Environmental and Social Due Diligence Report

Project Number: 47083-004
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INDIA: Accelerating Infrastructure Investment Facility in India – Tranche 3

Ashoka Ankleshwar Manubar Expressway Private Limited (Part 7 of 24)

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another GTS Benchmark. In the process of assigning levels of pillars, double tertiary levelling was carried out by two leveling teams in fore and back directions using Digital Levels from reference benchmark to another reference benchmark connecting all intermediate GPS to establish accurate MSL heights of all the control points. The discrepancy obtained between two reference benchmarks was adjusted wherever permissible in the ratio of the length of the level line to obtain final adjusted heights (Z values) of all the GPS and Subsidiary Control Points.

Out of the list of 10 numbers of GTS BM received from NHAI, only three numbers of GTS BM could be located on ground at Vadodara, Bharoch and at Surat. All these three BMs were used as reference Bench Marks and the level lines were adjusted as per the heights of these bench Marks. All the GPS control Points from GPS 236 to GPS 388 are properly connected and adjusted to GTS BM whereas all GPS control points from GPS 236 to GPS 124 are connected to GTS BM Surat but not connected to any other GTS BM since all GTS BM from Surat to Mumbai are not traceable on ground. However, the differential levelling was carried out by Digital levels in fore and back direction and rigorous checks were applied to contain propagation of errors. The inherent personal errors in levelling due to staff reading, recording and calculating levels are totally eliminated by using a Digital Level. From chainage 120km to Dahisar in Mumbai, two parallel level lines were run, one being along existing NH8 and another along the proposed alignment connecting all GPS control points en-route and these two lines were connected by tie lines at various places to create small loops at regular intervals to check against any probable propagation of errors.

At the end, another fragment level line bifurcated from Km 27 of main Vadodara Mumbai expressway along the spur alignment and was closed on a GTS BM (Transferred by PWD) at Panvel Dak Bungalow on NH4 and here the errors were found under permissible limits. Since this was not the Original GTS BM hence no adjustment of levels were carried out and this BM was used only for check.

Heights (Z values) of all the GPS control points obtained by GPS receivers were replaced by their adjusted leveling heights before using these control points for detailed topographical survey. The MSL values of all GPS control Points are given in **Annexure 5.2** along with the grid coordinates. These GPS control pillars are also treated as BMs.

5.11 DETAILED TOPOGRAPHICAL SURVEY

Based on the GPS and Traverse control points, the Easting (X), Northing (Y) and MSL Height (Z) coordinates of all important manmade and natural topographical features along the alignment within a corridor of 200m (100 m on each side of the proposed center line, or more wherever required) were recorded using Total Stations having automatic data recording devices with appropriate feature codes.

All man-made and natural topographical features were surveyed, including:

- Cross Road center line
- Pavement edges
- Outer shoulder edges
- Toe lines of fills and cuts
- Longitudinal and transverse drains/ ditches/irrigation canals etc.
- Water sources, River etc.
- Structures

- Buildings
- Utilities etc. as visible, falling inside the corridor
- Gas pipe lines, Oil pipe lines etc. with their ROW

At locations, where proposed alignment crosses other roads, the survey was extended to 200 m on either side of the road center to allow for geometric improvements. Cross sections at every 50 m interval in flat terrain and at lesser interval on undulating terrain or horizontal curves were also taken using Total Stations.

List of feature codes for physical data collection by total station is given in **Annexure 5.3.**

5.12 DATA PROCESSING

All data from the total stations, and other field records, was downloaded regularly on to the field computer and edited to make it compatible to Survey Control Centre (SCC), the data processing software. The data was then suitably processed to form ground feature and proper connectivity linear features. The hard copy output of the survey drawing on suitable scale was taken to the ground by senior surveyor for physical verification on the ground to check details and for picking up names of the villages and other relevant information to ensure completion of the data in the field itself. After complete examination, the data was sent to Design team for further processing for design and drawings.

5.13 ADDITIONAL SURVEY

Over the period of time, there have been many changes in the alignment due to various reasons and due to these changes in the proposed alignment, 254 kilometers of additional survey was carried out against total proposed length of 360 kilometers which comes out to 67% excess work. This is in addition to the surveys carried out for bridge sites, junctions, interchanges, ROBs etc. Surveys for longitudinal and cross-sections for major and minor streams were carried out to meet hydrological requirements.

5.14 ADDITIONAL SURVEY FOR HYDROLOGICAL MODELLING

The following survey requirements were projected by the hydrologists

1. Survey of physical objects causing obstructions to the flow of water inside Tapi and Narmada Rivers including the bridges with piers within a range of 10 kilometers Up-stream and 10 kilometers down-stream from the proposed bridge sites on respective rivers.

2. Provide ground control point for developing DEM from the stereo pairs of CARTOSAT 2.5m resolution satellite images for generating river cross sections at desired intervals. About 44 Ground control points were provided in about 324,000 Hectares of area covering 4 scenes of the satellite images by running level lines engaging 4 survey teams equipped with digital levels.

5.15 FEATURE CODES

Surveyors used unique codes for all ground features while picking up the X, Y and Z coordinates by Total Station during field survey of topographical details.

5.16 QUALITY CONTROL

Adequate quality assurance measures were incorporated in the methodology, which were followed at every stage. The senior surveyor assigned for the total survey work carried out constant supervision of day-to-day survey activities. The

senior surveyor had constant check on the accuracy part including proper adjustment procedures and ensured that criteria of adjustment required for traverse and levelling were within the allowable limits. The final survey sheets were physically verified by the senior surveyor by ground visits. Digital terrain models were generated at the field head quarter to ensure quality output.

5.17 PROBLEMS ENCOUNTERED

The topographical survey activities were carried out smoothly in Gujarat State except at few places close to the border of Dadra Nagar Haveli. However, strong public resistance was faced in DNH and Maharashtra resulting in considerable delay in completing the topographic surveys in this region. The survey activities were temporarily abandoned in the Union Territory of DNH and the state of Maharashtra. A number of meetings were held with local administration to resolve the issue with active support from NHAI officials. As a result, survey activities in these states were again restarted after a gap of about 6 months. However despite various efforts at all levels of local administration, there is still a gap of about 1.6 kilometers where the survey could not be conducted near Dadra (about 800m in Village Dadra under UT and about 800m in Lavachha village in Pardi Tahsil of District Valsad Gujarat). For the purpose of design the gap has been filled up by taking features from the imagery and interpolating the levels.

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SOIL AND MATERIAL INVESTIGATION

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6. SOILS AND MATERIAL INVESTIGATION

6.1 INTRODUCTION

As part of the comprehensive feasibility and preliminary design study, the Consultants conducted soil and materials investigation, analysis of top soil properties along the road alignment as well as investigation on sources of available construction materials for the proposed expressway.

The investigations covered all relevant aspects including the following:

- ***Investigation for foundation soil of road embankment along proposed alignment:*** *To assess the existing soil profile along the proposed project corridor for design and construction of sub-grade, embankment and foundation for road cross-section elements. This includes assessment of the design parameters for the new road alignment.*
- ***Investigation for Construction Materials:*** *To ascertain the availability of materials for construction and estimate design parameters for the same; including manufactured materials such as cement, bitumen, steel, etc. within a reasonable haulage distance.*

6.2 GEOLOGICAL STUDIES

Desk studies involved study of geology of the area. The stretch along Mumbai-Vadodara is represented by a monotonously uniform, flat-topped skyline. This topography of the area is the outcome of its geological structures. The geological formations met here are:

- Laterite, Alluvium and Soil
- Deccan Traps with inter-trappean beds

Though Deccan traps are the most important and extensive geological feature along the stretch in both the states, the recent alluvium deposits are also found in Gujarat near Vadodara. A few granites and gneisses are also occasionally seen along the proposed alignment near Surat and Bharuch.

Deccan Traps

The Deccan Traps are so designated on account of their step like or terraced appearance. The rocks are basaltic in composition. The rocks are well jointed. The traps show the typical exfoliation or spheroidal weathering. They are usually hard, compact, greenish grey to black in colour. Thus fine to medium grained traps can be grouped into two varieties non-vesicular and vesicular. The vesicular variety carries a lot of cavities which are often filled with secondary minerals such as quartz, calcite, agate and zeolites. This type is called as amygdaloidal basalt and is often soft and chocolate brown in colour generally forms the slopes and valley floors.

Inter-trappeans are the fluviatile and lacustrine beds deposited during the time interval between two successive lava flows. They generally consist of red and green clays, green chert and buff coloured limestone.

Laterite and Alluvium

This sequence rests over the Deccan Trap basalt. Laterite is formed in tropical climate under alternate dry and wet seasons. It is porous, pitted clay-like rock of variegated colours and has a limonitic crust on the exposed surface. It is soft when freshly dug but on exposure to air it quickly dehydrates and becomes quite hard.

