 1.5 9 1.5 10 1.5 2 1.5
LOAD COMB 17 1.2 * (DL+LL+EQX)
7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 1 1.2
LOAD COMB 18 1.2 * (DL+LL-EQX)
7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 1 1.2
LOAD COMB 19 1.2 * (DL+LL+EQZ)
7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 1 1.2
LOAD COMB 20 1.2 * (DL+LL-EQZ)
7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 1 1.2
LOAD COMB 21 0.9 * DL - 1.5 * EQX
7 0.9 8 0.9 9 0.9 10 0.9 1 1.5
LOAD COMB 22 0.9 * DL - 1.5 * EQX
7 0.9 8 0.9 9 0.9 10 0.9 1 1.5
LOAD COMB 23 0.9 * DL+ 1.5 * EQX
7 0.9 8 0.9 9 0.9 10 0.9 2 1.5
LOAD COMB 24 0.9 * DL+ 1.5 * EQX
7 0.9 8 0.9 9 0.9 10 0.9 2 1.5
LOAD COMB 25 1.5 * (DL+WX)
7 1.5 8 1.5 9 1.5 10 1.5 3 1.5
LOAD COMB 26 1.5 * (DL-WX)
7 1.5 8 1.5 9 1.5 10 1.5 5 1.5
LOAD COMB 27 1.5 * (DL+WX)
7 1.5 8 1.5 9 1.5 10 1.5 4 1.5
LOAD COMB 28 1.5 * (DL-WX)
7 1.5 8 1.5 9 1.5 10 1.5 6 1.5
LOAD COMB 29 1.2 * (DL+LL+WX)
7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 3 1.2
LOAD COMB 30 1.2 * (DL+LL-WX)
7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 5 -1.2
LOAD COMB 31 1.2 * (DL+LL+WZ)
7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 4 1.2
LOAD COMB 32 1.2 * (DL+LL-WZ)
7 1.2 8 1.2 9 1.2 10 1.2 11 1.2 6 -1.2
LOAD COMB 33 0.9 * DL+ 1.5 * WX
7 0.9 8 0.9 9 0.9 10 0.9 3 1.5
LOAD COMB 34 0.9 * DL - 1.5 * WX
7 0.9 8 0.9 9 0.9 10 0.9 5 -1.5
LOAD COMB 35 0.9 * DL+ 1.5 * WZ
7 0.9 8 0.9 9 0.9 10 0.9 4 1.5
LOAD COMB 36 0.9 * DL - 1.5 * WZ
7 0.9 8 0.9 9 0.9 10 0.9 6 -1.5
PERFORM ANALYSIS PRINT ALL
FINISH
STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 24-Dec-09
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES

STAAD INPUT FILE

INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES

STAAD SPACE
DEFINE MATERIAL ISOTROPIC CONCRETE
E 2.17185e+007
POISSON 0.17
DENSITY 23.5616
ALPHA 1e-005
DAMP 0.05
END DEFINE MATERIAL
MEMBER PROPERTY AMERICAN 2 5 6 8 9 32 TO 34 52 TO 54 59 61 62 64 66 109 TO 111 116 118 119 121 123 - 166 TO 168 173 175 176 180 223 TO 225 230 232 233 235 - 237 PRIS YD 0.3 ZD 0.6
1 10 13 TO 16 19 22 TO 24 265 TO 267 320 323 345 TO 347 PRIS YD 0.6 ZD 0.23
36 38 TO 41 44 46 47 67 TO 75 78 79 82 87 88 93 95 TO 98 101 103 104 - 124 TO 132 135 136 139 144 145 150 152 TO 155 158 160 161 181 TO 189 192 - 193 196 201 202 207 209 TO 212 215 217 218 238 TO 246 249 250 253 258 259 - 268 TO 319 325 326 330 331 335 336 340 341 348 TO 399 PRIS YD 0.5 ZD 0.2
MEMBER PROPERTY AMERICAN 3 60 117 174 231 PRIS YD 0.5 ZD 0.35
MEMBER PROPERTY AMERICAN 321 322 327 328 332 333 337 338 342 343 PRIS YD 0.3 ZD 0.4
MEMBER PROPERTY AMERICAN 11 12 56 58 113 115 170 172 227 229 PRIS YD 0.3 ZD 0.8
37 45 94 102 151 159 208 216 PRIS YD 0.8 ZD 0.3
CONSTANTS
MATERIAL CONCRETE ALL
SUPPORTS 1 2 5 6 9 10 13 14 27 TO 29 165 166 FIXED
DEFINE WIND LOAD

DEFINITION 
ZONE 0.24 RF 3 I 1.5 SS 1 DM 0.05 DT 2.5

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2 WEIGHT 7.952
3 WEIGHT 53.408
4 WEIGHT 53.408
5 WEIGHT 7.952
6 WEIGHT 7.952
7 WEIGHT 53.194
8 WEIGHT 53.194
9 13 165 WEIGHT 7.952
10 14 166 WEIGHT 7.952
11 15 163 WEIGHT 47.303
12 16 167 WEIGHT 47.303
13 165 WEIGHT 7.952
14 166 WEIGHT 7.952
15 163 WEIGHT 45.876
16 167 WEIGHT 45.876
17 WEIGHT 66.125
18 WEIGHT 51.662
19 20 164 WEIGHT 48.306
20 164 WEIGHT 59.869
27 WEIGHT 7.952
28 WEIGHT 7.952
29 WEIGHT 7.952
31 WEIGHT 252.101
32 WEIGHT 252.101
33 WEIGHT 376.928
34 WEIGHT 376.928
35 37 169 WEIGHT 291.626
36 38 171 WEIGHT 291.626
37 169 WEIGHT 174.935
38 171 WEIGHT 174.935
39 WEIGHT 490.059
40 WEIGHT 758.125
41 42 170 WEIGHT 612.534
42 170 WEIGHT 358.009
58 WEIGHT 253.526
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60 WEIGHT 378.061
61 WEIGHT 378.061
62 64 172 WEIGHT 294.235
63 65 174 WEIGHT 294.235
64 172 WEIGHT 176.371
65 174 WEIGHT 176.371
66 WEIGHT 488.438
67 WEIGHT 752.137
68 69 173 WEIGHT 609.883
69 173 WEIGHT 357.115
85 WEIGHT 254.713
86 WEIGHT 254.713
87 WEIGHT 377.672
88 WEIGHT 377.672
89 91 175 WEIGHT 296.117
90 92 177 WEIGHT 296.117
91 175 WEIGHT 177.533
92 177 WEIGHT 177.533
93 WEIGHT 488.047

52
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1893 LOAD X 1
LOAD 2 LOADTYPE Seismic TITLE EQZ
1893 LOAD Z 1
LOAD 3 LOADTYPE Wind TITLE WIND X
WIND LOAD X 1 TYPE 1 XR 0 32.4 YR 1 16.5 OPEN
LOAD 4 LOADTYPE Wind TITLE WIND Z
WIND LOAD Z 1 TYPE 1 XR 0 25.2 YR 3.3 16.5 OPEN
LOAD 5 LOADTYPE Wind TITLE WIND -X
WIND LOAD -X -1 TYPE 1 XR 0 32.4 YR 3.3 16.5 OPEN
LOAD 6 LOADTYPE Wind TITLE WIND -Z
WIND LOAD -Z -1 TYPE 1 XR 0 25.2 YR 3.3 16.5 OPEN
LOAD 7 LOADTYPE None TITLE SW
SELFWEIGHT Y -1
LOAD 8 LOADTYPE None TITLE WALL
MEMBER LOAD
36 TO 41 44 TO 47 67 TO 69 78 79 82 93 TO 98 101 TO 104 124 TO 126 135 136 -
139 150 TO 155 158 TO 161 181 TO 183 192 193 196 207 TO 212 215 TO 218 238 -
239 TO 240 249 250 253 325 326 330 331 335 336 340 341 UNI GY -5
LOAD 9 LOADTYPE None TITLE SLAB DL
FLOOR LOAD
YRANGE 4.6 4.8 FLOAD -4.8 GY
YRANGE 11.8 11.9 FLOAD -4.8 GY
YRANGE 15.4 15.5 FLOAD -4.8 GY
LOAD 10 LOADTYPE None TITLE FLOOR FINISH
FLOOR LOAD
YRANGE 4.6 4.8 FLOAD -1 GY
YRANGE 11.8 11.9 FLOAD -1 GY
YRANGE 15.4 15.5 FLOAD -1 GY
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FLOOR LOAD
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YRANGE 8.2 8.3 FLOAD -4 GY
YRANGE 11.8 11.9 FLOAD -4 GY
YRANGE 15.4 15.5 FLOAD -4 GY
LOAD COMB 12 1.5 * (DL+LL)
7 1.5 8 1.5 9 1.5 10 1.5 11 1.5
LOAD COMB 13 1.5 * (DL+EQX)
7 1.5 8 1.5 9 1.5 10 1.5 11 1.5
LOAD COMB 14 1.5 * (DL-EQX)
7 1.5 8 1.5 9 1.5 10 1.5 11 1.5
LOAD COMB 15 1.5 * (DL+EQZ)
7 1.5 8 1.5 9 1.5 10 1.5 2 1.5
LOAD COMB 16 1.5 * (DL-EQZ)
7 1.5 8 1.5 9 1.5 10 1.5 2 1.5
LOAD COMB 17 1.5 * (DL+LL+EQX)
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<tr>
<td>36</td>
<td>0.9</td>
<td>DL-1.5 WZ</td>
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</table>

PERFORM ANALYSIS
PRINT ALL
FINISH
### Footing Design Summary For Multi Level Parking

<table>
<thead>
<tr>
<th>Footing No</th>
<th>Axial Load</th>
<th>Length</th>
<th>Breadth</th>
<th>d</th>
<th>D</th>
<th>L</th>
<th>Reinforcement</th>
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<tbody>
<tr>
<td>F2</td>
<td>Pu = 3200</td>
<td>2900</td>
<td>3400</td>
<td>600</td>
<td>1340</td>
<td>200</td>
<td>20 @ 100 c/c</td>
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<tr>
<td>F3</td>
<td>Pu = 3000</td>
<td>3000</td>
<td>3300</td>
<td>700</td>
<td>1400</td>
<td>200</td>
<td>20 @ 100 c/c</td>
</tr>
<tr>
<td>F4</td>
<td>Pu = 1200</td>
<td>2000</td>
<td>2100</td>
<td>300</td>
<td>660</td>
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<td>16 @ 120 c/c</td>
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<tr>
<td>F5</td>
<td>Pu = 2000</td>
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<td>940</td>
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<td>16 @ 100 c/c</td>
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<tr>
<td>F6</td>
<td>Pu = 3220</td>
<td>3000</td>
<td>3500</td>
<td>600</td>
<td>1300</td>
<td>200</td>
<td>20 @ 100 c/c</td>
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<tr>
<td>F7</td>
<td>Pu = 9680</td>
<td>5700</td>
<td>5700</td>
<td>1300</td>
<td>2600</td>
<td>200</td>
<td>25 @ 100 c/c</td>
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<table>
<thead>
<tr>
<th>Combined Footing</th>
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<tbody>
<tr>
<td>Footing No</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>CF1</td>
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<tr>
<td>CF2</td>
</tr>
<tr>
<td>CF3</td>
</tr>
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<td>CF5</td>
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<td>CF8</td>
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<tr>
<td>CF9</td>
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<td>CF10</td>
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### Columns

<table>
<thead>
<tr>
<th>Column No</th>
<th>Load Case</th>
<th>Axial Force</th>
<th>Moment X</th>
<th>Moment Y</th>
<th>Size of column</th>
<th>Reinforcement</th>
<th>Stirrups</th>
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<tr>
<td>C1</td>
<td>1.5(DL-EQX)</td>
<td>374.77</td>
<td>223.8</td>
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<td>8 @ 200 c/c</td>
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<tr>
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<tr>
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<td>1.2(DL+LL-EQX)</td>
<td>366.32</td>
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<td>353.51</td>
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<td>1.5(DL-EQX)</td>
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<tr>
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<td>560.34</td>
<td>563.33</td>
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<td>169.29</td>
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<td>C10</td>
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<td>3015.88</td>
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### Plinth Beams

<table>
<thead>
<tr>
<th>Beam No</th>
<th>Load Case</th>
<th>Moments</th>
<th>Shear</th>
<th>B</th>
<th>D</th>
<th>Ast Top</th>
<th>Ast Bottom</th>
<th>Shear Rft</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB1</td>
<td>1.5(DL-EQX)</td>
<td>3080</td>
<td>127</td>
<td>152</td>
<td>151</td>
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### SLAB

<table>
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### GF, FF, SF, TF Roof Beams for 8.36 & 5.5

<table>
<thead>
<tr>
<th>Beam No</th>
<th>Load Case</th>
<th>Moments</th>
<th>Shear</th>
<th>B</th>
<th>D</th>
<th>Ast Top</th>
<th>Ast Bottom</th>
<th>Shear Rft</th>
<th>Legs</th>
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<tbody>
<tr>
<td></td>
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<td>Torsion</td>
<td>Support Midspan</td>
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<td>B-5</td>
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### SLAB Ramp

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### GF, FF, SF, TF Roof Beams for 8.36 & 5.5

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<thead>
<tr>
<th>Beam No</th>
<th>Load Case</th>
<th>Moments</th>
<th>Shear</th>
<th>B</th>
<th>D</th>
<th>Ast Top</th>
<th>Ast Bottom</th>
<th>Shear Rft</th>
<th>Legs</th>
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<tr>
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<td>Torsion</td>
<td>Support Midspan</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>RB4</td>
<td>1.5(DL-EQX)</td>
<td>283</td>
<td>120</td>
<td>0</td>
<td>90</td>
<td>139</td>
<td>300</td>
<td>600</td>
<td>4 of 25</td>
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</tbody>
</table>
DESIGN OF FOOTING
DESIGN OF ISOLATED FOOTING F2

Design Parameters

Maximum factored axial load coming on footing = 3200 kN
Safe Bearing capacity of the soil = 225 kN/m²
Grade of Concrete = M30
Grade of Steel = Fe415
Characteristic compressive strength of concrete, \( f_{ck} \) (N/mm²) = 30
Characteristic yield strength of steel, \( f_y \) (N/mm²) = 415
Unit weight of concrete, \( \gamma_c \) (kN/m³) = 24
Partial safety factor for concrete = 1.5
Nominal Cover to exposure condition (mm) = 50
Diameter of bars (mm) = 20

Column Dimensions

Breadth of the column (mm) B = 300
Depth of the column (mm) D = 800

Design

Maximum axial load coming on footing = 2000.00 kN
Add 10% toward the self-weight of footing = 200.00 kN
Total load = 2200.00 kN

SBC of Soil: 225 kN/m² is considered in the design of foundations.

Area of footing required = 2200 / 225 = 9.778 m²
L = 3.39 m
B = 2.89 m

Provide footing of size 3.4 m x 2.9 m

Projection beyond Column Faces = 1.29 m
Net Upward Pressure on the foundation = 306.812 kN/m²

B.M @ Section XX = Mx = 869.30 kNm
Factored Moment = Mux = 1303.95 kNm
Equating \( M_{ul,lim} \) to Mux = 0.138\( f_{ck} \)bd² = Mux
\( M_{ul,lim} = 3312 \ d^2 \)
627 mm

B.M @ Section YY = My = 741 kNm
Factored Moment = Muy = 1111 kNm
Equating \( M_{ul,lim} \) to Muy = 0.138\( f_{ck} \)bd² = Muy
\( M_{ul,lim} = 1242 \ d^2 \)
946 mm

Effective cover to lower layer of steel = 50 mm + 10 mm = 60 mm
Effective cover to upper layer of steel = 60 mm + 20 mm = 80 mm
Overall depth required = 946 mm + 80 mm = 1026 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd = 1340 mm
Effective depth for short span = 1340 mm - 60 mm = 1280 mm
Effective depth for long span = 1340 mm - 80 mm = 1260 mm

Steel Reqd for Longer Direction

\[ \frac{Muy}{bd^2} = 2.334 \]
\[ \% \text{ of steel} = 0.718 \% \]

Area of steel required = 2714 mm\(^2\)

Provide 9 bars of 20 mm dia

Spacing of 20 mm dia bars 115 mm c/c

Steel Reqd for Shorter Direction

\[ \frac{Mux}{bd^2} = 0.995 \]
\[ \% \text{ of steel} = 0.287 \% \]

Area of steel required = 2940 mm\(^2\)

Reinforcement Reqd for central band of 3.19 m = 2183 mm\(^2\)

Provide 9 bars of 20 mm dia

Spacing of 20 mm dia bars 143 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 1280 mm from the face of the column

Shear force at this critical section X1 X1

\[ V = 14 \text{ kN} \]
\[ Vu = 21 \text{ kN} \]

Overall depth of the critical section \( D' \) = 608 mm
Effective depth of the critical section \( d' \) = 548 mm
Breadth of the footing @ tp @this critical section \( b' \) = 3360 mm
Nominal shear stress \( \tau_n \) = 0.01 N/mm\(^2\)

Percentage of steel provided = 0.15 \%
Permissible punching shear stress = \( 0.25 \times \sqrt{fck} \)

\[ 1.37 \text{ N/mm}^2 > 0.01 \text{ N/mm}^2 \]

Provided Section is adequate.
DESIGN OF ISOLATED FOOTING F3

Design Parameters

Maximum factored axial load coming on footing = 3000 kN
Safe Bearing capacity of the soil = 225 kN/m²
Grade of Concrete M30
Grade of Steel Fe415
Characteristic compressive strength of concrete, f_{ck} (N/mm²) = 30
Characteristic yield strength of steel, f_{y} (N/mm²) = 415
Unit weight of concrete, γ_{c} (kN/m³) = 24
Partial safety factor for concrete = 1.5
Nominal Cover to exposure condition (mm) = 50
Diameter of bars (mm) = 20

Column Dimensions

Breadth of the column (mm) B = 300
Depth of the column (mm) D = 600

Design

Maximum axial load coming on footing = 2000.00 kN
Add 10% toward the self-weight of footing = 200.00 kN
Total load = 2200.00 kN
SBC of Soil : 225 kN/m² is considered in the design of foundations.

Area of footing required = \frac{2200}{225} = 9.778 m²
L = 3.28 m
B = 2.98 m

Provide footing of size 3.3 m x 3 m

Projection beyond Column Faces = 1.34 m
Net Upward Pressure on the foundation = 306.812 kN/m²

B.M @ Section XX = Mx = 904.04 kNm
Factored Moment = Mux = 1356.06 kNm
Equating Mu,lim to Mux = 0.138f_{ck}bd² = Mux
M_{u,lim} = 2484 d²
739 mm

B.M @ Section YY = My = 821 kNm
Factored Moment = Muy = 1232 kNm
Equating Mu,lim to Muy = 0.138f_{ck}bd² = Muy
M_{u,lim} = 1242 d²
996 mm

Effective cover to lower layer of steel = 50 mm + 10 mm = 60 mm
Effective cover to upper layer of steel = 60 mm + 20 mm = 80 mm
Overall depth required = 996 mm + 80 mm = 1076 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd = 1400 mm
Effective depth for short span = 1400 mm - 60 mm = 1340 mm
Effective depth for long span = 1400 mm - 80 mm = 1320 mm

Steel Req’d for Longer Direction

\[ \frac{Muy}{bd^2} = 2.357 \]
\% of steel = 0.726 %

Area of steel required = 2875 mm²
Provide 10 bars of 20 mm dia
Spacing of 20 mm dia bars 109 mm c/c

Steel Req’d for Shorter Direction

\[ \frac{Mux}{bd^2} = 1.259 \]
\% of steel = 0.367 %

Area of steel required = 2954 mm²
Reinforcement Req’d for central band of 3.08 m = 2238 mm²

Provide 10 bars of 20 mm dia
Spacing of 20 mm dia bars 140 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 1340 mm from the face of the column
Shear force at this critical section X1 X1

\[ V = 0 \text{ kN} \]
\[ V_u = 0 \text{ kN} \]

Factored Shear

Overall depth of the critical section \( D' \) = 700 mm
Effective depth of the critical section \( d' \) = 640 mm
Breadth of the footing @ tp @this critical section \( b' \) = 3280 mm
Nominal shear stress \( \tau_n \) = 0.00 N/mm²

Percentage of steel provided = 0.15 %
Permissible punching shear stress = \( 0.25 \times \sqrt{f_{ck}} \)

\[ 1.37 \text{ N/mm}^2 > 0.00 \text{ N/mm}^2 \]

Provided Section is adequate.
### DESIGN OF ISOLATED FOOTING F4

#### Design Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Maximum factored axial load coming on footing</td>
<td>1200 kN</td>
</tr>
<tr>
<td>Safe Bearing capacity of the soil</td>
<td>225 kN/m²</td>
</tr>
<tr>
<td>Grade of Concrete</td>
<td>M30</td>
</tr>
<tr>
<td>Grade of Steel</td>
<td>Fe415</td>
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<tr>
<td>Characteristic compressive strength of concrete $f_{ck}$ N/mm²</td>
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</tr>
<tr>
<td>Characteristic yield strength of steel $f_y$ N/mm²</td>
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<tr>
<td>Unit weight of concrete $\gamma_c$ kN/m³</td>
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<tr>
<td>Partial safety factor for concrete</td>
<td>1.5</td>
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<tr>
<td>Nominal Cover to exposure condition (mm)</td>
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</tr>
<tr>
<td>Diameter of bars (mm)</td>
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#### Column Dimensions

<table>
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<td>Breadth of the column (mm) B</td>
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<tr>
<td>Depth of the column (mm) D</td>
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#### Design

<table>
<thead>
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<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Maximum axial load coming on footing</td>
<td>800.00 kN</td>
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<tr>
<td>Add 10% toward the self-weight of footing</td>
<td>80.00 kN</td>
</tr>
<tr>
<td>Total load</td>
<td>880.00 kN</td>
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</table>

SBC of Soil : 225 kN/m² is considered in the design of foundations.

Area of footing required = 

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>880</td>
<td>/</td>
</tr>
<tr>
<td>225</td>
<td>m²</td>
</tr>
</tbody>
</table>

L = 2.05 m  
B = 1.90 m

**Provide footing of size 2.1 m x 2 m**

Projection beyond Column Faces = 0.78 m

Net Upward Pressure on the foundation = 306.749 kN/m²

B.M @ Section XX = Mx = 190.29 kNm
Factored Moment = Mux = 285.44 kNm

Equating $M_{u,lim}$ to $M_{ux} = 0.138f_{ck}bd^2 = M_{ux}$

$M_{u,lim} = 2070 d^2$  
$371$ mm

B.M @ Section YY = My = 176 kNm
Factored Moment = Muy = 265 kNm

Equating $M_{u,lim}$ to $M_{uy} = 0.138f_{ck}bd^2 = M_{uy}$

$M_{u,lim} = 1449 d^2$  
$427$ mm

Effective cover to lower layer of steel = 50 mm + 8 mm = 58 mm
Effective cover to upper layer of steel = 58 mm + 16 mm = 74 mm
Overall depth required = 427 mm + 74 mm = 501 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd = 660 mm
Effective depth for short span = 660 mm - 58 mm = 602 mm
Effective depth for long span = 660 mm - 74 mm = 586 mm

Steel Reqd for Longer Direction

\[ \frac{Muy}{bd^2} = 2.202 \]
\[ \% \text{ of steel} = 0.673 \% \]

Area of steel required = 1380 mm\(^2\)

Provide 7 bars of 16 mm dia
Spacing of 16 mm dia bars 145 mm c/c

Steel Reqd for Shorter Direction

\[ \frac{Mux}{bd^2} = 1.575 \]
\[ \% \text{ of steel} = 0.467 \% \]

Area of steel required = 1405 mm\(^2\)

Reinforcement Reqd for central band of 1.85 m = 1386 mm\(^2\)

Provide 9 bars of 16 mm dia
Spacing of 16 mm dia bars 145 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 602 mm from the face of the column
Shear force at this critical section X1 X1

V = 110 kN
Vu = 166 kN

Overall depth of the critical section D' = 381 mm
Effective depth of the critical section d' = 323 mm
Breadth of the footing b' = 1704 mm
Nominal shear stress \( \tau_n = 0.30 \text{ N/mm}^2 \)

Percentage of steel provided = 0.33 %
Permissible punching shear stress = 0.25 \times \sqrt{f_{ck}}

\[ 1.37 \text{ N/mm}^2 > 0.30 \text{ N/mm}^2 \]

Provided Section is adequate.
DESIGN OF ISOLATED FOOTING F5

Design Parameters

Maximum factored axial load coming on footing = 2000 kN
Safe Bearing capacity of the soil = 225 kN/ m²
Grade of Concrete = M30
Grade of Steel = Fe415
Characteristic compressive strength of concrete , \( f_{ck} \) ( N/mm² ) = 30
Characteristic yield strength of steel , \( f_y \) ( N/mm² ) = 415
Unit weight of concrete , \( \gamma_c \) ( kN/m³ ) = 24
Partial safety factor for concrete = 1.5
Nominal Cover to exposure condition( mm ) = 50
Diameter of bars (mm) = 16

Column Dimensions

Breadth of the column (mm) B = 350
Depth of the column (mm) D = 600

Design

Maximum axial load coming on footing = 1333.33 kN
Add 10% toward the self-weight of footing = 133.33 kN
Total load = 1466.67 kN
SBC of Soil : 225 kN/m² is considered in the design of foundations.

Area of footing required = \( \frac{1466.67}{225} \)
= 6.519 m²
L = 2.68 m
B = 2.43 m

Provide footing of size 2.7 m x 2.5 m

Projection beyond Column Faces = 1.04 m
Net Upward Pressure on the foundation = 306.796 kN/m²

B.M @ Section XX = Mx = 445.42 kNm
Factored Moment = Mux = 668.13 kNm
Equating \( M_{u,lim} \) to Mux = 0.138\( f_{ck}bd^2 \) = Mux
\( M_{u,lim} = 2484 \) d²
= 519 mm

B.M @ Section YY = My = 404 kNm
Factored Moment = Muy = 606 kNm
Equating \( M_{u,lim} \) to Muy = 0.138\( f_{ck}bd^2 \)² = Muy
\( M_{u,lim} = 1449 \) d²
= 647 mm

Effective cover to lower layer of steel = 50 mm + 8 mm = 58 mm
Effective cover to upper layer of steel = 58 mm + 16 mm = 74 mm
Overall depth required = 647 mm + 74 mm = 721 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd = 940 mm
Effective depth for short span = 940 mm - 58 mm = 882 mm
Effective depth for long span = 940 mm - 74 mm = 866 mm

Steel Reqd for Longer Direction

\[
\frac{Muy}{bd^2} = 2.308 \\
\% of steel = 0.709 \%
\]

Area of steel required = 2149 mm\(^2\)

Provide 11 bars of 16 mm dia
Spacing of 16 mm dia bars 100 mm c/c

Steel Reqd for Shorter Direction

\[
\frac{Mux}{bd^2} = 1.431 \\
\% of steel = 0.421 \%
\]

Area of steel required = 2229 mm\(^2\)

Reinforcement Reqd for central band of 2.48 m = 1905 mm\(^2\)

Provide 12 bars of 16 mm dia
Spacing of 16 mm dia bars 105 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 882 mm from the face of the column

Shear force at this critical section X1 X1

\[
V = 131 \text{ kN} \\
Vu = 196 \text{ kN}
\]

Overall depth of the critical section \(D' = 482 \text{ mm}\)
Effective depth of the critical section \(d' = 424 \text{ mm}\)
Breadth of the footing @ tp @this critical section \(b' = 2364 \text{ mm}\)
Nominal shear stress \(\tau_v = 0.20 \text{ N/mm}^2\)

Percentage of steel provided = 0.24 \%
Permissible punching shear stress = \(0.25 \times \sqrt{f_{ck}}\)

\[
1.37 \text{ N/mm}^2 > 0.20 \text{ N/mm2}
\]

Provided Section is adequate.
DESIGN OF ISOLATED FOOTING F6

Design Parameters

Maximum factored axial load coming on footing = 3220 kN
Safe Bearing capacity of the soil = 225 kN/m²
Grade of Concrete = M30
Grade of Steel = Fe415
Characteristic compressive strength of concrete, fck (N/mm²) = 30
Characteristic yield strength of steel, fy (N/mm²) = 415
Unit weight of concrete, γc (kN/m³) = 24
Partial safety factor for concrete = 1.5
Nominal Cover to exposure condition (mm) = 50
Diameter of bars (mm) = 20

Column Dimensions

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Breadth of the column (mm) B</td>
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<td>Depth of the column (mm) D</td>
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</tr>
</tbody>
</table>

Design

Maximum axial load coming on footing = 2146.67 kN
Add 10% toward the self-weight of footing = 214.67 kN
Total load = 2361.34 kN

SBC of Soil : 225 kN/m² is considered in the design of foundations.

Area of footing required = 2361.34 / 225 = 10.495 m²
L = 3.50 m
B = 3.00 m

Provide footing of size 3.5 m x 3 m

Net Upward Pressure on the foundation = 306.813 kN/m²

B.M @ Section XX = Mx = 906.66 kNm
Factored Moment = Mux = 1359.99 kNm
Equating Mu,lim to Mux = 0.138fckbd² = Mux
M_u,lim = 3726 d² = 604 mm

B.M @ Section YY = My = 777 kNm
Factored Moment = Muy = 1166 kNm
Equating Mu,lim to Muy = 0.138fckbd² = Muy
M_u,lim = 1656 d² = 839 mm

Effective cover to lower layer of steel = 50 mm + 10 mm = 60 mm
Effective cover to upper layer of steel = 60 mm + 20 mm = 80 mm
Overall depth required = 839 mm + 80 mm = 919 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd = 1300 mm
Effective depth for short span = 1300 mm - 60 mm = 1240 mm
Effective depth for long span = 1300 mm - 80 mm = 1220 mm

Steel Reqd for Longer Direction

\[
\frac{Muy}{bd^2} = 1.958 \\
\text{% of steel} = 0.591 \%
\]

Area of steel required = 2883 mm\(^2\)

Provide 10 bars of 20 mm dia
Spacing of 20 mm dia bars 108 mm c/c

Steel Reqd for Shorter Direction

\[
\frac{Muy}{bd^2} = 0.983 \\
\text{% of steel} = 0.283 \%
\]

Area of steel required = 3163 mm\(^2\)

Reinforcement Reqd for central band of 3.3 m = 2301 mm\(^2\)

Provide 10 bars of 20 mm dia
Spacing of 20 mm dia bars 136 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 1240 mm from the face of the column
Shear force at this critical section X1 X1

\[
V = 64 \text{ kN} \\
Vu = 96 \text{ kN}
\]

Overall depth of the critical section \(D'\) = 632 mm
Effective depth of the critical section \(d'\) = 572 mm
Breadth of the footing @ tp @this critical section \(b'\) = 3380 mm
Nominal shear stress \(\tau_{n}\) = 0.05 N/mm\(^2\)

Percentage of steel provided = 0.16 %
Permissible punching shear stress = \(0.25 \times \sqrt{f_{ck}}\)

\[
1.37 \text{ N/mm}^2 > 0.05 \text{ N/mm}^2
\]

Provided Section is adequate.
DESIGN OF ISOLATED FOOTING F7

Design Parameters

Maximum factored axial load coming on footing = 9860 kN
Safe Bearing capacity of the soil = 225 kN/m²
Grade of Concrete = M30
Grade of Steel = Fe415
Characteristic compressive strength of concrete, fck (N/mm²) = 30
Characteristic yield strength of steel, fy (N/mm²) = 415
Unit weight of concrete, γc (kN/m³) = 24
Partial safety factor for concrete = 1.5
Nominal Cover to exposure condition (mm) = 50
Diameter of bars (mm) = 25

Column Dimensions

Breadth of the column (mm) B = 800
Depth of the column (mm) D = 800

Design

Maximum axial load coming on footing = 6573.33 kN
Add 10% toward the self-weight of footing = 657.33 kN
Total load = 7230.67 kN
SBC of Soil : 225 kN/m² is considered in the design of foundations.

Area of footing required = 7230.67 / 225 = 32.137 m²
L = 5.67 m
B = 5.67 m

Provide footing of size 5.7 m x 5.7 m

Projection beyond Column Faces = 2.43 m
Net Upward Pressure on the foundation = 306.812 kN/m²

B.M @ Section XX = Mx = 5154.13 kNm
Factored Moment = Mux = 7731.20 kNm
Equating Mu,lim to Mux = 0.138fckbd² = Mux
M_u,lim = 3312 d²
1528 mm

B.M @ Section YY = My = 5154 kNm
Factored Moment = Muy = 7731 kNm
Equating Mu,lim to Muy = 0.138fckbd² = Muy
M_u,lim = 3312 d²
1528 mm

Effective cover to lower layer of steel = 50 mm + 12.5 mm = 62.5 mm
Effective cover to upper layer of steel = 62.5 mm + 25 mm = 87.5 mm
Overall depth required = 1528 mm + 87.5 mm = 1615 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd = 2600 mm
Effective depth for short span = 2600 mm - 62.5 mm = 2537.5 mm
Effective depth for long span = 2600 mm - 87.5 mm = 2512.5 mm

Steel Req'd for Longer Direction

\[
\frac{M_y}{bd^2} = 1.531
\]

% of steel = 0.453 %

Area of steel required = 9096 mm\(^2\)

Provide 19 bars of 25 mm dia
Spacing of 25 mm dia bars 100 mm c/c

Steel Req'd for Shorter Direction

\[
\frac{M_x}{bd^2} = 1.501
\]

% of steel = 0.443 %

Area of steel required = 8994 mm\(^2\)

Reinforcement Req'd for central band of 5.47 m = 4691 mm\(^2\)

Provide 12 bars of 25 mm dia
Spacing of 25 mm dia bars 104 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 2537.5 mm from the face of the column

Shear force at this critical section X1 X1

\[
V = -179 \text{ kN} \\
Vu = -269 \text{ kN}
\]

Overall depth of the critical section \(D'\) = 1245 mm
Effective depth of the critical section \(d'\) = 1182 mm
Breadth of the footing @ tp @this critical section \(b'\) = 5875 mm
Nominal shear stress \(\tau_{ns}\) = -0.04 N/mm\(^2\)

Percentage of steel provided = 0.08 %
Permissible punching shear stress = \(0.25 \times \sqrt{f_{ck}}\)

\[
1.37 \text{ N/mm}^2 > -0.04 \text{ N/mm2}
\]

Provided Section is adequate.
Combined Footing Analysis and Design

Dimensions:

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<thead>
<tr>
<th>Col. 1</th>
<th>Col. 2</th>
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<tbody>
<tr>
<td>Length, x (m)</td>
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<tr>
<td>Width, y (m)</td>
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</tr>
</tbody>
</table>

Distance, Xp (m) | 4.48 |
Distance, Xb (m) | 1.52 |
Distance, Xa (m) | 1 |
Eff. depth, d (m) | 0.6 |
Area, (m²) | 26.25 |

Material Properties:

| Conc comp strength f'c, (Mpa) | 30 |
| Steel comp strength fy, (Mpa) | 415 |
| Allow soil pressure, qa (kPa) | 281.25 |

Loads:

<table>
<thead>
<tr>
<th>Col. Load</th>
<th>Working loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead</td>
<td>Live</td>
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<td>P1 (kN)</td>
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<td>P2 (kN)</td>
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<tr>
<td>M2 (kN.m)</td>
<td>0</td>
</tr>
</tbody>
</table>

Checkings:

| Allowable soil pressure, qa (kPa) | 281.25 |
| Maximum soil pressure, qmax (kPa) | 249.134 | (qmax < qa) Ok |
| Minimum soil pressure, qmin (kPa) | 162.55 | (qmin > 0) Ok |
| Maximum wide beam shear, Vw (kN/m width) | 446.275 |
| Maximum punching shear, Vp (kN/m width) | 4437.18 |
| Wide beam shear strength, Vc1 (kN/m width) | 547.723 | Vw < Vc1, OK |
| Punching shear strength, Vc2 (kN/m width) | 3999.06 | Vp > Vc2, increase depth |

Area of Steel:

Use area of steel, As (cm²) 24.5 for bottom reinforcement
As (cm²) 20.241 for top reinforcement

Details:

<table>
<thead>
<tr>
<th>x</th>
<th>V, kN</th>
<th>M, kN-m</th>
<th>b, m</th>
<th>As, cm²/m</th>
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### Combined Footing Analysis and Design

**Dimensions:**

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<tr>
<th></th>
<th>Col.1</th>
<th>Col.2</th>
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</thead>
<tbody>
<tr>
<td>Length, x (m)</td>
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<td>Width, y (m)</td>
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<td>Distance, Xp (m)</td>
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<td>Left width, b (m)</td>
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<tr>
<td>Distance, Xb (m)</td>
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<td>Right width, a (m)</td>
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<tr>
<td>Distance, Xa (m)</td>
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<td>Length, L (m)</td>
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<tr>
<td>Eff. depth, d (m)</td>
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<td>Area, (m²)</td>
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</tbody>
</table>

**Material Properties:**

- Conc comp strength f'c, (Mpa) | 30 |
- Steel comp strength fy, (Mpa) | 415 |
- Allow soil pressure, qa (kPa) | 281.25 |

**Loads:**

<table>
<thead>
<tr>
<th></th>
<th>Col. Load</th>
<th>Working loads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dead</td>
<td>Live</td>
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<tr>
<td>M1 (kN.m)</td>
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<tr>
<td>M2 (kN.m)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Checkings:**

- Allowable soil pressure, qa (kPa) | 281.25 |
- Maximum soil pressure, qmax (kPa) | 274.953 |
- Minimum soil pressure, qmin (kPa) | 202.173 |
- Maximum wide beam shear, Vw (kN/m width) | 364.76 |
- Maximum punching beam shear, Vp (kN/m width) | 8200.62 |
- Wide beam shear strength, Vc1 (kN/m width) | 912.871 |
- Punching shear strength, Vc2 (kN/m width) | 3999.06 |

**Area of Steel:**

- Use area of steel, As (cm²) | 34 for bottom reinforcement |
  |                         | 33.7349 for top reinforcement |

**Details:**

<table>
<thead>
<tr>
<th>x</th>
<th>V, kN</th>
<th>M, kN.m</th>
<th>b, m</th>
<th>As, cm²/m</th>
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### Combined Footing Analysis and Design

#### Dimensions:

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<tbody>
<tr>
<td>Length, x (m)</td>
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</tr>
<tr>
<td>Width, y (m)</td>
<td>0.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

| Distance, Xp (m) | 4.555  |
| Left width, b (m)| 5      |
| Distance, Xb (m) | 3.585  |
| Right width, a (m)| 8      |
| Distance, Xa (m) | 2.36   |
| Length, L (m)  | 10.5   |

| Eff. depth, d (m) | 1.2 |
| Area, (m²)       | 68.25 |

#### Material Properties:

- Conc comp strength f’c, (Mpa) | 30 |
- Steel comp strength fy, (Mpa) | 415 |
- Allow soil pressure, qa (kPa) | 281.25 |

#### Loads:

<table>
<thead>
<tr>
<th>Col. Load</th>
<th>Working loads</th>
</tr>
</thead>
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<td>M2 (kN.m)</td>
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#### Checkings:

- Allowable soil pressure, qa (kPa) | 281.25 |
- Maximum soil pressure, qmax (kPa) | 256.964 |
- Minimum soil pressure, qmin (kPa) | 60.8704 |
- Maximum wide beam shear, Vw (kN/m width) | 295.907 |
- Maximum punching beam shear, Vp (kN/m width) | 9963.89 |
- Wide beam shear strength, Vc1 (kN/m width) | 1095.45 |
- Punching shear strength, Vc2 (kN/m width) | 3999.06 |

#### Area of Steel:

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<thead>
<tr>
<th>Use area of steel, As (cm²)</th>
<th>As (cm²)</th>
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<tbody>
<tr>
<td>for bottom reinforcement</td>
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<tr>
<td>for top reinforcement</td>
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#### Details:

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<th>As, cm²/m</th>
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Combined Footing Analysis and Design

Dimensions:

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Material Properties:

- Conc comp strength f'c, (Mpa) 30
- Steel comp strength fy, (Mpa) 415
- Allow soil pressure, qa (kPa) 281.25

Loads:

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<tr>
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<tr>
<td>M2 (kN.m)</td>
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Checkings:

- Allowable soil pressure, qa (kPa) 281.25
- Maximum soil pressure, qmax (kPa) 276 (qmax < qa) Ok
- Minimum soil pressure, qmin (kPa) 108.756 (qmin > 0) Ok
- Maximum wide beam shear, Vw (kN/m width) 440.731
- Maximum punching shear, Vp (kN/m width) 8842
- Wide beam shear strength, Vc1 (kN/m width) 1004.16 Vw < Vc1, OK
- Punching shear strength, Vc2 (kN/m width) 3999.06 Vp > Vc2, increase depth

Area of Steel:

- Use area of steel, As (cm²) 37.5 for bottom reinforcement
- As (cm²) 37.1084 for top reinforcement

Details:

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### Combined Footing Analysis and Design

**Project:** CF8

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| Distance, Xp (m) | 4.55 | Left width, b (m) | 7 |
| Distance, Xb (m) | 1.45 | Right width, a (m) | 5 |
| Distance, Xa (m) | 1    | Length, L (m)     | 7 |

| Eff. depth, d (m) | 1.5 |
| Area, (m^2)       | 42  |

### Material Properties:

- Conc comp strength f’c, (Mpa) 30
- Steel comp strength fy, (Mpa) 415
- Allow soil pressure, qa (kPa) 281.25

### Loads:

<table>
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### Checkings:

| Allowable soil pressure, qa (kPa) | 281.25 |
| Maximum soil pressure, qmax (kPa) | 280.014 |
| Minimum soil pressure, qmin (kPa) | 197.455 |

- (qmax < qa) Ok
- (qmin > 0) Ok

| Maximum wide beam shear, Vw (kN/m width) | 274.462 |
| Maximum punching shear, Vp (kN/m width) | 8158.51 |

| Wide beam shear strength, Vc1 (kN/m width) | 1369.31 |
| Punching shear strength, Vc2 (kN/m width) | 3999.06 |

- Vw < Vc1, OK
- Vp < Vc2, OK

### Area of Steel:

- Use area of steel, As (cm^2) 51 for bottom reinforcement
- As (cm^2) 50.6024 for top reinforcement

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### Combined Footing Analysis and Design

**Project:** CF9

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### Material Properties:

- Conc comp strength f'c, (Mpa) 30
- Steel comp strength fy, (Mpa) 415
- Allow soil pressure, qa (kPa) 281.25

### Loads:

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<th>Col. Load</th>
<th>Working loads</th>
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<th>Live</th>
<th>Wind</th>
<th>Seismic</th>
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### Checkings:

- Allowable soil pressure, qa (kPa) 281.25
- Maximum soil pressure, qmax (kPa) 277.825 (qmax < qa) Ok
- Minimum soil pressure, qmin (kPa) 208.369 (qmin > 0) Ok
- Maximum wide beam shear, Vw (kN/m width) 505.641
- Maximum punching shear, Vp (kN/m width) 8304.18
- Wide beam shear strength, Vc1 (kN/m width) 1095.45 Vw < Vc1, OK
- Punching shear strength, Vc2 (kN/m width) 3999.06 Vp < Vc2, OK

### Area of Steel:

- Use area of steel, As (cm²) 40.5 for bottom reinforcement
- As (cm²) 40.4819 for top reinforcement

### Details:

<table>
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<th>x</th>
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Combined Footing Analysis and Design

Issue: Design
Page 1 of 1

Revised by:

Checked by:
Combined Footing Analysis and Design

Dimensions:

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Material Properties:

- Conc comp strength f’c, (Mpa) 30
- Steel comp strength fy, (Mpa) 415
- Allow soil pressure, qa (kPa) 281.25

Loads:

<table>
<thead>
<tr>
<th>Col. Load</th>
<th>Working loads</th>
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<td>Dead</td>
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Checkings:

- Allowable soil pressure, qa (kPa) 281.25
- Maximum soil pressure, qmax (kPa) 275.215 (qmax < qa) Ok
- Minimum soil pressure, qmin (kPa) 206.256 (qmin > 0) Ok
- Maximum wide beam shear, Vw (kN/m width) 280.288
- Maximum punching shear, Vp (kN/m width) 8357.77
- Wide beam shear strength, Vc1 (kN/m width) 1049.8 Vw < Vc1, OK
- Punching shear strength, Vc2 (kN/m width) 3999.06 Vp < Vc2, OK

Area of Steel:

Use area of steel, As (cm2) 39 for bottom reinforcement
As (cm2) 38.7952 for top reinforcement

Details:

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DESIGN OF COLUMNS
Rectangular Short Column with Biaxial bending - Bresler method

**COLUMN NO C1**

Load Case 1.5*(DL - EQX)

Grade of Concrete M30

Grade of Steel Fe415

Characteristic compressive strength of concrete, $f_{ck} ( \text{N/mm}^2 )$ = 30

Characteristic yield strength of steel, $f_y ( \text{N/mm}^2 )$ = 415

Unit weight of concrete, $\gamma_c ( \text{kN/m}^3 )$ = 25

Partial safety factor for concrete = 1.5

Exposure condition Mild

Nominal Cover to exposure condition (mm) = 40

Assumed effective cover all around, $d'$ (mm) = 50

**Dimensions of the Column**

Unsupported length of column, $L$ = 3600 mm

Least lateral dimension = 230 mm

Breadth of the column $B$ (mm) = 230

Depth of the Column $D$ (mm) = 230

Effective length of the column, $l_{ex}$, (m) = 2.34

Effective length of the column, $l_{ey}$, (m) = 2.34

**Check for Slenderness ratio, $L/D$**

Slenderness ratio, $\lambda_{ex}$ = 10.17 <12 column is Short

Slenderness ratio, $\lambda_{ey}$ = 10.17 <12 column is Short

**Design Factors**

Factored load, $P_u$ = 275 KN

Factored moment acting parallel to the larger dimension, $M_{ux}$ = 25 KN-m

Factored moment acting parallel to the shorter dimension, $M_{uy}$ = 3 KN-m

1 Check for accidental eccentricity

Equivalent eccentricity of loads is given by

$M_{ux}/P_u$ = 90.91 mm

$M_{uy}/P_u$ = 327.27 mm

Both are more than 20mm minimum

2 Assume percentage of steel (assuming steel larger than required by $P$ and $M_x$)

$\frac{d'}{D}$ = 0.2

$\frac{M_x}{f_{ck} \times b \times D^2}$

$P_u = 0.07$

$\frac{M_x}{f_{ck} \times b \times D}$

$P_u = 0.17$
From SP16 chart

\[ \frac{P}{f_{ck}} = 0.06 \]  
From table

Assuming a higher value \(P/f_{ck} = 0.09\)

Assumed, \(P\) = 2.70 per cent

Area of steel, \(A_s\) = 1428.30 mm\(^2\)

Use 6 no.s of 20 mm

Area of steel provided = 1884 mm\(^2\)

3 Find the moment capacities \(M_{x1}\) and \(M_{y1}\)
   
   About X-axis
   
   \(d'/D\) = 0.22
   
   \(P/f_{ck} \times b \times D^2\) = 0.17
   
   \(P/f_{ck}\) = 0.09
   
   \(\frac{M_{x1}}{(f_{ck} \times b \times D^2)}\) = \(\frac{0.13}{0.09}\) From table

   \(M_{x1}\) = 47.45 KN-m
   
   About Y-axis
   
   \(d'/D\) = 0.22
   
   \(P/f_{ck} \times b \times D^2\) = 0.17
   
   \(P/f_{ck}\) = 0.09
   
   \(\frac{M_{y1}}{(f_{ck} \times D \times b^2)}\) = \(\frac{0.13}{0.09}\) From table

   \(M_{y1}\) = 47.45 KN-m

4 Calculate \(\alpha^n\)

\(P_z=0.45f_{ck}A_c+0.75f_yA_s\)

\(P_z\) = 1301 KN

\(P/P_z\) = 0.21

By formula

\(\alpha^n=2/3[1+5/2 \times P/P_z]\)

\(\alpha^n\) = 1.02

5 Criteria for biaxial bending

\((M_y/M_{x1})^{an}+(M_y/M_{y1})^{an} < 1.0\)

\(= 0.9000 < 1\)

Hence the column is safe
**Rectangular Short Column with Biaxial bending - Bresler method**

**COLUMN NO** C1a  
**Load Case** 1.5*(DL - EQX)  
**Grade of Concrete** M30  
**Grade of Steel** Fe415  
**Characteristic compressive strength of concrete, \( f_{ck} \) (N/mm\(^2\))** 30  
**Characteristic yield strength of steel, \( f_y \) (N/mm\(^2\))** 415  
**Unit weight of concrete, \( \gamma_c \) (kN/m\(^3\))** 25  
**Partial safety factor for concrete** 1.5  
**Exposure condition** Mild  
**Nominal Cover to exposure condition (mm)** 40  
**Assumed effective cover all around, \( d' \) (mm)** 50

**Dimensions of the Column**

-Unsupported length of column, \( L \) = 3600 mm  
-Least lateral dimension = 400 mm  
-Breadth of the column B (mm) = 400  
-Depth of the Column D (mm) = 700  

-Efficient length of the column, \( l_{ex} \) (m) = 2.34  
-Efficient length of the column, \( l_{ey} \) (m) = 2.34

**Check for Slenderness ratio, L/D**

-Slenderness ratio, \( \lambda_{ex} \) = 5.85 <12 column is Short  
-Slenderness ratio, \( \lambda_{ey} \) = 3.34 <12 column is Short

**Design Factors**

-Factored load, \( P_u \) = 1307.33 KN  
-Factored moment acting parallel to the larger dimension, \( M_{ux} \) = 340.03 KN-m  
-Factored moment acting parallel to the shorter dimension, \( M_{uy} \) = 769.88 KN-m

1. **Check for accidental eccentricity**  
   Equivalent eccentricity of loads is given by  
   \[
   M_{ux}/P_u = 260.10 \text{ mm}  
   M_{uy}/P_u = 68.84 \text{ mm}
   \]
   Both are more than 20mm minimum

2. **Assume percentage of steel**  
   (assuming steel larger than required by P and \( M_x \))  
   \[
   d'/D = \frac{M_x}{f_{ck} \times b \times D^2} = 0.1
   \]
\[
\frac{P_u}{f_{ck} \times b \times D} = 0.16
\]

From SP16 chart44

\[
\frac{P}{f_{ck}} = 0.05 \quad \text{From table}
\]

Assuming a higher value \( P/f_{ck} \)

\[\text{Assumed, } P = 2.25 \text{ per cent} \]

Area of steel, \( A_s \)

\[= 6300.00 \text{ mm}^2 \]

Use 16 no.s of 25 mm

Area of steel provided

\[= 7850 \text{ mm}^2 \]

3 Find the moment capacities \( M_{x1} \) and \( M_{y1} \)

About X-axis
\[
d'/D \quad = 0.07
\]
\[
\frac{P}{f_{ck} \times b \times D^2} \quad = 0.16
\]
\[
\frac{P}{f_{ck}} \quad = 0.075
\]

\[M_{x1}/(f_{ck} \times b \times D^2) = 0.12 \quad \text{From table} \]

\[M_{x1} = 705.60 \text{ KN-m} \]

About Y-axis
\[
d'/D \quad = 0.13
\]
\[
\frac{P}{f_{ck} \times D \times b^2} \quad = 0.16
\]
\[
\frac{P}{f_{ck}} \quad = 0.075
\]

\[M_{y1}/(f_{ck} \times D \times b^2) = 0.12 \quad \text{From table} \]

\[M_{y1} = 403.20 \text{ KN-m} \]

4 Calculate \( \alpha^n \)
\[P_z = 0.45f_{ck}A_s + 0.75f_yA_s \]

\[Pz = 6223 \text{ KN} \]

\[P/P_z = 0.21 \]

By formula
\[\alpha^n = \frac{2}{3}[1+5/2 \times P/P_z] \]

\[\alpha^n = 1.02 \]

5 Criteria for biaxial bending
\[(M_x/M_{x1})^{cm} + (M_y/M_{y1})^{cm} < or = 1.0 \]

\[= 0.6903 < or = 1\]

Hence the column is safe
### Rectangular Short Column with Biaxial bending - Bresler method

**COLUMN NO** C2  
**Load Case** 1.5*(DL - EQX)  
**Grade of Concrete** M30  
**Grade of Steel** Fe415  
**Characteristic compressive strength of concrete, \( f_{ck} \) (N/mm\(^2\))** 30  
**Characteristic yield strength of steel, \( f_y \) (N/mm\(^2\))** 415  
**Unit weight of concrete, \( \gamma_c \) (kN/m\(^3\))** 25  
**Partial safety factor for concrete** 1.5  
**Exposure condition** Mild  
**Nominal Cover to exposure condition (mm)** 40  
**Assumed effective cover all around, \( d' \) (mm)** 50  

#### Dimensions of the Column

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsupported length of column, ( L )</td>
<td>3750 mm</td>
</tr>
<tr>
<td>Least lateral dimension</td>
<td>350 mm</td>
</tr>
<tr>
<td>Breadth of the column ( B ) (mm)</td>
<td>350</td>
</tr>
<tr>
<td>Depth of the Column ( D ) (mm)</td>
<td>800</td>
</tr>
<tr>
<td>Effective length of the column, ( l_{ex} ) (m)</td>
<td>2.34</td>
</tr>
<tr>
<td>Effective length of the column, ( l_{ey} ) (m)</td>
<td>2.34</td>
</tr>
</tbody>
</table>

#### Check for Slenderness ratio, \( L/D \)

| Slenderness ratio, \( \lambda_{ex} \) | 7.80 <12 column is Short |
| Slenderness ratio, \( \lambda_{ey} \) | 2.93 <12 column is Short |

#### Design Factors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factored load, ( P_u )</td>
<td>925 KN</td>
</tr>
<tr>
<td>Factored moment acting parallel to the larger dimension, ( M_{ux} )</td>
<td>334 KN-m</td>
</tr>
<tr>
<td>Factored moment acting parallel to the shorter dimension, ( M_{uy} )</td>
<td>228.13 KN-m</td>
</tr>
</tbody>
</table>

1. Check for accidental eccentricity  
Equivalent eccentricity of loads is given by  
\[
\frac{M_{ux}}{P_u} = 362.01 \text{ mm}  \\
\frac{M_{uy}}{P_u} = 100.56 \text{ mm}
\]
Both are more than 20mm minimum

2. Assume percentage of steel  
(assuming steel larger than required by \( P \) and \( M_x \))

\[
d'/D = 0.1
\]

\[
\frac{M_x}{f_{ck} x b x D^2} = 0.06
\]
\[
\frac{P_u}{f_{ck} \times b \times D} = 0.12
\]

From SP16 chart 44
\[
\frac{P}{f_{ck}} = 0.05 \quad \text{From table}
\]

Assuming a higher value \(P/f_{ck}\)
\[
\text{Assumed }, P = 0.075
\]
\[
\text{per cent}
\]

Area of steel, \(A_s\)
\[
= 5400.00 \text{ mm}^2
\]

Use 12 no.s of 25 mm

Area of steel provided
\[
= 5888 \text{ mm}^2
\]

3 Find the moment capacities \(M_{x1}\) and \(M_{y1}\)

About X-axis
\[
d'/D = 0.06
\]
\[
P/f_{ck} \times b \times D^2 = 0.12
\]
\[
P/f_{ck} = 0.075
\]
\[
M_{x1}/(f_{ck} \times b \times D^2) = 0.12 \quad \text{From table}
\]
\[
M_{x1} = 691.20 \text{ KN-m}
\]

About Y-axis
\[
d'/D = 0.17
\]
\[
P/f_{ck} \times b \times D^2 = 0.12
\]
\[
P/f_{ck} = 0.075
\]
\[
M_{y1}/(f_{ck} \times D \times b^2) = 0.12 \quad \text{From table}
\]
\[
M_{y1} = 269.20 \text{ KN-m}
\]

4 Calculate \(\alpha^n\)
\[
P_z = 0.45f_{ck}A_s + 0.75f_yA_s
\]
\[
P_z = 5072 \text{ KN}
\]
\[
P/P_z = 0.18
\]

By formula
\[
\alpha^n = 2/3[1+5/2 \times P/P_z]
\]
\[
\alpha^n = 0.97
\]

5 Criteria for biaxial bending
\[
(M_x/M_{x1})^{cm} + (M_y/M_{y1})^{cm} < = 1.0
\]
\[
= 0.8613 < 1
\]

Hence the column is safe
Rectangular Short Column with Biaxial bending - Bresler method

COLUMN NO C3
Load Case 1.2*(DL + LL - EQX)
Grade of Concrete M30
Grade of Steel Fe415
Characteristic compressive strength of concrete, $f_{ck}$ (N/mm$^2$) 30
Characteristic yield strength of steel, $f_y$ (N/mm$^2$) 415
Unit weight of concrete, $\gamma_c$ (kN/m$^3$) 25
Partial safety factor for concrete 1.5
Exposure condition Mild
Nominal Cover to exposure condition (mm) 40
Assumed effective cover all around, $d'$ (mm) 60

Dimensions of the Column

Unsupported length of column, $L$ = 3600 mm
Least lateral dimension = 300 mm
Breadth of the column $B$ (mm) = 300
Depth of the Column $D$ (mm) = 600

Effective length of the column, $l_{ex}$ (m) = 2.34
Effective length of the column, $l_{ey}$ (m) = 2.34

Check for Slenderness ratio, $L/D$

$$\lambda_{ex} = 7.80 < 12 \text{ column is Short}$$
$$\lambda_{ey} = 3.90 < 12 \text{ column is Short}$$

Design Factors

Factored load, $P_u$ = 366.32 KN
Factored moment acting parallel to the larger dimension, $M_{ux}$ = 162.29 KN-m
Factored moment acting parallel to the shorter dimension, $M_{uy}$ = 353.51 KN-m

1 Check for accidental eccentricity
   Equivalent eccentricity of loads is given by
   $$M_{ux}/P_u = 443.03 \text{ mm}$$
   $$M_{uy}/P_u = 245.69 \text{ mm}$$
   Both are more than 20mm minimum

2 Assume percentage of steel
   (assuming steel larger than required by P and $M_x$)
   $$d'/D = 0.1$$
   $$\frac{M_x}{f_{ck} \times b \times D^2} = 0.05$$
\[
\frac{P_u}{f_{ck} \times b \times D} = 0.07
\]

From SP16 chart 44

\[
\frac{P}{f_{ck}} = 0.07 \quad \text{From table}
\]

Assuming a higher value \( P/f_{ck} \)

\[
\text{Assumed, } P = 3.15 \text{ per cent}
\]

Area of steel, \( A_s \)

\[
= 5670.00 \text{ mm}^2
\]

Use 12 no.s of 25 mm

Area of steel provided

\[
= 5888 \text{ mm}^2
\]

3 Find the moment capacities \( M_{x1} \) and \( M_{y1} \)

About X-axis

\[
d'/D = 0.10
\]

\[
P/f_{ck} \times b \times D^2 = 0.07
\]

\[
P/f_{ck} = 0.105
\]

\[
M_{x1}/(f_{ck} \times b \times D^2) = 0.125 \quad \text{From table}
\]

\[
M_{x1} = 405.00 \text{ KHN-m}
\]

About Y-axis

\[
d'/D = 0.20
\]

\[
P/f_{ck} \times b \times D^2 = 0.07
\]

\[
P/f_{ck} = 0.105
\]

\[
M_{y1}/(f_{ck} \times D \times b^2) = 0.125 \quad \text{From table}
\]

\[
M_{y1} = 202.50 \text{ KHN-m}
\]

4 Calculate \( \alpha^n \)

\[
P_z = 0.45f_{ck}A_s + 0.75f_{y}A_s
\]

\[
P_z = 4262 \text{ KN}
\]

\[
P/P_z = 0.09
\]

By formula

\[
\alpha^n = 2/3[1+5/2 \times P/P_z]
\]

\[
\alpha^n = 0.81
\]

5 Criteria for biaxial bending

\[
(M_x/M_{x1})^{cm} + (M_y/M_{y1})^{cm} < or = 1.0
\]

\[
= 0.9919 < or = 1
\]

Hence the column is safe
Rectangular Short Column with Biaxial bending - Bresler method

COLUMN NO  C4
Load Case  $1.2 \times (DL + LL - EQX)$
Grade of Concrete  M30
Grade of Steel  Fe415
Characteristic compressive strength of concrete , $f_{ck}$  (N/mm$^2$)  30
Characteristic yield strength of steel , $f_y$  (N/mm$^2$)  415
Unit weight of concrete , $\gamma_c$ (kN/m$^3$)  25
Partial safety factor for concrete  1.5
Exposure condition  Mild
Nominal Cover to exposure condition( mm )  40
Assumed effective cover all around , $d'$ ( mm )  60

Dimensions of the Column

Unsupported length of column, $L$  = 3600 mm
Least lateral dimension  = 350 mm
Breadth of the column $B$ (mm)  = 350
Depth of the Column $D$ (mm)  = 500

Effective length of the column , $l_{ex}$, ( m )  = 2.34
Effective length of the column , $l_{ey}$, ( m )  = 2.34

Check for Slenderness ratio, $L/D$

$\lambda_{ex} = 6.69 < 12$ column is Short
$\lambda_{ey} = 4.68 < 12$ column is Short

Design Factors

Factored load, $P_u$  = 226.3 KN
Factored moment acting parallel to the larger dimension , $M_{ux}$  = 138.53 KN-m
Factored moment acting parallel to the shorter dimension, $M_{uy}$  = 192.01 KN-m

1 Check for accidental eccentricity

Equivalent eccentricity of loads is given by

$M_{ux}/P_u = 612.15$ mm
$M_{uy}/P_u = 397.70$ mm

Both are more than 20mm minimum

2 Assume percentage of steel

(assuming steel larger than required by $P$ and $M_x$)

$d'/D = 0.1$

$M_x = \frac{f_{ck} \times b \times D^2}{1.5}$
\[
\frac{P}{f_{ck}} = 0.04
\]

From SP16 chart 44

\[
\frac{P}{f_{ck}} = 0.07 \quad \text{From table}
\]

Assuming a higher value \(P/f_{ck}\)

\[
\text{Assumed, } P = 0.105 \quad \text{per cent}
\]

Area of steel, \(A_s\)

\[
A_s = 5512.50 \text{ mm}^2
\]

Use 12 no.s of 25 mm

Area of steel provided = 5888 mm\(^2\)

3. Find the moment capacities \(M_{x1}\) and \(M_{y1}\)

About X-axis

\[
d'/D = 0.12
\]

\[
P/f_{ck} x b x D^2 = 0.04
\]

\[
P/f_{ck} = 0.06
\]

\[
M_{x1}/(f_{ck} x b x D^2) = 0.13 \quad \text{From table}
\]

\[
M_{x1} = 341.25 \text{ KN-m}
\]

About Y-axis

\[
d'/D = 0.17
\]

\[
P/f_{ck} x b x D^2 = 0.04
\]

\[
P/f_{ck} = 0.105
\]

\[
M_{y1}/(f_{ck} x D x b^2) = 0.13 \quad \text{From table}
\]

\[
M_{y1} = 238.88 \text{ KN-m}
\]

4. Calculate \(\alpha^n\)

\[
P_z = 0.45f_{ck}A_s + 0.75f_yA_s
\]

\[
Pz = 4195 \text{ KN}
\]

\[
P/P_z = 0.05
\]

By formula

\[
\alpha^n = \frac{2}{3}[1+5/2 \times P/P_z]
\]

\[
\alpha^n = 0.76
\]

5. Criteria for biaxial bending

\[
(M_x/M_{x1})^{\alpha^n} + (M_y/M_{y1})^{\alpha^n} < 1.0
\]

\[
= 0.9799 < 1
\]

Hence the column is safe.
Rectangular Short Column with Biaxial bending - Bresler method

**COLUMN NO C5**

Load Case 1.5*(DL - EQX)

Grade of Concrete M30

Grade of Steel Fe415

Characteristic compressive strength of concrete, $f_{ck}$ (N/mm$^2$) 30

Characteristic yield strength of steel, $f_y$ (N/mm$^2$) 415

Unit weight of concrete, $\gamma_c$ (kN/m$^3$) 25

Partial safety factor for concrete 1.5

Exposure condition Mild

Nominal Cover to exposure condition (mm) 40

Assumed effective cover all around, $d'$ (mm) 50

**Dimensions of the Column**

Unsupported length of column, $L$ = 3600 mm

Least lateral dimension = 350 mm

Breadth of the column $B$ (mm) = 350

Depth of the Column $D$ (mm) = 600

Effective length of the column, $l_{ex}$, (m) = 2.34

Effective length of the column, $l_{ey}$, (m) = 2.34

**Check for Slenderness ratio, L/D**

Slenderness ratio, $\lambda_{ex}$ = 6.69 <12 column is Short

Slenderness ratio, $\lambda_{ey}$ = 3.90 <12 column is Short

**Design Factors**

Factored load, $P_u$ = 830.8 KN

Factored moment acting parallel to the larger dimension, $M_{ux}$ = 59.63 KN-m

Factored moment acting parallel to the shorter dimension, $M_{uy}$ = 224.86 KN-m

1 Check for accidental eccentricity

Equivalent eccentricity of loads is given by

$$M_{ux}/P_u = 71.77 \text{ mm}$$

$$M_{uy}/P_u = 108.33 \text{ mm}$$

Both are more than 20mm minimum

2 Assume percentage of steel

(assuming steel larger than required by $P$ and $M_x$)

$$d'/D = 0.1$$

$$M_x = \frac{f_{ck} \times b \times D^2}{M_x} = 0.02$$
\[
\frac{P_u}{f_{ck} \times b \times D} = 0.13
\]

From SP16 chart 44

\[
\frac{P}{f_{ck}} = 0.05 \quad \text{From table}
\]

Assuming a higher value \( P/f_{ck} \)

Assumed, \( P = 2.25 \) per cent

Area of steel, \( A_s \)

\[
A_s = 4725.00 \, \text{mm}^2
\]

Use 10 no.s of 25 mm

Area of steel provided

\[
= 4906 \, \text{mm}^2
\]

3 Find the moment capacities \( M_{x1} \) and \( M_{y1} \)

About X-axis

\[
d'/D = 0.08
\]

\[
P/f_{ck} \times b \times D^2 = 0.13
\]

\[
P/f_{ck} = 0.075
\]

\[
M_{x1}/(f_{ck} \times b \times D^2) = 0.12 \quad \text{From table}
\]

\[
M_{x1} = 453.60 \, \text{KN-m}
\]

About Y-axis

\[
d'/D = 0.14
\]

\[
P/f_{ck} \times b \times D^2 = 0.13
\]

\[
P/f_{ck} = 0.075
\]

\[
M_{y1}/(f_{ck} \times D \times b^2) = 0.12 \quad \text{From table}
\]

\[
M_{y1} = 264.60 \, \text{KN-m}
\]

4 Calculate \( \alpha^n \)

\[
P_z = 0.45f_{ck}A_s + 0.75f_yA_s
\]

\[
Pz = 4362 \, \text{KN}
\]

\[
P/P_z = 0.19
\]

By formula

\[
\alpha^n = 2/3[1+5/2 \times P/P_z]
\]

\[
\alpha^n = 0.99
\]

5 Criteria for biaxial bending

\[
(M_x/M_{x1})^{cm} + (M_y/M_{y1})^{cm} < =1.0
\]

\[
= 0.4786 < or = 1
\]

Hence the column is safe
Rectangular Short Column with Biaxial bending - Bresler method

COLUMN NO  C6
Load Case  1.5*(DL - EQX)
Grade of Concrete  M30
Grade of Steel  Fe415
Characteristic compressive strength of concrete , $f_{ck}$ ( N/mm$^2$ )  30
Characteristic yield strength of steel , $f_y$ ( N/mm$^2$ )  415
Unit weight of concrete , $\gamma_c$ ( kN/m$^3$ )  25
Partial safety factor for concrete  1.5
Exposure condition  Mild
Nominal Cover to exposure condition( mm )  40
Assumed effective cover all around , $d'$ ( mm )  50

Dimensions of the Column

Unsupported length of column, $L$  =  3600 mm
Least lateral dimension  =  400 mm
Breadth of the column $B$ (mm)  =  400
Depth of the Column $D$ (mm)  =  900

effective length of the column , $l_{ex}$ , ( m )  =  2.34
Effective length of the column , $l_{ey}$ , ( m )  =  2.34

Check for Slenderness ratio, $L/D$

Slenderness ratio , $\lambda_{ex}$  =  5.85 <12 column is Short
Slenderness ratio , $\lambda_{ey}$  =  2.60 <12 column is Short

Design Factors

Factored load, $P_u$  =  560.34 KN
Factored moment acting parallel to the larger dimension , $M_{ux}$  =  563.33 KN-m
Factored moment acting parallel to the shorter dimension, $M_{uy}$  =  210.34 KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by
$M_{ux}/P_u$  =  1005.34 mm
$M_{uy}/P_u$  =  160.62 mm
Both are more than 20mm minimum

2 Assume percentage of steel
( assuming steel larger than required by $P$ and $M_u$)

$$d'/D = 0.1$$

$$\frac{M_u}{f_{ck} \times b \times D'^2} = 0.06$$
\[
\frac{P_u}{f_{ck} \times b \times D} = 0.05
\]

From SP16 chart 44
\[
\frac{P}{f_{ck}} = 0.045 \quad \text{From table}
\]

Assuming a higher value \( \frac{P}{f_{ck}} \)
Assumed, \( P \) = 0.0675

Area of steel, \( A_s \) = 7290.00 mm\(^2\)

Use 16 no.s of 25 mm

Area of steel provided = 7850 mm\(^2\)

3 Find the moment capacities \( M_{x1} \) and \( M_{y1} \)

About X-axis
\[
d'/D \quad = \quad 0.06
\]
\[
\frac{P}{f_{ck} \times b \times D^2} \quad = \quad 0.05
\]
\[
\frac{P}{f_{ck}} \quad = \quad 0.0675
\]
\[
M_{x1}/(f_{ck} \times b \times D^2) \quad = \quad 0.12 \quad \text{From table}
\]
\[
M_{x1} \quad = \quad 1166.40 \quad \text{KN-m}
\]

About Y-axis
\[
d'/D \quad = \quad 0.13
\]
\[
\frac{P}{f_{ck} \times b \times D^2} \quad = \quad 0.05
\]
\[
\frac{P}{f_{ck}} \quad = \quad 0.0675
\]
\[
M_{y1}/(f_{ck} \times D \times b^2) \quad = \quad 0.12 \quad \text{From table}
\]
\[
M_{y1} \quad = \quad 518.40 \quad \text{KN-m}
\]

4 Calculate \( \alpha^n \)
\[
P_z = 0.45f_{ck}A_x + 0.75f_yA_s
\]
\[
P_z \quad = \quad 7303 \quad \text{KN}
\]
\[
P/P_z \quad = \quad 0.08
\]

By formula
\[
\alpha^n = 2/3[1+5/2 \times P/P_z]
\]
\[
\alpha^n \quad = \quad 0.80
\]

5 Criteria for biaxial bending
\[
(M_x/M_{x1})^{cm} + (M_y/M_{y1})^{cm} < \text{or} = 1.0
\]
\[
= \quad 0.8063 \quad < \text{or} = 1
\]

Hence the column is safe
Rectangular Short Column with Biaxial bending - Bresler method

**COLUMN NO C7**

**Load Case** 1.5*(DL - EQX)

**Grade of Concrete** M30

**Grade of Steel** Fe415

**Characteristic compressive strength of concrete, f\text{ck} (N/mm}^2)\) 30

**Characteristic yield strength of steel, f\text{y} (N/mm}^2)\) 415

**Unit weight of concrete, γc (kN/m}^3)\) 25

**Partial safety factor for concrete** 1.5

**Exposure condition** Mild

**Nominal Cover to exposure condition (mm)** 40

**Assumed effective cover all around, d' (mm)** 60

**Dimensions of the Column**

- Unsupported length of column, L = 3600 mm
- Least lateral dimension = 800 mm
- Breadth of the column B (mm) = 800
- Depth of the Column D (mm) = 800

- Effective length of the column, l_{ex}, (m) = 2.34
- Effective length of the column, l_{ey}, (m) = 2.34

**Check for Slenderness ratio, L/D**

- Slenderness ratio, \(\lambda_{ex}\) = 2.93 <12 column is Short
- Slenderness ratio, \(\lambda_{ey}\) = 2.93 <12 column is Short

**Design Factors**

- Factored load, P\text{u} = 4861.81 KN
- Factored moment acting parallel to the larger dimension, M\text{ux} = 1817.69 KN-m
- Factored moment acting parallel to the shorter dimension, M\text{uy} = 0.23 KN-m

1. Check for accidental eccentricity

   Equivalent eccentricity of loads is given by
   
   \[
   \frac{M_{ux}}{P_u} = 373.87 \text{ mm}
   \]
   
   \[
   \frac{M_{uy}}{P_u} = 18.51 \text{ mm}
   \]

   Both are more than 20mm minimum

2. Assume percentage of steel

   (assuming steel larger than required by P and Mx)

   \[
   \frac{d'}{D} = 0.1
   \]

   \[
   \frac{M_x}{f_{ck} \times b \times D^2} = 0.12
   \]
\[
\frac{P_u}{f_{ck} \times b \times D} = 0.25
\]

From SP16 chart44
\[
\frac{P}{f_{ck}} = 0.055 \quad \text{From table}
\]
Assuming a higher value \(P/f_{ck}\)
\[
\text{Assumed, } P = 2.48 \text{ per cent}
\]
Area of steel, \(A_s\)
\[
A_s = 15840.00 \text{ mm}^2
\]

Use 20 no. s of 32 mm
Area of steel provided
\[
= 16077 \text{ mm}^2
\]

3 Find the moment capacities \(M_{x1}\) and \(M_{y1}\)

About X-axis
\[
d'/D = 0.08
\]
\[
\frac{P}{f_{ck} \times b \times D^2} = 0.25
\]
\[
P/f_{ck} = 0.0825
\]
\[
M_{x1}/(f_{ck} \times b \times D^2) = 0.13 \quad \text{From table}
\]
\[
M_{x1} = 1996.80 \text{ KN-m}
\]

About Y-axis
\[
d'/D = 0.08
\]
\[
\frac{P}{f_{ck} \times b \times D^2} = 0.25
\]
\[
P/f_{ck} = 0.0825
\]
\[
M_{y1}/(f_{ck} \times D \times b^2) = 0.13 \quad \text{From table}
\]
\[
M_{y1} = 1996.80 \text{ KN-m}
\]

4 Calculate \(\alpha^n\)
\[
P_z = 0.45f_{ck}A_s + 0.75f_yA_s
\]
\[
Pz = 13644 \text{ KN}
\]
\[
P/P_z = 0.36
\]

By formula
\[
\alpha^n = 2/3 \left[1 + 5/2 \times P/P_z \right]
\]
\[
\alpha^n = 1.27
\]

5 Criteria for biaxial bending
\[
(M_x/M_{x1})^{cm} + (M_y/M_{y1})^{cm} < \text{or} = 1.0
\]
\[
= 0.9075 < \text{or} = 1
\]

Hence the column is safe
RECTANGULAR SHORT COLUMN WITH BIAXIAL BENDING - BRESLER METHOD

COLUMN NO  C8

Load Case  1.5*(DL - EQX)
Grade of Concrete  M30
Grade of Steel  Fe415
Characteristic compressive strength of concrete, $f_{ck}$ (N/mm$^2$)  30
Characteristic yield strength of steel, $f_y$ (N/mm$^2$)  415
Unit weight of concrete, $\gamma_c$ (kN/m$^3$)  25
Partial safety factor for concrete  1.5
Exposure condition  Mild
Nominal Cover to exposure condition (mm)  40
Assumed effective cover all around, $d'$ (mm)  50

Dimensions of the Column

Unsupported length of column, $L$ = 3600 mm
Least lateral dimension = 300 mm
Breadth of the column B (mm) = 300
Depth of the Column D (mm) = 800

Effective length of the column, $l_{ex}$, (m) = 2.34
Effective length of the column, $l_{ey}$, (m) = 2.34

Check for Slenderness ratio, $L/D$

Slenderness ratio, $\lambda_{ex}$ = 7.80 <12 column is Short
Slenderness ratio, $\lambda_{ey}$ = 2.93 <12 column is Short

Design Factors

Factored load, $P_u$ = 895 KN
Factored moment acting parallel to the larger dimension, $M_{ux}$ = 324 KN-m
Factored moment acting parallel to the shorter dimension, $M_{uy}$ = 240.15 KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by
$M_{ux}/P_u$ = 362.01 mm
$M_{uy}/P_u$ = 100.56 mm
Both are more than 20mm minimum

2 Assume percentage of steel
(assuming steel larger than required by $P$ and $M_s$)

$$d'/D = 0.1$$

$$M_s = \frac{f_{ck} \times b \times D^2}{f_{ck} \times b \times D^2} = 0.06$$
\[
\frac{P_u}{f_{ck} \times b \times D} = 0.12
\]