The broad alluvial delta plains formed at the major rivers in the area extend inland for a considerable distance. The thickness of alluvium varies and averages about 150m. These alluvium layers are composed of reddish and brownish clays, with intercalation of gravel and with 'kankar'.

6.3 FIELD INVESTIGATION – SAMPLING AND TESTING

Borrow areas and quarries were identified within the vicinity of proposed project road alignment based on the information gathered from local enquiry, Contractors / Concessionaires engaged in the construction of nearby highway projects, and Client's officials. Samples of soil / construction materials were collected from natural ground along the proposed alignment, identified borrow areas, stone metal / sand quarries and water sources. **Table 6.1** presents the sampling criteria and tests and testing procedures adopted for various laboratory tests conducted on the collected samples.

6.4 INVESTIGATIONS ALONG THE ALIGNMENT SOIL OF THE PROJECT CORRIDOR

The main thrust of investigation was on soil investigation for evaluation of the characteristics of alignment soil. The various in-situ tests and laboratory tests conducted on soil samples along the alignment of the main expressway are summarized in **Table 6.1** Discussion on the tests conducted and results obtained are carried out in the following sections.

Table 6.1: Site Sampling and Testing Criteria

Sl. No.	Type of Soil Sample	Sampling Criteria	Testing Criteria	
			Description of Test	Standard Code Applicable
i)	Alignment soil samples from natural ground	Samples have been collected from Large Test Pits (60 cm x 60 cm) at intervals of 4 km to 6 km or closer depending on where the apparent changes in soil properties were observed and staggered left/right along the proposed alignment. A total of 3 samples have been collected and 3 samples tested.	Soil Classification	IS 1498
			Sieve Analysis	IS 2720 (Part-4)
			Atterberg Limits	IS 2720 (Part-5)
			Free Swelling Index	IS 2720 (Part-40)
		Samples have been collected from Small Test Pits (30 cm x 30 cm) at the intermittent locations of above test pits at intervals of 4 km to 6 km or closer depending on where the apparent changes in soil properties were observed and staggered	In-situ Density	IS 2720 (Part-29)
			In-situ Moisture Content	IS 2720(Part-2)
			Dynamic Cone Penetration Test	TRRL (U.K.) vide Road Note No. 31

Sl. No.	Type of Soil Sample	Sampling Criteria	Testing Criteria	
			Description of Test	Standard Code Applicable
		left/right along the proposed alignment. A total of 3 pits were dug and tested.		
ii)	Soil samples from borrow areas	Representative samples from each of the identified borrow areas within reasonable lead distance were collected. A total of 2 borrow were identified and tested.	Soil Classification	IS 1498
			Sieve Analysis	IS 2720 (Part-4)
			Atterberg Limits	IS 2720 (Part-5)
			Laboratory Compaction Test (Modified Proctor Test)	IS 2720 (Part-8)
			Free Swelling Index	IS 2720 (Part-40)
			4-day soaked CBR at 3 energy levels corresponding to 10, 35 & 65 blows of heavy compaction rammer.	IS 2720 (Part-16)
iii)	Stone metal samples from crushers/ quarries	Samples of various sizes of stone including stone dust were collected from one (1) crusher/quarry located within reasonable lead of the main expressway.	Sieve Analysis	IS 2386 (Part-1)
			Flakiness and Elongation Index	IS 2386 (Part-1)
			Specific Gravity and Water Absorption	IS 2386 (Part-3)
			Aggregate Impact Value (AIV)	IS 2386 (Part-4)
			Los Angeles Abrasion Value (LAV)	IS 2386 (Part-4)
			Soundness Test	IS 2386 (Part-5)
			Water sensitivity	AASHTO-T283
			Polished Stone Value	MoRT&H
			Stripping and Coating *[1]	IS 6241
			Alkali Aggregate Reactivity	IS 2386 (Part-7)

Sl. No.	Type of Soil Sample	Sampling Criteria	Testing Criteria	
			Description of Test	Standard Code Applicable
iv)	Fine Aggregates	Samples were collected from two river sources located within the vicinity of the main expressway.	Grain Size Analysis	IS 2386 (Part-1)
			Specific Gravity and Water Absorption	IS 2386 (Part-3)
v)	Water sample	One sample from each of the one (1) sources like tube wells and rivers located within the project influence area was collected and tested.	pH Value, Chlorides, Sulphates (SO_3), Acidity, Alkalinity, Organic, Inorganic impurities and suspended matter	MoRT&H Specification Clause 1010; IRC:21.
vi)	Fly Ash	One sample from each of the two sources identified within 100 Km along the alignment of the main expressway was collected and tested.	Sieve Analysis	IS 2720 (Part-4)
			Compaction Test (Modified Proctor Test)	IS 2720 (Part-8)
			CBR at single energy level	IS 2720 (Part-16)
			Chemical Analysis	IS 3812
			Shear Parameters (Direct Shear Test) on select samples	IS 2720 (Part-13)
			Permeability Test	IS 2720 (Part-17)
			Lime Reactivity	IS 1727
			Fineness	

6.4.1 In-situ properties of Alignment Soil

As the primary investigation of alignment soil indicated that the existing top soil in the stretch from Km.279.000 to Km 292.000 is either expansive in nature or low in strength, it was felt necessary to find out its in-situ properties, besides properties of remoulded samples. For the purpose, in the reach from Km.279.000 to Km 292.000, small trial pits were made and moisture content (FMC), density (FDD) and DCP-CBR (represented as Equivalent CBR) were conducted. The results are presented in **Table 6.2**.

Table 6.2: Summary of In-situ Test Results

Sl. No.	Location / Chainage (Km.)	Side	FMC %	FDD (gm/cc)	Eq. CBR
1	282.000	R/S	20.0	1.58	7
2	287.000	L/S	13.0	1.62	20
3	290.000	R/S	18.0	1.63	7

(I) FDD & FMC

Field dry density and field moisture content have been measured at the excavated pits. **Fig. 6.1** and **Fig. 6.2** exhibit representations of the test results.

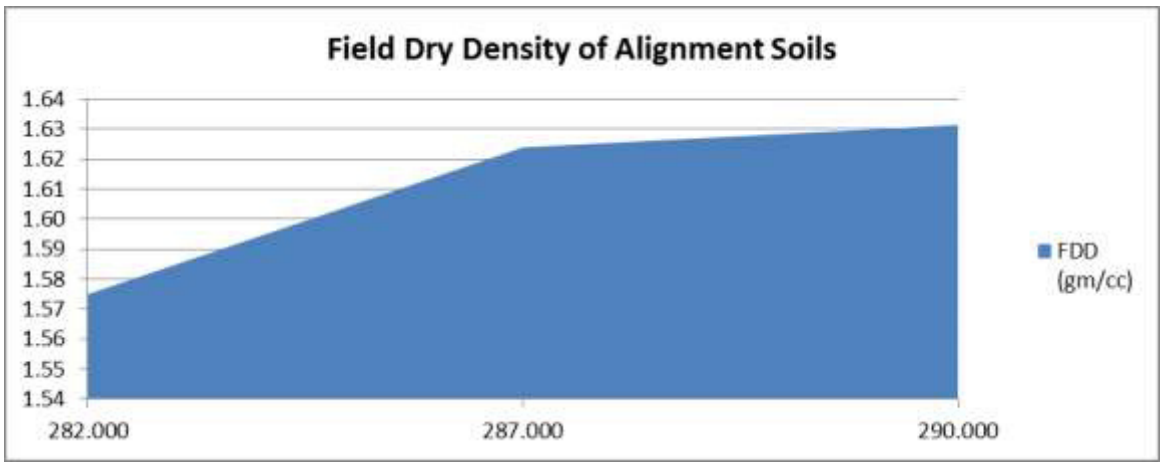

Fig. 6.1: Field Dry Density

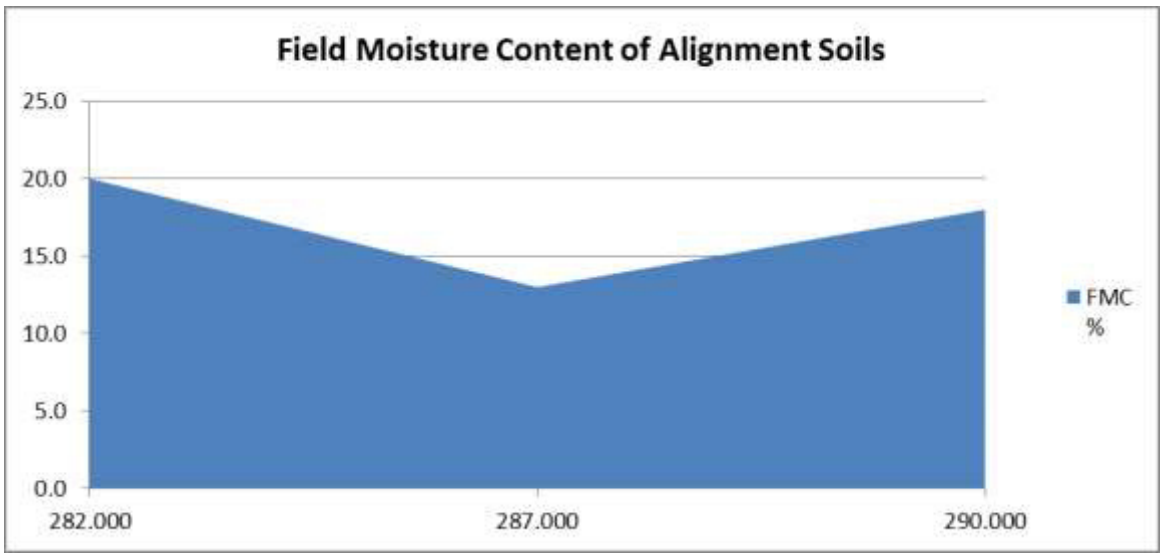

Fig. 6.2: Field Moisture Content

(II) Dynamic Cone Penetration Test

Dynamic Cone Penetration tests were conducted at the small pit locations to assess in-situ CBR on alignment soil, which will be below sub-grade level. The CBR value was calculated based on different soil layers encountered. The slope change in the graph (Penetration Vs Number of Blows) indicates the interface of two layers of different penetration resistance. From the graph, thickness of layer and slope (penetration mm/blow) were calculated. The following TRRL equation has been used to calculate the layer DCP-CBR value for each layer:

$$\log_{10}(\text{CBR}) = 2.48 - 1.057 * \log_{10}(\text{mm/Blow})$$

These layered CBR values have been converted to overall CBR value using Japanese formula for the purpose:

$$\text{Overall CBR} = \left\lceil \frac{\Sigma\,(\text{Layer thickness}\,(\text{DCP-CBR})^{1/3})}{\Sigma\,(\text{Layer thickness})} \right\rceil^{3}$$

Fig. 6.3 exhibits representation of the equivalent CBR based on DCP test results. Field dry density, field moisture content and DCP test results showing penetration of cone in cm and number of blows at each pit are plotted and given in **Annexure 6.9.** A summary of the results is presented in **Annexure 6.1**.

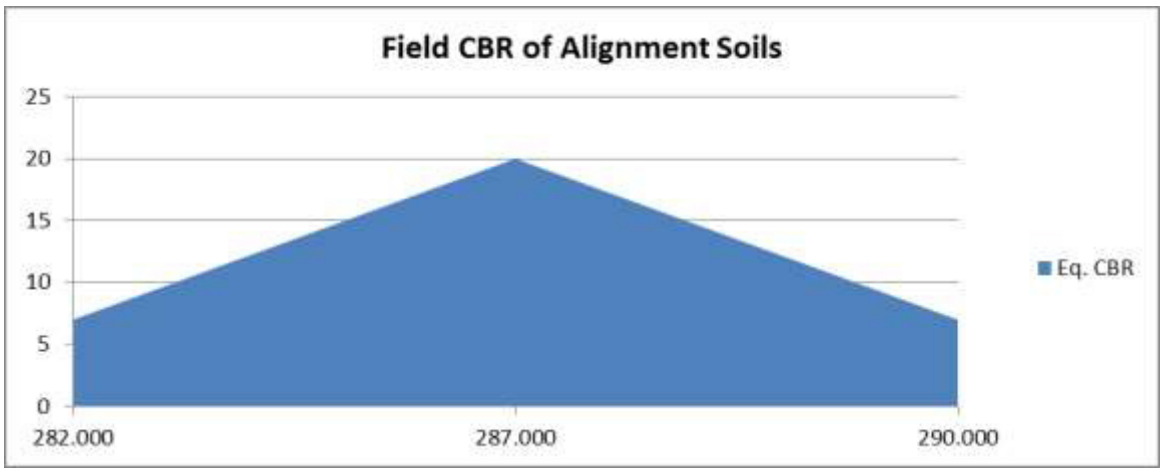

Fig. 6.3: DCP CBR (Equivalent)

6.4.2 Laboratory Tests of alignment soil

Large trial pits of size 60 cm x 60 cm were dug up to a depth of 1.0 m to 1.5 m and about 40 kg of soil sample was collected in bag from each such test pit for testing in the laboratory. The identification mark and location of the sample were recorded and sent to the laboratory installed at site for conducting the tests indicated in **Table 6.1**.

A total of 3 alignment soil samples were collected along this stretch of the project corridor.

(I) Classification and Distribution

The results of laboratory tests are furnished in **Annexure 6.2** for both directions.

The following **Table 6.3** provides a summary of the soil class and properties of the soil class encountered in the field along the alignment.

Table 6.3: Summary of Alignment Soil Properties (MVE Main)

Soil Class	**CI**
Number	3
Range of LL (%)	44-48
Range of PI (%)	18-24
Range of FSI (%)	36.4-70

(II) Free Swell Index

Due to the general prevalence of expansive soil and particularly black cotton soil in the area, Free Swell Index (FSI) test was performed on all samples. **Fig. 6.4** exhibits a representation of the test results.

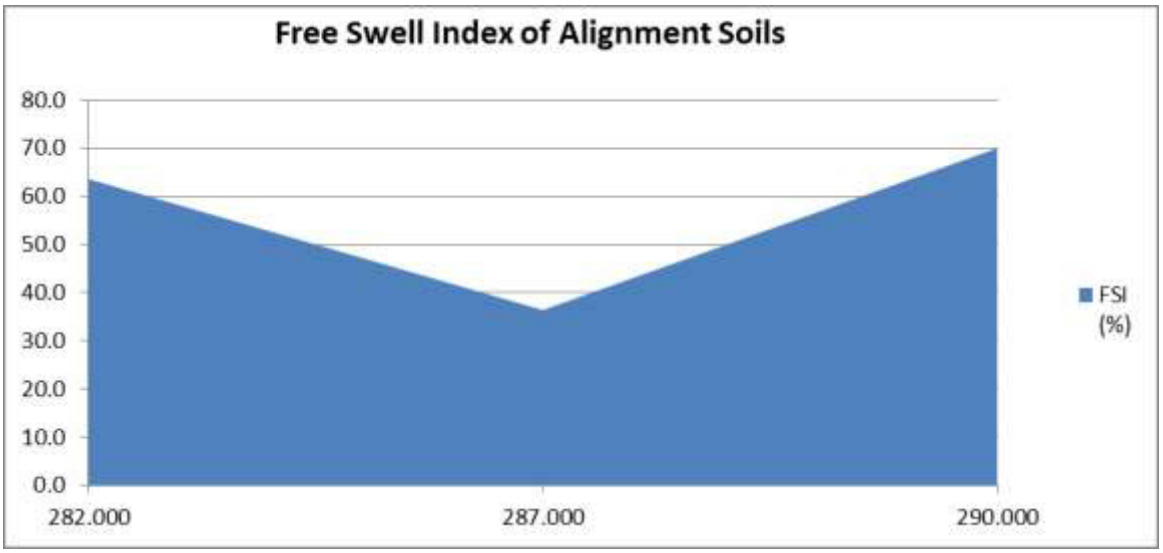

Fig. 6.4: Free Swell Index

6.4.3 Interpretation of test results and Recommendation

Based on the field observations and detailed study of the results of the investigations (*data in Annexure 6.2 and Plates 2.1 through 2.4 for Alignment Soil of MVE Main in Annexure 6.10*), following interpretations and recommendations are made:

It is evident that the entire roadway corridor will be built on embankment structure. Hence, the natural ground at its current level will hardly serve as the subgrade level. So, laboratory CBR test has not been performed on any of the samples.

- The primary investigation of alignment soil indicated that the existing top soil in the stretch from ***Km.279.000 to Km 292.000*** is either expansive in nature or low in strength. Moisture content (FMC), density (FDD) and DCP-CBR (represented as Equivalent CBR) were conducted on the in-situ samples in the reach from ***Km.279.000 to Km 292.000***. Plates 2.1 through 2.4 in Annexure 6.10 provide a schematic profile with remarks for each of the test pits conducted along the project corridor.
- Based on subsequent detailed geotechnical investigations carried out at the structure locations and considering the test pit data at the locations not covered by detailed geotechnical investigations, the following areas critical for high embankment construction are identified:

Table 6.4 Location of Critical High Embankment

Stretch	Remarks	
km 279 to km 292	Anticipated settlement is more than 600 mm for high embankment (>10 m) construction	Anticipated settlement is more than 300 mm (< 600 mm) for high embankment (>8 m) construction

Annexure 6.10A and **6.10B** provide summary and soil profile of the consolidation settlement anticipated for the various heights of the embankments envisaged along the project corridor respectively.