From SP16 chart44

\[
\frac{P}{f_{ck}} = 0.05 \quad \text{From table}
\]

Assuming a higher value \( P/f_{ck} \)

Assumed, \( P = 2.25 \) per cent

Area of steel, \( A_s \)

\[
A_s = 5400.00 \text{ mm}^2
\]

Use 12 no. s of 25 mm

Area of steel provided

\[
= 5888 \text{ mm}^2
\]

3 Find the moment capacities \( M_{x1} \) and \( M_{y1} \)

About X-axis
\[
d'/D = 0.06
\]
\[
P/f_{ck} \times b \times D^2 = 0.12
\]
\[
P/f_{ck} = 0.075
\]

\[
M_{x1}/(f_{ck} \times b \times D^2) = 0.12 \quad \text{From table}
\]

\[
M_{x1} = 691.20 \text{ KN-m}
\]

About Y-axis
\[
d'/D = 0.17
\]
\[
P/f_{ck} \times b \times D^2 = 0.12
\]
\[
P/f_{ck} = 0.075
\]

\[
M_{y1}/(f_{ck} \times D \times b^2) = 0.12 \quad \text{From table}
\]

\[
M_{y1} = 259.20 \text{ KN-m}
\]

4 Calculate \( \alpha^n \)

\[
P_Z = 0.45f_{ck}A_s + 0.75f_yA_s
\]

\[
P_z = 5072 \text{ KN}
\]

\[
P/P_z = 0.18
\]

By formula
\[
\alpha^n = 2/3[1+5/2 \times P/P_z]
\]

\[
\alpha^n = 0.97
\]

5 Criteria for biaxial bending

\[
(M_x/M_{x1})^{cm} + (M_y/M_{y1})^{cm} < 1.0
\]

\[
= 0.8413 < 1
\]

Hence the column is safe
Rectangular Short Column with Biaxial bending - Bresler method

**COLUMN NO C9**

Load Case 1.5*(DL - EQX)
Grade of Concrete M30
Grade of Steel Fe415
Characteristic compressive strength of concrete, fck (N/mm²) 30
Characteristic yield strength of steel, fy (N/mm²) 415
Unit weight of concrete, γc (kN/m³) 25
Partial safety factor for concrete 1.5
Exposure condition Mild
Nominal Cover to exposure condition (mm) 40
Assumed effective cover all around, d' (mm) 50

**Dimensions of the Column**

Unsupported length of column, L = 3600 mm
Least lateral dimension = 300 mm
Breadth of the column, B (mm) = 300
Depth of the Column, D (mm) = 400

Effective length of the column, lex (m) = 2.34
Effective length of the column, ley (m) = 2.34

**Check for Slenderness ratio, L/D**

\[ \lambda_{ex} = 7.80 \quad \text{<12 column is Short} \]
\[ \lambda_{ey} = 5.85 \quad \text{<12 column is Short} \]

**Design Factors**

Factored load, Pu = 717.13 KN
Factored moment acting parallel to the larger dimension, Mux = 112.72 KN-m
Factored moment acting parallel to the shorter dimension, Myy = 60.37 KN-m

1 Check for accidental eccentricity
   Equivalent eccentricity of loads is given by
   \[ \frac{M_{ux}}{P_u} = 157.18 \quad \text{mm} \]
   \[ \frac{M_{uy}}{P_u} = 125.50 \quad \text{mm} \]
   Both are more than 20mm minimum

2 Assume percentage of steel
   (assuming steel larger than required by P and Mx)
   \[ \frac{d'}{D} = 0.1 \]
   \[ \frac{M_x}{f_{ck} \times b \times D^2} = 0.08 \]

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\[
\frac{P_u}{f_{ck} \times b \times D} = 0.20
\]

From SP16 chart 44

\[
\frac{P}{f_{ck}} = 0.07 \quad \text{From table}
\]

Assuming a higher value \( P/f_{ck} \)

\[
\text{Assumed, } P = 0.105 \quad \text{per cent}
\]

Area of steel, \( A_s \)

\[
= 3780.00 \quad \text{mm}^2
\]

Use 8 no. s of 25 mm

Area of steel provided

\[
= 3925 \quad \text{mm}^2
\]

3 Find the moment capacities \( M_{x1} \) and \( M_{y1} \)

About X-axis

\[
d'/D = 0.13
\]

\[
\frac{P}{f_{ck} \times b \times D^2} = 0.20
\]

\[
\frac{P}{f_{ck}} = 0.105
\]

\[
M_{x1}/(f_{ck} \times b \times D^2) = 0.07 \quad \text{From table}
\]

\[
M_{x1} = 100.80 \quad \text{KN-m}
\]

About Y-axis

\[
d'/D = 0.17
\]

\[
\frac{P}{f_{ck} \times b \times D^2} = 0.20
\]

\[
\frac{P}{f_{ck}} = 0.105
\]

\[
M_{y1}/(f_{ck} \times D \times b^2) = 0.07 \quad \text{From table}
\]

\[
M_{y1} = 75.60 \quad \text{KN-m}
\]

4 Calculate \( \alpha^0 \)

\[
P_z = 0.45 \times f_{ck} A_s + 0.75f_{ck} A_s
\]

\[
P_z = 2842 \quad \text{KN}
\]

\[
P/P_z = 0.25
\]

By formula

\[
\alpha^0 = 2/3[1+5/2 \times P/P_z]
\]

\[
\alpha^0 = 1.09
\]

5 Criteria for biaxial bending

\[
(M_x/M_{x1})^{0.6} + (M_y/M_{y1})^{0.6} < \text{or} = 1.0
\]

\[
= 0.9000 < \text{or} = 1
\]

Hence the column is safe
**Rectangular Short Column with Biaxial bending - Bresler method**

**COLUMN NO**  C10
Load Case  1.5*(DL - EQX)
Grade of Concrete  M30
Grade of Steel  Fe415
Characteristic compressive strength of concrete, $f_{ck}$ (N/mm$^2$)  30
Characteristic yield strength of steel, $f_y$ (N/mm$^2$)  415
Unit weight of concrete, $\gamma_c$ (kN/m$^3$)  25
Partial safety factor for concrete  1.5
Exposure condition  Mild
Nominal Cover to exposure condition (mm)  40
Assumed effective cover all around, d' (mm)  50

**Dimensions of the Column**

Unsupported length of column, L = 3600 mm
Least lateral dimension = 550 mm
Breadth of the column B (mm) = 550
Depth of the Column D (mm) = 850

Effective length of the column, $l_{ex}$, (m) = 2.34
Effective length of the column, $l_{ey}$, (m) = 2.34

**Check for Slenderness ratio, L/D**

Slenderness ratio, $\lambda_{ex}$ = 4.25 <12 column is Short
Slenderness ratio, $\lambda_{ey}$ = 2.75 <12 column is Short

**Design Factors**

Factored load, $P_u$ = 3015.88 KN
Factored moment acting parallel to the larger dimension, $M_{ux}$ = 918.44 KN-m
Factored moment acting parallel to the shorter dimension, $M_{uy}$ = 2 KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by

\[
M_{ux}/P_u = 304.53 \text{ mm} \\
M_{uy}/P_u = 29.84 \text{ mm}
\]

Both are more than 20mm minimum

2 Assume percentage of steel
(assuming steel larger than required by $P$ and $M_x$)

\[
d'/D = 0.1 \\
M_x = \frac{f_{ck} \times b \times D^2}{f_y}
\]

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\[ \frac{P_u}{f_{ck} x b x D} = 0.22 \]

From SP16 chart44

\[ \frac{P}{f_{ck}} = 0.05 \quad \text{From table} \]

Assuming a higher value \( P/f_{ck} \)

Assumed, \( P \) = 2.25 per cent

Area of steel, \( A_s \) = 10518.75 mm\(^2\)

Use 22 no. s of 25 mm

Area of steel provided = 10794 mm\(^2\)

3 Find the moment capacities \( M_{x1} \) and \( M_{y1} \)

About X-axis

\[ \frac{d'/D}{P/f_{ck} x b x D^2} = 0.06 \]

\[ P/f_{ck} = 0.22 \]

\[ M_{x1}/(f_{ck} x b x D^2) = 0.125 \quad \text{From table} \]

\[ M_{x1} = 1490.16 \text{ KN-m} \]

About Y-axis

\[ \frac{d'/D}{P/f_{ck} x b x D^2} = 0.09 \]

\[ P/f_{ck} = 0.22 \]

\[ M_{y1}/(f_{ck} x D x b^2) = 0.125 \quad \text{From table} \]

\[ M_{y1} = 964.22 \text{ KN-m} \]

4 Calculate \( \alpha^n \)

\[ P_z = 0.45f_{ck}A_s + 0.75f_yA_s \]

\[ P_z = 9671 \text{ KN} \]

\[ P/P_z = 0.31 \]

By formula

\[ \alpha^n = 2/3[1+5/2 \times P/P_z] \]

\[ \alpha^n = 1.19 \]

5 Criteria for biaxial bending

\[ (M_x/M_{x1})^{cm} + (M_y/M_{y1})^{cm} < \text{or} = 1 = 0.6207 < \text{or} = 1 \]

Hence the column is safe
DESIGN OF BEAMS
**Beam PB1 Support**

**Design Parameters**

Load Case 14 \[1.5(DL - EQX)\]

- Grade of Concrete: \(\text{M30}\)
- Grade of Steel: \(\text{Fe415}\)
- Characteristic compressive strength of concrete, \(f_{ck}\) (N/mm\(^2\)): 30
- Characteristic yield strength of steel, \(f_y\) (N/mm\(^2\)): 415
- Unit weight of concrete, \(\gamma_c\) (kN/m\(^3\)): 24
- Partial safety factor for concrete: 1.5
- Exposure condition: Mild
- Nominal Cover to exposure condition (mm): 20

**Dimensions of the beam**

- C/C Span of the beam, \(l\) (m): 10.80
- Breadth of the beam, \(b\) (mm): 250
- Overall depth of the beam, \(D\) (mm): 600

**Details of reinforcements**

- Diameter of tension reinforcement (mm): 25
- Diameter of compression reinforcement (mm): 25
- Diameter of stirrups (mm): 8

**Effective depth**

- Effective depth, \(d\) (mm): \((600-20-8-25/2) = 560\)

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

- Torsional Moment: 0 kN-m
- Bending Moment \(M_u\) (kN-m): 380
- Equivalent Bending Moment, \(M_e\) (kNm): 380
- Shear force at critical distance, \(V_{ud}\) (kN): 152
- Equivalent Shear (kN): 152

**Singly reinforced or doubly reinforced section?**

The *limiting moment of resistance*, \(M_{u,lim}\) is given by

\[
M_{u,lim} = 0.362f_{ck} \times \frac{bxu_{\text{max}}}{d} \times 0.416xu_{\text{max}}
\]

Where
- \(b\) = Breadth of the Section
- \(xu_{\text{max}}\) = Limiting depth of Neutral Axis
- \(d\) = Effective depth of the Section

The limiting percentage of steel, \(p_{\text{lim}}\) is given by
The area of steel for a singly reinforced section with width, $b$ and depth, $d$ and ultimate moment, $M_u$ is given by:

$$\frac{Pt}{100} = \frac{Ast \times fck}{bd \times 2fy} = 4.598 \frac{R}{fck}$$

Where $R = \frac{Mu}{bd^2}$

For (M30 and Fe415) $M_{u,lim} = 0.1389 \ fck \ b \ d^2$

$x_{u,max} / d = 0.48$

$$\Rightarrow M_{u,lim} = \left( 0.1389 \times 30 \times 250 \times 559.5^2 / 1000000 \right) = 326.11 \text{ kNm}$$

$$\Rightarrow p_{t,lim} = \left( 41.3 \times 30 / 415 \times 0.48 \right) = 1.433$$

If $M_u > M_{u,lim}$, the section has to be
i) get increased by depth or width (preferably depth)
ii) doubly reinforced

If $M_u < M_{u,lim}$, the section can be designed as singly reinforced.

**Check for the type of section**

$$M_i = 380.00 \text{ kNm}$$

$$M_{u,lim} = 326.11 \text{ kNm}$$

$$\Rightarrow \text{section cannot be designed as singly reinforced. Doubly Reinforced Section Neede}$$

**Determining $A_{st}$**

- Considering a 'balanced section' ($x_u = x_{u,max}$)

  $$A_{st} = A_{st,lim} + \Delta A_{st}$$

  where $A_{st,lim} = p_{t,lim} / 100 \ (b \times d)$

  $$\Rightarrow A_{st,lim} = \left( 1.433 / 100 \times 250 \times 559.5 \right) = 2004 \text{ mm}^2$$

- Assuming 25 mm bars for compression steel,

  $$d' \approx \left( 20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2 \right) = 40.5 \text{ mm}$$
\[ \begin{align*}
\Delta A_{st} &= \frac{M_u - M_{u,\text{lim}}}{0.87 f_y} \frac{d}{d'} \\
\Delta p_t &= \frac{R - R_{\text{lim}}}{0.87 f_y} \frac{d'}{d}
\end{align*} \]

\[ M_u = 0.87 f_y^{\text{Ast}} d (1 - (\text{Ast} f_y)/b d' f_{ck}) \]

\[ \text{Ast Req'd} = 2498 \text{ mm}^2 \]

\[ \therefore \] No of tension bars required ( # )

\[ \frac{2498}{(\pi/4 \times 25^2)} = 6.00 \]

Actual percentage of steel, \( p_t (\%) \)

\[ \frac{6 \times \pi/4 \times 25^2}{250 \times 560 \times 100} = 2.11 \]

Actual area of steel, \( A_{st} (\text{mm}^2) \)

\[ \frac{6 \times \pi/4 \times 25^2}{250 \times 560} = 2945 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by

\[ A_{sc} = \frac{0.87 f_y}{f_{sc} - 0.447 f_{ck}} \]

or

\[ p_c = \frac{0.87 f_y}{f_{sc} - 0.447 f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,\text{max}} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d' / d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td></td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td></td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
</tr>
<tr>
<td>Fe500</td>
<td></td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u,\text{max}} \), for \( d' / d = (40.5 / 559.5) = 0.072 \)
  From the above table: by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \geq p_{c,\text{lim}} \)
where \( p_c \) is given by

\[
p_c = \frac{0.87 f_y}{0.447 f_{ck}}
\]

Actual \( p_t \) provided : \( p_t = 2.11 \)
Actual \( p_c \) provided : \( p_c = 0.35 \)

\[
\Rightarrow p_c^* = \frac{0.87 \times 415 \times (2.106 - 1.433)}{(354.73 - 0.447 \times 30)}
\]

\[
\Rightarrow p_c^* = 0.71
\]

Section is over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10 m, the limiting \( l/d \) ratios are specified by the Code (Cl. 23.2.1) as:

\[
\frac{l}{d} \leq \begin{cases} 
7 & \text{for cantilever spans} \\
20 & \text{for simply supported spans} \\
26 & \text{for continuous spans}
\end{cases}
\]

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor \( F \)

\[
F = \frac{10}{\text{span in metres}}
\]

The modification factors \( F_1 \) (which varies with \( p_t \) and \( f_{st} \)) and \( F_2 \) (which varies with \( p_c \)) are as given in Fig.4 and Fig.5 of the code.

Code permits an approximate calculation of \( f_{st} \) as follows:

\[
f_{st} = (0.58 \times 415 \times 2292 / 2945) = 187.32 \text{ N/mm}^2
\]

\[
F = 0.93 \\
F_1 = 0.77
\]
\[ F_2 = 0.90 \]
\[ \therefore \quad \frac{l}{d} \text{ max} = \left( 26 \times 0.93 \times 0.77 \times 0.9 \right) = 16.69 \]
\[ \frac{l}{d} \text{ provided} = 19.30 \]
\[ \Rightarrow \quad \text{Not O.K} \]

*Check for shear*

Shear force at critical distance, \( V_{ud} \) (kN) 152

The critical section for shear is at a distance of 560 mm from the face of the support.

*Check for adequacy of section*

Nominal shear stress, \( \tau_v \)
\[
(152 \times 1000) / (250 \times 560) = 1.09 \text{ N/mm}^2
\]

The maximum shear stress is given by:
\[
\tau_{c,\text{max}} = 0.62 f_{ck} \]
\[
\Rightarrow \quad \tau_{c,\text{max}} = (0.62 \times \text{Sqrt}(30)) = 3.40 \text{ N/mm}^2
\]
\[ \Rightarrow \quad \text{Adopted section is adequate} \]

*Design shear resistance at critical section*

At critical section, \( A_{st} \) is given by 2945 mm²
Percentage of steel, \( p_t \) (\%) 2.11

The design shear strength of the concrete, \( \tau_c \), is given by:
\[
\frac{0.86}{0.85} \text{ Sqrt}(30) \quad 1 \quad 0.85 \quad 6.89 p_t \quad 102
\]

where \( \tau_c \) whichever is greater

For (M30 and Fe415)
\[
\Rightarrow \quad \tau_c = 0.86 \quad \text{N/mm}^2
\]
\[
\Rightarrow \quad V_{uc} = (0.86 \times 250 \times 560 / 1000) = 120 \text{ kN}
\]

*Design of "vertical" stirrups*

The shear to be resisted by steel, \( V_{us} \) is given by:
\[
\Rightarrow \quad V_{us} = V_u - V_{uc}
\]
\[
\Rightarrow \quad V_{us} = (152 - 120) = 32 \text{ kN}
\]

Using 8 mm bars and
No of legs 2
Area of stirrups, \( A_{sv} \) (\( \text{mm}^2 \)) 101

\[ \Rightarrow \text{required spacing } s_v \leq \left( \frac{0.87 \times 415 \times 101 \times 560}{32 \times 1000} \right) \]

\[ \Rightarrow \text{Spacing, } s_v = 635 \text{ mm} \]

*Check whether \( \tau_v > 0.5 \tau_c \)*

Nominal shear stress, \( \tau_v \) (\( \text{N/mm}^2 \)) 1.09
Design shear stress, \( \tau_c \) (\( \text{N/mm}^2 \)) 0.86

\[ \tau_v > 0.5 \tau_c \quad \text{Yes} \]

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress \( \tau_v \) exceeds 0.5 \( \tau_c \):

\[ \frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} \quad \text{When } s_v = 0.5tc \]

\[ s_v = \frac{2.175 f_y A_{sv}}{b} \]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[ s_v \leq 0.75 d \]

\[ \leq 300 \text{ mm} \]

Code requirements for maximum spacing:

i) \( \leq \left( \frac{2.175 \times 415 \times 101}{250} \right) = 363 \text{ mm} \)
ii) \( \leq \left( \frac{0.75 \times 559.5}{300 \text{ mm}} \right) = 420 \text{ mm} \)
iii) \( \leq 300 \text{ mm} \)
iv) \( \leq \left( \frac{0.87 \times 415 \times 101 \times 560}{32 \times 1000} \right) = 635 \text{ mm} \)
**Beam PB1 Mid Span**

*Design Parameters*

- **Load Case 14**: \([1.5 \times (DL - EQX)]\)
- **Grade of Concrete**: M30
- **Grade of Steel**: Fe415
- **Characteristic compressive strength of concrete**, \(f_{ck}\) (N/mm\(^2\)): 30
- **Characteristic yield strength of steel**, \(f_y\) (N/mm\(^2\)): 415
- **Unit weight of concrete**, \(\gamma_c\) (kN/m\(^3\)): 24
- **Partial safety factor for concrete**: 1.5
- **Exposure condition**: Mild
- **Nominal Cover to exposure condition**: 20 mm

*Dimensions of the beam*

- **C/C Span of the beam**, \(l\), (m): 4.96
- **Breadth of the beam**, \(b\), (mm): 250
- **Overall depth of the beam**, \(D\), (mm): 600

*Details of reinforcements*

- **Diameter of tension reinforcement**, (mm): 25
- **Diameter of compression reinforcement**, (mm): 25
- **Diameter of stirrups**, (mm): 8

*Effective depth*

- **Effective depth**, \(d\), (mm): \((600 - 20 - 8 - 25/2) = 560\) mm

*Design Moment, Shear Force*

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

- **Torsional Moment**: 0 kN-m
- **Bending Moment**, \(M_u\) (kN-m): 289
- **Equivalent Bending Moment**, \(M_e\) (kN-m): 289
- **Shear force at critical distance**, \(V_{ud}\) (kN): 179
- **Equivalent Shear** (kN): 179

*Singly reinforced or doubly reinforced section?*

The *limiting moment of resistance*, \(M_{u,lim}\) is given by

\[
M_{u,lim} = 0.362f_{ck} \times \frac{b x_u_{max} \times 0.416 x_u_{max}}{d}
\]

Where
- **\(b\)** = Breadth of the Section
- **\(x_u_{max}\)** = Limiting depth of Neutral Axis
- **\(d\)** = Effective depth of the Section

The limiting percentage of steel, \(p_{s,lim}\) is given by
The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
\frac{Pt}{100} x \frac{A_{st}}{bd} x \frac{fck}{2fy} = 4.598 \frac{R}{fck} \\
Where \quad R = \frac{Mu}{bd^2}
\]

For (M30 and Fe415) \( M_{u,\text{lim}} \), \( f_{ck} = 250 \), \( f_{cy} = 559.5 \)

\[
x_{u,\text{max}} / d = 0.48
\]

\[
\Rightarrow M_{u,\text{lim}} = \left( 0.1389 \times 30 \times 250 \times 559.5^2 / 1000000 \right) = 326.11 \text{ kNm}
\]

\[
\Rightarrow p_{u,\text{lim}} = \left( 41.3 \times 30 / 415 \times 0.48 \right) = 1.433
\]

If \( M_u > M_{u,\text{lim}} \), the section has to be
   i) get increased by depth or width (preferably depth)
   ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
M_u = 289.00 \text{ kNm} \\
M_{u,\text{lim}} = 326.11 \text{ kNm}
\]

\[
\Rightarrow \text{Section can be designed as singly reinforced.}
\]

**Determining \( A_{st} \)**

- Considering a 'balanced section' (\( x_c = x_{u,\text{max}} \))

\[
A_{st} = A_{st,\text{lim}} + \Delta A_{st}
\]

where \( A_{st,\text{lim}} = \frac{p_{u,\text{lim}}}{100} \times b \times d \)

\[
\Rightarrow A_{st,\text{lim}} = \left( 1.433 / 100 \times 250 \times 559.5 \right) = 2004 \text{ mm}^2
\]

- Assuming 25 mm bars for compression steel,

\[
d' \approx \left( 20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2 \right) = 40.5 \text{ mm}
\]
\[ M_u = 0.87 f_y A_s (1 - (A_s f_y) / (b d f_{ck})) \]

\[ A_{st\text{ Req'd}} = 1725 \text{ mm}^2 \]

\[ \therefore \text{No of tension bars required} = \left( \frac{1725}{\pi / 4 \times 25^2} \right) = 4.00 \]

\[ \text{Actual percentage of steel, } p_t (\%) = \left( \frac{4 \times \pi / 4 \times 25^2}{250 \times 560} \right) \times 100 = 1.40 \]

\[ \text{Actual area of steel, } A_{st} (\text{mm}^2) = 1963 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by

\[ A_{sc} = \frac{0.87 f_y}{f_{sc}} \cdot \frac{1}{0.447 f_{ck}} \]

or

\[ p_c = \frac{0.87 f_y}{f_{sc}} \cdot \frac{p_t}{f_{ck}} \cdot \frac{p_t}{f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,\text{max}} \) for various \( d'/d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( \frac{d'}{d} )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td></td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td></td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
</tr>
<tr>
<td>Fe500</td>
<td></td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u,\text{max}} \), for \( d'/d = \left( \frac{40.5}{559.5} \right) = 0.072 \)

  From the above table: by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \geq p_{c^*} \)
where $p_c^*$ is given by

$$p_c^* = \frac{0.87 f_y}{0.447 f_{ck}}$$

Actual $p_t$ provided: $p_t = 1.40$
Actual $p_c$ provided: $p_c = 0.35$

$$\Rightarrow p_c^* = \frac{(0.87 \times 415 \times (1.404 - 1.433))}{(354.73 - 0.447 \times 30)}$$
$$\Rightarrow p_c^* = -0.03$$

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

$$\frac{l}{d} \text{max}$$

where

$$\frac{l}{d} \text{basic} = \begin{cases} 7 & \text{for cantilever spans} \\ 20 & \text{for simply supported spans} \\ 26 & \text{for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor $F$.

$$F = \frac{10}{\text{span in metres}}$$

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig.4 and Fig.5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

$$f_{st} = \frac{0.58 f_y}{A_{\text{cross-section of steel required}}} = \frac{0.58 	imes 415 	imes 1806}{1963} = 221.45 \text{ N/mm}^2$$

$F = 1.00$
$F_1 = 0.87$
\[ F_2 = 0.90 \]

\[ \therefore \frac{l}{d} \max = \frac{26 \times 1 \times 0.87 \times 0.9}{8.87} = 20.28 \]

\[ \frac{l}{d} \text{ provided} = 8.87 \]

\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_u \) (kN)

The critical section for shear is at a distance of 560 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[ (179 \times 1000)/(250 \times 560) = 1.28 \text{ N/mm}^2 \]

The maximum shear stress is given by:

\[ T_{c \max} = 0.62 f_{ck} \]

\[ \Rightarrow \tau_{c,\max} = (0.62 \times \text{sqrt}(30)) = 3.40 \text{ N/mm}^2 \]

\[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

At critical section, \( A_{st} \) is given by

\[ 1963 \text{ mm}^2 \]

Percentage of steel, \( p_t \) (%)

1.40

The design shear strength of the concrete, \( \tau_c \), is given by:

\[
\frac{0.86}{0.85} \frac{0.8 f_{ck}}{0.89 P_t} \frac{1}{1}
\]

where \( 0.8 f_{ck} \) is the cube strength of the concrete.

\[ F_{ck} \]

wherever is greater

\[ 1 \]

For (M30 and Fe415)

\[ \Rightarrow \tau_c = 0.74 \text{ N/mm}^2 \]

\[ \Rightarrow V_{uc} = (0.74 \times 250 \times 560/1000) = 104 \text{ kN} \]

- **Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by:

\[ V_{us} = V_u \times V_{uc} \]

\[ \Rightarrow V_{us} = (179 - 104) = 75 \text{ kN} \]

Using 8 mm bars and

No of legs 2
Area of stirrups, $A_{sv}$ (mm$^2$) = 101

$\Rightarrow$ required spacing $s_{v} \leq \left(0.87 \times 415 \times 101 \times 560 / (74.88 \times 1000)\right)$

$\Rightarrow$ Spacing, $s_{v} = 271$ mm

**Check whether $\tau_{v} > 0.5 \tau_{c}$**

Nominal shear stress, $\tau_{v}$ (N/mm$^2$) = 1.28
Design shear stress, $\tau_{c}$ (N/mm$^2$) = 0.74

$\tau_{v} > 0.5 \tau_{c}$ \hspace{1cm} Yes

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress $\tau_{v}$ exceeds 0.5 $\tau_{c}$:

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 \frac{f_{y}}{f_{y}}} \text{ When } s_{v} = 0.5t_{c}$$

$$s_{v} = \frac{2.175 f_{y}A_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

$$s_{v} \leq \left\{ \begin{array}{lcl} 0.75 & 0.75 \text{ d} & \\ 300 \text{ mm} & 300 \text{ mm} & \\ & 300 \text{ mm} & \\ & 271 \text{ mm} & \end{array} \right. $$

**Code requirements for maximum spacing**

i) $< (2.175 \times 415 \times 101 / 250) = 363$ mm
ii) $\leq (0.75 \times 559.5) = 420$ mm
iii) $\leq 300$ mm
iv) $\leq (0.87 \times 415 \times 101 \times 560 / (74.88 \times 1000)) = 271$ mm
**Beam B1 Support**

**Design Parameters**

Load Case 13 \[1.5*(DL + EQX)\]

Grade of Concrete \[M30\]
Grade of Steel \[Fe415\]
Characteristic compressive strength of concrete, \( f_{ck} \) (N/mm\(^2\)) 30
Characteristic yield strength of steel, \( f_y \) (N/mm\(^2\)) 415
Unit weight of concrete, \( \gamma_c \) (kN/m\(^3\)) 24
Partial safety factor for concrete 1.5
Exposure condition Mild
Nominal Cover to exposure condition (mm) 20

**Dimensions of the beam**

C/C Span of the beam, \( l \) (m) 4.96
Breadth of the beam, \( b \) (mm) 400
Overall depth of the beam, \( D \) (mm) 900

**Details of reinforcements**

Diameter of tension reinforcement (mm) 25
Diameter of compression reinforcement (mm) 25
Diameter of stirrups (mm) 8

**Effective depth**

Effective depth, \( d \) (mm) \((900-20-8-25/2) = 860\)

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

Torsional Moment 150 kN-m
Bending Moment \( M_u \) (kN-m) 1053
Equivalent Bending Moment, \( M_e \) (kNm) 1340
Shear force at critical distance, \( V_{ud} \) (kN) 233
Equivalent Shear (kN) 833

**Singly reinforced or doubly reinforced section?**

The limiting moment of resistance, \( M_{u,lim} \) is given by

\[
M_{u,lim} = 0.362f_{ck} \times \frac{bx_u}{d} \times 0.416x_u
\]

Where

- \( b \) = Breadth of the Section
- \( x_u \) = Limiting depth of Neutral Axis
- \( d \) = Effective depth of the Section

The limiting percentage of steel, \( p_{t,lim} \) is given by
The area of steel for a singly reinforced section with width, b and depth, d and ultimate moment, \( M_u \) is given by:

For (M30 and Fe415) \( x_{u,\text{max}} / d = 0.48 \)

\[
\Rightarrow M_{u,\text{lim}} = \frac{0.1389 \times 30 \times 400 \times 859.5^2}{1000000} = 1,231.33 \text{ kNm}
\]

\[
\Rightarrow p_{t,\text{lim}} = \frac{41.3 \times 30}{415 \times 0.48} = 1.433
\]

If \( M_u > M_{u,\text{lim}} \), the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
M_u = 1,339.76 \text{ kNm}
\]

\[
M_{u,\text{lim}} = 1,231.33 \text{ kNm}
\]

\[
\Rightarrow \text{Section cannot be designed as singly reinforced. Doubly Reinforced Section Needed}
\]

**Determining \( A_{st} \)**

- Considering a 'balanced section' \( x_t = x_{u,\text{max}} \)
  \[ A_{st} = A_{st,\text{lim}} + \Delta A_{st} \]
  where \( A_{st,\text{lim}} = p_{t,\text{lim}} / 100 \times (b \times d) \)

\[
\Rightarrow A_{st,\text{lim}} = \frac{1.433}{100 \times 400 \times 859.5} = 4927 \text{ mm}^2
\]

- Assuming 25 mm bars for compression steel,

\[
d' \approx \frac{20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2}{2} = 40.5 \text{ mm}
\]
Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

\[ A_{st\text{ Req'd}} = 5562 \text{ mm}^2 \]

\[ \therefore \text{ No of tension bars required ( # )} \]
\[ \frac{5562}{\left( \frac{\pi}{4} \times 25^2 \right)} = 12.00 \]

Actual percentage of steel, p_t ( % )
\[ \left( 12 \times \frac{\pi}{4} \times 25 \times 2 / 400 / 860 \times 100 \right) = 1.71 \]

Actual area of steel, A_st ( mm² )
\[ \left( 12 \times \frac{\pi}{4} \times 25 \times 2 \right) = 5890 \]

**Determining A_{sc}**

The compression steel, A_{sc}, is given by
\[ A_{sc} = \frac{0.87 f_y}{f_{sc} - 0.447 f_{ck}} \]

or
\[ p_c = \frac{0.87 f_y}{f_{sc} - 0.447 f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,\text{max}} \) for various \( d'/d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d'/d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td></td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td></td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
</tr>
<tr>
<td>Fe500</td>
<td></td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u,\text{max}} \), for \( d'/d = \) \( \left( 40.5 / 859.5 \right) = 0.047 \)

From the above table: by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \geq p_c^* \)
where $p_c^*$ is given by

$$p_c^* = \frac{0.87 f_y}{0.447 f_{ck}}$$

Actual $p_t$ provided : $p_t = 1.71$
Actual $p_c$ provided : $p_c = 0.14$

$$\Rightarrow \quad p_c^* = \frac{(0.87 \times 415 \times (1.713 - 1.433))}{(354.98 - 0.447 \times 30)}$$
$$\Rightarrow \quad p_c^* = 0.30$$

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

- For simply supported spans: $F = 10$
- For cantilever spans: $F = 7$
- For continuous spans: $F = 26$

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig.4 and Fig.5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

$$f_{st} = \frac{0.58 f_y}{Area of cross-section of steel required} \times \frac{Area of cross-section of steel provided}{5294 / 5890} = 216.31 \text{ N/mm}^2$$

$F = 1.00$
$F_1 = 0.79$
\[ F_2 = 0.55 \]

\[
\therefore \quad \frac{(l/d)}{max} = \frac{(26 \times 1 \times 0.79 \times 0.55)}{5.77} = 11.30
\]

\[
\Rightarrow \quad \text{Hence O.K.}
\]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN)

The critical section for shear is at a distance of 860 mm from the face of the support.

- **Check for adequacy of section**

  Nominal shear stress, \( \tau_v \)
  \[
  ( \frac{833 \times 1000}{400 \times 860} ) = 2.42 \text{ N/mm}^2
  \]

  The maximum shear stress is given by:
  \[
  T_{c} \text{ max} = 0.62 f_{ck}
  \]
  \[
  \Rightarrow \quad \tau_{c,\text{max}} = (0.62 \times \sqrt{30}) = 3.40 \text{ N/mm}^2
  \]
  \[
  \Rightarrow \quad \text{Adopted section is adequate}
  \]

- **Design shear resistance at critical section**

  At critical section, \( A_{st} \) is given by 5890 mm\(^2\)

  Percentage of steel, \( p_t \) (%)

  The design shear strength of the concrete, \( \tau_c \), is given by:

  \[
  \frac{0.8 f_{ck}}{6.89 p_t} \quad \text{whichever is greater}
  \]

  For (M30 and Fe415)
  \[
  \Rightarrow \quad \tau_c = 0.80 \text{ N/mm}^2
  \]
  \[
  \Rightarrow \quad V_{uc} = (0.8 \times 400 \times 860 / 1000) = 275 \text{ kN}
  \]

- **Design of "vertical" stirrups**

  The shear to be resisted by steel, \( V_{us} \) is given by:
  \[
  V_{us} = V_u - V_{uc}
  \]
  \[
  \Rightarrow \quad V_{us} = (833 - 275) = 558 \text{ kN}
  \]

  Using 12 mm bars and
  No of legs 4
Area of stirrups, $A_{sv}$ (mm$^2$)  

$\Rightarrow$ required spacing $s_v \leq \frac{0.87 \times 415 \times 452 \times 860}{(558.2 \times 1000)}$

$\Rightarrow$ Spacing, $s_v = 251$ mm

Check whether $\tau_v > 0.5 \tau_c$

Nominal shear stress, $\tau_v$ (N/mm$^2$) 2.42  
Design shear stress, $\tau_c$ (N/mm$^2$) 0.80

$\tau_v > 0.5 \tau_c$  Yes

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress $\tau_v$ exceeds $0.5 \tau_c$:

$$\frac{A_{sv}}{bsv} = \frac{0.4}{0.87 f_y} \text{ When } s_v = 0.5tc$$

$$s_v = \frac{2.175 f_y A_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

$$s_v \leq \frac{0.75 d}{300 \text{ mm}}$$

Code requirements for maximum spacing:

i) $< \frac{2.175 \times 415 \times 452}{400} = 1021$ mm

ii) $\leq \frac{0.75 \times 859.5}{300} = 645$ mm

iii) $\leq 300$ mm 300 mm

iv) $\leq \frac{0.87 \times 415 \times 452 \times 860}{(558.2 \times 1000)} = 251$ mm
Beam B1 Mid

Design Parameters

Load Case 13  \([1.5*(DL + EQX)]\)
Grade of Concrete \(\text{M30}\)
Grade of Steel \(\text{Fe415}\)
Characteristic compressive strength of concrete , \(f_{ck}\) (N/mm\(^2\)) \(30\)
Characteristic yield strength of steel , \(f_y\) (N/mm\(^2\)) \(415\)
Unit weight of concrete , \(\gamma_c\) (kN/m\(^3\)) \(24\)
Partial safety factor for concrete \(1.5\)
Exposure condition \(\text{Mild}\)
Nominal Cover to exposure condition( mm ) \(20\)

Dimensions of the beam

| C/C Span of the beam , \(l\) , ( m ) | 4.96 |
| Breadth of the beam , \(b\) ( mm ) | 400 |
| Overall depth of the beam , \(D\) ( mm ) | 900 |

Details of reinforcements

| Diameter of tension reinforcement ( mm ) | 25 |
| Diameter of compression reinforcement ( mm ) | 25 |
| Diameter of stirrups ( mm ) | 8 |

Effective depth

Effective depth , \(d\) ( mm ) \(( 900-20-8-25/2 ) = 860\)

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

| Torsional Moment | 156 \(\text{kN-m}\) |
| Bending Moment Mu(kN-m) | 331 |
| Equivalent Bending Moment , \(M_e\) ( kNm ) | 629 |
| Shear force at critical distance , \(V_{ud}\) ( kN ) | 218 |
| Equivalent Shear (kN) | 842 |

Singly reinforced or doubly reinforced section ?

The limiting moment of resistance , \(M_{u,lim}\) is given by

\[
M_{u,lim} = 0.362f_{ck} \times \frac{b x_u}{d} \times 0.416 x_{\text{max}}
\]

Where \(b = \text{Breadth of the Section}\)
\(x_u\) \(= \text{Limiting depth of Neutral Axis}\)
\(d = \text{Effective depth of the Section}\)

The limiting percentage of steel , \(\rho_{u,lim}\) is given by
The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

For (M30 and Fe415)

\[
M_{u,lim} = \frac{(0.1389 \times 30 \times 400 \times 859.5^2)}{1000000} = 1231.33 \text{ kNm}
\]

\[
p_{t,lim} = \frac{41.3 \times 30}{415 \times 0.48} = 1.433
\]

If \( M_u > M_{u,lim} \), the section has to be
i) get increased by depth or width (preferably depth)
ii) doubly reinforced

If \( M_u < M_{u,lim} \), the section can be designed as singly reinforced.

Check for the type of section

\[
M_u = 629.24 \text{ kNm}
\]

\[
M_{u,lim} = 1231.33 \text{ kNm}
\]

\[\Rightarrow \text{Section can be designed as singly reinforced.}\]

Determining \( A_{st} \)

- Considering a 'balanced section' (\( x_u = x_{u,max} \))

\[
A_{st} = A_{st,lim} + \Delta A_{st}
\]

where \( A_{st,lim} = p_{t,lim} / 100 \times b \times d \)

\[\Rightarrow A_{st,lim} = \frac{1.433}{100 \times 400 \times 859.5} = 4927 \text{ mm}^2\]

- Assuming 25 mm bars for compression steel,

\[
d' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2) = 40.5 \text{ mm}\]
\[ Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck) \]

\[ Ast \text{ Reqd} = 2227 \text{ mm}^2 \]

\[ \therefore \text{ No of tension bars required } = \frac{2227}{(\pi/4 \times 25^2)} = 5.00 \]

Actual percentage of steel, \( p_t \) (%)
\[ \frac{(5 \times \pi/4 \times 25^2 \times 254}{400 \times 860 \times 100} = 0.71 \]

Actual area of steel, \( A_{st} \) (mm²)
\[ (5 \times \pi/4 \times 25^2) = 2454 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by
\[ A_{sc} = \frac{0.87 f_y}{f_{sc} - 0.447 f_{ck}} \]

or
\[ p_c = \frac{0.87 f_y}{f_{sc} - 0.447 f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,max} \) for various \( d'/d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d'/d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td></td>
</tr>
<tr>
<td>Fe415</td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
<td></td>
</tr>
<tr>
<td>Fe500</td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
<td></td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u,max} \), for \( d'/d = \frac{40.5}{859.5} = 0.047 \)
  
  From the above table: by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,max} \), it suffices to establish \( p_c \geq p_c^* \).
where $P_c^*$ is given by

$$p_c^* = \frac{0.87 f_y}{0.447 f_{ck}}$$

Actual $p_t$ provided : $p_t = 0.71$

Actual $p_c$ provided : $p_c = 0.71$

$$\Rightarrow p_c^* = \left( 0.87 \times 415 \times (0.714 - 1.433) / (354.98 - 0.447 \times 30) \right)$$

$$\Rightarrow p_c^* = -0.76$$

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

$$F_1 = 1.00$$

$$F_2 = 1.08$$

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$F = 1.00$

$F_1 = 1.08$

$$f_{st} = (0.58 \times 415 \times 2891 / 2454) = 283.49 \text{ N/mm}^2$$
\[ F_2 = 1.16 \]

\[ \therefore \frac{l}{d}_{\text{max}} = \frac{26 \times 1 \times 1.08 \times 1.16}{5.77} = 32.39 \]

\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN)

842

The critical section for shear is at a distance of 860 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[
\frac{(842 \times 1000)}{(400 \times 860)} = 2.45 \text{ N/mm}^2
\]

The maximum shear stress is given by:

\[ T_{c, \text{max}} = 0.62 f_{ck} \]

\[ \Rightarrow \tau_{c, \text{max}} = (0.62 \times \text{Sqrt}(30)) = 3.40 \text{ N/mm}^2 \]

\[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

At critical section, \( A_{st} \) is given by

2454 mm²

Percentage of steel, \( p_t \) (%)

0.71

The design shear strength of the concrete, \( \tau_c \), is given by:

\[
\frac{0.8f_{ck}}{0.85} \cdot \frac{1}{\tau_{c, \text{max}}} \cdot \frac{6}{6.89 p_t} \cdot \frac{1}{\text{whichever is greater}}
\]

For (M30 and Fe415)

\[ \Rightarrow \tau_c = 0.57 \text{ N/mm}^2 \]

\[ \Rightarrow V_{uc} = \frac{(0.57 \times 400 \times 860)}{1000} = 198 \text{ kN} \]

- **Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by:

\[ V_{us} = V_u - V_{uc} \]

\[ \Rightarrow V_{us} = (842 - 198) = 644 \text{ kN} \]

Using 12 mm bars and

No of legs 4
Area of stirrups, \( A_{sv} \) (mm\(^2\)) = 452

\[\Rightarrow \text{required spacing } s_v \leq \left( \frac{0.87 \times 415 \times 452 \times 860}{644.46 \times 1000} \right)\]

\[\Rightarrow \text{Spacing, } s_v = 218 \text{ mm}\]

**Check whether** \( \tau_v > 0.5 \tau_c \)

Nominal shear stress, \( \tau_v \) (N/mm\(^2\)) = 2.45

Design shear stress, \( \tau_c \) (N/mm\(^2\)) = 0.57

\[\tau_v > 0.5 \tau_c \quad \text{Yes}\]

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress \( \tau_v \) exceeds 0.5 \( \tau_c \):

\[\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} \quad \text{When } s_v = 0.5t_c\]

\[s_v = \frac{2.175 f_y A_{sv}}{b}\]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[s_v \leq \frac{0.75 \Phi}{300 \text{ mm}}\]

**Code requirements for maximum spacing**:

\[i) \quad < \left( \frac{2.175 \times 415 \times 452}{400} \right) = 1021 \text{ mm}\]

\[ii) \quad \leq \left( \frac{0.75 \times 859.5}{300} \right) = 645 \text{ mm}\]

\[iii) \quad \leq 300 \text{ mm}\]

\[iv) \quad \leq \left( \frac{0.87 \times 415 \times 452 \times 860}{644.46 \times 1000} \right) = 218 \text{ mm}\]
**Beam B2 Support**

**Design Parameters**

Load Case 14 \[1.5*(DL - EQX)\]
Grade of Concrete M30
Grade of Steel Fe415
Characteristic compressive strength of concrete, \(f_{ck}\) (N/mm\(^2\)) 30
Characteristic yield strength of steel, \(f_y\) (N/mm\(^2\)) 415
Unit weight of concrete, \(\gamma_c\) (kN/m\(^3\)) 24
Partial safety factor for concrete 1.5
Exposure condition Mild
Nominal Cover to exposure condition (mm) 20

**Dimensions of the beam**

- C/C Span of the beam, \(l\) (m) 10.80
- Breadth of the beam, \(b\) (mm) 800
- Overall depth of the beam, \(D\) (mm) 900

**Details of reinforcements**

- Diameter of tension reinforcement (mm) 25
- Diameter of compression reinforcement (mm) 25
- Diameter of stirrups (mm) 8

**Effective depth**

- Effective depth, \(d\) (mm) \(= (900-20-8-25/2) = 860\)

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

- Torsional Moment 125 kN-m
- Bending Moment \(M_u\) (kN-m) 2065
- Equivalent Bending Moment, \(M_e\) (kNm) 2221
- Shear force at critical distance, \(V_{ud}\) (kN) 908
- Equivalent Shear (kN) 1158

**Singly reinforced or doubly reinforced section?**

The limiting moment of resistance, \(M_{u,lim}\) is given by

\[
M_{ulim} = 0.362fck * \frac{b x_u_{max}}{d} * 0.416x_{u_{max}}
\]

Where \(b = \) Breadth of the Section
\(x_{u_{max}} = \) Limiting depth of Neutral Axis
\(d = \) Effective depth of the Section

The limiting percentage of steel, \(p_{u,lim}\) is given by
The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
P_t \times x_Ast \times x_{fck} \times 2 \frac{f_y}{f_{ck}} = \frac{4.598 \times R}{L_{ck}}
\]

Where \( R = \frac{M_u}{bd^2} \)

For (M30 and Fe415)

\[
M_{u,\text{lim}} = 0.1389 \frac{f_{ck}}{f_{ck}^2} b d^2
\]

\[
x_{u,\text{max}} / d = 0.48
\]

\[
\Rightarrow M_{u,\text{lim}} = \left( 0.1389 \times 30 \times 800 \times 859.5^2 / 1000000 \right) = 2,462.66 \text{ kNm}
\]

\[
\Rightarrow p_{t,\text{lim}} = \left( 41.3 \times 30 / 415 \times 0.48 \right) = 1.433
\]

If \( M_u > M_{u,\text{lim}} \), the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
M_i = 2,221.25 \text{ kNm}
\]

\[
M_{u,\text{lim}} = 2,462.66 \text{ kNm}
\]

\[
\Rightarrow \text{Section can be designed as singly reinforced.}
\]

**Determining \( A_s \)**

- Considering a 'balanced section' (\( x_u = x_{u,\text{max}} \))

\[
A_{st} = A_{st,\text{lim}} + \Delta A_{st}
\]

where \( A_{st,\text{lim}} = p_{t,\text{lim}} / 100 \times (b \times d) \)

\[
\Rightarrow A_{st,\text{lim}} = (1.433 / 100 \times 800 \times 859.5) = 9854 \text{ mm}^2
\]

- Assuming 25 mm bars for compression steel,

\[
d' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2) = 40.5 \text{ mm}
\]
\[ Mu = 0.87 f_y^* Ast \cdot d(1-(Ast \cdot f_y)/b \cdot d \cdot f_{ck}) \]

\[ Ast \text{ Req'd} = 8670 \text{ mm}^2 \]

\[ \therefore \text{No of tension bars required ( # )} \]

\[ (8670 / (\pi / 4 \times 25^2) = 18.00 \]

Actual percentage of steel , \( p_t \) ( % )
\[ (18 \times \pi / 4 \times 25^2 / 800 / 860 \times 100) = 1.29 \]

Actual area of steel , \( A_{st} \) ( mm² )
\[ (18 \times \pi / 4 \times 25^2) = 8836 \]

**Determining \( A_{sc} \)**

The compression steel , \( A_{sc} \), is given by

\[ A_{sc} = \frac{0.87 f_y}{f_{sc}} \left| \frac{1 - A_{st}}{0.447 f_{ck}} \right| \]

or

\[ p_c = \frac{0.87 f_y}{f_{sc}} \left| \frac{1 - p_{t,lim}}{0.447 f_{ck}} \right| \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,max} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

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<thead>
<tr>
<th>Grade of steel</th>
<th>( \frac{d'}{d} )</th>
<th>0.05</th>
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<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
<td></td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u,max} \), for \( d' / d = (40.5 / 859.5) = 0.047 \)

From the above table : by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,max} \), it suffices to establish \( p_c \geq p_{c}^* \)
where $p_c^*$ is given by

$$p_c^* = \frac{0.87 f_y}{0.447 f_{ck}}$$

Actual $p_t$ provided : $p_t = 1.29$
Actual $p_c$ provided : $p_c = 0.14$

$$\Rightarrow \quad p_c^* = \frac{(0.87 \times 415 \times (1.285 - 1.433))}{(354.98 - 0.447 \times 30)}$$
$$\Rightarrow \quad p_c^* = -0.16$$

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor $F$

$$F = \frac{10}{\text{span in metres}}$$

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig. 4 and Fig. 5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

$$f_{st} = \frac{0.58 f_y \times \text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

$$\Rightarrow \quad f_{st} = \frac{(0.58 \times 415 \times 9037 / 8836)}{246.19} = 246.19 \text{ N/mm}^2$$

$F = 0.93$

$F_1 = 0.85$
\[ F_2 = 0.55 \]

\[
\therefore \quad \frac{l}{d} \max = \left( 26 \times 0.93 \times 0.85 \times 0.55 \right) = 11.21
\]

\[
\left( \frac{l}{d} \right)_\text{provided} = 12.57
\]

\[ \Rightarrow \text{Not O.K} \]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN)

The critical section for shear is at a distance of 860 mm from the face of the support.

- **Check for adequacy of section**

  Nominal shear stress, \( \tau_v \)

  \[
  \left( \frac{1158 \times 1000}{800 \times 860} \right) = 1.68 \text{ N/mm}^2
  \]

  The maximum shear stress is given by:

  \[ T_{\text{c,max}} = 0.62 f_{ck} \]

  \[ \Rightarrow \tau_{c,max} = (0.62 \times \text{Sqrt}(30)) = 3.40 \text{ N/mm}^2 \]

  \[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

  At critical section, \( A_{st} \) is given by 8836 mm²

  Percentage of steel, \( p_t \) (\%)

  1.29

  The design shear strength of the concrete, \( \tau_c \), is given by:

  \[ \frac{0.85}{0.85 - \tau_c} \times 1 \]

  \[ \begin{array}{c}
  \begin{array}{c}
  \frac{0.85}{0.85 - \tau_c} \times 1 \\
  \frac{0.85}{0.85 - \tau_c} \times 1
  \end{array}
  \end{array} \]

  where \( \frac{0.85}{0.85 - \tau_c} \times 1 \) whichever is greater

  \[ \Rightarrow \tau_c = 0.72 \text{ N/mm}^2 \]

  \[ \Rightarrow V_{uc} = \left( 0.72 \times 800 \times 860 / 1000 \right) = 496 \text{ kN} \]

- **Design of "vertical" stirrups**

  The shear to be resisted by steel, \( V_{us} \) is given by:

  \[ V_{us} = V_u - V_{uc} \]

  \[ \Rightarrow V_{us} = (1158 - 496) = 662 \text{ kN} \]

  Using 12 mm bars and

  No of legs 4
Area of stirrups, $A_{sv}$ (mm$^2$) 452

⇒ required spacing $s_v \leq \left( \frac{0.87 \times 415 \times 452 \times 860}{662.45 \times 1000} \right)$

⇒ Spacing, $s_v = 212$ mm

**Check whether $\tau_v > 0.5 \tau_c$**

Nominal shear stress, $\tau_v$ (N/mm$^2$) 1.68
Design shear stress, $\tau_c$ (N/mm$^2$) 0.72

$\tau_v > 0.5 \tau_c \quad \text{Yes}$

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress $\tau_v$ exceeds $0.5 \tau_c$:

$$
\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 \ f_y} \quad \text{When} \ s_v = 0.5 t_c
$$

$$
s_v = \frac{2.175 \ f_y A_{sv}}{b}
$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

$$
s_v \leq \left( \frac{0.75 \ d}{300 \ \text{mm}} \right)
$$

Code requirements for maximum spacing:

i) $< \left( \frac{2.175 \times 415 \times 452}{800} \right) = 510$ mm

ii) $\leq \left( \frac{0.75 \times 859.5}{300} \right) = 645$ mm

iii) $\leq 300$ mm

iv) $\leq \left( \frac{0.87 \times 415 \times 452 \times 860}{662.45 \times 1000} \right) = 212$ mm
**Beam B2 Mid**

**Design Parameters**

Load Case 14 \[1.5*(DL - EQX)\]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade of Concrete</td>
<td>M30</td>
</tr>
<tr>
<td>Grade of Steel</td>
<td>Fe415</td>
</tr>
<tr>
<td>Characteristic compressive strength of concrete, ( f_{ck} ) (N/mm(^2))</td>
<td>30</td>
</tr>
<tr>
<td>Characteristic yield strength of steel, ( f_y ) (N/mm(^2))</td>
<td>415</td>
</tr>
<tr>
<td>Unit weight of concrete, ( \gamma_c ) (kN/m(^3))</td>
<td>24</td>
</tr>
<tr>
<td>Partial safety factor for concrete</td>
<td>1.5</td>
</tr>
<tr>
<td>Exposure condition</td>
<td>Mild</td>
</tr>
<tr>
<td>Nominal Cover to exposure condition (mm)</td>
<td>20</td>
</tr>
</tbody>
</table>

**Dimensions of the beam**

- C/C Span of the beam, \( l \) (m): 10.80
- Breadth of the beam, \( b \) (mm): 800
- Overall depth of the beam, \( D \) (mm): 900

**Details of reinforcements**

- Diameter of tension reinforcement (mm): 25
- Diameter of compression reinforcement (mm): 25
- Diameter of stirrups (mm): 8

**Effective depth**

Effective depth, \( d \) (mm): \( (900-20-8-25/2) = 860 \) mm

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

- Torsional Moment: 125 kN-m
- Bending Moment \( Mu(kN-m) \): 855
- Equivalent Bending Moment, \( M_e \) (kNm): 1011
- Shear force at critical distance, \( V_{ud} \) (kN): 884
- Equivalent Shear (kN): 1134

**Singly reinforced or doubly reinforced section?**

The limiting moment of resistance, \( M_{u,\text{lim}} \) is given by

\[
M_{u,\text{lim}} = 0.362f_{ck} \cdot \frac{bx_{\text{max}}}{d} \cdot 0.416x_{\text{max}}
\]

Where:\n- \( b \) = Breadth of the Section\n- \( x_{\text{max}} \) = Limiting depth of Neutral Axis\n- \( d \) = Effective depth of the Section

The limiting percentage of steel, \( p_{u,\text{lim}} \) is given by
\[ Pt_{\text{lim}} = 41.61 \times \frac{f_{ck} \times x_{u,\text{max}}}{f_y} \]

Where \( f_{ck} = \text{Characteristic Compressive strength of concrete} \)

\( f_y = \text{Characteristic strength of steel} \)

The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[ M_{u,\text{lim}} = \left( 0.1389 \times 30 \times 800 \times 859.5^2 / 100000 \right) = 2462.66 \text{ kNm} \]

\[ p_{t,\text{lim}} = \left( 41.3 \times 30 / 415 \times 0.48 \right) = 1.433 \]

If \( M_u > M_{u,\text{lim}} \), the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[ M_u = 1011.25 \text{ kNm} \]

\[ M_{u,\text{lim}} = 2462.66 \text{ kNm} \]

\[ \Rightarrow \text{Section can be designed as singly reinforced.} \]

**Determining \( A_{st} \)**

- Considering a 'balanced section' (\( x_u = x_{u,\text{max}} \))

\[ A_{st} = A_{st,\text{lim}} + \Delta A_{st} \]

where \( A_{st,\text{lim}} = p_{t,\text{lim}} / 100 \times (b \times d) \)

\[ \Rightarrow A_{st,\text{lim}} = \left( 1.433 / 100 \times 800 \times 859.5 \right) = 9854 \text{ mm}^2 \]

- Assuming 25 mm bars for compression steel,

\[ d^* \approx \left( 20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2 \right) = 40.5 \text{ mm} \]
\[ \mu = \frac{M_u}{0.87 f_y d (1 - (A_{st} f_y) / b d f_{ck})} \]

\[ A_{st \text{ Reqd}} = 3506 \text{ mm}^2 \]

\[ \therefore \text{No of tension bars required ( # )} \]

\[ \frac{3506}{(\pi / 4 \times 25^2)} = 8.00 \]

Actual percentage of steel, \( p_t \) (%)

\[ \frac{(8 \times \pi / 4 \times 25^2 / 800 / 860 \times 100)}{8.00} = 0.57 \]

Actual area of steel, \( A_{st} \) (mm\(^2\))

\[ (8 \times \pi / 4 \times 25^2) = 3927 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by

\[ A_{sc} = \frac{0.87 f_y}{f_{sc}} \left(1 + \frac{A_{st}}{A_{lim}}\right) \]

or

\[ p_c = \frac{0.87 f_y}{f_{sc}} \left(1 - \frac{p_t}{p_t \text{lim}}\right) \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,\text{max}} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d' / d )</th>
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</table>

- Assuming \( x_u = x_{u,\text{max}} \), for \( d' / d = (40.5 / 859.5) = 0.047 \)
  
  From the above table: by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \geq p_t^* \).
where $p_c^*$ is given by

$$
p_c^* = \frac{0.87 f_y}{0.447 f_{ck}} \left( \frac{b_1 - p_{t,\text{lim}}}{354.98 - 0.447 \times 30} \right)
$$

Actual $p_t$ provided : $p_t = 0.57$
Actual $p_c$ provided : $p_c = 0.79$

$$
\Rightarrow p_c^* = \left( \frac{0.87 \times 415 \times (0.571 - 1.433)}{354.98 - 0.447 \times 30} \right)
$$

$$
\Rightarrow p_c^* = -0.91
$$

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

$$
\frac{l}{d_{\text{basic}}} = \begin{cases} 
7 & \text{for cantilever spans} \\
20 & \text{for simply supported spans} \\
26 & \text{for continuous spans}
\end{cases}
$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor $F_{10}$.

$$
F = \frac{F_{10}}{\text{span in metres}}
$$

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig. 4 and Fig. 5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

$$
\frac{f_{st}}{f_{y}} = \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}
$$

$$
\Rightarrow f_{st} = \left( \frac{0.58 \times 415 \times 4945}{3927} \right) = 303.12 \text{ N/mm}^2
$$

$$
F = 0.93 \\
F_1 = 1.18
$$
\[ F_2 = 1.19 \]

\[ \therefore \quad \frac{l}{d}_{\text{max}} = \left( 26 \times 0.93 \times 1.18 \times 1.19 \right) = 33.53 \]

\[ \frac{l}{d}_{\text{provided}} = 12.57 \]

\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN)

\[ V_{ud} = 1134 \]

The critical section for shear is at a distance of 860 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[ \frac{1134 \times 1000}{(800 \times 860)} = 1.65 \text{ N/mm}^2 \]

The maximum shear stress is given by:

\[ T_c \max = 0.62 f'_{ck} \]

\[ \Rightarrow \quad \tau_{c,\max} = (0.62 \times \text{Sqrt}(30)) = 3.40 \text{ N/mm}^2 \]

\[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

At critical section, \( A_{st} \) is given by

\[ A_{st} = 3927 \text{ mm}^2 \]

Percentage of steel, \( p_t \) (%)

\[ p_t = 0.57 \]

The design shear strength of the concrete, \( \tau_c \), is given by:

\[ \tau_c = \frac{0.85}{6} \left[ \tau_{c,\max} \right] \]

where \( \frac{0.85}{6} \left[ \tau_{c,\max} \right] \) whichever is greater

For (M30 and Fe415)

\[ \Rightarrow \quad \tau_c = 0.52 \text{ N/mm}^2 \]

\[ \Rightarrow \quad V_{uc} = \left( 0.52 \times 800 \times 860 / 1000 \right) = 361 \text{ kN} \]

- **Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by

\[ V_{us} = V_u - V_{uc} \]

\[ \Rightarrow \quad V_{us} = (1134 - 361) = 773 \text{ kN} \]

Using 12 mm bars and

No of legs 4
Area of stirrups, \( A_{sv} \) (\( \text{mm}^2 \)) \( = 452 \)

\[ \Rightarrow \text{required spacing} \ s_v \leq \ (0.87 \times 415 \times 452 \times 860 \div (773.14 \times 1000)) \]

\[ \Rightarrow \text{Spacing,} \ s_v = 182 \ \text{mm} \]

**Check whether** \( \tau_v > 0.5 \tau_c \)

Nominal shear stress \( \tau_v \) (N/mm\(^2\)) \( = 1.65 \)

Design shear stress \( \tau_c \) (N/mm\(^2\)) \( = 0.52 \)

\[ \tau_v > 0.5 \tau_c \quad \text{Yes} \]

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress \( \tau_v \) exceeds 0.5 \( \tau_c \):

\[ \frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 \ f_y} \quad \text{When} \ s_v = 0.5tc \]

\[ s_v = \frac{2.175 \ f_y A_{sv}}{b} \]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[ s_v \leq \frac{0.75 \ \phi}{300 \ \text{mm}} \]

**Code requirements for maximum spacing**

i) \( < \ (2.175 \times 415 \times 452 \div 800) = 510 \ \text{mm} \)

ii) \( \leq \ (0.75 \times 859.5) = 645 \ \text{mm} \)

iii) \( \leq \ 300 \ \text{mm} \)

iv) \( \leq \ (0.87 \times 415 \times 452 \times 860 \div (773.14 \times 1000)) = 182 \ \text{mm} \)
**Beam B2A Support**

**Design Parameters**

Load Case 15 \[1.5 \times (DL + EQZ)\]  
Grade of Concrete \[\text{M30}\]  
Grade of Steel \[\text{Fe415}\]  
Characteristic compressive strength of concrete, \(f_{ck}\) (N/mm\(^2\)) 30  
Characteristic yield strength of steel, \(f_y\) (N/mm\(^2\)) 415  
Unit weight of concrete, \(\gamma_c\) (kN/m\(^3\)) 24  
Partial safety factor for concrete 1.5  
Exposure condition Mild  
Nominal Cover to exposure condition (mm) 20

**Dimensions of the beam**

\[ \begin{align*}
\text{C/C Span of the beam} & \quad (\text{m}) \quad 4.96 \\
\text{Breadth of the beam} & \quad (\text{mm}) \quad 550 \\
\text{Overall depth of the beam} & \quad (\text{mm}) \quad 900
\end{align*} \]

**Details of reinforcements**

\[ \begin{align*}
\text{Diameter of tension reinforcement} & \quad (\text{mm}) \quad 25 \\
\text{Diameter of compression reinforcement} & \quad (\text{mm}) \quad 25 \\
\text{Diameter of stirrups} & \quad (\text{mm}) \quad 8
\end{align*} \]

**Effective depth**

\[ \text{Effective depth, } d \quad (\text{mm}) \quad (900-20-8-25/2) = 860 \]

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

\[ \begin{align*}
\text{Torsional Moment} & \quad 163 \quad \text{kN-m} \\
\text{Bending Moment } M_u \text{(kN-m)} & \quad 1428 \\
\text{Equivalent Bending Moment, } M_e \text{ (kNm)} & \quad 1681 \\
\text{Shear force at critical distance, } V_{ud} \text{ (kN)} & \quad 199 \\
\text{Equivalent Shear (kN)} & \quad 673
\end{align*} \]

**Singly reinforced or doubly reinforced section?**

The limiting moment of resistance, \(M_{u,\text{lim}}\) is given by

\[ M_{\text{ulim}} = 0.362f_{ck} \times \frac{b x_u \text{max}}{d} \times 0.416x_u \text{max} \]

Where \(b\) = Breadth of the Section  
\(x_u \text{max}\) = Limiting depth of Neutral Axis  
\(d\) = Effective depth of the Section

The limiting percentage of steel, \(p_{u,\text{lim}}\) is given by
The area of steel for a singly reinforced section with width, \( w \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
\frac{Pt}{100} \times \frac{Ast}{bd} \times \frac{fck}{2fy} = 4.598 \frac{R}{fck}
\]

Where \( R = \frac{M_u}{bd^2} \)

For (M30 and Fe415) \( M_u,\text{lim} \) \( 0.1389 \ fck \ b \ d^2 \)

\[
x_{u,max} / d = 0.48
\]

\[
\Rightarrow M_u,\text{lim} = (0.1389 \times 30 \times 550 \times 859.5^2 / 1000000) = 1693.08 \text{ kNm}
\]

\[
\Rightarrow p_{t,\text{lim}} = (41.3 \times 30 / 415 \times 0.48) = 1.433
\]

If \( M_u > M_u,\text{lim} \), the section has to be
- get increased by depth or width (preferably depth)
- doubly reinforced

If \( M_u < M_u,\text{lim} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
M_u = 1680.78 \text{ kNm}
M_u,\text{lim} = 1693.08 \text{ kNm}
\]

\[
\Rightarrow \text{Section can be designed as singly reinforced.}
\]

**Determining \( A_{st} \)**

- Considering a 'balanced section' (\( x_d = x_{u,\text{max}} \))
  \[
  A_{st} = A_{st,\text{lim}} + \Delta A_{st}
  \]
  where \( A_{st,\text{lim}} = p_{t,\text{lim}} / 100 (b \times d) \)

\[
\Rightarrow A_{st,\text{lim}} = (1.433 / 100 \times 550 \times 859.5) = 6774 \text{ mm}^2
\]

- Assuming 25 mm bars for compression steel,

\[
d' \approx (20 \text{ mm clear cover + 8 mm stirrup + 25 / 2}) = 40.5 \text{ mm}
\]
\( \Delta A_{\text{st}} = \frac{M_u - M_{u,\text{lim}}}{0.87 f_y - d'} \)

\( \Delta p_t = \frac{R - R_{\text{lim}}}{0.87 f_y - d'} \)

\[
M_u = 0.87 f_y \cdot A_{\text{st}} \cdot d (1 - (A_{\text{st}} f_y)/b \cdot d' f_{ck})
\]

\( A_{\text{st}} \ \text{Reqd} = 6749 \ \text{mm}^2 \)

\[ \therefore \ \text{No of tension bars required ( # )} \]

\[ (6749 / (\pi / 4 \times 25^2)) = 14.00 \]

Actual percentage of steel, \( p_t \) (\%)

\[
(14 \times \pi / 4 \times 25^2 / 550 / 860 \times 100) = 1.45
\]

Actual area of steel, \( A_{\text{st}} \) (\text{mm}²)

\[ (14 \times \pi / 4 \times 25^2) = 6872 \]

**Determining \( A_{\text{sc}} \)**

The compression steel, \( A_{\text{sc}} \), is given by

\[ A_{\text{sc}} = \frac{0.87 f_y - d'}{f_{\text{sc}} - 0.447 f_{ck}} \]

or

\[ p_c = \frac{0.87 f_y - p_{\lim}}{f_{\text{sc}} - 0.447 f_{ck}} \]

where \( f_{\text{sc}} \) is the stress in compression steel.

The values of \( f_{\text{sc}} \) (in MPa units) at \( x_u = x_{u,\text{max}} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d' / d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td></td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td></td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
</tr>
<tr>
<td>Fe500</td>
<td></td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u,\text{max}} \), for \( d' / d = (40.5 / 859.5) = 0.047 \)

  From the above table : by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \geq p_{\text{c}} \).
where $p_c^*$ is given by

$$p_c^* = \frac{0.87 f_y}{0.447 f_{ck}}$$

Actual $p_t$ provided : $p_t = 1.45$
Actual $p_c$ provided : $p_c = 0.10$

$$\Rightarrow p_c^* = \frac{0.87 \times 415 \times (1.454 - 1.433)}{(354.98 - 0.447 \times 30)}$$

$$\Rightarrow p_c^* = 0.02$$

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig.4 and Fig.5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

$$f_{st} = \frac{0.58 f_y \cdot \text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

$$\Rightarrow f_{st} = \frac{0.58 \times 415 \times 6733}{6872} = 235.82 \text{ N/mm}^2$$

$F = 1.00$
$F_1 = 0.82$
\[ F_2 = 0.44 \]

\[
(l / d)_{\text{max}} = (26 \times 1 \times 0.82 \times 0.44) = 9.36
\]

\[
(l / d)_{\text{provided}} = 5.77
\]

\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN) 673.18182

The critical section for shear is at a distance of 860 mm from the face of the support.

- **Check for adequacy of section**

  Nominal shear stress, \( \tau_v \)
  \[
  (673.181818181818 \times 1000 / (550 \times 860)) = 1.42 \text{ N/mm}^2
  \]

  The maximum shear stress is given by:
  \[ T_c_{\text{max}} = 0.62 f_{ck} \]
  \[ \Rightarrow \tau_{c,\text{max}} (0.62 \times \text{Sqrt}(30)) = 3.40 \text{ N/mm}^2 \]
  \[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

  At critical section, \( A_{st} \) is given by 6872 mm\(^2\)
  Percentage of steel, \( p_t \) (\%) 1.45

  The design shear strength of the concrete, \( \tau_c \), is given by:
  \[
  \tau_c = \sqrt{\frac{0.89 \cdot f_{ck}}{0.85 \cdot p_t}}
  \]
  where \( 0.89 \cdot p_t \) whenever is greater 1

  For (M30 and Fe415)
  \[ \Rightarrow \tau_c = 0.75 \text{ N/mm}^2 \]
  \[ \Rightarrow V_{uc} = (0.75 \times 550 \times 860 / 1000) = 356 \text{ kN} \]

- **Design of "vertical" stirrups**

  The shear to be resisted by steel, \( V_{us} \) is given by:
  \[ V_{us} = V_u - V_{uc} \]
  \[ \Rightarrow V_{us} = (673 - 356) = 317 \text{ kN} \]

  Using 12 mm bars and
  No of legs 2

138
Area of stirrups, \( A_{sv} \ (\text{mm}^2) \) \[226\]

\[\Rightarrow \text{required spacing } s_v \leq \left( 0.87 \times 415 \times 226 \times 860 / (316.79 \times 1000) \right)\]

\[\Rightarrow \text{Spacing, } s_v = 222 \ \text{mm}\]

**Check whether \( \tau_v > 0.5 \tau_c \)**

Nominal shear stress, \( \tau_v \ (\text{N/mm}^2) \) \[1.42\]

Design shear stress, \( \tau_c \ (\text{N/mm}^2) \) \[0.75\]

\[\tau_v > 0.5 \tau_c \quad \text{Yes}\]

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress \( \tau_v \) exceeds 0.5 \( \tau_c \):

\[\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} \quad \text{When } s_v = 0.5 \tau_c\]

\[s_v = \frac{2.175 f_y A_{sv}}{b}\]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[s_v \leq \frac{0.75 \phi d}{300 \text{ mm}}\]

**Code requirements for maximum spacing.**

\[\begin{align*}
i) & \quad < & \left( 2.175 \times 415 \times 226 \ / 550 \right) = 371 \ \text{mm} \\
ii) & \quad \leq & \left( 0.75 \times 859.5 \right) = 645 \ \text{mm} \\
iii) & \quad \leq & 300 \ \text{mm} \quad 300 \ \text{mm} \\
iv) & \quad \leq & \left( 0.87 \times 415 \times 226 \times 860 / (316.79 \times 1000) \right) = 222 \ \text{mm}
\end{align*}\]
**Beam B2A Mid**

*Design Parameters*

Load Case 15 \([1.5*(DL + EQZ)]\)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade of Concrete</td>
<td>M30</td>
</tr>
<tr>
<td>Grade of Steel</td>
<td>Fe415</td>
</tr>
<tr>
<td>Characteristic compressive strength of concrete, (f_{ck}) (N/mm²)</td>
<td>30</td>
</tr>
<tr>
<td>Characteristic yield strength of steel, (f_y) (N/mm²)</td>
<td>415</td>
</tr>
<tr>
<td>Unit weight of concrete, (\gamma_c) (kN/m³)</td>
<td>24</td>
</tr>
<tr>
<td>Partial safety factor for concrete</td>
<td>1.5</td>
</tr>
<tr>
<td>Exposure condition</td>
<td>Mild</td>
</tr>
<tr>
<td>Nominal Cover to exposure condition (mm)</td>
<td>20</td>
</tr>
</tbody>
</table>

*Dimensions of the beam*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/C Span of the beam, (l) (m)</td>
<td>4.96</td>
</tr>
<tr>
<td>Breadth of the beam, (b) (mm)</td>
<td>550</td>
</tr>
<tr>
<td>Overall depth of the beam, (D) (mm)</td>
<td>900</td>
</tr>
</tbody>
</table>

*Details of reinforcements*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of tension reinforcement (mm)</td>
<td>25</td>
</tr>
<tr>
<td>Diameter of compression reinforcement (mm)</td>
<td>25</td>
</tr>
<tr>
<td>Diameter of stirrups (mm)</td>
<td>8</td>
</tr>
</tbody>
</table>

*Effective depth*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective depth, (d) (mm)</td>
<td>860</td>
</tr>
</tbody>
</table>

*Design Moment, Shear Force*

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsional Moment</td>
<td>163 kN-m</td>
</tr>
<tr>
<td>Bending Moment, (M_u)(kN-m)</td>
<td>746</td>
</tr>
<tr>
<td>Equivalent Bending Moment, (M_e) (kNm)</td>
<td>999</td>
</tr>
<tr>
<td>Shear force at critical distance, (V_{ud}) (kN)</td>
<td>184</td>
</tr>
<tr>
<td>Equivalent Shear (kN)</td>
<td>658</td>
</tr>
</tbody>
</table>

*Singly reinforced or doubly reinforced section ?*

The *limiting moment of resistance*, \(M_{u,\text{lim}}\) is given by

\[
M_{u,\text{lim}} = 0.362f_{ck} \times \frac{bx_{\text{max}}}{d} \times 0.416x_{\text{max}}
\]

Where \(b\) = Breadth of the Section
\(x_{\text{max}}\) = Limiting depth of Neutral Axis
\(d\) = Effective depth of the Section

The limiting percentage of steel, \(\rho_{u,\text{lim}}\) is given by
The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
Pt \times \frac{Ast}{bd} \times \frac{fck}{2fy} = 4.598 \times \frac{R}{f_y}
\]

Where \( R = \frac{Mu}{bd^2} \)

For (M30 and Fe415) \( M_{u,lim} = 0.1389 \times f_{ck} \times b \times d^2 \)

\[
x_{u, max} / d = 0.48
\]

\[
\Rightarrow M_{u,lim} = (0.1389 \times 30 \times 550 \times 859.5^2 / 10000000) = 1693.08 \text{ kNm}
\]

\[
\Rightarrow Pt_{lim} = (41.3 \times 30 / 415 \times 0.48) = 1.433
\]

If \( M_u > M_{u,lim} \), the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If \( M_u < M_{u,lim} \), the section can be designed as singly reinforced.

Check for the type of section:

\[
M_u = 998.78 \text{ kNm}
\]

\[
M_{u,lim} = 1693.08 \text{ kNm}
\]

\[
\Rightarrow \text{Section can be designed as singly reinforced.}
\]

Determining \( A_{st} \)

- Considering a 'balanced section' (\( x_d = x_{u, max} \))

\[
A_{st} = A_{st,lim} + \Delta A_{st}
\]

where \( A_{st,lim} = Pt_{lim} / 100 \times b \times d \)

\[
\Rightarrow A_{st,lim} = (1.433 / 100 \times 550 \times 859.5) = 6774 \text{ mm}^2
\]

- Assuming 25 mm bars for compression steel,

\[
d' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2) = 40.5 \text{ mm}
\]
\[ \mu = 0.87 \cdot f_y \cdot A_{st} \cdot d \cdot (1 - \frac{A_{st} \cdot f_y}{b \cdot f_{ck}}) \]

Ast Req'd = 3597 mm²

∴ No of tension bars required ( # )

\[
\frac{3597}{\left( \frac{\pi}{4} \times 25^2 \right)} = 8.00
\]

Actual percentage of steel, \( p_t \) ( % )

\[
\frac{8 \times \pi / 4 \times 25^2 / 550 / 860 \times 100}{8 \times \pi / 4 \times 25^2} = 0.83
\]

Actual area of steel, \( A_{st} \) ( mm² )

\[
\frac{8 \times \pi / 4 \times 25^2}{8 \times \pi / 4 \times 25^2} = 3927
\]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by

\[
A_{sc} = \frac{0.87 \cdot f_y \cdot 0.447 \cdot f_{ck}}{f_{sc}}
\]

or

\[
p_c = \frac{0.87 \cdot f_y \cdot p_t \cdot p_{c,lim}}{f_{sc} \cdot 0.447 \cdot f_{ck}}
\]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) ( in MPa units ) at \( x_u = x_{u,\text{max}} \) for various \( d'/d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d'/d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td></td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td></td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
</tr>
<tr>
<td>Fe500</td>
<td></td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
</tr>
</tbody>
</table>

• Assuming \( x_u = x_{u,\text{max}} \), for \( d'/d = \frac{40.5}{859.5} \) = 0.047

From the above table : by interpolation

**Design Check**

• To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \geq p^* \).
where $p_c^{*}$ is given by

$$p_c^{*} = \frac{0.87 f_y}{0.447 f_{ck}}$$

Actual $p_t$ provided: $p_t = 0.83$
Actual $p_c$ provided: $p_c = 0.62$

$$\Rightarrow p_c^{*} = \frac{0.87 \times 415 \times (0.831 - 1.433)}{(354.98 - 0.447 \times 30)}$$

$$\Rightarrow p_c^{*} = -0.64$$

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans up to 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

$$\frac{l}{d_{\text{basic}}} F_1 F_2$$

where

- $l/d_{\text{max}}$ for cantilever spans
- $l/d_{\text{basic}}$ for simply supported spans
- $l/d_{\text{basic}}$ for continuous spans

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor $F$

$$F = \frac{10}{\text{span in metres}}$$

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig.4 and Fig.5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

$$f_{st} = \frac{0.58 f_y}{\text{Area of cross-section of steel required}} \times \frac{\text{Area of cross-section of steel provided}}{3927}$$

$$\Rightarrow f_{st} = \frac{0.58 \times 415 \times 4426}{3927} = 271.31 \text{ N/mm}^2$$

$F = 1.00$
$F_1 = 1.02$
\[ F_2 = 1.11 \]

\[ (l/d)_{\text{max}} = (26 \times 1 \times 1.02 \times 1.11) = 29.37 \]
\[ (l/d)_{\text{provided}} = 5.77 \]

\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN)

\[ 658.18182 \]

The critical section for shear is at a distance of 860 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[ (658.1818181818 \times 1000 / (550 \times 860)) = 1.39 \text{ N/mm}^2 \]

The maximum shear stress is given by:

\[ T_{c \text{ max}} = 0.62 f'_{ck} \]

\[ \Rightarrow \tau_{c,\text{max}} = (0.62 \times \text{Sqrt}(30)) = 3.40 \text{ N/mm}^2 \]

\[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

At critical section, \( A_{ut} \) is given by

\[ 3927 \text{ mm}^2 \]

Percentage of steel, \( p_t \) (%)

\[ 0.83 \]

The design shear strength of the concrete, \( \tau_c \), is given by:

\[ \frac{0.85}{\tau_c} = 1 \]
\[ \frac{0.8f_{ck}}{0.89p_t} \text{ whichever is greater} \]

For (M30 and Fe415)

\[ \Rightarrow \tau_c = 0.61 \text{ N/mm}^2 \]

\[ \Rightarrow V_{uc} = (0.61 \times 550 \times 860 / 1000) = 288 \text{ kN} \]

- **Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by:

\[ V_{us} = V_u - V_{uc} \]

\[ \Rightarrow V_{us} = (658 - 288) = 370 \text{ kN} \]

Using 12 mm bars and

No of legs 2
Area of stirrups, $A_{sv}$ (mm$^2$) 226

$\Rightarrow$ required spacing $s_v \leq \left( \frac{0.87 \times 415 \times 226 \times 860}{369.72 \times 1000} \right)$

$\Rightarrow$ Spacing, $s_v = 190$ mm

Check whether $\tau_v > 0.5 \tau_c$

Nominal shear stress, $\tau_v$ (N/mm$^2$) 1.39
Design shear stress, $\tau_c$ (N/mm$^2$) 0.61

$\tau_v > 0.5 \tau_c \quad \text{Yes}$

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress $\tau_v$ exceeds $0.5 \tau_c$:

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} \quad \text{When } s_v = 0.5tc$$

$$s_v = \frac{2.175 f_y A_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

$s_v \leq \frac{0.75 \phi}{300}$ mm

Code requirements for maximum spacing:

i) $< \left( \frac{2.175 \times 415 \times 226}{550} \right) = 371$ mm
ii) $\leq \left( \frac{0.75 \times 859.5}{300} \right) = 645$ mm
iii) $\leq 300$ mm
iv) $\leq \left( \frac{0.87 \times 415 \times 226 \times 860}{369.72 \times 1000} \right) = 190$ mm
**Beam B3 Support**

*Design Parameters*

Load Case 16 \[1.5*(DL - EQZ)\]
Grade of Concrete \(M30\)
Grade of Steel \(Fe415\)
Characteristic compressive strength of concrete, \(f_{ck}\) (N/mm²) \(30\)
Characteristic yield strength of steel, \(f_y\) (N/mm²) \(415\)
Unit weight of concrete, \(\gamma_c\) (kN/m³) \(24\)
Partial safety factor for concrete \(1.5\)
Exposure condition \(Mild\)
Nominal Cover to exposure condition (mm) \(20\)

*Dimensions of the beam*

C/C Span of the beam, \(l\) (m) \(8.36\)
Breadth of the beam, \(b\) (mm) \(300\)
Overall depth of the beam, \(D\) (mm) \(900\)

*Details of reinforcements*

Diameter of tension reinforcement (mm) \(25\)
Diameter of compression reinforcement (mm) \(25\)
Diameter of stirrups (mm) \(8\)

*Effective depth*

Effective depth, \(d\) (mm) \((900-20-8-25/2) = 860\)

*Design Moment, Shear Force*

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment \(11\) kN-m
Bending Moment \(M_u(kN-m)\) \(672\)
Equivalent Bending Moment, \(M_e\) (kNm) \(698\)
Shear force at critical distance, \(V_{ud}\) (kN) \(60\)
Equivalent Shear (kN) \(119\)

*Singly reinforced or doubly reinforced section?*

The limiting moment of resistance, \(M_{u,lim}\) is given by

\[
M_{ulim} = 0.362f_{ck} \times \frac{bx_u}{d} \times 0.416x_u \times d
\]

Where \(b\) = Breadth of the Section
\(x_u\) = Limiting depth of Neutral Axis
\(d\) = Effective depth of the Section

The limiting percentage of steel, \(p_{u,lim}\) is given by
The area of steel for a singly reinforced section with width, \( b \), and depth, \( d \), and ultimate moment, \( M_u \), is given by:

\[
Pt_{\text{lim}} = 41.61 \times \frac{f_{ck} \times x_{u,\text{max}}}{f_y \times d}
\]

Where \( f_{ck} = \text{Characteristic Compressive strength of concrete} \)
\( f_y = \text{Characteristic strength of steel} \)

The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \), is given by:

\[
Pt \times \frac{Ast}{bd} \times \frac{f_{ck}}{2f_y} = 4.598 \times \frac{R}{f_{ck}}
\]

Where \( R = \frac{M_u}{bd^2} \)

For (M30 and Fe415)

\[
M_{u,\text{lim}} \leq 0.1389 \times f_{ck} \times b \times d^2
\]

\[
x_{u,\text{max}} / d = 0.48
\]

\[
\Rightarrow M_{u,\text{lim}} = \left( 0.1389 \times 30 \times 300 \times 859.5^2 / 1000000 \right) = 923.50 \text{ kNm}
\]

\[
\Rightarrow p_{u,\text{lim}} = \left( 41.3 \times 30 / 415 \times 0.48 \right) = 1.433
\]

If \( M_u > M_{u,\text{lim}} \), the section has to be
  i) get increased by depth or width (preferably depth)
  ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
M_u = 697.88 \text{ kNm}
\]
\[
M_{u,\text{lim}} = 923.50 \text{ kNm}
\]

\[
\Rightarrow \text{Section can be designed as singly reinforced.}
\]

**Determining \( A_{st} \)**

- Considering a 'balanced section' (\( x_u = x_{u,\text{max}} \))

\[
A_{st} = A_{st,\text{lim}} + \Delta A_{st}
\]

where \( A_{st,\text{lim}} = p_{u,\text{lim}} / 100 \times (b \times d) \)

\[
\Rightarrow A_{st,\text{lim}} = \left( 1.433 / 100 \times 300 \times 859.5 \right) = 3695 \text{ mm}^2
\]

- Assuming 25 mm bars for compression steel,

\[
d' \approx \left( 20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2 \right) = 40.5 \text{ mm}
\]
\[ \mu = 0.87 \cdot f_y \cdot \text{Ast} \cdot d \cdot (1 - (\text{Ast} \cdot f_y) / b \cdot d \cdot f_{ck}) \]

\[ A_{\text{st Reqd}} = 2616 \text{ mm}^2 \]

\[ \therefore \text{No of tension bars required ( # )} \]

\[ (2616 / (\pi / 4 \times 25^2)) = 6.00 \]

Actual percentage of steel, \( p_t \) (%)

\[ (6 \times \pi / 4 \times 25^2 / 300 / 860 \times 100) = 1.14 \]

Actual area of steel, \( A_{\text{st}} \) (mm²)

\[ (6 \times \pi / 4 \times 25^2) = 2945 \]

**Determining \( A_{\text{sc}} \)**

The compression steel, \( A_{\text{sc}} \), is given by

\[ A_{\text{sc}} = \frac{0.87 \cdot f_y}{f_{sc} - 0.447 \cdot f_{ck}} \]

or

\[ p_{ct} = \frac{0.87 \cdot f_y}{f_{sc} - 0.447 \cdot f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u, \text{max}} \) for various \( d'/d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( \frac{d'}{d} )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td></td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td></td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
</tr>
<tr>
<td>Fe500</td>
<td></td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u, \text{max}} \), for \( d'/d = (40.5 / 859.5) \) = 0.047

From the above table: by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u, \text{max}} \), it suffices to establish \( p_{ct} \geq p_{ct}^* \)
where \( p_c^* \) is given by

\[
p_c^* = \frac{0.87 f_y}{0.447 f_{ck}}
\]

Actual \( p_t \) provided : \( p_t = 1.14 \)
Actual \( p_c \) provided : \( p_c = 0.38 \)

\[
⇒ p_c^* = \left( 0.87 \times 415 \times (1.142 - 1.433) / (354.98 - 0.447 \times 30) \right)
\]

\[
⇒ p_c^* = -0.31
\]

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting \( l/d \) ratios are specified by the Code (Cl. 23.2.1) as:

\[
deformation
d basic
\]

where

- 7 for cantilever spans
- 20 for simply supported spans
- 26 for continuous spans

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor \( F \)

\[
F = \frac{10}{\text{span in metres}}
\]

The modification factors \( F_1 \) (which varies with \( p_t \) and \( f_{st} \)) and \( F_2 \) (which varies with \( p_c \)) are as given in Fig. 4 and Fig. 5 of the code.

Code permits an approximate calculation of \( f_{st} \) as follows:

\[
f_{st} = 0.58 \times f_y \times \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}
\]

\[
⇒ f_{st} = \left( 0.58 \times 415 \times 2932 / 2945 \right) = 239.63 \text{ N/mm}^2
\]

\[
F = 1.00
\]

\[
F_1 = 0.93
\]
F_2 = 0.93

\[
\frac{L}{d} \text{max} = (26 \times 1 \times 0.93 \times 0.93) = 22.37
\]

\[
\frac{L}{d} \text{provided} = 9.73
\]

\[\Rightarrow \text{Hence O.K.}\]

**Check for shear**

Shear force at critical distance, \( V_u (\text{kN}) \)

\[ V_u = 118.6667 \]

The critical section for shear is at a distance of 860 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[
(118.666666666667 \times 1000 / (300 \times 860)) = 0.46 \text{ N/mm}^2
\]

The maximum shear stress is given by:

\[ Tc_{\text{max}} = 0.62 f_{ck} \]

\[ \Rightarrow \tau_{c,max} = (0.62 \times \text{Sqrt}(30)) = 3.40 \text{ N/mm}^2 \]

\[\Rightarrow \text{Adopted section is adequate}\]

- **Design shear resistance at critical section**

At critical section, \( A_s \) is given by

\[ A_s = 2945 \text{ mm}^2 \]

Percentage of steel, \( p_t (\%) \)

\[ p_t = 1.14 \]

The design shear strength of the concrete, \( \tau_c \), is given by:

\[
\frac{0.85}{6} \frac{0.85 f_{ck}}{6.89 p_t} \frac{1}{1} \]

where \( \frac{0.85 f_{ck}}{6.89 p_t} \) whichever is greater

For (M30 and Fe415)

\[ \Rightarrow \tau_c = 0.69 \text{ N/mm}^2 \]

\[ \Rightarrow V_{uc} = (0.69 \times 300 \times 860 / 1000) = 178 \text{ kN} \]

- **Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by:

\[ V_{us} = V_u - V_{uc} \]

\[ \Rightarrow V_{us} = (119 - 178) = -59 \text{ kN} \]

Using 8 mm bars and

No of legs 2

150
Area of stirrups, \( A_{sv} \) (mm\(^2\)) = 101

\[ \Rightarrow \text{required spacing } s_v \leq \left( \frac{0.87 \times 415 \times 101 \times 860}{-59.19 \times 1000} \right) \]

\[ \Rightarrow \text{Spacing, } s_v = -527 \text{ mm} \]

**Check whether \( \tau_v > 0.5 \tau_c \)**

Nominal shear stress, \( \tau_v \) (N/mm\(^2\)) = 0.46

Design shear stress, \( \tau_c \) (N/mm\(^2\)) = 0.69

\( \tau_v > 0.5 \tau_c \) **Yes**

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress \( \tau_v \) exceeds 0.5 \( \tau_c \):

\[ \frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} \quad \text{When } s_v = 0.5t_c \]

\[ s_v = \frac{2.175 f_y A_{sv}}{b} \]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[ s_v \geq \frac{0.75 d}{300 \text{ mm}} \]

**Code requirements for maximum spacing.**

\[
\begin{align*}
\text{i)} & \quad < \left( \frac{2.175 \times 415 \times 101}{300} \right) = 302 \text{ mm} \\
\text{ii)} & \quad \leq \left( \frac{0.75 \times 859.5}{300} \right) = 645 \text{ mm} \\
\text{iii)} & \quad \leq 300 \text{ mm} = 300 \text{ mm} \\
\text{iv)} & \quad \leq \left( \frac{0.87 \times 415 \times 101 \times 860}{-59.19 \times 1000} \right) = -527 \text{ mm} 
\end{align*}
\]
**Beam B3 Mid**

**Design Parameters**

Load Case 16 \[1.5*(DL - EQZ)]
Grade of Concrete M30
Grade of Steel Fe415
Characteristic compressive strength of concrete , \( f_{ck} \) ( N/mm\(^2\) ) 30
Characteristic yield strength of steel , \( f_y \) ( N/mm\(^2\) ) 415
Unit weight of concrete , \( \gamma_c \) ( kN/m\(^3\) ) 24
Partial safety factor for concrete 1.5
Exposure condition Mild
Nominal Cover to exposure condition( mm ) 20

**Dimensions of the beam**

- C/C Span of the beam , \( l \) ( m ) 8.36
- Breadth of the beam , \( b \) ( mm ) 300
- Overall depth of the beam , \( D \) ( mm ) 900

**Details of reinforcements**

- Diameter of tension reinforcement ( mm ) 20
- Diameter of compression reinforcement ( mm ) 20
- Diameter of stirrups ( mm ) 8

**Effective depth**

Effective depth , \( d \) ( mm ) ( 900-20-8-20/2 ) = 862

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

- Torsional Moment 11 kN-m
- Bending Moment Mu(kN-m) 303
- Equivalent Bending Moment , \( M_e \) ( kNm ) 329
- Shear force at critical distance , \( V_{ud} \) ( kN ) 47
- Equivalent Shear (kN) 106

**Singly reinforced or doubly reinforced section ?**

The *limiting moment of resistance*, \( M_{u,\text{lim}} \) is given by

\[
M_{\text{lim}} = 0.362f_{ck} \cdot \frac{bx_{\text{max}}}{d} = 0.416x_{\text{max}}
\]

Where \( b \) = Breadth of the Section
\( x_{\text{max}} \) = Limiting depth of Neutral Axis
\( d \) = Effective depth of the Section

The limiting percentage of steel , \( p_{\text{lim}} \) is given by
Area of steel for a singly reinforced section with width, b, and depth, d, and ultimate moment, $M_u$, is given by:

\[ M_{u,\text{lim}} = \frac{0.1389 \times 30 \times 300 \times 862^2}{1000000} = 928.88 \text{ kNm} \]

\[ \rho_{\text{t,lim}} = \frac{41.3 \times 30}{415 \times 0.48} = 1.433 \]

If $M_u > M_{u,\text{lim}}$, the section has to be

i) increased by depth or width (preferably depth)

ii) doubly reinforced

If $M_u < M_{u,\text{lim}}$, the section can be designed as singly reinforced.

**Check for the type of section**

\[ M_i = 328.88 \text{ kNm} \]

\[ M_{u,\text{lim}} = 928.88 \text{ kNm} \]

\[ \Rightarrow \text{Section can be designed as singly reinforced.} \]

**Determining $A_{st}$**

- Considering a 'balanced section' ($x_u = x_{u,\text{max}}$)

\[ A_{st} = A_{st,\text{lim}} + \Delta A_{st} \]

where $A_{st,\text{lim}} = \rho_{\text{t,lim}} / 100 \times (b \times d)$

\[ \Rightarrow A_{st,\text{lim}} = (1.433 / 100 \times 300 \times 862) = 3706 \text{ mm}^2 \]

- Assuming 20 mm bars for compression steel,

\[ d' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 20 / 2) = 38 \text{ mm} \]
\[ \mu = 0.87 \times f_y \times A_{st} \times d (1 - (A_{st} \times f_y) / b \times d \times f_{ck}) \]

\[ A_{st\ Reqd} = 1124 \text{ mm}^2 \]

\[ \therefore \text{No of tension bars required ( # )} = \frac{1124}{\left( \frac{\pi}{4} \times 20^2 \right)} = 4.00 \]

Actual percentage of steel, \( p_t \) (%)
\[ \frac{4 \times \pi / 4 \times 20^2 / 300 / 862 \times 100}{\text{Actual area of steel, } A_{st} \text{ ( mm}^2\text{)}} \]
\[ = \frac{1257}{4} \times \frac{\pi}{4} \times 20^2 \text{ mm}^2 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by
\[ A_{sc} = \frac{0.87 \times f_y \times U_A + \mu}{f_{sc} - 0.447 \times f_{ck}} \]

or
\[ p_c = \frac{0.87 \times f_y \times p_t + p_{lim}}{f_{sc} - 0.447 \times f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u, max} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d' / d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td>217.5</td>
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<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
<td></td>
</tr>
</tbody>
</table>

• Assuming \( x_u = x_{u, max} \), for \( d' / d = (38 / 862) = 0.044 \)
  
  From the above table: by interpolation

**Design Check**

• To ensure \( x_u \leq x_{u, max} \), it suffices to establish \( p_c \geq p_c \).
where \( p_c^* \) is given by

\[
\begin{align*}
p_c^* &= \frac{0.87 f_y}{0.447 f_{ck}}
\end{align*}
\]

Actual \( p_t \) provided : \( p_t = 0.49 \)
Actual \( p_c \) provided : \( p_c = 0.85 \)

\[
\begin{align*}
\Rightarrow \quad p_c^* &= (0.87 \times 415 \times (0.486 - 1.433) / (354.8 - 0.447 \times 30)) \\
\Rightarrow \quad p_c^* &= -1.00
\end{align*}
\]

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans up to 10 m, the limiting \( l / d \) ratios are specified by the Code (Cl. 23.2.1) as:

- \( F_1 \) (which varies with \( p_t \) and \( f_{st} \))
- \( F_2 \) (which varies with \( p_c \)) are as given in Fig. 4 and Fig. 5 of the code.

The modification factors \( F_1 \) (which varies with \( p_t \) and \( f_{st} \)) and \( F_2 \) (which varies with \( p_c \)) are as given in Fig. 4 and Fig. 5 of the code.

Code permits an approximate calculation of \( f_{st} \) as follows:

\[
\begin{align*}
f_{st} &= 0.58 \frac{f_y}{f_{ck}} \\
\Rightarrow \quad f_{st} &= \frac{(0.58 \times 415 \times 1689)}{1257} = 323.54 \text{ N/mm}^2
\end{align*}
\]

\[
\begin{align*}
F &= 1.00 \\
F_1 &= 1.23
\end{align*}
\]
\[ F_2 = 1.21 \]

\[ \therefore \quad \frac{l}{d}_{\text{max}} = \left( \frac{26 \times 1 \times 1.23 \times 1.21}{9.70} \right) = 38.53 \]

\[ \Rightarrow \quad \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_{uc} \) (kN)

105.66667

The critical section for shear is at a distance of 862 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[ \left( \frac{105.666666666667 \times 1000}{300 \times 862} \right) = 0.41 \text{ N/mm}^2 \]

The maximum shear stress is given by:

\[ T_{c_{\text{max}}} = 0.62 f_{ck} \]

\[ \Rightarrow \quad \tau_{c,\text{max}} = \left( 0.62 \times \sqrt{30} \right) = 3.40 \text{ N/mm}^2 \]

\[ \Rightarrow \quad \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

At critical section, \( A_{st} \) is given by

1257 mm²

Percentage of steel, \( p_t \) ( %)

0.49

The design shear strength of the concrete, \( \tau_c \), is given by:

\[ \tau_c = \frac{0.85 f_{ck} T_c}{1 + 0.8 p_t} \]

\[ \text{where} \quad \frac{0.85 f_{ck} T_c}{1 + 0.8 p_t} \text{ whichever is greater} \]

For (M30 and Fe415)

\[ \Rightarrow \quad \tau_c = 0.49 \text{ N/mm}^2 \]

\[ \Rightarrow \quad V_{uc} = \left( \frac{0.49 \times 300 \times 862}{1000} \right) = 127 \text{ kN} \]

- **Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by:

\[ V_{us} = V_u - V_{uc} \]

\[ \Rightarrow \quad V_{us} = \left( 106 - 127 \right) = -21 \text{ kN} \]

Using 8 mm bars and

No of legs 2
Area of stirrups, $A_{sv}$ (mm$^2$) = 101

$$\Rightarrow \text{required spacing } s_v \leq \frac{0.87 \times 415 \times 101 \times 862}{-21.27 \times 1000}$$

$$\Rightarrow \text{Spacing, } s_v = 1471 \text{ mm}$$

*Check whether $\tau_v > 0.5 \tau_c$*

Nominal shear stress, $\tau_v$ (N/mm$^2$) = 0.41
Design shear stress, $\tau_c$ (N/mm$^2$) = 0.49

$\tau_v > 0.5 \tau_c \quad \text{Yes}$

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress $\tau_v$ exceeds 0.5 $\tau_c$:

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} \quad \text{When } s_v = 0.5\tau_c$$

$$s_v = \frac{2.175 f_y A_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

$$s_v \leq \frac{0.75 d}{300 \text{ mm}}$$

*Code requirements for maximum spacing.*

\[
\begin{array}{ll}
i) & < \quad (2.175 \times 415 \times 101 / 300) = 302 \text{ mm} \\
ii) & \leq \quad (0.75 \times 862) = 647 \text{ mm} \\
iii) & \leq \quad 300 \text{ mm} \\
iv) & \leq \quad (0.87 \times 415 \times 101 \times 862 / (-21.27 \times 1000)) = -1471 \text{ mm}
\end{array}
\]
**Beam B4 Support**

**Design Parameters**

Load Case 15 \[1.5*(DL + EQZ)]
Grade of Concrete \(M30\)
Grade of Steel \(Fe415\)
Characteristic compressive strength of concrete, \(f_{ck}\) \(N/mm^2\) 30
Characteristic yield strength of steel, \(f_y\) \(N/mm^2\) 415
Unit weight of concrete, \(\gamma_c\) \(kN/m^3\) 24
Partial safety factor for concrete 1.5
Exposure condition Mild
Nominal Cover to exposure condition (mm) 20

**Dimensions of the beam**

C/C Span of the beam, \(l\) (m) 1.45
Breadth of the beam, \(b\) (mm) 350
Overall depth of the beam, \(D\) (mm) 900

**Details of reinforcements**

Diameter of tension reinforcement (mm) 25
Diameter of compression reinforcement (mm) 25
Diameter of stirrups (mm) 8

**Effective depth**

Effective depth, \(d\) (mm) \((900-20-8-25/2) = 860\)

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

- Torsional Moment 20 kN-m
- Bending Moment Mu(kN-m) 706
- Equivalent Bending Moment, \(M_e\) (kNm) 753
- Shear force at critical distance, \(V_{ud}\) (kN) 282
- Equivalent Shear (kN) 389

**Singly reinforced or doubly reinforced section?**

The limiting moment of resistance, \(M_{u,lim}\) is given by

\[\text{Mulim} = 0.362 f_{ck} \frac{bx_{u,\text{max}}}{d} \times 0.416 xu_{\text{max}}\]

Where \(b = \text{Breadth of the Section}\)
\(xu_{\text{max}} = \text{Limiting depth of Neutral Axis}\)
\(d = \text{Effective depth of the Section}\)

The limiting percentage of steel, \(p_{u,lim}\) is given by
The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
\frac{P_t \times A_{st}}{100 \times b \times d} = 4.598 \frac{R}{f_{ck}}
\]

Where \( R = \frac{M_u}{b d^2} \)

For (M30 and Fe415), \( M_{u,\text{lim}} = 0.1389 \times 30 \times 300 \times 859.5^2 / 1000000 = 923.50 \text{ kNm} \)

\( \Rightarrow x_{u,\text{max}} / d = 0.48 \)

\( \Rightarrow M_{u,\text{lim}} = (0.1389 \times 30 \times 300 \times 859.5^2 / 1000000) = 923.50 \text{ kNm} \)

\( \Rightarrow p_{u,\text{lim}} = (41.3 \times 30 / 415 \times 0.48) = 1.433 \)

If \( M_u > M_{u,\text{lim}} \), the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
\begin{align*}
M_u &= 753.06 \text{ kNm} \\
M_{u,\text{lim}} &= 923.50 \text{ kNm}
\end{align*}
\]

\( \Rightarrow \text{Section can be designed as singly reinforced.} \)

**Determining \( A_{st} \)**

- Considering a 'balanced section' (\( x_e = x_{u,\text{max}} \))
  \[
  A_{st} = A_{st,\text{lim}} + \Delta A_{st}
  \]
  where \( A_{st,\text{lim}} = p_{u,\text{lim}} / 100 \times b \times d \)

\( \Rightarrow A_{st,\text{lim}} = (1.433 / 100 \times 300 \times 859.5) = 3695 \text{ mm}^2 \)

- Assuming 25 mm bars for compression steel,
  \[
  d' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2) = 40.5 \text{ mm}
  \]
\[ \mu = 0.87 f_y * \text{Ast} * d (1 - (\text{Ast} * f_y) / b * f_{ck}) \]

\[ \text{Ast Req'd} = 2868 \text{ mm}^2 \]

\[ \therefore \text{No of tension bars required (\#)} \]
\[ (\frac{2868}{(\frac{\pi}{4} \times 25^2)} = 6.00 \]

Actual percentage of steel, \( p_t \) (\%)
\[ (\frac{6 \times \pi}{4 \times 25^2} / 300 / 860 \times 100) = 1.14 \]

Actual area of steel, \( A_{\text{st}} \) (\text{mm}^2)
\[ (\frac{6 \times \pi}{4 \times 25^2}) = 2945 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by
\[ A_{sc} = \frac{0.87 f_y}{f_{sc}} \left( \frac{1}{0.447 f_{ck}} \right) \]

or
\[ p_c = \frac{0.87 f_y}{f_{sc}} \left( \frac{p_t}{p_{\text{lim}}} \right) \frac{1}{0.447 f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,\text{max}} \) for various \( d'/d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d'/d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td></td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td></td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
</tr>
<tr>
<td>Fe500</td>
<td></td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u,\text{max}} \), for \( d'/d = \) \( \frac{40.5}{859.5} \) = 0.047
- From the above table: by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \geq p_c^* \)
where $p_c^{*}$ is given by

$$p_c^{*} = \frac{0.87 f_y}{0.447 f_{ck}}$$

Actual $p_t$ provided : $p_t = 1.14$
Actual $p_c$ provided : $p_c = 0.38$

$$\Rightarrow p_c^{*} = \frac{(0.87 \times 415 \times (1.142 - 1.433))}{(354.98 - 0.447 \times 30)}$$

$$\Rightarrow p_c^{*} = -0.31$$

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

- For cantilever spans: $7$
- For simply supported spans: $20$
- For continuous spans: $26$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor $F$

$$F = \frac{10}{\text{span in metres}}$$

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig. 4 and Fig. 5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

$$\Rightarrow f_{st} = \frac{0.58 \times 415 \times 3119}{2945} = 254.88 \text{ N/mm}^2$$
\[ F_2 = 0.93 \]

\[ \therefore \ (l/d)_{\text{max}} = (26 \times 1 \times 0.89 \times 0.93) = 21.40 \]
\[ (l/d)_{\text{provided}} = 1.69 \]
\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN) = 388.66667

The critical section for shear is at a distance of 860 mm from the face of the support.

- **Check for adequacy of section**

  Nominal shear stress, \( \tau_v \)
  \[ \left( \frac{388.666667 \times 1000}{300 \times 860} \right) = 1.51 \text{ N/mm}^2 \]

  The maximum shear stress is given by:
  \[ Tc_{\text{max}} = 0.62 f_{ck} \]
  \[ \Rightarrow \tau_{c,\text{max}} = (0.62 \times \sqrt{30}) = 3.40 \text{ N/mm}^2 \]

  \[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

  At critical section, \( A_{st} \) is given by 2945 mm²

  Percentage of steel, \( p_t \) (\%) = 1.14

  The design shear strength of the concrete, \( \tau_c \), is given by:
  \[
  \frac{0.85}{\sqrt{3c}} - 1
  \]
  \[ \text{where} \quad \frac{0.8 f_{ck}}{0.85 p_t} \text{ whichever is greater} \]

  For (M30 and Fe415)
  \[ \Rightarrow \tau_c = 0.69 \text{ N/mm}^2 \]
  \[ \Rightarrow V_{uc} = \left( \frac{0.69 \times 300 \times 860}{1000} \right) = 178 \text{ kN} \]

- **Design of "vertical" stirrups**

  The shear to be resisted by steel, \( V_{us} \) is given by:
  \[ V_{us} = V_u \cdot V_{uc} \]
  \[ \Rightarrow V_{us} = (389 - 178) = 211 \text{ kN} \]

  Using 8 mm bars and No of legs 2
Area of stirrups, $A_{sv}$ (mm$^2$) = 101

⇒ required spacing $s_v \leq \frac{0.87 \times 415 \times 101 \times 860}{(210.81 \times 1000)}$

⇒ Spacing, $s_v = 148$ mm

Check whether $\tau_v > 0.5 \tau_c$

Nominal shear stress, $\tau_v$ (N/mm$^2$) = 1.51
Design shear stress, $\tau_c$ (N/mm$^2$) = 0.69

$\tau_v > 0.5 \tau_c \quad \text{Yes}$

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress $\tau_v$ exceeds $0.5 \tau_c$:

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} \quad \text{When } s_v = 0.5tc$$

$$s_v = \frac{2.175 f_y A_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

$$s_v \leq \frac{0.75 d}{300 \text{ mm}}$$

Code requirements for maximum spacing:

i) $s_v < \frac{(2.175 \times 415 \times 101 / 300)}{300 \text{ mm}} = 302 \text{ mm}$
ii) $s_v \leq \frac{0.75 \times 859.5}{645 \text{ mm}} = 300 \text{ mm}$
iii) $s_v \leq 300 \text{ mm}$
iv) $s_v \leq \frac{(0.87 \times 415 \times 101 \times 860 / (210.81 \times 1000))}{148 \text{ mm}} = 300 \text{ mm}$
**Beam B4 Mid**

**Design Parameters**

Load Case 15 \([1.5 \times (DL + EQZ)]\)

- Grade of Concrete: M30
- Grade of Steel: Fe415
- Characteristic compressive strength of concrete, \(f_{ck} (\text{N/mm}^2)\): 30
- Characteristic yield strength of steel, \(f_y (\text{N/mm}^2)\): 415
- Unit weight of concrete, \(\gamma_c (\text{kN/m}^3)\): 24
- Partial safety factor for concrete: 1.5
- Exposure condition: Mild
- Nominal Cover to exposure condition (mm): 20

**Dimensions of the beam**

- C/C Span of the beam, \(I (\text{m})\): 1.45
- Breadth of the beam, \(b (\text{mm})\): 300
- Overall depth of the beam, \(D (\text{mm})\): 900

**Details of reinforcements**

- Diameter of tension reinforcement (mm): 20
- Diameter of compression reinforcement (mm): 20
- Diameter of stirrups (mm): 8

**Effective depth**

- Effective depth, \(d (\text{mm})\): \(900 - 20 - 8 - 20/2 = 862\)

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

- Torsional Moment: 20 kN-m
- Bending Moment Mu(kN-m): 314
- Equivalent Bending Moment, \(M_e (\text{kNm})\): 361
- Shear force at critical distance, \(V_{ud} (\text{kN})\): 259
- Equivalent Shear (kN): 366

**Singly reinforced or doubly reinforced section?**

The *limiting moment of resistance*, \(M_{u,\text{lim}}\) is given by

\[
M_{u,\text{lim}} = 0.362f_{ck} \times \frac{bx_u}{d} \times 0.416x_{u,\text{max}}
\]

Where:
- \(b\) = Breadth of the Section
- \(x_u\) = Limiting depth of Neutral Axis
- \(d\) = Effective depth of the Section

The limiting percentage of steel, \(p_{t,\text{lim}}\) is given by
The area of steel for a singly reinforced section with

width, b and depth, d and ultimate moment, \( M_u \) is given by:

\[
\frac{Pt}{100} \times \frac{A_{st}}{bd} \times \frac{f_{ck}}{2fy} = 4.598 \frac{R}{f_{ce}}
\]

Where \( R = \frac{M_u}{bd^2} \)

For (M30 and Fe415) \( M_{u,lim} \geq 0.1389 \ f_{ck} b d^2 \)

\[
x_{u,max} / d = 0.48
\]

\[
M_{u,lim} = (0.1389 \times 30 \times 300 \times 862^2 / 1000000) = 928.88 \text{ kNm}
\]

\[
p_{t,lim} = (41.3 \times 30 / 415 \times 0.48) = 1.433
\]

If \( M_u > M_{u,lim} \), the section has to be

i) get increased by depth or width (preferably depth)
   ii) doubly reinforced

If \( M_u < M_{u,lim} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
M_u = 361.06 \text{ kNm}
\]

\[
M_{u,lim} = 928.88 \text{ kNm}
\]

\[
\Rightarrow \text{Section can be designed as singly reinforced.}
\]

**Determining \( A_{st} \)**

- Considering a 'balanced section' (\( x_u = x_{u,max} \))

\[
A_{st} = A_{st,lim} + \Delta A_{st}
\]

where \( A_{st,lim} = p_{t,lim} / 100 \ (b \times d) \)

\[
\Rightarrow \ A_{st,lim} = (1.433 / 100 \times 300 \times 862) = 3706 \text{ mm}^2
\]

- Assuming 20 mm bars for compression steel,

\[
d' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 20 / 2) = 38 \text{ mm}
\]
\[ \mu = 0.87 \ast \frac{f_y}{d'} \ast d(1 - \ast \frac{Ast}{b} \ast \frac{f_y}{d'} \ast f_{ck}) \]

\[ \text{Ast Reqd} = 1243 \text{ mm}^2 \]

\[ \therefore \quad \text{No of tension bars required ( \# )} \]

\[ \left( \frac{1243}{\frac{\pi}{4} \ast 20^2} \right) = 5.00 \]

Actual percentage of steel, \( p_t \) (%)

\[ \left( \frac{4 \ast \pi / 4 \ast 20^2}{300 / 862 \ast 100} \right) = 0.49 \]

Actual area of steel, \( A_{st} \) (mm\(^2\))

\[ \left( \frac{4 \ast \pi / 4 \ast 20^2}{300 / 862 \ast 100} \right) = 1571 \]

**Determining A\(_{sc}\)**

The compression steel, \( A_{sc} \), is given by

\[ A_{sc} = \frac{0.87 \ast f_y}{f_{sc} - 0.447 \ast f_{ck}} \]

or

\[ p_c = \frac{0.87 \ast f_y}{f_{sc} - 0.447 \ast f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,\text{max}} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d' / d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td></td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td></td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
</tr>
<tr>
<td>Fe500</td>
<td></td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
</tr>
</tbody>
</table>

\[ \therefore \quad \text{Assuming } x_u = x_{u,\text{max}}, \text{ for } d' / d = \left( \frac{38}{862} \right) = 0.044 \]

From the above table: by interpolation

**Design Check**

\[ \therefore \quad \text{To ensure } x_u \leq x_{u,\text{max}}, \text{ it suffices to establish } p_c \geq p_{c,*} \]
where $p_c^*$ is given by

\[
p_c^* = \frac{0.87 f_y}{0.447 f_{ck}}
\]

Actual $p_t$ provided : $p_t = 0.49$
Actual $p_c$ provided : $p_c = 0.85$

\[
\Rightarrow p_c^* = \frac{(0.87 \times 415 \times (0.486 - 1.433))}{(354.8 - 0.447 \times 30)}
\]

\[
\Rightarrow p_c^* = -1.00
\]

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

\[
\frac{l}{d_{max}} = \begin{cases} 
7 & \text{for cantilever spans} \\
20 & \text{for simply supported spans} \\
26 & \text{for continuous spans}
\end{cases}
\]

where $d_{basic}$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor $F_{10}$

\[
F = \frac{10}{\text{span in metres}}
\]

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig.4 and Fig.5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

\[
f_{st} = 0.58 \frac{f_y}{A_{sec - of - cross - section - of - steel - required}}
\]

\[
f_{st} = 0.58 \frac{1797}{1257} = 344.26 \text{ N/mm}^2
\]

$F = 1.00$
$F_1 = 1.13$
\[ F_2 = 1.21 \]

\[
\therefore \quad \frac{l}{d}_{\text{max}} = (26 \times 1 \times 1.13 \times 1.21) = 35.62
\]

\[
\left( \frac{l}{d} \right)_{\text{provided}} = 1.68
\]

\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN)

\[ 365.6667 \]

The critical section for shear is at a distance of 862 mm from the face of the support.

• **Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[
\left( \frac{365.666666666667 \times 1000}{(300 \times 862)} \right) = 1.41 \text{ N/mm}^2
\]

The maximum shear stress is given by:

\[ T_{c, \text{max}} = 0.62 f_{ck} \]

\[ \Rightarrow \quad \tau_{c, \text{max}} = (0.62 \times \text{sqrt}(30)) = 3.40 \text{ N/mm}^2 \]

\[ \Rightarrow \text{Adopted section is adequate} \]

• **Design shear resistance at critical section**

At critical section, \( A_{st} \) is given by

\[
1257 \text{ mm}^2
\]

Percentage of steel, \( p_t \) (\%)

\[
0.49
\]

The design shear strength of the concrete, \( \tau_c \), is given by:

\[
\tau_c = \frac{0.86 f_{ck}}{\min\left[1, \frac{0.85}{0.85 + 0.8 f_{ck} \frac{p_t}{100 - 0.8 f_{ck} p_t}}\right]}
\]

For (M30 and Fe415)

\[ \Rightarrow \quad \tau_c = 0.49 \text{ N/mm}^2 \]

\[ \Rightarrow \quad V_{uc} = \left(0.49 \times 300 \times 862 / 1000\right) = 127 \text{ kN} \]

• **Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by:

\[ V_{us} = V_u - V_{uc} \]

\[ \Rightarrow \quad V_{us} = (366 - 127) = 239 \text{ kN} \]

Using 8 mm bars and 2 legs.
Area of stirrups, \( A_{sv} \) (mm\(^2\)) = 101

\[ \Rightarrow \text{required spacing } s_v \leq \left( \frac{0.87 \times 415 \times 101 \times 862}{238.73 \times 1000} \right) \]

\[ \Rightarrow \text{Spacing, } s_v = 131 \text{ mm} \]

**Check whether} \( \tau_v > 0.5 \tau_c \)**

Nominal shear stress, \( \tau_v \) (N/mm\(^2\)): 1.41
Design shear stress, \( \tau_c \) (N/mm\(^2\)): 0.49

\[ \tau_v > 0.5 \tau_c \quad \text{Yes} \]

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress \( \tau_v \) exceeds 0.5 \( \tau_c \):

\[ \frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\, f_y} \quad \text{When } s_v = 0.5\, t_c \]

\[ s_v = \frac{2.175 \, f_y A_{sv}}{b} \]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[ s_v \leq \frac{0.75 \, d}{300 \, \text{mm}} \]

**Code requirements for maximum spacing**.

\[ i) \leq \left( \frac{2.175 \times 415 \times 101}{300} \right) = 302 \text{ mm} \]
\[ ii) \leq \left( \frac{0.75 \times 862}{300} \right) = 647 \text{ mm} \]
\[ iii) \leq \left( \frac{300}{300} \right) = 300 \text{ mm} \]
\[ iv) \leq \left( \frac{0.87 \times 415 \times 101 \times 862}{238.73 \times 1000} \right) = 131 \text{ mm} \]
**Beam B6 Support**

*Design Parameters*

Load Case 14 \[1.5\times(\text{DL} - \text{EQX})\]
Grade of Concrete \(\text{M30}\)
Grade of Steel \(\text{Fe415}\)
Characteristic compressive strength of concrete \(f_{ck}\) (N/mm\(^2\)) \(30\)
Characteristic yield strength of steel \(f_y\) (N/mm\(^2\)) \(415\)
Unit weight of concrete \(\gamma_c\) (kN/m\(^3\)) \(24\)
Partial safety factor for concrete \(1.5\)
Exposure condition \(\text{Mild}\)
Nominal Cover to exposure condition (mm) \(20\)

*Dimensions of the beam*

- C/C Span of the beam, \(l\), (m) \(1.40\)
- Breadth of the beam, \(b\) (mm) \(250\)
- Overall depth of the beam, \(D\) (mm) \(550\)

*Details of reinforcements*

- Diameter of tension reinforcement (mm) \(20\)
- Diameter of compression reinforcement (mm) \(20\)
- Diameter of stirrups (mm) \(8\)

*Effective depth*

\[
\text{Effective depth, } d \text{ (mm)} = (550-20-8-20/2) = 512
\]

*Design Moment, Shear Force*

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

- Torsional Moment \(10\) kN-m
- Bending Moment \(M_u\) (kN-m) \(245\)
- Equivalent Bending Moment, \(M_e\) (kNm) \(264\)
- Shear force at critical distance, \(V_{ud}\) (kN) \(55\)
- Equivalent Shear (kN) \(119\)

*Singly reinforced or doubly reinforced section?*

The *limiting moment of resistance*, \(M_{u,lim}\) is given by

\[
M_{u,lim} = 0.362f_{ck} \times \frac{bx_u_{max}}{d} \times 0.416x_{u_{max}}
\]

Where \(b\) = Breadth of the Section,
\(x_{u_{max}}\) = Limiting depth of Neutral Axis,
\(d\) = Effective depth of the Section.

The limiting percentage of steel, \(p_{u,lim}\) is given by
The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
\frac{Pt}{100} \times \frac{Ast}{bd} \times \frac{fck}{2fy} = 4.598 \frac{R}{f_{ck}}
\]

Where \( R = \frac{Mu}{bd^2} \)

For (M30 and Fe415) \( M_{u,\text{lim}} \geq 0.1389 \times f_{ck} \times b \times d^2 \)

\[
\frac{x_{u,\text{max}}}{d} = 0.48
\]

\[
\Rightarrow M_{u,\text{lim}} = \frac{0.1389 \times 30 \times 250 \times 512^2}{1000000} = 273.09 \text{ kNm}
\]

\[
\Rightarrow p_{t,\text{lim}} = \frac{41.3 \times 30}{415 \times 0.48} = 1.433
\]

If \( M_u > M_{u,\text{lim}} \), the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
M_u = 263.82 \text{ kNm}
\]

\[
M_{u,\text{lim}} = 273.09 \text{ kNm}
\]

\[
\Rightarrow \text{Section can be designed as singly reinforced.}
\]

**Determining \( A_{st} \)**

- Considering a 'balanced section' (\( x_u = x_{u,\text{max}} \))

\[
A_{st} = A_{st,\text{lim}} + \Delta A_{st}
\]

where \( A_{st,\text{lim}} = p_{t,\text{lim}} / 100 \times (b \times d) \)

\[
\Rightarrow A_{st,\text{lim}} = 1.433 / 100 \times 250 \times 512 = 1834 \text{ mm}^2
\]

- Assuming 20 mm bars for compression steel,

\[
d' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 20 / 2) = 38 \text{ mm}
\]
\[ \mu = 0.87f_y A_{st}(d - (A_{st} f_y) / b d' f_{ck}) \]

\[ A_{st \text{ Reqd}} = 1763 \text{ mm}^2 \]

\[ \therefore \] No of tension bars required ( # )

\[ (1763 / (\pi / 4 \times 20^2)) = 6.00 \]

Actual percentage of steel , \( p_t \) ( % )

\[ (6 \times \pi / 4 \times 20^2 / 250 / 512 \times 100) = 1.47 \]

Actual area of steel , \( A_{st} \) ( mm² )

\[ (6 \times \pi / 4 \times 20^2) = 1885 \]

**Determining \( A_{sc} \)**

The compression steel , \( A_{sc} \), is given by

\[ A_{sc} = \frac{0.87 f_y}{f_{sc} - 0.447 f_{ck}} \]

\[ \text{or} \]

\[ p_c = \frac{0.87 f_y - p_{t,\text{lim}}}{f_{sc} - 0.447 f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) ( in MPa units ) at \( x_u = x_{u,\text{max}} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d' / d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td></td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td></td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
</tr>
<tr>
<td>Fe500</td>
<td></td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
</tr>
</tbody>
</table>

• Assuming \( x_u = x_{u,\text{max}} \), for \( d' / d = (38 / 512) = 0.074 \)

From the above table : by interpolation

**Design Check**

• To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \geq p_{c,*} \).
where $p_c^*$ is given by

$$p_c^* = \frac{0.87 f_y}{0.447 f_{ck}} \frac{b}{d}$$

Actual $p_t$ provided : $p_t = 1.47$
Actual $p_c$ provided : $p_c = 0.25$

$\Rightarrow$ $p_c^* = (0.87 \times 415 \times (1.473 - 1.433) / (354.61 - 0.447 \times 30))$  
$\Rightarrow$ $p_c^* = 0.04$

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

$$F_1 = 0.83, \quad F_2 = 1.00$$

where

- $l/d_{\text{basic}}$ for cantilever spans
- $7$ for cantilever spans
- $20$ for simply supported spans
- $26$ for continuous spans

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor $F$:

$$F = \frac{10}{\text{span in metres}}$$

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig.4 and Fig.5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

$$f_{st} = 0.58 f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

$\Rightarrow$ $f_{st} = (0.58 \times 415 \times 1780 / 1885) = 227.32$ N/mm$^2$

$F = 1.00$

$F_1 = 0.83$
\[ F_2 = 0.75 \]

\[ \therefore \quad \frac{(l/d)_{\text{max}}}{(l/d)_{\text{provided}}} = \frac{(26 \times 1 \times 0.83 \times 0.75)}{2.73} = 16.36 \rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_u \) (kN)

The critical section for shear is at a distance of 512 mm from the face of the support.

- **Check for adequacy of section**

  Nominal shear stress, \( \tau_v \)
  \[
  \frac{(119 \times 1000)}{(250 \times 512)} = 0.93 \text{ N/mm}^2
  \]

  The maximum shear stress is given by:
  \[
  \tau_{\text{c,max}} = 0.62 \sqrt{30} \quad 3.40 \text{ N/mm}^2
  \]

  \[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

  At critical section, \( A_{st} \) is given by 1885 mm²
  Percentage of steel, \( p_t \) (\% ) 1.47

  The design shear strength of the concrete, \( \tau_c \), is given by:
  \[
  \frac{0.86}{0.85} \begin{bmatrix} 0.81f_{ck} \end{bmatrix} \begin{bmatrix} 1 \end{bmatrix} = 0.81f_{ck} \quad 0.85
  \]
  where \( f_{ck} \) whichever is greater

  For (M30 and Fe415)
  \[ 0.76 \quad \text{N/mm}^2 \]

  \[ V_{uc} = \frac{(0.76 \times 250 \times 512 \times 1000)}{1000} = 97 \text{ kN} \]

- **Design of "vertical" stirrups**

  The shear to be resisted by steel, \( V_{us} \) is given by:
  \[ V_{us} = V_u - V_{uc} \]

  \[ \Rightarrow V_{us} = (119 - 97) = 22 \text{ kN} \]

Using 8 mm bars and
No of legs 2
Area of stirrups, $A_{sv} \ (\text{mm}^2) \quad 101$

\[ \Rightarrow \text{required spacing } s_v \leq \left( \frac{0.87 \times 415 \times 101 \times 512}{22.05 \times 1000} \right) \]

\[ \Rightarrow \text{Spacing, } s_v = 843 \ \text{mm} \]

*Check whether* $\tau_v > 0.5 \ \tau_c$

Nominal shear stress, $\tau_v \ (\text{N/mm}^2) \quad 0.93$
Design shear stress, $\tau_c \ (\text{N/mm}^2) \quad 0.76$

$\tau_v > 0.5 \ \tau_c \quad \text{Yes}$

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress $\tau_v$ exceeds $0.5 \ \tau_c$:

\[
\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 \ f_y} \quad \text{When } s_v = 0.5 t_c
\]

\[ s_v = \frac{2.175 \ f_y A_{sv}}{b} \]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[ s_v \leq \frac{0.75 \ d}{300 \ \text{mm}} \]

**Code requirements for maximum spacing.**

i) $< \left( \frac{2.175 \times 415 \times 101}{250} \right) = 363 \ \text{mm}$

ii) $\leq \left( 0.75 \times 512 \right) = 384 \ \text{mm}$

iii) $\leq 300 \ \text{mm} = 300 \ \text{mm}$

iv) $\leq \left( \frac{0.87 \times 415 \times 101 \times 512}{22.05 \times 1000} \right) = 843 \ \text{mm}$
### Beam B6 Mid

**Design Parameters**

- **Load Case 14**  \([1.5 \times (DL - EQX)]\)
- **Grade of Concrete**  M30
- **Grade of Steel**  Fe415
- **Characteristic compressive strength of concrete**, \(f_{ck}\)  (N/mm\(^2\))  \(30\)
- **Characteristic yield strength of steel**, \(f_y\)  (N/mm\(^2\))  \(415\)
- **Unit weight of concrete**, \(\gamma_c\)  (kN/m\(^3\))  \(24\)
- **Partial safety factor for concrete**  \(1.5\)
- **Exposure condition**  Mild
- **Nominal Cover to exposure condition**  (mm)  \(20\)

**Dimensions of the beam**

- **C/C Span of the beam**, \(l\)  (m)  \(1.40\)
- **Breadth of the beam**, \(b\)  (mm)  \(250\)
- **Overall depth of the beam**, \(D\)  (mm)  \(550\)

**Details of reinforcements**

- **Diameter of tension reinforcement**  (mm)  \(20\)
- **Diameter of compression reinforcement**  (mm)  \(20\)
- **Diameter of stirrups**  (mm)  \(8\)

**Effective depth**

\[
\text{Effective depth, } d \text{ (mm)} = (550-20-8-20/2) = 512
\]

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

- **Torsional Moment**  \(10\)  kN-m
- **Bending Moment**  \(M_u (kN-m)\)  \(118\)
- **Equivalent Bending Moment**  \(M_e\)  (kNm)  \(137\)
- **Shear force at critical distance,**  \(V_{ud}\)  (kN)  \(55\)
- **Equivalent Shear**  (kN)  \(119\)

**Singly reinforced or doubly reinforced section?**

The *limiting moment of resistance*, \(M_{u,lim}\) is given by

\[
M_{u,lim} = 0.362f_{ck} \times \frac{bxu_{max}}{d} \times 0.416xu_{max}
\]

Where
- \(b\) = Breadth of the Section
- \(xu_{max}\) = Limiting depth of Neutral Axis
- \(d\) = Effective depth of the Section

The limiting percentage of steel, \(p_{u,lim}\) is given by
The area of steel for a singly reinforced section with width, \( b \), and depth, \( d \), and ultimate moment, \( M_u \), is given by:

\[
Pt_{\text{lim}} = 41.61 \times \frac{\text{f}_{ck} \times x_{u,\text{max}}}{\text{f}_{y}} \times \frac{\text{f}_{ck}}{d}
\]

Where \( f_{ck} = \text{Characteristic Compressive strength of concrete} \)
\( f_{y} = \text{Charcteristic strength of steel} \)

The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
\frac{Pt}{100} \times \frac{A_{st}}{bd} \times \frac{f_{ck}}{2f_{y}} = 4.598 \times \frac{R}{f_{ck}}
\]

\( Where \ R = \frac{M_{u}}{bd^{2}} \)

For (M30 and Fe415)

\[
M_{u,\text{lim}} = 0.1389 \times f_{ck} \times b \times d^{2}
\]

\[
x_{u,\text{max}} / d = 0.48
\]

\[
\Rightarrow M_{u,\text{lim}} = \left( 0.1389 \times 30 \times 250 \times 512^{2} / 1000000 \right) = 273.09 \text{ kNm}
\]

\[
\Rightarrow p_{t,\text{lim}} = \left( 41.3 \times 30 / 415 \times 0.48 \right) = 1.433
\]

If \( M_u > M_{u,\text{lim}} \), the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
M_{u} = 136.82 \text{ kNm}
\]

\[
M_{u,\text{lim}} = 273.09 \text{ kNm}
\]

\[
\Rightarrow \text{Section can be designed as singly reinforced.}
\]

**Determining \( A_{st} \)**

- Considering a 'balanced section' (\( x_d = x_{u,\text{max}} \))

\[
A_{st} = A_{st,\text{lim}} + \Delta A_{st}
\]

where \( A_{st,\text{lim}} = p_{t,\text{lim}} / 100 \times b \times d \)

\[
\Rightarrow A_{st,\text{lim}} = \left( 1.433 / 100 \times 250 \times 512 \right) = 1834 \text{ mm}^{2}
\]

- Assuming 20 mm bars for compression steel,

\[
d'' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 20 / 2) = 38 \text{ mm}
\]
\[ \mu = 0.87 f_y^{*} A_{st} d (1 - (A_{st} f_y/b) b f_{ck}) \]

\[ A_{st} \text{ Reqd} = 811 \text{ mm}^2 \]

\[ \therefore \text{ No of tension bars required ( # )} \]
\[ \left( \frac{811}{(\pi / 4 \times 20^2)} \right) = 3.00 \]

\[ \text{Actual percentage of steel, } p_t (\%) \]
\[ \left( \frac{3 \times \pi / 4 \times 20^2}{250 \times 512 \times 100} \right) = 0.74 \]

\[ \text{Actual area of steel, } A_{st} (\text{mm}^2) \]
\[ \left( \frac{3 \times \pi / 4 \times 20^2}{250 \times 512 \times 100} \right) = 942 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by

\[ A_{sc} = \frac{0.87 f_y^{*} A_{st}}{f_{sc}^{*} 0.447 f_{ck}} \]

or

\[ p_c = \frac{0.87 f_y^{*} p_t}{f_{sc}^{*} 0.447 f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,max} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d' / d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td></td>
</tr>
<tr>
<td>Fe415</td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
<td></td>
</tr>
<tr>
<td>Fe500</td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
<td></td>
</tr>
</tbody>
</table>

• Assuming \( x_u = x_{u,max} \), for \( d' / d = \left( \frac{38}{512} \right) = 0.074 \)

From the above table: by interpolation

**Design Check**

• To ensure \( x_u \leq x_{u,max} \), it suffices to establish \( p_c \geq p_c^{*} \)
where \( p_c^* \) is given by

\[
p_c^* = \frac{0.87 f_y}{0.447 f_{ck}} \left( \frac{0.736 - 1.433}{354.61 - 0.447 \times 30} \right)
\]

Actual \( p_t \) provided : \( p_t = 0.74 \)
Actual \( p_c \) provided : \( p_c = 0.74 \)

\[
\Rightarrow p_c^* = \left( 0.87 \times 415 \times (0.736 - 1.433) / (354.61 - 0.447 \times 30) \right)
\]
\[
\Rightarrow p_c^* = -0.74
\]

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans up to 10m, the limiting \( l/d \) ratios are specified by the Code (Cl. 23.2.1) as:

\[
l/d_{\text{max}} = \frac{F_1}{F_2}
\]

where

\[
l/d_{\text{basic}} = \begin{cases} 7 & \text{for cantilever spans} \\ 20 & \text{for simply supported spans} \\ 26 & \text{for continuous spans} \end{cases}
\]

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor \( F_{10} \):

\[
F_{10} = \frac{\text{span in metres}}{10}
\]

The modification factors \( F_1 \) (which varies with \( p_t \) and \( f_{st} \)) and \( F_2 \) (which varies with \( p_c \)) are as given in Fig. 4 and Fig. 5 of the code.

Code permits an approximate calculation of \( f_{st} \) as follows:

\[
f_{st} = (0.58 \times 415 \times 1038 / 942) = 265.12 \text{ N/mm}^2
\]

\[
F = 1.00
\]

\[
F_1 = 1.13
\]
Check for shear

Shear force at critical distance, \( V_{ud} \) (kN)

The critical section for shear is at a distance of 512 mm from the face of the support.

- **Check for adequacy of section**

  Nominal shear stress, \( \tau_v \)
  \[
  \frac{(119 \times 1000)}{(250 \times 512)} = 0.93 \text{ N/mm}^2
  \]

  The maximum shear stress is given by:
  \[
  T_{c,\text{max}} = 0.62 f_{ck}
  \]

  \[
  \Rightarrow \tau_{c,\text{max}} = (0.62 \times \sqrt{30}) = 3.40 \text{ N/mm}^2
  \]

  \( \Rightarrow \text{Adopted section is adequate} \)

- **Design shear resistance at critical section**

  At critical section, \( A_{st} \) is given by
  \[
  942 \text{ mm}^2
  \]

  Percentage of steel, \( p_t \) (%)
  \[
  0.74
  \]

  The design shear strength of the concrete, \( \tau_c \), is given by:
  \[
  \begin{align*}
  \tau_c &= \frac{0.85}{\sqrt[6]{0.85 f_{ck}}} \\
  &= \frac{1}{\sqrt[6]{0.85 \times 62}} \\
  &= 1 \\
  \end{align*}
  \]

  \[
  \text{where} \quad \frac{0.85}{\sqrt[6]{0.85 f_{ck}}} \quad \text{whichever is greater}
  \]

  For (M30 and Fe415)
  \[
  \Rightarrow \tau_c = 0.58 \text{ N/mm}^2
  \]

  \[
  \Rightarrow V_{uc} = \frac{(0.58 \times 250 \times 512)}{1000} = 74 \text{ kN}
  \]

- **Design of "vertical" stirrups**

  The shear to be resisted by steel, \( V_{us} \) is given by:
  \[
  V_{us} = V_u - V_{uc}
  \]

  \[
  \Rightarrow V_{us} = (119 - 74) = 45 \text{ kN}
  \]

  Using 8 mm bars and
  No of legs 2
Area of stirrups, $A_{sv}$ (mm$^2$) = 101

⇒ required spacing $s_v \leq \frac{(0.87 \times 415 \times 101 \times 512)}{(44.54 \times 1000)}$

⇒ Spacing, $s_v = 417$ mm

**Check whether** $\tau_v > 0.5 \tau_c$

Nominal shear stress, $\tau_v$ (N/mm$^2$) = 0.93
Design shear stress, $\tau_c$ (N/mm$^2$) = 0.58

$\tau_v > 0.5 \tau_c \quad \text{Yes}$

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress $\tau_v$ exceeds 0.5 $\tau_c$:

$$\frac{A_{sv}}{b_{sv}} = 0.4 \times \frac{0.87}{f_y} \text{When } s_v = 0.5\tau_c$$

$$s_v = \frac{2.175 \times f_y A_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

$$s_v \leq \frac{0.75 \phi}{300 \text{ mm}}$$

**Code requirements for maximum spacing.**

i) $\leq \frac{(2.175 \times 415 \times 101}{250} = 363$ mm

ii) $\leq (0.75 \times 512) = 384$ mm

iii) $\leq 300$ mm

iv) $\leq \frac{(0.87 \times 415 \times 101 \times 512)}{(44.54 \times 1000)} = 417$ mm
Beam RB1 Support

Design Parameters

Load Case 14  \[1.5*(DL - EQX)\]
Grade of Concrete M30
Grade of Steel Fe415
Characteristic compressive strength of concrete , \( f_{ck} \) (N/mm\(^2\)) 30
Characteristic yield strength of steel , \( f_y \) (N/mm\(^2\)) 415
Unit weight of concrete , \( \gamma_c \) (kN/m\(^3\)) 24
Partial safety factor for concrete 1.5
Exposure condition Mild
Nominal Cover to exposure condition( mm ) 20

Dimensions of the beam

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C/C Span of the beam , ( l ), (m)</td>
<td>5.35</td>
</tr>
<tr>
<td>Breadth of the beam , ( b ), (mm)</td>
<td>300</td>
</tr>
<tr>
<td>Overall depth of the beam , ( D ), (mm)</td>
<td>500</td>
</tr>
</tbody>
</table>

Details of reinforcements

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of tension reinforcement (mm)</td>
<td>25</td>
</tr>
<tr>
<td>Diameter of compression reinforcement (mm)</td>
<td>25</td>
</tr>
<tr>
<td>Diameter of stirrups (mm)</td>
<td>8</td>
</tr>
</tbody>
</table>

Effective depth

Effective depth , \(d\) (mm) \( = 500-20-8-25/2 = 460\)

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

<table>
<thead>
<tr>
<th></th>
<th>kN-m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsional Moment</td>
<td>0</td>
</tr>
<tr>
<td>Bending Moment Mu(kN-m)</td>
<td>235</td>
</tr>
<tr>
<td>Equivalent Bending Moment , ( M_e ) (kNm)</td>
<td>235</td>
</tr>
<tr>
<td>Shear force at critical distance , ( V_{ud} ) (kN)</td>
<td>125</td>
</tr>
<tr>
<td>Equivalent Shear (kN)</td>
<td>125</td>
</tr>
</tbody>
</table>

Singly reinforced or doubly reinforced section?

The limiting moment of resistance , \( M_{u,lim} \) is given by

\[
M_{u,lim} = 0.362f_{ck} \times \frac{b x_u}{d} \times 0.416 x_u \]

Where
- \( b \) = Breadth of the Section
- \( x_u \) = Limiting depth of Neutral Axis
- \( d \) = Effective depth of the Section

The limiting percentage of steel , \( p_{t,lim} \) is given by
The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
P_t x A_{st} x \frac{f_{ck}}{2 f_y} = 4.598 \frac{R}{f_{ck}}
\]

Where \( R = \frac{M_u}{b d^2} \)

For (M30 and Fe415)

\[
M_{u,\text{lim}} = 0.1389 f_{ck} b d^2 \\
x_{u,\text{max}} / d = 0.48
\]

\[
\Rightarrow M_{u,\text{lim}} = \left( 0.1389 \times 30 \times 300 \times 459.5^2 / 100000 \right) = 263.95 \text{ kNm}
\]

\[
\Rightarrow p_{t,\text{lim}} = \left( 41.3 \times 30 / 415 \times 0.48 \right) = 1.433
\]

If \( M_u > M_{u,\text{lim}} \), the section has to be
i) get increased by depth or width (preferably depth)
ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
M_i = 235.00 \text{ kNm} \\
M_{u,\text{lim}} = 263.95 \text{ kNm}
\]

\[
\Rightarrow \text{Section can be designed as singly reinforced.}
\]

**Determining \( A_{st} \)**

- Considering a 'balanced section' \( (x_u = x_{u,\text{max}}) \)
  \[
  A_{st} = A_{st,\text{lim}} + \Delta A_{st}
  \]
  where \( A_{st,\text{lim}} = p_{t,\text{lim}} / 100 \times (b \times d) \)

\[
\Rightarrow A_{st,\text{lim}} = \left( 1.433 / 100 \times 300 \times 459.5 \right) = 1975 \text{ mm}^2
\]

- Assuming 25 mm bars for compression steel,
  \[
  d' \approx \left( 20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2 \right) = 40.5 \text{ mm}
  \]
\[ M_u = 0.87 f_y A_{st} d \left( 1 - \frac{A_{st} f_y}{b d f_{ck}} \right) \]

\[
\begin{array}{c|c|c}
\hline
\text{Grade of steel} & \frac{d'}{d} & p_t \\
\hline
\text{Fe250} & 0.05 & 217.5 \\
& 0.10 & 217.5 \\
& 0.15 & 217.5 \\
& 0.20 & 217.5 \\
\text{Fe415} & 0.05 & 355.1 \\
& 0.10 & 351.9 \\
& 0.15 & 342.4 \\
& 0.20 & 329.2 \\
\text{Fe500} & 0.05 & 423.9 \\
& 0.10 & 411.3 \\
& 0.15 & 395.1 \\
& 0.20 & 370.3 \\
\hline
\end{array}
\]

- Assuming \( x_u = x_{u,\text{max}} \), for \( \frac{d'}{d} = \left( \frac{40.5}{459.5} \right) = 0.088 \)
  From the above table: by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \geq p_c^* \)
where \( p_c^* \) is given by

\[
\begin{align*}
p_c^* = & \frac{0.87 f_{y}}{0.447 f_{ck}} \\
\text{Actual } p_t \text{ provided : } p_t = & \ 1.42 \\
\text{Actual } p_c \text{ provided : } p_c = & \ 0.36
\end{align*}
\]

\[
\Rightarrow \ p_c^* = \left( 0.87 \times 415 \times (1.424 - 1.433) / (353.38 - 0.447 \times 30) \right)
\]

\[
\Rightarrow \ p_c^* = -0.01
\]

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting \( l/d \) ratios are specified by the Code (Cl. 23.2.1) as:

\[
\begin{align*}
l/d \text{ max} & = 7 \text{ for cantilever spans} \\
l/d \text{ basic} & = 20 \text{ for simply supported spans} \\
& = 26 \text{ for continuous spans}
\end{align*}
\]

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor \( F \)

\[
\begin{align*}
F = & \frac{10}{\text{span in metres}}
\end{align*}
\]

The modification factors \( F_1 \) (which varies with \( p_c \) and \( f_{st} \)) and \( F_2 \) (which varies with \( p_c \)) are as given in Fig.4 and Fig.5 of the code.

Code permits an approximate calculation of \( f_{st} \) as follows:

\[
\text{The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.}
\]

\[
f_{st} = 0.58 f_y \times \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}
\]

\[
\Rightarrow \ f_{st} = \left( 0.58 \times 415 \times 1784 / 1963 \right) = 218.71 \ \text{N/mm}^2
\]

\[
F = \ 1.00 \\
F_1 = \ 0.87
\]
\[ F_2 = 0.90 \]

\[ (l/d)_{\text{max}} = (26 \times 1 \times 0.87 \times 0.9) = 20.41 \]

\[ (l/d)_{\text{provided}} = 11.63 \]

\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN)

The critical section for shear is at a distance of 460 mm from the face of the support.

- **Check for adequacy of section**

  Nominal shear stress, \( \tau_v \)
  \[ (125 \times 1000 / (300 \times 460)) = 0.91 \text{ N/mm}^2 \]

  The maximum shear stress is given by:
  \[ T_{c\text{max}} = 0.62 f_{ck} \]
  \[ \Rightarrow \tau_{c,\text{max}} = (0.62 \times \text{Sqrt}(30)) = 3.40 \text{ N/mm}^2 \]

  \[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

  At critical section, \( A_{st} \) is given by
  \[ 1963 \text{ mm}^2 \]
  Percentage of steel, \( p_t \) (%)
  \[ 1.42 \]

  The design shear strength of the concrete, \( \tau_c \), is given by:
  \[ \frac{0.85 \cdot f_{ck}}{0.85 \cdot f_{ck} + 0.85 \cdot p_t \cdot 0.85} \cdot 1 \]
  \[ \text{where} \quad \frac{0.85 \cdot f_{ck}}{0.85 \cdot f_{ck} + 0.85 \cdot p_t \cdot 0.85} \text{ whichever is greater} \]

  For (M30 and Fe415)
  \[ \Rightarrow \tau_c = 0.75 \text{ N/mm}^2 \]
  \[ \Rightarrow V_{uc} = (0.75 \times 300 \times 460 / 1000) = 103 \text{ kN} \]

- **Design of "vertical" stirrups**

  The shear to be resisted by steel, \( V_{us} \) is given by:
  \[ V_{us} = V_u - V_{uc} \]
  \[ \Rightarrow V_{us} = (125 - 103) = 22 \text{ kN} \]

  Using 12 mm bars and
  No of legs 2
Area of stirrups, \( A_{sv} \) (mm\(^2\)) = 226

\[ \Rightarrow \text{required spacing } s_v \leq \left( \frac{0.87 \times 415 \times 226 \times 460}{21.84 \times 1000} \right) \]

\[ \Rightarrow \text{Spacing, } s_v = 1718 \text{ mm} \]

**Check whether** \( \tau_v > 0.5 \tau_c \)

Nominal shear stress, \( \tau_v \) (N/mm\(^2\)) = 0.91
Design shear stress, \( \tau_c \) (N/mm\(^2\)) = 0.75

\( \tau_v > 0.5 \tau_c \) \hspace{1cm} \text{Yes}

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress \( \tau_v \) exceeds 0.5 \( \tau_c \):

\[ \frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87} \frac{f_y}{f_v} \text{ When } s_v = 0.5 \tau_c \]

\[ s_v = \frac{2.175 f_y A_{sv}}{b} \]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[ s_v \square \left[ \frac{0.75 d}{300 \text{ mm}} \right] \]

**Code requirements for maximum spacing**.

i) \( < \left( \frac{2.175 \times 415 \times 226}{300} \right) = 681 \text{ mm} \)

ii) \( \leq \left( \frac{0.75 \times 459.5}{300} \right) = 345 \text{ mm} \)

iii) \( \leq 300 \text{ mm} \)

iv) \( \leq \left( \frac{0.87 \times 415 \times 226 \times 460}{21.84 \times 1000} \right) = 1718 \text{ mm} \)
Beam RB1 Mid

Design Parameters

Load Case 14 \[1.5*(DL - EQX)\]
Grade of Concrete \(M30\)
Grade of Steel \(Fe415\)
Characteristic compressive strength of concrete , \(f_{ck}\) (N/mm\(^2\)) \(30\)
Characteristic yield strength of steel , \(f_y\) (N/mm\(^2\)) \(415\)
Unit weight of concrete , \(\gamma_c\) (kN/m\(^3\)) \(24\)
Partial safety factor for concrete \(1.5\)
Exposure condition \(Mild\)
Nominal Cover to exposure condition (mm) \(20\)

Dimensions of the beam

C/C Span of the beam, \(l\), (m) \(5.35\)
Breadth of the beam, \(b\) (mm) \(300\)
Overall depth of the beam, \(D\) (mm) \(500\)

Details of reinforcements

Diameter of tension reinforcement (mm) \(25\)
Diameter of compression reinforcement (mm) \(25\)
Diameter of stirrups (mm) \(8\)

Effective depth

Effective depth , \(d\) (mm) \(\left(500-20-8-25/2\right) = 460\)

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

<table>
<thead>
<tr>
<th>Moment Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsional Moment</td>
<td>0 kN-m</td>
</tr>
<tr>
<td>Bending Moment (Mu) (kN-m)</td>
<td>150</td>
</tr>
<tr>
<td>Equivalent Bending Moment (M_e) (kNm)</td>
<td>150</td>
</tr>
<tr>
<td>Shear force at critical distance (V_{ud}) (kN)</td>
<td>120</td>
</tr>
<tr>
<td>Equivalent Shear (kN)</td>
<td>120</td>
</tr>
</tbody>
</table>

Singly reinforced or doubly reinforced section?

The limiting moment of resistance , \(M_{u,lim}\) is given by

\[M_{u,lim} = 0.362f_{ck} \cdot \frac{b \cdot x_{u,\text{max}}}{d} \cdot 0.416x_{u,\text{max}}\]

Where \(b\) = Breadth of the Section
\(x_{u,\text{max}}\) = Limiting depth of Neutral Axis
\(d\) = Effective depth of the Section

The limiting percentage of steel , \(\rho_{u,lim}\) is given by
The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

For (M30 and Fe415)

\[
\frac{Pt}{100} \times \frac{A_{st}}{bd} \times \frac{f_{ck}}{2f_y} = 4.598 \times \frac{R}{f_{ck}}
\]

Where \( R = \frac{M_u}{bd^2} \)

For (M30 and Fe415)

\( M_u,\text{lim} = 0.1389 \times f_{ck} \times b \times d^2 \)

\( x_{u,max} / d = 0.48 \)

\( M_\text{u,lim} = (0.1389 \times 30 \times 300 \times 459.5^2 / 1000000) = 263.95 \text{ kNm} \)

\( p_{t,\text{lim}} = (41.3 \times 30 / 415 \times 0.48) = 1.433 \)

If \( M_u > M_u,\text{lim} \), the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If \( M_u < M_u,\text{lim} \), the section can be designed as singly reinforced.

**Check for the type of section**

\( M_u = 150.00 \text{ kNm} \)

\( M_u,\text{lim} = 263.95 \text{ kNm} \)

\( \Rightarrow \) Section can be designed as singly reinforced.

**Determining \( A_{st} \)**

- Considering a 'balanced section' (\( x = x_{u,\text{max}} \))

\( A_{st} = A_{st,\text{lim}} + \Delta A_{st} \)

where \( A_{st,\text{lim}} = p_{t,\text{lim}} / (b \times d) \)

\( \Rightarrow A_{st,\text{lim}} = (1.433 / 100 \times 300 \times 459.5) = 1975 \text{ mm}^2 \)

- Assuming 25 mm bars for compression steel,

\( d^* \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2) = 40.5 \text{ mm} \)
\[ \mu = 0.87 \cdot f_y \cdot A_{st} \cdot d \cdot (1 - (A_{st} \cdot f_y) / b \cdot d \cdot f_{ck}) \]

\[ A_{st \text{ Reqd}} = 1006 \text{ mm}^2 \]

\[ \therefore \text{ No of tension bars required ( # )} \]
\[ (1006 / ( \pi / 4 \times 25^2 ) = 3.00 \]

\[ \text{Actual percentage of steel, } p_t \text{ ( % )} \]
\[ (3 \times \pi / 4 \times 25^2 / 300 / 460 \times 100) = 1.07 \]

\[ \text{Actual area of steel, } A_{st} \text{ ( mm}^2 \text{)} \]
\[ (3 \times \pi / 4 \times 25^2) = 1473 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by

\[ A_{sc} = \frac{0.87 \cdot f_y}{f_{sc} - 0.447 \cdot f_{ck}} \]

or

\[ p_c = \frac{0.87 \cdot f_y}{f_{sc} - 0.447 \cdot f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,\text{max}} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d' / d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td></td>
</tr>
<tr>
<td>Fe415</td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
<td></td>
</tr>
<tr>
<td>Fe500</td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
<td></td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u,\text{max}} \), for \( d' / d = (40.5 / 459.5) = 0.088 \)
  From the above table: by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \geq p_c' \)
where $p_c^*$ is given by

$$p_c^* \leq \frac{0.87 f_y}{0.447 f_{ck}}$$

Actual $p_t$ provided : $p_t = 1.07$

Actual $p_c$ provided : $p_c = 0.71$

$\Rightarrow p_c^* = \frac{(0.87 \times 415 \times (1.068 - 1.433))}{(353.38 - 0.447 \times 30)}$

$\Rightarrow p_c^* = -0.39$

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

$$\frac{l}{d} \leq 7 \text{ for cantilever spans}$$
$$\frac{l}{d} \leq 20 \text{ for simply supported spans}$$
$$\frac{l}{d} \leq 26 \text{ for continuous spans}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor $F_{10}$.

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig.4 and Fig.5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

$$f_{st} = \frac{0.58 f_y \times 1222}{1473} = 199.78 \text{ N/mm}^2$$

$F = 1.00$
$F_1 = 1.10$
\[ F_2 = 1.15 \]

\[ \therefore \frac{l}{d} \max = \left( 26 \times 1 \times 1.1 \times 1.15 \right) = 33.00 \]

\( \frac{l}{d} \) provided = \( \frac{26 \times 1 \times 1.1 \times 1.15}{11.63} \) = 33.00

\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN)

The critical section for shear is at a distance of 460 mm from the face of the support.

**Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[ (120 \times 1000) / (300 \times 460) = 0.87 \text{ N/mm}^2 \]

The maximum shear stress is given by:

\[ Tc \max = 0.62 f_{ck} \]

\[ \Rightarrow \tau_{c,\max} = (0.62 \times \sqrt{30}) = 3.40 \text{ N/mm}^2 \]

\[ \Rightarrow \text{Adopted section is adequate} \]

**Design shear resistance at critical section**

At critical section, \( A_{sd} \) is given by 1473 mm\(^2\)

Percentage of steel, \( p_t \) (\%)

1.07

The design shear strength of the concrete, \( \tau_c \), is given by:

\[ \frac{0.86}{\tau_c} = 6 \]

\[ \Rightarrow \tau_c = 6.89 p_t \]

where \( \tau_c \) whichever is greater

\[ \text{For (M30 and Fe415)} \]

\[ \Rightarrow \tau_c = 6.89 \times 0.07 = 0.67 \text{ N/mm}^2 \]

\[ \Rightarrow V_{uc} = (0.67 \times 300 \times 460 / 1000) = 93 \text{ kN} \]

**Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by:

\[ V_{us} = V_u - V_{uc} \]

\[ \Rightarrow V_{us} = (120 - 93) = 27 \text{ kN} \]

Using 12 mm bars and

No of legs 4
Area of stirrups, \( A_{sv} \) (mm\(^2\)) = 452

\[ \Rightarrow \text{required spacing } s_v \leq \frac{0.87 \times 415 \times 452 \times 460}{(27.29 \times 1000)} \]

\[ \Rightarrow \text{Spacing, } s_v = 2750 \text{ mm} \]

**Check whether** \( \tau_v > 0.5 \tau_c \)

Nominal shear stress, \( \tau_v \) (N/mm\(^2\)) = 0.87

Design shear stress, \( \tau_c \) (N/mm\(^2\)) = 0.67

\( \tau_v > 0.5 \tau_c \quad \Rightarrow \text{Yes} \)

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress \( \tau_v \) exceeds 0.5 \( \tau_c \):

\[
\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} \quad \text{When } s_v = 0.5 \tau_c
\]

\[
s_v = \frac{2.175 f_y A_{sv}}{b}
\]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[ s_v \leq \frac{0.75 d}{300 \text{ mm}} \]

**Code requirements for maximum spacing..**

\[
i) \quad < \frac{(2.175 \times 415 \times 452)}{300} = 1361 \text{ mm}
\]

\[
ii) \quad \leq \frac{0.75 \times 459.5}{300} \quad = \quad 345 \text{ mm}
\]

\[
iii) \quad \leq \quad 300 \text{ mm} \quad = \quad 300 \text{ mm}
\]

\[
iv) \quad \leq \frac{0.87 \times 415 \times 452 \times 460}{(27.29 \times 1000)} = 2750 \text{ mm}
\]

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**Beam RB2 Support**

**Design Parameters**

Load Case 14 \([1.5 \times (DL - EQX)]\)
Grade of Concrete \(M30\)
Grade of Steel \(Fe415\)
Characteristic compressive strength of concrete, \(f_{ck}\) (N/mm\(^2\)) \(30\)
Characteristic yield strength of steel, \(f_y\) (N/mm\(^2\)) \(415\)
Unit weight of concrete, \(\gamma_c\) (kN/m\(^3\)) \(24\)
Partial safety factor for concrete \(1.5\)
Exposure condition \(Mild\)
Nominal Cover to exposure condition (mm) \(20\)

**Dimensions of the beam**

- C/C Span of the beam, \(l\) (m) \(5.36\)
- Breadth of the beam, \(b\) (mm) \(300\)
- Overall depth of the beam, \(D\) (mm) \(400\)

**Details of reinforcements**

- Diameter of tension reinforcement (mm) \(25\)
- Diameter of compression reinforcement (mm) \(25\)
- Diameter of stirrups (mm) \(8\)

**Effective depth**

- Effective depth, \(d\) (mm) \(610\)

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

- Torsional Moment \(16\) kN-m
- Bending Moment \(325\) kN-m
- Equivalent Bending Moment, \(M_e\) (kNm) \(355\)
- Shear force at critical distance, \(V_{ud}\) (kN) \(70\)
- Equivalent Shear (kN) \(155\)

**Singly reinforced or doubly reinforced section?**

The *limiting moment of resistance*, \(M_{u,lim}\) is given by

\[
M_{u,lim} = 0.362f_{ck} \times \frac{b x_u \max}{d} \times 0.416x_u \max
\]

Where \(b =\) Breadth of the Section
\(x_u \max =\) Limiting depth of Neutral Axis
\(d =\) Effective depth of the Section

The limiting percentage of steel, \(p_{u,lim}\) is given by
The area of steel for a singly reinforced section with width $b$ and depth $d$ and ultimate moment $M_u$ is given by:

For (M30 and Fe415)

$$x_{u,\text{max}} / d = 0.48$$

$$M_{u,\text{lim}} = (0.1389 \times 30 \times 300 \times 609.5^2 / 1000000) = 464.40 \text{ kNm}$$

$$p_{t,\text{lim}} = (41.3 \times 30 / 415 \times 0.48) = 1.433$$

If $M_u > M_{u,\text{lim}}$, the section has to be
i) get increased by depth or width (preferably depth)
ii) doubly reinforced

If $M_u < M_{u,\text{lim}}$, the section can be designed as singly reinforced.

Check for the type of section

$$M_u = 354.80 \text{ kNm}$$

$$M_{u,\text{lim}} = 464.40 \text{ kNm}$$

⇒ Section can be designed as singly reinforced.

Determining $A_{st}$

• Considering a 'balanced section' ($x_u = x_{u,\text{max}}$)

$$A_{st} = A_{st,\text{lim}} + \Delta A_{st}$$

where $A_{st,\text{lim}} = p_{t,\text{lim}} / 100 \ (b \times d)$

$$\Rightarrow A_{st,\text{lim}} = (1.433 / 100 \times 300 \times 609.5) = 2620 \text{ mm}^2$$

• Assuming 25 mm bars for compression steel,

$$d' = (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2) = 40.5 \text{ mm}$$
\[ \mu = 0.87 f_y \ast d (1 - \frac{\ast d}{b * f_{ck}}) \]

\[ A_{\text{st Reqd}} = 1880 \text{ mm}^2 \]

\[ \ast \text{ No of tension bars required} \ (\#) \]
\[ \frac{1880}{(\pi / 4 \times 25^2)} = 4.00 \]

\[ \ast \text{ Actual percentage of steel , } p_t (\%) \]
\[ \frac{4 \times \pi / 4 \times 25^2 / 300 / 610 \times 100}{(4 \times \pi / 4 \times 25^2)} = 1.07 \]

\[ \ast \text{ Actual area of steel , } A_{\text{st}} (\text{mm}^2) \]
\[ \frac{4 \times \pi / 4 \times 25^2}{(4 \times \pi / 4 \times 25^2)} = 1963 \]

**Determining \( A_{sc} \)**

The compression steel , \( A_{sc} \), is given by

\[ A_{sc} \begin{cases} \frac{0.87 f_y}{f_{sc}} \frac{1}{0.447 f_{ck}} \\ \text{or} \\ \frac{0.87 f_y}{f_{sc}} \frac{P_{tlim}}{0.447 f_{ck}} \end{cases} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,\text{max}} \) for various \( d'/d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( \frac{d'}{d} )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
<td></td>
</tr>
<tr>
<td>Fe500</td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
<td></td>
</tr>
</tbody>
</table>

- \( \ast \) Assuming \( x_u = x_{u,\text{max}} \), for \( d'/d = \frac{40.5}{609.5} = 0.066 \)

From the above table : by interpolation

**Design Check**

- \( \ast \) To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_t \geq p_{t^*} \).
where \( p_c^* \) is given by

\[
p_c^* = \frac{0.87 f_y}{0.447 f_{ck}}
\]

Actual \( p_t \) provided: \( p_t = 1.07 \)
Actual \( p_c \) provided: \( p_c = 0.54 \)

\[
p_c^* = (0.87 \times 415 \times (1.074 - 1.433) / (355.03 - 0.447 \times 30))
\]

\[
p_c = -0.38
\]

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans up to 10 m, the limiting \( l/d \) ratios are specified by the Code (Cl. 23.2.1) as:

\[
\frac{l}{d_{\text{max}}} = \begin{cases} 
 7 & \text{for cantilever spans} \\
 20 & \text{for simply supported spans} \\
 26 & \text{for continuous spans}
\end{cases}
\]

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor \( F \)

The modification factors \( F_1 \) (which varies with \( p_t \) and \( f_{st} \)) and \( F_2 \) (which varies with \( p_c \)) are as given in Fig.4 and Fig.5 of the code.

Code permits an approximate calculation of \( f_{st} \) as follows:

\[
f_{st} = 0.58 f_y \times \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}
\]

\[
\Rightarrow f_{st} = (0.58 \times 415 \times 2087 / 1963) = 255.82 \text{ N/mm}^2
\]

\[
F = 1.00 \\
F_1 = 0.91
\]
\[ F_2 = 1.06 \]

\[ (l/d)_{\text{max}} = (26 \times 1 \times 0.91 \times 1.06) = 25.16 \]

\[ (l/d)_{\text{provided}} = 13.72 \]

\[ \therefore \] Hence O.K.

**Check for shear**

Shear force at critical distance, \( V_u \) (kN)

155.33333

The critical section for shear is at a distance of 610 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[
(155.33333 \times 1000 / (300 \times 610)) = 0.85 \text{ N/mm}^2
\]

The maximum shear stress is given by:

\[ T_{c\text{ max}} = 0.62 f_{ck} \]

\[ \Rightarrow \tau_{c,\text{max}} = (0.62 \times \sqrt{30}) = 3.40 \text{ N/mm}^2 \]

\[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

At critical section, \( A_{st} \) is given by

1963 mm\(^2\)

Percentage of steel, \( p_t (\%) \)

1.07

The design shear strength of the concrete, \( \tau_c \), is given by:

\[ \begin{align*}
\frac{0.85}{0.62} & \quad \frac{1}{0.8 f_{ck}} \\
0.8 f_{ck} & \quad 6.89 p_t \\
\end{align*} \]

whichever is greater

\[ \tau_c = 0.67 \text{ N/mm}^2 \]

\[ \Rightarrow V_{uc} = (0.67 \times 300 \times 610 / 1000) = 123 \text{ kN} \]

- **Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by:

\[ V_{us} = V_u - V_{uc} \]

\[ \Rightarrow V_{us} = (155 - 123) = 32 \text{ kN} \]

Using 12 mm bars and

No of legs 2
Area of stirrups, \( A_{sv} \) (mm\(^2\)) = 226

\[ \Rightarrow \text{required spacing} \; s_v \leq \left( \frac{0.87 \times 415 \times 226 \times 610}{32.12 \times 1000} \right) \]

\[ \Rightarrow \text{Spacing}, \; s_v = 1550 \text{ mm} \]

**Check whether** \( \tau_v > 0.5 \tau_c \)

Nominal shear stress, \( \tau_v \) (N/mm\(^2\)) = 0.85
Design shear stress, \( \tau_c \) (N/mm\(^2\)) = 0.67

\( \tau_v > 0.5 \tau_c \) \quad Yes

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress \( \tau_v \) exceeds 0.5 \( \tau_c \):

\[
\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 \; f_y} \quad \text{When} \; s_v = 0.5t_c
\]

\[
s_v = \frac{2.175 \; f_y A_{sv}}{b}
\]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[ s_v \geq \frac{0.75 \; d}{300 \; \text{mm}} \]

**Code requirements for maximum spacing.**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>i) ( &lt; ) ( \left( 2.175 \times 415 \times 226 / 300 \right) )</td>
<td>681 mm</td>
</tr>
<tr>
<td>ii) ( \leq ) ( \left( 0.75 \times 609.5 \right) )</td>
<td>457 mm</td>
</tr>
<tr>
<td>iii) ( \leq ) 300 mm</td>
<td>300 mm</td>
</tr>
<tr>
<td>iv) ( \leq ) ( \left( 0.87 \times 415 \times 226 \times 610 / (32.12 \times 1000) \right) )</td>
<td>1550 mm</td>
</tr>
</tbody>
</table>
**Beam RB2 Mid**

**Design Parameters**

Load Case 14  \[1.5 \times (DL - EQX)\]
Grade of Concrete M30
Grade of Steel Fe415
Characteristic compressive strength of concrete , \(f_{ck}\) (N/mm\(^2\)) 30
Characteristic yield strength of steel , \(f_y\) (N/mm\(^2\)) 415
Unit weight of concrete , \(\gamma_c\) (kN/m\(^3\)) 24
Partial safety factor for concrete 1.5
Exposure condition Mild
Nominal Cover to exposure condition( mm ) 20

**Dimensions of the beam**

C/C Span of the beam , \(l\) (m) 5.36
Breadth of the beam , \(b\) (mm) 300
Overall depth of the beam , \(D\) (mm) 400

**Details of reinforcements**

Diameter of tension reinforcement (mm) 25
Diameter of compression reinforcement (mm) 25
Diameter of stirrups (mm) 8

**Effective depth**

Effective depth , \(d\) (mm) \((650-20-8-25/2) = 610\)

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

<table>
<thead>
<tr>
<th>Moment Type</th>
<th>Value (kN-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsional Moment</td>
<td>16</td>
</tr>
<tr>
<td>Bending Moment Mu</td>
<td>190</td>
</tr>
<tr>
<td>Equivalent Bending Moment , (M_e)</td>
<td>220</td>
</tr>
<tr>
<td>Shear force at critical distance , (V_{ud})</td>
<td>165</td>
</tr>
<tr>
<td>Equivalent Shear (kN)</td>
<td>250</td>
</tr>
</tbody>
</table>

**Singly reinforced or doubly reinforced section ?**

The limiting moment of resistance , \(M_{u,lim}\) is given by

\[
m_{ulim} = 0.362f_{ck} \times \frac{b\times x_{umax}}{d} \times 0.416x_{umax}
\]

Where \(b = \) Breadth of the Section
\(x_{umax} = \) Limiting depth of Neutral Axis
\(d = \) Effective depth of the Section

The limiting percentage of steel , \(p_{slim}\) is given by
The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
Pt_{\text{lim}} = 41.61 \times \frac{f_{ck} \cdot x_{u,\text{max}}}{f_y \cdot d}
\]

Where \( f_{ck} = \text{Characteristic Compressive strength of concrete} \)

\( f_y = \text{Characteristic strength of steel} \)

The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
\frac{Pt}{100} \times \frac{x}{bd} \times \frac{f_{ck}}{2f_y} = 4.598 \times \frac{R}{f_{ck}}
\]

Where \( R = \frac{M_u}{bd^2} \)

For (M30 and Fe415) \( M_u,\text{lim} = 0.1389 \times f_{ck} \cdot b \cdot d^2 \)

\[
x_{u,\text{max}} / d = 0.48
\]

\[
\Rightarrow M_u,\text{lim} = (0.1389 \times 30 \times 300 \times 609.5^2 / 1000000) = 464.40 \text{ kNm}
\]

\[
\Rightarrow p_{t,\text{lim}} = (41.3 \times 30 / 415 \times 0.48) = 1.433
\]

If \( M_u > M_u,\text{lim} \), the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If \( M_u < M_u,\text{lim} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
\begin{align*}
M_u &= 219.80 \text{ kNm} \\
M_u,\text{lim} &= 464.40 \text{ kNm}
\end{align*}
\]

\[\Rightarrow \text{Section can be designed as singly reinforced.}\]

**Determining \( A_{st} \)**

- Considering a ‘balanced section’ (\( x_u = x_{u,\text{max}} \))

\[
A_{st} = A_{st,\text{lim}} + \Delta A_{st}
\]

where \( A_{st,\text{lim}} = p_{t,\text{lim}} / 100 \times (b \times d) \)

\[
\Rightarrow A_{st,\text{lim}} = (1.433 / 100 \times 300 \times 609.5) = 2620 \text{ mm}^2
\]

- Assuming 25 mm bars for compression steel,

\[
d' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2) = 40.5 \text{ mm}
\]
\[ \mu = 0.87 \cdot f_y \cdot A_{st} \cdot d \left( 1 - \frac{A_{st} \cdot f_y}{b \cdot d \cdot f_{ck}} \right) \]

<table>
<thead>
<tr>
<th>Ast Reqd</th>
<th>1088 mm²</th>
</tr>
</thead>
</table>

\[ \therefore \text{ No of tension bars required ( # )} \]
\[ = \frac{1088}{\pi / 4 \times 25^2} = 3.00 \]

\[ \text{Actual percentage of steel, } p_t \ (\%) \]
\[ = \frac{3 \times \pi / 4 \times 25^2}{300 \times 610 \times 100} = 0.81 \]

\[ \text{Actual area of steel, } A_{st} \ (\text{mm}^2) \]
\[ = \frac{3 \times \pi / 4 \times 25^2}{610 \times 100} = 1473 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by

\[ A_{sc} \leq \frac{0.87 \cdot f_y}{f_{sc}} \cdot \frac{1 - \frac{d'}{d}}{0.447 \cdot f_{ck}} \]

or

\[ p_c \leq \frac{0.87 \cdot f_y}{f_{sc}} \cdot \frac{p_t - p_{lim}}{0.447 \cdot f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,\text{max}} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d' / d )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Fe250</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td>355.1</td>
</tr>
<tr>
<td>Fe500</td>
<td>423.9</td>
</tr>
</tbody>
</table>

\[ \text{Assuming } x_u = x_{u,\text{max}}, \text{ for } d' / d = \left( \frac{40.5}{609.5} \right) = 0.066 \]

From the above table: by interpolation

**Design Check**

\[ \text{To ensure } x_u = x_{u,\text{max}}, \text{ it suffices to establish } p_c \geq p_c^* \]
where $p_c^*$ is given by

$$p_c^* = \frac{0.87 f_y}{0.447 f_{ck}}$$

Actual $p_t$ provided: $p_t = 0.81$
Actual $p_c$ provided: $p_c = 0.81$

$$\Rightarrow p_c^* = \frac{0.87 \times 415 \times (0.805 - 1.433)}{(355.03 - 0.447 \times 30)}$$

$$\Rightarrow p_c = -0.66$$

*Section is not over reinforced*

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

<table>
<thead>
<tr>
<th>$l/d$ maximum</th>
<th>$l/d$ Basic</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 for cantilever spans</td>
<td>20 for simply supported spans</td>
</tr>
<tr>
<td>26 for continuous spans</td>
<td></td>
</tr>
</tbody>
</table>

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor $F$

$$F = \frac{10}{\text{span in metres}}$$

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig. 4 and Fig. 5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_{st} = \frac{0.58 f_y}{\frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}}$$

$$\Rightarrow f_{st} = \frac{(0.58 \times 415 \times 1430)}{1430} = 233.69 \text{ N/mm}^2$$

$$F = 1.00$$
$$F_1 = 1.19$$
F₂ = 1.19

\[ \therefore \frac{l}{d}_{\text{max}} = \left( 26 \times 1 \times 1.19 \times 1.19 \right) = 36.82 \]
\[ \left( \frac{l}{d} \right)_{\text{provided}} = 13.72 \]
\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN) 250.3333

The critical section for shear is at a distance of 610 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[ \left( \frac{250.3333}{1000} \times \left( \frac{300 \times 610}{3000} \right) \right) = 1.37 \text{ N/mm}^2 \]

The maximum shear stress is given by:

\[ Tc_{\text{max}} = 0.62 \cdot f_{ck} \]

\[ \Rightarrow \tau_{c,\text{max}} = (0.62 \times \sqrt{30}) = 3.40 \text{ N/mm}^2 \]

\[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

At critical section, \( A_{st} \) is given by 1473 mm²

Percentage of steel, \( p_t \) (% ) 0.81

The design shear strength of the concrete, \( \tau_c \), is given by:

\[ \frac{0.85}{6} \left( \frac{6.89 \cdot p_t}{1} \right) \]

where \( \frac{0.85}{6} \) whichever is greater

For (M30 and Fe415)

\[ \Rightarrow \tau_c = 0.60 \text{ N/mm}^2 \]

\[ \Rightarrow V_{uc} = \left( 0.6 \times 300 \times 610 / 1000 \right) = 110 \text{ kN} \]

- **Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by:

\[ V_{us} = V_u - V_{uc} \]

\[ \Rightarrow V_{us} = (250 - 110) = 140 \text{ kN} \]

Using 12 mm bars and No of legs 2
Area of stirrups, $A_{sv}$ (mm$^2$) = 226

$⇒$ required spacing $s_v \leq \left( \frac{0.87 \times 415 \times 226 \times 610}{140.11 \times 1000} \right)$

$⇒$ Spacing, $s_v = 355$ mm

*Check whether $\tau_v > 0.5 \tau_c$*

Nominal shear stress, $\tau_v$ (N/mm$^2$) = 1.37

Design shear stress, $\tau_c$ (N/mm$^2$) = 0.60

$\tau_v > 0.5 \tau_c$  

Yes

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress $\tau_v$ exceeds 0.5 $\tau_c$:

$$ \frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} $$

*When $s_v = 0.5 \tau_c$*

$$ s_v = \frac{2.175 f_y A_{sv}}{b} $$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

$$ s_v \leq \frac{0.75 \, \phi}{300 \, \text{mm}} $$

Code requirements for maximum spacing:

i) $< \left( \frac{2.175 \times 415 \times 226}{300} \right) = 681$ mm

ii) $\leq \left( 0.75 \times 609.5 \right) = 457$ mm

iii) $\leq 300$ mm = 300 mm

iv) $\leq \left( \frac{0.87 \times 415 \times 226 \times 610}{140.11 \times 1000} \right) = 355$ mm
**Beam RB3 Support**

**Design Parameters**

Load Case 16 \[1.5^* (DL - EQZ)\]

- **Grade of Concrete**: M30
- **Grade of Steel**: Fe415
- **Characteristic compressive strength of concrete**, \( f_{ck} \) (N/mm\(^2\)): 30
- **Characteristic yield strength of steel**, \( f_y \) (N/mm\(^2\)): 415
- **Unit weight of concrete**, \( \gamma_c \) (kN/m\(^3\)): 24
- **Partial safety factor for concrete**: 1.5
- **Exposure condition**: Mild
- **Nominal Cover to exposure condition (mm)**: 20

**Dimensions of the beam**

- **C/C Span of the beam**, \( l \) (m): 10.80
- **Breadth of the beam**, \( b \) (mm): 300
- **Overall depth of the beam**, \( D \) (mm): 850

**Details of reinforcements**

- **Diameter of tension reinforcement** (mm): 25
- **Diameter of compression reinforcement** (mm): 25
- **Diameter of stirrups** (mm): 8

**Effective depth**

- **Effective depth**, \( d \) (mm): \((850-20-8-25/2) = 810\)

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

- **Torsional Moment**: 6 kN-m
- **Bending Moment**, \( M_u \) (kN-m): 803
- **Equivalent Bending Moment**, \( M_e \) (kNm): 817
- **Shear force at critical distance**, \( V_{ud} \) (kN): 377
- **Equivalent Shear** (kN): 409

**Singly reinforced or doubly reinforced section?**

The **limiting moment of resistance**, \( M_{u,lim} \) is given by

\[ M_{ulim} = 0.362f_{ck} \cdot \frac{bx_{u,\text{max}}}{d} \cdot 0.416x_{u,\text{max}} \]

Where \( b \) = Breadth of the Section
\( x_{u,\text{max}} \) = Limiting depth of Neutral Axis
\( d \) = Effective depth of the Section

The limiting percentage of steel, \( p_{u,\text{lim}} \) is given by
The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
\frac{P_t}{100} \times \frac{x_{u,\text{max}}}{\frac{f_c}{f_y}} = 4.598 \frac{R}{f_{c,k}}
\]

Where \( f_{c,k} = \text{Characteristic Compressive strength of concrete} \)
\( f_y = \text{Characteristic strength of steel} \)

The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
\frac{P_t}{100} \times \frac{x_{u,\text{max}}}{\frac{f_c}{f_y}} = 4.598 \frac{R}{f_{c,k}}
\]

For (M30 and Fe415)

\[
M_{u,\text{lim}} = \frac{0.48}{d} = 0.48
\]

\[
M_{u,\text{lim}} = 819.18 \text{ kNm}
\]

\[
p_{\text{lim}} = 1.433
\]

If \( M_u > M_{u,\text{lim}} \), the section has to be
- i) get increased by depth or width (preferably depth)
- ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

Check for the type of section

\[
M_u = 816.53 \text{ kNm}
\]

\[
M_{u,\text{lim}} = 819.18 \text{ kNm}
\]

\[
\Rightarrow \text{Section can be designed as singly reinforced.}
\]

Determining \( A_{st} \)

- Considering a 'balanced section' (\( x_u = x_{u,\text{max}} \))

\[
A_{st} = A_{st,\text{lim}} + \Delta A_{st}
\]

where \( A_{st,\text{lim}} = p_{\text{lim}} / 100 (b \times d) \)

\[
\Rightarrow A_{st,\text{lim}} = (1.433 / 100 \times 300 \times 809.5) = 3480 \text{ mm}^2
\]

- Assuming 25 mm bars for compression steel,

\[
d' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2) = 40.5 \text{ mm}
\]
\[ M_u = 0.87 f_y^* A_s t * d (1 - (A_s t * f_y)/b* d * f_{ck}) \]

\[ A_{st \text{ Req d}} = 3486 \text{ mm}^2 \]

\[ \therefore \text{No of tension bars required ( # )} \]
\[ (3486 / (\pi / 4 \times 25^2)) = 8.00 \]

Actual percentage of steel, \( p_t (\%) \)
\[ (8 \times \pi / 4 \times 25^2 / 300 / 810 \times 100) = 1.62 \]

Actual area of steel, \( A_{st} (\text{mm}^2) \)
\[ (8 \times \pi / 4 \times 25^2) = 3927 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by

\[ A_{sc} = \frac{0.87 f_y^*}{f_{sc} - 0.447 f_{ck}} \]

or

\[ p_c = \frac{0.87 f_y}{f_{sc} - 0.447 f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u, \text{max}} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d' / d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td></td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td></td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
</tr>
<tr>
<td>Fe500</td>
<td></td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u, \text{max}} \), for \( d' / d = (40.5 / 809.5) = 0.050 \)
  
  From the above table: by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u, \text{max}} \), it suffices to establish \( p_c \geq p_c^* \).
where $p_c^*$ is given by

\[
p_c^* = \frac{0.87 f_y}{0.447 f_{ck}}
\]

Actual $p_t$ provided: $p_t = 1.62$
Actual $p_c$ provided: $p_c = 0.20$

\[\Rightarrow p_c^* = (0.87 \times 415 \times (1.617 - 1.433) / (355.1 - 0.447 \times 30))\]
\[\Rightarrow p_c^* = 0.19\]

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

\[
F = \frac{7}{l/d_{\text{max}}} \quad \text{for cantilever spans}
\]
\[
F = \frac{20}{l/d_{\text{basic}}} \quad \text{for simply supported spans}
\]
\[
F = 26 \quad \text{for continuous spans}
\]

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor $F$.

\[
F = \frac{10}{\text{span in metres}}
\]

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig.4 and Fig.5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

\[
f_{st} = \frac{0.58 f_y \text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}
\]

\[\Rightarrow f_{st} = \frac{(0.58 \times 415 \times 3471 / 3927)}{212.73} = \text{N/mm}^2
\]

$F = 0.93$
$F_1 = 0.83$
\[ F_2 = 0.68 \]

\[
\therefore \quad \frac{l}{d}_{\text{max}} = \frac{(26 \times 0.93 \times 0.83 \times 0.68)}{13.48}
\]

\[
\frac{l}{d}_{\text{provided}} = 13.34 \Rightarrow \text{Hence O.K.}
\]

**Check for shear**

Shear force at critical distance, \(V_{ud}\) (kN)

\[ V_{ud} = 409 \]

The critical section for shear is at a distance of 810 mm from the face of the support.

- **Check for adequacy of section**

  Nominal shear stress, \(\tau_v\)
  
  \[
  \frac{(409 \times 1000)}{(300 \times 810)} = 1.68 \text{ N/mm}^2
  \]

  The maximum shear stress is given by:
  
  \[ Tc_{\text{max}} = 0.62 f_{ck} \]
  
  \[
  \Rightarrow \quad \tau_{c,\text{max}} = (0.62 \times \text{sqrt}(30)) = 3.40 \text{ N/mm}^2
  \]

  \[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

  At critical section, \(A_s\) is given by 3927 mm\(^2\)

  Percentage of steel, \(p_t\) (%)

  1.62

  The design shear strength of the concrete, \(\tau_c\), is given by:

  \[
  \tau_c = \begin{cases} \frac{0.85 f_{ck}}{6} & \text{where } \frac{0.85 f_{ck}}{6} \leq \frac{0.85 f_{ck}}{6.89 p_t} \leq 1 \\
  \frac{0.85 f_{ck}}{6.89 p_t} & \text{whichever is greater} \end{cases}
  \]

  For (M30 and Fe415)

  \[
  \Rightarrow \quad \tau_c = 0.78 \text{ N/mm}^2
  \]

  \[
  \Rightarrow \quad V_{uc} = (0.78 \times 300 \times 810 / 1000) = 190 \text{ kN}
  \]

- **Design of "vertical" stirrups**

  The shear to be resisted by steel, \(V_{us}\) is given by:
  
  \[ V_{us} = V_u \cdot V_{uc} \]

  \[
  \Rightarrow \quad V_{us} = (409 - 190) = 219 \text{ kN}
  \]

  Using 12 mm bars and

  No of legs 2
Area of stirrups, $A_{sv}$ (mm$^2$) 226

⇒ required spacing $s_v \leq (0.87 \times 415 \times 226 \times 810 / (218.81 \times 1000))$

⇒ Spacing, $s_v = 302$ mm

**Check whether $\tau_v > 0.5 \tau_c$**

Nominal shear stress, $\tau_v$ (N/mm$^2$) 1.68
Design shear stress, $\tau_c$ (N/mm$^2$) 0.78

$\tau_v > 0.5 \tau_c$  \hspace{1cm} Yes

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress $\tau_v$ exceeds 0.5 $\tau_c$:

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} \quad \text{When} \quad s_v = 0.5 \tau_c$$

$$s_v = \frac{2.175 f_y A_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

$$s_v \leq \frac{0.75 d}{300 \text{ mm}}$$

Code requirements for maximum spacing:

i) $\leq (2.175 \times 415 \times 226 / 300) = 681$ mm
ii) $\leq (0.75 \times 809.5) = 607$ mm
iii) $\leq 300$ mm
iv) $\leq (0.87 \times 415 \times 226 \times 810 / (218.81 \times 1000)) = 302$ mm
**Beam RB3 Mid**

*Design Parameters*

Load Case 16 \[1.5*(DL - EQZ)\]

Grade of Concrete \[M30\]

Grade of Steel \[Fe415\]

Characteristic compressive strength of concrete \(f_{ck}\) (N/mm\(^2\)) \[30\]

Characteristic yield strength of steel \(f_y\) (N/mm\(^2\)) \[415\]

Unit weight of concrete \(\gamma_c\) (kN/m\(^3\)) \[24\]

Partial safety factor for concrete \[1.5\]

Exposure condition \[Mild\]

Nominal Cover to exposure condition (mm) \[20\]

*Dimensions of the beam*

<table>
<thead>
<tr>
<th>C/C Span of the beam, (l), (m)</th>
<th>10.80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breadth of the beam, (b) (mm)</td>
<td>300</td>
</tr>
<tr>
<td>Overall depth of the beam, (D) (mm)</td>
<td>850</td>
</tr>
</tbody>
</table>

*Details of reinforcements*

<table>
<thead>
<tr>
<th>Diameter of tension reinforcement (mm)</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of compression reinforcement (mm)</td>
<td>25</td>
</tr>
<tr>
<td>Diameter of stirrups (mm)</td>
<td>8</td>
</tr>
</tbody>
</table>

*Effective depth*

Effective depth, \(d\) (mm) \((850-20-8-25/2) = 810\)

*Design Moment, Shear Force*

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

<table>
<thead>
<tr>
<th>Torsional Moment</th>
<th>6 kN-m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending Moment Mu(kN-m)</td>
<td>360</td>
</tr>
<tr>
<td>Equivalent Bending Moment, (M_e) (kNm)</td>
<td>374</td>
</tr>
<tr>
<td>Shear force at critical distance, (V_{ud}) (kN)</td>
<td>270</td>
</tr>
<tr>
<td>Equivalent Shear (kN)</td>
<td>302</td>
</tr>
</tbody>
</table>

*Singly reinforced or doubly reinforced section?*

The *limiting moment of resistance*, \(M_{u,lim}\) is given by

\[
M_{u,lim} = 0.362 f_{ck} \frac{b x_u_{max}}{d} \times 0.416 x_{u_{max}}
\]

Where \(b\) = Breadth of the Section

\(x_{u_{max}}\) = Limiting depth of Neutral Axis

\(d\) = Effective depth of the Section

The limiting percentage of steel, \(p_{u,lim}\) is given by
The area of steel for a singly reinforced section with width, b and depth, d and ultimate moment, $M_u$ is given by:

For (M30 and Fe415) \[ M_{u,\text{lim}} = \frac{0.1389 \times 30 \times 300 \times 809.5^2}{1000000} = 819.18 \text{ kNm} \]

\[ p_{t,\text{lim}} = \frac{41.3 \times 30}{415 \times 0.48} = 1.433 \]

If $M_u > M_{u,\text{lim}}$, the section has to be
i) get increased by depth or width (preferably depth)
ii) doubly reinforced

If $M_u < M_{u,\text{lim}}$, the section can be designed as singly reinforced.

**Check for the type of section**

\[ M_u = 373.53 \text{ kNm} \]
\[ M_{u,\text{lim}} = 819.18 \text{ kNm} \]

\[ \Rightarrow \text{Section can be designed as singly reinforced.} \]

**Determining $A_{st}$**

- Considering a 'balanced section' ($x_u = x_{u,\text{max}}$)
\[ A_{st} = A_{st,\text{lim}} + \Delta A_{st} \]

where $A_{st,\text{lim}} = p_{t,\text{lim}} / 100 \times ( b \times d )$

\[ \Rightarrow A_{st,\text{lim}} = \frac{1.433}{100} \times 300 \times 809.5 = 3480 \text{ mm}^2 \]

- Assuming 25 mm bars for compression steel,
\[ d' \approx \left( 20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2 \right) = 40.5 \text{ mm} \]
\[ \mu = 0.87 f_y \ast d (1 - (\ast f_y / b \ast f_{ck}) \]

\[ \text{A}_{\text{st}} \text{ Req'd} = 1388 \text{ mm}^2 \]

\[ \therefore \text{No of tension bars required ( # ) } \]

\[ (1388 / ( \pi / 4 \times 25^2 ) = 3.00 \]

Actual percentage of steel, \( p_t \) ( % )

\[ (3 \times \pi / 4 \times 25^2 / 300 / 810 \times 100 ) = 0.61 \]

Actual area of steel, \( A_{\text{st}} \) ( mm² )

\[ (3 \times \pi / 4 \times 25^2 ) = 1473 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by

\[ A_{sc} \frac{0.87 f_y}{f_{sc}} \frac{1}{0.447 f_{ck}} \]

or

\[ p_c \frac{0.87 f_y}{f_{sc}} \frac{f_t}{0.447 f_{ck}} \lim \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) ( in MPa units ) at \( x_u = x_{u,\text{max}} \) for various \( d'/d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( \frac{d'}{d} )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td></td>
</tr>
<tr>
<td>Fe415</td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
<td></td>
</tr>
<tr>
<td>Fe500</td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
<td></td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u,\text{max}} \), for \( d'/d = (40.5/809.5) = 0.050 \)
  From the above table : by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \leq p_c^* \)
where $p_c^*$ is given by

$$
p_c^* = \frac{0.87 \cdot f_y - 0.447 \cdot f_{ck}}{0.606 - 1.433 / (355.1 - 0.447 \cdot 30)}
$$

Actual $p_t$ provided: $p_t = 0.61$
Actual $p_c$ provided: $p_c = 0.81$

$\Rightarrow p_c^* = (0.87 \cdot 415 \cdot (0.606 - 1.433) / (355.1 - 0.447 \cdot 30))$

$\Rightarrow p_c^* = -0.87$

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans up to 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

For simply supported and continuous spans over 10m, these ratios are multiplied by a factor $F_{10}$ span in metres.

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig. 4 and Fig. 5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

$$
f_{st} = (0.58 \cdot 415 \cdot 1875 / 1473) = 306.48 \text{ N/mm}^2
$$

$F = 0.93$

$F_1 = 1.11$
\( F_2 = 1.19 \)

\[ (l/d)_{\text{max}} = (26 \times 0.93 \times 1.11 \times 1.19) = 31.96 \]
\[ (l/d)_{\text{provided}} = 13.34 \]

\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_u \) (kN)

The critical section for shear is at a distance of 810 mm from the face of the support.

- **Check for adequacy of section**

  Nominal shear stress, \( \tau_v \)
  \[ (302 \times 1000 / (300 \times 810)) = 1.24 \text{ N/mm}^2 \]

  The maximum shear stress is given by:
  \[ \Rightarrow \tau_{c,\text{max}} = 0.62 \times \sqrt{30} = 3.40 \text{ N/mm}^2 \]

  \[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

  At critical section, \( A_{st} \) is given by 1473 mm²
  Percentage of steel, \( p_t \) (%)

  The design shear strength of the concrete, \( \tau_c \), is given by:
  \[ \min \left\{ \frac{0.85}{0.85 f_{ck}} \times 1, \frac{0.8 f_{ck} \times 0.89 p_t}{0.89 p_t} \right\} \]
  \[ \text{where} \ \frac{0.8 f_{ck}}{0.89 p_t} \text{ whichever is greater} \]

  For (M30 and Fe415)
  \[ \Rightarrow \tau_c = 0.54 \text{ N/mm}^2 \]
  \[ \Rightarrow V_{uc} = (0.54 \times 300 \times 810 / 1000) = 131 \text{ kN} \]

- **Design of "vertical" stirrups**

  The shear to be resisted by steel, \( V_{us} \) is given by:
  \[ V_{us} = V_u - V_{uc} \]
  \[ \Rightarrow V_{us} = (302 - 131) = 171 \text{ kN} \]

  Using 12 mm bars and
  No of legs 2
Area of stirrups, $A_{sv}$ (mm$^2$) = 226

$\Rightarrow$ required spacing $s_v \leq \frac{0.87 \times 415 \times 226 \times 810}{171.38 \times 1000}$

$\Rightarrow$ Spacing, $s_v = 386$ mm

**Check whether $\tau_v > 0.5 \tau_c$**

Nominal shear stress, $\tau_v$ (N/mm$^2$) = 1.24
Design shear stress, $\tau_c$ (N/mm$^2$) = 0.54

$\tau_v > 0.5 \tau_c \quad \text{Yes}$

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress $\tau_v$ exceeds 0.5 $\tau_c$:

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87} \frac{f_y}{f_y} \quad \text{When } s_v = 0.5 \tau_c$$

$$s_v = \frac{2.175 \ f_y A_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

$$s_v \leq \frac{0.75 \ d}{300 \ mm}$$

**Code requirements for maximum spacing.**

i) $< \frac{2.175 \times 415 \times 226}{300} = 681$ mm
ii) $\leq \frac{0.75 \times 809.5}{300} = 607$ mm
iii) $\leq 300$ mm = 300 mm
iv) $\leq \frac{0.87 \times 415 \times 226 \times 810}{171.38 \times 1000} = 386$ mm
**Beam RB4 Support**

**Design Parameters**

Load Case 16 \[1.5*(DL - EQZ)]

- **Grade of Concrete**: M30
- **Grade of Steel**: Fe415
- **Characteristic compressive strength of concrete**, $f_{ck}$ (N/mm$^2$): 30
- **Characteristic yield strength of steel**, $f_y$ (N/mm$^2$): 415
- **Unit weight of concrete**, $\gamma_c$ (kN/m$^3$): 24
- **Partial safety factor for concrete**: 1.5
- **Exposure condition**: Mild
- **Nominal Cover to exposure condition (mm)**: 20

---

**Dimensions of the beam**

- **C/C Span of the beam, $l$ (m)**: 5.50
- **Breadth of the beam, $b$ (mm)**: 300
- **Overall depth of the beam, $D$ (mm)**: 600

---

**Details of reinforcements**

- **Diameter of tension reinforcement (mm)**: 25
- **Diameter of compression reinforcement (mm)**: 25
- **Diameter of stirrups (mm)**: 8

---

**Effective depth**

- **Effective depth, $d$ (mm)**: (600-20-8-25/2) = 560

---

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

- **Torsional Moment**: 16 kN-m
- **Bending Moment $M_u$ (kN-m)**: 283
- **Equivalent Bending Moment, $M_e$ (kNm)**: 311
- **Shear force at critical distance, $V_{ud}$ (kN)**: 90
- **Equivalent Shear (kN)**: 175

---

**Singly reinforced or doubly reinforced section?**

The limiting moment of resistance, $M_{u,lim}$ is given by

$$M_{u,lim} = 0.362f_{ck} \times \frac{b x_u_{max} \times 0.416 x_u_{max}}{d}$$

Where $b = $ Breadth of the Section
$x_u_{max} = $ Limiting depth of Neutral Axis
$d = $ Effective depth of the Section

The limiting percentage of steel, $p_{u,lim}$ is given by
The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
\frac{Pt}{100} = 0.48 \frac{f_{ck}}{f_y} \frac{x_{u,\text{max}}}{d}
\]

Where \( f_{ck} = \text{Characteristic Compressive strength of concrete} \)
\( f_y = \text{Characteristic strength of steel} \)

The area of steel for a singly reinforced section with width, \( b \) and depth, \( d \) and ultimate moment, \( M_u \) is given by:

\[
\frac{Pt}{100} = 0.48 \frac{f_{ck}}{f_y} \frac{x_{u,\text{max}}}{d}
\]

Where \( R = \frac{M_u}{f_{ck}bd^2} \)

For (M30 and Fe415) \( M_{u,\text{lim}} < 0.1389 f_{ck} b d^2 \)

\[
x_{u,\text{max}} / d = 0.48
\]

\[
M_{u,\text{lim}} = \frac{(0.1389 \times 30 \times 300 \times 559.5^2)}{1000000} = 391.33 \text{ kNm}
\]

\[
p_{u,\text{lim}} = \frac{(41.3 \times 30)}{415 	imes 0.48} = 1.433
\]

If \( M_u > M_{u,\text{lim}} \), the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[
M_u = 311.24 \text{ kNm}
\]

\[
M_{u,\text{lim}} = 391.33 \text{ kNm}
\]

\[
\Rightarrow \text{Section can be designed as singly reinforced.}
\]

**Determining \( A_{st} \)**

- Considering a 'balanced section' (\( x_u = x_{u,\text{max}} \))

\[
A_{st} = A_{st,\text{lim}} + \Delta A_{st}
\]

where \( A_{st,\text{lim}} = p_{u,\text{lim}} / 100 (b \times d) \)

\[
\Rightarrow A_{st,\text{lim}} = \frac{(1.433 \times 100 \times 300 \times 559.5)}{2405} = 2405 \text{ mm}^2
\]

- Assuming 25 mm bars for compression steel,

\[
d' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 25 / 2) = 40.5 \text{ mm}
\]
\[ \mu = 0.87 f_y \cdot \text{Ast} \cdot d \cdot (1 - (\text{Ast} \cdot f_y) / b \cdot d \cdot f_{ck}) \]

\[ \text{Ast Reqd} = 1811 \text{ mm}^2 \]

\[ \therefore \text{No of tension bars required ( # )} \]

\[ (1811 / (\pi / 4 \times 25^2)) = 4.00 \]

Actual percentage of steel, \( p_t \) ( % )
\[ (4 \times \pi / 4 \times 25^2 / 300 / 560 \times 100) = 1.17 \]

Actual area of steel, \( A_{st} \) ( mm² )
\[ (4 \times \pi / 4 \times 25^2) = 1963 \]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by

\[ A_{sc} = \frac{0.87 f_y \cdot \text{Ast} \cdot d' \cdot d}{f_{sc} \cdot 0.447 f_{ck}} \]

or

\[ p_c = \frac{0.87 f_y \cdot p_t \cdot p_{lim}}{f_{sc} \cdot 0.447 f_{ck}} \]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) ( in MPa units ) at \( x_u = x_{u,max} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( d' / d )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td></td>
</tr>
<tr>
<td>Fe415</td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
<td></td>
</tr>
<tr>
<td>Fe500</td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
<td></td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u,max} \), for \( d' / d = (40.5 / 559.5) = 0.072 \)
  From the above table : by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,max} \), it suffices to establish \( p_c \geq p_c^* \)
where \( p_c^* \) is given by

\[
\begin{align*}
p_c^* &= \frac{0.87 f_y}{0.447 f_{ck}} \\
p_c^* &= \frac{(0.87 \times 415 \times (1.17 - 1.433))}{(354.73 - 0.447 \times 30)} \\
p_c^* &= -0.28
\end{align*}
\]

\[\Rightarrow\] Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m, the limiting \( I / d \) ratios are specified by the Code (Cl. 23.2.1) as:

\[
\begin{align*}
F_1 &= 1.00 \\
F_2 &= 0.91
\end{align*}
\]

\[\Rightarrow\] For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor \( F \)

The modification factors \( F_1 \) (which varies with \( p_t \) and \( f_{st} \)) and \( F_2 \) (which varies with \( p_c \)) are as given in Fig. 4 and Fig. 5 of the code.

Code permits an approximate calculation of \( f_{st} \) as follows:

\[
f_{st} = 0.58 f_y \left( \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}} \right)
\]

\[
\Rightarrow f_{st} = \left( 0.58 \times 415 \times 1978 / 1963 \right) = 242.47 \text{ N/mm}^2
\]

\[\Rightarrow\]
\[ F_2 = 0.82 \]
\[
\text{.: } ( l / d )_{\text{max}} = ( 26 \times 1 \times 0.91 \times 0.82 ) = 19.42
\]
\[
(l / d)_{\text{provided}} = 9.83
\]
\[
\Rightarrow \text{Hence O.K.}
\]

**Check for shear**

Shear force at critical distance, \( V_{ud} \) (kN)

175.33333

The critical section for shear is at a distance of 560 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[
( 175.333333333333 \times 1000 / (300 \times 560) ) \quad 1.04 \quad \text{N/mm}^2
\]

The maximum shear stress is given by:

\[
T_{c \text{ max}} = 0.62f_{ck}
\]

\[
\Rightarrow \tau_{c,\text{max}} = (0.62 \times \sqrt{30}) = 3.40 \quad \text{N/mm}^2
\]

\[
\Rightarrow \text{Adopted section is adequate}
\]

- **Design shear resistance at critical section**

At critical section, \( A_{st} \) is given by

1963 \( \text{mm}^2 \)

Percentage of steel, \( p_t (\%) \)

1.17

The design shear strength of the concrete, \( \tau_c \), is given by:

\[
0.85 \left( \frac{0.8f_{ck}}{0.89p_t} \right) \frac{1}{1} \quad \text{N/mm}^2
\]

where \( \frac{0.8f_{ck}}{0.89p_t} \) whichever is greater

For (M30 and Fe415)

\[
\Rightarrow \tau_c = 0.70 \quad \text{N/mm}^2
\]

\[
\Rightarrow V_{uc} = (0.7 \times 300 \times 560 / 1000) = 117 \quad \text{kN}
\]

- **Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by:

\[
V_{us} = V_u \cdot V_{uc}
\]

\[
\Rightarrow V_{us} = (175 - 117) = 59 \quad \text{kN}
\]

Using 12 mm bars and

No of legs 2
Area of stirrups, \( A_{sv} \) (mm\(^2\)) = 226

\[
\Rightarrow \text{required spacing } sv \leq \left( \frac{0.87 \times 415 \times 226 \times 560}{58.52 \times 1000} \right)
\]

\[
\Rightarrow \text{Spacing, } sv = 781 \text{ mm}
\]

**Check whether** \( \tau_v > 0.5 \tau_c \)

- Nominal shear stress, \( \tau_v \) (N/mm\(^2\)) = 1.04
- Design shear stress, \( \tau_c \) (N/mm\(^2\)) = 0.70

\[
\tau_v > 0.5 \tau_c \quad \text{Yes}
\]

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress \( \tau_v \) exceeds 0.5 \( \tau_c \):

\[
\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} \quad \text{When } sv = 0.5 \tau_c
\]

\[
sv = \frac{2.175 f_y A_{sv}}{b}
\]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[
sv \geq \frac{0.75 d}{300 \text{ mm}}
\]

**Code requirements for maximum spacing**.

i) \( < \left( \frac{2.175 \times 415 \times 226}{300} \right) = 681 \text{ mm} \)

ii) \( \leq \left( \frac{0.75 \times 559.5}{300} \right) = 420 \text{ mm} \)

iii) \( \leq 300 \text{ mm} \)

iv) \( \leq \left( \frac{0.87 \times 415 \times 226 \times 560}{58.52 \times 1000} \right) = 781 \text{ mm} \)
**Beam RB4 Mid**

**Design Parameters**

Load Case 16 \[1.5*(DL - EQZ)\]

Grade of Concrete \(M30\)

Grade of Steel \(Fe415\)

Characteristic compressive strength of concrete, \(f_{ck}\) \(N/mm^2\) 30

Characteristic yield strength of steel, \(f_y\) \(N/mm^2\) 415

Unit weight of concrete, \(\gamma_c\) \(kN/m^3\) 24

Partial safety factor for concrete 1.5

Exposure condition Mild

Nominal Cover to exposure condition (mm) 20

**Dimensions of the beam**

C/C Span of the beam, \(l\) (m) 5.50

Breadth of the beam, \(b\) (mm) 300

Overall depth of the beam, \(D\) (mm) 600

**Details of reinforcements**

Diameter of tension reinforcement (mm) 20

Diameter of compression reinforcement (mm) 20

Diameter of stirrups (mm) 8

**Effective depth**

Effective depth, \(d\) (mm) \((600-20-8-20/2) = 562\)

**Design Moment, Shear Force**

The moments and shears given below are taken from the STAAD.Pro 2004 output file. The partial factors of safety are already incorporated into the analysis.

<table>
<thead>
<tr>
<th>Moment / Shear</th>
<th>Value (kN-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsional Moment</td>
<td>0</td>
</tr>
<tr>
<td>Bending Moment (M_u)</td>
<td>120</td>
</tr>
<tr>
<td>Equivalent Bending Moment (M_e)</td>
<td>120</td>
</tr>
<tr>
<td>Shear force at critical distance (V_{ud})</td>
<td>139</td>
</tr>
<tr>
<td>Equivalent Shear (kN)</td>
<td>139</td>
</tr>
</tbody>
</table>

**Singly reinforced or doubly reinforced section?**

The *limiting moment of resistance*, \(M_{u,\text{lim}}\) is given by

\[
M_{u,\text{lim}} = 0.362f_{ck} \cdot \frac{bx_{u,\text{max}}}{d} \cdot 0.416x_{u,\text{max}}
\]

Where \(b = \text{Breadth of the Section}\)

\(x_{u,\text{max}} = \text{Limiting depth of Neutral Axis}\)

\(d = \text{Effective depth of the Section}\)

The limiting percentage of steel, \(p_{u,\text{lim}}\) is given by
The area of steel for a singly reinforced section with width, b and depth, d and ultimate moment, M is given by:

\[ M_{u,\text{lim}} = \frac{0.1389 \times 30 \times 300 \times 562^2 / 1000000}{100} = 394.84 \text{ kNm} \]

\[ p_{\text{lim}} = \frac{41.3 \times 30}{415 \times 0.48} = 1.433 \]

If \( M_u > M_{u,\text{lim}} \), the section has to be
i) get increased by depth or width (preferably depth)
ii) doubly reinforced

If \( M_u < M_{u,\text{lim}} \), the section can be designed as singly reinforced.

**Check for the type of section**

\[ M_i = 120.00 \text{ kNm} \]
\[ M_{u,\text{lim}} = 394.84 \text{ kNm} \]

\[ \Rightarrow \text{Section can be designed as singly reinforced.} \]

**Determining } A_{\text{st}}**

- Considering a 'balanced section' \( ( x_u = x_{u,\text{max}} ) \)
  \[ A_{\text{st}} = A_{\text{st,lim}} + \Delta A_{\text{st}} \]
  where \( A_{\text{st,lim}} = p_{\text{lim}} / 100 \times \text{b} \times \text{d} \)

\[ \Rightarrow A_{\text{st,lim}} = (1.433 / 100 \times 300 \times 562) = 2416 \text{ mm}^2 \]

- Assuming 20 mm bars for compression steel,
  \[ d' \approx (20 \text{ mm clear cover} + 8 \text{ mm stirrup} + 20 \div 2) = 38 \text{ mm} \]
\[ \mu = 0.87 f_y A_{st} d (1 - (A_{st} f_y) / b d f_{ck}) \]

\[
\begin{align*}
A_{st} & = \frac{\mu a_{st}}{0.87 f_y d} \\
p_t & = \frac{R_{lim}}{100} \frac{R}{0.87 f_y d}
\end{align*}
\]

\[ \mu = 0.87 f_y A_{st} d (1 - (A_{st} f_y) / b d f_{ck}) \]

\[ A_{st} \text{ Reqd} = 623 \text{ mm}^2 \]

\[
\therefore \text{ No of tension bars required ( # )}
\]

\[
(623 / (\Pi / 4 x 20^2)) = 2.00
\]

\[
\text{Actual percentage of steel, } p_t (\%) \quad (2 x \Pi / 4 x 20^2 / 300 / 562 x 100) = 0.37
\]

\[
\text{Actual area of steel, } A_{st} (\text{ mm}^2) \quad (2 x \Pi / 4 x 20^2) = 628
\]

**Determining \( A_{sc} \)**

The compression steel, \( A_{sc} \), is given by

\[
A_{sc} = \frac{0.87 f_y A_{st}}{f_{sc} - 0.447 f_{ck}}
\]

or

\[
p_c = \frac{0.87 f_y p_t - p_{t,lim}}{f_{sc} - 0.447 f_{ck}}
\]

where \( f_{sc} \) is the stress in compression steel.

The values of \( f_{sc} \) (in MPa units) at \( x_u = x_{u,\text{max}} \) for various \( d' / d \) ratios and different grades of compression steel are given in the table below.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>( \frac{d'}{d} )</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe250</td>
<td></td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
<td>217.5</td>
</tr>
<tr>
<td>Fe415</td>
<td></td>
<td>355.1</td>
<td>351.9</td>
<td>342.4</td>
<td>329.2</td>
</tr>
<tr>
<td>Fe500</td>
<td></td>
<td>423.9</td>
<td>411.3</td>
<td>395.1</td>
<td>370.3</td>
</tr>
</tbody>
</table>

- Assuming \( x_u = x_{u,\text{max}} \), for \( d' / d = (38 / 562) = 0.068 \)

From the above table: by interpolation

**Design Check**

- To ensure \( x_u \leq x_{u,\text{max}} \), it suffices to establish \( p_c \geq p_c^* \)
where $p_c^*$ is given by

$$p_c^* = \frac{0.87 f_y}{0.447 f_{ck}}$$

Actual $p_t$ provided: $p_t = 0.37$
Actual $p_c$ provided: $p_c = 0.93$

$$\Rightarrow p_c^* = \left( 0.87 \times 415 \times (0.373 - 1.433) / (354.98 - 0.447 \times 30) \right)$$

$$\Rightarrow p_c^* = -1.12$$

Section is not over reinforced

**Check for deflection control**

For prismatic beams of rectangular sections and slabs of uniform thickness and spans up to 10m, the limiting $l/d$ ratios are specified by the Code (Cl. 23.2.1) as:

- For cantilever spans, $l/d_{max} = 7$
- For simply supported spans, $l/d_{max} = 20$
- For continuous spans, $l/d_{max} = 26$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor $F$:

$$F = \frac{10}{\text{span in metres}}$$

The modification factors $F_1$ (which varies with $p_t$ and $f_{st}$) and $F_2$ (which varies with $p_c$) are as given in Fig. 4 and Fig. 5 of the code.

Code permits an approximate calculation of $f_{st}$ as follows:

$$f_{st} = 0.58 \frac{f_{y}}{f_{ck}} \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

$$\Rightarrow f_{st} = \left( 0.58 \times 415 \times 963 / 628 \right) = 369.08 \text{ N/mm}^2$$

$F = 1.00$
$F_1 = 1.26$
\[ F_2 = 1.24 \]

\[ \therefore \frac{l}{d}_{\text{max}} = \frac{26 \times 1 \times 1.26 \times 1.24}{9.79} = 40.32 \]

\[ \frac{l}{d}_{\text{provided}} = \]

\[ \Rightarrow \text{Hence O.K.} \]

**Check for shear**

Shear force at critical distance, \( V_u \) (kN)

The critical section for shear is at a distance of 562 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress, \( \tau_v \)

\[ \tau_v = \frac{139 \times 1000}{300 \times 562} = 0.82 \text{ N/mm}^2 \]

The maximum shear stress is given by:

\[ T_{c\text{ max}} = 0.62 f_{ck} \]

\[ \Rightarrow \tau_{c\text{, max}} = (0.62 \times \sqrt{30}) = 3.40 \text{ N/mm}^2 \]

\[ \Rightarrow \text{Adopted section is adequate} \]

- **Design shear resistance at critical section**

At critical section, \( A_{st} \) is given by 628 mm²

Percentage of steel, \( p_t (\%) \) 0.37

The design shear strength of the concrete, \( \tau_c \), is given by:

\[ \frac{0.85}{0.85} \left( \frac{0.8 f_{ck}}{t_s} \right) \frac{1}{1} \]

where \( \frac{0.8 f_{ck}}{t_s} \) whichever is greater

\[ \Rightarrow \tau_c = 0.44 \text{ N/mm}^2 \]

\[ \Rightarrow V_{uc} = \frac{0.44 \times 300 \times 562}{1000} = 74 \text{ kN} \]

- **Design of "vertical" stirrups**

The shear to be resisted by steel, \( V_{us} \) is given by:

\[ V_{us} = V_u - V_{uc} \]

\[ \Rightarrow V_{us} = (139 - 74) = 65 \text{ kN} \]

Using 8 mm bars and

No of legs 2
Area of stirrups, \( A_{sv} \) (mm\(^2\)) = 101

\[ \Rightarrow \text{required spacing } s_v \leq \frac{0.87 \times 415 \times 101 \times 562}{65.03 \times 1000} \]

\[ \Rightarrow \text{Spacing, } s_v = 314 \text{ mm} \]

\textit{Check whether } \tau_v > 0.5 \tau_c

Nominal shear stress, \( \tau_v \) (N/mm\(^2\)) = 0.82
Design shear stress, \( \tau_c \) (N/mm\(^2\)) = 0.44

\[ \tau_v > 0.5 \tau_c \quad \text{Yes} \]

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress \( \tau_v \) exceeds 0.5 \( \tau_c \):

\[ \frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87 f_y} \quad \text{When } s_v = 0.5 t_c \]

\[ s_v = \frac{2.175 f_y A_{sv}}{b} \]

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal "vertical" stirrups, the requirement is

\[ s_v \leq \frac{0.75 d}{300 \text{ mm}} \]

Code requirements for maximum spacing:

i) \( < \frac{2.175 \times 415 \times 101}{300} \) = 302 mm
ii) \( \leq \frac{0.75 \times 562}{300} \) = 422 mm
iii) \( \leq 300 \text{ mm} \) = 300 mm
iv) \( \leq \frac{0.87 \times 415 \times 101 \times 562}{65.03 \times 1000} \) = 314 mm
DESIGN OF SLAB
Design of Grid Slab

Grade of concrete = 30 kN/m²
Grade of steel = 415 N/mm²
Unit weight of concrete = 24 kN/m³
Live Load = 3 kN/m²
Cover = 20 mm
Roof Finish Load = 1 kN/m²

\[ L_y = 8.36 \text{ m} \]
\[ L_x = 4.96 \text{ m} \]

Aspect Ratio \( r = \frac{L_y}{L_x} = 1.69 \approx 4.2 \)

Grid Spacing

\[ X - \text{Dir} = 1.240 \text{ m} \]
\[ Y - \text{Dir} = 1.400 \text{ m} \]

No of Beams in X - Direction = 3 Nos
No of Beams in Y - Direction = 5 Nos
Thickness of the Slab \( D_f = 120 \text{ mm} \)
Thickness of the Web \( b_w = 250 \text{ mm} \)
Depth of the Web \( D = 430 \text{ mm} \)

Design of the Section:

Self weight of Slab = 2.88 kN/m²
Total Load of Slab = 119.42 kN
Weight of Rib = 1.86 kN/m
Total weight of Beams (x-direction) = 45.86 kN
Total weight of Beams (y-direction) = 39.71 kN
Total weight of Floor Finish = 41.4656 kN
Total Live Load = 124.3968 kN

Total Load = 370.9 kN/m²

Load per m² \( q = 8.9 \text{ kN/m}² \)
Approximate Method (Moments)

If $q_1$ & $q_2$ are the moments shared in the x & y directions

$$q_1 = q \left( \frac{b_y^4}{a_x^4 + b_y^4} \right)$$

$q_1 = 8.0 \text{ kN/m}^2$

$$q_2 = q \left( \frac{a_x^4}{a_x^4 + b_y^4} \right)$$

$q_1 = 1.0$

Moments in x & y directions at centre of grid for 2 m width is obtained as:

$$M_x = \left( \frac{q_1 b_y a_x^2}{8} \right)$$

$M_x = 30.5 \text{ kN.m}$

$$M_y = \left( \frac{q_2 a_x b_y^2}{8} \right)$$

$M_y = 12.1 \text{ kN.m}$

$Q_x = 24.6 \text{ kN}$

$Q_y = 5.8 \text{ kN}$

Design of Reinforcement

Max working moment $M_{w} = 18.3 \text{ kN.m/m}$

Moment resisted by central rib in x-direction over 1.24 m width $= 22.7 \text{ kN.m}$

Ultimate moment $M_{u} = 34.0 \text{ kN.m}$

Moment capacity of flange section

$$M_{uf} = 0.36 f_{ck} b_y D_f (d - 0.42 D_f)$$

$M_{uf} = 513.6 \text{ kN.m}$

$M_u < M_{uf}$ N.A falls within the Flange
\[ M_u = 0.87 f_y A_{st} d \left[ 1 - \frac{A_{st} f_y}{b.d.f_{ck}} \right] \]

Ast reqd = 300 mm²

20 mm = 1 Nos

Ast Provided = 314 mm²

Max ultimate shear = 25 kN

\[ \tau_v = \frac{V_u}{bd} \quad \tau_v = 0.3 \quad \text{N/mm}^2 \]

Assuming 2 bars to be bent up near support

Ast at supports = 628 mm²

\[ \frac{100 A_{st}}{bd} = 0.68 \]

\[ \tau_c = 0.56 \quad \text{N/mm}^2 \]

Nominal Shear reinforcement is Required

<table>
<thead>
<tr>
<th>8 mm</th>
<th>50 mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of stirrup legs</td>
<td>2</td>
</tr>
<tr>
<td>100.5 mm²</td>
<td></td>
</tr>
</tbody>
</table>

\[ S_v = \frac{A_s 0.87 f_y}{0.4b} \quad S_v = 363.0 \quad \text{mm} \]

Provide 8 mm dia 2 legged stirrups at 360 mm c/c at support & the spacing can be gradually increased at centre.
Design of Slab for Lift Machine room

Grade of concrete = 30 \text{ KN/m}^2
Grade of steel = 415 \text{ N/mm}^2
Live Load = 3 \text{ kN/m}^2
Cover = 20 \text{ mm}

\begin{align*}
L_y & = 1.85 \text{ m} \\
L_x & = 1.6 \text{ m}
\end{align*}

Breadth of slab = 1000 \text{ mm}

\[ \frac{L_y}{L_x} = 1.16 \]

Design as a Two way Slab

Depth of the Slab

\begin{align*}
\text{Depth} & = 70 \text{ mm} \\
\text{Effective Depth} & = 95 \text{ mm} \\
\text{Overall Depth} & = 115 \text{ mm}
\end{align*}

Effective Span = 1.83

Loads

\begin{align*}
\text{Self weight} & = 1.875 \text{ kN/m}^2 \\
\text{Live Load} & = 2 \text{ kN/m}^2 \\
\text{Floor Finish} & = 0.6 \text{ kN/m}^2 \\
\text{Service Load} & = 4.475 \text{ kN/m}^2 \\
\text{Design Load} & = 6.71 \text{ kN/m}^2
\end{align*}

Design moments in the x and y directions

\begin{align*}
\alpha_x &= 0.069 \\
\alpha_y &= 0.056
\end{align*}

\[ \alpha_x - \alpha_y \]

INTERPOLATION

\begin{tabular}{ccc}
1.2 & 1.16 & 1.3 \\
0.072 & 0.069 & 0.079
\end{tabular}

\begin{align*}
M_x & = 1.55 \text{ KN-m} \\
M_y & = 1.26 \text{ KN-m} \\
V_{ux} & = 6.14 \text{ KN}
\end{align*}

Check for depth

\begin{align*}
d & = 19.35 \text{ mm} \\
d & = 110 \text{ mm}
\end{align*}

Total depth = 39.35 \text{ mm}

Reinforcement (short and long span)
<table>
<thead>
<tr>
<th></th>
<th>Shorter span</th>
<th>Longer span</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>4.99</td>
<td>4.99</td>
</tr>
<tr>
<td>(b)</td>
<td>36105.00</td>
<td>36105.00</td>
</tr>
<tr>
<td>(c)</td>
<td>1549679.93</td>
<td>1258851.51</td>
</tr>
<tr>
<td>(b^2-4ac)</td>
<td>1272611364</td>
<td>1278421564</td>
</tr>
<tr>
<td>(2a)</td>
<td>9.99</td>
<td>9.99</td>
</tr>
<tr>
<td>(SQ)</td>
<td>35673.68</td>
<td>35755.02</td>
</tr>
<tr>
<td>(A_{St1})</td>
<td>43.18 mm(^2)</td>
<td>35.04 mm(^2)</td>
</tr>
<tr>
<td>(A_{St2})</td>
<td>-7185.73627 mm(^2)</td>
<td>-7193.87945 mm(^2)</td>
</tr>
</tbody>
</table>

Reinforcement in Shorter Direction:
- Spacing of 10 mm = 1818 mm c/c
- Provide 12 mm bars at 150 mm c/c

Reinforcement in Longer Direction:
- Spacing of 10 mm = 2241 mm c/c
- Spacing of 12 mm = 3228 mm c/c
- Provide 12 mm bars at 150 mm c/c

Check for shear stress

Considering the short span & unit width of slab:
\[
\zeta_v = \frac{Vu}{bd} = 0.0614 \text{ N/mm}^2
\]
\[
Pt = 0.043
\]

**INTERPOLATION**

<table>
<thead>
<tr>
<th>(\zeta_v)</th>
<th>0.5</th>
<th>0.04</th>
<th>0.75</th>
<th>Table19</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\zeta_c)</td>
<td>0.48</td>
<td><strong>0.334</strong></td>
<td>0.56</td>
<td></td>
</tr>
</tbody>
</table>

Check for deflection & shear:
\[
\zeta_c > \zeta_v \quad \text{Shear reinforcement is not reqd}
\]

Modification Factor From IS 456:
\[
K = 1.2
\]
Design of Slab for Ramp

Grade of concrete = 30 KN/m$^2$
Grade of steel = 415 N/mm$^2$
Live Load = 4 kN/m2
Cover = 20 mm

\[ L_y = 5.345 \text{ m} \]
\[ L_x = 3.6 \text{ m} \]
Breadth of slab = 1000 mm
\[ L_y/L_x = 1.48 \]

Depth of the Slab

Depth = 112.5 mm
Effective Depth = 112.5 mm
Overall Depth = 137.5 mm

Effective Span = 3.83

Loads

Self weight = 3.4375 kN/m2
Live Load = 4 kN/m2
Floor Finish = 0.6 kN/m2
Service Load = 8.0375 kN/m2
Design Load = 12.06 kN/m2

Design moments in the x and y directions
\[ \alpha_x + 0.092 \]
\[ \alpha_y + 0.056 \]
\[ \alpha_x - \]
\[ \alpha_y - \]

INTERPOLATION

\[
\begin{array}{ccc}
1.2 & 1.48 & 1.3 \\
0.072 & 0.092 & 0.079 \\
\end{array}
\]

\[ M_x = 16.26 \text{ KN-m} \]
\[ M_y = 9.90 \text{ KN-m} \]
\[ V_{ux} = 23.09 \text{ KN} \]

Check for depth
\[ d = 62.67 \text{ mm} \]
\[ d = 130 \text{ mm} \]

Total depth = 82.67 mm

Reinforcement (short and long span)

Reinforcement in Shorter Direction
spacing of 10 mm = 218 mm c/c
spacing of 12 mm = 314 mm c/c
Provide 12 mm bars at 100 mm c/c

Reinforcement in Longer Direction
spacing of 10 mm = 363 mm c/c
spacing of 12 mm = 524 mm c/c
Provide 12 mm bars at 150 mm c/c

Considering the short span & unit width of slab
\[ \zeta = \frac{V_u}{bd} \]
\[ \begin{align*}
Pt &= 0.1776 \text{ N/mm}^2 \\
\text{INTERPOLATION} \\
0.5 & \quad 0.28 & \quad 0.75 & \quad \text{Table19} \\
0.48 & \quad \bf{0.409} & \quad 0.56 \\
\zeta_c &= 0.409 \text{ N/mm}^2 \\
\zeta_c > \zeta_v & \quad \text{Shear reinforcement is not reqd} \\
\text{Check for deflection Control} \\
\text{Modification Factor From IS 456} \\
K &= 1.2
\end{align*} \]
BILL OF QUANTITIES
<table>
<thead>
<tr>
<th>Sl. No</th>
<th>SOR Ref No</th>
<th>Description of Work</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate (Rs)</th>
<th>Amount (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01</td>
<td>251a</td>
<td>Excavation in foundation in ordinary soil (loam, clay or sand) including lift upto 1.5m and lead upto 30m and including filling watering and ramming of excavated earth into the trenches or into the space between the building and the sides of the foundation trenches or into the plinth and removal and disposal of surplus earth as directed by engineer in charge upto a distance of 30m from the foundation trenches</td>
<td>cum</td>
<td>4,569.00</td>
<td>38.00</td>
<td>173,622.00</td>
</tr>
<tr>
<td>1.01a</td>
<td>254a</td>
<td>Extra for every additional 30m lead or part of 30m or for every additional 1.5m lift or part of 1.5m</td>
<td>cum</td>
<td>3,040.00</td>
<td>43.00</td>
<td>130,720.00</td>
</tr>
<tr>
<td>1.01b</td>
<td>254a</td>
<td>Extra for every additional 30m lead or part of 30m or for every additional 1.5m lift or part of 1.5m</td>
<td>cum</td>
<td>183.00</td>
<td>48.00</td>
<td>8,784.00</td>
</tr>
<tr>
<td>1.02</td>
<td>255a</td>
<td>Sand filling in plinth including supply of necessary quantity of sand from a distance not exceeding 8 km from the site of work and including watering, dressing etc labour and T&amp;P etc required for the proper completion of the work, saplings of girth upto 30cm measured at a height of 1m above ground level and removal of rubbish upto a distance of 50m outside the periphery of area cleared</td>
<td>cum</td>
<td>4,560.00</td>
<td>220.00</td>
<td>1,003,200.00</td>
</tr>
<tr>
<td>1.03</td>
<td>2.27 CPWD</td>
<td>Supplying and filling in plinth with Jamuna sand under floors including, watering, ramming consolidating and dressing complete.</td>
<td>cum</td>
<td>852.27</td>
<td>331.65</td>
<td>282,656.00</td>
</tr>
<tr>
<td>1.04</td>
<td>281</td>
<td>Cement concrete with 40mm gauge approved stone ballast, coarse sand &amp; cement in the proportion of 8:4:1 including supply of all materials, labour, tools &amp; plants etc. required for proper completion of the work.</td>
<td>cum</td>
<td>469.00</td>
<td>2,500.00</td>
<td>1,172,500.00</td>
</tr>
<tr>
<td>1.05</td>
<td>5.33 CPWD</td>
<td>Providing and laying in position machine batched, machine mixed and machine vibrated design mix cement concrete of specified grade for reinforced cement concrete work including pumping of concrete to site of laying but excluding the cost of centering, shuttering, finishing and reinforcement, including Admixtures in recommended proportions as per IS 9103 to accelerate, retard setting of concrete, improve workability without impairing strength and durability as per direction of Engineer-in-charge. M-25 grade reinforced cement concrete by using 410kg. of cement per cum of concrete. All work up to floor V level.</td>
<td>cum</td>
<td>21,148.00</td>
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<td>5.34.1 CPWD</td>
<td>Add or deduct for providing richer or leaner mixes respectively at all floor levels. Providing M-30 grade concrete by using 420kg of cement per cum of concrete instead of M-25 grade B.M.C/ R.M.C.</td>
<td>cum</td>
<td>21,148.00</td>
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<td>M.S (Tor steel or Plain) in plain work such as RCC or R.B work including bending for proper shape and including supply of steel and its wastage, bends hooks and authorised overlapping shall be measured and including cost of binding wire.</td>
<td>MT</td>
<td>3,984.61</td>
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<td>M-150 Brick work in 1:6 one cement and six fine sand mortar including necessary cutting and moulding of brick as required of one brick thick including supply of all materials labour tools and plant etc required for proper completion of the work.</td>
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<td>Extra for Superstructure</td>
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<td>CPWD 12 mm cement plaster finished with a floating coat of neat cement of mix :1:4 (1 cement: 4 fine sand)</td>
<td>sqm</td>
<td>1,604.00</td>
<td>97.90</td>
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<td>1.09</td>
<td>13.8.2</td>
<td>CPWD 15 mm cement plaster on rough side of single or half brick wall finished with a floating coat of neat cement of mix : 1:4 (1 cement: 4 fine sand)</td>
<td>sqm</td>
<td>1,604.00</td>
<td>110.70</td>
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<td>13.16</td>
<td>CPWD Plastering with CM 1:3 mix (one cement and three sand) 6mm thick including cost, conveyance, labour charges etc. complete as per standard specification- for ceiling</td>
<td>sqm</td>
<td>32,134.00</td>
<td>62.15</td>
<td>1,997,128.00</td>
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<td>1.11</td>
<td>13.48.1</td>
<td>CPWD Finishing walls with Deluxe Multi surface paint system for interiors and exteriors using Primer as per manufacturers specifications :Two or more coats applied @ 1.25 ltr/10 sqm. over and including one coat of Special primer applied @ 0.75 ltr / 10 sqm.</td>
<td>sqm</td>
<td>68,256.00</td>
<td>62.25</td>
<td>4,248,936.00</td>
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<td>1.12</td>
<td>13.37.1</td>
<td>CPWD White washing with whitling to give an even shade - new work (three or more coats). For ceiling including cost of materials and labour charges etc. complete as per standard specification</td>
<td>sqm</td>
<td>32,134.00</td>
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<td>1.13</td>
<td>11.9.5</td>
<td>CPWD 40 mm thick marble chips flooring rubbed and polished to granolithic finish, under layer 34 mm thick cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone aggregate 12.5mm nominal size) and top layer 6mm thick with white, black, chocolate, grey, yellow or green marble chips of sizes from 1mm to 4mm nominal size laid in cement marble powder mix 3:1 (3 cement : 1 marble powder) by weight in proportion of 4:7 (4 cement marble powder mix : 7 marble chips) by volume including cement slurry etc. complete : Light shade pigment with ordinary cement.</td>
<td>sqm</td>
<td>8,566.00</td>
<td>313.35</td>
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<td>16.64</td>
<td>CPWD Providing and laying 75mm thick compacted bed of dry brick aggregate of 40mm thick nominal size including spreading, well ramming, consolidating and grouting with jamuna sand including finishing smooth etc. complete as per direction of Engineer-in-charge.</td>
<td>sqm</td>
<td>8,208.00</td>
<td>63.15</td>
<td>518,335.00</td>
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<td>1.15</td>
<td>12.15</td>
<td>CPWD Painting top of roofs with bitumen of approved quality at 17kg per 10 sqm impregnated with a coat of coarse sand at 60 cudm per 10sqm including cleaning the slab surface with brushes and finally with a piece of cloth lightly soaked in kerosene oil complete : With residual type petroleum bitumen of penetration 80/100</td>
<td>sqm</td>
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<td>5.9.13</td>
<td>CPWD Centering and shuttering including strutting, propping etc. and removal of form for : Vertical and horizontal fins individually or forming box louvers band, facias and eaves boards.</td>
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<td>4,333.00</td>
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<td>CPWD Reinforced cement concrete work in vertical and horizontal fins individually or forming box louvers, facias and eaves boards up to floor five level excluding the cost of centering, shuttering, finishing and reinforcement with 1:1½:3 (1 cement : ½ coarse sand : 3 graded stone aggregate 20mm nominal size).</td>
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<td>Centering and shuttering including strutting, propping etc. and removal of form for: Foundations, footings, bases of columns, etc. for mass concrete.</td>
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<td>Centering and shuttering including strutting, propping etc. And removal of form for: Columns, Pillars, Piers, Abutments, Posts and Struts.</td>
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<td>Centering and shuttering including strutting, propping etc. and removal of form for: Suspended floors, roofs, landings, balconies and access platform.</td>
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<td>Centering and shuttering including strutting, propping etc. and removal of form for: Stairs, (excluding landings) except spiral-staircases.</td>
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<td>Providing and filling in position bitumen mix filler of Proportion 80 kg. of hot bitumen, 1 kg. of cement and 0.25 cubic metre of coarse sand for expansion joints.</td>
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<td>5.29.1.1 CPWD</td>
<td>Providing and fixing sheet covering over expansion joints with iron screws as per design to match the colour / shade of wall Non-asbestos fibre cement board 6 mm thick as per IS: 14862. 150mm wide.</td>
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<td>Cautionary /warning sign boards of equilateral triangular shape having each side of 900mm with support length of 3650mm.</td>
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DETAILED QUANTITY ESTIMATE
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1.05 5.33 CPWD M30 Concrete Building cum 21,148.00

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7 0.74 5.26 27.25 F2 C8
5 3.00 3.30 0.70 34.65 F3 C3
5 0.70 5.22 18.27 F3 C3
9 2.00 2.10 0.30 11.34 F4 C4
9 0.36 2.36 7.65 F4 C4
1 2.50 2.70 0.40 2.70 F5 C5
1 0.54 3.67 1.98 F5 C5
10 3.00 3.50 0.60 63.00 F6 C6
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38 5.70 5.70 1.30 1,605.01 F7 C7
38 1.30 16.85 832.39 F7 C7
2 3.90 5.20 1.10 44.62 F7 C5,C5
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1 8.00 10.50 1.00 84.00 F7 C7(2),C8(2)
4 4.00 10.50 1.00 168.00 F7 C7,C8
2 7.00 7.50 0.70 73.50 F7 C5,C10
6 6.60 6.60 0.90 235.22 F7 C7,C7
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Stair case footing 1 1.35 0.75 0.30 0.30

Pedestal
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2 0.70 1.10 0.75 1.16 Raft C1a
6 0.53 0.53 0.75 1.26 Raft C1
9 0.65 1.10 0.75 4.83 F2 C2
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5 0.60 0.90 0.75 2.03 F3 C3
9 0.65 0.80 0.75 3.51 F4 C4
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38 1.10 1.10 0.75 34.49 F7 C7
2 1.15 1.52 0.75 2.62 F7 C10,C10
10 1.15 1.42 0.75 12.25 F7 C2,C10,C10
2 0.80 1.02 0.75 1.22 F7 C3,C4,C4

Stair case pedestal 1 1.00 0.40 0.35 0.14

Columns upto Plinth Level 2 0.55 0.85 1.20 1.12 Raft C10
2 0.40 0.80 1.20 0.77 Raft C1a
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**ARCHITECTURAL & STRUCTURAL WORKS**
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Asian Development Bank
National Capital Region Planning Board

Capacity Development of the
National Capital Region Planning Board
Package 2 Component B
TA No. 7055-IND

Volume V-D2: Economic & Financial Analysis
DPR for Multi-level Parking Facility in Ghaziabad

WilburSmith ASSOCIATES
July 2010
Capacity Development of the National Capital Region Planning Board (NCRPB) – Component B (TA No. 7055-IND)

FINAL REPORT
Volume V-D2: DPR for Multi-level Parking Facility at Ghaziabad
Economic & Financial Analysis

July 2010
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1. **ECONOMIC ANALYSIS**

A. **Review of Macroeconomic Context**

1. *City / Town Profile*

   1. Ghaziabad is one of the most important cities of UP sub-region of NCR and can easily be termed as Gateway of UP. It is located at about 22 kms. from NCT Delhi and is an important industrial and trading center in Delhi Metropolitan Area (DMA). The City is spread and developed on both the sides of River Hindan, an important tributary of River Yamuna. The city is bounded by the NCT Delhi in the west and NOIDA in south. This is an important town of U.P due to rapid growth of industrial, commercial activities.