- Generally, locations having CI type as soil where FSI is found to be generally more than 50, are unsuitable for embankment's foundation base. Based on the anticipated settlement as per the expected height of the embankment at these locations, replacement by better soil up to a minimum depth of 0.5 m to 1 m is required for the construction of embankment.

6.5 SURVEY AND INVESTIGATION OF BORROW MATERIALS FOR CONSTRUCTION

The materials commonly used in highway construction comprise of the following broad items:

1) Borrow materials like soil and gravel
2) Quarry materials like hard stone metal (aggregates) and sand (fine aggregates)
3) Manufactured materials like cement, steel, and bitumen
4) Other construction materials like water ,fly ash, etc.

It is a prime task to identify the potential source of these materials near the project site so as to economize the cost of construction besides early completion of the project.

6.5.1 Borrow Area Soil

Extensive survey was conducted to locate the potential source of borrow area soil required for the construction of embankment and subgrade.

A total of 2 borrow areas located on both sides along the project road were identified. The locations, lead, owner and tentative area of borrow soil available are given in **Annexure 6.3**.

Table 6.5 presents a summary of the tests conducted and evaluation of borrow soil for construction of embankment and subgrade. *Plates 2.1 through 2.4* for Borrow Area Soil in **Annexure 6.11** provide a schematic profile with remarks for each of the borrow area test pits conducted along the project corridor.

Table 6.5: Summary of Tests and Evaluation of Borrow Soil (VME Main)

(Refer to **Annexure 6.3** *and Plates 2.1 through 2.4 of* ***Annexure 6.11*** *for detailed test results)*

Sl. No.	Class of soil	No. of borrow areas	Anticipated lead (km)	Range of CBR at 97% of MDD (%)	Free Swell Index (FSI)	Suitability
1	Silt with low compressibility (ML)	1	2	7	16.6	Suitable for embankment construction. Stabilization of soil is required for use in subgrade
2	Clay with medium compressibility (CI)	1	1.7	4.1	31.8	Suitable for embankment construction. Stabilization of soil is required for use in subgrade

The basis of determining suitability has been guided by the following factors.

Table 6.6: Criteria for Suitability of Borrow Area Soil (VME Main)

Sl. No.	Type of Suitability	Free Swell Index (FSI) %	CBR (%)	Remarks
1	Suitable for both embankment and subgrade	< 50	> 10	0 % of the investigated borrow areas meet the requirements.
2	Unsuitable for subgrade; soil stabilization will be required for use in subgrade.	< 50	<10	100 % of the borrow areas will be subject to stabilization if used in subgrade
3	Suitable for embankment	< 50	> 4	100 % of the borrow areas qualify
4	Borrow areas unsuitable for road construction	> 50	NA	0 % of the borrow areas rejected (Refer to Clause 305.2.1.2 MoRT&H)

The distance of these borrow areas from the project road location varies in the range of 1.7 to 2 km as shown in the borrow areas Lead Chart placed in **Annexure 6.12**.

Laboratory Permeability test results on select samples showed no discharge when samples were kept under testing for two to three weeks period of time.

6.5.2 Inferences and Recommendations

From the type of soil locally available in the area, and their engineering characteristics ascertained from laboratory test results, the following inferences / recommendations are made:

- Giving due allowance for possible variability during construction operations, it is suggested that soil from borrow areas which have shown a soaked CBR in the range of 4-7 % (not meeting CBR of 10 %) and FSI < 50 be considered for embankment construction as indicated in **Table 6.6.** Accordingly, following recommendations are made in respect of the sub-grade CBR to be considered in the design of pavement:
    - From Km Km.279.000 to Km 292.000: 10 % with lime stabilization
- Based on the above recommendations, approximate lead of the borrow areas identified for sub-grade and embankment material during field study is assessed and the same are furnished hereunder:

  (a) For Embankment (Natural Soil)
    - Km.279.000 to Km 292.000.

  (b) For Sub-grade with lime stabilisation

  Km.279.000 to Km 292.000

The above leads are based on the findings of limited time and scope of this investigation and can be considered in estimating the project cost. It is likely that during actual execution of the project Contractors will carry out more detailed

investigation and the leads may be less than what has been established here in this report and lime stabilization require to achive effective subgrade CBR of 10 %.

- Approximate quantity of embankment and sub-grade material which is likely to be available in the borrow areas identified during the field investigation are estimated as follows:
  - Embankment Material of CBR > 4%: Sufficient quantity
  - Sub-grade Material of CBR (lime stabilization)> 10%:Sufficient quantity

  As mentioned in the preceding paragraph, during actual execution at site, Contractor will make effort to identify additional borrow areas with lesser lead. Hence, selected earth is anticipated to be available meeting the sufficient requirements over and above the estimated quantity.
- A comparative study of the CBR achieved on randomly selected borrow area soil samples stabilized with lime (2 %) and/or cement (2 %) /sand as presented in **Table 6.7**. Sand stabilization has resulted in no substantial positive improvement. Detailed results are presented in **Annexure 6.4.**

Table 6.7: Summary of Tests on Stabilization of Borrow Soil (MVE Main)

Sl. No.	Chainage of Borrow Area Soil Tested	CBR			
		Without Stabilization	Lime (2 %) Stabilization	Cement (2 %) Stabilization	Sand Stabilization
1	280+500	4	40.5	-	4

Choice of Stabilization Process

Suitability based on type of subsoil:

As is evident from the test results, lime stabilization will be appropriate and suitable for the type of soils encountered in the borrow areas within the stretch(s) exhibiting CBR<10 and FSI<50. The soils within the subject stretch meet the requirements outlined in Clause 3.2.2 of IRC 51: 1992 on Guidelines for the use of Soil-Lime Mixes in Road Construction stating that for effective stabilization, a soil must have a fraction passing 425 micron mesh not less than 15 % and a minimum PI of 10 %.

As per Clause 3.1.2 of IRC: 50 – 1973 on Recommended Design Criteria for the use of Cement Modified Soil in Road Construction, cement stabilization is not suitable for heavy clays including black cotton soil.

Suitability based on Strength Gain:

According to Clause 4.2 of IRC 51: 1992 on Guidelines for the use of Soil-Lime Mixes in Road Construction, the CBR value in the field should be adopted as 60 to 70 % of that obtained in the laboratory depending on related site factors during construction. Under the unpredictable circumstances related to mixing, placing and curing during construction, it is recommended to add a minimum of 2 % lime for soil-lime stabilization purposes in order to achieve an optimum design CBR.

Based on the criteria of strength gain also, lime stabilization suffices as the appropriate process.

Quality Control for Lime Stabilization

(i) In addition to the contents of Clause 7.4 of IRC 51: 1992 on the degree of pulverization, reference should be drawn to IRC 49: 1973 on Recommended Practice for the Pulverization of Black Cotton Soils for Lime Stabilization.

(ii) In addition to the contents of Clause 7.5 of IRC 51: 1992 on Moisture Content prior to compaction, it is recommended that the moisture content of the borrow soil subject to lime stabilization be maintained at 8 % to 10 % for effective stabilization. This may require drying of the borrow soil at some locations where the in-situ moisture content exceed the indicated percentage.

Recommendation on design CBR for lime stabilized soil:

Based on the results of the tests carried out on soil stabilized with lime in the laboratory, 2% lime is recommended to be added with soil of CBR less than 5% to achieve minimum 4-days soaked CBR of 26% in the laboratory, which means with 2% lime stabilization, the pavement can be designed with minimum CBR of 10%. But adoption of lime stabilized sub-grade at site has many disadvantages in respect of following aspects:

- Availability of raw materials for producing limes of desired quality. From enquiry made during field investigation it is learnt that minimum lead of limestone from project road will be more than 500 km.
- For producing required quantities of lime, a number of plants are to be installed at site.
- Close supervision is required to maintain the quality of lime that will be produced in the site plants
- Intense supervision is required during mixing, placing and testing of stabilized sub-grade.
- The cost of lime stabilized sub-grade is more than double the cost of preparing sub-grade with selected earth transported from a lead of 15 km.
- Progress of the construction of lime stabilized sub-grade will be much less than that of constructing sub-grade with selected earth of leads even greater than 15 km.