   2. The status of Ghaziabad was upgraded from Municipal Board to Municipal Corporation, known as Ghaziabad Nagar Nigam (GNN) on 31 August 1994 following 74th constitution Amendment Act 1992 and conformity legislation by state government. The Municipal administration has been decentralized in five zones and 80 administrative wards.

   3. Area of Ghaziabad Nagar Nigam (GNN) was confined to the core area of the city i.e. only 63.94 sq km till 1991 with population of 5, 11,759 but by 2001, area increased to 171.43 sq km with census population as 9, 68,521.

   4. The city is growing at a very high pace and the population base has increased from 0.5 to 1.0 million during 1991-2001. During the last twenty years the population concentration has been on the periphery of the municipal board boundary. The city is growing spatially. Private developers promoted by Public – Private Partnership policy (PPP) are now supporting the urban development. The quality and quantity of housing is improving and reflecting the contribution of the private sector. Estimated population of GNN and GDA in 2041 is 4.4 million and 6.1 million respectively.

   5. *Major Economic Activity*. The economy of the town has been bi-functional – industries cum services since 1971. Industries form an important component of the economic base of the city. Ghaziabad is one of the largest industrial cities, next to Kanpur, in Uttar Pradesh. It is also an important centre for trade and commerce in western UP sub-region. Various products and equipments are supplied to the regional, national and international markets. The workforce participation rate and percentage workers in secondary sector are marginally declining but the size of work force in the city has maintained its increasing trend.

   6. A number of famous major industries like Bharat Electronics Limited (a public sector unit of Central Government), UPTRON (a public sector unit of Uttar Pradesh Government), Dabur, Mohan Meakins, Gagan Vanaspati, Sri Ram Piston, Bhushan Steel and Weston Television are located in Ghaziabad. Sahaibabad industrial area and commercial activities are concentrated in the western part of the town. According to the statistics of the District
Industrial Centre, 106 units of medium and large industries employed 24,595 workers in 2001.

7. Number of small and medium industrial units was 13,720 in 2000 with 71,245 workers increased to 15,848 in 2002 with 87,832 workers. The main reason behind increase in small and medium industrial units in Ghaziabad is due to recent Hon’ble Supreme Court Order for shifting of polluting industries from NCT Delhi.

8. It is an important city in NCR area, which is being developed to decongest National Capital Delhi by improving infrastructure in NCR towns with the aim of shifting some of the offices and establishments of Government of India. With all the required facilities and proximity to Delhi, Ghaziabad has become one of the fast developing city in NCR.

9. Ghaziabad Development Authority (GDA) in coordination with the National Capital Region Planning Board (NCRPB) is responsible for the planned development of Ghaziabad city. As per the Master Plan of Ghaziabad, 2021 the total development area of Ghaziabad is 8455 hectares, of which 4670 hectares is under residential use constituting 55.03 per cent of the developed land. This is followed by industrial use (20.16 per cent) and 6.13 per cent use under the roads, bus stands. The master plan proposes land use plan for the city with the intention of achieving balanced distribution of various land uses.

10. The NCR Regional Plan was approved on 9th July 2005. It is proposed that solid waste disposal and management should be planned for a minimum 20 years and at least controlled tipping should be adopted in the disposal of the solid waste. Areas should be identified in all the towns for sanitary landfill and all the towns above one lakh population should have arrangements to properly manage the waste disposal.

2. **Economic Policy**

11. *Implication on Town’s growth.* The Millennium Development Goals (MDGs) (Goal No.7) enjoin upon the signatory nations requiring them “to halving the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015” and 100 percent access by 2025. This implies extending coverage to households which are presently without improved sanitation, and providing proper sanitation facilities in public places to make cities open-defecation free

12. *National Urban Sanitation Policy.* Based on the recommendations of National Urban Sanitation Task Force in 2005, a National Urban Sanitation Policy has been approved by the Government of India in October 2008. The vision of the policy is that all Indian cities and towns become totally sanitized, healthy and livable and ensure and sustain good public health and environmental outcomes for all their citizens with a special focus on hygienic and affordable sanitation facilities for the urban poor and women with the following goals:

- Awareness Generation and Behavioral Change:
- Open Defecation Free Cities:
• Integrated City Wide Sanitation.
• Sanitary and Safe Disposal: the environment
• Proper Operation and Maintenance of all Sanitary Installations:

13. Eleventh Five Year Plan of GoI with the support of states including UP have identified action program to achieve 100 per cent population coverage for sewerage, sewage treatment and low cost sanitation facilities in urban areas.

14. National Urban Transport Policy. Ministry of Urban Development, Government of India, has announced the much needed National Urban Transport Policy in 2008. The vision of the policy is that to make our cities the most livable in the world and enable them to become the “engines of economic growth” that power India’s development in the 21st century and to allow our cities to evolve into an urban form that is best suited for the unique geography of their locations and is best placed to support the main social and economic activities that take place in the city. Major strategies of the policy include:

• Integrating land use and transport planning
• Equitable allocation of road space
• Priority to the use of public transport
• Quality and pricing of Public Transport
• Technologies for Public Transport
• Integrated public transport systems
• Priority to non-motorized transport
• Parking
• Freight traffic
• Capacity building
• Use of cleaner technologies
• Innovative financing mechanisms using land as a resource
• Association of the private sector

15. The NCR Regional Plan 2021 defined Central NCR (CNCR) and area of NCR except CNCR i.e. outside CNCR and proposed 7 metro centres and 11 regional centres. Ghaziabad city (including Loni) has been proposed as a major metro centre within CNCR and population estimated is as follows: 1.9 million in 2011 and 30.19 million in (2021)

16. Ghaziabad Development Authority (GDA) is developing residential sectors with private sector participation along the highway corridors which will attract more related activities and will fasten the town growth.

17. Density norms suggested for residential purpose had increased to 200 persons per hectare in Regional Plan-2021 from 150 persons per hectare from earlier Plan. This will increase the residential density in the city in coming years.

18. Construction of expressways and four laning of the NH24 and NH 58 connecting
Ghaziabad had attracted major educational, institutional, tourism and industrial activities. These together will have more pressure on Ghaziabad and subsequently for urban civic infrastructure including solid waste management.

**B. Review of Sector Context**

1. **Present Status**

19. The important national Highways passing through the Ghaziabad city are NH-58 which goes to Merrut, NH-24 which goes to Hapur and NH-91 which goes to Sikandrabad. Along with these highways, there is Hapur bypass passing through Ghaziabad connecting Madan Mohan Malviya marg and NH 91. The Y junction on NH 24 connecting NH 58 (near Mahamaya sports stadium) has become the most critical intersection in the city. The modal distribution of traffic at this junction is a mix of all types of vehicles with HTV/commercial vehicles more during night and early morning hours. The GT road carries large volume of traffic to an extent that it has exceeded its capacity by 50-60%.

20. Ghaziabad is connected with the city bus service, shared auto service which constitutes a major portion of the transport along with cycle carts and private vehicles. The city being an industrial area, a large number of truck traffic can be observed all over the city.

21. Rapid urbanization has lead to a sharp increase in travel demand. While the road layout in the city is well-planned, efforts to improve the condition of non-arterial roads should continue. Presently the mass transport within and around or from Delhi to Ghaziabad is mainly handled by bus and private owned transport. However, owing to the limited accessibility and congestion, there is a large increase in personalized modes of transport and IPT modes like auto rickshaw in Ghaziabad.

22. **Existing Inadequacy Level.** Despite the increasing importance of the town in the economic growth of the national capital region, the urban infrastructure is not adequate. Existing transport system in the city is observed with many deficiencies which include the following major ones:

- Inadequate and poor condition of internal roads
- Virtually non-existent intra-city public transport.
- Mofussil Bus Stand with inadequate facilities
- Inadequate pedestrian facilities
- Inadequate parking facilities resulting in haphazard on-street parking
- Absence of Truck Terminal parking areas.
- Inadequate facilities for non-motorized modes of transport

23. Urban transport infrastructure in Ghaziabad, like other cities, is handled by multiple agencies including GNN, State PWD, Ministry of Road Transport & Highways, Government of India, UP State Road Transport Corporation, Ghaziabad Development
Authority, traffic Police are the other major agencies involved in planning and implementation of transport infrastructure in the city along with the private operators. Lack of coordination among these agencies to address the city transport problems is the major issue in the sector.

24. GNN is responsible for development and maintenance of urban roads and other related issues like parking, goods traffic facilities, pedestrian facilities, traffic signals etc. Majority of the existing urban transport problems identified earlier were attributed to the urban roads under GNN and this may be due to inadequate provisions for this sector. Unfortunately the available data from GNN could not explain the present expenditure level for the development and maintenance of these urban roads.

25. Therefore, the inadequacy in provision of transport is likely to be the major constraint to the potential economic growth in the National Capital Region. Reduction of disparities through targeting less developed areas was a core element of the Government of India’s 10th Five Year Plan (2002-2007). The objective of the 11th Five Year Plan is ‘faster and more inclusive growth,’ citing the issues on inequitable share of growth, which was seen as increasing disparities among states, and regions within states, between urban and rural areas, and between various sections of the community. In order to realize the Five Year Plans, investment into transport sector in Ghaziabad city is necessary.

C. Justification for Government Intervention to Sector

26. The basic urban services include water supply, sewerage, drainage, transport and solid waste management (SWM). All of them are the mandatory functions of urban local bodies (ULB) under the 74th Constitutional Amendment Act (CAA). Unfortunately, immediate transfer of functions from the states to ULB is highly impractical due to the inadequate technical and financial strength of the ULB. Consequently, many of the state governments take initiative on capital investment and operation of water supply and sewerage while delegating SWM to ULB, which require less technical and financial strength than water supply and sewerage. In some states, the state governments take initiative on capital investment on water supply and sewerage projects and on completion of the construction they will be handed over to the ULBs for operation and maintenance, similar to UP. In UP, generally UP Jal Nigam will develop the sewage/SWM project and will hand over to ULB for O&M and this will be applicable to Ghaziabad SWM scheme also. In transport, ULBs will look after the internal road network and related issues through outsourcing and the major arterial roads will be the responsibility of technically equipped state PWD or central government agencies. Also the transport related infrastructure like off-street parking facilities, terminals for buses and goods vehicles etc are the responsibilities by ULBs.

27. In addition to being a constitutional obligation, provision of these services has economic rationales for government intervention for the following reasons: (i) many of the services (especially wastewater treatment, drainage, urban roads and solid waste management) are natural monopolies unsuited to unregulated private investment, and hence justify government intervention at least in regulation; (ii) environmental sanitation improvement (a) protects a public good such as a hygienic environment, and (b) prevents a negative
situation arising from pollution; and (iii) poverty alleviation programs minimize the inefficiency in economic growth in the urban areas. The economic rationale for government intervention is therefore sound.

D. Demand Analysis

28. Service delivery in not commensurate with existing traffic scenario in Ghaziabad and the strategy adopted for selection of urban transport and roads improvement sub-projects was to improve accessibility in Program towns so that residents would have better access to economic and social activities. Sub-projects identified would increase the supply of effective road space by removing impedances to traffic flow including road side drains, road strengthening, road widening, grade separators (flyovers), bus terminals, parking facilities and Road over Bridges (ROB) to provide better and uninterrupted connectivity.

29. Present sub-project component in Ghaziabad City considered for the present report comprises construction of a multi-storied parking facility. The unprecedented growth of personalized vehicles and the unplanned road infrastructure have made the provision for parking an important aspect of transportation planning. The frontage of almost all the roads in the CBD area (around GDA and Nagar Nigam) has been converted into commercial land use without taking into account the demand for parking of the vehicles. As there is no planned parking space available, vehicles can be seen parked an all the roads resulting in reducing the capacity of the carriageways and endangering pedestrians and motorists alike. The increased demand for vehicular parking around GDA and Nagar Nigam area necessitates the construction of a Multilevel Parking facility in that area.

30. This proposed project location is one of the critical locations that carry a high volume of on-street parking demand creating traffic related problems in that area. The location specific parking study conducted on this location also confirmed the heavy parking demand. The study has mandated a multi-storied parking facility to be built at this location. Since, the local officials also feel that a multi-storied parking facility is required at this location on a priority basis; this project is selected from the Transport Master Plan prepared for preparing Detailed Project Report (DPR).

31. Based on the intersection volume count survey conducted in December 2008, about 28,000 vehicles were found using this intersection on an average daily subjecting to more delay due to frequent congestion and this is likely to aggravate further in future. Construction of a flyover with related improvements like pedestrian facilities and other traffic safety measures will benefit 28,000 vehicles daily which is further to increase at about 5 – 6% every year. Benefits to these vehicles include i) reduced vehicle operation cost, ii) reduced delay time, iii) reduced in traffic accidents and iv) improvement to environment. Data sources considered were primary road inventory and traffic surveys carried out as part of the Program preparation, and available secondary data on the road network and previous traffic surveys.

32. Proposed DPR is selected from the recommendations were made at Master plan in the following stages.
Based on a comprehensive investigation of existing scenario and estimation of future requirements a transport master plan was prepared that had outlined the required transport infrastructure requirements to meet short, medium and long term traffic demand in Ghaziabad City.

As per the requirement of this study the present requirement is to identify four sample projects emerging out of the master plan proposals to be taken up for DPR. The four improvement proposals considered are:

- A grade separator
- Road widening on a corridor stretch
- A multi-level parking facility
- A bus terminal

The medium / long term proposals emerged out of the study were presented to the officials of NCR in Delhi, NCR cell in Ghaziabad, Ghaziabad Nagar Nigam, Ghaziabad Development Authority and others. The proposals to be taken up for DPR were extensively discussed between the Consultants and these officials. The schemes that are essential for the current scenario of Ghaziabad were finally identified by GDA and NCR.

33. The proposed grade separator at Mohan Nagar (Patel Chowk) was thus identified and selected for DPR preparation. Design parameters considered to the project design are listed below.

- The guidelines of Indian Road Congress (IRC) appropriate to intersection improvements, urban roads capacity evaluation, construction of grade separators etc.
- As part of planning, design and project formulation process, the basic design parameters have been followed to suit the projected road capacity and the intersection flow particularly to accommodate the peak hour flow.

1. Existing Transport System in Ghaziabad City

34. Master Plan Report (MPR) of Ghaziabad Transport was prepared in April 2009 with the objective to design a suitable integrated urban transport infrastructure system, by assessing the resource requirement for next 20 years and suggesting suitable measures for improvement of system.

35. Based on discussions with the stakeholders including different government agencies, detailed reconnaissance survey, review of available secondary data and finally scientifically planned primary traffic surveys, the existing traffic problems in the city and its environment was assessed.

36. Primary traffic surveys carried out for assessment include:
- Road network inventory
- Screen line traffic counts
• Intersection Classified Volume Counts
• Roadside Interview Surveys
• Speed and delayed surveys
• Parking surveys
• Pedestrian Crossing Count Surveys

37. Transport system deficiencies observed in general in Ghaziabad city include:

• Inadequacy of roadways
• Absence of intra-city public transport:
• Inadequate pedestrian facilities
• Deficient Junctions:
• Lack of Traffic Control Devices
• Improper location of Bus Stops
• Loading and unloading of goods at unauthorized places, obstructing the traffic and pedestrians alike
• Absence of Truck Terminal
• Inadequate facilities for non-motorized modes of transport
• Intermixing of Regional and local traffic:

38. Projected traffic at major corridors and intersections indicate that the existing traffic system in the city will experience severe congestion and that will result in speed reduction drastically and will affect the service delivery considerably. This underlines the need for improvement intervention in the system considerably.

39. Of the 15 intersections where turning volume count survey was done, eight intersections have peak hour traffic of more than 5000 PCUs (Passenger Car Unit) and this indicates most of the intersections in the city require improvement intervention to meet the present and the fast growing future turning traffic.

40. Results of the Road Side Interview Survey conducted at three locations on NH24, NH58 and NH91 indicated that:

• daily trips are more with 41% followed by alternate days and weekly trips with about 25% and 14% respectively.
• trips are for business purpose averaging about 43% comparing with 23% of work, 18% social and recreation, 8% tourism, 7% of education and 19% other trips respectively.

41. Average journey speed observed from the major roads is indicated below
### Table 1-1: Summary of Journey Speed Data

<table>
<thead>
<tr>
<th></th>
<th>NH 24</th>
<th>NH 58</th>
<th>NH 91</th>
<th>Hapur Bypass</th>
<th>Loni Bhopura</th>
<th>Ambedkar Marg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average JS - peak Hour</td>
<td>41</td>
<td>38</td>
<td>41</td>
<td>20</td>
<td>27</td>
<td>23</td>
</tr>
<tr>
<td>Average JS - Off Peak Hour</td>
<td>58</td>
<td>41</td>
<td>59</td>
<td>25</td>
<td>45</td>
<td>36</td>
</tr>
</tbody>
</table>

JS - Journey Speed in kmph

42. Results of parking survey conducted at four critical locations in the city had indicated that the available parking space is less than the actual demand. It can be seen that near GDA complex, the demand is in excess of the available supply considerably. With regard to parking duration, about 80% of the vehicles were parked for less than 30 minutes and this indicates high parking turn out. Another 21% of vehicles were parked more than 30 minutes but less than three hours.

43. Results of the Base Line Survey conducted in Ghaziabad city in 2008 revealed the following opinions about the existing transport infrastructure services:

- 20% of the non-slum households and 47% percent of slum households were not satisfied about the road conditions;
- 30% of the non-slum households and about 20% percent of slum households were not satisfied about the services of street lights;
- 77% of the non-slum households and 65% percent of slum households feel that there is no proper drainage facilities along the roads;
- 75% of the non-slum households and 94% percent of slum households were not satisfied about the available vehicular parking facilities;
- 78% of the non-slum households and 84% percent of slum households felt that there is no adequate parking space for commercial vehicles;

2. Effective Demand for Urban Transport

44. The socio-economic baseline survey\(^1\) was aimed at understanding the perception of the public towards the existing urban civic infrastructure and their service levels including their opinion towards the improvement of these services and their willingness to pay for assessing the ‘effective demand’. Though this survey had covered the ‘willingness to pay’ aspect, it was not given specific focus so as to amend the results to statistical framework.

45. The Base line Survey results had indicated that:

- nearly 43 percent non-slum household spends between Rs 1000 and above and Rs 2000 per month as fuel and vehicle maintenance. More than 47.2 percent slum household spends less than Rs.200. Another 33 percent non-slum household spends

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\(^1\) conducted as part of the present project (2008) in Ghaziabad City (with 0.5% sample size with stratified sampling approach giving representation to all administrative wards and all notified slums)
between Rs. 200 to 1000 per month as fuel and vehicle maintenance.

- More than 90 percent of non-slum household spend between Rs. 500-1,000 per month to go to their respective work place. In case of slum, more than 65 percent household spend more than an hour to reach to their work place with a monthly expenditure ranges between Rs. 100-500.
- Nearly 51 percent non-slum and 30.5 percent slum households are willing to pay upto Rs. 5 per hours for 2-wheeler parking.
- Better frequencies, better comfort and better coverage are the type of improvements commuters expect from the public transport system;
- Around 98 percent non-slum and cent percent slum households are willing to pay more than 5-10 percent if the frequencies of service level of public transport improve. For better comfort and coverage of services the same trend is prevalent.

These facts discussed above justify the need for the improved transport subprojects in the city and the proposed subprojects like parking facility, terminals for public transport, grade separator and improving road corridor backed up by effective demand.

**E. Identification of Project Rationale**

47. The present transport system has inadequate and less quality infrastructure including mostly bad road conditions, inadequate parking facilities and pedestrian facilities, not properly designed intersections, over utilized and congested road sections, inadequate terminal facilities for public transport, intermediate public transport vehicles and trucks, inadequate public transport service delivery etc. In general, major transport problems in the city include:

- Lack of coverage and
- Inefficient functioning of the existing system

48. Also the Transport Master Plan (TMP) prepared for the town has identified deficiencies and formulated recommendations to be implemented in phased manner that include (i) short term improvements, (ii) medium and long term improvements that include integrate terminals for public transport and trucks, improvement to identified critical intersections through grade separators etc, capacity augmentation to arterials roads through widening, dedicated multi storied parking facilities, development of new road links etc., to meet the requirements of horizon year demand. Thus the main project rationale lies for the rehabilitation of the Transport system for Ghaziabad city in filling the demand – supply gap resulted from and the present subproject of construction of a multi-storied vehicular parking facility is selected from the Transport Master Plan in consultation with the stake holders of concerned Government Departments and agencies Ghaziabad City.

**F. Identification of Project Alternatives**

49. For the selected subproject of multi-storied vehicular parking facility (near GDA Office)
for which detailed project report is prepared, alternative designs were assessed on three aspects, namely, cost-effectiveness, operation and maintenance capacity of the states governments and ULB, and safety to beneficiaries. The proposed design of the project incorporates that (i) service coverage to the full GNN area, (ii) selected optimum network with least cost options including equipments and material (iii) decision on rehabilitation of the existing system (iv) selection of new terminal sites with reference to Ghaziabad Development / Master Plan proposals (v) selected technologies meet geographical restrictions and can be operated and maintained by the asset owners with minor training, and (vii) materials and equipments are locally available and incur least cost during construction and maintenance, but are internationally accepted as health hazard free. These Assessments are discussed in the design section of this DPR.

G. Identification and Comparison of Project Costs and Benefits

1. Economic Cost

50. From the cost estimate discussed in Section of this report, the ‘base’ project financial cost is estimated to Rs. 348 million. Considering the contingency and allowances of additional 12% (Physical contingency (3%), DSC + Third Party Inspection (TPI) - 3%, IEC activities 1%, o Incremental Administration (PIU) – 2%, Environmental mitigation 1%, Social intervention 1%, and Institutional development and capacity building activities1%), the total project financial cost was worked out to Rs 435 million and this is phased during the two year construction period as follows:

- 2011-12 – 40%
- 2012-13 – 60%

51. Considering the standard procedures recommended for economic feasibility analysis, the above financial cost was converted into economic cost for the analysis. Details of economic cost analysis are presented in Appendix 1-1.

2. Project Benefits

52. Project beneficiaries will be those travelers for whom accessibility to economic and social activities will be improved through better road conditions and traffic flows brought about by the sub-projects. This improvement is achieved by reducing the effort or inconvenience of travel between the origin of the traveler and the destination offering these activities.

53. The subproject is in Ghaziabad near the GDA Office which is the main commercial and institutional area in Ghaziabad city with transport network at present experiencing tremendous traffic congestion and this is mainly due to the heavy presence of on-street parking of private and IPT vehicles. The unprecedented growth of personalized vehicles and the unplanned road infrastructure have made the provision for parking an important aspect of transportation planning. The frontage of almost all the roads in the CBD area
(around GDA and Nagar Nigam) has been converted into commercial land use without taking into account the demand for parking of the vehicles. As there is no planned parking space available, vehicles can be seen parked on all the roads resulting in reducing the capacity of the carriageways and endangering pedestrians and motorists alike. The increased demand for vehicular parking around GDA and Nagar Nigam area necessitates the construction of a Multilevel Parking facility in that area.

54. The sub proposal is to construct a multi-storied parking facility so as to reduce the on-street parking on the project impact roads with free flow and the remaining turning with less waiting time. Subproject proposals will benefit the vehicular traffic on the impact roads with less traffic congestion, less traffic conflict at junctions, increase the travel speed resulting in savings in vehicle operating cost (VOC) and travel time, accommodate the fast growing vehicular traffic, uninterrupted movement for the major through traffic through the region, pedestrian safety including reduced road crossing time etc.

55. The economic benefits considered in the present analysis for the multi-storied parking subproject in transport component in Ghaziabad city include:

(i) Value of Passenger Travel Time Savings on the project impact road Sections
(ii) User charges collected from the parked vehicles, and
(iii) Rental charges collected from the commercial establishments and utilities operated at the ground floor.

56. *Exclusions.* The following benefits of transport component for the off-street parking construction have not been quantified for want of adequate data and quantification techniques. These qualitative benefits along with the quantifiable benefits discusses above, the proposed multi-storied parking construction will tend to provide better living condition in the project town.

(i) Improvement in the environment of the project site;
(ii) Savings in VOC due to the reduction in traffic congestion at the junction;
(iii) Savings in traffic accidents cost due to better traffic management; and
(iv) Effects on tourism and tourist-related businesses.
H. Economic Feasibility Analysis

1. Analysis Period

57. The analysis period of the project is taken as 24 years from the base year 2010 for different sections of the project road as follows:

- Base Year 2010
- Construction period – 2011 to 2012
- Project opened start year – 2013
- End of the analysis period – 2032

58. Number of operating years after project improvement, considered for economic analysis – 20 years. Thus, 20 years of operation, in effect, from the operation start of the proposed project i.e. 2013 have been considered for economic evaluation for the project road.

2. Economic Feasibility Criteria

59. The cost – benefit analysis is carried out by using the discounted cash flow (DCF) technique to obtain the economic internal rate of return (EIRR) and economic net present value (ENPV) for the proposed investments and the likely quantified project benefits linked with the project during the defined project analysis period


60. Given the complexity of estimating country-specific economic opportunity cost of capital (EOCC), a discount rate of 12% in constant economic prices is generally used as a proxy for EOCC in the economic analysis of ADB-financed projects. The EIRR must be compared with the economic opportunity cost of capital, for interpretation purpose of project feasibility. Results of the analysis are presented in Table 1-2.

Table 1-2: Economic Cost-Benefit Analysis for Multi-level Parking in Ghaziabad

<table>
<thead>
<tr>
<th>Details</th>
<th>Present Value (Rs. million) a/</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Capital costs</td>
<td></td>
</tr>
<tr>
<td>Transport (Multilevel parking)</td>
<td>273</td>
</tr>
<tr>
<td>O&amp;M costs</td>
<td></td>
</tr>
<tr>
<td>Transport (Multilevel parking)</td>
<td>20</td>
</tr>
<tr>
<td>Total costs</td>
<td>293</td>
</tr>
<tr>
<td><strong>Benefits</strong></td>
<td></td>
</tr>
<tr>
<td>Transport (Multilevel parking)</td>
<td></td>
</tr>
</tbody>
</table>
Details | Present Value (Rs. million) a/  
--- | ---  
- Travel Time Savings | 647  
- Parking Charges | 86  
- Commercial Space Revenue | 218  
**Total benefits** | **952**  
Economic Return Measures |  
Net present value (Rs. Million) | 658  
**EIRR (%)** | **33.86%**  

a/ In 2009-10 prices. Discounted to 2009-10 at 12% real discount rate.

I. Sensitivity Analysis

61. Sensitivity analysis was carried out to their economic feasibility results for the following scenarios:

- Capital cost increase by 20%
- O&M costs increased by 20%
- Target beneficiaries reduced by 20%
- Delay in accrual of benefit by 1 year
- Combined adverse condition

62. Results of the sensitivity analysis for the proposed project are summarized below in Table 1-2:

<table>
<thead>
<tr>
<th>Details</th>
<th>EIRR</th>
<th>Switching Value c/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Evaluation (Base Case) a/</td>
<td>33.9%</td>
<td></td>
</tr>
<tr>
<td>Capital Cost Overrun b/</td>
<td>29.4%</td>
<td>240.0%</td>
</tr>
<tr>
<td>O&amp;M Cost Overrun d/</td>
<td>33.7%</td>
<td>3250.0%</td>
</tr>
<tr>
<td>Decrease in Project Benefits e/</td>
<td>28.3%</td>
<td>69.0%</td>
</tr>
<tr>
<td>One Year Delay in Implementation</td>
<td>33.8%</td>
<td></td>
</tr>
<tr>
<td>All Four Tests Combined</td>
<td>24.26%</td>
<td></td>
</tr>
</tbody>
</table>

a/ From Table 1-2.  
b/ 20% increase in capital cost estimates.  
c/ Calculated as the percentage change in a variable required for EIRR to reduce to 12%. For example the capital cost can increase by 230% or project benefits can reduce by 68% to get the minimum required level of EIRR of 12%  
d/ 20% increase in O&M cost.  
e/ 20% decrease in project benefits
63. Of the four sensitivity scenarios (cost overrun, O&M cost increase, reduced beneficiaries, delay in implementation) reduced beneficiaries is the most vulnerable to EIRR, followed by cost overrun. Considering the more sensitiveness of these variables, following implementation arrangements need to be focused more so as minimize the project risk:

- Ensuring adequate project coverage of beneficiaries through advance commitment from HHs for individual access or making mandatory for all individual access through project design;
- Timely implementation of the project through appropriate procurement method in which incentive for early completion may be included;
- Adequate focus for LA related project components

J. Conclusion

64. The main evaluation has indicated that the proposed transport sub project (construction of a Multistoried Parking) for Ghaziabad city was found to be economically viable, with the calculated EIRR values exceeding the economic opportunity cost of capital. The sensitivity analysis has demonstrated the robustness of this result, with the subproject component economically viable even when the combination of changed assumptions was tested.

65. Furthermore, for the proposed drainage subproject, the calculated EIRR value is considered minimum estimates of economic return, as there are a number of economic benefits of reduced pollution, a cleaner city and improved transport environment that have not been quantified.
2. FINANCIAL MANAGEMENT AND ANALYSIS OF PROJECTS

A. Introduction

66. Financial analysis for subprojects generally consists of both (i) Financial Management Assessment and (ii) Financial Analysis and this is the specific requirements for the financial analysis to the projects funded by ADB. The minimum requirement for Financial Management Assessment and analysis, are described in ADB’s ‘Financial Management and Analysis of Projects (the Guidelines)’.

67. Financial Management Assessment, the first part of analysis, concentrates on the assessment review of Executing Agency (EA) and Implementing Agency (IA) with respect to the subproject subjected to financial analysis. Assessment review will cover the areas like financing policies; accounting policies; project implementation plan; financing plan; disbursement procedures and fund-flow mechanisms and regulatory provisions.

68. Second part of the analysis is the ‘Financial Analysis’ for subprojects. This will mainly focus on the review of EA, IA and the proposed subproject with respect to the following components:
   • Past and present financial condition
   • Cost Recovery and Profitability
   • Financial Improvement Action Plan
   • Affordability Analysis
   • Projected Financial Forecasts
   • Cost benefit analysis
   • Sensitivity Analysis

69. The proposed subproject of Multistoried Parking in Ghaziabad City is likely to be funded from ADB fund through NCRPB. However for the present analysis, it is considered that the proposed subproject will funded by NCRPB to the end-borrower (Ghaziabad Nagar Nigam – GNN). Accordingly GNN with the guarantee of the Uttar Pradesh State will become both the Executing Agency (EA) as it will have the direct control of NCRPB Loan and the Implementing Agency (IA) as GNN is the asset owner and responsible for the implementation and operation of the proposed subproject, utilizing the loan proceed. Accordingly, both GNN as EA and IA is considered for financial management assessment purpose.

70. Considering the focus of the present assignment ‘to support the project preparation efforts of the implementing agencies by preparing demonstration feasibility studies and DPRs that include all due diligence documentations required for processing of the project in accordance with the best practices, including the proposed NCRPB’s policies and guidelines’, the following requirement in carrying out the financial analysis emerge:
the subprojects funded through ADB loan; and
the subprojects funded through NCRPB own fund,

71. In both cases, NCRPB only will be the lender to the end borrowers (ULBs or line departments / agencies) for the subprojects and hence only the end-borrower will be assessed.

72. With this background, the present financial feasibility analysis concentrates more on the project financial analysis as this is the area where the capacity of the IAs needs to be enhanced for both format of loans. Also the financial management assessment part of the analysis is covered to the level of data availability. On finalization of the projects for ADB funding (in which the present subprojects under review may or may not be a part), subsequent consultancies will improve this financial management assessment part of the financial analysis.

B. Financial Management Assessment

1. Policy Context

73. Subsequent to the 74th Constitution Amendment Act (CAA), 1992 (Refer Appendix 2-1) the Government of Uttar Pradesh (GoUP) embarked on a policy of decentralization of powers to local governments. Uttar Pradesh Local Self Government Laws (Amendment) Act, 1994 was drafted based on decentralization principles laid down in the 74th CAA, which came into force w.e.f. 31.05.1994. Impact of 73rd & 74th Amendments on ULBs in Uttar Pradesh State is summarized in Appendix 2-3.

74. Key features of the decentralization initiative comprised (i) transferring health related institutions (except medical colleges and regional specialty hospitals) to local governments; (ii) transferring all schools to Urban Local Bodies (ULBs); (iii) planning and implementing centrally sponsored poverty alleviation schemes through ULBs; (iv) planning social welfare schemes, implementing Integrated Child Development Scheme (ICDS), payment of various social security pensions, and creating centre for disabled care are ULB responsibilities; (v) planning and providing urban basic services, including water supply, sanitation, storm water drainage and urban roads (excluding those provided / maintained by the State Public Works Department); (vi) Ward Committees in all municipal corporations and municipalities which have a population of three lakhs or more; and (vii) increase of financial power for ULB Heads.

75. Constitution of State Finance Commission (SFC). Consequent up to 73rd and 74th Amendments to the Constitution of India, and in exercise of the powers conferred by Article 243(1) & (X), the Governor vide Finance Departments Notification no. RG-1933/x-53-94 dated October 22, 1994 constituted the State Finance Commission (Panchayat Raj & Local Bodies). Two SFCs were constituted in UP and the UP Government had mostly accepted their recommendations (more than 80 percent). Status of
the recommendations of the SFCs on tax sharing to local bodies is summarized in Table 2-1. In Indian Federal structure, SFC created by 73rd and 74th CAA is the only channel to address issues of state-local fiscal relations. SFCs thus acquire unique place in fiscal decentralization and local finance issues.

Table 2-1: SFC Recommendations on Tax Sharing – Uttar Pradesh

<table>
<thead>
<tr>
<th>State</th>
<th>Recommended and accepted share of Local Bodies ( Urban &amp; Rural)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First SFC</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>10 % of net own tax revenue receipts of state govt. (7 % for ULBs)</td>
</tr>
</tbody>
</table>

Source: Decentralization and Local Finance Issues - The Workings of State Finance Commissions in India, Dr. Ravikant Joshi

76. Some of the major recommendations from SFCs that affect the financial management of ULBs in UP include:

(i) Conversion of certain category of loans sanctioned to the urban local bodies which was over due on 31st March as state grants

(ii) Rates of Non-Tax Revenue have been revised and as mentioned earlier the power to further revise these rates in future by framing or amending the bye laws has been delegated to urban local bodies.

(iii) To increase the own sources of tax revenue of urban local bodies the target has been fixed to fix the demand as per the estimated population of 1997, minimum per capita of Rs. 120 for municipal Corporation and Rs. 40 to 90 per capita in Nagar Palika Parishad (depending upon the population) and Rs. 20 per capita in Nagar Panchayats vide g.o. No. 3488/IX-9-97-55/97 dated October 22, 1997.

(iv) Imposition of all types of taxes enumerated in the Act, has been made compulsory vide g.o. No. 2371(1)/IX-91998 dated September 23, 1998.

(v) The recommendations in respect of profession tax have been accepted by most states as per the available information.

(vi) Participation of the community and the private sector, especially in the delivery of urban services is being emphasized. In Uttar Pradesh, decisions have been taken on providing civic services on contract basis and to promote citizen participation

(vii) The Finance Commissions of Uttar Pradesh have given importance to devolution of functions, functionaries and powers along with a transfer of funds.

77. The share of transfers from state governments in the revenues of municipalities was 31.7 per cent (2001/02). This is, however, the average; municipalities in several states are almost entirely transfer-dependent for running of local services. The dependence of urban local bodies was as high as 83.71 per cent in case of Jammu & Kashmir, 83.33 in case of Rajasthan and 74.48 in case of Uttar Pradesh.

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2 Decentralization and Local Finance Issues - The Workings of State Finance Commissions in India, Dr. Ravikant Joshi
78. This scenario is a result of the following three factors:

- The inferior local taxes which have low elasticity and buoyancy;
- Poor administration of tax and other powers by local governments; and
- Absence of autonomy for local governments in respect of tax rate setting, rate revision and other spheres of their functioning.

79. Government of India (GoI): GoI in its Tenth Five Year Plan (2002-2007) emphasized the role of the ULBs:

- To be responsive and accountable to the community;
- to develop cities with standards of service comparable to the best in that particular category;
- to constantly improve their capabilities so as to equip themselves to undertake their tasks in resource-raising, service provision, and poverty alleviation.

80. Tenth Plan had focused the reforms in land and housing policy, and of pricing of utilities, should be to augment the resources of the ULBs, provide for adequate maintenance of civic services, and undertake expansion of infrastructure to meet growing needs.

81. Apart from the State Finance Commissions, GoI has found providing support to ULBs through various schemes including AUWSP, IDSMT, JNNURM, Mega City Scheme, NCR PLAN, HUDCO loan assistance, Tax-Free Bonds scheme and external assistance from multilateral lending agencies like the Asian Development Bank (ADB), World Bank and bilateral agencies.

82. Govt. of Uttar Pradesh (GoUP). Based on the lessons learnt through the 9th FYP, the 10th FYP (2002-07) for Uttar Pradesh is based upon local government’s development plan and focuses on (i) reforms and improving organization efficiencies; (ii) increasing allocation in information technology, tourism infrastructure, poverty reduction and health; (iii) planning programs to facilitate employment generation; (iv) promoting private sector investment in economic development; (v) preparing sub-plans for poverty reduction with participation of women groups and focus on vulnerable sections of the society; (vi) evolving a plan for the disabled and women beneficiaries; (vii) strengthening decentralization and improving the planning process; (viii) continuing support to increased use of information technology in all facets of development; (ix) continuing support to tourism infrastructure development; (x) promoting the development of village and small industries; (xi) promoting the participation of private sector in providing education; and (xii) improving service delivery in key areas like health, revenue, education, etc.

83. Govt. of Uttar Pradesh had allotted Rs 102066 Lakhs for the urban development during the Tenth Plan (2002-2007) which was about 2% of the total plan outlay. However, the actual plan outlay during the plan period was increased to Rs 143142 Lakhs (Table 2-2). Also the annual budget for 2009-10 during the Eleventh Plan for urban development was
Urban Development, Government of India. NCRPB has a mandate to systematically develop the National Capital Region (NCR) of India which comprises of (i) National Capital Territory Delhi (constitutes 4.4 percent of NCR area); (ii) Haryana Sub-region (40.0 percent of NCR area); (iii) Rajasthan Sub-region (23.3 percent of NCR area); (iv) Uttar Pradesh Sub-region (32.3 percent of NCR area) and (v) Five Counter Magnet Areas (CMA) The project town Ghaziabad City also part of the NCR.

85. According to the NCRPB Act, 1985 major functions of the Board include: (i) Preparation of the Regional Plan and Functional Plans; (ii) Coordinate enforcement and implementation of the Regional Plan, Functional Plans, Sub-regional Plans, and Project Plans through the participating states and NCT; (iii) Ensure proper and systematic programming by the participating states and the NCT in project formulation, determination of priorities in NCR or Sub-regions and phasing of the development of NCR in accordance with the stages indicated in regional plan; and, (v) Arrange and oversee the financing of selected development project in the NCR through Central and State Plan funds and other sources of revenue.

86. NCRPB has prepared regional plan for NCR area with the perspective year 2021. Further, the Board also initiated preparation of functional plans to elaborate one or more elements of the Regional Plan. Accordingly the functional plan for water supply and transport is under preparation but plans for other infrastructure is yet to take off (Appendix 2-2).

3. **Ghaziabad Nagar Nigam**

73 The status of Ghaziabad was upgraded from Municipal Board to Municipal Corporation, known as Ghaziabad Nagar Nigam (GNN) on 31 August 1994 following 74th constitution Amendment Act 1992 and conformity legislation by state government. The Municipal administration has been decentralized in five zones and 80 administrative wards. City zone has 24 wards; Kabir Nagar has 17 wards; Vasundra zone has 11 wards; Mohan Nagar zone has 14 and Vijay Nagar Zone has 14 wards.

87. Urban development and service delivery in Ghaziabad Nagar Nigam (GNN) is the combined responsibility of a set of state level and city level institutions. These institutions and their key functions are listed in Table 2-4 below segregated in terms of institutions functioning at the state level and city level.
increased to Rs 180420 Lakhs (Table 2-3) in which water supply, sanitation and urban development were the focus areas. These together underline the importance given to the urban development by the GoUP, which includes the project city of Ghaziabad.

Table 2-2: Tenth Plan Allocation for Urban Development in Uttar Pradesh

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Plan Allocation for Urban Development during the Tenth Five Year Plan (Rs. Lakhs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002-03</td>
<td>22,347</td>
</tr>
<tr>
<td>2003-04</td>
<td>14,378</td>
</tr>
<tr>
<td>2004-05</td>
<td>14,174</td>
</tr>
<tr>
<td>2005-06</td>
<td>23,489</td>
</tr>
<tr>
<td>2006-07</td>
<td>68,754</td>
</tr>
<tr>
<td>Total</td>
<td>143,142</td>
</tr>
</tbody>
</table>

Source: Govt. of UP

Table 2-3: Major head summary for the Budget Year 2009-2010 for Urban Development, Uttar Pradesh (Rs. Thousands)

<table>
<thead>
<tr>
<th>Major Head and Description</th>
<th>Current year Budget (2009-10)</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plan</td>
<td>Non Plan</td>
</tr>
<tr>
<td>2015—Elections</td>
<td>-</td>
<td>83,836</td>
</tr>
<tr>
<td>2052--Secretariat - General Services</td>
<td>542</td>
<td>62,350</td>
</tr>
<tr>
<td>2053--District Administration</td>
<td>2</td>
<td>98,278</td>
</tr>
<tr>
<td>2070--Other Administrative Services</td>
<td>-</td>
<td>5,171</td>
</tr>
<tr>
<td>2215--Water Supply and Sanitation</td>
<td>1,220,000</td>
<td>-</td>
</tr>
<tr>
<td>2217--Urban Development</td>
<td>2,755,324</td>
<td>1,036,092</td>
</tr>
<tr>
<td>2230--Labour and Employment</td>
<td>125,404</td>
<td>-</td>
</tr>
<tr>
<td>3054--Roads and Bridges</td>
<td>-</td>
<td>550</td>
</tr>
<tr>
<td>3604--Compensation and Assignments to Local Bodies and Panchayati Raj</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4070--Capital Outlay on Other Administrative Services</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>4215--Capital Outlay on Water Supply And Sanitation</td>
<td>1,480,003</td>
<td>-</td>
</tr>
<tr>
<td>4217--Capital Outlay on Urban Development</td>
<td>9,024,502</td>
<td>150,000</td>
</tr>
<tr>
<td>6215--Loans for Water Supply and Sanitation</td>
<td>2,000,000</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>16,605,778</td>
<td>1,436,277</td>
</tr>
</tbody>
</table>

Source: http://budget.up.nic.in/Estimates/maj_sumry.asp

2. **National Capital Region Planning Board (NCRPB)**

84. The National Capital Region Planning Board (NCRPB), constituted in 1985 under the provisions of NCRPB Act, 1985\(^3\), is a statutory body functioning under the Ministry of

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\(^3\) The National Capital Region Planning Board Act, 1985, No.2 OF 1985, 9th February, 1985, published by The Gazette of India on FEBRUARY 11, 1985. This Act provide for the constitution of a Planning Board for the preparation of a plan for the development of the National Capital Region and for co-ordinating and
### Table 2-4: Institutions and Their Functions

<table>
<thead>
<tr>
<th>Institution</th>
<th>Key Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. State Level</strong></td>
<td></td>
</tr>
<tr>
<td>UP Pollution Control Board (UPPCB)</td>
<td>Pollution control and monitoring especially river water quality and regulating industries</td>
</tr>
<tr>
<td>Public Works Department (PWD)</td>
<td>Construction of roads main roads and transport infrastructure including construction and maintenance of Government houses and Institutions</td>
</tr>
<tr>
<td>State Urban Development Authority (SUDA)</td>
<td>Apex policy-making and monitoring agency for the urban areas of the state. Responsible for providing overall guidance to the District Urban Development Authority (DUDA) for implementation of community development programs</td>
</tr>
<tr>
<td>Town and Country Planning Department (TCPD)</td>
<td>Preparation of Master Plans including infrastructure for the state (rural and urban)</td>
</tr>
<tr>
<td>UP Jal Nigam (JN)</td>
<td>Water supply and sewerage including design of water supply and sewerage networks. In the last two decades ‘pollution control of rivers’ has become one of their primary focus areas</td>
</tr>
<tr>
<td>UP Avas Vikas Parishad (AVP)</td>
<td>Nodal agency for housing in the state. Additionally involved in planning, designing, construction and development of almost all types of urban development projects in the state. Autonomous body generating its own resources through loans from financial institutions</td>
</tr>
<tr>
<td><strong>II. City Level</strong></td>
<td></td>
</tr>
<tr>
<td>Ghaziabad Nagar Nigam (GNN)</td>
<td>Nodal agency for municipal service delivery and O&amp;M. Its key functions include:</td>
</tr>
<tr>
<td></td>
<td>• Primary Collection of Solid Waste</td>
</tr>
<tr>
<td></td>
<td>• Maintenance of Storm Water Drains</td>
</tr>
<tr>
<td></td>
<td>• Maintenance of internal roads</td>
</tr>
<tr>
<td></td>
<td>• Allotment of Trade Licenses under the Prevention of Food Adulteration Act</td>
</tr>
<tr>
<td></td>
<td>• O&amp;M of internal sewers and community toilets</td>
</tr>
<tr>
<td></td>
<td>• Management of ghats</td>
</tr>
<tr>
<td></td>
<td>• Construction of Community Toilets</td>
</tr>
<tr>
<td>Ghaziabad Development Authority (GDA)</td>
<td>Responsible for preparing spatial Master Plans for land use and development of new areas as well as provision of housing and necessary infrastructure</td>
</tr>
<tr>
<td>District Urban Development Authority (DUDA)</td>
<td>Implementing agency for plans prepared by SUDA. Responsible for the field work relating to community development – focusing on the development of slum communities, construction of community toilets, assistance in construction of individual household latrines, awareness generation etc.</td>
</tr>
</tbody>
</table>

88. **In real sense, 74th Amendment is partially implemented in UP. GNN, Jal Nigam and various other government agencies are functioning in Ghaziabad and are playing different roles of a ULB under different capacities (and other cities of UP). This makes the municipal corporation inadequate resulting in limited power and weak municipal administration. These cities are dependent on the state legislature for decisions concerning**
their regulations and it is critical for the decision making process required at a local level. However, with regard to the issue of reforms, current status and future proposals the state government /ULB are in the process of initiating steps in this direction and the willingness of the governments to undertake the required reforms.

4. **Private Sector Participation**

89. The current legal and political climate for the involvement of FI’s or Private parties for building urban infrastructure and or operating urban services in UP Cities including Ghaziabad does not look very promising in its present form, as revealed from available CDP Reports. Many reforms, legislative changes and a greater commitment from the local body as well as the GoUP are required for attracting private investment and safeguarding investors’ interest. However, three broad areas can be identified and explored for private investment for urban infrastructure, namely transportation services including bus/truck terminals, Parking (multilevel parking with commercial space] and Solid Waste Management.

5. **User Charges**

90. Ghaziabad Municipal Corporation is not in a position to collect user charges from different authorities in the desired manner to reflect the actual usage of different urban services. For example in water supply there is not a meter system in place, the user fee is being charged on per connection basis without taking into account the actual expenses on O&M for the provision the service.

91. The property tax collection in force in GNN has provisions for water and sewer components as indicated below. It does not have the provision for SWM component in the property tax...

<table>
<thead>
<tr>
<th>ARV Based Property Tax System followed in Ghaziabad City</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Rental Value (ARV) = Plinth Area (sqft) x Rs. 0.60 x 12 months</td>
</tr>
<tr>
<td>House Tax = 10% of ARV</td>
</tr>
<tr>
<td>Water Tax = 10% of ARV</td>
</tr>
<tr>
<td>Sewer Tax = 4% of ARV</td>
</tr>
</tbody>
</table>

92. Though GNN does not have multistoried parking facility at present, there are few dedicated off-street parking facilities operated by GNN or other agencies with user charges. Also there are initiatives to develop multistoried parking facilities at locations like Raj Nagar District Centre, Kaushambi in Ghaziabad City under PPP format (DBFOT). Existing user fee for parking is around Rs. 10 per hour for cars and Rs. 5 per hour for two wheelers. Proposed multistoried parking facilities under DBFOT basis proposed user charges of Rs. 20 for cars (upto four hours) and Rs 10 for two wheelers (upto four hours). Parking fee charged at selected commercial complexes are also more or less close to this and some times little more.
6. *Financing Plan*

93. Total investment program will be shared between NCRPB and GNN through participating states in such a way that NCRPB share will be 75% as loan and GNN will be the balance 25%. The terms of the loan will of
   - 10 years tenure with two years moratorium and eight years repayment period
   - 9 percent interest rate

94. As per the existing arrangements, for UP state, the entire 75% loan component will be transferred to GNN with the guarantee support of states but without grant component from NCRPB and hence the total contribution by GNN will be 100% (25% own contribution + 75% NCRPB loan). For 75% Loan component and 25% own equity component, GNN will be the responsibility. For implementation, GNN will be the Executing Agency for the Investment Program and responsible for overall strategic guidance, technical supervision and work quality and ensuring compliance with loan and PFR provisions and due diligence.

7. *Operation and Maintenance:*

95. It is observed that in the UP State, and in many other states in India, operating and maintaining the parking facility will be the responsibility of the GNN in case of implementing the project by itself. Accordingly GNN will operate and manage O&M of the improved SWM facilities in Ghaziabad with adequate fund provision and the required technical capability. If necessary GNN can outsource the responsibility to private operators.

8. *Cost Recovery*

96. Present multistoried vehicular parking project is considered under full cost recovery and so levy of user charges for the facilities offered like parking facilities and commercial activities is important. Also levy of parking fee is presently followed in the city by different agencies as discussed earlier. Considering all the user fee followed presently by different agencies, an appropriate user fee structure was followed with periodical renewal mechanism is followed for the present project towards the cost recovery objective, as shown below.

<table>
<thead>
<tr>
<th>Details</th>
<th>Car</th>
<th>TW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking Fee (Rs. / two hour)</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Increase in Parking Fee (at every 3rd year)</td>
<td>15%</td>
<td>15%</td>
</tr>
</tbody>
</table>

Source: Consultants Estimate
Table 2-6: Estimation of Revenue from Commercial Space - Multistoried Parking

<table>
<thead>
<tr>
<th>Details</th>
<th>Commercial Space Rent Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area proposed for Commercial Purpose (Sqm)</td>
</tr>
<tr>
<td>Ground Floor</td>
<td>3200</td>
</tr>
<tr>
<td>First Floor</td>
<td>-</td>
</tr>
</tbody>
</table>


97. Loan disbursement is a key element in the project cycle. NCRPB expects that proposed disbursement procedures and fund-flow mechanisms will be suitable for the particular project. NCRPB procedures for withdrawal of loan proceeds are standardized to facilitate disbursements under most loans.

98. In the present case, it is assumed that the NCRPB Loan will be passed on, to the GNN with the UP State government guarantee. Thus GNN will be the borrower from NCRPB with the UP State support. GNN will enter into supply and civil work contracts and issues and signs the payment checks through a suitable arrangement agreed with NCRPB. Created assets will be owned by GNN as SWM will be its responsibility. With regards to repayment of the interest and principle, GNN will pay to NCRPB and this will be governed by the NCRPB’s terms and conditions agreeable in the disbursement procedures.

10. *Accounting Policy*

99. Long-, medium- and short-term planning should be the primary elements in financial management. Long- and medium-term plans are often referred to as corporate plans. Short-term financial plans are usually called budgets. NCRPB will seek assurance that satisfactory plans and budgets will be prepared in a regular, orderly and timely manner. Also NCRPB will consider the acceptability of accounting policies, including standards of financial reporting and general accounting practices. In line with the existing market best practices followed for infrastructure financing, NCRPB expects these policies to be materially consistent with accepted national or international standards and practices.

100. Accordingly the potential agency Ghaziabad Nagar Nigam (GNN) that will be involved in the project loan was considered for review. Discussion on GNN’s accounting policy is given below.

101. GNN maintains records on single entry cash based system of accounting. The output of this cash basis of accounting is a Statement of Receipts and Payments that classifies cash receipts and cash payments under different heads. A statement of assets and liabilities is not prepared.
102. The cash basis of accounting fails to meet most of financial reporting objectives. The measurement of performance and financial position under the cash basis of accounting is unlikely to yield correct results, because the evaluation of performance requires the measurement of accomplishment (the revenues) during a period and the efforts expended for those accomplishments (the expenses). In current scenario, the timings of cash receipts and cash payments may not coincide with earning of revenues or incurrence of expenses. Thus cash basis of accounting fails to meet most of the financial reporting objectives.

103. GNN accounts of receipts and expenditure shall be maintained in such a manner as prescribed as per Section 142 of MC Adhiniyam, 1959. There is no mandatory provision for the maintenance of accounts on double entry accrual based system of accounting as per Municipal Act. Recently great development has taken place in all over the country in this regard. UP Government has issued an order for switching over the accounts from single entry to Double entry accrual based system.

104. JNNURM accounting reforms mandates are not applicable to GNN as Ghaziabad is not a JNNURM city and so it is following the accounting procedures required for UP State.

105. Based on the on-going lending practice, existing accounting policies and procedures followed by agencies in Uttar Pradesh including GNN is not the major hindrance for NCRPB for completing the project.

11. Financial Regulations

106. A sound accounting system is underpinned by financial regulations. These are usually designed to define the objectives of—and responsibilities within—the financial management system. In the interest of the funding agency, an acceptable financial regulations need to be in place.

107. For the present multistoried parking Subproject, the proposed project will be funded by National Capital Region Planning Board (NCRPB) through loan to Ghaziabad Nagar Nigam (GNN), GNN will be both Executing Agency (EA) and implementing agency (IA).

- Financial regulations for NCRPB, as part of the Ministry of Urban Development, Govt. of India, will be governed by the well defined regulatory system designed by Govt. of India.
- Ghaziabad Nagar Nigam (GNN) will be governed by the financial regulation provisions laid by Uttar Pradesh State under Municipal Act.
- Both regulation procedures will cover all the required aspects to be considered under financial regulations review which are normally required under the ‘best practice’ followed in the market, though there may be variations in quality and quantity aspects in between them.
C. Financial Analysis

1. Present Financial Condition

108. Ghaziabad Nagar Nigam (GNN). Financial sustainability addresses the required as well as appropriate taxation and tariff reforms. Ghaziabad Nagar Nigam Revenue Account and sub-project cash flows take cognizance of policy directives undertaken by Ghaziabad Nagar Nigam in addressing infrastructure investment and sustenance needs – the focus is on property taxation, water, sewer/drainage and conservancy charges. While the Nagar Nigam continues to draw a substantial proportion of its income from government grant, in lieu of Octroi, in the long-term, the strategy of GNN shall be to capitalize on the benefits accruing from property taxes. Urban infrastructure investments as part of the city development plan (CDP) should recognize the fact that property taxes pay for capital investments and user charges pay for system operation and maintenance – given the aforesaid approach, the financial sustainability analysis focuses on reviewing net cash flows arising out of taxation and tariff reforms.

109. The review of finances involves a time-series analysis of the income and expenditure of the Ghaziabad Nagar Nigam (GNN) to ascertain the trends and the major sources and uses of funds. In addition to this, certain key financial indicators relating to property tax, water tax, per capita income, per capita expenditure and debt servicing; have been considered to assess the financial performance of the GNN.

110. The Municipal Accounts code of Government of Uttar Pradesh prescribes the organization of the municipal fund into three broad categories of General Account, Capital Account and Debt and Suspense (or Extraordinary) Account. Based on the availability, revenue account data collected from the annual accounts of GNN were compiled and analyzed. For the purpose of municipal fiscal assessment, financial data pertaining to the last seven years (2001-02 to 2007-08) were compiled in an abstract format (Table 2-7). Detailed analysis on GNN municipal financial performance is presented in Appendix 2-4.
### Table 2-7: GNN Revenue Expenditure Account

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<td>I.</td>
<td>Revenue</td>
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<tr>
<td>1</td>
<td>Income from Taxes</td>
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<tr>
<td></td>
<td>i) House Tax</td>
<td>14.64%</td>
<td>727</td>
<td>850</td>
<td>866</td>
<td>1,085</td>
<td>1,162</td>
<td>1,157</td>
<td>1,650</td>
</tr>
<tr>
<td></td>
<td>ii) Water Tax</td>
<td>19.41%</td>
<td>345</td>
<td>469</td>
<td>478</td>
<td>590</td>
<td>709</td>
<td>705</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>iii) Sewer Tax</td>
<td>16.73%</td>
<td>166</td>
<td>201</td>
<td>203</td>
<td>274</td>
<td>324</td>
<td>337</td>
<td>420</td>
</tr>
<tr>
<td></td>
<td>iii) Other Taxes</td>
<td>-17.14%</td>
<td>652</td>
<td>688</td>
<td>122</td>
<td>1,147</td>
<td>644</td>
<td>27</td>
<td>211</td>
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<tr>
<td></td>
<td>Total Taxes</td>
<td>9.63%</td>
<td>1,890</td>
<td>2,208</td>
<td>1,669</td>
<td>3,096</td>
<td>2,839</td>
<td>2,226</td>
<td>3,281</td>
</tr>
<tr>
<td></td>
<td>Total Taxes</td>
<td>9.63%</td>
<td>1,890</td>
<td>2,208</td>
<td>1,669</td>
<td>3,096</td>
<td>2,839</td>
<td>2,226</td>
<td>3,281</td>
</tr>
<tr>
<td>2</td>
<td>Other Income</td>
<td>13.26%</td>
<td>488</td>
<td>875</td>
<td>1,148</td>
<td>887</td>
<td>1,238</td>
<td>413</td>
<td>1,030</td>
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<td>3</td>
<td>Water charges</td>
<td>-25.82%</td>
<td>12</td>
<td>24</td>
<td>24</td>
<td>14</td>
<td>24</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Govt. Transfers/ Grants</td>
<td>11.66%</td>
<td>1787</td>
<td>2056</td>
<td>2262</td>
<td>2438</td>
<td>2668</td>
<td>3102</td>
<td>9233</td>
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<tr>
<td>5</td>
<td>Revenue from Sale</td>
<td>-8.46%</td>
<td>204</td>
<td>178</td>
<td>62</td>
<td>35</td>
<td>46</td>
<td>342</td>
<td>120</td>
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<td>TOTAL</td>
<td>20.88%</td>
<td>4,381</td>
<td>5,341</td>
<td>5,165</td>
<td>6,470</td>
<td>6,815</td>
<td>6,087</td>
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<tr>
<td>1</td>
<td>General Administration</td>
<td>8.82%</td>
<td>412</td>
<td>435</td>
<td>475</td>
<td>505</td>
<td>583</td>
<td>623</td>
<td>684</td>
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<td></td>
<td></td>
<td>9.5%</td>
<td>9.3%</td>
<td>9.1%</td>
<td>8.4%</td>
<td>11.6%</td>
<td>10.8%</td>
<td>9.7%</td>
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<td>2</td>
<td>Health &amp; Sanitation Works</td>
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<tr>
<td></td>
<td>i) Salaries</td>
<td>4.11%</td>
<td>952</td>
<td>872</td>
<td>1,055</td>
<td>1,004</td>
<td>966</td>
<td>1,175</td>
<td>1,212</td>
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<tr>
<td></td>
<td>ii) Contracted Sanitation Works</td>
<td>22.08%</td>
<td>187</td>
<td>249</td>
<td>298</td>
<td>388</td>
<td>452</td>
<td>443</td>
<td>619</td>
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<tr>
<td></td>
<td>iii) Repairs &amp; Maintenance of Sanitation Implements</td>
<td>7.92%</td>
<td>69</td>
<td>107</td>
<td>82</td>
<td>51</td>
<td>56</td>
<td>95</td>
<td>109</td>
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<td>iv) Diesel, etc</td>
<td>23.06%</td>
<td>74</td>
<td>109</td>
<td>120</td>
<td>167</td>
<td>187</td>
<td>199</td>
<td>257</td>
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**WSA_NCRPB_FR GZB MLP (15 Jul 10)**
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<td>v)</td>
<td>Others</td>
<td>2.97%</td>
<td>78</td>
<td>33</td>
<td>48</td>
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<td>84</td>
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<td>Total Sanitation</td>
<td>9.07%</td>
<td>1,360</td>
<td>1,370</td>
<td>1,603</td>
<td>1,656</td>
<td>1,745</td>
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<td>31.5%</td>
<td>29.2%</td>
<td>30.8%</td>
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<td>34.6%</td>
<td>32.4%</td>
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<td>3</td>
<td>Development Works &amp; Repairs</td>
<td>4.31%</td>
<td>1,349</td>
<td>1,774</td>
<td>1,619</td>
<td>1,514</td>
<td>1,045</td>
<td>1,152</td>
<td>1,738</td>
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<td></td>
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<td>31.2%</td>
<td>37.8%</td>
<td>31.1%</td>
<td>25.0%</td>
<td>20.9%</td>
<td>19.9%</td>
<td>24.6%</td>
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<tr>
<td>3</td>
<td>Water Supply &amp; Distribution</td>
<td>13.96%</td>
<td>698</td>
<td>626</td>
<td>752</td>
<td>1,442</td>
<td>1,045</td>
<td>1,266</td>
<td>1,529</td>
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<td></td>
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<td>16.2%</td>
<td>13.3%</td>
<td>14.5%</td>
<td>23.8%</td>
<td>20.9%</td>
<td>21.9%</td>
<td>21.7%</td>
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<td>4</td>
<td>Others</td>
<td>8.53%</td>
<td>500</td>
<td>494</td>
<td>755</td>
<td>930</td>
<td>590</td>
<td>681</td>
<td>817</td>
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<td>11.6%</td>
<td>10.5%</td>
<td>14.5%</td>
<td>15.4%</td>
<td>11.8%</td>
<td>11.8%</td>
<td>11.6%</td>
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<td>Loan Repayment</td>
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<td>0.0%</td>
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<td>0.0%</td>
<td>1.1%</td>
<td>0.0%</td>
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<tr>
<td></td>
<td>TOTAL</td>
<td>8.53%</td>
<td>4319</td>
<td>4699</td>
<td>5204</td>
<td>6047</td>
<td>5008</td>
<td>5782</td>
<td>7058</td>
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<td>100.0%</td>
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<td>III.</td>
<td>Surplus / Deficit</td>
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<td></td>
<td></td>
<td>62</td>
<td>642</td>
<td>(39)</td>
<td>423</td>
<td>1,407</td>
<td>305</td>
<td>6,608</td>
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Source: GNN.
111. Revenue income found increased at a compounded annual growth rate (CAGR) of 21 percent during the assessment period. Further analysis of Revenue Income components Ghaziabad indicate that own tax revenue found increased at 10 percent CAGR and non-tax revenue also increased considerably (13 percent). Major sources of own revenue comprise property tax, other taxes, water charges, revenue grants and other miscellaneous fees and charges. Though total revenue income for GNN found increasing during the review period, the share of tax revenue was found decreasing from 43 percent (2001-02) to 24 percent (2007-08). Property Tax formed as a major component of own tax revenues contributing 50 percent of the total own tax revenues in FY07-08. During the review period, the property tax found with 15 percent CAGR. While property tax should be an important component of internally generated resources, Ghaziabad Nagar Nigam has still potential to exploit. With increasing trend, Revenue grant is one of the major revenue sources for GNN (68 percent). Amongst the non-tax revenues, water charges contributed only 0.4 percent of total revenue income and have found with more fluctuating growth trend.

112. Revenue expenditure has been found to be with steady increase from FY 2001-02 during the analysis period except FY 2005-06. Expenditure on general establishment and administration accounted for 10 percent of the total revenue expenditure in FY08. Of the total revenue expenditure, expenditure on operation and maintenance of municipal services constituted 78 percent 10 percent on other expenditure. Expenditure on development works mostly of capital works executed through grant funds and their repair (25 percent), public health and conservancy (32 percent), water supply (22 percent), are found to be the major components in the operation and maintenance expenditure during the review period. Operation and maintenance expenditure for sanitation has witnessed an increase at a CAGR of 9 percent and water supply & distribution expenditure has increased at a CAGR of 14 percent.

113. **Key Financial Indicators.** A set of key financial indicators have been derived using the financial data procured from the GNN for the assessment period. These indicators are used to assess the municipal performance with regards resource mobilization, fund utilization, financial performance and collection efficiencies.

   (i) **Resource Mobilization indicators.** These indicators summarize the performance of the GNN with regards sources of funds. GNN derives about 32 per cent of its revenue income from own sources (2007-08), which is a good sign but with scope for further improvements.

   (ii) **Fund Application indicators.** These indicators are a measure to ascertain the utilization from the municipal fund. Only 10 per cent of the revenue expenditure is spent on establishment heads, leaving a good amount of over 90 per cent for O&M of municipal assets and services that include 21 percent for water supply account. Establishment expenditure accounts for about 21 per cent of the total own-tax revenue generated by the GNN.

   (iii) **Overall Financial Performance indicators.** These indicators are a measure to assess the overall financial performance of the municipality with regards operational performance and effective growth in revenue income and expenditure. The average
operating ratio during the assessment period was less than unity and it was observed more than unity only for one year during the assessment period (FY 2003-04). The indicators of growth in per capita income and expenditure item heads indicate the effective growth, giving a performance measure relative to the growing population. Annual growth in per capita revenue income found to be consistently with increasing trend where as the per capita revenue expenditure during the assessment period, found to be with increasing trend except FY 2004-05 and FY 2006-07 (Table 2-7).

Table 2-8: Details of Per Capita Revenue Income and Expenditure – Ghaziabad Nagar Nigam

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<tbody>
<tr>
<td>1</td>
<td>Population</td>
<td>968,521</td>
<td>1,010,446</td>
<td>1,054,186</td>
<td>1,099,819</td>
<td>1,147,428</td>
<td>1,197,112</td>
<td>1,248,947</td>
</tr>
<tr>
<td>2</td>
<td>Revenue Income (Rs. Lakhs)</td>
<td>4,381</td>
<td>5,341</td>
<td>5,165</td>
<td>6,470</td>
<td>6,815</td>
<td>6,087</td>
<td>13,666</td>
</tr>
<tr>
<td>3</td>
<td>Revenue Expenditure (Rs. Lakhs)</td>
<td>4,319</td>
<td>4,699</td>
<td>5,204</td>
<td>6,047</td>
<td>5,008</td>
<td>5,782</td>
<td>7,058</td>
</tr>
<tr>
<td>4</td>
<td>Revenue Account Surplus (Rs. Lakhs)</td>
<td>62</td>
<td>642</td>
<td>(39)</td>
<td>423</td>
<td>1,807</td>
<td>305</td>
<td>6,608</td>
</tr>
<tr>
<td>5</td>
<td>Per Capita Revenue Income (Rs.)</td>
<td>452</td>
<td>529</td>
<td>490</td>
<td>588</td>
<td>594</td>
<td></td>
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</tr>
<tr>
<td>6</td>
<td>Per Capita Revenue Expenditure (Rs.)</td>
<td>446</td>
<td>465</td>
<td>494</td>
<td>550</td>
<td>436</td>
<td>508</td>
<td>1094</td>
</tr>
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</table>

114. Key Issues. Financial management and fiscal status of Ghaziabad Nagar Nigam is summarized below:

(i) Maintenance and Reporting of Accounts. A common accounting and financial reporting code, updated annually, with interim up-dations when required, supported with a user manual and organized training of municipal accounts staff will substantially streamline financial accounting and reporting.

(ii) Revenue Realization. Taxes and charges are major own sources of revenue income. Being more dynamic in nature and within the control of the GNN, these revenue incomes have potential to contribute more to the municipal fund. Key issues regarding revenue realization comprise (i) coverage of properties under property tax, (ii) poor collection of water charges; (iii) unclear status on extent of outstanding taxes and charges collectable; and (iv) extent of gap between the cost of service provided and user charges levied.

(iii) Fund Application. Key issues regarding application from the municipal fund comprise (i) most of the revenue expenditure is accounted for by establishment item heads, (ii) an efficient system of costing to enable the actual cost of services provided in a scientific manner thus enabling logical mechanism for tariff structuring and (iii) the absence of information with regard to actual assets and liabilities of GNN at a particular point of time render it difficult to ascertain the actual fiscal position.

(iv) Operating Ratio. Ghaziabad Nagar Nigam has mostly maintained an operating ratio (OR) less than unity (ranging from 0.73 in FY06 to 0.99 in FY02) during the assessment year, except for one year with more than unity. A key reason for the mixed performance is tax revenue collection and expenditure management. However, Ghaziabad Nagar Nigam has untapped revenue potentials from property
tax and water charges. While the OR indicates efficiency in revenue management, inability to capitalize on property tax and user charge revenues indicates over dependency on revenue grants and a level of complacency regarding other revenue income sources.

2. **Cost Recovery and Profitability**

115. Where cost recovery and/or profitability are primary objectives, the financial consequences of policies, strategies, and practices relating to the entity’s (IA) operations or trade should be set out, for instance: (i) policies on recovery of costs of its products and/or services, (ii) tariffs and charges levied, (iii) systems of establishing costs of products and/or services, (iv) inventory controls, and (v) possibility and extent of external regulation (e.g., by government).

116. *Existing Scenario.* Traffic responsibility in the city lies with multiple agencies and Ghaziabad Nagar Nigam (GNN) is responsible for the traffic problems in city roads including parking facilities. Presently parking facilities are provided by GNN and other agencies including private sector with user fee. Accordingly, the proposed project also has envisaged with user fee for its sustainability.

117. *Policy Initiatives.* GNN does not have adequate operational income to finance operational expenses. This calls for institutional reform to improve the financial base in the short term, including (i) an increase in the property tax base by reassessment or mapping and computerized database, (ii) a gradual increase in user charges, and (iii) improvement in collection efficiency. The memorandum of agreement for the JNNURM financing requires ULBs, amongst others things, to adopt (i) accrual-based double-entry accounting, (ii) geographic information systems based property tax with collection efficiency at 85% within the next 7 years, and (iii) reasonable user charges for O&M cost recovery within the next 7 years. This stimulates considerable reform approach among the states in municipal administration, including UP State.

118. Both ADB and JNNURM, the major urban development partners of the state, have focused on 100% O&M cost recovery through user charges as the medium term targets for urban infrastructure projects.

119. *User Charges.* The project benefits are city-wide and this is an obligatory public traffic safety function (cost recovery project). Presently though there is property tax there is no levying of transport component in the property tax. Also private sector and GNN are engaged in providing dedicated off-street parking for nominal monthly charges. Therefore it would be necessary for the Municipal Corporation to follow the same user fee system to raise revenues to meet the O&M cost and to recover the capital cost also.
3. **Financial Projections with Multi-storied Parking Project Impact:**

120. Presently there is no separate component in property tax for transport and no monthly user charges from households. However, there are similar user charges for vehicular parking and commercial place rentals in Ghaziabad city at different locations. Willingness to pay survey results from the Baseline Survey in Ghaziabad MC also reveals that better scope for user charges with better service delivery. In case of GNN implementing the project, responsibility of the loan (both capital and interest repayments) and the initial equity participation along with the O&M will be from GNN fund. Also the estimated revenue from the project will also go to GNN. With this background, it has become necessary to ascertain that projected cash flow of the GNN can support all these project related aspects.

121. Financial projections for GNN was carried out with the objective of assessing the likely future financial position of the GNN with respect to meet the existing revenue expenditure commitments and also availability of surplus fund to sustain the proposed parking project from its general fund without resorting for new revenue source for the project through tax. With this objective, i) financials of the GNN was carried out for the near future and ii) impact analysis of the proposed project, provided it is funded through the GNN budget.

122. Towards this the GNN municipal account was projected upto 2020-21 (that covers the implementation and debt service period) with the assumption that the trend observed during the last seven years will continue further. Details of projection of GNN accounts and project specific cash flow are presented in Appendix 2-5.

123. For the project impact analysis, the funding requirements of the project were loaded into the financial projections through additional project cash flow and find out the net projected deficit / surplus after the project funding.

- For the same the proposed Parking project with total cost of Rs 435 million is proposed to be implemented in two years from FY2010-11 with the funding from NCRPB was considered. The tenure of the loan will be of 10 years (two years moratorium and eight years repayment) with about 9 percent. Balance equity of 25 percent will be from GNN internal fund.
- Also the debt service for the proposed NCRPB loan, required project equity component and the incremental O&M cost also projected and loaded into the GNN financials.

124. Analysis results indicate that the proposed parking subproject with NCRPB loan funding can be sustained by GNN from its general account. This is mainly due to the increase in tax revenue and government transfer / grant and the resultant growth in surplus fund.