It is evident that there is some direct savings in the cost of bituminous layers of the designed pavement composition due to improved sub-grade CBR by use of lime stabilization. However, the disadvantages of lime stabilized soil outweigh the direct cost savings by manifold. Hence, it is recommended to use sub-grade materials from identified borrow areas irrespective of the considerable lead. This will result in constructional convenience, achieve desired quality of work, work progress and overall cost savings. However, at the time of execution, if it is found difficult to get sufficient quantities of selected earth of design CBR, lime stabilization (with 2% lime of quality specified under clause 402.2.2 of MoRT&H) may be considered as an alternative option.

6.6 QUARRY MATERIALS

(I) Stone Metal

One (1) stone quarries were identified as the potential source of coarse aggregates required for road construction, the lead distance from the project road

is found in the range from 50 km. The test results are presented in **Annexure 6.5A** whereas the lead charts are given in **Annexure 6.12**.

Table 6.8 presents a summary of the tests conducted and evaluation of stone metal for construction of pavement.

Table 6.8: Summary of Tests and Evaluation of Stone Metal

(Refer to **Annexure 6.5A** *for detailed test results)*

Sl. No.	Quarry Location	Specific Gravity	Water Absorption	Flakiness	Elongation	AIV (%)	LAV (%)	Soundness (%)	Suitability
1	Km 258+221 R/S Netrang / Near Ankaleswar	Ok	Ok	X	X	√	NA	NA	*Suitable for construction of road work including bituminous work and concrete work involved in the structures as all properties except flakiness and elongation are satisfactory with respect to their specified / desired values.*

Legend: "√"indicates MoRT&H specifications are met for use in bituminous and granular base layers

"X" indicates MoRT&H specifications are not met for use in bituminous and granular base layers,

One aggregate sample of AIV 7.5% was tested for Polished Stone Value (PSV), which is the indicative of skid resistance, to ascertain the suitability of material for use in Bituminous Concrete (BC) and the results are found in the range 56.5 which is more than 55 specified for BC in MoRT&H specification. The affinity of coarse aggregate for bitumen is one of the important factors, which affects durability of bituminous mix. To assess this property of aggregate, results of following two tests are required.

- The Stripping and Coating test of aggregate-bitumen mixture as per IS 6241, which will give qualitative indication of adhesion property of aggregate with bitumen.
- Water sensitivity test as per AASHTO-T283, which is done by Marshall Testing machine with two 12.7 mm wide metal strips. It will give quantitative value to predict the long term stripping susceptibility. Stripping was carried out on selected samples of other packages. Test result was found to be satisfactory and test result is presented in **Annexure 6.5A.**

(II) Sand and Stone Dust

A total of one (1) sources were identified as potential sources for sand. The lead distance from the project vicinity is found in 4 km. Lead chart of these identified sources is shown in **Annexure 6.6**.

Table 6.9 presents a summary of the tests conducted and evaluation of sand for use in different pavement courses and cement concrete. **Table 6.10** presents test result of stone dust for use as fine aggregate.

Table 6.9: Summary of Tests and Evaluation of Sand (Main MVE)

(Refer to **Annexure 6.6** *for detailed test results)*

Sl. No.	Source	Specific Gravity	Fineness Modulus	Zone	Suitability
1	Narmada River Sand	Ok	√	II	Suitable for all grades of concrete and also can be considered to be used in granular base and sub-base course of pavement structure.

Legend: "√" indicates MoRT&H specifications are met

Table 6.10: Summary of Tests and Evaluation of Stone Dust (Main MVE)

(Refer to **Annexure 6.5A** *for detailed test results)*

Sl. No.	Quarry Location	Specific Gravity	Water Absorption	Zone	Suitability
1	Km 258.221 R/S	√	√	II	Stone dust available from crusher plants and assigned with a "Zone" are suitable for use in concrete as these belong to Zone II and Zone I as per IS: 383.Materials are also suitable for use in all the layers of pavement structure.

(III) Fly Ash

Fly ash is proposed to be used as light weight fill material for the embankments. The use of fly ash will potentially reduce the settlement for locations where high embankments are anticipated.

Fly ash samples have been collected from two sources namely Nani Naroli (GIPCL, Surat) and Ukai (GETPC, Ukai).

Fly ash sample from Nani Naroli exhibits a CBR of 175 % and the other one from Ukai exhibits a CBR of 5 %. Tests were repeated to confirm the high CBR from Nani Naroli, which may be due to its chemical composition. Some of the observations are noted below. Refer to **Annexure 6.7** for the detailed test results.

- Owing to the good CBR and reasonably low dry density and specific gravity, the fly ash can be considered as good embankment material.
- Since its permeability is on higher side of the range generally specified for fly-ash, no constructional problem is anticipated during rainy season as it will behave as free draining material.
- The only deficiency observed is its angle of internal friction which is observed to be much less than the usual range of 35 - 42 degree for fly-ash. Therefore,

when used in high embankment, adequate provision of good quality of cover soil is to be made to ensure stability of slopes.

- Fraction passing 75 micron is observed to be more than 50 %. These kinds of properties indicate that it can also be used in cement concrete to replace 15 - 20 % cement.

6.7 WATER

Water samples were collected from available sources (river, hand pump and bore well) located within the project-influenced area.

Table 6.11 presents a summary of the tests conducted and evaluation of water for use in construction work.

Table 6.11: Summary of Tests and Evaluation of Water (MVE Main)

(Refer to **Annexure 6.8** *for detailed test results)*

Sl. No.	Source	pH	Chloride	Sulphate	Acidity	Alkalinity	Organic Matter	Inorganic Matter	Suspended Matter	Suitability
1	Narmada River (Ch 284.419)	√	√	√	√	√	√	√	√	Suitable material for any road work; recommends to be limited to concrete related work

Legend: "√" indicates MoRT&H and/or IRC specifications are met

6.8 MANUFACTURED MATERIALS

(I) Cement

Ordinary Portland cement of Grade 43 and 53 manufactured by various manufacturers are locally available. Cement shall be conforming to IS: 8112 and / or IS: 12269. During material survey, 19 factories are identified nearby the project area. List of factories are shown in **Table 6.12**.

Table 6.12: List of Cement Factories available near the Main Expressway

Sl. No.	Name of the Factory	Name of the City	Name of the State	Lead Distance (Km)	
				From Mumbai	From Vadodara
1	ACC Ltd	Chanda	Maharashtra	935	960
2	Century Textiles & Industries Ltd	Manikgarh		910	965
3	Grasim Industries Ltd	Hotgi		370	800
4	Ultra Tech Cement Ltd	Chandrapur		930	955

Sl. No.	Name of the Factory	Name of the City	Name of the State	Lead Distance (Km)	
				From Mumbai	From Vadodara
5	Ambuja Cement Ltd	Chandrapur		930	955
6	Narmada Cement Co Ltd	Ratnagiri		355	790
7	Indorama Cement Ltd	Raigad		35	400
8	Orient Cement	Jalgaon		430	450
9	Shree Digvijay Cement Company Ltd.	Sikka	Gujarat	825	395
10	Saurashtra Cement Ltd.	Ranavav		920	490
11	Gujarat Sidhee Cement Ltd.	Veraval		935	505
12	HMP Cements Ltd.	Porbandar		930	500
13	UltraTech Cement Ltd.	Pipavav		745	315
14	UltraTech Cement Ltd.	Jafrabad		775	345
15	UltraTech Cement Ltd.	Magdalla		310	170
16	Ambuja Cements Ltd.	Kodinar		980	550
17	Ambuja Cements Ltd.	Kodinar		980	550
18	Ambuja Cements Ltd.	Magdalla		310	170
19	Sanghi Indus. Ltd.	Abdasa		1065	635

(II) Structural Steel

High strength deformed bars manufactured by various steel manufacturing companies conforming to IS 1786 are available with local stockists. Before incorporation into the work, steel shall be got approved by the engineer.

(III) Bitumen

Since the project road will be subjected to high intensity of traffic during the design period, it is recommended to use elastomeric type of Polymer Modified Bitumen (PMB – Styrene Butadiene Styrene i.e. SBS) in the bituminous wearing course. Elastomeric type of PMB is preferred over plastomeric type PMB as the former has the ability to resist permanent deformation as well as to minimize fatigue cracking, thermal cracking and ageing. The strength of bituminous mix of

SBS type of PMB increases with elongation and hence will be more suitable for high traffic growth.

For binder course, viscosity grade of bitumen conforming to IS: 73 – 2006 is suggested. Considering the climatic condition prevailing in the project influence area, VG-30 grade will be suitable.

Three (3) sources are identified as nearest sources of bitumen one is HPCL, Mumbai in Maharashtra State, IOCL, Vadodara and Jamnagar in Gujarat State.

6.9 EVALUATION OF MANUFACTURED MATERIALS

These materials are manufactured items and conforming to the relevant IS codes and complying with the provisions made in the specifications of MoRT&H.