125. This underlines the fact that GNN can implement the project under the present revenue pattern without any fresh tax and / or user charges. However, in line with the JNNURM policy reform initiatives, GNN will implement this project as ‘cost recovery’ one through suitable user charges.
Table 2-8: Details of Projected Project Cash Flow for Multi-level Parking Project, Ghaziabad

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<tbody>
<tr>
<td>I.</td>
<td>Annual Surplus / Deficit</td>
<td>7,664</td>
<td>8,268</td>
<td>8,915</td>
<td>9,604</td>
<td>10,337</td>
<td>11,112</td>
<td>11,930</td>
<td>12,789</td>
<td>13,685</td>
<td>14,616</td>
<td>15,575</td>
</tr>
<tr>
<td>II.</td>
<td>Project Cash Flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>Inflow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loan Drawdown</td>
<td>326</td>
<td>1,632</td>
<td>1,306</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incremental Project Revenues</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Inflow</td>
<td>326</td>
<td>1,632</td>
<td>1,306</td>
<td>383</td>
<td>389</td>
<td>446</td>
<td>446</td>
<td>454</td>
<td>521</td>
<td>521</td>
<td>521</td>
</tr>
<tr>
<td>B.</td>
<td>Outflow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAPEX (Equity + Loan)</td>
<td>435</td>
<td>2,176</td>
<td>1,741</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incremental O&amp;M a/ b/</td>
<td></td>
<td></td>
<td></td>
<td>44</td>
<td>48</td>
<td>53</td>
<td>58</td>
<td>64</td>
<td>70</td>
<td>77</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>Debt Service</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intrest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>206</td>
<td>257</td>
<td>220</td>
<td>184</td>
<td>147</td>
<td>110</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>Loan Repayment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>408</td>
<td>408</td>
<td>408</td>
<td>408</td>
<td>408</td>
<td>408</td>
<td>408</td>
</tr>
<tr>
<td></td>
<td>Total Debt Service</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>614</td>
<td>665</td>
<td>628</td>
<td>592</td>
<td>555</td>
<td>518</td>
<td>481</td>
</tr>
<tr>
<td></td>
<td>Total Outflow</td>
<td>435</td>
<td>2,176</td>
<td>1,741</td>
<td>657</td>
<td>713</td>
<td>681</td>
<td>650</td>
<td>619</td>
<td>588</td>
<td>559</td>
<td>530</td>
</tr>
<tr>
<td>C.</td>
<td>Net Surplus / Deficit After Debt Service</td>
<td>7,555</td>
<td>7,724</td>
<td>8,480</td>
<td>9,330</td>
<td>10,013</td>
<td>10,877</td>
<td>11,727</td>
<td>12,624</td>
<td>13,618</td>
<td>14,578</td>
<td>15,566</td>
</tr>
</tbody>
</table>
4. **Financial Improvement Action Plan**

126. ULB level financial projection analysis indicates that even in the case of not introduction of property tax based transport tax along with increase in collection efficiency or not implementing the user fee for vehicular parking, the full parking project can be supported by the Ghaziabad ULB. This is with the assumption that the present trend in income and expenditure pattern will continue for the near future. Also this is mainly because the projected revenue account and the resultant overall status of financial for Ghaziabad ULB do have adequate strength to support the present project in total. However, as a cost recovery function, GNN initiate the necessary actions to introduce project specific revenue source through user charges for parking and commercial rental to sustain the same in the long run.

127. **Affordability Analysis.** With the backdrop of the willingness to pay survey results for the transport system in Ghaziabad, it is evident that the use of user charges for vehicular parking services already in practice and accepted by the users. The required tariff rates (user charges) for the year 2013-14 presented in Table 2-9 found to be reasonable and within the affordable level. This underlines the ‘effective demand’ for the proposed urban infrastructure services, backed-up with affordability from the consumers. Considering these, an appropriate ‘Financial Improvement Action Plan’ (FIAP) is worked out and presented in Table 2-11.

| Table 2-9: Details of Estimated Parking User Charges Requirement- Ghaziabad City |
|------------------|---------|--------|
| **Details** | **Car** | **TW** |
| Parking Space available (Nos.) | 812 | 458 |
| Maximum Parking demand Capacity / Day @ 5 turnover / space for TW and @ 3 turnover / space for cars & 90 % utilisation (No. of vehicles) | 3,654 | 2,885 |
| Initial Year Parking Demand (No. of vehicles/Day) | 3,289 | 2,597 |
| Annual Growth Rate for Parking Demand | 6% | 6% |
| Parking Fee (Rs. / two hour) (2012-14) | 10 | 5 |
| Increase in Parking Fee ( at every 3rd year) | 15% | 15% |

| Table 2-10: Estimation of Revenue from Commercial Space - Multistoried Parking |
|------------------|------------------|------------------|
| **Details** | **Commercial Space Rent Revenue (2013-14)** |
| | **Area proposed for Commercial Purpose (Sqm)** | **Monthly Rent (Rs/Sqm)** | **Annual Rent (Rs/Sqm)** | **Annual Rent (Rs Million)** |
| Ground Floor | 3,200 | 1,000 | 1,2000 | 30.72 |
| First Floor | - | 1,000 | 1,2000 | 0.00 |
| Total | | | | 30.72 |
Table 2-11: Financial Improvement Action Plan

<table>
<thead>
<tr>
<th>Item</th>
<th>Current</th>
<th>Project Implementation Period</th>
<th>Post Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2010-11</td>
<td>2011-12</td>
</tr>
<tr>
<td>Solid Waste Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parking Charges - Car (Rs. / 2 hour)</td>
<td>Nil</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Parking Charges – Two Wheeler (Rs. / 2 hour)</td>
<td>Nil</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Commercial Space Rent (Rs. / sqm)</td>
<td>Nil</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Analysis

5. Cost Benefit Analysis

128. The projects for the purpose of financial analysis have been categorized as Service, Cost Recovery and Remunerative. The present project of multi-storied parking is a Cost Recovery one and accordingly feasibility analysis is carried out.

129. Weighted Average Cost of Capital. The financial viability of subprojects was assessed by comparing the subproject’s financial internal rate of return (FIRR) with the financial opportunity cost of capital. As proxy for the financial opportunity cost of capital, the weighted average cost of capital (WACC) of the subprojects in real terms is used. The FIRR is the discount rate that equalizes the present values of costs and revenues over the subproject life, while the WACC represents the cost incurred by the GNN with the support of the UP State government in raising the capital necessary to implement the subprojects. The WACC was estimated based on the central government’s on lending policy.

Table 2-12: Weighted Average Cost of Capital (%) - Uttar Pradesh & Haryana

<table>
<thead>
<tr>
<th>Item</th>
<th>NCRPB Lending b</th>
<th>Govt. of India Grant a</th>
<th>ULB Equity</th>
<th>WACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount weighting</td>
<td>75%</td>
<td>0%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Nominal cost</td>
<td>9.00%</td>
<td>8.50%</td>
<td>10.00%</td>
<td></td>
</tr>
<tr>
<td>Tax Rate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Tax-Adjustable Nominal Cost</td>
<td>9.00%</td>
<td>8.50%</td>
<td>10.00%</td>
<td></td>
</tr>
<tr>
<td>Inflation Rate</td>
<td>4.50%</td>
<td>4.50%</td>
<td>5.50%</td>
<td></td>
</tr>
<tr>
<td>Real Cost</td>
<td>4.50%</td>
<td>4.00%</td>
<td>4.50%</td>
<td></td>
</tr>
<tr>
<td>Minimum rate test [ 4.0%]d</td>
<td>4.00%</td>
<td>4.00%</td>
<td>4.50%</td>
<td></td>
</tr>
<tr>
<td>Weighted Component of WACC</td>
<td>3.38%</td>
<td>0.00%</td>
<td>1.13%</td>
<td>4.50%</td>
</tr>
</tbody>
</table>

WACC = weighted average cost of capital, UP = Uttar Pradesh,

a - Nominal cost of Government of India grant is estimated at 8.5%, based on the Government’s long-term bond rate.
b - Indicative Lending Rates for Loans by NCRPB for urban infrastructure projects
d - Preparing and Appraising Investment Projects, Guidelines for the Financial Governance and Management of Investment Projects Financed by ADB (pp 26)

D. Financial Analysis of Subprojects

130. The revenue streams for the financial analysis of sub project include parking fee and rental from commercial space provided in the ground floor. A decision on implementing the above discussed revenue stream is critical to project sustenance. Apart from a revision on completion of the capital works, it would be necessary to revise the parking related user charges periodically so as to compensate the increasing O&M cost.

131. The proposed multi-storied parking subproject is treated as ‘cost recovery’ project that has to sustain itself both for the capital and O&M through its user charges revenue stream. As similar practice of off-street parking with user fee is followed presently in the city, implementation of user charges for the project will not pose a problem. The project will be implemented by GNN and its impact on the GNN financials found to be satisfactory, as discussed above. However, a project specific financial analysis was carried out to ascertain its sustainability.

132. Initial project capital cost is estimated to Rs.435 million to be implanted during the two year constriction period (Table 2-13)

Table 2-13: Project Capital Cost - Rs Million

<table>
<thead>
<tr>
<th>Details</th>
<th>Cost Rs Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Cost</td>
<td>348</td>
</tr>
<tr>
<td>Landed Cost</td>
<td>435</td>
</tr>
</tbody>
</table>

Source: Consultant

133. Financial sustainability and viability analysis results for the proposed cost out flow (capital and O&M) and the user charge based revenue inflow indicate that there is substantial cost recovery in terms positive FIRR (13.1%). This underlines the full cost recovery potential to the subproject during the analysis period. Thus the project is found to be financially feasible as a standalone project, compared to its WACC of 4.5%.

134. Sensitivity analysis results shown in Table 2.13 indicate that the project is found to be financially viable even at the worst scenario of combined effect of 10% increase in capital and O&M cost and 10% reduction in project revenue, the FIRR is estimated to 10.9%, which is well above the minimum requirement of 4.5% (WACC).
Table 2-14: Sensitivity Analysis Results

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Scenario</th>
<th>FIRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Base Case</td>
<td>13.1%</td>
</tr>
<tr>
<td>2</td>
<td>10% increase in capital cost</td>
<td>12.1%</td>
</tr>
<tr>
<td>3</td>
<td>10% increase in O&amp;M cost</td>
<td>13.0%</td>
</tr>
<tr>
<td>4</td>
<td>10% decrease in Project revenue</td>
<td>11.9%</td>
</tr>
<tr>
<td>5</td>
<td>Combined effect of 10% increase in capital and O&amp;M cost and 10% reduction in project revenue</td>
<td>10.9%</td>
</tr>
</tbody>
</table>

Source: Consultant

1. **Risk Analysis**

135. Of the three sensitivity scenarios (cost overrun, O&M cost increase and reduced beneficiaries) decrease in project revenue is the most vulnerable to project cash flow, followed by cost overrun. Considering the more sensitiveness of these variables, following implementation arrangements need to be focused more so as minimize the project risk:
   - Timely implementation of the project user charges through appropriate method;
   - Timely implementation of the project through appropriate procurement method in which incentive for early completion may be included;
   - Ensuring adequate project coverage of beneficiaries through proper traffic enforcement in the impact region for parking;
   - Adequate focus for LA related project components

2. **Conclusion**

136. The main evaluation has indicated that the proposed multi-storied parking was found to be financially viable, with the calculated FIRR values are more to the WACC (4.15%), for the recommended user charges under FIAP. This under lines that the project can support cost recovery. In tune to the present state policy, the project can recover 100% O&M through user charges along with full capital cost recovery.
1. Economic Cost

The economic costs of capital works and annual operation and maintenance are calculated from the financial cost estimates on the following basis:

(i) Price contingencies are excluded but physical contingencies are included because they represent real consumption of resources;

(ii) Import duties and taxes are excluded because they represent transfer payments. For this the shadow exchange rate factor worked out below was used;

Table 1: Shadow exchange rate factor

<table>
<thead>
<tr>
<th>Details</th>
<th>2008-09</th>
<th>2007-08</th>
<th>2006-07</th>
<th>2005-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>National export (free on board) = Ex *</td>
<td>RE</td>
<td>Actual</td>
<td>Actual</td>
<td>Actual</td>
</tr>
<tr>
<td></td>
<td>766,934</td>
<td>655,864</td>
<td>571,779</td>
<td>456,418</td>
</tr>
<tr>
<td>National import (CIF) = Im*</td>
<td>1,305,503</td>
<td>1,012,312</td>
<td>840,506</td>
<td>660,409</td>
</tr>
<tr>
<td>Customs Duties = Ct*</td>
<td>84,710</td>
<td>72,029</td>
<td>62,819</td>
<td>46,645</td>
</tr>
<tr>
<td>AD-HOC STANDARD CONVERSION FACTOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(CF = (Ex + Im)/(Ex + Im + Ct))</td>
<td>0.961</td>
<td>0.959</td>
<td>0.957</td>
<td>0.960</td>
</tr>
<tr>
<td>Shadow exchange rate factor (Y) (Y=1/CF)</td>
<td>1.04</td>
<td>1.04</td>
<td>1.04</td>
<td>1.04</td>
</tr>
</tbody>
</table>

* - Source : Reserve Bank of India
RE - Revised Estimates
Note: Calculation Method based on the handout on Economic Analysis

(iii) The existence of unemployment and under-employment for unskilled workers within the Indian economy means that the opportunity cost of unskilled labour can be considered to be lower than its wage rate – a conversion factor of 0.5 of the market wage rate for agriculture casual labour is used to estimate the shadow wage rate;

Table 2: Shadow Wage-rate Factor (Y)

<table>
<thead>
<tr>
<th>Casual agriculture labor cost (Rs. per day)* (L)</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>National minimum wage of unskilled worker (Rs. per day)**</td>
<td>159</td>
</tr>
<tr>
<td>Shadow Wage-rate Factor (Y); Y = L/M</td>
<td>0.50</td>
</tr>
</tbody>
</table>

* - Minimum Agricultural Labor wage fixed by many states incl. Tamil Nadu at Rs. 80 a day (for men working six hours) and Rs. 70 (for women working five hours)
** Uttar Pradesh: Minimum Wages w.e.f. 01.04.2009 to 30.09.2009, Labor Department, Government of Uttar Pradesh.

(iv) The market wage rate for skilled labour and the acquisition cost of land are considered to represent opportunity costs, as both factors are in demand;

(v) All costs are valued using the domestic price numeraire, to enable an easier comparison with the information used to measure benefits (e.g. a significant component of benefit is the savings in resources, which would be used in the without project situation).
2. Estimated financial base cost without contingencies and allowances for the Ghaziabad Transport project (construction of a multi-storied parking in Ghaziabad City) is estimated Rs 435 million (excluding utility shifting, R&R and environment management expenditure) as shown in **Table 3**. Using the basis, the economic cost (resource cost) was estimated both for capital cost and operation & maintenance costs and presented in **Tables 4 to 5**. For estimating the economic cost from the financial cost, the following other assumptions were also considered:

**A. Capital Cost**

- Contingences and other allowances considered to the base cost (12%):
  - Design Supervision Consultancy (DSC)+ Third Party Inspection (TPI) - 3%,
  - Information, Education & Communication (IEC) activities 1%,
  - Incremental Administration (PIU) – 2%,
  - Physical contingency 3%,
  - Environmental mitigation 1%,
  - Social intervention 1%,
  - Institutional development and capacity building activities 1%

- Share of foreign cost to total project cost

<table>
<thead>
<tr>
<th>Sector</th>
<th>Services</th>
<th>Materials</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Supply</td>
<td>0.75%</td>
<td>2%</td>
<td>2.75%</td>
</tr>
<tr>
<td>Sewerage</td>
<td>0.75%</td>
<td>0%</td>
<td>0.75%</td>
</tr>
<tr>
<td>Drainage</td>
<td>0.75%</td>
<td>0%</td>
<td>0.75%</td>
</tr>
<tr>
<td>SWM</td>
<td>0.75%</td>
<td>0%</td>
<td>0.75%</td>
</tr>
<tr>
<td>Urban Transport</td>
<td>0.75%</td>
<td>0%</td>
<td>0.75%</td>
</tr>
</tbody>
</table>

- Tax and duties
  - Local cost – 12%
  - Foreign Cost – 4%

- Share of unskilled labor in Local Cost – 12%

**B. Maintenance Cost**

- Share of foreign cost to total project cost
  - Water supply – 0%
  - Sewer – 0%
  - Strom water Drainage – 0%
  - Solid Waste Management – 0%
  - Urban Transport – 0%

- Tax and duties
  - Local cost – 12%
  - Foreign Cost – 4%

- Share of unskilled labor in Local Cost – 15%
Table 3: Details of Base Financial Cost – Ghaziabad (Multi-storied parking Construction)

<table>
<thead>
<tr>
<th>Item</th>
<th>2010-12 Rs. Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of a Multi-storied parking at the Old Bus Terminal in Ghaziabad city</td>
<td>435.22</td>
</tr>
<tr>
<td>Total</td>
<td>435.22</td>
</tr>
</tbody>
</table>

Source: Consultant

Table 4: Details of Resource Cost Estimation – Capital Cost (Ghaziabad Transport Component - Multi-storied parking Construction)

<table>
<thead>
<tr>
<th>Details</th>
<th>Financial Cost (Capital)</th>
<th>Resource Cost (Capital)</th>
<th>S P Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Cost</td>
<td>348.26</td>
<td>348.26</td>
<td></td>
</tr>
<tr>
<td>Allowances</td>
<td>12%</td>
<td>41.79</td>
<td></td>
</tr>
<tr>
<td>Foreign Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Base cost &amp; allowance</td>
<td>1%</td>
<td>2.93</td>
<td>2.70</td>
</tr>
<tr>
<td>- Taxes &amp; Duties</td>
<td>4%</td>
<td>0.11</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3.04</td>
<td>2.70</td>
<td></td>
</tr>
<tr>
<td>Local Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Unskilled labour</td>
<td>12%</td>
<td>46.45</td>
<td>23.23</td>
</tr>
<tr>
<td>- Skilled labour &amp; Others</td>
<td>88%</td>
<td>340.67</td>
<td>340.67</td>
</tr>
<tr>
<td>- Taxes &amp; Duties</td>
<td>12%</td>
<td>45.06</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>432.18</td>
<td>363.89</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>435.22</td>
<td>366.60</td>
<td></td>
</tr>
</tbody>
</table>

Note:
1. Shadow Exchange Rate Factor was worked on the RBI data on national exports, imports and exports and using the Method based on the ADB Handout on Economic Analysis
### Table 5: Details of Resource Cost Estimation – O&M Cost (Ghaziabad Transport – Multi-storied parking Construction)

<table>
<thead>
<tr>
<th>Details</th>
<th>Financial Cost</th>
<th>Resource Cost (Capital)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rs Million (coll. &amp; trans.)</td>
<td>Rs Million (Dist.&amp; treat..)</td>
</tr>
<tr>
<td>O&amp;M Cost</td>
<td>4.35</td>
<td>-</td>
</tr>
<tr>
<td>Foreign Cost</td>
<td>0%</td>
<td>-</td>
</tr>
<tr>
<td>- Base cost</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Local Cost</td>
<td>100%</td>
<td>-</td>
</tr>
<tr>
<td>- Unskilled labour (25%)</td>
<td>1.09</td>
<td>0.00</td>
</tr>
<tr>
<td>- Skilled labour &amp; Others (75%)</td>
<td>3.26</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td>4.35</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Consultant

3. Considering 2009-10 as base year followed by three construction period and 20 years implementation period considered for the analysis, the cash outflow for economic cost was worked out and presented in **Table 6**.

### Table 6: Details of Phasing and Expenditure Flow

Economic Cost – Transport – Multi-storied parking Construction (Ghaziabad City, Uttar Pradesh)

<table>
<thead>
<tr>
<th>Phasing</th>
<th>Year</th>
<th>Capital Cost</th>
<th>O &amp; M Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.00%</td>
<td>2010-11</td>
<td>146.64</td>
<td>-</td>
</tr>
<tr>
<td>60.00%</td>
<td>2011-12</td>
<td>219.96</td>
<td>1.52</td>
</tr>
<tr>
<td>0.00%</td>
<td>2012-13</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td></td>
<td>2013-14</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td></td>
<td>2014-15</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td></td>
<td>2015-16</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td></td>
<td>2016-17</td>
<td>-</td>
<td>3.81</td>
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<tr>
<td></td>
<td>2017-18</td>
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<td>3.81</td>
</tr>
<tr>
<td></td>
<td>2018-19</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td></td>
<td>2019-20</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td></td>
<td>2020-21</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td></td>
<td>2021-22</td>
<td>-</td>
<td>3.81</td>
</tr>
</tbody>
</table>

*all values in Rs. Million*
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2022-23</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td>2023-24</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td>2024-25</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td>2025-26</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td>2026-27</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td>2027-28</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td>2028-29</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td>2029-30</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td>2030-31</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td>2031-32</td>
<td>-</td>
<td>3.81</td>
</tr>
<tr>
<td>2032-33</td>
<td>-</td>
<td>3.81</td>
</tr>
</tbody>
</table>

Source: Consultant
1. The benefits arising from improved urban transport infrastructure results in improved service level delivery in urban transport travel requirements in the Project city / town. Benefits are achieved through more effective connectivity, better speed, less traffic related issues like congestion, accidents etc.

2. Project beneficiaries will be those travelers for whom accessibility to economic and social activities will be improved through better road conditions and traffic flows brought about by the sub-projects. This improvement is achieved by reducing the effort or inconvenience of travel between the origin of the traveler and the destination offering these activities.

3. Support urban infrastructure facilities like off-street vehicular parking, planned terminal for bus or trucks will also improve the quality of service delivery in terms of less traffic congestion on major city roads, improvement in traffic environment, better safety etc.

4. The unprecedented growth of personalized vehicles and the unplanned road infrastructure have made the provision for parking an important aspect of transportation planning. The frontage of almost all the roads in the CBD area (around GDA and Nagar Nigam) has been converted into commercial land use without taking into account the demand for parking of the vehicles. As there is no planned parking space available, vehicles can be seen parked all the roads resulting in reducing the capacity of the carriageways and endangering pedestrians and motorists alike. The increased demand for vehicular parking around GDA and Nagar Nigam area necessitates the construction of a Multilevel Parking facility in that area.

The subproject in Ghaziabad is the proposed multistory parking facility at the old bus stand accommodates for business and commercial center in the ground floor and parking facility for two wheelers and cars on the first and the second floor with third floor and the terrace for car parking only. In total 812 car parking spaces and 458 two wheeler parking spaces are provided to meet the future demand.

5. Subproject proposals will benefit the vehicular traffic on the road network around the project with less traffic congestion, less on-street parking at junctions, increase the travel speed resulting in savings in vehicle operating cost (VOC) and travel time, pedestrian safety including reduced road crossing time, improvement in the traffic environment and aesthetics etc.

6. The economic benefits considered in the present analysis for the grade separator (flyover) subproject in transport component in Ghaziabad city include:

   (i) Value of Passenger Travel Time Savings on the project impact road Sections

   (ii) User charges collected from the parked vehicles, and
(iii) rental charges collected from the commercial establishments and utilities operated at the ground floor.

7. **Value of Passenger Travel Time Savings**: Construction of multi-storied parking will result in reduction of the existing traffic congestion in the project impact roads due to the removal of the on-street parking for all the vehicles and subsequently savings in travel time for the road users using this area.

8. In the absence of detailed traffic modeling, assumptions were made regarding impact of improvements on road network performance, in terms of likely Program benefit including savings in travel time. These assumptions and methodology followed include:

(i) Average travel speed in peak conditions is assumed to increase from the existing levels (this increase in speed/service level shall be achieved due to Project components by eliminating the existing haphazard on-street parking). Even though increased speed levels are expected more, only 50 percent is assumed on conservative side. The improvement in travel speed is used to estimate the savings in travel time and further costing the time saved. This benefit is assumed for the limited road sections which are critically affected by the on-street parking and also only during the peak hours when the parking problem is acute.

9. Travel time savings for the passengers held up at the project impact road sections, in terms of hours and its monetary value using the time unit rates for different vehicle was estimated from the following data collected at field as well guidelines stipulated by Indian Roads Congress (IRC), and relevant study reports:

- Average vehicle occupancy – the number of passengers by vehicle type, plus paid driver and crew where applicable;
- Traffic category – traffic using the project impact road sections only during parking peak hours;
- Traffic composition – the percentage of each vehicle type in the traffic stream;
- Passenger composition – the percentage of each socio-economic category using each vehicle type and the percentage of passengers who are in the workforce;
- Savings in travel time – estimated based on the existing delay and the proposed delay at the proposed project site;
- Unit cost of travel time for different vehicle users – Based on a relevant study report, unit time cost at 2009 price level.

10. Road user cost unit rates including VOC and travel time for different vehicles used for the analysis is given in Table 1. Vehicle occupancy details and estimated vehicle hours time costs for different using vehicle occupancy and time cost unit rates are presented in Tables 2 and 3.

11. Considering the project design and the existing traffic problems on the impact roads, only the peak hour that was put into congestion problem during heavy on-street parking was considered for the analysis. This is with the assumption that during the lean or no on-street...
parking hours on the project impact roads, the traffic will not be affected by travel delay with respect to the proposed project and not considered for the analysis. The base year peak hour traffic on the project impact roads is presented in Table 4 and the estimated travel time savings in Table 5.

**Table 1: Details of Road User Cost adopted for the Study**

<table>
<thead>
<tr>
<th>Vehicle Category</th>
<th>VOC (Rs. / Vehicle Km)</th>
<th>Travel Time (Rs. / Hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2008 1</td>
<td>2009 3</td>
</tr>
<tr>
<td>Car - New Technology (Maruti 800)</td>
<td>4.07</td>
<td>4.27</td>
</tr>
<tr>
<td>Bus</td>
<td>16.37</td>
<td>17.19</td>
</tr>
<tr>
<td>TW</td>
<td>1.40</td>
<td>1.47</td>
</tr>
<tr>
<td>Auto rickshaw</td>
<td>3.98</td>
<td>4.18</td>
</tr>
<tr>
<td>Share-Auto</td>
<td>4.49</td>
<td>4.71</td>
</tr>
<tr>
<td>Taxi</td>
<td>4.70</td>
<td>4.94</td>
</tr>
<tr>
<td>2-Axle Truck</td>
<td>14.77</td>
<td>15.51</td>
</tr>
<tr>
<td>LCV</td>
<td>10.96</td>
<td>11.51</td>
</tr>
<tr>
<td>Goods Tempo</td>
<td>4.61</td>
<td>4.84</td>
</tr>
<tr>
<td>Goods Auto</td>
<td>3.59</td>
<td>3.77</td>
</tr>
</tbody>
</table>

Source: Analysis
2. Estimated using the RUCS Study, 2001 results (Rs 25,000/Tonne) for the year 2001 and escalated to 2008 with 5% annual growth.
3. Escalated to 2009 with 5% annual growth.

**Table 2: Vehicle Occupancy (No. of passengers/vehicle)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bus</strong></td>
<td></td>
</tr>
<tr>
<td>Bus</td>
<td>40</td>
</tr>
<tr>
<td>Minibus</td>
<td>15</td>
</tr>
<tr>
<td><strong>Private &amp; IPT</strong></td>
<td></td>
</tr>
<tr>
<td>Car/Jeep/Van</td>
<td>3.5</td>
</tr>
<tr>
<td>Two Wheelers</td>
<td>1.5</td>
</tr>
<tr>
<td>Autorickshaws</td>
<td>2</td>
</tr>
<tr>
<td><strong>Goods Vehicles (crew)</strong></td>
<td></td>
</tr>
<tr>
<td>Trucks</td>
<td>2</td>
</tr>
<tr>
<td>MAV</td>
<td>2</td>
</tr>
<tr>
<td>LCV</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Indian Roads Congress (IRC)
Table 3: Value of Travel Time Savings

<table>
<thead>
<tr>
<th>Vehicle Category</th>
<th>Rs./Vehicle Hour in 2009 prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>955.92</td>
</tr>
<tr>
<td>Minibus</td>
<td>430.13</td>
</tr>
<tr>
<td><strong>Private &amp; IPT</strong></td>
<td></td>
</tr>
<tr>
<td>Car/Jeep/Van</td>
<td>175.67</td>
</tr>
<tr>
<td>Two Wheelers</td>
<td>50.20</td>
</tr>
<tr>
<td>Autorickshaws</td>
<td>57.35</td>
</tr>
<tr>
<td><strong>Goods Vehicles</strong></td>
<td></td>
</tr>
<tr>
<td>Trucks</td>
<td>14.22</td>
</tr>
<tr>
<td>MAV</td>
<td>37.33</td>
</tr>
<tr>
<td>LCV</td>
<td>10.13</td>
</tr>
</tbody>
</table>

Source: Analysis

Table 4: Peak Hour Traffic on the Project Impact Roads

<table>
<thead>
<tr>
<th>Vehicle Category</th>
<th>No. of vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>131</td>
</tr>
<tr>
<td>Minibus</td>
<td>23</td>
</tr>
<tr>
<td>Car/Jeep/Van</td>
<td>1,511</td>
</tr>
<tr>
<td>Two Wheelers</td>
<td>2,600</td>
</tr>
<tr>
<td>Autorickshaws</td>
<td>1,608</td>
</tr>
<tr>
<td>Trucks</td>
<td>7</td>
</tr>
<tr>
<td>MAV</td>
<td>3</td>
</tr>
<tr>
<td>LCV</td>
<td>160</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6,043</td>
</tr>
</tbody>
</table>

Source: Survey, 2009

Table 5: Estimated Annual Travel Time Savings due to Construction of Off-Street Parking Facility (Rs. In Million)

<table>
<thead>
<tr>
<th>Year</th>
<th>Bus</th>
<th>Minibus</th>
<th>Car/Jeep/Van</th>
<th>Two Wheelers</th>
<th>Autorickshaws</th>
<th>Trucks</th>
<th>MAV</th>
<th>LCV</th>
<th>Total Fast Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>70.00</td>
<td>2.07</td>
<td>12.98</td>
<td>2.74</td>
<td>2.58</td>
<td>0.00</td>
<td>0.00</td>
<td>0.02</td>
<td>90.40</td>
</tr>
<tr>
<td>2007</td>
<td>74.55</td>
<td>2.21</td>
<td>13.83</td>
<td>2.91</td>
<td>2.74</td>
<td>0.00</td>
<td>0.00</td>
<td>0.02</td>
<td>96.27</td>
</tr>
<tr>
<td>2008</td>
<td>79.39</td>
<td>2.35</td>
<td>14.72</td>
<td>3.10</td>
<td>2.92</td>
<td>0.00</td>
<td>0.00</td>
<td>0.03</td>
<td>102.53</td>
</tr>
<tr>
<td>2009</td>
<td>84.55</td>
<td>2.50</td>
<td>15.68</td>
<td>3.30</td>
<td>3.11</td>
<td>0.00</td>
<td>0.00</td>
<td>0.03</td>
<td>109.19</td>
</tr>
<tr>
<td>2010</td>
<td>90.05</td>
<td>2.67</td>
<td>16.70</td>
<td>3.52</td>
<td>3.32</td>
<td>0.00</td>
<td>0.00</td>
<td>0.03</td>
<td>116.29</td>
</tr>
<tr>
<td>2011</td>
<td>95.90</td>
<td>2.84</td>
<td>17.79</td>
<td>3.75</td>
<td>3.53</td>
<td>0.00</td>
<td>0.00</td>
<td>0.03</td>
<td>123.85</td>
</tr>
<tr>
<td>2012</td>
<td>102.14</td>
<td>3.03</td>
<td>18.94</td>
<td>3.99</td>
<td>3.76</td>
<td>0.00</td>
<td>0.00</td>
<td>0.03</td>
<td>131.90</td>
</tr>
<tr>
<td>2013</td>
<td>108.78</td>
<td>3.22</td>
<td>20.17</td>
<td>4.25</td>
<td>4.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.04</td>
<td>140.47</td>
</tr>
<tr>
<td>2014</td>
<td>115.85</td>
<td>3.43</td>
<td>21.49</td>
<td>4.53</td>
<td>4.27</td>
<td>0.00</td>
<td>0.01</td>
<td>0.04</td>
<td>149.60</td>
</tr>
</tbody>
</table>
## Table 6: Parameters considered for the Estimation of Revenue from Parking Fee – Multi-storied Parking

<table>
<thead>
<tr>
<th>Details</th>
<th>Car</th>
<th>Two Wheelers (TW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking Space available (Nos.)</td>
<td>812</td>
<td>458</td>
</tr>
<tr>
<td>Maximum Parking demand Capacity / Day @ 5 turnover / space for TW and @ 3 turnover / space for cars &amp; 90 % utilisation (No. of vehicles)</td>
<td>3654</td>
<td>2885</td>
</tr>
<tr>
<td>Initial Year Parking Demand (No. of vehicles/Day)</td>
<td>3289</td>
<td>2597</td>
</tr>
<tr>
<td>Annual Growth Rate for Parking Demand</td>
<td>6%</td>
<td>6%</td>
</tr>
<tr>
<td>Parking Fee (Rs. / two hour)</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Increase in Parking Fee (at every 3rd year)</td>
<td>15%</td>
<td>15%</td>
</tr>
</tbody>
</table>

12. *User charges collected from the parked vehicles:* Based on the detailed parking demand study results and the existing trend in the vehicular parking business in the region, the following parameters were considered for estimating the parking revenue.

13. *Rental charges collected from the commercial establishments and utilities operated at the ground floor:* Based on the detailed demand study and the existing trend in the commercial rental business in the region, the following parameters were considered for estimating the rental revenue.
Table 7: Estimation of Revenue from Commercial Space - Multistoried Parking

<table>
<thead>
<tr>
<th>Details</th>
<th>Area proposed for Commercial Purpose (Sqm)</th>
<th>Monthly Rent (Rs/Sqm)</th>
<th>Annual Rent (Rs/Sqm)</th>
<th>Annual Rent (Rs Million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Floor</td>
<td>3200</td>
<td>1000</td>
<td>12000</td>
<td>30.72</td>
</tr>
<tr>
<td>First Floor</td>
<td>0</td>
<td>1000</td>
<td>12000</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td><strong>30.72</strong></td>
</tr>
</tbody>
</table>

Note: only 40% of the total available space in the ground floor (8000 sqm) is considered for rental purpose.

14. Finally the estimated project benefits during the analysis period are given in Table 8.

Table 8: Estimated Project Benefits – Multi-storied Parking in Ghaziabad

<table>
<thead>
<tr>
<th>Year</th>
<th>Savings in Travel Time Cost</th>
<th>Parking Charges</th>
<th>Commercial Space Revenue</th>
<th>Total Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009-10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2010-11</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2011-12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2012-13</td>
<td>131.90</td>
<td>10.32</td>
<td>31.62</td>
<td>173.84</td>
</tr>
<tr>
<td>2013-14</td>
<td>140.47</td>
<td>10.94</td>
<td>31.62</td>
<td>183.03</td>
</tr>
<tr>
<td>2014-15</td>
<td>149.60</td>
<td>11.60</td>
<td>31.62</td>
<td>192.82</td>
</tr>
<tr>
<td>2015-16</td>
<td>159.33</td>
<td>13.34</td>
<td>36.22</td>
<td>208.89</td>
</tr>
<tr>
<td>2016-17</td>
<td>169.68</td>
<td>13.34</td>
<td>36.22</td>
<td>219.24</td>
</tr>
<tr>
<td>2017-18</td>
<td>180.71</td>
<td>14.23</td>
<td>36.22</td>
<td>231.16</td>
</tr>
<tr>
<td>2018-19</td>
<td>192.46</td>
<td>16.36</td>
<td>41.52</td>
<td>250.34</td>
</tr>
<tr>
<td>2019-20</td>
<td>204.97</td>
<td>16.36</td>
<td>41.52</td>
<td>262.85</td>
</tr>
<tr>
<td>2020-21</td>
<td>218.29</td>
<td>16.36</td>
<td>41.52</td>
<td>276.17</td>
</tr>
<tr>
<td>2021-22</td>
<td>232.48</td>
<td>18.81</td>
<td>47.62</td>
<td>298.91</td>
</tr>
<tr>
<td>2022-23</td>
<td>247.59</td>
<td>21.16</td>
<td>47.62</td>
<td>316.37</td>
</tr>
<tr>
<td>2023-24</td>
<td>263.69</td>
<td>21.16</td>
<td>47.62</td>
<td>332.47</td>
</tr>
<tr>
<td>2024-25</td>
<td>280.83</td>
<td>24.34</td>
<td>54.63</td>
<td>359.79</td>
</tr>
<tr>
<td>2025-26</td>
<td>297.68</td>
<td>24.34</td>
<td>54.63</td>
<td>376.64</td>
</tr>
<tr>
<td>2026-27</td>
<td>315.54</td>
<td>24.34</td>
<td>54.63</td>
<td>394.50</td>
</tr>
<tr>
<td>2027-28</td>
<td>334.47</td>
<td>27.99</td>
<td>62.68</td>
<td>425.14</td>
</tr>
<tr>
<td>2028-29</td>
<td>354.54</td>
<td>27.99</td>
<td>62.68</td>
<td>445.21</td>
</tr>
<tr>
<td>2029-30</td>
<td>375.81</td>
<td>27.99</td>
<td>62.68</td>
<td>466.48</td>
</tr>
<tr>
<td>2030-31</td>
<td>398.36</td>
<td>32.19</td>
<td>71.95</td>
<td>502.50</td>
</tr>
<tr>
<td>2031-32</td>
<td>422.26</td>
<td>32.19</td>
<td>71.95</td>
<td>526.40</td>
</tr>
<tr>
<td>Total</td>
<td><strong>5,070.65</strong></td>
<td><strong>405.33</strong></td>
<td><strong>966.78</strong></td>
<td><strong>6,442.76</strong></td>
</tr>
</tbody>
</table>
15. Exclusions. The following benefits of transport component for the off-street parking construction have not been quantified for want of adequate data and quantification techniques. These qualitative benefits along with the quantifiable benefits discussed above, the proposed multi-storied parking construction will tend to provide better living condition in the project town.

(i) improvement in the environment of the project site;
(ii) savings in VOC due to the reduction in traffic congestion at the junction;
(iii) savings in traffic accidents cost due to better traffic management; and
(iv) Effects on tourism and tourist-related businesses.
## Appendix 1-3: Economic Cost-Benefit Analysis - Multi-Level Parking

<table>
<thead>
<tr>
<th>Year Ending March</th>
<th>Economic Cost</th>
<th>Economic Benefits</th>
<th>Net Cash Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capital Cost</td>
<td>O &amp; M Cost</td>
<td>Total Cost</td>
</tr>
<tr>
<td>2009-10</td>
<td>-</td>
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Appendix 1-3: Sensitivity Analysis - Multi-Level Parking
Appendix 2-1

The Constitution (Seventy-Fourth Amendment) Act, 1992

An Act Further to amend the Constitution of India

Be it enacted by Parliament in the Forty-third Year of the Republic of India as follows:-

1. (1) This Act may be called the Constitution (Seventy-fourth Amendment) Act, 1992
(2) It shall come into force on such date as the Central Government may, by notification in the Official Gazette, appoint

2. After Part IX of the Constitution, the following Part shall be inserted, namely:-

1. ‘PART IXA’
THE MUNICIPALITIES

1.1 243P. In this Part, unless the context otherwise requires,-

(a) “Committee” means a Committee constituted under article 243S;

(b) “district’ means a district of a State;

(c) “Metropolitan area” means an area having a population of ten lakhs or more comprised in one or more districts and consisting of two or more Municipalities or Panchayats or other contiguous areas, specified by the Governor by public notification to be a Metropolitan area for the purposes of this Part;

(d) “Municipal area” means the territorial area of a Municipality as is notified by the Governor;

(e) “Municipality” means an institution of self-government constituted under article 243Q;

(f) “Panchayat” means a Panchayat constituted under article 243B;

(a) “population” means the population as ascertained at the last preceding census of which the relevant figures have been published.

243Q. (1) There shall be constituted in every State,-

(a) a Nagar Panchayat (by whatever name called) for a transitional area, that is to say, an area in transition from a rural area to an urban area;

(b) a Municipal Council for a smaller urban area; and

(c) a Municipal Corporation for a larger urban area,

in accordance with the provisions of this Part:
Provided that a Municipality under this clause may not be constituted in such urban area or part thereof as the Governor may, having regard to the size of the area and the municipal services being provided or proposed to be provided by an industrial establishment in that area and such other factors as he may deem fit, by public notification, specify to be an industrial township.

(2) In this article, “a transitional area” “a smaller urban area” or “a larger urban area” means such area as the Governor may, having regard to the population of the area, the density of the population therein the revenue generated for local administration, the percentage of employment in non-agricultural activities, the economic importance or such other factors as he may deem fit, specify by public notification for the purposes of this Part.

243R. (1) Save as provided in clause (2), all the seats in a Municipality shall be filled by persons chosen by direct election from the territorial constituencies in the Municipal area and for this purpose each Municipal area shall be divided into territorial constituencies to be known as wards.

(2) The Legislature of a State may, by law, provide,-

(a) for the representation in a Municipality of –
(i) persons having special knowledge or experience in Municipal administration;
(ii) the members of the House of the People and the members of the Legislative Assembly of the State representing constituencies which comprise wholly or partly the Municipal area;
(iii) the members of the Council of States and the members of the Legislative Council of the State registered as electors within the Municipal area;
(iv) the Chairpersons of the Committees constituted under clause (5) of article 243S.
Provided that the persons referred to in paragraph (i) shall not have the right to vote in the meetings of the Municipality:
(b) the manner of election of the Chairperson of a Municipality.

243S. (1) There shall be constituted Wards Committees, consisting of one or more wards, within the territorial area of a Municipality having a population of three lakhs or more.
(2) The Legislature of a State may, by law, make provision with respect to-
(a) the composition and the territorial area of a Wards Committee;
(b) the manner in which the seats in a Wards Committee shall be filled
(3) A member of a Municipality representing a ward within the territorial area of the Wards Committee shall be a member of that Committee.
(4) Where a Wards Committee consists of –

(a) one ward, the member representing that ward in the Municipality; or
(b) two or more wards, one of the members representing such wards in the Municipality elected by the Members of the Wards Committee, shall be the Chairperson of that Committee.

(5) Nothing in this article shall be deemed to prevent the Legislature of a State from making any provision for the constitution of Committees in addition to the Wards Committees.

243T. (1) Seats shall be reserved for the Scheduled Castes and the Scheduled Tribes in every Municipality and the number of seats so reserved shall bear, as nearly as may be, the same proportion to the total number of seats to be filled by direct election in that Municipality as the population of the Scheduled Castes in the Municipal area or of the Scheduled Tribes in the Municipal area bears to the total population of that area and such seats may be allotted by rotation to different constituencies in a Municipality.
(2) Not less than one-third of the total number of seats reserved under clause (1) shall be reserved for women belonging to the Scheduled Castes or, as the case may be, the Scheduled Tribes.
(3) Not less than one-third (including the number of seats reserved for women belonging to the Scheduled Castes and the Scheduled Tribes) of the total number of seats to be filled by direct election in every Municipality shall be reserved for women and such seats may be allotted by rotation to different constituencies in a Municipality.
(4) The office of Chairpersons in the Municipalities shall be reserved for the Scheduled Castes, the Scheduled Tribes and women in such manner as the Legislature of a State may, by law, provide.
(5) The reservation of seats under clauses (1) and (2) and the reservation of office of Chairpersons (other than the reservation for women) under clause (4) shall cease to have effect on the expiration of the period specified in article 334.
(6) Nothing in this Part shall prevent the Legislature of a State from making any provision for reservation of seats in any Municipality or office of Chairpersons in the Municipalities in favour of backward class of citizens.

243U. (1) Every Municipality, unless sooner dissolved under any law for the time being in force, shall continue for five years from the date appointed for its first meeting and no longer:
Provided that a Municipality shall be given a reasonable opportunity of being heard before its dissolution.
(2) No amendment of any law for the time being in force shall have the effect of causing dissolution of a Municipality at any level, which is functioning immediately before such amendment, till the expiration of its duration specified in clause (1).
(3) An election to constitute a Municipality shall be completed—

(a) before the expiry of its duration specified in clause (1);
(b) before the expiration of a period of six months from the date of its dissolution:

Provided that where the remainder of the period for which the dissolved Municipality would have continued is less than six months, it shall not be necessary to hold any election under this clause for constituting the Municipality for such period.

(4) A Municipality constituted upon the dissolution of Municipality before the expiration of its duration shall continue only for the remainder of the period for which the dissolved Municipality would have continued under clause (1) had it not been so dissolved.

243V. (1) A person shall be disqualified for being chosen as, and for being, a member of a Municipality-

(a) if he is so disqualified by or under any law for the time being in force for the purposes of elections to the Legislature of the State concerned:

Provided that no person shall be disqualified on the ground that he is less than twenty-five years of age, if he has attained the age of twenty-one years;

(b) if he is so disqualified by or under any law made by the Legislature of the State.

(2) If any question arises as to whether a member of a Municipality has become subject to any of the disqualifications mentioned in clause (1), the question shall be referred for the decision of such authority and in such manner as the Legislature of a State may, by law, provide.

243W. Subject to the provisions of this Constitution, the Legislature of State may, by law, endow-

(a) The Municipalities with such powers and authority as may be necessary to enable them to function as institutions of self-government and such law may contain provision for the devolution of powers and responsibilities upon Municipalities, subject to such conditions as may be specified therein, with respect to-

(i) the preparation of plans for economic development and social justice;

(ii) the performance of functions and the implementation of schemes as may be entrusted to them including those in relation to the matter listed in the Twelfth Schedule;

(b) the committees with such powers and authority as may be necessary to enable them to carry out the responsibilities conferred upon them including those in relation to the matters listed in the Twelfth Schedule.

1.2 243X. The Legislature of a State may, by law-

(a) authorise a Municipality to levy, collect and appropriate such taxes, duties, tolls and fees in accordance with such procedure and subject to such limits;

(b) assign to a Municipality such taxes, duties, tolls and fees levied and collected by the State Government for such purposes and subject to such conditions and limits;

(c) provide for making such grants-in-aid to the Municipalities from the Consolidated Fund of the State; and

(d) provide for constitution of such funds for crediting all moneys received, respectively, by or on behalf of the Municipalities and also for the withdrawal of such moneys therefrom, as may be specified in the law.

243Y. (1) The Finance Commission constituted under article 243-I shall also review the financial position of the Municipalities and make recommendations to the Governor as to-

(a) the principles which should govern-
(i) the distribution between the State and the Municipalities of the net proceeds of the taxes, duties, tolls and fees leviable by the State, which may be divided between them under this Part and the allocation between the Municipalities at all levels of their respective shares of such proceeds;

(ii) the determination of the taxes duties, tolls and fees which may be assigned to, or appropriated by, the Municipalities;
(iii) the grants-in-aid to the Municipalities from the Consolidated Fund of the State;

(b) the measures needed to improve the financial position of the Municipalities;

(c) any other matter referred to the Finance Commission by the Governor in the interests of sound finance of the Municipalities.

(2) The Governor shall cause every recommendation made by the Commission under this article together with an explanatory memorandum as to the action taken thereon to be laid before the Legislature of the State.

243Z. The Legislature of a State may, by law, make provisions with respect to the maintenance of accounts by the Municipalities and the audit of such accounts.

243ZA. (1) The superintendence, direction and control of the preparation of electoral rolls for, and the conduct of, all elections to the Municipalities shall be vested in the State Election Commission referred to in article 243K.

(2) Subject to the provisions of this Constitution, the Legislature of a State may, by law, make provision with respect to all matters relating to or in connection with, elections to the Municipalities.

243ZB. The provisions of this Part shall apply to the Union territories and shall, in their application to a Union territory, have effect as if the references to the Governor of a State were references to the Administrator of the Union Territory appointed under article 239 and references to the Legislature or the Legislative Assembly of a State were references in relation to a Union Territory having a Legislative Assembly, to that Legislative Assembly. Provided that the President may, by public notification, direct that the provisions of this Part shall apply to any Union territory or part thereof subject to such exceptions and modifications as he may specify in the notification.

243ZC. (1) Nothing in this Part shall apply to the Scheduled Areas referred to in clause (1), and the tribal areas referred to in clause (2), of article 244.

(2) Nothing in this Part shall be construed to affect the functions and powers of the Darjeeling Gorkha Hill Council constituted under any law for the time being in force for the hill areas of the distinct of Darjeeling in the State of West Bengal.

(3) Notwithstanding anything in this Constitution, Parliament may, by law, extend the provisions of this Part to the Scheduled Areas and the tribal areas referred to in clause (1) subject to such exceptions and modifications as may be specified in such law, and no such law shall be deemed to be an amendment of this Constitution for the purposes of article 368.

243ZD. (1) There shall be constituted in every State at the district level a District Planning Committee to consolidate the plans prepared by the Panchayats and the Municipalities in the district and to prepare a draft development plan for the district as a whole.

(2) The Legislature of a State may by law, make provision with respect to-

(a) the composition of the District Planning Committees;

(b) the manner in which the seats in such Committees shall be filled:
Provided that not less than four-fifths of the total number of members of such Committee shall be elected by, and from amongst, the elected members of the Panchayat at the diacritic level and of the Municipalities in the district in proportion to the ratio between the population of the rural areas and of the urban areas in the district;
(c) the functions relating to district planning which may be assigned to such Committees;

(d) the manner in which the Chairpersons of such Committee shall be chosen.

(3) Every District Planning Committee shall, in preparing the draft development plan -

(a) have regard to -

(i) matters of common interest between the Panchayats and the Municipalities including spatial planning, sharing of water and other physical and natural resources, the integrated development of infrastructure and environmental conservation;
(ii) the extent and type of available resources whether financial or otherwise;
(b) consult such institutions and organisations as the Governor may, by order, specify.

(4) The Chairpersons of every District Planning Committee shall forward the development plan, as recommended by such Committee, to the Government of the State.

243ZE.(1) There shall be constituted in every metropolitan area a Metropolitan Planning Committee to prepare a draft development plan for the Metropolitan area as a whole.

(2) The legislature of a State may, by law, make provision with respect to –

(a) the composition of the Metropolitan Planning Committees;
(b) the manner in which the seats in such Committees shall be filled:

Provided that not less than two-thirds of the members of such Committee shall be elected by, and from amongst the elected members of the municipalities and chairpersons of the Panchayats in the Metropolitan area in proportion to the ratio between the population of the Municipalities and of the Panchayats in that area;
(c) the representation in such Committees of the Government of India and the Government of the State and of such organisation and institutions as may be deemed necessary for carrying out of functions assigned to such Committees;
(d) the functions relating to planning and coordination for the metropolitan area which may be assigned to such Committees;
(e) the manner in which the Chairpersons of such Committees shall be chosen.

(3) Every Metropolitan Planning Committee shall, in preparing the draft development plan -

(a) have regard to –

(i) the plans prepared by the Municipalities and the Panchayats in the Metropolitan area;

(ii) matter of common interest between the Municipalities and the Panchayats, including coordinated spatial planning of the area, sharing of water and other physical and natural resources, the integrated development of infrastructure and environmental conservation;
(iii) the overall objectives and priorities set by the Government of India and the Government of the State;
(iv) the extent and nature of investments likely to be made in Metropolitan area by agencies of the Government of India and of the Government of the State and other available resources whether financial or otherwise;
(b) consult such institutions and organizations as the Governor may, by order, specify.
(4) The Chairperson of every Metropolitan Planning Committee shall forward the development plan, as recommended by such Committee, to the Government of the State.

243ZF. Notwithstanding anything in this Part, any provision of any law relating to Municipalities in force in a State immediately before the commencement of the Constitution (Seventy-fourth Amendment) act, 1992, which is inconsistent with the provisions of this Part, shall continue to be in force until amended or repealed by the competent Legislature or other competent authority or until the expiration of one year from such commencement, whichever is earlier:
Provided that all the Municipalities existing immediately before such commencement shall continue till the expiration of their duration, unless sooner dissolved by a resolution passed to that effect by the Legislative Assembly of that State or, in the case of a State having a Legislative Council, by each House of the Legislature of the State.

243ZG. Notwithstanding anything in this Constitution -
(a) the validity of any law relating to the delimitation of constituencies or the allotment of seats to such constituencies, made or purporting to be made under article 243ZA shall not be called in question in any count;
(b) no election to any Municipality shall be called in question except by an election petition presented to such authority and in such manner as is provided for by or under any law made by the Legislature of a State;
(c) the measures needed to augment the Consolidated Fund of a State to supplement the resources of the Municipalities in the State on the basis of the recommendations made by the Finance Commission of the State;”.

(4) After the Eleventh Schedule to the Constitution, the following Schedule shall be added, namely:-

“TWELFTH SCHEDULE
(Article 243W)
1. Urban Planning including town planning
2. Regulation of land-use and construction of buildings.
3. Planning for economic and social developments
4. Roads and bridges.
5. Water supply for domestic, industrial and commercial purposes.
6. Public health, sanitation conservancy and solid waste management.
7. Fire services.
8. Urban forestry, protection of the environment and promotion of ecological aspects.
9. Safeguarding the interests of weaker sections of society, including the handicapped and mentally retarded.
10. Slum improvement and upgradation.
11. Urban poverty alleviation.
12. Provision of urban amenities and facilities such as parks, gardens, playgrounds.
13. Promotion of cultural, educational and aesthetic aspects.
14. Burials and burial grounds; cremations, cremation grounds and electric crematoriums.
15. Cattle pounds; prevention of cruelty to animals.
16. Vital statistics including registration of births and deaths.
17. Public amenities including street lighting, parking lots, bus stops and public conveniences.
18. Regulation of slaughter houses and tanneries”.
243-I. (1) The Governor of a State shall, as soon as may be within one year from the commencement of the Constitution (Seventy-third Amendment) Act, 1992, and thereafter at the expiration of every fifth year, constitute a Finance Commission to review the financial position of the Panchayats and to make recommendations to the Governor as to:

(a) the principles which should govern-
(i) the distribution between the State and the Panchayats of the net proceeds of the taxes, duties, tolls and fees leviable by the State, which may be divided between them under this Part and the allocation between the Panchayats at all levels of their respective shares of such proceeds;
(ii) the determination of the taxes, duties, tolls and fees which may be assigned to, or appropriated by, the Panchayats;
(iii) the grants-in-aid to the Panchayats from the Consolidated Fund of the State;
(b) the measures needed to improve the financial position of the Panchayats;
(c) any other matter referred to the Finance Commission by the Governor in the interests of sound finance of the Panchayats.

(2) The Legislature of a State may, by law, provide for the composition of the Commission, the qualifications which shall be requisite for appointment as members thereof and the manner in which they shall be selected.

(3) The Commission shall determine their procedure and shall have such powers in the performance of their functions as the Legislature of the State may, by law, confer on them.

(4) The Governor shall cause every recommendation made by the Commission under this article together with an explanatory memorandum as to the action taken thereon to be laid before the Legislature of the State.

243-K(1) The Superintendence, direction and control of the preparation of electoral rolls for, and the conduct of, all elections to the Panchayats shall be vested in a State Election Commission consisting of a State Election Commissioner to be appointed by the Governor.

(2) Subject to the provisions of any law made by the Legislature of a State, the conditions of service and tenure of office of the State Election Commissioner shall be such as the Governor may by rule determine;
Provided that the State Election Commissioner shall not be removed from his office except in like manner and on the like grounds as judge of High Court and the conditions of service of the State Election Commissioner shall not be varied to his disadvantage after his appointment.

(3) The Governor shall, when so requested by the State Election Commission, make available to the State Election Commission such staff as may be necessary for the discharge of the functions conferred on the State Election Commission by Clause (1).

(4) Subject to the provisions of this Constitution, the Legislature of a State may, by law, make provision with respect to all matters relating to, or in connection with elections to the Panchayats.

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National Capital Region Planning Board (NCRPB)

1. The National Capital Region Planning Board (NCRPB), constituted in 1985 under the provisions of NCRPB Act, 1985, is a statutory body functioning under the Ministry of Urban Development, Government of India. NCRPB has a mandate to systematically develop the National Capital Region (NCR) of India which comprises of (i) National Capital Territory Delhi (constitutes 4.4 percent of NCR area); (ii) Haryana Sub-region (40.0 percent of NCR area); (iii) Rajasthan Sub-region (23.3 percent of NCR area); (iv) Uttar Pradesh Sub-region (32.3 percent of NCR area) and (v) Five Counter Magnet Areas (CMA) The project town Ghaziabad City also part of the NCR.

2. According to the NCRPB Act, 1985 major functions of the Board include: (i) Preparation of the Regional Plan and Functional Plans; (ii) Coordinate enforcement and implementation of the Regional Plan, Functional Plans, Sub-regional Plans, and Project Plans through the participating states and NCT; (iii) Ensure proper and systematic programming by the participating states and the NCT in project formulation, determination of priorities in NCR or Sub-regions and phasing of the development of NCR in accordance with the stages indicated in regional plan; and, (v) project in the NCR through Central and State Plan funds and other sources of revenue.

3. NCRPB has prepared regional plan for NCR area with the perspective year 2021. Further, the Board also initiated preparation of functional plans to elaborate one or more elements of the Regional Plan. Accordingly the functional plan for water supply and transport is under preparation but plans for other infrastructure is yet to take off.

4. NCRPB has been providing financial assistance to the participating state governments, ULBs, and other IAs in the NCR and in counter magnet towns. Till March 2008, NCRPB has financed 212 infrastructure projects involving total project outlays exceeding Rs. 139 billion. It has sanctioned loans amounting to Rs. 53 billion and disbursed Rs. 33.3 billion. NCRPB gives significant emphasis for building water supply and sanitation infrastructure.

5. NCRPB Act 1985, Chapter VI discusses the provisions for finance, accounts and audit that regulate

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1 THE NATIONAL CAPITAL REGION PLANNING BOARD ACT, 1985, No.2 OF 1985, 9th February, 1985, published by The Gazette of India on FEBRUARY 11, 1985. This Act provide for the constitution of a Planning Board for the preparation of a plan for the development of the National Capital Region and for co-ordinating and monitoring the implementation of such plan and for evolving harmonized policies for the control of land-uses and development of infrastructure in the National Capital Region so as to avoid any haphazard development of that region and for matters connected therewith or incidental thereto

2 Annual Report 2007-2008, NCRPB
NCRPB accounting policies. It discusses about the financial sources, constitution of NCRPB Fund, requirement of annual budget, annual report etc, account and audit requirements, Annual auditors’ report and report to be laid before Parliament.

6. The accounts of the NCRPB will be maintained and audited in such manner as may be prescribed in consultation with the Comptroller and Auditor-General of India and the Board will furnish, to the Central Government, before such date as may be prescribed, a copy of its audited accounts together with the auditors’ report thereon. Annual auditors’ report and report to be laid before Parliament.

7. NCRPB maintains annual accounts in the form of Income & Expenditure Account (Plan & Non-Plan), Balance Sheets and detailed Receipts & Payment Account with appropriate Schedules. Review of NCRPB Annual Accounts during the period FY 2002-03 to FY 2008-09 indicate the following: (Table Error! No text of specified style in document.-1)

- Income, expenditure and net revenue under Plan head form the major revenue source
- Plan income is observed with fluctuating trend over the analysis period.
- Plan expenditure found drastically reduced from Rs 1055 million in FY 2002-03 to Rs 252 million in FY 2008-09 which had resulted in increase trend of net plan income.
- Under Non-Plan head, both income and expenditure found to be more or less equal resulting no surplus during the analysis period.
- Under non-plan, salaries and office expenses are the major expenditure items and grant in-aids and interest receipts from provident fund are the major revenue item.
### NCRPB - Summary of Income & Expenditure Account

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<td>1,136.77</td>
<td>1,141.03</td>
<td>1,411.11</td>
</tr>
<tr>
<td>Excess of Plan Income Over Plan Expenditure</td>
<td>740.60</td>
<td>794.00</td>
<td>758.14</td>
<td>732.88</td>
<td>1,077.20</td>
<td>1,158.63</td>
</tr>
<tr>
<td>Non-Plan Expenditure</td>
<td>15.14</td>
<td>17.94</td>
<td>18.96</td>
<td>18.32</td>
<td>59.99</td>
<td>24.62</td>
</tr>
<tr>
<td>Non-Plan Income</td>
<td>15.92</td>
<td>18.03</td>
<td>19.07</td>
<td>18.38</td>
<td>19.55</td>
<td>24.84</td>
</tr>
<tr>
<td>Excess of Non-Plan Income Over Non-Plan Expenditure</td>
<td>0.78</td>
<td>0.10</td>
<td>0.10</td>
<td>0.06</td>
<td>(40.44)</td>
<td>0.22</td>
</tr>
<tr>
<td>Total Expenditure</td>
<td>1,070.69</td>
<td>808.41</td>
<td>451.27</td>
<td>422.21</td>
<td>123.83</td>
<td>277.10</td>
</tr>
<tr>
<td>Total Income</td>
<td>1,812.07</td>
<td>1,602.50</td>
<td>1,209.51</td>
<td>1,155.15</td>
<td>1,160.58</td>
<td>1,435.95</td>
</tr>
<tr>
<td>Excess of Total Income Over Total Expenditure</td>
<td>741.38</td>
<td>794.10</td>
<td>758.25</td>
<td>732.94</td>
<td>1,036.75</td>
<td>1,158.85</td>
</tr>
</tbody>
</table>

Source: NCRPB Annual Reports & Annual Accounts

8. NCR Planning Board continued to provide financial assistance to the constituent States / NCT of Delhi and their implementing agencies in the form of loans up to a maximum of 75% of the estimated cost of Projects. The constituent States of NCR/ NCT of Delhi or its implementing agency contributed a minimum of 25% of the project cost as its counter-part share. During the recent years, NCRPB’s lending activity had increased considerably and from the FY 2005-06 its annual loan dispersal had crossed Rs 300 crores. Rs 705 crores were distributed as loan to infrastructure development projects during the FY 2007-08 in which transport, power and water supply were the major sectors constituting 81% of the loan dispersal.

9. There recovery rate of interest and installment of principal amount from any State Government or its implementing agencies was found to be good over the years, except one from the Patiala Urban Planning & Development Authority (PDA), Govt. of Punjab in respect of sewerage scheme of Patiala Municipal Corporation.
10. In order to meet the gap between budgetary support and actual fund requirement for providing financial assistance for the infrastructure development, the Board raises from the capital market by issuing unsecured redeemable non-convertible taxable bonds periodically. The bonds have also been listed at National Stock Exchange (NSE)-WDM segment.
Appendix 2-3
Impact of 73rd & 74th Amendments on ULBs in Uttar Pradesh

The two historic and much talked about 73rd and 74th amendments to the Constitution of India, envisaged a total change in the process of self-governance and planning. The objectives of the amendments were loud and clear: a better plan and its better implementation.

Consequent to the enactment of the 73rd Constitution Amendment Act Uttar Pradesh enacted appropriate legislations for setting up strong, viable local bodies. The Uttar Pradesh Local Self Government Laws (Amendment) Act 1994 was passed by the legislature of Uttar Pradesh to incorporate the mandatory provisions of the CAA 1992. The new laws came into force from 31.5.1994.

Various aspects of Self Governance, under the Urban Local Bodies systems have been discussed below in greater detail.

Urban Local Bodies

Following the 74th Constitutional Amendment Act, 1992, the Government of Uttar Pradesh has taken steps to set up the democratic governance in urban local bodies have been accorded Constitutional Status, they have also been made democratic by way of providing representation of weaker sections of society and women. The functional domain of the ULBs has also been enlarged.

Conformity Legislations in State

The Uttar Pradesh Local Self Government Laws (Amendment ) Act, 1994 was passed by the legislature of Uttar Pradesh to incorporate the mandatory provisions of the CCA 1992. The new laws came into force from 31.05.1994. Some of the salient changes made in the municipal laws through the Amendment Act, 1994 have been highlighted below.

The U.P. Municipal Corporations Act, 1959 and U.P. Municipalities Act, 1966 have been amended and renamed as U.P. Nagar Nigam Act, 1959 and U.P. Nagar Palika Act 1916, while the United provinces Town Area Act, 1914 has been repeated.

Through these amendments following three categories of Urban Local Bodies have been created in the State:

- Nagar Nigams (Municipal Corporations) 12
- Nagar Palika Parishads (Municipal Boards) 194
- Nagar Panchayats (Town Panchayats) 422

Total: 628

Expanding Functional Domains of ULBs

As provided under XII th Schedule of the Constitution, following 12 functions have been added to the duties of the urban local bodies:

- Providing water supply for domestic, industrial and commercial purpose,
- Establishing maintaining and assisting maternity center and child welfare and birth control clinics and promoting control family welfare and small family norm,
- Regulating tanneries,
  - Construction and maintenance of parking lots, bus stops and public convenience:
  - Promoting urban forestry and ecological aspects and protection of the environment.
- Safeguarding the interests of weaker sections of society including the handicapped and mentally retarded,
- Promoting cultural educational and aesthetic aspects
- Constructing and maintaining cattle ponds and preventing cruelty to animals,
- Slum improvement and upgradation,
- Urban poverty alleviation and facilities such as gardens, public parks and play grounds.

**Delegation of Rule Making Powers:**

Powers regarding the framing and making the bye-laws has been delegated to the local bodies subject to the only condition that the bye-laws will take effect only after the have been confirmed by the State Government and published in the official gazette.

Previously State Government was empowered by the Act to make rules for Nagar Palika Parishads and Nagar Panchayats. These Powers have now been decentralized and delegated to the Divisional Commissioners, who are the Prescribed Authority for this purpose.

**Financial Autonomy**

Financial powers of Nagar Ayukt in case of Nagar Nigams and President in case of Nagar Palika Parishads and Nagar Panchayats have been increased as under:

<table>
<thead>
<tr>
<th>Type of ULBs</th>
<th>Authority</th>
<th>Financial Powers Before 74th Amendment</th>
<th>Financial Powers After 74th Amendment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nagar Nigams</td>
<td>Nagar Ayukt</td>
<td>Upto Rs. 10,000</td>
<td>Upto Rs. 1,00,000</td>
</tr>
<tr>
<td>Nagar Palika Parishads</td>
<td>President</td>
<td>Upto Rs. 10,000</td>
<td>Upto Rs. 50,000</td>
</tr>
<tr>
<td>Nagar Panchayats</td>
<td>President</td>
<td>Upto Rs. 3000</td>
<td>Upto Rs. 15,000</td>
</tr>
</tbody>
</table>

**Devolution of State Revenues**

The First State Finance Commission of U.P. has recommended that 7 percent of net tax receipts of the State Government should be transferred to ULBs, the respective shares of Nagar Nigams, Nagar Palika Parishads and Nagar Panchayats were 3.12%, 3.12% and 0.76%. Inter-se distribution within each category was on the basis of population and area (1991) with respective weight of 80% and 20%. The State Government accepted this recommendations. With this, the flow of funds to ULBs has become regular and its distribution among ULBs has been rationalized and limited to objective criteria. In this context, the Second State Finance Commission of U.P. has recommended that 7.5 percent of net tax receipts of the State Government should be transferred to ULBs. The flow of funds to ULBs has substantially increased in recent years as shown in the table below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Funds Developed (Rs. in crore)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997-98</td>
<td>415.83</td>
</tr>
<tr>
<td>1998-99</td>
<td>504.22</td>
</tr>
<tr>
<td>1999-2000</td>
<td>537.89</td>
</tr>
<tr>
<td>2000-01</td>
<td>628.92</td>
</tr>
<tr>
<td>2001-02</td>
<td>682.31</td>
</tr>
<tr>
<td>2002-03</td>
<td>765.74</td>
</tr>
<tr>
<td>2003-04</td>
<td>825.00</td>
</tr>
<tr>
<td>2004-05</td>
<td>877.00</td>
</tr>
</tbody>
</table>
To improve the financial position of ULBs and compel them to take more internal resources, imposition of all taxes enumerated in the Municipal Acts, has been made compulsory since September 1998. Ten percent of devolution share has been linked to the financial performance of ULBs. Previously, the State Government was empowered by the Act, to make rules regarding taxation and other purpose for Nagar Palika Parishad and Nagar Panchayat. These powers have been decentralized and delegated to the Divisional Commissioners, who are the Prescribed Authority for this purpose.

Property Tax constitutes the most important own source of revenue of ULBs. The First Finance Commission made several suggestions to reform the property tax system in the state, which were accepted by the State Government. An area based self-assessment system of property tax has been introduced in 11 Municipal Corporation Towns of the State in the first place to strengthen the financial position of the ULBs.

Inspite of all these measures, the financial position of ULBs in the State continues to be precarious and they are often unable to meet expenditure on salaries and other essential services like power dues. As a result, the quality of urban services remains poor. Urgent steps are therefore, called to revamp the financial situation of ULBs. The fiscal domain of these bodies needs to be expanded and they have to be persuaded to take steps to raise revenue from their own resources. Assess of these bodies to institutional sources of funding and capital market has to be improved.

Thus the enactment of 73rd and 74th Constitutional Amendment Bills 1992 has paved the way for the creation of institutional structures for realizing the goals of self governance under the Panchayati Raj and Urban Local Bodies systems. It has accelerated the socio-economic development through democratic decentralization of governance within a participatory framework at the grassroot level.
Appendix 2-4: Municipal Financial Performance – Ghaziabad Nagar Nigam

A. Overview

1. Financial sustainability of infrastructure investments is determined based on Ghaziabad Nagar Nigam (GNN) ability to sustain investments (through debt servicing, equity contribution and operation and maintenance) from the municipal fund. Most sub-projects undertaken in ULBs (in the State and across Ghaziabad) are financially unviable if they are to take recourse to project revenue. Municipal taxes and non-taxes generally supplement the shortfall in debt repayment and O&M. Financial sustainability analysis for Ghaziabad Nagar Nigam is therefore based on the municipal fund’s ability to pay for sub-project costs. Reforms initiatives are subsequently based on resource mobilization and expenditure management initiatives required for CDP sustainability.

2. The current section on Financial Sustainability reviews Ghaziabad Nagar Nigam’s fiscal status (Revenue/Current Account and Capital Account) and assesses the GNN’s ability to finance and sustain the proposed infrastructure investments.

3. Financial sustainability addresses the required as well as appropriate taxation and tariff reforms. Ghaziabad Nagar Nigam Revenue Account and sub-project cash flows take cognizance of policy directives undertaken by Ghaziabad Nagar Nigam in addressing infrastructure investment and sustenance needs – the focus is on property taxation, water, sewer/drainage and conservancy charges. While the Nagar Nigam continues to draw a substantial proportion of its income from government grant, in lieu of Octroi, in the long-term, the strategy of GNN shall be to capitalize on the benefits accruing from property taxes. Urban infrastructure investments as part of the city development plan (CDP) should recognize the fact that property taxes pay for capital investments and user charges pay for system operation and maintenance – given the aforesaid approach, the financial sustainability analysis focuses on reviewing net cash flows arising out of taxation and tariff reforms.

B. Structure of Municipal Finances in ULB

4. The review of finances involves a time-series analysis of the income and expenditure of the Ghaziabad Nagar Nigam (GNN) to ascertain the trends and the major sources and uses of funds. In addition to this, certain key financial indicators relating to property tax, water tax, per capita income, per capita expenditure and debt servicing; have been considered to assess the financial performance of the GNN. The booking of transactions in GNN is carried out under major and minor heads. The GNN perform a series of obligatory and discretionary functions according to the powers vested through the Uttar Pradesh Municipal Corporations Act, 1959 and Uttar Pradesh Local Self Government Laws (Amendment) Act, 1994. Under this Act, the GNN is empowered to levy taxes and rates. The Act, allows the GNN to levy property tax, duty on transfers of immovable property in the shape of an additional stamp duty, and tax on advertisements. To improve the financial position of ULBs and compel them to take more internal resources imposition of all taxes enumerated in the Municipal Acts, has been made compulsory since September 1998.
5. Property Tax constitutes the most important own source of revenue of ULBs. The First Finance Commission made several suggestions to reform the property tax system in the state, which were accepted by the State Government. An area based self-assessment system of property tax has been introduced in 11 Municipal Corporation Towns of the State in the first place to strengthen the financial position of the ULBs.

6. Most of the ULBs including GNN in UP State are following the single entry manual accounting system, which is highly inefficient in terms transparency of information like current liabilities and assets and lack of financial management information. Also, manual accounting system proved time-consuming. Instead, the double entry computerized accounting system will be quick, efficient and systematic. Various items in the balance sheet could now be bifurcated into various components and information for different period was made available. This facilitated fast and efficient strategic decisions.

7. While urban local bodies are service organizations, efficient management of municipal finances is imperative to service the urban populace. Key sources of revenue consist of taxes, charges, and state transfers; and key items of expenditure are staff salaries, establishment charges, and operation and maintenance of infrastructure.

8. The Municipal Accounts code of Government of Uttar Pradesh prescribes the organization of the municipal fund into three broad categories of General Account, Capital Account and Debt and Suspense (or Extraordinary) Account. Based on the availability, revenue account data collected from the annual accounts of GNN were compiled and analyzed. For the purpose of municipal fiscal assessment, financial data pertaining to the last five years (2001-02 to 2005-06) were compiled in an abstract format (Table 1).

Table 1 : Details of Revenue & Expenditure - Ghaziabad Nagar Nigam

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>Revenue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Income from Taxes</td>
<td>1,890</td>
<td>2,208</td>
<td>1,669</td>
<td>3,096</td>
<td>2,839</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43.1%</td>
<td>41.3%</td>
<td>32.3%</td>
<td>47.9%</td>
<td>41.7%</td>
</tr>
<tr>
<td>2</td>
<td>Other Income</td>
<td>488</td>
<td>875</td>
<td>1,148</td>
<td>887</td>
<td>1,238</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.1%</td>
<td>16.4%</td>
<td>22.2%</td>
<td>13.7%</td>
<td>18.2%</td>
</tr>
<tr>
<td>3</td>
<td>Water charges</td>
<td>12</td>
<td>24</td>
<td>24</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3%</td>
<td>0.4%</td>
<td>0.5%</td>
<td>0.2%</td>
<td>0.4%</td>
</tr>
<tr>
<td>4</td>
<td>Govt. Transfers/ Grants</td>
<td>1787</td>
<td>2056</td>
<td>2262</td>
<td>2438</td>
<td>2668</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40.8%</td>
<td>38.5%</td>
<td>43.8%</td>
<td>37.7%</td>
<td>39.1%</td>
</tr>
<tr>
<td>5</td>
<td>Revenue from Sale</td>
<td>204</td>
<td>178</td>
<td>62</td>
<td>35</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.7%</td>
<td>3.3%</td>
<td>1.2%</td>
<td>0.5%</td>
<td>0.7%</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>4,381</td>
<td>5,341</td>
<td>5,165</td>
<td>6,470</td>
<td>6,815</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>II</td>
<td>Expenditure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>General Administration</td>
<td>412</td>
<td>435</td>
<td>475</td>
<td>505</td>
<td>583</td>
</tr>
</tbody>
</table>
C. Revenue Account

9. The Revenue Account comprises of recurring items of income and expenditure, which are essentially financial transactions related to Ghaziabad Nagar Nigam’s daily operations. Accruals to the municipal fund are applied to carry out designated municipal functions and services.

Revenue Account comprises: (i) Revenue Income, comprising taxes, non-taxes, assigned revenues, and grants and contributions; and (ii) Revenue Expenditure, comprising establishment, operation and maintenance (on urban basic services) and debt servicing.

Table below summarizes the status of GNN’s Revenue Account.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue Income</td>
<td>4,381</td>
<td>5,341</td>
<td>5,165</td>
<td>6,470</td>
<td>6,815</td>
</tr>
<tr>
<td>Revenue Expenditure</td>
<td>4319</td>
<td>4699</td>
<td>5204</td>
<td>6047</td>
<td>5008</td>
</tr>
<tr>
<td>Surplus / Deficit</td>
<td>62</td>
<td>642</td>
<td>(39)</td>
<td>423</td>
<td>1,807</td>
</tr>
</tbody>
</table>

Source: Ghaziabad Nagar Nigam.
fees and charges. Property Tax formed as a major component of own tax revenues contributing 42 percent of the total own tax revenues in FY05-06. While property tax should be an important component of internally generated resources, Ghaziabad Nagar Nigam has still potential to exploit. With increasing trend, Revenue grant is one of the major revenue sources for GNN (39.1 percent). Amongst the non-tax revenues, water charges contributed only 0.4 percent of total revenue income and have found with more fluctuating growth trend.

(i) **Own Sources-Tax.** This item head comprises of income primarily sourced from consolidated property tax (general purpose tax, water tax, lighting tax and scavenging tax) and other taxes as a percentage of the Annual Ratable Value (ARV). On an average, through the assessment period, own source/tax income constitutes 41 percent of the GNN’s revenue income. Property tax, water and sewer taxes income found with increasing trend whereas other tax components found decreased or fluctuating considerably during the assessment period.

(ii) **Own Sources-Non Tax.** This item head comprises of income from municipal properties, fees on municipal services (building permission, etc.), user charges (water charges and connection deposit), road cutting charges, revenue from Ghaziabad Development Authority (GDA).

(iii) **Revenue Grants and Contribution.** This item mainly comprises State Finance Commission grants, special establishment grants and other special grants that the State Government may transfer from time-to-time to GNN.