6.10 MIXED MATERIALS OF PAVEMENT

The flexible pavement has been designed to comprise the following materials:

Surface/Wearing course	-	Bituminous Concrete (BC) / Stone Matrix Asphalt (SMA)
Bituminous Base Course	-	Dense Bituminous Macadam (DBM)
Granular Base Course	-	Wet Mix Macadam (WMM)
Cemented Base Course (optional)	-	Cement Treated Base (CTB)
Sub-base Course	-	Granular sub-base (GSB)

The rigid pavement has been designed to comprise the following materials:

Drainage Layer	-	Granular Sub-base (GSB)
Sub-base Course	-	Dry Lean Concrete (DLC)
Wearing Course	-	Pavement Quality Concrete (PQC) / Steel Fiber Reinforced Concrete (SFRC)

During the investigation the locally available materials have been given due consideration for reducing cost of construction.

6.10.1 Granular Sub-base (GSB)

The composition of GSB material will comprise crushed aggregates of the identified quarries and sand classified as zone -1 of identified sources. The results of the tests carried out on samples of aggregates and sand suggest that their mix of gradation as specified under Clause 401.2 of MoRT&H will give much more than desired CBR of 30% and Ten Percent Fines Value of 50 kN. Since the GSB layer will also function as a drainage layer, it is suggested to adopt Grading I of MoRT&H Specification Table 400 – 1 with minor changes in gradation limit of 0.425 mm & 0.075 mm. The modified gradation is recommended as follows:

Sieve Designation	Grading
20 mm	100%
13.2 mm	70 – 80%
9.5 mm	60 70%
4.75 mm	28 – 36%
2.38 mm	4 – 8%
2.00 mm	0%

6.10.2 Wet Mix Macadam (WMM)

WMM will comprise crushed, graded aggregate and crusher run stone dust produced from the rocks of identified quarries. It is recommended not to use river sand. Based on the gradation of different size of aggregates produced in the crusher plant, job mix formula will be established so that resulting gradation of designed mix conform to the grading requirements given in Table 400 – 11 of MoRT&H.

6.10.3 Cement Treated Base (CTB)

CTB is being contemplated to be laid over subgrade of minimum CBR 10 % and a layer of GSB of 30% CBR. Over CTB layer, a layer of WMM (which will give minimum CBR of 80%) will be provided. Considering this sequence of layers, CTB will be designed for a minimum CBR of 60% and E-value of 2000 Mpa which has been considered in one of the design options. Material used for the CTB will comprise graded aggregate (gradation as per Table 400 – 4 of MoRT&H), sand of identified quarries and cement complying with the requirements of IS 269, 455 or 1489. It is envisaged that 4% cement content will produce CTB mix of desired properties.

6.10.4 Dense Bituminous Macadam (DBM)

DBM will comprise crushed, graded aggregate and crusher run stone dust produced from the rocks of identified quarries. Viscosity grade of VG – 30 conforming to IS: 73-2006 will be used in DBM mix. Based on the individual gradation of aggregates, job mix formula will be established in accordance with MS-2 of Asphalt Institute and MoRT&H specification.

6.10.5 Bituminous Concrete (BC)

BC will comprise crushed, graded aggregate and crusher run stone dust produced from the rocks of any of the identified quarries except Oteva and Zankharwadi quarry. Elastomeric type polymer modified bitumen of Grade- 40 (PMB-40 conforming to IRC: SP 53) is considered to be used in the BC mix. Based on the individual gradation of aggregates, Job Mix Formula will be established in accordance with MS – 2 of Asphalt Institute and MoRT&H specifications.

6.10.6 Stone Matrix Asphalt (SMA)

Since the project road is likely to experience heavy traffic during second stage of the design period, it is proposed to provide SMA, which is considered as highly rut resistant bituminous course, both in binder and wearing course of the overlay designed for the subsequent stages of construction after the first stage. Besides resistance to deformation at high pavement temperature, it will improve skid resistance and reduces noise over conventional wearing course like BC.

The 13 mm SMA as per Table 3 of IRC: SP 79 – 2008 is proposed for wearing course of designed thickness and the 19 mm SMA as per same Table is suggested for binder course. Only those aggregates of identified quarries, water absorption of which have been obtained as less than 2%, will be used in the SMA mix. Other physical requirements specified for coarse aggregates of SMA are observed to be satisfactory for the aggregates samples collected from the said identified quarries. Mineral filler and stabilizer additive in the form of pelletized cellulose are other two components of SMA mix. Stone dust of grading requirement given in Table 2 of IRC: SP 79 is recommended to be used as Mineral Filler. The SMA mixture will be designed using AASHTO MP8 - Standard Specification for Designing Stone Matrix Asphalt and AASHTO PP41- Standard Practice for Designing Stone Matrix Asphalt. Though cost of SMA will be about 25 – 30% higher than that of

conventional BC, the pavement layers prepared with SMA will be much more durable and rut resistant than BC mix and hence the cost of maintenance will get minimized.

6.10.7 Dry Lean Concrete

Dry lean concrete will be provided as the sub-base of the PQC of rigid pavement. Aggregates of the identified sources will be used in the concrete mix. Since the test results of more than 50% of total water samples collected during the field investigation shows sulphate content more than the specified limit, it is envisaged that the soil around DLC may have soluble sulphates in excess of 0.5% and hence as per IRC: 15 – 2002, it is advisable to use sulphate resistant cement conforming to IS: 6909 in the stretches where founding soil contains excessive sulphate content. Otherwise, OPC 33 Grade (IS: 269) and OPC 43 Grade (IS: 8112) are proposed to be used. Fly ash based Portland Pozzolona Cement (PPC) conforming to IS: 1489 may also be considered to be used in view of the fact that PPC offers greater resistance to the attack of aggressive water containing sulphates & chlorides (a situation which is prevailing in the stretch falling in the state of Maharashtra).

6.10.8 Pavement Quality Concrete (PQC)

Pavement Quality Concrete (PQC) will be provided as the wearing course of the rigid pavement. Aggregates of all the identified sources are found suitable for PQC. In view of excess sulphate content in the surrounding soil / water used for the construction work, it is advisable to use sulphate resistant cement conforming to IS: 12330 for PQC. Alternatively, it is suggested to use blended cement using Portland Slag Cement (PSC) conforming to IS: 455 and Portland Pozzolona Cement (PPC) conforming to IS: 1489 in designed proportion. Laboratory Study (refer technical paper “Pavement Quality Concrete using Blended Cement” by Tiwari and A.K Bandyopadhyay, The Indian Concrete Journal, February 2002, vol.76, No.2) made on such type of blended cement suggests that the flexural strength, which is the guiding criteria of the rigid pavement design, is obtained as high as 6.9 Mpa against the required 4.5 Mpa as prescribed in Clause 4.1.4 and 4.4 of IRC: 15-2002.

6.10.9 Steel Fiber Reinforced Concrete (SFRC)

Steel fiber reinforced concrete is being considered as alternative to the conventional plain PQC as stated in previous Section 2.9.8. Consultant has experienced that widespread cracking due to secondary effects like temperature and shrinkage in fresh concrete is quite common, which affects the performance of the rigid pavement. Therefore, with a view to improve flexural strength, ductility and fatigue resistance of the pavement concrete, SFRC in which small steel fibers are spread randomly throughout the concrete mix, is suggested as better alternative to plain PQC. It is an established fact that incorporation of fibers in concrete not only increases its flexural strength considerably but also gives the concrete well defined post cracking behavior. Therefore, applying these criteria, designed thickness determined as per para 2.2 of IRC: SP: 46 - 1997 will be decreased. Various laboratory studies have shown that there is an appreciable increase of about 30 – 40% in modulus of rupture due to addition of 0.8% fiber to plain concrete. Based on these findings, it is observed that designed thickness of 330 mm of PQC can be substituted by 280 mm of SFRC i.e., 50 mm decrease in pavement thickness.

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HYDRAULIC AND HYDROLOGICAL INVESTIGATION

7

7. HYDRAULIC AND HYDROLOGICAL INVESTIGATION

7.1 INTRODUCTION

This alignment passes through plain terrain and hydro-meteorological region of state of Gujarat. Hydrological investigations of this alignment have been carried out by devoting independent time and human resources. Findings of the detailed investigations and design reports have, thereafter, been presented into this comprehensive write up. The proposed alignment, for a few kilometers, runs through the ravines of Rivers Mahi and Meni before it ends at NE-1 near Vadodara at Km 378+740 The ravine area is stated to be erosion prone and full of deep gorges. The embankment of the proposed road over these gorges requires protections like retaining wall and / or stone pitching. As such, it runs through regions having varied hydro-meteorological characteristics apart from being distinctly different in terms of land use, land cover and soil parameters.

As the proposed alignment mostly runs parallel to existing NH8, rivers crossing the proposed alignment were studied at the proposed crossing points and at the existing bridge points on NH8. The performances of these bridges during critical flood years (2004 and 2006) were recorded from local enquiry.

Data collected from the Reconnaissance were collated and duly analysed. Data from other agencies were also collected during reconnaissance to substantiate the preliminary design.

7.1.1 Objective of the Visit

The reconnaissance surveys of Main Expressway were carried out with the following objectives:

- To get a general idea regarding the topography of the catchment areas.
- To collect information regarding performance of the existing bridges on NH8 and other nearby Roads during recent critical flood years (1998, 2004 and 2006 for Expressway).
- To collect information regarding performance of the NH8 embankment and other important road embankments during critical flood years.
- To collect field data regarding HFL, LWL, HTL of the rivers / streams.
- To collect discharge and HFL data, to the extent feasible, from local offices of Central Water Commission and other Government Agencies like MIDC, State PWD and Irrigation.

7.1.2 Observations and Data Collected during Site Investigations

Following are some important points observed during the Hydrological Investigations:

This package passes through plain terrain

- Many of the minor proposed bridges are in the vicinity of old vented causeway structures constructed over the local roads across local streams. These existing structures shall have a bearing on the hydraulic design of the proposed structures. Apart from these vented causeways, weirs are also there across local streams for facilitating local irrigation. These weirs, when in the vicinity of the proposed crossing points, shall also affect the design of the proposed structures.

- In many places within the stretch between Vadodara and Ghodbandar, NH8 has been / is being widened. It was observed that the bridges over the widened portions (new) were higher than the older ones though the distances between their abutments (Gross waterway) were, in most of the cases, same. This observation gave an idea that the vertical clearances of the older bridges were encroached while passing some critical discharge. The new bridges have fewer piers providing more net waterway for passing flood discharge. Local enquiry reveals that the new bridges, in most of the cases, have passed 2004 / 2006 floods without any harmful afflux. However, scour holes and dislocation of bed blocks were clearly visible in many bridges on NH8. Some of the appended photographs show difference in levels of new and old bridges over NH8.

New and Old Bridges over Wanki on NH-8 showing difference of level

- No instance of outflanking of bridge abutment was visible or informed.
- No instance of NH8 overtopping was visible or informed.
- The rivers which have overtopped the existing high level bridge decks during recent floods are as follows:
  - River Dhadhar on Karjan-Padra Road Bridge, Pingalwara, in the Year 2006, 3.68 Km upstream of the proposed crossing (Km 336+830).
  - River Meni on Vadodara-Singhrot Road Bridge, in the Year 2006, 5.08 Km downstream of the proposed crossing (Km 365+976).
  - Frequent overtopping of Bajwa Chhanni Road Bridge, 150 m downstream of proposed crossing of local stream at km 372+028.

  Annexure 7.1 reflects the bridge points visited and information about their hydraulic performances during recent floods.
- The major river Narmada experience tidal fluctuations in water levels at the proposed crossing points with the expressway. The maximum extent of tidal fluctuation generally observed was 3m, as informed by the local people. Men made barriers are constructed across the river because of manmade barrier constructed across them to prevent ingress of saline sea water into the landward course. Such weirs prevent sea water from coming into the main course but at the same time cause a constant pool of water to remain in the river. Such pools are, as in the case of Mahi, used to draw water for drinking / industrial purpose. The hydraulic consequence of construction of such weirs is reduction of effective area of the rivers, upstream of such weirs, irrespective of prevalent tidal cycle at any particular instant. The heights of most of these gated weirs are not more than 2m - 2.5m above average bed levels of the rivers.
- **Annexure 7.2** shows the data collected from The Office of the Executive Engineer, Tapi Division, Central Water Commission, Surat. These data do not include the flood data for the Year 2006.
- In addition, some additional data relating to annual series of peak discharge and corresponding water level for river Narmada have been received from CWC in connection with river modeling study.

- The following **Table 7.1** reflects some additional data collected during the site visit:

Table 7.1: Additional Data Collected

Sl. No	Date	Name of River	Location	HFL (m), CWC Datum	Max Discharge observed in Cumec	Corresponding Measured (Local) Rainfall (24 Hour) in mm.
1	Sept., 1970	Narmada	Golden Bridge	12.65	Discharge data not available	Not Available

The following **Table 7.2** reflects some additional data relating to some river bridges on NH8 collected from the Office of the Project Director, NHAI, Vadodara

Table 7.2: Additional Data Collected from PIU, NHAI

Sl. No	River	Location	Design Discharge (Cumec)	Length of Existing Bridges (m)	HFL (m, Datum not specified)
1	Narmada	NH8	73650	1346.65	14.17
2	Dhadhar	NH8	3800	221	99.92

River Modeling

It was decided that physical modeling study for Rivers Tapi and Narmada shall be carried out to finalize hydraulic design of proposed bridges across these rivers and to decide the alignment and details of the guide bundhs, if required. Central Water and Power Research Station (CWPRS) has been assigned to carry out these studies with requisite input from ICT. Additional hydraulic data for the Rivers Tapi and Narmada have been procured by ICT from CWC to facilitate the studies. Satellite Imageries of Cartosat-1 (Stereo Orthokit Digital Data) from National Remote Sensing Centre, Hyderabad, were also purchased. These imagery data were processed in GIS platform with the help of control points picked up from sample topographical survey of the study area. Cross sections and longitudinal sections for long stretches of Rivers Tapi and Narmada were generated from the processed satellite Imageries. Cross sections generated from processed imageries, however, were found grossly inconsistent with actual cross section survey carried out in limited areas. These data could not, therefore, be used for modeling studies.

Fresh cross section and longitudinal surveys were carried out along and across these two major rivers covering a length of about 10 km upstream and downstream of the proposed crossings, to generate cross / long sections of these two rivers, The sections of these rivers, generated from actual survey, were handed over to CWPRS for modeling studies. Set of Data required by CWPRS was provided. On consideration of the above data, CWPRS submitted the river modeling report for both the major bridges.

The hydrological model study report of CWPRS for Narmada River (Technical Report No. 5269) is enclosed as **Annexure 7.11.** The design and drainages have been review in line with CWPRS report.

7.2 COMPILATION, STUDY, ANALYSES OF DATA AND FORMULATION OF DESIGN APPROACH

The Design Approach has been formulated through careful examination of data collected from site, relevant Offices of State / Central Govt. and desk study of the imageries of west flowing river Mahi.

7.2.1 Rivers / Streams in General

The following table provides brief description of the major Rivers either crossing or running (near and) parallel to the project road. Although River Mahi shall not be crossing the proposed alignment, it has influence on the proposed crossing with River Meni, one of its main tributary. The HFL of River Meni is to a large extent dependant on the flood level at its confluence with Mahi. Other tributary rivers are there in the proposed reach between, which experience similar problems of choked outlet as river Meni faces.

Table 7.3 showing brief details of the outfall points / estuaries of relevant major west flowing rivers is given below.

Table 7.3: Details of Outfalls / Estuaries

Sl. No.	Name of River	Type of River at crossing point	Approximate Km of crossing	Distance of Crossing Point or confluence with main river from sea mouth (Km)	Brief details of outfall / Estuary	Tidal Fluctuation at Crossing point / confluence point
1	Mahi	NA	NA	80.26	Gulf of Khambat	NA
2	Meni	Narrow, Deep	365+976	7.85 (proposed crossing point from confluence with Mahi)	Mahi, 2.2 km downstream of Singrot dam	Not felt at proposed crossing point
3	Dhadhar	Narrow, Deep	336+830	83.18	Gulf of Khambat	Not felt
4	Narmada	Shallow Wide	284+428	41.23	Wide and Shallow	Observed

Note: A Wide, shallow Channel has Width / Depth of Flow > 50.

River Mahi and River Dhadhar discharge into the Gulf of Khambhat which is shallow and full of sandbanks and shoals. The effect of tidal fluctuation in the Arabian Sea becomes alarming in the gulf owing to its relatively narrow expanse and shallow depth. Though the proposed crossing with Dhadhar is more than 83 Km away from the sea mouth and does not experience tidal fluctuations, it is understood that the river, at its outfall, cannot discharge with ease into the shallow gulf during rising tides. The proposed crossing of Dhadhar is at a distance of 3.1 Km from its confluence with River Viswamitri. The waterway of the existing bridge on Karjan Padra Road seems to be under designed. The bridge gets overtopped frequently.

HFL enquiry at proposed Dhadhar Crossing

HFL mark at CWC GD Station_Pingalwada

Rivers Narmada, also discharge into the Gulf. But the influence of tidal fluctuations, in isolation, in the gulf on these rivers is rather normal as the outfall points are wider and the rivers can spill into a large expanse of sea water with relative ease. As per information received from local enquiry, the high tides and storm surges in 2004 synchronized with peak flood discharges, during this synchronized adverse meteorological event, though very unlikely to happen frequently, flood water became a vast sheet extending from River Narmada to River Mindhola.