### Table 3: Ghaziabad Nagar Nigam (GNN) Revenue Income

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Income from Taxes</td>
<td>1,890</td>
<td>2,208</td>
<td>1,669</td>
<td>3,096</td>
<td>2,839</td>
</tr>
<tr>
<td>2</td>
<td>Other Income</td>
<td>488</td>
<td>875</td>
<td>1,148</td>
<td>887</td>
<td>1,238</td>
</tr>
<tr>
<td>3</td>
<td>Water charges</td>
<td>12</td>
<td>24</td>
<td>24</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>Govt. Transfers/ Grants</td>
<td>1,787</td>
<td>2,056</td>
<td>2,262</td>
<td>2,438</td>
<td>2,668</td>
</tr>
<tr>
<td>5</td>
<td>Revenue from Sale</td>
<td>204</td>
<td>178</td>
<td>62</td>
<td>35</td>
<td>46</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>4,381</strong></td>
<td><strong>5,341</strong></td>
<td><strong>5,165</strong></td>
<td><strong>6,470</strong></td>
<td><strong>6,815</strong></td>
</tr>
</tbody>
</table>

*Source: Ghaziabad Nagar Nigam*
11. **Revenue Expenditure.** Revenue expenditure has been found to be with steady increase from FY 2001-02 for four years and started to decline beyond that. Expenditure on general establishment and administration accounted for 12 percent of the total revenue expenditure in FY06. Of the total revenue expenditure, expenditure on operation and maintenance of municipal services constituted 88 percent. Expenditure on development works mostly of capital works executed through grant funds and their repair (21 percent), public health and conservancy (35 percent), water supply (21 percent), horticulture (7 percent) and street lighting (3 percent) are found to be the major components in the operation and maintenance expenditure during the review period. Operation and maintenance expenditure has witnessed a decrease at a CAGR of 3.8 percent and water supply & distribution expenditure has increased at a CAGR of 11 percent.

Table 1 provides a trend of revenue expenditure items.

**Table 1:** Ghaziabad Nagar Nigam Revenue Expenditure

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General Administration</td>
<td>412</td>
<td>435</td>
<td>475</td>
<td>505</td>
<td>583</td>
</tr>
<tr>
<td>2</td>
<td>Development Works &amp; Repairs</td>
<td>1349</td>
<td>1774</td>
<td>1619</td>
<td>1514</td>
<td>1045</td>
</tr>
<tr>
<td>3</td>
<td>Water Supply &amp; Distribution</td>
<td>698</td>
<td>626</td>
<td>752</td>
<td>1442</td>
<td>1045</td>
</tr>
<tr>
<td>4</td>
<td>Others</td>
<td>1860</td>
<td>1864</td>
<td>2358</td>
<td>2586</td>
<td>2335</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>4319</strong></td>
<td><strong>4699</strong></td>
<td><strong>5204</strong></td>
<td><strong>6047</strong></td>
<td><strong>5008</strong></td>
</tr>
</tbody>
</table>

Source: Ghaziabad Nagar Nigam.

**D. Water Supply and Distribution Account**

12. Assessment of the Water supply Account provides an indication of Ghaziabad Naga Nigam’s efforts to recover costs of providing access to safe drinking water.

Table 2 provides a trend of income on water supply and distribution. While there is no separate
account for financial management of water (WS) services, the current analysis is a step in determining the cost recovery options for a sustainable service. Additionally, the assessment also provides insight into options of ring-fencing the water supply service to determine institutional options of operating the water supply services as a profit centre.

- **Income.** Water charges including the connection charges constitute almost 100 percent of total water income and 0.4 percent of GNN’s revenue income. Low tariffs and even lower collection performance has contributed to this poor income status in the WS Account. There is no separate charge for drainage services.

- **Expenditure.** O&M expenditure is the major expenditure item for water & sanitation account and Water supply Account constitute 21 percent GNN’s revenue expenditure.

**Table 2: Water and Sanitation Account**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Income from Water charges</td>
<td>12</td>
<td>24</td>
<td>24</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>2</td>
<td>Expenditure on Water Supply &amp; Distribution</td>
<td>698</td>
<td>626</td>
<td>752</td>
<td>1442</td>
<td>1045</td>
</tr>
<tr>
<td>3</td>
<td>Surplus / Deficit</td>
<td>-686</td>
<td>-602</td>
<td>-728</td>
<td>-1428</td>
<td>-1021</td>
</tr>
</tbody>
</table>

**Source:** Ghaziabad Nagar Nigam.

**E. Fiscal Status of GNN**

1. **Key Financial Indicators**

13. A set of key financial indicators have been derived using the financial data procured from the GNN for the assessment period. These indicators are used to assess the municipal performance with regards resource mobilization, fund utilization, financial performance and collection efficiencies.

14. **Resource Mobilization indicators.** These indicators summarize the performance of the GNN with regards sources of funds. GNN derives about 42 per cent of its revenue income from own sources, which is a good sign but with scope for further improvements.

15. **Fund Application indicators.** These indicators are a measure to ascertain the utilization
from the municipal fund. Only 12 per cent of the revenue expenditure is spent on establishment heads, leaving a good amount of over 88 per cent for O&M of municipal assets and services that include 21 percent for water supply account. Establishment expenditure accounts for about 20 per cent of the total own-tax revenue generated by the GNN.

16. **Overall Financial Performance indicators.** These indicators are a measure to assess the overall financial performance of the municipality with regards operational performance and effective growth in revenue income and expenditure. The average operating ratio during the assessment period was less than unity and it was observed more than unity only for one year during the assessment period (FY 2003-04). The indicators of growth in per capita income and expenditure item heads indicate the effective growth, giving a performance measure relative to the growing population. Annual growth in per capita revenue income found to be consistently with increasing trend where as the per capita revenue expenditure during the assessment period, found to be with increasing trend upto FY 2004-05 and declined after that (Table 6).

Table 6: Details of Percapita Revenue Income and Expenditure - Ghaziabad Nagar Nigam

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<tbody>
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<td>1</td>
<td>Population</td>
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<td>1054186</td>
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<td>2</td>
<td>Revenue Income ( Rs. Lakhs)</td>
<td>4,381</td>
<td>5,341</td>
<td>5,165</td>
<td>6,470</td>
<td>6,815</td>
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<tr>
<td>3</td>
<td>Revenue Expenditure ( Rs. Lakhs)</td>
<td>4319</td>
<td>4699</td>
<td>5204</td>
<td>6047</td>
<td>5008</td>
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<td>4</td>
<td>Revenue Account Surplus (Rs. Lakh)</td>
<td>62</td>
<td>642</td>
<td>(39)</td>
<td>423</td>
<td>1,807</td>
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<tr>
<td>5</td>
<td>Per Capita Revenue Income (Rs.)</td>
<td>452</td>
<td>529</td>
<td>490</td>
<td>588</td>
<td>594</td>
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<td>6</td>
<td>Per Capita Revenue Expenditure (Rs.)</td>
<td>446</td>
<td>465</td>
<td>494</td>
<td>550</td>
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</tr>
</tbody>
</table>

2. **Key Issues**

17. Financial management and fiscal status of Ghaziabad Nagar Nigam is summarized below:

(i) **Maintenance and Reporting of Accounts.** A common accounting and financial reporting code, updated annually, with interim up-dations when required, supported with a user manual and organized training of municipal accounts staff will substantially streamline financial accounting and reporting.

(ii) **Revenue Realization.** Taxes and charges are major own sources of revenue income. Being more dynamic in nature and within the control of the GNN, these revenue incomes have potential to contribute more to the municipal fund. Key issues regarding revenue realization comprise (i) coverage of properties under property tax, (ii) poor collection of water charges; (iii) unclear status on extent of outstanding taxes and charges collectable; and (iv) extent of gap between the cost of service provided and user charges levied.

(iii) **Fund Application.** Key issues regarding application from the municipal fund comprise (i) most of the revenue expenditure is accounted for by establishment item
heads, (ii) an efficient system of costing to enable the actual cost of services provided in a scientific manner thus enabling logical mechanism for tariff structuring and (iii) the absence of information with regard to actual assets and liabilities of GNN at a particular point of time render it difficult to ascertain the actual fiscal position.

(iv) Operating Ratio. Ghaziabad Nagar Nigam has mostly maintained an operating ratio (OR) less than unity (ranging from 0.73 in FY06 to 0.99 in FY02) during the assessment year, except for one year with more than unity. A key reason for the mixed performance is tax revenue collection and expenditure management. However, Ghaziabad Nagar Nigam has untapped revenue potentials from property tax and water charges. While the OR indicates efficiency in revenue management, inability to capitalize on property tax and user charge revenues indicates over dependency on revenue grants and a level of complacency regarding other revenue income sources.

<table>
<thead>
<tr>
<th>Box 1: Municipal Finance Sector Goal</th>
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</table>

**Key Issues**
- Maintenance and Reporting of Accounts
- Revenue Realization
- Fund Application
- Operating Ratio

**Future Strategies**
- A common accounting and financial reporting code, updated annually, with interim updations when required, supported with a user manual
- Widening the coverage of taxes and charges with better collection efficiency
- Sustainable and efficient tariff structure
- Upto-date information with regard to actual assets and liabilities
- Increase the revenue base and control over the revenue expenditure so as to have operating ratio with less than unity continuously.

**Prospective Interventions:**
- Double entry computerized accounting system with adequate training to municipal officials
- Development of GIS based property and other service details through MIS and achievement of 85 percent collection efficiency for both property tax and water charges
- Sector based accounting system for service deliveries and sustainable tariff system that ensure full O&M recovery and part capital cost recovery
- Detailed MIS on assets and liabilities for better fiscal control
- Increase the revenue base through own sources and better control over establishment expenditure
I. Revenue | | | | | | | | | | | | | | | | | | |
1. Income from Taxes | | | | | | | | | | | | | | | | | | |
2. Water charges | -25.82% | -47.72% | -50.00% | | | | | | | | | | | | | | | | |
3. Govt. Transfers/ Grants | 11.66% | 55.87% | 197.65% | | | | | | | | | | | | | | | | |
4. General Administration | 8.82% | 10.64% | 9.79% | | | | | | | | | | | | | | | | |
5. Other Income | | | | | | | | | | | | | | | | | | |
1. Revenue from Sale | -8.46% | 50.79% | -64.91% | | | | | | | | | | | | | | | | |
2. Water Supply & Distribution | 13.96% | 1.97% | 20.77% | | | | | | | | | | | | | | | | |
3. Health & Sanitation Works | | | | | | | | | | | | | | | | | | |
4. Development Works & Repairs | 4.31% | 50.50% | 31.90% | | | | | | | | | | | | | | | | |
5. Loan Repayment | | | | | | | | | | | | | | | | | | |
TOTAL | | | | | | | | | | | | | | | | | | |
II. Expenditure | | | | | | | | | | | | | | | | | | |
1. General Administration | 8.82% | 10.64% | 9.79% | | | | | | | | | | | | | | | | |
2. Health & Sanitation Works | | | | | | | | | | | | | | | | | | |
1. Salaries | 4.11% | 6.48% | 3.15% | | | | | | | | | | | | | | | | |
2. Contracted Sanitation Works | 22.06% | 16.85% | 39.73% | | | | | | | | | | | | | | | | |
3. Repairs & Maintenance of Sanitation Implements | 7.92% | 28.81% | 14.74% | | | | | | | | | | | | | | | | |
4. Diesel, etc | 23.06% | 15.48% | 29.15% | | | | | | | | | | | | | | | | |
5. Others | 2.97% | 26.45% | 6.90% | | | | | | | | | | | | | | | | |
TOTAL | | | | | | | | | | | | | | | | | | |
III. Surplus / Deficit | | | | | | | | | | | | | | | | | | |
1. Income from Taxes | 14.64% | 15.00% | 42.61% | 10.00% | | | | | | | | | | | | | | | | |
2. Water Tax | 19.41% | 19.23% | 41.84% | 10.00% | | | | | | | | | | | | | | | | |
3. Sewer Tax | 16.75% | 13.90% | 20.63% | 10.00% | | | | | | | | | | | | | | | | |
4. Govt. Transfers/ Grants | 11.66% | 55.87% | 197.65% | | | | | | | | | | | | | | | | |
5. Income from Sale | -8.46% | 50.79% | -64.91% | | | | | | | | | | | | | | | | |
6. Water Supply & Distribution | 13.96% | 1.97% | 20.77% | | | | | | | | | | | | | | | | |
7. Health & Sanitation Works | | | | | | | | | | | | | | | | | | |
8. Development Works & Repairs | 4.31% | 50.50% | 31.90% | | | | | | | | | | | | | | | | |
9. Loan Repayment | | | | | | | | | | | | | | | | | | |
TOTAL | | | | | | | | | | | | | | | | | | |
**TOTAL** | 20.88% | 28.31% | 124.51% | | | | | | | | | | | | | | | | |
**TOTAL** | 8.53% | 5.29% | 22.07% | | | | | | | | | | | | | | | | |
## Project Cash Flow

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<th>Outflow</th>
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<td>435</td>
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<tr>
<td>Incremental Project Revenues</td>
<td></td>
<td></td>
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<tr>
<td>Total Inflow</td>
<td>326</td>
<td>435</td>
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<tr>
<td>CAPEX (Equity + Loan)</td>
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<td>Incremental O&amp;M a/ b/ IV</td>
<td>1,632</td>
<td>2,176</td>
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<tr>
<td>Debt Service</td>
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<td>1,741</td>
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<tr>
<td>Interest</td>
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<tr>
<td>Loan Repayment</td>
<td></td>
<td></td>
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<tr>
<td>Total Debt Service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Outflow</td>
<td>1,632</td>
<td>2,176</td>
</tr>
<tr>
<td>Net Surplus / Deficit After Debt Service</td>
<td>62, 642, (39), 423, 1,807, 305, 6,608, 6,574, 7,099, 7,555, 7,724, 8,480</td>
<td>423, 1,807, 305, 6,608, 6,574, 7,099, 7,555, 7,724, 8,480</td>
</tr>
</tbody>
</table>

b/ 10% Annual increase in incremental O&M is considered
## Details of Revenue & Expenditure

**Ghaziabad Nagar Nigam**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>2,923</td>
<td>3,215</td>
<td>3,537</td>
<td>3,891</td>
<td>4,280</td>
<td>4,708</td>
<td>5,178</td>
<td>5,696</td>
</tr>
<tr>
<td>Expenditure</td>
<td>1,772</td>
<td>1,949</td>
<td>2,144</td>
<td>2,358</td>
<td>2,594</td>
<td>2,853</td>
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<td>3,452</td>
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<td>% Change</td>
<td>15.2%</td>
<td>14.0%</td>
<td>12.9%</td>
<td>11.9%</td>
<td>10.9%</td>
<td>10.0%</td>
<td>9.2%</td>
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<tr>
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<td>1,825</td>
<td>2,007</td>
<td>2,208</td>
<td>2,429</td>
<td>2,672</td>
<td>2,939</td>
<td>3,233</td>
<td>3,556</td>
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<td>1,098</td>
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<td>% Change</td>
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<td>9.0%</td>
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</tr>
<tr>
<td>Revenue</td>
<td>161,222</td>
<td>171,167</td>
<td>183,490</td>
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<tr>
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</table>

### Notes
- Figures in the table represent the financial breakdown for each year from 2013-14 to 2020-21.
- Revenue and Expenditure are detailed for Ghaziabad Nagar Nigam for the specified years.
- % Change indicates the percentage change from the previous year.

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**Appendix 2-5**

**Details of Revenue & Expenditure**

**Ghaziabad Nagar Nigam**

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**Appendix 2-5**

**Details of Revenue & Expenditure**

**Ghaziabad Nagar Nigam**

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Asian Development Bank
National Capital Region Planning Board

Capacity Development of the National Capital Region Planning Board Package 2 Component B TA No. 7055-IND

Volume V-D3: Initial Environmental Examination DPR for Multi-level Parking Facility in Ghaziabad

WilburSmith ASSOCIATES
July 2010
Capacity Development of the National Capital Region Planning Board (NCRPB) – Component B (TA No. 7055-IND)

FINAL REPORT
Volume V-D3: DPR for Construction of Multi-Level Parking Facility in Ghaziabad
Initial Environmental Examination Report

July 2010
Abbreviations

ADB : Asian Development Bank
BOD : Biochemical Oxygen Demand
CC : Construction Contractor
CGWA : Central Ground Water Authority
CGWB : Central Ground Water Board
CMA : Counter Magnet Areas
COD : Chemical Oxygen Demand
DFR : Draft Final Report
DPR : Detailed Project Report
EAC : Environmental Appraisal Committee
EC : Environmental Clearance
EIA : Environmental Impact Assessment
EMP : Environmental Management Plan
ESMC : Environmental & Social Management Cell of NCRPB
ESMS : Environmental & Social Management System of NCRPB
GDA : Ghaziabad Development Authority
GNN : Ghaziabad Nagar Nigam
GoH : Government of Haryana
GoI : Government of India
GoUP : Government of Uttar Pradesh
IA : Implementing Agencies
IEE : Initial Environmental Examination
IPT : Intermediate Public Transport
IRC : Indian Road Congress
Km : Kilometer
KMPH : Kilometer per Hour
LA : Land Acquisition
LCV : Light Commercial Vehicle
LPCD : Liters per capita per day
MLD : Million Liters per Day
MLP : Multi-Level Parking Facility
MoRTH : Ministry of Road Transport and Highways
MoEF : Ministry of Environment & Forests
NCR : National Capital Region
NCRPB : National Capital Region Planning Board
NCT : National Capital Territory
NGO : Non-governmental Organizations
NH : National Highway
O & M : Operation and Maintenance
PCU : Passenger Car Unit
ROW : Right of Way
RCC : Reinforced Cement Concrete
SH : State Highway
SPM : Suspected Particulate Matter
TA : Technical Assistance
UP : Uttar Pradesh
UPJN : Uttar Pradesh Jal Nigam
UPSRTC : Uttar Pradesh State Road Transport Corporation
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1. INTRODUCTION

A. Background

1. Ghaziabad City is located in the western part of Uttar Pradesh State sharing the borders with the National Capital Territory Delhi. It is the district headquarters of Ghaziabad District. Owing to its location close to Delhi, and with good connectivity, it is one of the important and fast developing city in the State of Uttar Pradesh and as well as in the National Capital Region. City is well connected with important cities of the state and the country; three National Highways (NH 58, NH 91 and NH 24 - Delhi-Lucknow-Muradabad Road) pass through the City connecting it will Delhi, Meerut, Lucknow, Sikandrabad, Kolkata etc. Besides, it is well connected with its hinterland and surrounding towns by regional and local road network. It is also well connected with railways. Location of Ghaziabad is depicted in Figure 1-1.

2. The rapid development of city has also put its infrastructure on tremendous pressure. Due to rapid increase in vehicles and traffic, the road infrastructure is severely affected. The unprecedented growth of personalized vehicles and the unplanned road infrastructure have made the provision for parking an important aspect of transportation planning. The area surrounding the old Bus Stand at Navyug Chowk is a major centre and is the CBD of Ghaziabad. This centre is busy with various activities; a number of commercial establishments, markets, government offices and the bus stand are situated here. Since most of these places are frequented by public and busy with floating population, the demand for parking has increased. The growth of personal transport vehicles is another main reason for increasing parking demand. Since the existing bus stand is proposed to be shifted to a new location on Loni Road as per the Ghaziabad Master Plan 2021, this site is proposed for development of multi-level parking facility to cater to the parking demand.

3. The subproject of construction of Multi-Level Parking Facility at Old Bus Stand location is selected for detailed study and preparation of a model Detailed Project Report under this ADB TA Component B. NCR Planning Board, a statutory body of Ministry of Urban Development, Government of India, is a likely source of funding for the subproject in Ghaziabad.

4. This Initial Environmental Examination (IEE) Report is prepared in accordance with NCRPB Environmental and Social Management System (ESMS) and Policy for project funding.
2. POLICY & LEGAL FRAMEWORK

A. Extent of IEE Study

5. The subproject implementation shall comply with the policies of Government of India (GoI), Government of Uttar Pradesh (GoUP) and procedures/policies of NCRPB. Government regulations and the NCRPB policy require that impacts of the development projects have to be identified at the beginning and mitigation measures be incorporated in the project to reduce those impacts to acceptable levels. This is generally done through the process of environmental impact assessment.

B. Government Law and Policies

6. The GoI EIA Notification of 2006 (replacing the EIA Notification of 1994), sets out the requirement for Environmental Assessment in India. This states that Environmental Clearance (EC) is required for specified activities/projects, and this must be obtained before any construction work or land preparation (except land acquisition) may commence. Projects are categorized as A or B depending on the scale of the project and the nature of its impacts.

7. Category A projects require EC from the national Ministry of Environment and Forests (MoEF). The proponent is required to provide preliminary details of the project in the prescribed manner with all requisite details, after which an Expert Appraisal Committee (EAC) of the MoEF prepares comprehensive Terms of Reference (ToR) for the EIA study. On completion of the study and review of the report by the EAC, MoEF considers the recommendation of the EAC and provides the EC if appropriate.

8. Category B projects require environmental clearance from the State Environment Impact Assessment Authority (SEIAA). The State level EAC categorizes the project as either B1 (requiring EIA study) or B2 (no EIA study), and prepares ToR for B1 projects within 60 days. On completion of the study and review of the report by the EAC, the SEIAA issues the EC based on the EAC recommendation. The Notification also provides that any project or activity classified as category B will be treated as category A if it is located in whole or in part within 10 km from the boundary of protected areas, notified areas or inter-state or international boundaries.

9. With the total built up area of over 20,000 sq. m, this sub project falls under the ambit of the EIA Notification under Category B project. This requires environmental clearance from SEIAA of Uttar Pradesh State.
C. **Environmental and Social Management System of NCRPB**

10. Recognizing the importance of environmental and social issues that can arise in infrastructure projects, NCRPB has formulated an Environmental and Social Management Systems (ESMS) in line with Government and other multilateral agencies like ADB safeguard requirements for Financial Intermediaries (FIs). The ESMS provides an overall management system to NCRPB to identify, assess, and mitigate environmental and social issues that are likely to arise in projects funded by NCRPB. The ESMS outlines the policies, methods of assessments and procedures that will enable NCRPB to ensure that a project that it funds is developed in accordance with ESMS and is adequately protected from associated risks. Implementing Agencies (IAs) will have to comply with the ESMS and Policy.

1. **Environmental Policy**

11. **Policy Statement.** “National Capital Regional Planning Board (NCRPB) will continually strive to ensure and enhance effective environmental management practices in all its operations”. This is aimed to achieve through:

- Minimizing negative environmental (including health & safety) impacts in its operations and risks to the environment (particularly eco-sensitive areas and culturally important areas) and people who may be affected through formulating and implementing commensurate plans
- Ensuring that environmental safeguards - defined as requirements of applicable Indian environmental legislation and multilateral / bilateral funding agencies - are being adequately integrated by the project proponent / IA in the planning, design, construction prior to its financing and in its implementation during the operational phase.
- Ensuring that compliance to all applicable national and local environmental legislation.
- Encouraging that public and stakeholder consultation be carried out by the project proponent / IA and disclosing the required information in all stages of the project cycle.
- Integrating environmental risk into its overall internal risk management analysis.
- Including environmental management considerations in all aspects of operations and interactions with the project proponent / IAs in all stages of the project cycle.

12. This policy statement emphasizes NCRPB's sensitivity, concern and commitment to environmental safeguards. NCRPB will strive to ensure that the projects that it supports meets government policies and as well as of the bilateral/multilateral agencies such as ADB.
2. **Environmental Assessment Requirements**

13. The nature of the assessment required for a project depends on the significance of its likely environmental impacts, which are related to the type and location of the project, the sensitivity, scale, nature and magnitude of its potential impacts, and the availability of cost-effective mitigation measures. According to NCRPB ESMS, the projects are screened for their expected environmental impacts and are assigned to one of the following categories: E1, E2 or E3.

### Table 2-1: Environmental Category

<table>
<thead>
<tr>
<th>Environmental Scenario</th>
<th>NCRPB’s Categorization</th>
<th>MOEF's Categorization</th>
<th>ADB Categorization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant impacts or in eco-sensitive area</td>
<td>E1</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Limited impacts</td>
<td>E2</td>
<td>B1 or B2 or No Category</td>
<td>B</td>
</tr>
<tr>
<td>No impacts</td>
<td>E3</td>
<td>No Category</td>
<td>C</td>
</tr>
</tbody>
</table>

(i) **Significant impacts or in eco-sensitive areas (Category E1):** If the project has significant adverse environmental impacts that are irreversible, diverse, or unprecedented, then it is regarded to have environmental scenario. These impacts may affect an area larger than the sites or facilities subject to physical works. These impacts will be considered significant if these are in eco-sensitive areas.

(ii) **Limited environmental impacts (Category E2):** If the project has impacts that are site-specific, few if any of them are irreversible, and in most cases mitigation measures can be designed.

(iii) **No environmental impacts (Category E3):** If the project is likely to have minimal or no adverse environmental impacts, then it is regarded to have this environmental scenario.

14. The proposed subproject of Construction of Multi-level Parking Facility in Ghaziabad is unlikely to have significant impacts. The project site is also not located or near any eco-sensitive area. The subproject is however likely to have typical impacts associated with the construction activity in urban areas and therefore classified as Category E2.

15. According to ESMS, E2 projects require carrying out Initial Environmental Examination (IEE) and preparation of IEE Report. This IEE report is prepared accordingly.
3. DESCRIPTION OF PROJECT

A. Project Need

16. The unprecedented growth of personalized vehicles and the unplanned road infrastructure have made the provision for parking an important aspect of transportation planning. As part of the traffic study conducted in this ADB TA, a parking study was conducted at important locations in Ghaziabad. The area surrounding the old Bus Stand at Navyug Chowk is a major centre and is the CBD of Ghaziabad. This centre is busy with various activities; a number of commercial establishments, markets, government offices (Ghaziabad Nagar Nigam and Ghaziabad Development Authority) and the bus stand are situated here. Since most of these places are frequented by public and busy with floating population, the demand for parking has increased. The growth of personal transport vehicles is another main reason for increasing parking demand.

17. On-street parking is observed on all the roads surrounding Old Bus Stand and Navyug Market. Many cars and two wheelers are seen parked on either side of the roads. Both angular as well as parallel type of parking was noticed on almost all the stretches of the roads. This has reduced the capacity of the carriageway and endangering pedestrians and motorists alike. The frontage of almost all the roads in this area has been converted into commercial land use without taking into account the demand for parking of the vehicles. There is no planned parking space available.

18. Recognizing the importance of decongesting this area, Ghaziabad Master Plan -2021, has identified and earmarked a site along NH 24 for shifting the existing Bus Stand and constructing a new Bus Terminal. In view of this, the GDA is considering the existing Bus Stand site in the CBD to develop a multi-level parking facility. The project preparation for the same is taken up for model DPR.

19. Subsequently, detailed parking surveys were conducted in the area and the present and future demand has been estimated (Table 3-1). These values are used as base to develop a multi-level parking facility on the bus stand site.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Year</th>
<th>Demand (No. of Vehicles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2010</td>
<td>650</td>
</tr>
<tr>
<td>2</td>
<td>2020</td>
<td>723</td>
</tr>
<tr>
<td>3</td>
<td>2025</td>
<td>805</td>
</tr>
<tr>
<td>4</td>
<td>2039</td>
<td>896</td>
</tr>
</tbody>
</table>
B. Project Description

20. The existing Bus Stand, the site for proposed multi-level parking facility, is located next to GDA Office and the near junction of Dr Ambedkar Road and NH-24 (Hapur Road). The total area of the site is 10,040 sq m and is located in a busy commercial and institutional area.

21. Considering the demand, the multi-level parking facility is designed to accommodate parking of 2-wheelers and cars. As shown in the following Table, the proposed facility will have space for parking 777 cars and 330 two-wheelers. In addition to parking facility, commercial space will also be developed within the building to generate additional revenue and make it attractive for private sector participation. The facility will be developed in 4 levels, with the upper most level open to sky. Ground floor (lower most level) is reserved for developing commercial area and parking facility for two wheelers. The upper floors will be utilized for car parking.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site area</td>
<td>Sq. m</td>
<td>10,040</td>
</tr>
<tr>
<td>2</td>
<td>Area (Ground Floor)</td>
<td>Sq. m</td>
<td>8,323</td>
</tr>
<tr>
<td>3</td>
<td>Area (1st, 2nd and 3rd Floors)</td>
<td>Sq. m</td>
<td>25,833</td>
</tr>
<tr>
<td>3</td>
<td>Commercial/Retail (Ground Floor)</td>
<td>Sq. m</td>
<td>5,000</td>
</tr>
<tr>
<td>4</td>
<td>Parking (Ground Floor) – 2-wheelers</td>
<td>No. s</td>
<td>117</td>
</tr>
<tr>
<td>5</td>
<td>Parking (1st floor) – 2-wheelers</td>
<td>No. s</td>
<td>213</td>
</tr>
<tr>
<td>6</td>
<td>Parking (1st, 2nd and 3rd Floors) – Cars</td>
<td>No. s</td>
<td>777</td>
</tr>
</tbody>
</table>

22. Map of the proposed site is shown in Figure 3-1. Plan of the proposed building is shown in Figure 3-1 and Figure 3-2.
Figure 3-1: Proposed Site for Multi-level Parking Facility
Figure 3-2: Ground Floor Plan of the Proposed Multilevel Parking

GROUND FLOOR PLAN
**Figure 3-3:** Typical Floor Plan of the Proposed Multilevel Parking Facility
4. DESCRIPTION OF ENVIRONMENT

A. Physical Resources

1. Location

23. Ghaziabad City is located in the western part of Uttar Pradesh State sharing the borders with the National Capital Territory Delhi. It is the district headquarter of Ghaziabad District. Owing to its location close to Delhi, and with good connectivity, it is one of the important and fast developing city in the State of Uttar Pradesh and as well as in the National Capital Region. Geographically, Ghaziabad is situated at 28° 40’ N latitude and 77° 25’ E Longitude. Ghaziabad is situated at about 20 Km east of Delhi, and 432 km west of the State Capital, Lucknow.

24. It is well connected with important cities of the state and the country; three National Highways (NH 58, NH 91 and NH 24 - Delhi-Lucknow-Muradabad Road) pass through the City connecting it will Delhi, Meerut, Lucknow, Sikandarabad, Kolkata etc. Besides, it is well connected with its hinterland and surrounding towns by regional and local road network. The Main railway line and the two branches of northern railway (Meerut Branch & Moradabad Branch) pass through the City. It is an important railway junction in the Northern Railway. Base map of Ghaziabad is at Figure 4-1.

2. Topography, soil and geology

25. Originally established on the eastern side of River Hindon, present sprawling development of Ghaziabad can be observed on both sides of the River. Hindon River is an important tributary of Yamuna River of the Ganges River System. Flowing north-south, Hindon River passes through middle of the City and meets Yamuna about 35 km south of Ghaziabad. The topography of the City is almost plain and the general slope is from north to south.

26. Geologically, Ghaziabad forms a part of the Indo-Gangetic alluvium. Soil is characterized mainly by silty sand and loamy soils. Geotechnical investigations conducted at the proposed flyover site indicates that there is no hard rock till 25 m below ground level.

27. As per the seismic zoning map of India, Ghaziabad falls in sever intensity zone (Zone IV). However, there were no major earthquakes occurred in Ghaziabad till date.
3. Climate

28. Typical humid subtropical climate of north India prevails in Ghaziabad, with high variation between summer and winter temperatures and precipitation. There are three distinct seasons – first of which is the monsoon season - hot and humid season from mid-June to September. Second season, winter, is the cool and dry season from October to March. The third phase, summer, is characterized by hot and dry weather which prevails from April to mid-June.

29. Rains in the region are concentrated in the monsoon season. The region receives rainfall mainly under the influence of southwest monsoon from July to September. Over 75 percent of the total rainfall is received during the monsoon months and the remaining rainfall is received during December to February. The annual average rainfall is 732 mm. Dust and thunderstorms occur in summer season while fog occurs in the winter.

Table 4-1: Rainfall Pattern in Ghaziabad (2004-2008)

<table>
<thead>
<tr>
<th>Month</th>
<th>Normal</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>20.5</td>
<td>7.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>February</td>
<td>20.6</td>
<td>0</td>
<td>23.9</td>
<td>0</td>
<td>45</td>
<td>NA</td>
</tr>
<tr>
<td>March</td>
<td>17.4</td>
<td>0</td>
<td>19</td>
<td>NA</td>
<td>64</td>
<td>NA</td>
</tr>
<tr>
<td>April</td>
<td>5.8</td>
<td>30.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>May</td>
<td>12.8</td>
<td>75</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>June</td>
<td>43.8</td>
<td>20.6</td>
<td>80.5</td>
<td>34.2</td>
<td>64.1</td>
<td>16.4</td>
</tr>
<tr>
<td>July</td>
<td>216.5</td>
<td>36.8</td>
<td>185.7</td>
<td>250.5</td>
<td>84.1</td>
<td>124.4</td>
</tr>
<tr>
<td>August</td>
<td>234.5</td>
<td>520.6</td>
<td>57.9</td>
<td>20.4</td>
<td>99.8</td>
<td>58.1</td>
</tr>
<tr>
<td>September</td>
<td>129.2</td>
<td>50.4</td>
<td>284.2</td>
<td>114</td>
<td>4.7</td>
<td>8.7</td>
</tr>
<tr>
<td>October</td>
<td>34.1</td>
<td>12.6</td>
<td>0</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>November</td>
<td>4.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NA</td>
<td>2</td>
</tr>
<tr>
<td>December</td>
<td>6.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NA</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>745.6</td>
<td>754.2</td>
<td>651.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 4-2: Long-term Annual Rainfall Pattern of Ghaziabad (in millimeter)
30. Owing to its sub-tropical continental monsoon climate with hot summers and cold winters, Ghaziabad experiences large variations in temperature across the year. May and June experiences high temperatures and the lowest is recorded in the months of December and January. **Figure 4-3** depicts the monthly averages of minimum, mean and maximum temperature. Winds predominantly blows from north, north-west and west direction, followed by from east and south-east direction.

**Figure 4-3**: Average Monthly Temperature (in Degrees Centigrade)

4. **Air Quality**

31. Ambient Air Quality in Ghaziabad is monitored by Uttar Pradesh Pollution Control Board (UPPCB). Due to dry weather coupled with dusty roads, particulate matter is high while levels of oxides of sulphur and nitrogen are well within the National Ambient Air Quality Standards (NAAQS). According to UPPCB, air pollution status in Ghaziabad has been termed as “low”.

**Table 4-2**: Air Pollution Status in Ghaziabad (2008)

<table>
<thead>
<tr>
<th>Land use</th>
<th>Sulphur Dioxide (SO2)</th>
<th>Nitrogen Dioxide (NOx)</th>
<th>SPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>L</td>
<td>L</td>
<td>C</td>
</tr>
<tr>
<td>Industrial</td>
<td>L</td>
<td>L</td>
<td>H</td>
</tr>
</tbody>
</table>

C – Critical; L – Low; H – High (see below Table for values); NA: Data not available

**Table 4-3**: Air Pollution Classification based on Annual Mean Concentration Range (μg/m3)

<table>
<thead>
<tr>
<th>Air Pollution Status</th>
<th>Industrial Area</th>
<th>Residential Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SO2 &amp; NOX</td>
<td>SPM</td>
</tr>
<tr>
<td>Low ( L )</td>
<td>0 – 40</td>
<td>0 - 180</td>
</tr>
<tr>
<td>Moderate (M)</td>
<td>40 – 80</td>
<td>180 - 360</td>
</tr>
<tr>
<td>High (H)</td>
<td>80 – 120</td>
<td>360 - 540</td>
</tr>
<tr>
<td>Critical (C)</td>
<td>&gt;120</td>
<td>&gt;540</td>
</tr>
</tbody>
</table>

Source: UPPCB
Table 4-4: NAAQ Standard – Annual Average Concentration in μg/m³

<table>
<thead>
<tr>
<th>Land use</th>
<th>RSPM</th>
<th>SPM</th>
<th>SOx</th>
<th>NOx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>60</td>
<td>140</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Industrial</td>
<td>120</td>
<td>360</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>

Source: CPCB

5. Surface Water

32. Hindon River is an important tributary of Yamuna River of the Ganges River System. Hindon meets Yamuna about 35 km south of Ghaziabad. The confluence is located about 40 Km downstream of Okhla barrage. A short cut canal called the Hindon Cut joins River Yamuna at Okhla barrage from where the Agra canal takes off. The Hindon Cut thus serves to make the Hindon river water, including the supplemental discharge from the upper Ganga Canal, available for diversion to the Agra canal for irrigational use. The river stretch remains dry, except during rains. During winter and summer seasons, river flow is mainly limited to industrial effluents discharged from various industries located in Ghaziabad and as well as upstream areas.

33. Due to illegal entry of industrial and domestic wastewater, Hindon River water is polluted. As per the CPCB, the dissolved oxygen content in the river is low and BOD is presence in notable quantities. Illegal disposal of untreated/partially treated effluent from textile dying and printing industries located in Shahid Nagar and Janakpuri in the trans-Hindon area are said to be one of the main reasons for pollution of Hindon River stretch in Ghaziabad.

6. Groundwater

34. Due to its location in Gangetic Plains, the underlain aquifers have good groundwater potential. However, the rapid development and increase in demand for water has put tremendous stress on groundwater reserves, both in terms of quantity and as well as quality. The groundwater decline is at much rapid phase and considering this alarming situation the Central Ground Water Authority (CGWA) has notified the area under GMC limits for regulation and control of groundwater extraction. No groundwater extraction is allowed without prior permission of Central Ground Water Board (CGWB).

35. General groundwater quality in Ghaziabad is good except in certain industrial and residential pockets where there is concentration of nitrates, fluorides and heavy metals beyond permissible limits. Indiscriminate disposal of untreated industrial and domestic wastewater is said to be the main reason for pollution of groundwater.

B. Ecological Resources

36. There are no forests or any other environmental sensitive locations in or near project site. Ghaziabad City is an urban area surrounded by land that was converted for agricultural use many years ago. There is no remaining natural habitat in the city, and the flora is limited to artificially planted trees and shrubs, and the fauna comprises domesticated animals plus
other species able to live close to man. Tree cover along few main corridors is considerable; main tree species include Keekar (*Acacia karoo*); Neem (*Azadirachta indica*); Peepal (*Ficus religiosa*); Honge (*Pongamia Pinnata*); and eucalyptus.

**C. Economic Development**

1. **Land Use**

37. Owing to its location, adjacent to the National Capital, Delhi, over the years, Ghaziabad City has experienced a very rapid development and urbanization. Originally established on the eastern side of River Hindon, present sprawling development of Ghaziabad can be observed on both sides of the River. The City is almost merged with Delhi - City’s development stretching towards Delhi on west side and vis-à-vis Delhi expanding to east towards Ghaziabad.

38. Ghaziabad Master Plan 2001 was formulated for an area of 100.4 sq. km, of which by 2001, about 84.8 sq. km was developed. As depicted in the following figure, the existing land use of Ghaziabad development area (84.8 sq km) shows that 60 percent of the land is under residential use followed by industrial areas. There are no agricultural areas within this development area. The gross density of the population is 130 persons per hectare. Anticipating a big growth in the near future, the Ghaziabad Master Plan 2021 has been formulated to an area of 155.54 sq. km.

![Figure 4-4: Existing Land Use](image)

2. **Industry & Agriculture**

39. The City of Ghaziabad is known for medium and large scale industries. During 1970-80 decade a number of prestigious and large scale industries are established along Meerut Road, Bulandhshahar Road, Link Road, Sahibabad and Loni Road in Ghaziabad City. In addition to UPSIDC developed industrial areas, there are a number of industries located in
Mohan Nagar and Mohan Industrial Area. Ghaziabad houses a variety of industries including distilleries, chemical, engineering, steel, and textile and dying units etc.

40. Industrial sector is a major employment generator in Ghaziabad. Industrial development in Ghaziabad however declined in the decade of 1991-2001 and no new industries were established during that decade.

41. Within the city limits, there are no agricultural areas left. Almost all of the land is converted for residential or for other development.

3. Infrastructure

42. Water Supply. Two agencies are involved in provision of water supply service in Ghaziabad; while the state line agency Uttar Pradesh Jal Nigam (UPJN) is responsible for development of new infrastructure and all capital works, the Ghaziabad Nagar Nigam (GNN) is responsible for its day-to-day operation and maintenance. Water supply system in Ghaziabad is groundwater based. Water is extracted from 186 bore wells and a total of 160 MLD of water is supplied everyday at a rate of 145 LPCD (gross supply). In industrial areas, water is supplied by UPSIDC.

43. Sewerage System. UPJN carries out all new and capital works while the GNN operates and maintains the sewerage system in the City. Around 70 – 75 percent of the city population is covered with underground sewerage system. At present an estimated 128 MLD of sewage is generated in the City. There are 17 sewage pumping stations in the City to pump the sewage to two sewage treatment plant for treatment and further disposal. The total treatment capacity available is 126 MLD however present usage is only about 71 percent. Industrial waste water treatment and disposal is managed by individual industries and UPSIDC.

44. Solid Waste Management. Municipal solid waste management is the responsibility of Ghaziabad Nagar Nigam. At present about 750 tons of solid waste is generated daily in Ghaziabad at a rate of 550 gm per capita per day. City is divided into five zones for better management of solid waste collection and disposal. There is no door-to-door collection system in the City. The solid waste is collected through bins located at various places in the neighborhood. Sanitary workers collect waste from bins and transport to disposal site at Sai Upvan on the banks of Hindon River. There is no proper disposal facility; the waste is disposed by crude open dumping method.

4. Transportation

45. Ghaziabad City is well connected with important cities of the state and the country; three National Highways (NH 58, NH 91 and NH 24 - Delhi-Lucknow-Muradabad Road) pass through the City connecting it with Delhi, Meerut, Lucknow, Sikandrabad, Kolkata etc. Besides, it is well connected with its hinterland and surrounding towns by regional and local road network. The Main railway line and the two branches of northern railway (Meerut Branch & Moradabad Branch) pass through the City. It is an important railway
junction in the Northern Railway.

46. It is 20 km east of Delhi and 46 km southwest of Meerut. Other roads lead northwest to Loni and Baghpat and east to Hapur and Garhmukteshwar. Buses run at frequent intervals to Delhi, Meerut, Aligarh, Bulandshahar, Moradabad, Lucknow and other cities. The City acts as the main entrance of Uttar Pradesh and is also called the “Gateway of Uttar Pradesh”.

47. Internal road network within the town is well developed. Most of the roads however are congested with traffic, pedestrians and activities such as parking of trucks/other vehicles and presence of informal business activities (squatters and vendors) within the ROW.

48. According to available 2003 data, over 70 percent of the vehicles in the town are two wheelers followed by cars. Internal travel in the city is mainly through public transport (buses and mini buses) and intermediate public transport system consisting of Auto Rickshaws.

D. Social and Cultural Resources

1. Demography

49. According to the national census the population of Ghaziabad was 968,521 in 2001, increased from 511,759 in 1991, recording an unprecedented growth rate of 89.3 percent over the decade. The population of overall GDA area in 2001 was 1,327,330, which was increased from 732,957 in 1991, with a growth rate of 81 percent.

Table 4-5: Population Growth of Ghaziabad City

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
<th>Decadal Growth Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>128,036</td>
<td></td>
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<tr>
<td>1981</td>
<td>287,170</td>
<td>124.3%</td>
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<tr>
<td>1991</td>
<td>511,759</td>
<td>78.2%</td>
</tr>
<tr>
<td>2001</td>
<td>968,521</td>
<td>89.3%</td>
</tr>
</tbody>
</table>

Source: Census of India

50. Overall literacy is 80 percent, reported at 87 percent for males and 72 percent for females, which is considerably better than literacy in the state, which is 60.4 percent overall, and 75.7 percent for males and 44.0 percent for females. Sex ratio is however significantly below the natural 1:1 ratio, being 858 females per 1000 males, lower than both the state and national averages (879 and 929 respectively).

51. According to the census 2001, workforce participation rate (WPR) in Ghaziabad was 28 percent. As shown in the following figure, nearly 95 percent of the total workforce was engaged in service sector (formal, informal, trade, commerce and industrial and other service sectors). Contribution of other sectors is very minimal – about 3.1 percent are
engaged in household industries the remaining 2.3 percent of population are engaged in primary sector activities.

**Figure 4-5: Occupational Structure**

<table>
<thead>
<tr>
<th>Occupational Group</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Cultivators</td>
<td>1.7%</td>
</tr>
<tr>
<td>Agri. Labourers</td>
<td>0.6%</td>
</tr>
<tr>
<td>HH Industry</td>
<td>3.1%</td>
</tr>
<tr>
<td>Others (service)</td>
<td>94.7%</td>
</tr>
</tbody>
</table>

52. Majority of people in Ghaziabad are Hindus and the remainder are mainly Muslims, Sikhs, Jains, Christians and Bhudhists. Hindi is the main language of the area. Around 16% of the population belongs to scheduled castes (SC) category. Population belonging to Scheduled Tribe (ST) category in Ghaziabad are negligible and are part of the mainstream population.

2. **Health & Education Facilities**

53. Ghaziabad is a main centre for educational and health facilities in the region. There are a number of schools, colleges, professional education institutions, general and special health care facilities in the City, serving a large number of population from the City and the other near and far areas.

3. **History, Culture and Tourism**

54. The City was founded in 1740 by the Emperor, Ghazi-ud-din, who called it Ghaziuddin Nagar after himself and built a spacious structure consisting of 120 rooms of masonry with pointed arches. Only the gate, a few portions of the boundary wall and a massive pillar about fourteen feet high remain now, the precincts now being inhabited. His mausoleum still stands in the city but is in a bad state. Ghaziabad played active role in the Indian freedom struggle, the revolt of 1857. An encounter took place between the freedom fighters and British force in Ghaziabad during that time. This was regarded as the first war of independence and it brought Ghaziabad much of its glory. On 14th November 1976, Ghaziabad became a separate district. Then on, Ghaziabad has developed in all fronts and it is now one of the biggest and fast developing centers in NCR.

55. There are no notified or protected monuments or sites of archeological and historical
importance in the City. The tourism potential of is minimal.

E. Profile of Proposed Flyover Site

56. The site is located in the central location of the city (Figure 4-6). Site is bounded by roads on all sides and there are no residential or sensitive areas in the vicinity. Ghaziabad Development Authority (GDA) office is located adjacent to the site. This is predominantly a commercial and institutional area. The topography of the site is plain. There are no water bodies/streams in the vicinity. The soil is characterized by silty sand and clay. Groundwater depth is 25 m below ground level.

57. A bus stand is presently functioning at the site. The site consists of a building housing its UPSDRTC office and some commercial establishments. In addition there are temporary structures, a water tank, and few open covered sheds with seating arrangement, and toilet and water facilities provided for commuting bus passengers. Except, these, the site has no structure, buses are parked on open site. Bus stand is protected by a compound wall all around. There are three matured Neem trees within the site.
Photographs of the Site:
5. ENVIRONMENTAL IMPACTS & MITIGATION MEASURES

A. Overview

58. As a general practice, an IEE should evaluate impacts due to the location, design, construction and operation of the project. Construction and operation are the two activities in which the project interacts physically with the environment, so they are the two activities during which the environmental impacts occur. In assessing the effects of these processes therefore, all potential impacts of the project should be identified, and mitigation is devised for any negative impacts. Following sections evaluate the impacts of the proposed Multi-level Parking Facility in Ghaziabad.

B. Construction Impacts

59. This subproject will involve construction of the following elements at the old bus stand at Navyug Chowk in Ghaziabad:

- Construction of a building with 4 levels including the ground level with a ramp facility to approach different levels with adequate fire protection and lighting facilities
- Provision of basic facilities such as water, sewer, to cater for operation of commercial establishments in ground floor

<table>
<thead>
<tr>
<th>Table 5-1: Construction Method &amp; Materials of Flyover</th>
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<tbody>
<tr>
<td><strong>Element</strong></td>
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<tr>
<td>Multi-level Parking Facility</td>
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</table>
60. Total quantity of earthwork excavation has been estimated as 7,792 m$^3$. In addition, waste rubble will be generated from dismantling of existing structures on the site. All reusable/recyclable material like wooden, steel, glass, roof sheets etc will be retrieved. The waste material will mostly be cement concrete and brick rubble.

61. Ready mix concrete, procured and brought to site on truck from nearest plant, will be utilized in construction. The other construction material that is required in bulk will be sand, aggregate, cement, cement concrete blocks/clay bricks, etc. Construction materials like sand and aggregate will be sourced from quarries approved by the respective Mines & Geology Departments. Yamuna Nagar in Haryana about 200 km away is a known source for stone aggregates, Ghaghar, 180 km away and Haridwar, 160 km away are sources for sand.

1. Impacts on Physical Resources

62. Construction will involve dismantling of existing structures, excavation for foundations, and disposal of the waste material which could have physical impacts.

63. In earthwork most of the impacts are related to disposal of surplus soil. Therefore the rubble and surplus soil needs to be disposed without any major impacts. The contractor shall therefore implement the following measures:

- Salvage the recyclable and reusable material as much as possible and reduce the quantity that needs to be disposed of
- Estimates the quantity of rubble and prepare a rubble management plan
- Dispose rubble only in solid waste dumping sites or filling up abandoned quarries or as recommended by UPPCB
- Utilize excavated soil in construction – to raise the ground-level or road construction
- The waste soil can be utilized for raising the ground-level of the site on Loni Road, which is proposed for development of new Bus Terminal.

64. Dismantling and excavation activities could cause physical impacts, including creation of the dust during dry weather and silt-laden runoff during rainfall, both of which would affect people who live and work near the site and reduce the quality of adjacent land. Earthwork will not mostly be conducted in rainy season, so this will avoid any problems from runoff. In Ghaziabad, dry weather prevails in most part of the year, and therefore generation of dust may be significant. Since the site is located in a busy commercial and institutional area the impact will be significant. It will therefore be necessary to prevent dust, which could be generated in quite large quantities. The Contractor should therefore:

- Wrap the site/construction area with geo-textile fabric or install dust barriers to the necessary height
- Apply water and maintain soils in a visible damp or crusted condition for temporary stabilization
• Apply water prior to leveling or any other earth moving activity to keep the soil moist throughout the process;
• Use tarpaulins to cover loose material/soil that is transported to and from the site by truck
• Control dust generation while unloading the loose material (particularly aggregate) at the site by sprinkling water and unloading inside the barricaded area
• Clean wheels and undercarriage of haul trucks prior to leaving construction site
• Stabilize surface soils where loaders, support equipment and vehicles will operate by using water and maintain surface soils in a stabilized condition where loaders, support equipment and vehicles will operate
• Don't allow access in the work area except workers to limit soil disturbance and prevent access by fencing

65. As the shallow excavations (maximum depth 3.25 m) will be made for foundations, there is no possibility of groundwater collecting in voids. The groundwater table depth at the site is about 25 m below ground level.

2. Ecological Resources

66. There are no protected areas in or around the site and no known areas of ecological interest. There are three trees in the site, which need to be cut off.

67. Necessary approvals from competent authority (Forest Department/Ghaziabad Nagar Nigam) shall be obtained and the guidelines for compensatory measures, if any of the competent authority, must be adhered to. In any case, as a compensatory measure, three trees will be planted and maintained for each tree felled.

3. Economic Development

68. The proposed site (existing bus stand) belongs to Uttar Pradesh State Road Transport Corporation (UPSRTC), a state-government owned autonomous corporation. It is proposed to shift the existing bus stand to a newly identified site as per the Ghaziabad Master Plan. The existing bus stand site will be transferred to Ghaziabad Development Authority for development and maintenance of proposed parking facility. This project therefore does not involve any private land acquisition.

69. Within in the bus stand premises, seven shops of different functional types and a bi-cycle stand is located. Those shops and the bi-cycle stand were provided space by UPSRTC on monthly lease rent. The proposed sub-project will directly impacted upon the livelihood of those 7 affected persons. NCRPB Environmental and Social Management System (ESMS) and Policy provides that the owners and tenants of these businesses do not suffer economically as a result of the project, and a Resettlement Plan have been prepared to assess the nature and extent of the losses and the compensation that is needed.
70. The traffic on the surrounding roads, which are already congested by vehicles and pedestrians, will be increased further due to movement of construction vehicles transporting material to the site. Following measures shall be followed by the Contractor:

- Plan work to avoid peak traffic hours
- Plan routes to avoid narrow streets, congested roads, etc

4. Social and Cultural Resources

71. There are no historical or cultural heritage sites in Ghaziabad in general or at the project site in particular. Therefore there are no likely impacts.

72. The site is located in a central area of the city, with large commercial and institutional areas. Action should be taken to minimize nuisance and disturbance due to construction work as far as possible. This will require:

- Consultation with the local community to inform them of the nature, duration and likely effects of the construction work, and the mitigation measures in place
- Implementing measures to reduce dust generation (as stated above)
- Implementing measures to control noise:
  - During construction work ambient noise level should not exceed more than 65 dB(A).
  - Do not cut materials (like floor tiles) without proper dust control/noise control facility
  - Proper planning of work programme so that any particularly noisy or otherwise invasive activities can be scheduled to avoid sensitive times;
- Utilising modern vehicles and machinery with the requisite adaptations to limit noise and exhaust emissions, and ensuring that these are maintained to manufacturers’ specifications at all times.

73. There is invariably a safety risk when substantial construction such as this is conducted in an urban area, and precautions will thus be needed to ensure the safety of both workers and citizens. This should include such measures as:

- Following standard, safe and quality construction practices;
- Excluding the public from the site – enclosing/barricading the construction area; providing warning boards and sign boards and posting of security guards throughout the day and night
- Ensuring that all workers are provided with and use appropriate Personal Protective Equipment (helmet, hand gloves, boots, masks, safety hoists when working at height, etc);
- Barricade the entire area that may come under influence in case of accidents – this may particularly critical if heavy duty cranes are used;
- Follow standard practices of safety checks as prescribed before use of equipments
such as cranes, hoists, etc.

- Provide on-site Health and Safety Training for all site personnel;
- Report accidents to the authorities promptly, and maintain records

74. There could be some short-term socio-economic benefits from the construction work if local people gain employment in the workforce. To ensure that these benefits are directed to local people, the Contractor should be required to employ as much of his labour force as possible from the local communities. Drawing of majority of workforce from local communities will avoid problems that can occur if workers are imported, including social conflicts and issues of health and sanitation due to labour camps. If temporary labour camps are to be provided; Contractor should ensure that they are maintained well with proper water supply and sanitation facilities.

C. Operation Stage Impacts

75. The parking facility would operate without the need for major maintenance or repair, therefore there are no major impacts envisaged. During operation, the impacts are mainly due to resource consumption (water and electricity), generation of wastewater (from toilet and bath facilities to cater to the commercial space provided in the facility), health & safety hazard (fire and other accidents) and noise generation (from moving vehicles in the facility at higher elevation).

76. Water consumption will be very minimal and limited to commercial space requirements. An individual water connection of commercial category will be taken from Ghaziabad Nagar Nigam. This additional demand generated by the proposed parking facility unlikely to have any effect on the existing water supply infrastructure or consumption pattern. Similarly, the domestic wastewater that is generated from toilets and baths will be disposed into the nearest sewer of GNN for treatment and further disposal. The contribution of this sewage to the total sewage generation of the city (about 128 MLD) is negligible. Nevertheless, at present, the sewage treatment plants are underutilized at 71 percent and therefore the additional sewage generation will not have any impact on the existing facilities.

77. Electricity consumption will be limited by designing environmental friendly building that requires less power.

78. The facility will be designed as per the local guidelines and meeting approved fire and hazard safety norms. Exit facilities shall be designed so as to enable evacuation from the facility in not more than 2.5 minutes. Fire escape routes shall be enclosed by fire resistant construction. The Developer will design, erect, test, and commission the entire Fire Protection System (FPS) as per the requirements of National Building Code of India (NBC). Fire Alarm System shall be complete with detectors, manual call points, fire alarm panels, battery, etc and shall be in accordance with the National Building Code. It is the responsibility of the Developer to get the building and installed Fire Protection System inspected and approved by the local Fire Service Officer, or other Government and /or Local Authorities.
79. Generation of noise from vehicles parking at higher level may have impacts on surrounding buildings. This impact however is considered minimal as there are no sensitive land uses in the immediate vicinity. The facility surrounded by roads on three sides.

80. There could be a positive impact as it is proposed to develop a rainwater harvesting system for the building.

81. To sum up the above, the following measures being included in the design and development of the proposed multi-level parking facility to minimize the operation stage impacts, if any.

- Water supply shall be sourced from water supply network of Ghaziabad Nagar Nigam; no bore wells or any groundwater extraction structures shall be built in the site;
- Develop rainwater harvesting system; minimize water usage
- Connect the wastewater outlet to nearest sewer of GNN
- Design the structure utilizing more natural light to reduce artificial lighting requirement;
- Minimize use of air conditioners in the commercial area by good orientation and appropriate construction materials
- Design the building in compliance with fire safety norm and provide Fire Protection System as per the requirements of National Building Code of India (NBC)

D. Location and Design Impacts

82. In many environmental assessments there are certain effects that, although they will occur during either the construction or operation stage, should be considered as impacts primarily of the location or design of the project, as they would not occur if an alternative location or design was chosen.

83. However in case of this subproject it is not considered that there are any impacts that are a result of the design or location. This is because:

- The project will be built on a government owned site and involves straightforward construction and low-maintenance operation, in an environment that is not especially sensitive, so it is unlikely that there will be major impacts;
- Most of the predicted impacts are associated with the construction process, and are produced because that process involves quite extensive construction work. However the routine nature of the impacts means that most can be easily mitigated, and
- The operation stage impact mostly related to fire risk and safety hazard, which are duly considered in the design and necessary measures and included in the project.
6. INSTITUTIONAL ARRANGEMENTS

A. Institutions Involved

84. Following agencies will be involved in implementing this Multilevel Parking Facility subproject at Navyug Chowk in Ghaziabad:

(i) **NCRPB**: National Capital Region Planning Board is the funding agency for the project.

(ii) **Implementing Agency (IA)**: Implementing Agency of the Project will be Ghaziabad Development Authority. IA will be responsible for the project implementation. Operation & maintenance will also be the responsibility of the IA.

(iii) **Design and Supervision Consultants**: Implementing Agency will be assisted by Design and Supervision Consultants (DSC) in tendering, and reviewing and revising designs during the construction, if required, and supervising the construction to ensure quality.

(iv) **Construction Contractors**: IA will appoint Construction Contractors (CC) to build the infrastructure elements.

85. Implementing the project according to and in compliance with the policies the funding agency, NCRPB, will be the responsibility of the Implementing Agency (IA). The Environmental and Social Management Cell (ESMC) of NCRPB will deal with environmental and social safeguard issues. ESMC would guide and monitor IA in complying with its ESMS and Policy.

86. **ESMC**. The ESMC will be housed inside the appraisal function of NCRPB and will have two distinct sub-functions, i.e. managing environmental safeguards and social safeguards. ESMC will be provided with one full-time staff - safeguards officer, who will look after the day-to-day activities related to the safeguard compliance. Safeguard Officer will be responsible for both environmental and social safeguard functions. Based on the necessity, the Safeguards Officer will source expertise from outside/external consultants on a case-to-case basis.

87. ESMC will review and approve IEE, oversee disclosure and consultations, and will monitor the implementation of environmental monitoring plan and environmental management plan where required. The Construction Contractor (CC) will implement mitigation measures in construction. IA or DSC will monitor the implementation of mitigation measures by the CC. ESMC will oversee the implementation of EMP. Implementation of mitigation and monitoring measures during the operation and maintenance (O&M) stage will be the responsibility of the implementing agency.
7. ENVIRONMENTAL MANAGEMENT PLAN

A. Environmental Management Plan

88. The proposed subproject and its components, the baseline environmental profile of the subproject area, the anticipated environmental impacts and appropriate mitigation measures to avoid/ reduce/ mitigate/compensate for the identified impacts have been discussed in detailed in earlier sections.

89. This Environmental Management Plan is developed for implementation listing the impacts, appropriate mitigation measures, delegating the responsibility of implementation to concerned agencies. This is shown in the following Table 7-1.

B. Environmental Monitoring Plan

90. A program of monitoring will be conducted to ensure that all the parties take the specified action to provide the required mitigation, to assess whether the action has adequately protected the environment, and to determine whether any additional measures may be necessary. Regular monitoring of implementation of mitigations measures by Construction Contractor will be conducted by the Implementing Agency. Periodic monitoring and overseeing of implementation of mitigation measures will be conducted by the ESMC of NCRPB. Monitoring during operation stage will be conducted by the Operating Agency.

91. Most of the mitigation measures are fairly standard methods of minimizing disturbance from building in urban areas (public inconvenience and traffic disruptions). Monitoring of such measures normally involves making observations in the course of site visits, although some require more formal checking of records and other aspects.

106. Table 7-2 shows the proposed Environmental Monitoring Plan (EMP) for this Project, which specifies the various monitoring activities to be conducted during different phases of the project. The EMP describes: (i) mitigation measures, (ii) location, (iii) measurement method, (iv) frequency of monitoring and (v) responsibility (for both mitigation and monitoring).
**Table 7-1: Environmental Management Plan**

<table>
<thead>
<tr>
<th>Potential Negative Impacts</th>
<th>Sig</th>
<th>Dur</th>
<th>Mitigation measures</th>
<th>Responsibility</th>
<th>Location</th>
<th>Cost</th>
</tr>
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<tbody>
<tr>
<td><strong>Preconstruction</strong></td>
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<tr>
<td>Involuntary resettlement</td>
<td>L</td>
<td>P</td>
<td>• Implement compensatory measures as recommended by the Resettlement Plan prepared in accordance with NCRPB ESMS</td>
<td>GDA</td>
<td>MLP Site</td>
<td>Part of RP Cost</td>
</tr>
<tr>
<td><strong>Description:</strong> Displacement of lease holders and squatters</td>
<td></td>
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<tr>
<td><strong>Construction</strong></td>
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<tr>
<td>Tree Cutting</td>
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<td>• Obtain necessary approvals from Forest Department/Ghaziabad Nagar Nigam for tree cutting</td>
<td>CC</td>
<td>MLP Site</td>
<td>Part of project cost</td>
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<tr>
<td><strong>Description:</strong> The proposed work requires cutting of 3 trees of domesticated local species</td>
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<tr>
<td>Dismantling and excavation will produce large quantity of waste soil, which needs proper disposal.</td>
<td>L</td>
<td>P</td>
<td>• Salvage the recyclable and reusable material as much as possible and reduce the quantity that needs to be disposed off</td>
<td>CC</td>
<td>MLP Site and Disposal Site</td>
<td>Part of standard contract</td>
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<td>Potential Negative Impacts</td>
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<td>Mitigation measures</td>
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</tr>
</tbody>
</table>
| Dust nuisance due to construction | M   | T   | • Wrap the site/construction area with geo-textile fabric or install dust barriers to the necessary height  
• Apply water and maintain soils in a visible damp or crusted condition for temporary stabilization  
• Apply water prior to leveling or any other earth moving activity to keep the soil moist throughout the process;  
• Use tarpaulins to cover loose material/soil that is transported to and from the site by truck  
• Control dust generation while unloading the loose material (particularly aggregate) at the site by sprinkling water and unloading inside the barricaded area  
• Clean wheels and undercarriage of haul trucks prior to leaving construction site  
• Stabilize surface soils where loaders, support equipment and vehicles will operate by using water and maintain surface soils in a stabilized condition where loaders, support equipment and vehicles will operate  
• Don't allow access in the work area except workers to limit soil disturbance and prevent access by fencing | CC  | MLP Site | Part of standard contract |
| Impacts due to improper mining for construction materials | L   | P   | • Ensure that construction materials (sand, aggregate and gravel) are obtained from quarries licensed by Geology and Mining Departments of respective state governments (Haryana/ Uttar Pradesh /Uttarakhand) | CC  | NA      | Part of standard contract |
| Increase in traffic due to trucks carrying construction material and heavy equipment | L   | T   | • Plan work to avoid peak traffic hours  
• Plan routes to avoid narrow streets, congested roads, and places of religious importance | CC  | NA      | Part of standard contract |
<table>
<thead>
<tr>
<th>Potential Negative Impacts</th>
<th>Sig</th>
<th>Dur</th>
<th>Mitigation measures</th>
<th>Responsibility</th>
<th>Location</th>
<th>Cost</th>
</tr>
</thead>
</table>
| Nuisance to noise, dust and other construction related activities to the general public and surrounding land use |     |     | • Consul with the local community to inform them of the nature, duration and likely effects of the construction work, and the mitigation measures in place  
• Implement measures to reduce dust generation (as stated)  
• Implementing measures to control noise:  
  o During construction work ambient noise level should not exceed more than 65 dB(A).  
  o Do not cut materials (like floor tiles) without proper dust control/noise control facility  
  o Proper planning of work programme so that any particularly noisy or otherwise invasive activities can be scheduled to avoid sensitive times;  
• Utilize modern vehicles and machinery with the requisite adaptations to limit noise and exhaust emissions, and ensuring that these are maintained to manufacturers’ specifications at all times. | CC            | MLP Site | Part of standard contract                                                                                     |
| Workers and public at risk from accidents on site                                          | M   | T   | • Following standard, safe and quality construction practices;  
• Excluding the public from the site – enclosing/barricading the construction area; providing warning boards and sign boards and posting of security guards throughout the day and night  
• Ensuring that all workers are provided with and use appropriate Personal Protective Equipment (helmet, hand gloves, boots, masks, safety hoists when working at height, etc);  
• Barricade the entire area that may come under                                                                                           | CC            | MLP Site | Part of standard contract                                                                                     |
<table>
<thead>
<tr>
<th>Potential Negative Impacts</th>
<th>Sig</th>
<th>Dur</th>
<th>Mitigation measures</th>
<th>Responsibility</th>
<th>Location</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influence in case of accidents – this may particularly critical if heavy duty cranes are used; Follow standard practices of safety checks as prescribed before use of equipments such as cranes, hoists, etc. Provide on-site Health and Safety Training for all site personnel; Report accidents to the authorities promptly, and maintain records</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Economic benefits for people employed in workforce</td>
<td>L</td>
<td>T</td>
<td>Ensure that most of the unskilled workforce is from local communities</td>
<td>CC</td>
<td>MLP Site</td>
<td>NA</td>
</tr>
<tr>
<td>Impact on water resources; water supply and sewerage infrastructure</td>
<td></td>
<td></td>
<td>Water supply shall be sourced from water supply network of Ghaziabad Nagar Nigam; no bore wells or any groundwater extraction structures shall be built in the site; Develop rainwater harvesting system; minimize water usage Connect the wastewater outlet to nearest sewer of GNN</td>
<td>GDA/developer</td>
<td>MLP Site</td>
<td></td>
</tr>
<tr>
<td>Power consumption</td>
<td></td>
<td></td>
<td>Design the structure utilizing more natural light to reduce artificial lighting requirement; Minimize use of air conditioners in the commercial area by good orientation and appropriate construction materials</td>
<td>GDA/developer</td>
<td>MLP Site</td>
<td></td>
</tr>
<tr>
<td>Safety &amp; fire risk</td>
<td></td>
<td></td>
<td>Design the building in compliance with fire safety norm and provide Fire Protection System as per the requirements of National Building Code of India (NBC)</td>
<td>GDA/developer</td>
<td>MLP Site</td>
<td></td>
</tr>
</tbody>
</table>
### Table 7-2: Environmental Monitoring Plan

<table>
<thead>
<tr>
<th>Mitigation measures</th>
<th>Responsible for Mitigation</th>
<th>Monitoring Method &amp; Parameters</th>
<th>Monitoring Frequency</th>
<th>Responsible for monitoring</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-Construction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Implement measures as recommended by RP</td>
<td>GDA</td>
<td>Records review; interview with APs</td>
<td>As needed</td>
<td>ESMC</td>
<td>Part of project management cost</td>
</tr>
</tbody>
</table>
| • Obtain necessary approvals for tree cutting  
• Plant and maintain three tree for each tree felled | CC | Records review; on-site observation | As needed | GDA | Part of construction supervision cost |
| • Water supply shall be sourced from local network  
• No bore wells or groundwater extraction structures  
• Develop rainwater harvesting system  
• Connect the wastewater outlet to nearest sewer of GNN  
• Design the structure to reduce power consumption  
• Design the building in compliance with fire safety norms | GDA | Design review and site observations | As needed | ESMC | Part of project management cost |
| **Construction** |                            |                               |                      |                             |                               |
| • Salvage the recyclable material as much as possible  
• Prepare a rubble management plan  
• Dispose rubble only in solid waste dumping sites or filling up abandoned quarries  
• Utilize excavated soil in construction  
• Wrap the site/construction area with geo-textile fabric or install dust barriers to the necessary height  
• Apply water and maintain soils in a visible damp  
• Apply water prior to leveling or any earth moving activity  
• Use tarpaulins to cover loose material/soil in transport  
• Control dust generation in unloading the loose material  
• Clean wheels and undercarriage of haul trucks  
• Stabilize surface soils in work place | CC | Observations on-site/off-site; CC records | Weekly | GDA | Part of construction supervision cost |
<table>
<thead>
<tr>
<th>Mitigation measures</th>
<th>Responsible for Mitigation</th>
<th>Monitoring Method &amp; Parameters</th>
<th>Monitoring Frequency</th>
<th>Responsible for monitoring</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Don't allow access in the work area except workers</td>
<td>CC</td>
<td>Observations on-site/off-site; CC records</td>
<td>Weekly</td>
<td>GDA</td>
<td>Part of construction supervision cost</td>
</tr>
<tr>
<td>• Obtain construction materials from approved mines</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>• Plan routes to avoid narrow streets/congested roads</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>• Plan work to avoid peak traffic hours</td>
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<tr>
<td>• Consult with the local community to inform them of work</td>
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<tr>
<td>• Ambient noise level not to exceed 65 dB(A)</td>
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<tr>
<td>• Utilize modern vehicles and machinery</td>
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<td></td>
<td></td>
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<tr>
<td>• Follow standard, safe and quality construction practices</td>
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<tr>
<td>• Ensure that all workers are provided with and use PPE</td>
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<tr>
<td>• Barricade the entire area</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>• Follow standard practices of safety checks for cranes</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>• Provide on-site Health and Safety Training</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>• Report accidents and maintain records</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Draw unskilled workforce is from local communities</td>
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</tbody>
</table>
8. PUBLIC CONSULTATION AND INFORMATION DISCLOSURE

A. Project Stakeholders

92. Most of the main stakeholders have already been identified and consulted during preparation of this IEE, and any others that are identified during project implementation will be brought into the process in the future. Primary stakeholders are:

- People near the old bus stand area and Navyug market;
- Public representatives and prominent citizens;
- Ghaziabad Nagar Nigam;
- Ghaziabad Development Authority

93. Secondary stakeholders are:

- Other concerned government institutions (utilities, regulators, etc)
- NGOs and CBOs working in the local area;
- Other community representatives (prominent citizens, religious leaders, elders, women’s groups);
- The beneficiary community in general
- NCRPB as the Funding Agency

B. Consultation and Disclosure

94. A series of public consultation meetings were conducted during project preparation. Various forms of public consultations (consultation through household surveys, ad hoc discussions on site) have been used to discuss the project and involve the community in planning the project and mitigation measures.
9. RECOMMENDATION AND CONCLUSION

A. Recommendation

95. The process described in this document has assessed the environmental impacts of the proposed Multi-level Parking Facility in Ghaziabad. Potential negative impacts were identified in relation to design, location, construction and operation of the proposed flyover. Mitigation measures have been developed to reduce all negative impacts to acceptable levels. These were discussed with specialists responsible for the engineering aspects, and measures have been included in the designs. This means that the number of impacts and their significance has already been reduced by amending the design. These include:

- Construction of the facility on government owned site
- Design as per seismic zone to eliminate risk
- Compensatory tree plantation – 3 trees for each tree felled

96. Regardless of these and various other actions taken during the IEE process and in developing the project, there will still be impacts on the environment when the infrastructure is built. This is mainly because clearance of lease holders of commercial establishments in the bus stand area and as well as squatters. Following are some of the important mitigation measures suggested:

- Implementation of compensatory measures for clearance of encroachments as recommended by the Resettlement Plan prepared in compliance with NCRPB policies
- Condition that the all compensatory/resettlement measures must be implemented before the signing of contract for civil works

97. During the construction phase, impacts mainly arise from generation of waste and dust from dismantling of existing structures, soil excavation and refilling; and from the disturbance to surrounding offices and commercial establishments by the construction work. These are common impacts of construction in urban areas, and there are well developed methods for their mitigation. Among these, disposal rubble and waste soil; dust and noise nuisance, and public and worker safety due to large scale construction is considered to be significant. Important measures suggested include:

- Salvaging the recyclable and reusable material as much as possible and reduce the quantity that needs to be disposed off
- Preparation of a rubble management plan
- Wrap the site/construction area with geo-textile fabric or install dust barriers
- Apply water and maintain soils in a visible damp or crusted condition Use
tarpaulins to cover loose material/soil that is transported to and from the

- Don't allow access in the work area except workers to limit soil disturbance and prevent access by fencing
- Noise control measures; during construction work ambient noise level should not exceed more than 65 dB (A).
- Following standard, safe and quality construction practices;
- Ensuring that all workers are provided with and use appropriate Personal Protective Equipment (helmet, hand gloves, boots, masks, safety hoists when working at height, etc);
- Provide on-site Health and Safety Training for all site personnel;

98. During the operation, the impacts are mainly due to consumption of resource like water and electricity, stress of existing infrastructure and disposal of wastewater generated from toilet and bath facilities. Fire safety is another impact aspect. The following measures are included in the design:

- Water supply shall be sourced from water supply network of Ghaziabad Nagar Nigam; no bore wells or any groundwater extraction structures shall be built in the site;
- Develop rainwater harvesting system; minimize water usage
- Connect the wastewater outlet to nearest sewer of GNN
- Design the structure utilizing more natural light and air to reduce the power consumption
- Design the building in compliance with fire safety norm and provide Fire Protection System as per the requirements of National Building Code of India (NBC)

99. The main beneficiaries of the facility will be the citizens of Ghaziabad and parking users in general.

100. Mitigation will be assured by a program of environmental monitoring conducted to ensure that all measures are provided as intended, and to determine whether the environment is protected as envisaged. This will include observations on and off site, document checks, and interviews with workers and beneficiaries, and any requirements for remedial action will be reported to the NCRPB.

101. Stakeholders were involved in developing the IEE through both face-to-face discussions on site and a large public meeting will be held in the town, after which views expressed will be incorporated into the IEE and the planning and development of the project.

102. There are two essential recommendations that need to be followed to ensure that the environmental impacts of the project are successfully mitigated. The IA shall ensure that:

- All mitigation, compensation and enhancement measures proposed in this IEE
report and in the Resettlement Plan (RP) of the subproject are implemented in full, as described in these two documents;

- The Environmental Monitoring Plan proposed in this report and the internal and external monitoring proposed in the Resettlement Plan are also implemented in full.

B. Conclusion

103. The environmental impacts of the proposed Multi-level Parking Facility in Ghaziabad have been assessed by the Initial Environmental Examination reported in this document, conducted according to the NCRPB ESMS. Issues related to Involuntary Resettlement were assessed by a parallel process of resettlement planning and will be compensated by measures set out in detail in the Resettlement Framework for the subproject.

104. The overall conclusion of both processes is that providing the mitigation, compensation and enhancement measures are implemented in full, there should be no significant negative environmental impacts as a result of location, design, construction or operation of the subproject.

105. There are no uncertainties in the analysis, and no additional work is required to comply with NCRPB procedure or national law. There is thus no need for further study or Environmental Assessment.
Asian Development Bank
National Capital Region Planning Board

Capacity Development of the
National Capital Region Planning Board
Package 2 Component B
TA No. 7055-IND

Volume V-D4: Short Resettlement Plan
DPR for Multi-level Parking Facility in Ghaziabad

WilburSmith ASSOCIATES
July 2010
Capacity Development of the National Capital Region Planning Board (NCRPB) – Component B
(TA No. 7055-IND)

FINAL REPORT
Volume V-D4: DPR for Multi-level Parking Facility at Ghaziabad Short Resettlement Plan

July 2010
# Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>ADB</td>
<td>Asian Development Bank</td>
</tr>
<tr>
<td>AF</td>
<td>Affected Family</td>
</tr>
<tr>
<td>AP</td>
<td>Affected Person</td>
</tr>
<tr>
<td>BPL</td>
<td>Below Poverty Line</td>
</tr>
<tr>
<td>BSR</td>
<td>Basic Schedule of Rates</td>
</tr>
<tr>
<td>CPR</td>
<td>Common Property Resource</td>
</tr>
<tr>
<td>DPR</td>
<td>Detailed Project Report</td>
</tr>
<tr>
<td>EA</td>
<td>Executing Agency</td>
</tr>
<tr>
<td>FGD</td>
<td>Focus Group Discussions</td>
</tr>
<tr>
<td>GoI</td>
<td>Government of India</td>
</tr>
<tr>
<td>GRC</td>
<td>Grievance Redressal Committee</td>
</tr>
<tr>
<td>GDA</td>
<td>Ghaziabad development Authority</td>
</tr>
<tr>
<td>GNN</td>
<td>Ghaziabad Nagar Nigam</td>
</tr>
<tr>
<td>HH</td>
<td>Household</td>
</tr>
<tr>
<td>HOH</td>
<td>Head of Household</td>
</tr>
<tr>
<td>INR</td>
<td>Indian National Rupee</td>
</tr>
<tr>
<td>IP</td>
<td>Indigenous Peoples</td>
</tr>
<tr>
<td>IO</td>
<td>Implementing Organisations</td>
</tr>
<tr>
<td>IA</td>
<td>Implementing Agency</td>
</tr>
<tr>
<td>IPSA</td>
<td>Initial Poverty &amp; Social Assessment</td>
</tr>
<tr>
<td>LA</td>
<td>Land Acquisition</td>
</tr>
<tr>
<td>LTH</td>
<td>Legal Title Holder</td>
</tr>
<tr>
<td>NCRPB</td>
<td>National Capital Region Planning Board</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Government Organizations</td>
</tr>
<tr>
<td>NPRR</td>
<td>National Policy on Resettlement &amp; Rehabilitation</td>
</tr>
<tr>
<td>PMU</td>
<td>Project Management Unit</td>
</tr>
<tr>
<td>PRA</td>
<td>Participatory Rural Appraisal</td>
</tr>
<tr>
<td>R&amp;R</td>
<td>Resettlement &amp; Rehabilitation</td>
</tr>
<tr>
<td>ROW</td>
<td>Right of Way</td>
</tr>
<tr>
<td>RO</td>
<td>Resettlement Officer</td>
</tr>
<tr>
<td>RP</td>
<td>Resettlement Plan</td>
</tr>
<tr>
<td>SC</td>
<td>Schedule Caste</td>
</tr>
<tr>
<td>ST</td>
<td>Schedule Tribe</td>
</tr>
<tr>
<td>TORs</td>
<td>Terms of Reference</td>
</tr>
<tr>
<td>WHH</td>
<td>Women Headed Household</td>
</tr>
</tbody>
</table>
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Appendix 6: TOR for Independent External Monitor for Monitoring & Evaluation of RP implementation
Appendix 7: Census and SES Questionnaire Format
Appendix 8: Involuntary Resettlement Categorization Form
Appendix 9: Summary Poverty Reduction and Social Strategy
### Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Affected Person (or Household)</strong></td>
<td>People (households) affected by project-related changes in use of land, water, forest, grazing land, or other natural resources</td>
</tr>
<tr>
<td><strong>Compensation</strong></td>
<td>Payment in cash or kind to which the people affected are entitled in order to replace the lost asset, resource or income</td>
</tr>
<tr>
<td><strong>Entitlement</strong></td>
<td>Range of measures comprising compensation, income restoration, transfer assistance, income substitution, and relocation which are due to the affected persons, depending on the nature of their losses, to restore their economic and social base to pre-project situation</td>
</tr>
<tr>
<td><strong>Grievance Redress Committee</strong></td>
<td>The committee formed to resolve grievances of the project affected persons/families/communities.</td>
</tr>
<tr>
<td><strong>Involuntary Resettlement</strong></td>
<td>Development project results in unavoidable resettlement losses that people affected have no option but to rebuild their lives, incomes, and asset bases elsewhere.</td>
</tr>
<tr>
<td><strong>Land Acquisition</strong></td>
<td>It is the process whereby land and properties of individuals/community are acquired for the purpose of project construction</td>
</tr>
<tr>
<td><strong>Relocation</strong></td>
<td>Rebuilding housing, assets, including productive land, and public infrastructure in another location</td>
</tr>
<tr>
<td><strong>Rehabilitation</strong></td>
<td>Re-establishing incomes, livelihoods, living and social system</td>
</tr>
<tr>
<td><strong>Replacement rate</strong></td>
<td>Cost of replacing lost assets and incomes, including cost of transactions</td>
</tr>
<tr>
<td><strong>Resettlement effects</strong></td>
<td>Loss of physical and non-physical assets, including homes, communities, productive land, income-earning assets and sources, subsistence, resources, cultural sites, social structures, networks and ties, cultural identity and mutual help mechanisms</td>
</tr>
<tr>
<td><strong>Resettlement Plan</strong></td>
<td>A time-bound action plan with budget setting out resettlement strategy, objectives, entitlement, actions, responsibilities, monitoring and evaluation</td>
</tr>
<tr>
<td><strong>Vulnerable groups</strong></td>
<td>Distinct groups of people who might suffer disproportionately from resettlement effects.</td>
</tr>
</tbody>
</table>

EXECUTIVE SUMMARY

1. **Description of the Project.** As part of the Component B of ADB TA-7055 for capacity development of NCRPB, several DPRs for different subprojects have been prepared for NCR towns. As part of traffic and transportation improvement Plan of Ghaziabad city, four sub projects have been selected for the preparation of DPR. It has been recommended in the Master Plan of Ghaziabad -2021, to shift the existing Old Bus Station to the proposed land on NH 24. In the event of this, the Old Bus Station land proposed to be utilized for building a Multi-Storey parking lot. As per the Parking Survey, Maximum parking is observed near GDA office which is located near the proposed site of car parking facility, accounts about 356 vehicles in peak hours. With a view to improve the traffic situation; the objective of the subproject is to Multi-Storey parking lot.

2. **Objectives of the Short Resettlement Plan.** In keeping with ADB’s Policy on Involuntary Resettlement, a Short Resettlement Plan (SRP) has been prepared for the subproject. The survey and assessment undertaken during preparation of the subproject indicates that the subproject will entail some degree of resettlement impact and this SRP has been prepared in accordance with ADB’s Policy on Involuntary Resettlement to address those impacts. This short RP identifies the broad scope of the subproject and outlines the policy, procedures for compensation and other assistance measures for affected persons and institutional requirements for implementation, budget etc. of RP under NCRPB project.

3. **Scope of Land Acquisition & Resettlement.** The present bus station is proposed to be shifted to a new area. The land to be released by the present bus station is proposed to be utilized for the sub –project of multi-level car parking. The land of the present bus station belongs to Uttar Pradesh State Road Transport Corporation (UPSRTC), a public sector undertaking of Government of Uttar Pradesh. Since land belongs to a quasi government body, before appraisal of the sub- project, the issues related to land transfer needs to be looked into in detail. There are 6 shop and 1 bi-cycle stand indifferent types are currently located within the bus station. Those shops and the bi- cycle stand were provided space by UPSRTC on monthly lease rent. The proposed sub-project will directly impacted upon the livelihood of those 7 affected persons.

4. **Socioeconomic Information and Profile.** A census and socio-economic survey was undertaken in the bus station. An estimated 07 APs will be affected. All 7 shop owners/ households are commercial in nature. They run their business like canteen, book store, long distance call telephone booth etc, and earn their livelihood. During consultations, the APs expressed their willingness to shift their business and requested for alternative space. During census and Socio-economic survey 1 shop was closed. The socio-economic survey was carried out for 6 shop owner. The number of total affected population as derived from the 06 surveyed households is 42, thereby making the average family size as 7. There are no vulnerable persons among the affected households have been found from the census and socio economic survey. Main occupation of the surveyed households is small trade & business. The average household income is Rs.1,38,000.
5. **Information Disclosure and Consultation.** The social team carried out preliminary consultations, through Focus Group Discussions (FGDs) and meetings with the APs as well as the general public. FGDs were conducted primarily in the area with problems of traffic congestion as the bus station is located in the heart of the city. FGDs were also conducted with the APs wherein policy related issues, i.e., displacements and other issues. As part of the preparation for the project, state level workshop was conducted with participation from key stakeholders, line agencies/institutions, government officials, and others. The purpose of the stakeholder workshop was to present and discuss the different aspects of project and approach to social impacts and resettlement. The short RP will be translated in Hindi language and will be made available to the affected people by the Executing Agency (EA) for review and comments on the policy and mitigation measures, particularly the compensation package, by means of subproject-level Disclosure workshops prior to loan negotiation. Copies of the short RP will also be made available at the local level public offices such as GDA, Municipal Corporation to the stakeholders for local inputs prior to award of civil work contract. The proceedings of the disclosure workshop and the feedback received will be sent to ADB for review. The final RP will also be disclosed on the ADB Website and NCRPB website.


7. All the 6 structures/shops are commercial in nature and small business activities were observed within the structures. No encroachers are found to be carrying out any productive occupation within the bus station premises. Relocation assistance and income loss assistance has been considered for the rented shop owners. Since, all the small business have been considered as productive and support livelihood, assistance for loss of income has also been considered in the entitlement matrix prepared for the subproject. As some commercial activities is also proposed in the multi-level car parking area, the engineering team also earmarked some area for the project affected shop owners where all the 7 shop owners will be given space to run the business activities. As the census survey was carried out between 15 - 20 October, 2009, this may be considered as Cut-off date for the Non-titleholder APs. The economic rehabilitation grant money will be deposited in bank accounts to be released only for the purchase of income generating assets. NCRPB/EA and IA(Ghaziabad Development Authority) will use the RP as a planning tool, verify and update the inventory prior to implementation of the project, and provide ID cards to the entitled affected persons for compensation and resettlement purposes. The principles applicable in defining the entitlements and compensation packages for the affected households shall remain unchanged.

8. **Grievance Redress Mechanism.** A Grievance Redressal Committee (GRC) will be established in Ghaziabad for timely and satisfactory completion of RP related activities and other requirements of the Resettlement Plan (RP) to facilitate satisfactory implementation of all ADB funded projects. The primary objective of creating GRC is to
provide a mechanism in order to address and sort out all disputes related to implementation of resettlement plan, most importantly, to mediate conflict and disputes concerning compensation payments and cut down on lengthy litigation.

9. **Institutional Arrangements and Implementation Schedule.** National Capital Planning Board (NCRPB) will be the Executing Agency (EA) for the Project. Ghaziabad Development Authority (GDA) would act as implementing agency (IA). A separate independent unit in IAs office will constitute for the purpose of overall coordination and management of the project and it will be called as The Project Management Unit (PMU) will also implement the RP with assistance of Design & Supervision Consultants (DSC) & an experienced NGO/agency/institution, acting as Implementing Organization (IO) who will shoulder the primary responsibility of the RP implementation. The PMU would ensure monitoring any changes to subproject design which may require re-evaluation of the need for and adequacy of the RP. If necessary, RP will be updated keeping changed design in view while entitlement principle remaining unchanged. The PMU will ensure resettlement budgets are delivered on time for timely RP implementation, prior to commencement of construction work. The total time period for completion of the RP implementation has been proposed as 12 months. An independent agency/monitoring expert will be engaged by the PMU in agreement with ADB to undertake biannual external monitoring of the project implementation. This expert will submit its reports biannually directly to ADB and NCRPB.

10. **Resettlement Budget.** The total estimated budget for implementation of Resettlement Plan (RP) including payment of compensation and assistance to the entitled AP, preparation of identity card, cost of resettlement operation and management for the Project through Implementing Agency and engaging Independent Monitor is INR Rs 0.90 Million.
1. SHORT RESETTLEMENT PLAN

A. Description of the Project

11. On Government of India’s request, Asian Development Bank (ADB) has formulated the technical assistance (TA) to enhance the capacities of National Capital Region Planning Board and its associated implementing agencies. The TA has been designed in three components: Component A relates to improving the business processes in NCRPB; Component B relates to improving the capacity of the implementing agencies in project identification, feasibility studies and preparing detailed engineering design; and Component C relates to urban planning and other activities. As part of the Component B, several DPRs of different subprojects have been prepared for NCR towns. As part of traffic and transportation improvement Plan of Ghaziabad city, four sub projects have been selected for the preparation of DPR. It has been recommended in the Master Plan of Ghaziabad -2021, to shift the existing Old Bus Station to the proposed land on NH 24. In the event of this, the Old Bus Station land proposed to be utilized for building a Multi-Storey parking lot. As per the Parking Survey, Maximum parking is observed near GDA office which is located near the proposed site of car parking facility, accounts about 356 vehicles in peak hours. This report is the Resettlement Plan of Multi-Storey parking lot. Figure 1 shows the location of the bus stand where the multi-storied car parking is proposed. Photographs of the proposed site are at Appendix 1.

12. With a view to improve the traffic situation; the objective of the subproject is to Multi-Storey parking lot. In keeping with ADB’s Policy on Involuntary Resettlement, this Short Resettlement Plan (SRP) has been prepared for the subproject. The project is expected to bring quite a few benefits viz.

- Improved road transport corridors;
- Road network connectivity;
- Improved management of road sector institutions, and
- Basic amenities to the town.

13. The project is also expected to indirectly help alleviate development constraints in trade & commerce, education, health, social welfare, and public safety and contribute to general expansion and diversification of development activities.

14. As per the requirement of Asian Development Bank Safe guard policy, 2009 require social impact assessment during the design stage to avoid, reduce or mitigate potential negative impacts of project action and enhance positive impacts, sustainability and development benefits has been carried out. The assessments also contribute to engineering design and result in the preparation of social action plans governing project implementation and the resettlement and rehabilitation of those who may be displaced by road improvements.
15. The survey and assessment undertaken during preparation of the subproject indicates that the subproject will entail some degree of resettlement impact and this SRP has been prepared in accordance with ADB’s Policy on Involuntary Resettlement to address those impacts. This short RP identifies the broad scope of the subproject and outlines the policy, procedures for compensation and other assistance measures for affected persons and institutional requirements for implementation, budget etc. of RP under NCRPB project.

B. Objectives of the Short Resettlement Plan

16. This Short Resettlement Plan (SRP) has been prepared to mitigate land acquisition and resettlement impact considering outcome of the preliminary engineering and technical design and topographic survey. Social screening was undertaken in conjunction with project feasibility studies. It provides important inputs and guidance to engineering designs.

17. The RP has been prepared based on census and socio-economic survey that was carried out register and document the status of the potentially affected population within the project impact area, their loss of assets, and sources of livelihood. The Census data provided the basis for establishing a cut-off date for non-title holders in order to determine who may be entitled to relocation assistance or other benefits from the project.

18. Socio-economic survey has also been carried out in order to establish the mitigation measures and that includes comprehensive examination of people’s loss of assets, incomes, important cultural or religious networks or sites, and other sources of support such as common property resources. Analyses of survey results cover the needs and resources of different groups and individuals.

19. Preparation of the Resettlement Plan (RP) was undertaken within the project’s social assessment component. A key prerequisite of the RP is a policy framework for resettlement containing categories of impacts and their corresponding entitlements. The RP provide detailed guidance on how to implement provisions in the policy framework, including institutional arrangements and budgets based on enumeration of project-affected people with entitlements under the framework.

C. Scope of Land Acquisition & Resettlement

20. The present bus station is proposed to be shifted to a new area. The land to be released by the present bus station is proposed to be utilized for the sub-project of multi-level car parking. The land of the present bus station belongs to Uttar Pradesh State Road Transport Corporation (UPSRTC), a public sector undertaking of Government of Uttar Pradesh. Since land belongs to a quasi government body, before appraisal of the sub-project, the issues related to land transfer needs to be looked into in detail. There are 7 shops of different functional types and 1 bi-cycle stand are currently located within the bus station. Those shops and the bi-cycle stand were provided space by UPSRTC on monthly lease rent. The proposed sub-cycle stand will directly impacted upon the livelihood of those 7 affected persons.
21. A census and socio-economic survey was undertaken in the bus station. An estimated 07 APs will be affected. All 07 shop owners/ households are commercial in nature. They run their business like canteen, book store, long distance call telephone booth etc, and earn their livelihood. During consultations, the APs expressed their willingness to shift their business and requested for alternative space. During census and Socio-economic survey 1 shop was closed. The socio-economic survey was carried out for 6 shop owner. The number of total affected population as derived from the 06 surveyed households is 42, thereby making the average family size as 7. A list of Affected Households/APs is annexed as Appendix 2.

**Table 1-1: Status of Census & Socio-economic Survey**

<table>
<thead>
<tr>
<th>S. No</th>
<th>Details</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total Affected APs/Household</td>
<td>07</td>
</tr>
<tr>
<td>2</td>
<td>Household / Shops not found</td>
<td>01</td>
</tr>
<tr>
<td>3</td>
<td>Total household / Shops surveyed</td>
<td>06</td>
</tr>
<tr>
<td>4</td>
<td>Total Affected Population (As per Survey of 06 Shops)</td>
<td>42</td>
</tr>
</tbody>
</table>

**Source:** Census & Socio-economic survey, October, 2009

**Table 1-2: Summary Profile of the Affected Households**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total APs – Surveyed</td>
<td>06</td>
</tr>
<tr>
<td>Total Affected Population</td>
<td>42</td>
</tr>
<tr>
<td>Average Family Size of Affected HH</td>
<td>7</td>
</tr>
<tr>
<td>Total No. of Scheduled Caste HH</td>
<td>00</td>
</tr>
<tr>
<td>Total No. of Woman Headed Households</td>
<td>00</td>
</tr>
<tr>
<td>Total No. of Below Poverty Line Households</td>
<td>00</td>
</tr>
<tr>
<td>Main Occupation of the Affected Persons</td>
<td>Small Trade &amp; Business (Shops)</td>
</tr>
<tr>
<td>Average Annual Household /Shop Income</td>
<td>138000</td>
</tr>
</tbody>
</table>

**Source:** Census & Socio-economic survey, October, 2009
24. The Resettlement Framework prepared for NCRPB classifies several groups of population as socially “vulnerable” and has provided special assistance for them. The Vulnerable groups are: (a) those who are below the poverty line (BPL); (b) those who belong to scheduled castes (SC), scheduled tribes (ST); (c) female-headed households (FHH); (d) elderly and (e) disabled persons. There are no vulnerable persons among the affected households have been found from the census and socio economic survey. Main occupation of the surveyed households is small trade & business. The average household income is Rs.138,000.

25. Based on the data of the 06 surveyed households, social stratification of the affected households can be ascertained (Table 1-3). Of the total APs, all are belongs to Hindu community. All the APs, 06 in number, are of joint family type. The predominant family size is “large” with up to 5 persons. The average family size is 7, as stated earlier.

Table 1-3: Social Stratification details of APs

<table>
<thead>
<tr>
<th>S. No</th>
<th>Criteria</th>
<th>Classification</th>
<th>No. of AFs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Community</td>
<td>Hindu</td>
<td>06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Muslim</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SC</td>
<td>-</td>
</tr>
<tr>
<td>2.</td>
<td>Family Type</td>
<td>Joint</td>
<td>06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nuclear</td>
<td>-</td>
</tr>
<tr>
<td>3.</td>
<td>Family Size</td>
<td>Up to 3</td>
<td>02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4-5</td>
<td>06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More than 5</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Census & Socio-economic survey, October, 2009

26. Literacy status among the affected families is impressive. As per information collected during census and socio economic survey (Table 1-4). The majority of the APs, comprising about 50 %, are having the education level up to secondary. Nearly 38 % achieved the education level up to middle. Only 12.50 % of the affected population have achieved higher education up to intermediate level.

Table 1-4: Educational Structure (Age more than 6)

<table>
<thead>
<tr>
<th>S. No</th>
<th>Occupation</th>
<th>No. of Person</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Illiterate</td>
<td>00</td>
<td>00.00%</td>
</tr>
<tr>
<td>2.</td>
<td>Informally Literate</td>
<td>00</td>
<td>00.00%</td>
</tr>
<tr>
<td>3.</td>
<td>Primary (Class IV)</td>
<td>00</td>
<td>00.00%</td>
</tr>
<tr>
<td>4.</td>
<td>Middle (Class VIII)</td>
<td>12</td>
<td>37.50%</td>
</tr>
<tr>
<td>5.</td>
<td>Secondary (Class X)</td>
<td>16</td>
<td>50.00%</td>
</tr>
<tr>
<td>6.</td>
<td>Intermediate (Class XII)</td>
<td>04</td>
<td>12.50%</td>
</tr>
<tr>
<td>7.</td>
<td>Graduate and above</td>
<td>00</td>
<td>00.00%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>32</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: Census & Socio-economic survey, October, 2009

27. The proportion of the working population among the APs is 40 %. The unemployed and
retired population accounting for about 25% (Table 1-5). So far as occupational structure is concerned, about 38 percent surveyed working population are engaged in trade and commerce. Twenty five percent population are employed in private service.

<table>
<thead>
<tr>
<th>Table 1-5: Occupation Structure (Age more than 18 yrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S. No</strong></td>
</tr>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
<tr>
<td>4.</td>
</tr>
<tr>
<td>5.</td>
</tr>
<tr>
<td>6.</td>
</tr>
<tr>
<td>7.</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

Source: Census & Socio-economic survey, October, 2009

It is evident from the data on annual household income of 19 APs, that there are no APs belong to Below Poverty Line (Table 1-6). The proportion of families with annual income between Rs. 80,000 and 1,00,000 is the highest, 50%. While nearly 33% of the APs earn an income varying from Rs. 60,000 to Rs. 80,000. The average annual household income of the affected families has been calculated as Rs.1,38,000.

<table>
<thead>
<tr>
<th>Table 1-6: Annual Income Pattern of Affected Households</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S. No</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
<tr>
<td>4.</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

Source: Census & Socio-economic survey, October, 2009

It can be seen from household asset holding pattern (Table 1-7) that all the APs are having mobile phone and two-wheeler. APs are possessing sizeable number of electronic gadgets.

<table>
<thead>
<tr>
<th>Table 1-7: Household Asset Holding pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S. No</strong></td>
</tr>
<tr>
<td>1.</td>
</tr>
<tr>
<td>A.</td>
</tr>
<tr>
<td>B.</td>
</tr>
<tr>
<td>C.</td>
</tr>
<tr>
<td>D.</td>
</tr>
</tbody>
</table>

Source: Census & Socio-economic survey, October, 2009
E. Information Disclosure, and Consultation

30. The detailed design was primarily aimed at providing a congenial environment for implementation with less negative impact on land and people accordingly public consultations were carried out within the bus station premises to evolve a consensus. The social team carried out preliminary consultations, through Focus Group Discussions (FGDs) and meetings with the APs as well as the general public. FGDs were conducted primarily in the area with problems of traffic congestion as the bus station is located in the heart of the city. FGDs were also conducted with the APs wherein policy related issues, i.e., displacements and other issues.

31. As part of the preparation for the project, state level workshop was conducted with participation from key stakeholders, line agencies/institutions, government officials, and others. The purpose of the stakeholder workshop was to present and discuss the different aspects of project and approach to social impacts and resettlement. A summary report on Stakeholder consultation is annexed at Appendix 3.

32. The short RP will be translated in Hindi language and will be made available to the affected people by the Executing Agency (EA) for review and comments on the policy and mitigation measures, particularly the compensation package, by means of subproject-level Disclosure workshops prior to loan negotiation. Copies of the short RP will also be made available at the local level public offices such as GDA, Municipal Corporation to the stakeholders for local inputs prior to award of civil work contract. The proceedings of the disclosure workshop and the feedback received will be sent to ADB for review. The final RP will also be disclosed on the ADB Website and NCRPB website. In addition, a Public Consultation & Disclosure Plan has been prepared for the subproject and is enclosed as Appendix 4.

F. Resettlement Principles and Policy Framework


34. Compensation and resettlement assistance for various types of loss have been determined following the provision made in the resettlement framework of NCRPB. In general, the people affected by the Sub-Project will be entitled to the following types of compensation and assistance. The basic resettlement principles and guidelines adopted for this project from the Resettlement Framework of NCRPB includes:

- Non-titleholders/ the shop owners’ those who are in the lease rent in bus station premises will be provided with “shop” for “shop”.
• Shifting assistance to the owners of the commercial structures for shifting of goods and assets
• Transitional assistance to APs due to inability to maintain livelihood during shifting.
• Affected persons will be assisted in their efforts to improve their livelihood and standards of living or at least to restore them, in real terms
• Rehabilitation assistance i.e., assistance for re-establishing lost businesses and workdays (including employees) due to the project.
• APs will be meaningfully consulted and will have opportunities to participate in planning and implementing resettlement programs
• Appropriate grievance redress mechanism will be established at the town level to ensure speedy resolution of disputes, if any.
• All activities related to resettlement planning, implementation, and monitoring would ensure involvement of women. Efforts will also be made to ensure that vulnerable groups are included.
• Before taking possession of the affected assets, the compensation will be paid to the project affected people prior to civil construction work and R&R assistance will be deposited in the joint account of APs.
• Provisions will be kept in the budget for those who were not present at the time of enumeration. However, anyone moving into the project area after the cut-off date will not be entitled to assistance.
• The Resettlement Plan will include a fully itemized budget and an implementation schedule.

35. The RP is based on the general findings of the census, socio-economic survey, observation during field visits, and participatory consultation meetings with various groups including the affected persons in the subproject area. The census was carried out during the period between 15 - 20 October, 2009. As the census survey was carried out between 15 - 20 October, 2009, this may be considered as Cut-off date for the Non-titleholder APs.

36. The economic rehabilitation grant money will be deposited in bank accounts to be released only for the purchase of income generating assets.

37. The entitlement matrix (Table 1-8) has been prepared in accordance with the Resettlement Framework of the NCRPB, for the people and the community affected by the project and provisions will be kept in the budget for those who were not present at the time of census survey, after verifying their claim for legal ownership. However, people moving in the project area after the cut-off date will not be entitled to any assistance.

38. NCRPB/EA and IA(Ghaziabad Development Authority) will use the RP as a planning tool, verify and update the inventory prior to implementation of the project, and provide ID cards to the entitled affected persons for compensation and resettlement purposes. The principles applicable in defining the entitlements and compensation packages for the affected households shall remain unchanged.
Table 1-8: Entitlement Matrix

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Type of Loss</th>
<th>Unit of Entitlement</th>
<th>Entitlement</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Assets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Loss of Structure/Business</td>
<td>Rental/Lease</td>
<td>Structure for Structure</td>
<td>Equal area of suitable space as per the choice of APs will be provided in the commercial space allotted in the Multi level car parking area.</td>
</tr>
<tr>
<td>E. Rehabilitation Assistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 5.     | Loss of Structure/Business | Owner of affected structure | grant | a) A lump sum transfer grant at the rate of Rs.5,000 for each structure/shop for shifting assets and other belongings temporarily.  
b) Rental Assistance for 6 months @ Rs. 3000/ month. |
| 7.     | Any unanticipated adverse impact due to project intervention | Owner of affected structure | grant | One time Economic Rehabilitation Grant per shop owner/commercial structure owner of Rs.30000 for loss of income due to business loss to reestablish the livelihood. |
| G. Grievance Redress Mechanism                                                                                     |
| 39.    | A Grievance Redressal Committee (GRC) will be established in Ghaziabad for timely and satisfactory completion of RP related activities and other requirements of the Resettlement Plan (RP) to facilitate satisfactory implementation of all ADB funded projects. The primary objective of creating GRC is to provide a mechanism in order to address and sort out all disputes related to implementation of resettlement plan, most importantly, to mediate conflict and disputes concerning compensation payments and cut down on lengthy litigation. The GRC is constituted as follows: |
| 1.     | Vice-Chairman, Ghaziabad development Authority : Chairman |
| 2.     | Chief Town Planner, NCR Cell, Ghaziabad : Member |
| 3.     | Social & Resettlement Expert of PMU : Member-Secretary |
| 4.     | 2 Representative of affected persons : Member |
| 5.     | Panchyats/Ward Members of Sub project. : Member |
| H. Institutional Arrangements, and Implementation Schedule                                                          |
| 40.    | National Capital Planning Board (NCRPB) will be the Executing Agency (EA) for the |
Project. Ghaziabad Development Authority (GDA) would act as implementing agency (IA). A separate independent unit in IAs office will constitute for the purpose of overall coordination and management of the project and it will be called as The Project Management Unit (PMU) will also implement the RP with assistance of Design & Supervision Consultants (DSC) & an experienced NGO/agency/institution, acting as Implementing Organization (IO) who will shoulder the primary responsibility of the RP implementation. The PMU would ensure monitoring any changes to subproject design which may require re-evaluation of the need for and adequacy of the RP. If necessary, RP will be updated keeping changed design in view while entitlement principle remaining unchanged. The PMU will ensure resettlement budgets are delivered on time for timely RP implementation, prior to commencement of construction work. A brief Terms of Reference for implementing organization/NGO is annexed in Appendix 5.

41. In addition, establishment of a High Powered Committee (HPC) to supervise pre-construction activities including implementation of RP under ADB assisted project is proposed. The HPC will consist of the following personnel:
   - Divisional Commissioner – NCR Cell (U.P)
   - Vice Chair man, GDA
   - Revenue Department Officer
   - NCRPB Representative
   - Representatives of the Affected Persons/Eminent person

42. The Committee will establish the transitional allowance and other assistance like economic rehabilitation grant to be provided to affected persons based on the prevailing rates to restore the pre-project levels of livelihoods, in case of loss of livelihood. The HPC will undertake direct negotiation settlements with the APs, wherever required.

43. The entitled APs will be given advance notice of the date, time and place of payment through public announcement. All the payment will be made in cheques payable to the entitled AP and his/her spouse. Photocopy of the cheques will be preserved by PMU as an evidence of transparent manner of payment. The payment of compensation will be monitored and verified by NGO/Executing Agency as well as representatives of the affected households. All compensation and other assistances\(^1\) will be paid to the APs prior to commencement of civil works.

44. The item wise tentative implementation schedule has been explained in Table 1-9. Total time period for completion of the RP implementation has been proposed as 12 months.

\(^1\) Compensation and assistances including that payable to Vulnerable AP are required to be disbursed prior to taking possession of the asset, land in this case. If during further verification or updating of AP database due to change in project design, relocation or livelihood assistance, or rehabilitation measures become necessary, implementation of resettlement plan may take longer period of time beyond commencement of civil work construction. Affected people will be provided with certain resettlement entitlements, such as land and asset compensation and allowances, prior to their displacement, dispossession, or restricted access.
Table 1-9: Tentative Implementation Schedule

<table>
<thead>
<tr>
<th>S. No.</th>
<th>RP Implementation Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Engaging NGO/Implementing Agency</td>
</tr>
<tr>
<td>2</td>
<td>Public consultation/Dissemination of information on Project</td>
</tr>
<tr>
<td>3</td>
<td>Verification of AP with Census cut-off-date</td>
</tr>
<tr>
<td>4</td>
<td>Updating census data in respect of changed design (if required)</td>
</tr>
<tr>
<td>5</td>
<td>Finalization of entitled APs</td>
</tr>
<tr>
<td>6</td>
<td>Preparation of photo Identity Card of Entitled AP</td>
</tr>
<tr>
<td>7</td>
<td>Opening Bank Account (Joint A/c in the name of HOH &amp; his spouse/next of kin)</td>
</tr>
<tr>
<td>8</td>
<td>Distribution of ID Card</td>
</tr>
<tr>
<td>9</td>
<td>Computation of Compensation/Assistance</td>
</tr>
<tr>
<td>10</td>
<td>Disbursement of payment of compensation</td>
</tr>
<tr>
<td>11</td>
<td>Disbursement of payment of other Assistance</td>
</tr>
<tr>
<td>12</td>
<td>Setting up of GRC</td>
</tr>
<tr>
<td>13</td>
<td>Grievance Redress Initiation</td>
</tr>
<tr>
<td>14</td>
<td>Preparation of Database of AP</td>
</tr>
<tr>
<td>15</td>
<td>Engaging External Monitor</td>
</tr>
</tbody>
</table>

| Year 1: Schedule Completion | Q1 | Q2 | Q3 | Q4 |

I. Resettlement Budget

45. The total estimated budget for implementation of Resettlement Plan (RP) including payment of compensation and assistance to the entitled AP, preparation of identity card, cost of resettlement operation and management for the Project through Implementing Agency and engaging Independent Monitor is INR Rs 0.90 Million. A break up of cost estimate is given in the following Table 1-10.

Table 1-10: Resettlement Budget

<table>
<thead>
<tr>
<th>S. No</th>
<th>Item</th>
<th>Unit</th>
<th>Qty.</th>
<th>Unit Cost in Rs/million</th>
<th>Total cost in Million INR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. Compensation for Structure- Replacement Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Commercial/Shops(7 in Nos)</td>
<td>Shop for Shop to be provided by the project Authority.</td>
<td></td>
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<tr>
<td>2</td>
<td>Transfer grant for structure/Shops</td>
<td>07</td>
<td>5000</td>
<td>0.035</td>
<td></td>
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<tr>
<td>3</td>
<td>Rental assistance for 3 months</td>
<td>07</td>
<td>6</td>
<td>3000</td>
<td>0.126</td>
</tr>
<tr>
<td></td>
<td>Economic Rehabilitation Grant</td>
<td>07</td>
<td>30000</td>
<td>0.21</td>
<td></td>
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<tr>
<td></td>
<td>Sub-Total of B</td>
<td></td>
<td></td>
<td>0.371</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. Resettlement Assistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Engaging NGO for RP Updating &amp; Implementation</td>
<td>L/s</td>
<td>0.100</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Social and Resettlement Team of PMU And EA including Logistics</td>
<td>L/s</td>
<td>0.100</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Training</td>
<td>L/s</td>
<td>0.100</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Independent External Monitoring</td>
<td>L/s</td>
<td>0.150</td>
<td>0.15</td>
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</tr>
</tbody>
</table>
J. Training, Monitoring & Evaluation

46. The RP will have both internal and external monitoring. Internal Monitoring will be a regular activity for PMU, Social development & Resettlement specialist and will oversee the timely implementation of R&R activities.

47. An orientation and training in resettlement management will be provided under the Project to the NGO/agencies by the Social Development & Resettlement specialist at the PMU level. The training activities will focus on issues concerning – (i) principles and procedures of land acquisition; (ii) the policies and principles agreed under the ADB loan; (iii) public consultation and participation; (iv) entitlements and compensation disbursement mechanisms; (v) Grievance redressal and (vi) monitoring of resettlement operation.

48. The NGO/agency, assisting in preparation and implementation of a RP, will submit monthly progress report of RP implementation to the EA through the respective PMU. The PMU will conduct regular internal monitoring of resettlement implementation and prepare quarterly progress reports for submission to ADB. The reports will contain progress made in RP implementation with particular attention to compliance with the principles and entitlement matrix set out in the resettlement plan. The report will also document consultation activities conducted, provide summary of issues or problems identified and actions taken to resolve the issues, and provide summary of grievances or complaints lodged by households and actions taken to redress such complaints.

49. An independent agency/monitoring expert will be engaged by the PMU in agreement with ADB to undertake biannual external monitoring of the project implementation. This expert will submit its reports biannually directly to ADB and NCRPB. A brief Terms of Reference for External Monitor is annexed (Appendix 6).
Appendix 1: Photographs of Old Bus Stand – Proposed Site for Multi-level Parking
### Appendix 2: List of Affected Persons

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Affected Person Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jamedar</td>
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<tr>
<td>2</td>
<td>Shilu</td>
</tr>
<tr>
<td>3</td>
<td>Rajdeep Verma</td>
</tr>
<tr>
<td>4</td>
<td>Subash Choudhary-Cycle Stand</td>
</tr>
<tr>
<td>5</td>
<td>Samaranta Dev</td>
</tr>
<tr>
<td>6</td>
<td>Bejender</td>
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</tbody>
</table>
### Appendix 3: Stakeholders’ Participatory Consultation – Abstracts

<table>
<thead>
<tr>
<th>Dates/consultation</th>
<th>Key Outcomes</th>
<th>Integration into Project Design and Action Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Government level consultations were started with a kick off workshop on 10.12.09.</td>
<td>The people wanted to know the details about the project, especially compensation for the affected shops. Those losing structure wanted to know what alternative would be provided. Most asked for alternative site.</td>
<td>The project background was given by the PA. Compensation will be paid based on the Project Policy. For those losing commercial structure – alternative option will be provided in the Project Policy, taking into consideration the extent of loss. The project Authorities will hold further meetings to resolve issues where there is no consensus. It was informed that during implementation the NGOs will hold detailed consultations.</td>
</tr>
<tr>
<td>2. There were constant consultations with GDA and NCR Planning cell from January 2009 to October 2009. Around 10 consultative meetings were held during this period.</td>
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<tr>
<td>3. AP level consultations and FGDs were held from October 15 to 20 2009. Around 03 consultative meetings were held during this period.</td>
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</tbody>
</table>
**Appendix 4: Public Consultation and Disclosure Plan**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Task</th>
<th>Timing (Date /Period)</th>
<th>No. of People</th>
<th>Agencies</th>
<th>Feedback/Issues/ Concerns Raised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholder Identification</td>
<td>Mapping of the project area</td>
<td>From February, 09 to Sept, 09</td>
<td>15 persons</td>
<td>TA Consultants – Technical, Environmental &amp; Social Safeguard Specialists and GDA</td>
<td>The project area was observed with a view to identify suitable place for rehabilitation.</td>
</tr>
<tr>
<td>Project information Dissemination</td>
<td>Dissemination of information</td>
<td>From October, 08 to Sept, 09</td>
<td>-</td>
<td>TA Consultants – Technical, Environmental &amp; Social Safeguard Specialists and GDA</td>
<td>-</td>
</tr>
<tr>
<td>Consultative meetings with APs during Scoping Phase</td>
<td>Discuss potential impacts of the project</td>
<td>August and September 2009</td>
<td>25 persons</td>
<td>TA Consultants – Technical, Environmental &amp; Social Safeguard Specialists</td>
<td>Issues related to impact of the project: Job/labour opportunity during construction/implementation of the project</td>
</tr>
<tr>
<td>Project information Dissemination</td>
<td>Informal Meetings with affected persons (APs)</td>
<td>-</td>
<td>All the APs &amp; other important persons of the locality</td>
<td>TA Consultants – Technical, Environmental &amp; Social Safeguard Specialists</td>
<td>-</td>
</tr>
<tr>
<td>Public Notification</td>
<td>Publish list of affected lands/sites in a local newspaper; Establish eligibility cut-off date</td>
<td>-</td>
<td>-</td>
<td>Collector, Land Acquisition.</td>
<td>-</td>
</tr>
<tr>
<td>Socio-Economic Survey</td>
<td>Collect socio-economic information of AP’s and their perception on the project</td>
<td>15-20 Oct, 2009</td>
<td>10-15</td>
<td>TA Consultant &amp; Social Survey team</td>
<td>Information and census data collected on: No. of affected families Socio-economic profile of the AFs Awareness created about project concept &amp; resettlement impact.</td>
</tr>
<tr>
<td>Consultative meetings on Resettlement Mitigation</td>
<td>Discuss entitlements, compensation rates,</td>
<td>-</td>
<td>-</td>
<td>IA&amp;EA(GDA and NCRPB)</td>
<td>-</td>
</tr>
<tr>
<td>Activity</td>
<td>Task</td>
<td>Timing (Date /Period)</td>
<td>No. of People</td>
<td>Agencies</td>
<td>Feedback/Issues/Concerns Raised</td>
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<tr>
<td>Measures</td>
<td>grievance redress Mechanisms</td>
<td></td>
<td></td>
<td>IA&amp;EA(GDA and NCRPB)</td>
<td>-</td>
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<tr>
<td>Publicize the resettlement plan</td>
<td>Distribute Leaflets or Booklets in local language</td>
<td>-</td>
<td>-</td>
<td>IA&amp;EA(GDA and NCRPB)</td>
<td>-</td>
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<tr>
<td>(RP) (Proposed date)</td>
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<tr>
<td>Full Disclosure of the RP to</td>
<td>Distribute short RP in local language to APs</td>
<td>-</td>
<td>-</td>
<td>IA&amp;EA(GDA and NCRPB)</td>
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<tr>
<td>Affected families (Proposed</td>
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<td>date)</td>
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<tr>
<td>Web Disclosure of the short RP</td>
<td>Short RP posted on ADB and/or EA website</td>
<td>-</td>
<td>-</td>
<td>IA&amp;EA(GDA and NCRPB)</td>
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<tr>
<td>(Proposed date)</td>
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<tr>
<td>Consultative Meetings during</td>
<td>Face to Face meetings with APs</td>
<td>-</td>
<td>-</td>
<td>IA&amp;EA(GDA and NCRPB)</td>
<td>-</td>
</tr>
<tr>
<td>DMS</td>
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</tr>
<tr>
<td>Disclosure after Detailed</td>
<td>Disclose updated short RP to APs</td>
<td>-</td>
<td>-</td>
<td>IA&amp;EA(GDA and NCRPB)</td>
<td>-</td>
</tr>
<tr>
<td>Measurement Survey (DMS)</td>
<td></td>
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</tr>
<tr>
<td>Web Disclosure of the Updated</td>
<td>Updated short RP posted on ADB and/or EA website</td>
<td>-</td>
<td>-</td>
<td>IA&amp;EA(GDA and NCRPB)</td>
<td>-</td>
</tr>
<tr>
<td>short RP (subject to change of</td>
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<td>technical design)</td>
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</tbody>
</table>
Appendix 5: Terms of Reference for RP Implementing Agency / NGO

Project Description

On Government of India’s request, Asian Development Bank (ADB) has formulated the technical assistance (TA) to enhance the capacities of National Capital Region Planning Board and its associated implementing agencies. The TA has been designed in three components: Component A relates to improving the business processes in NCRPB; Component B relates to improving the capacity of the implementing agencies in project identification, feasibility studies and preparing detailed engineering design; and Component C relates to urban planning and other activities. As part of the Component B, several DPRs of different subprojects have been prepared for NCR towns. As part of traffic and transportation improvement Plan of Ghaziabad city, four subprojects have been selected for the preparation of DPR. It has been recommended in the Master Plan of Ghaziabad -2021, to shift the existing Old Bus Station to the proposed land on NH 24. In the event of this, the Old Bus Station land proposed to be utilized for building a Multi-Storey parking lot. As per the Parking Survey, Maximum parking is observed near GDA office which is located near the proposed site of car parking facility, accounts about 356 vehicles in peak hours.

IA/PMU will engage experienced non-government organizations (NGOs) or institution to assist in the implementation of the RP, particularly to conduct public consultation program and to develop public awareness and action programs to facilitate implementation of the subproject. The proactive role of the people living in the vicinity of the sanitary land fill site area is a requisite condition for success of the project. The NGOs to be hired would be responsible to the PMU and will function in close cooperation with and under the guidance of the R&R Expert of PMU.

Scope of Work – General

To design and produce information materials such as project brochures, pamphlets, posters, and billboards to be used in the information and awareness campaign in the project area, particularly to create awareness on environmental protection.

To assist the R&R Expert, in implementation of RP provisions with special attention on timely payment disbursement to the entitled APs prior to commencement of civil construction work.

Specific Tasks

- Information campaign on the proposed project and Resettlement Plan for the project affected persons.
- Prepare and update AP database, if required, with reference to changed design and census cut-off-date. Create computerized updated database of the entitled APs.
- Assist APs to open bank account, jointly with their spouses, or next of kin, prior to payment disbursement.
- Assist PMU in verification and updating of record of rights of the title holders.
- Prepare photo identity cards of the entitled APs.
• Assist the APs to resolve their grievances, specially regarding payment of compensation, through interaction with the GRC.
• Participate in and organize community consultation with the various groups of stakeholders for smooth progress of project implementation.
• Contribute towards capacity building of the community based organizations, specially in the land fill site where the unemployed youth can be actively engaged in the project.
• Formation of groups that can maintain and protect the green belt around the landfill site.
• Prepare quarterly reports on work completed and progress made. Provide specific examples of community involvements in the process and local capacity building to deal with the issues.

Qualifications
The NGOs must have at least 5 years of work experience in the above activities with good track records. Local NGOs in the project area with good credentials will be preferred. If local experienced NGOs are not available any reputed institute may be engaged after proper orientation and RP implementation training is provided to the selected staff of the agency.

Time Frame
The NGO/Implementing Agency will be engaged for a period of 12 months and the agency will commence their work from the beginning of RP implementation. A budgetary allocation has been provided in the Tentative Budget for RP implementation.
Appendix 6: TOR for Independent External Monitor for Monitoring & Evaluation of RP implementation

Project Description
On Government of India’s request, Asian Development Bank (ADB) has formulated the technical assistance (TA) to enhance the capacities of National Capital Region Planning Board and its associated implementing agencies. The TA has been designed in three components: Component A relates to improving the business processes in NCRPB; Component B relates to improving the capacity of the implementing agencies in project identification, feasibility studies and preparing detailed engineering design; and Component C relates to urban planning and other activities. As part of the Component B, several DPRs of different subprojects have been prepared for NCR towns. As part of traffic and transportation improvement Plan of Ghaziabad city, four sub projects have been selected for the preparation of DPR. It has been recommended in the Master Plan of Ghaziabad -2021, to shift the existing Old Bus Station to the proposed land on NH 24. In the event of this, the Old Bus Station land proposed to be utilized for building a Multi-Storey parking lot.

Scope of Work
The Independent External Monitor will be supervising and monitoring RP implementation activities and will work in coordination with R&R Expert, PMU. The key tasks of the External Monitor will be to as follows:

- To review and verify the progress in resettlement implementation as outlined in the Resettlement Plan (RP).
- To assess whether resettlement objectives, particularly living standard of the Affected Persons (APs) has been restored or enhanced.
- To assess resettlement efficiency, effectiveness, impact and sustainability, drawing both on policies and practices and to suggest any corrective measures, if necessary.

Specific Tasks and Methodology
1. Review pre-project baseline data on income and expenditure, occupational and livelihood patterns, arrangements for use of common property, social organization, leadership patterns, community organizations and cultural parameters.
2. Identify an appropriate set of indicators for gathering and analyzing information on resettlement impacts; the indicators shall include but not limited to issues like disbursement of payment of entitlement packages and level of satisfaction by the APs in post-Project period.
3. Review results of internal monitoring and verify claims through random checking at the field level to assess whether resettlement objectives have been generally met. Involve the APs, host population, and community groups in assessing the impact of resettlement for monitoring and evaluation purposes.
4. Conduct both individual and community level impact analysis through the use of formal and informal surveys, key informant interviews, focus group discussions, community public meetings, and in-depth case studies of APs and other stakeholders from various social classes to assess the impact of resettlement.
5. Identify the strengths and weaknesses of basic resettlement objectives and approaches, implementation strategies, including institutional issues, and provide suggestions for improvements in future resettlement policy making and planning.

**Time Frame and Reporting**

The External Monitor will be engaged for a period of 15 months about 3 months after commencement of RP implementation so that some activities will be in progress. The Monitor will submit quarterly report to the PMU and to ADB concurrently each completion of each quarter of the year.

**Budget**

The budgetary allocation has been provided in the Tentative Budget prepared for RP implementation. The logistics for supervising RP activities may be provided by PMU.
Appendix 7: Census & SES Format
Appendix 7: Census & SES Format

Questionnaire No. : 

Date of Census/ Survey : 
d d m m y y y y

Name of the Investigator : 

1.0 HOUSEHOLD (PAF) IDENTIFICATION

1.1 House / Plot / Khasra No. : 

1.2 Ward / Mouza No. : 

1.3 Name of Ward / Mouza : 

1.4 Name of Town / Block / Tehsil : 

1.5 Name of District : 

2.0 PAH — CHARACTERISTICS

(The Respondent should be preferably the Head of Household (HOH) or the Owner of SBE).

2.1 Name of the HOH/ Owner : 

2.2 Name of the Respondent : 

2.3 Relationship with the HOH / Owner : 

01 Self 02 Spouse 03 Son/ Daughter-in-law 04 Daughter/ Son-in-law 05 Brother/ Sister 06 Father/ Mother 07 Other Relatives 08 Tenant 09 Business Partner

3.0 SOCIAL GROUP PARTICULARS FOR THE HOH/OWNER

3.1 Family Type : 

01 Joint 02 Nuclear 03 Extended

3.2 A. Community

What category do you belong to : 

01 SC 02 ST 03 OBC 04 General 05 Muslim

3.3 Vulnerability

What V.G. do you belong to? : 

01 WHH 02 BPL 03 SC / ST 04 PHC 05 Elderly person living alone / Orphan
1.1. CODE LIST FOR HOUSEHOLD PARTICULARS

B. Column 2  Relationship with the Head of the Household/ Owner of the Shop/ Business/ Enterprise

- 01 Self
- 04 Daughter / Son-in-law
- 07 Other Relatives
- 15 Employee

- 02 Spouse
- 05 Brother / Sister
- 08 Tenant
- 99 Others

- 03 Son / Daughter-in-law
- 06 Father / Mother
- 09 Business Partner

C. Column 3  Sex

- 01 Male
- 02 Female

D. Column 5  Marital status

- 01 Married
- 04 Separated without Court Order
- 09 Others (Specify)

- 02 Unmarried
- 05 Widow / Widower

- 03 Divorced
- 06 Deserted

E. Column 6  Education

- 01 Illiterate
- 04 Middle Educated (upto Class 8)
- 07 Graduate & Above

- 02 Informally Literate
- 05 Secondary Educated (upto Class 10)
- 08 Diploma

- 03 Primary Educated (upto Class 4)
- 06 Intermediate Educated (upto Class 12)
- 99 Others

F. Column 7  Occupation

- 01 Cultivation
- 04 Government Service
- 07 Small Entrepreneur
- 99 Others (Specify)

- 02 Allied agricultural activities (e.g., dairy, animal husbandry/Fisherman)
- 05 Private Service in Organised Sector
- 08 Trade & Business

- 03 Labour (daily waged)
- 06 Private Service in Un-organised Sector
- 09 Professional (Doctor, Engineer, Mechanic etc.)
4.0 **HOUSEHOLD PARTICULARS/OWNER OF BUSINESS & EMPLOYEE DETAILS**

<table>
<thead>
<tr>
<th>Sl.</th>
<th>Name of the members of the family/ Business Enterprise</th>
<th>Relationship with HOH/Owner</th>
<th>Sex</th>
<th>Age</th>
<th>Marital status</th>
<th>Education</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>Monthly Income from Occupations</th>
<th>Skill Possessed by adult members</th>
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</thead>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Main</td>
<td>Subsidiary</td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>11.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Main</td>
<td>Subsidiary</td>
</tr>
<tr>
<td>12.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Please see Clarifications & the Codes for different Columns in the previous Page.
5.0

G. Ownership of Structure / Land

5.1 Use of Land / Structure

<table>
<thead>
<tr>
<th>Use</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>01</td>
</tr>
<tr>
<td>Rented</td>
<td>02</td>
</tr>
<tr>
<td>Commercial</td>
<td>03</td>
</tr>
<tr>
<td>Agricultural</td>
<td>04</td>
</tr>
<tr>
<td>Fallow</td>
<td>05</td>
</tr>
<tr>
<td>Gazing</td>
<td>06</td>
</tr>
<tr>
<td>Allied Agri.</td>
<td>07</td>
</tr>
<tr>
<td>Others (Specify)</td>
<td>99</td>
</tr>
</tbody>
</table>

5.2 Do you own the structure / Land?

<table>
<thead>
<tr>
<th>Ownership</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner</td>
<td>01</td>
</tr>
<tr>
<td>Tenant</td>
<td>02</td>
</tr>
<tr>
<td>Lessee</td>
<td>03</td>
</tr>
</tbody>
</table>

5.3 If Yes, since when

<table>
<thead>
<tr>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

5.4 If you are an owner do you have legal document to support your claim?

<table>
<thead>
<tr>
<th>Document</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>01</td>
</tr>
<tr>
<td>No</td>
<td>02</td>
</tr>
</tbody>
</table>

5.5 Name the documents

1. 
2. 
3. 
4. 
5. 

5.6 If you are a tenant, have you paid any advance/ deposit to the owner?

<table>
<thead>
<tr>
<th>Deposit</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>01</td>
</tr>
<tr>
<td>No</td>
<td>02</td>
</tr>
</tbody>
</table>

5.7 How much?

<table>
<thead>
<tr>
<th>Rs.</th>
</tr>
</thead>
</table>

5.8 Is the advance/ security deposit refundable?

<table>
<thead>
<tr>
<th>Refundable</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>01</td>
</tr>
<tr>
<td>No</td>
<td>02</td>
</tr>
</tbody>
</table>

5.9 Do you have legal document to support your claim?

<table>
<thead>
<tr>
<th>Document</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>01</td>
</tr>
<tr>
<td>No</td>
<td>02</td>
</tr>
</tbody>
</table>

5.10 As a tenant have you erected/extended any essential structure on your owner’s property?

<table>
<thead>
<tr>
<th>Structure</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>01</td>
</tr>
<tr>
<td>No</td>
<td>02</td>
</tr>
</tbody>
</table>

5.11 If Yes, then specify

<table>
<thead>
<tr>
<th>Sq. m.</th>
</tr>
</thead>
</table>

5.12 Cost of the structure built by you?

<table>
<thead>
<tr>
<th>Rs. in year</th>
</tr>
</thead>
</table>
### 6.0 AGRICULTURAL LAND USAGE (OF AREA TO BE ACQUIRED)

#### 6.1 LAND UTILIZATION

Kindly give details of your landholdings

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>H. PARTICULARS</th>
<th>Unit (in acres/local unit)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I.</td>
<td>OWN LAND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J.</td>
<td>CULTIVATED LAND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K.</td>
<td>FALLOW LAND</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NB: If unit of area is in local unit state the conversion rate in acre/ Hectare

### 7.0 DETAILS OF TREES, ORCHARDS AND BUSHES

<table>
<thead>
<tr>
<th>Trees Name</th>
<th>No.</th>
<th>Domestic</th>
<th>Sale</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Orchards Name</th>
<th>No.</th>
<th>Domestic</th>
<th>Sale</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bushes Name</th>
<th>No.</th>
<th>Domestic</th>
<th>Sale</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 8.0 HOUSEHOLD EXPENDITURE

<table>
<thead>
<tr>
<th>L. Items of expenses</th>
<th>M. Consumption per month</th>
<th>1.1. Expenditure (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>N. FOODING</td>
<td>O.</td>
</tr>
<tr>
<td>2. Clothing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Fuel &amp; Firewood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Others (Specify)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Q. TOTAL              |                          |                        |                        |
### 9.0 HOUSEHOLD INCOME
Kindly give details of your income from various sources during the last one year.

<table>
<thead>
<tr>
<th>R. Source</th>
<th>1.1. Annual Income (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cultivation</td>
<td></td>
</tr>
<tr>
<td>2. <strong>S. ALLIED AGRICULTURE/SHEEP FARMING/etc</strong></td>
<td></td>
</tr>
<tr>
<td>3. Small Entrepreneurships</td>
<td></td>
</tr>
<tr>
<td>4. Trade &amp; Business</td>
<td></td>
</tr>
<tr>
<td>5. Profession</td>
<td></td>
</tr>
<tr>
<td>6. Salary / Commission from Service</td>
<td></td>
</tr>
<tr>
<td>7. Rent/Lease (of agri. Land / equipment / animals)</td>
<td></td>
</tr>
<tr>
<td>8. Labour</td>
<td></td>
</tr>
<tr>
<td>9. Any Others (Specify)</td>
<td></td>
</tr>
<tr>
<td><strong>T. TOTAL</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Respondent may not be in a position to give yearly income. In that case ask how many days in a month he works and how much is his earnings per day.

### 10.0 ASSET HOLDINGS

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Type of Assets</th>
<th>UNITS No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1. U. Durable Assets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Gold and Silver Jewellery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Motor Cycle/ Scooter/ Car</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Mobile Phone / Electronic Gadgets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Others (Specify)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.2. W. Livestock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Cow / Buffalo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Goat / Sheep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Poultry Birds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Others (Specify)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.3. AGRICULTURAL ASSETS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Tractor and Threshers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Power Tiller</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Others (Specify)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
11.0  COVERAGE UNDER GOVERNMENT DEVELOPMENT SCHEMES

11.1  Have you availed of any benefit under any Government schemes?

:  
01  Yes  
02  No  

11.2  If yes, kindly give us the following details

<table>
<thead>
<tr>
<th>X.</th>
<th>MENTION NAME OF THE SCHEME</th>
<th>Kind of help</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>01</th>
<th>Loan</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>Training</td>
</tr>
<tr>
<td>99</td>
<td>Others, Specify</td>
</tr>
</tbody>
</table>

11.3  If Loan (01), kindly indicate the amount  :  Rs.  

11.4  If Training (02), kindly indicate the type  :  

11.5  When did you receive the help?  :  

11.6  After availing this scheme did your annual income increase?  :  
01  Yes  
02  No  

11.7  If yes, how much?  :  Rs.  

11.8  If No, Why?  :  

11.9  Are you still continuing with the activity?  :  
01  Yes  
02  No  

11.10  If No, why?  :  

12.0  REMARKS, IF ANY
IN Voluntary ReSettlement Categorization

A. Introduction

Projects\(^1\) are assigned an involuntary resettlement category depending on the *significance* of the probable involuntary resettlement impacts. “Significant” means 200 or more people will experience major impacts. Major impacts are (i) being physically displaced from housing, or (ii) losing 10% or more of productive assets or both.

Initial screening for involuntary resettlement is to be conducted as early as possible in the project cycle, at the project concept stage where feasible, and no later than project or program preparatory technical assistance, project preparatory note fact-finding, or due diligence.

B. Instructions

1. (i) The checklist and categorization form is to be completed by the Project Team Leader (PTL) with the assistance of a Resettlement Specialist or Social Development Specialist in the Operations Department. This form, endorsed by the Sector Division Director, is then submitted by the PTL to the Environment and Social Safeguard Division (RSES) for endorsement by RSES Director, and for approval by the Chief Compliance Officer (CCO) of the Regional and Sustainable Development Department (RSDD).

   (ii) The involuntary resettlement categorization of a project is a continuing process. If there is a change in a project that may result in category change, the Sector Division should resubmit a categorization form for endorsement by RSES Director and approval by the CCO. The previous checklist should be attached to the revised checklist for reference.

---

\(^1\) ADB projects include (i) public sector project loans, program loans, sector loans, sector development program loans, financial intermediation loans, private sector loans or equity investments, and guarantees for funding of specific projects or subprojects; (ii) all project components regardless of the source of financing.
## C. Screening Questions for Resettlement Categorization

<table>
<thead>
<tr>
<th>Probable Involuntary Resettlement Effects*</th>
<th>Yes</th>
<th>No</th>
<th>Not Known</th>
<th>Possible</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Will the project include any physical construction work?</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the project include upgrading or rehabilitation of existing physical facilities?</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are any project effects likely lead to loss of housing, other assets, resource use or incomes/livelihoods?</td>
<td>✓</td>
<td></td>
<td></td>
<td>To some extent.</td>
<td></td>
</tr>
<tr>
<td>Is land acquisition likely to be necessary?</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is the site for land acquisition known?</td>
<td>✓</td>
<td></td>
<td>Not Applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is the ownership status and current usage of the land known?</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will easements be utilized within an existing Right of Way?</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are there any non-titled people who live or earn their livelihood at the site or within the Right of Way?</td>
<td>✓</td>
<td></td>
<td></td>
<td>An estimated 07 APs will be affected. All 07 shop owners/households are commercial in nature. They run their business like canteen, book store, long distance call telephone booth etc, and earn their livelihood. During consultations, the APs expressed their willingness to shift their business and requested for alternative space.</td>
<td></td>
</tr>
<tr>
<td>Will there be loss of housing?</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will there be loss of agricultural plots?</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will there be losses of crops, trees, and fixed assets?</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will there be loss of businesses or enterprises?</td>
<td>✓</td>
<td></td>
<td></td>
<td>All 07 shop owners those who are on rent.</td>
<td></td>
</tr>
<tr>
<td>Will there be loss of incomes and livelihoods?</td>
<td>✓</td>
<td></td>
<td></td>
<td>An estimated 07 APs will be affected. All 07 shop owners/households are commercial in nature. They run their business like canteen, book store, long distance call telephone booth etc, and earn their livelihood.</td>
<td></td>
</tr>
<tr>
<td>Will people lose access to facilities, services, or natural resources?</td>
<td>✓</td>
<td></td>
<td></td>
<td>Not Applicable</td>
<td></td>
</tr>
</tbody>
</table>
Will any social or economic activities be affected by land use-related changes? √

An estimated 07 APs will be affected. All 07 shop owners/households are commercial in nature. They run their business like canteen, book store, long distance call telephone booth etc, and earn their livelihood.

If involuntary resettlement impacts are expected:

- Are local laws and regulations compatible with ADB’s Involuntary Resettlement policy? √
  
  To some extent.

- Will coordination between government agencies be required to deal with land acquisition? Not Applicable

- Are there sufficient skilled staff in the Executing Agency for resettlement planning and implementation? √
  
  Capacity building of the existing staff and recruitment of new staff is required.

- Are training and capacity-building interventions required prior to resettlement planning and implementation? √
  
  Before implementation capacity building through training is essential.

*Whenever possible, consider also any future subprojects or investments.*

Information on Affected Persons:

Any estimate of the likely number of households that will be affected by the Project?

[ √ ] No [ ] Yes If yes, approximately how many?

[ √ ] No [ ] Yes Are any of them poor, female-heads of households, or vulnerable to poverty risks?

[ √ ] No [ ] Yes If yes, please briefly describe their situation: Are any APs from indigenous or ethnic minority groups? If yes, please explain?

Additional Information Requirements for Private Sector projects:

[ ] Resettlement and land acquisition completed

[ ] PSOD is lending to a Financial Intermediary

[ ] Resettlement to be completed

[ ] The project is an Equity Investment

[ ] Project entails risk by association (e.g associated Risk Guarantee

  facilities are part of the project but not funded by the proponent)

  Others, please describe______________________

D. Involuntary Resettlement Category [ √ ] New [ ] Re-categorization

After reviewing the answers above, the Project Team Leader and Social Development/ Resettlement Specialist agree subject to confirmation, that the project:
1. Project Categorization and Resettlement Planning Requirements

[ ] Category A, Significant IR impact, a full Resettlement Plan is required.
[ √] Category B, Non-significant IR impact, a short Resettlement Plan is required.
[ ] Category C, No IR impact, no resettlement report is required.

[ ] Additional information is needed for categorization and is to be gathered by the Project Team Leader. In the interim, the project is classified as:
[ ] Category A/B
[ √] Category B/C
[ ] Social Development/ Resettlement Specialist to participate in Fact Finding
[ ] Consultant support is required to prepare Resettlement Plan/Resettlement Framework (RP/RF), therefore the TOR for a Social Development/ Resettlement Specialist should be included in TA Report

2. Additional Requirements for Sector, Sector Development Program/Project Loans, Emergency Loans and Hybrid Loans

[ √] Resettlement Framework
[ ] Core Subproject Resettlement Plans

Note:
A draft RP/RF disclosed to APs and endorsed by the Executing Agency is required before Management Review Meeting (MRM).
A summary RP/RF should be included as a core appendix in the draft RRP for MRM.
A satisfactory RF/RP is required before Appraisal.
Indigenous Peoples Impact Categorization Form

B. Identification of indigenous peoples in project area

<table>
<thead>
<tr>
<th>Impact on indigenous peoples (IPs)/ethnic minority(EM)</th>
<th>Not known</th>
<th>Yes</th>
<th>No</th>
<th>Remarks or identified problems, if any</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are there IPs or EM groups present in project locations?</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do they maintain distinctive customs or economic activities that may make them vulnerable to hardship?</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will the project restrict their economic and social activity and make them particularly vulnerable in the context of project?</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will the project change their socioeconomic and cultural integrity?</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will the project disrupt their community life?</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will the project positively affect their health, education, livelihood or social security status?</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will the project negatively affect their health, education, livelihood or social security status?</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will the project alter or undermine the recognition of their knowledge, preclude customary behaviors or undermine customary institutions?</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In case no disruption of indigenous community life as a whole, will there be loss of housing, strip of land, crops, trees and other fixed assets owned or controlled by individual indigenous households?</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C. Anticipated project impacts on indigenous peoples

<table>
<thead>
<tr>
<th>Project activity and output</th>
<th>Anticipated positive effect</th>
<th>Anticipated negative effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not applicable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
D. Decision on Categorization

After reviewing the answer above, the Mission Leader and Social Development Specialist agree that the project:

☐ Should be categorized as an A project, an Indigenous Peoples Development Plan (IPDP) is required or, for sector/FI projects, an Indigenous Peoples Development Framework (IPDF) is required

☑ Should be categorized as a B project, a specific action favorable to indigenous peoples/ethnic minority is required and addressed through a specific provision in RRP and in related plans such as a Resettlement Action Plan, a Gender Action Plan or a general Community Participatory Plan

☐ Should be categorized as a C project, no IPDP/IPDF or specific action required

Project Team Comments:
The present bus station is proposed to be shifted to a new area. The land to be released by the present bus station is proposed to be utilized for the sub –project of multi-level car parking. The land of the present bus station belongs to Uttar Pradesh State Road Transport Corporation (UPSRTC), a public sector undertaking of Government of Uttar Pradesh. Since land belongs to a quasi government body, before appraisal of the sub- project, the issues related to land transfer needs to be looked into in detail. There are 7 shop of different functional types and 1 bi-cycle stand are currently located within the bus station. Those shops and the bi- cycle stand were provided space by UPSRTC on monthly lease rent. The proposed sub-project will directly impacted upon the livelihood of those 7 affected persons. The likely APs are ready to cooperate during the project implementation. If there is any change in sub project design the proposed RP needs to be updated before implementation.

RSES Comments:

Arup Khan
Social Development &
Resettlement Specialist, TA No.
7055-IND

Narendra Singh Shekhawat
TA Team Leader, TA No.
7055-IND
Country/Project Title: (TA No. 7055-IND)-Capacity Development of the National Capital Region Planning Board (NCRPB) – Component B Sub-Project: Proposed Multi Level Parking, Ghaziabad

<table>
<thead>
<tr>
<th>Lending/Financing Modality:</th>
<th>Department/ Division:</th>
</tr>
</thead>
</table>

I. POVERTY ANALYSIS AND STRATEGY

A. Linkages to the National Poverty Reduction Strategy and Country Partnership Strategy

The Program is primarily designed to improve the urban infrastructure and services in the Municipal Area of Ghaziabad Development Authority. Investments in urban infrastructure have positive spinoffs in terms of economic growth and poverty reduction. The proposed NCRPB capacity development project is expected to boost the regional economy through the provision of improved urban services. The city of Ghaziabad is a fast growing land locked city within the National Capital Region of Delhi. Ghaziabad is listed amongst the world’s fastest growing cities and as one of the most dynamic economies of the world. Ghaziabad is well connected by National Highways and other Major roads to Delhi, and NCR towns like Meerut, Bulandshahr, Moradabad etc., and shares its boundary with Delhi. Ghaziabad acts as a major gateway into Uttar Pradesh. The population growth of Ghaziabad is 89.25 per cent during 1991-2001 in comparison to 62.46 per cent population growth in urban areas of UP sub-region of National Capital Region (NCR). This signifies that the city’s population has been growing at a very rapid pace compared to other cities of Uttar Pradesh (UP) sub-region. The City of Ghaziabad once known for small and medium scale industries, has had witnessed tremendous commercialization of urban populace over the last couple of decades. The municipal limits of the city have outgrown fast, accommodating the urban sprawl. The regional influence of the city is compounded by its proximity to Delhi apart being part of National Capital Region. The city is a gateway to newly carved out state of Uttaranchal and important cities of Western and Central UP. It has been recommended in the Master Plan of Ghaziabad -2021, to shift the existing Old Bus Station to the proposed land on NH 24. In the event of this, the Old Bus Station land proposed to be utilized for building a Multi-Storey parking lot. As per the Parking Survey, Maximum parking is observed near GDA office which is located near the proposed site of car parking facility, accounts about 356 vehicles in peak hours. The project will help address traffic scenario as the chronic capacity shortage in the road system of Ghaziabad is a problem. The project is consistent with Master Plan(2021) of GDA. The project will also create in direct employment and wider employment opportunities around the parking lot.

B. Poverty Analysis

Targeting Classification: General intervention (GI)

1. Key Issues

The National Human Development Report, 2001 prepared by Planning Commission of India presents poverty scenario at national and state level during the period 1999-2000 based on various parameters. By Head Count Ratio the proportion of poor for India as a whole was 26.1%, while rural areas recorded 27.1% against 23.6% in urban areas. The estimates for 2000-01 on HDI shows that UP’s rank 12 amongst the States in India. UP’s rank shows some improvement between 1991 and 2001. The Human Poverty Index indicates human deprivation in terms of development in economic, educational and heath dimension. Uttar Pradesh belongs to the category of high poverty States. In 1993-94 the State ranked 11th...
out of the 14 major States of India in poverty levels with 36 Per Cent of persons below the poverty line. One striking feature of poverty in the State has been that urban poverty ratios have remained above the rural poverty ratio. The official estimate shows that poverty may have declined by about 10 Per Cent points in UP between 1993-94 and 1999-00.

Per capita net state domestic product in Uttar Pradesh in current prices doubled from Rs. 5,066 in 1993/94 to Rs. 10,289 in 2002/03. NSS UP data show that the pattern of growth between 1993/94 and 2002/03 was pro-poor, meaning that per capita expenditures of the poorest one-tenth of the population increased faster (by 109 percent in nominal terms) than that of the richest one-tenth (which increased by 62 percent in nominal terms). The head count poverty rate for UP fell from 40.9 percent to 29.2 percent between 1993/94 and 2002/03. In absolute terms, the absolute number of poor in UP declined from 59.3 million in 1993/94 to 48.8 million in 2002/03. The poverty rate in rural areas of UP fell from 42.3 percent to 28.5 percent, while that in urban areas declined only slightly from 35.1 to 32.3 percent.

The important national Highways passing through Ghaziabad are NH-58 which goes to Merrut, NH-24 which goes to Hapur and NH-91 which goes to Sikandrabad. Along with these highways, there is Hapur bypass passing through Ghaziabad connecting Madan Mohan Malviya Marg and NH 91. The Y junction on NH 24 connecting NH 58 (near Mahamaya sports stadium) has become one of the most critical intersections in the city. The modal distribution of traffic at this junction is a mix of all types of vehicles with HTV/commercial vehicles high during night and early morning hours. The GT Road carries large volume of traffic to an extent that it has exceeded its capacity by 50-60%. Rapid urbanization has lead to a sharp increase in travel demand. It has been recommended in the Master Plan of Ghaziabad -2021, to shift the existing Old Bus Station to the proposed land on NH 24. In the event of this, the Old Bus Station land proposed to be utilized for building a Multi-Storey parking lot. As per the Parking Survey, Maximum parking is observed near GDA office which is located near the proposed site of car parking facility, accounts about 356 vehicles in peak hours. The project will help address the chronic capacity shortage in the road system of Ghaziabad. The project is consistent with Master Plan(2021) of GDA. Although direct poverty alleviation is not envisaged the project will provide an essential urban service to improve considerably the urban transport scenario. Besides, unskilled labour available in the locality will be engaged during implementation of the project providing employment opportunity to the poor families.

2. Design Features
There is no specific pro poor design for this project. But as mentioned above the poor /underemployed families stand to gain from implementation of the sub project.

C. Poverty Impact Analysis for Policy-Based Lending
Not Applicable

II. SOCIAL ANALYSIS AND STRATEGY

A. Findings of Social Analysis

Key Issues

National Capital Region (NCR), a unique region, is the fastest growing region. It has the best economic base for growth of industries and new economy as well (software, Export Promotion Zone (EPZ) and Special Economic Zones (SEZ)). Within NCR, Ghaziabad is one of the fast developing Delhi metropolitan area city. Ghaziabad district, carved out of Meerut district in 1976, had Ghaziabad as class I city. During partition of India, it was a class III town. With onset of industrialisation of the surrounding areas, it became class II town in 1961 and with growth rate of 82.10% in 1961-1971, it acquired the status...
of class I city in 1971. After Kanpur, Ghaziabad is the biggest industrial city in Uttar Pradesh (U.P.) state. The city has grown at very fast pace during the last three decades to emerge as a Metro and strengthen its economic base. The city has one of the best road and rail connections among cities in U.P. State.

The urban development of the city has been achieved through Master Plan 1981 and Master Plan 2001 from a population base of 70000 (1961) to 2.72 (1981) lakh and 9.68 lakh (2001), an emerging metro as per census. River Hindon flows through the city dividing it into east of Hindon (Cis Hindon Area i.e. CHA) and west of Hindon (Trans Hindon Area i.e. THA). CHA constitutes 2/3rd in area and population while THA constitutes 1/3rd area and population. The proportion of the slum population to total population is one third.

As per the Parking Survey, Maximum parking is observed near GDA office which is located near the proposed site of car parking facility, accounts about 356 vehicles in peak hours. The project will help address traffic scenario as the chronic capacity shortage in the road system of Ghaziabad is a problem. The project is consistent with Master Plan(2021) of GDA. The project will also create in direct employment and wider employment opportunities around the parking lot.

The present bus station is proposed to be shifted to a new area. The land to be released by the present bus station is proposed to be utilized for the sub –project of multi-level car parking. The land of the present bus station belongs to Uttar Pradesh State Road Transport Corporation (UPSRTC), a public sector undertaking of Government of Uttar Pradesh. Since land belongs to a quasi government body, before appraisal of the sub-project, the issues related to land transfer needs to be looked into in detail. There are 7 shop of different functional types and 1 bi-cycle stand are currently located within the bus station. Those shops and the bi-cycle stand were provided space by UPSRTC on monthly lease rent. The proposed sub-project will directly impacted upon the livelihood of those 8 affected persons.

### B. Consultation and Participation

1. In the course of social assessment informal participatory discussion was held with the people with the help of structured questionnaires. All the persons consulted expressed satisfaction regarding proposed multi level car parking project. As the proposed project will reduce congestion and also reduce the travel time, the participants’ well- come the project. The likely project affected people requested the team for providing compensation and assistance enabling them to restore their livelihood.

2. What level of consultation and participation (C&P) is envisaged during the project implementation and monitoring?
   - ☒ Information sharing
   - ☒ Consultation
   - ☐ Collaborative decision making
   - ☐ Empowerment

3. Was a C&P plan prepared? ☐ Yes ☒ No

To make the project effective public awareness & participation are essential so that adequate cooperation is being received from the local population. It is envisaged that after the sub project is approved, the details of the project design and requirement will be disclosed to the people before commencement of implementation through community consultation.

### C. Gender and Development

1. **Key Issues**

The sub-project will not cause any specific gender issue and is neither focused particularly on women. However, execution of project will have indirect positive impact on women’s mobility.
2. **Key Actions.** Measures included in the design to promote gender equality and women’s empowerment—access to and use of relevant services, resources, assets, or opportunities and participation in decision-making process:

- Gender plan
- Other actions/measures
- ☒ No action/measure

<table>
<thead>
<tr>
<th>III. SOCIAL SAFEGUARD ISSUES AND OTHER SOCIAL RISKS</th>
<th>Issue</th>
<th>Significant /Limited/ No Impact</th>
<th>Strategy to Address Issue</th>
<th>Plan or Other Measures Included in Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involuntary Resettlement</td>
<td>Limited</td>
<td>The present bus station is proposed to be shifted to a new area. The land to be released by the present bus station is proposed to be utilized for the sub-project of multi-level car parking. The land of the present bus station belongs to Uttar Pradesh State Road Transport Corporation (UPSRTC), a public sector undertaking of Government of Uttar Pradesh. Since land belongs to a quasi government body, before appraisal of the sub-project, the issues related to land transfer needs to be looked into in detail. There are 7 shop of different functional types and 1 bi-cycle stand are currently located within the bus station. Those shops and the bi-cycle stand were provided space by UPSRTC on monthly lease rent. The proposed sub-project will directly impacted upon the livelihood of those 8 affected persons. A Resettlement Plan will be prepared to address the issue of relocation of commercial shop owners.</td>
<td>☐ Full Plan  ☒ Short Plan  ☒ Resettlement Framework  ☐ No Action</td>
<td></td>
</tr>
<tr>
<td>Indigenous Peoples</td>
<td>No impact</td>
<td>There are no indigenous people residing in the project area that will either be required for acquisition or will be displaced.</td>
<td>☐ Plan  ☒ Other Action  ☒ Indigenous Peoples Framework  ☒ No Action</td>
<td></td>
</tr>
<tr>
<td>Labor  ☒ Employment opportunities  ☒ Labor retrenchment  ☐ Core labor standards</td>
<td>Limited</td>
<td>There will be opportunity of employment generation during construction of the project component. No loss of job or other form waged labor is envisaged.</td>
<td>☐ Plan  ☒ Other Action  ☒ No Action</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No impact</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No impact</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No impact</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No user fees/tax exists as of today.
<table>
<thead>
<tr>
<th>Affordability</th>
<th>No impact</th>
<th>Awareness campaign and public consultation may be needed to encourage people to take house connections to the road side sewer chambers.</th>
<th>Action</th>
<th>No Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Risks and/or Vulnerabilities</td>
<td>No impact</td>
<td>No impact</td>
<td>Plan</td>
<td>Other Action</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>Human trafficking</td>
<td>Others(conflict, political instability, etc), please specify</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### IV. MONITORING AND EVALUATION

Are social indicators included in the design and monitoring framework to facilitate monitoring of social development activities and/or social impacts during project implementation?  

- Yes  
- No