Shapes of these rivers vary widely between deep, narrow section with confined flow to shallow, wide section with wide flood plain. Banks and beds of these rivers also vary widely between rock to fine silt.

The proposed alignment is crossing some streams flowing through the irrigated agricultural lands. These streams carry the surplus irrigation supplies from irrigated lands during non-monsoon periods. During flood, canal supplies cease but these nalas carry the surface runoff to the nearest outfall streams. As such, flow is observed in these streams all through the years.

Old bridge over Ankleswar-Hasot Road across Amla Khadi

Some channels (Amla Khadi and MS29 Khadi to name a few) carry discharges from the industrial areas. Amla khadi and MS29 Khadi cross the proposed alignment in the flood plain of River Narmada at km 280+600 and km 281+540 respectively. These channels appear to be manmade artificial ones and perhaps not aligned along natural valleys. Spill from Amla Khadi is known to flood the low points of Ankleswar-Hasot Road.

These channels, though very long, do not carry discharges proportionate to the area they are supposed to cater. Drainage Index Method should be the appropriate method to estimate discharges for these channels flowing through irrigated lands.

7.2.2 Selection of Bridge Sites

The following hydraulic considerations have been addressed while selecting a bridge site:

1. The crossing should be as square as possible
2. The crossing should not preferably be near a confluence point.
3. The crossing, wherever possible, should be over a straight reach and not over a meandering reach of the river / nala.
4. Where two or more streams meet near the alignment, the alignment has been shifted in such a manner as to reduce the number of crossings and avoid the turbulence generally anticipated near a confluence.
5. Realignment / Training of small streams and protection of embankment has been resorted to in a techno-economically efficient and environment friendly manner.
6. The banks should be firm and high.

7.2.3 Hydro-Meteorologically Homogenous Sub zones

For estimation of Design Flood, The Central Water Commission has divided the Geographical Territory of India into 26 distinct hydro-meteorologically homogenous Sub zones. The Study area of Main Expressway comes under three such different sub zones namely Sub zone 3(a) for Mahi and Sabarmati Basin, Sub zone 3(b) for Lower Narmada and Tapi Basin of the study area. River bridges of the study area shall come under relevant Hydro-Meteorologically Homogenous Sub zones based on the locations of proposed crossing.

Proposed Crossing of Narmada River

7.2.4 Design Rainfall

The Design Rainfall (24 Hr. maximum) for the study area has been judiciously selected from the following:

a) The 50 Year / 100 Year Isopluvial Maps of the Sub zones concerned

b) The recorded and published daily maximum rainfalls of relevant districts of Gujarat and Maharashtra.

c) The recorded daily maximum rainfall as collected during reconnaissance survey.

CWC Flood Estimation Report for Sub zone 3(b) does not contain 100Year-24 Hr Isopluvial Map. In absence of this Map, 100 Year-24 Hr Isopluvial has been interpolated for the sub zone on the basis of maps of abutting sub zones.

The following **Table 7.4** reflects the Return Periods and corresponding maximum 24-Hr Rainfall adopted for design of the proposed major bridges of Main Expressway.

Table 7.4: Return Period and Rainfall Adopted for Main Expressway Bridges

Sl. No.	Proposed bridge over river	Approximate km of crossing	100-Year / 24-Hr rainfall (mm)	50-Year / 24-Hr rainfall (mm)
1	Meni	365+976	360	290
2	Dhadhar	336+830	350	290
3	Narmada	284+428	360	260

Annexure 7.3 and **Annexure 7.4** reflect the 100 Year Isopluvial Map and 50 Year Isopluvial Map (taken from the Flood Estimation Reports of CWC) respectively reproduced over the study area with the help of ArcGIS Software.

7.2.5 Basin Parameters and Area-weighted Average Rainfall

The watersheds of the rivers at the proposed crossing points have been delineated with the help of ArcGIS 9.2 Software. The watershed area, total and centroidal stream lengths, segmental stream length and corresponding falls have been determined with the help of GIS Software. The superimposition of delineated catchment areas over the digitized Isopluvial Maps (50 Year / 100 Year-24 Hr) has also been done with the help of this software to determine the area weighted design Rainfall for the watershed.

For Narmada Watersheds, the total area is far in excess of 2500 Sq.Km. As such, the watershed areas have been subdivided into sub basins having area around 2500 Sq.Km, as CWC suggests to preferably limit, for best results, the applicability of SUH Method to catchment areas upto 2500 Sq.Km. However, SUH can analyse catchment areas maximum upto 5000 Sq.Km. with reasonable accuracy.

For small watersheds not traceable in Digital Elevation Model, catchment areas, stream lengths and falls have been estimated through study of toposheets of the concerned area and satellite imagery.

7.2.6 Estimation of Design Flood

Estimation of Design Flood for catchment areas more than 25 Sq. Km and less than 2500 Sq.Km has been done by 1-hour Synthetic Unit Hydrograph Method as explained in CWC Flood Estimation Reports. In a very few cases, SUH Method has been applied for catchments over 2500 Sq.Km (but less than 5000 Sq.Km). Whenever the catchment area is more than 5000 Sq.Km, the watershed has been split into sub-basins having area less than 2500 Sq.Km and contributions from sub basins, adjusted for lag, have been added up to arrive at the discharge from the whole watershed. For assessing the discharge of River Narmada (having catchment areas far in excess of 5000 Sq.Km), observed discharges at Garudeswar / Chhanwada (for Narmada) have been given due priority.

Annexure 7.5 reflect the catchment areas over the whole study areas of Expressway, delineated with the help of ArcGIS Software.

For arriving at the discharge of River Narmada (total catchment area being 93726.07 Sq.Km), annual series of peak discharge data of Narmada at Garudeswar and Chhanwada have been considered. Added with the routed values are the estimated discharges from two downstream catchments (each having area less than 2500 Sq.Km) to get the design discharge at the proposed crossing point.

Design discharge of Narmada at Jadeswar Bridge (NH8) has been considered as a check.

Similar procedure has been followed for estimating discharges from Tapi Catchment (total catchment area is 63507.94 Sq.Km).

Rational Formula, as given in IRC SP 13:2004 has been relied upon for calculation of discharge for catchments having areas less than 25 Sq. Km.

Empirical Methods (Catchment Area Methods), without any assigned return period, have been used as a check for the adopted Design Flood.

Slope Area Method demands accurate information regarding HFL at the particular crossing point. Despite serious efforts during site visit, reliable information regarding Highest Flood Levels (at proposed crossing point) of memorable past could not be collected. Moreover, discharge computed by Slope-Area Method could not be assigned any Return Period, unless annual series of HFLs are available. The approach, therefore, relies less upon the Slope Area Method for determination of Design Flood.

Maximum observed discharge as collected from CWC has been compared with estimated discharge to fix the discharge to be adopted for design.

The discharges adopted have been compared with the adopted discharges for major river crossing points on NH8, as reflected in the publication “Bridges in Gujarat”.

7.2.7 Design Return Period

For Waterway

The Terms of Reference (TOR) stipulates that the hydraulic Design of structures shall be done for the maximum flood of 100 Years return period. IRC-5:1998 recommends determination of Waterway on the basis of 50 Years return flood. For determination of waterway, the standard practice is to adopt Q_{100} and Q_{50} for major and minor bridges respectively. The proposed alignment of the Main Expressway runs parallel to existing NH8. Even in some stretches, it runs within a few kilometer of the existing NH8. The existing old bridges on NH8, which are likely to affect the performances of the proposed bridges, may have been designed on the basis of 50 Years Flood. As such, while following the TOR stipulations in letter and spirit, it becomes mandatory on the part of the design engineer to give due importance to the 50 Years Flood too. Therefore, the trial waterways start from a lower value and go on increasing till acceptable velocity and afflux are reached while passing Q_{100}. In other terms, for fixing waterways, Q_{50} has been chosen as the base flood and Q_{100} has been the check flood for all the proposed bridges of Main Expressway and Spur as well.

For HFL

The HFLs for culverts and bridges have been adopted on the basis of 100 Year Return Period. Information collected from local enquiry, as available, have also been given due importance to while adopting the design HFL.

For bridge over the Navigation Channel namely Narmada, Navigational HFLs have been considered as HFLs corresponding to 20Year Flood, as per provisions (Annexure “E”) of IRC – 6, 2014.

The Design HFLs of these rivers shall be the higher of the following:

1. HFL corresponding to 100 year Flood + 1.5m (Vertical clearance, general)
2. HFL corresponding to 20 Year Flood (or HTL whichever is higher) + 10m (Vertical clearance, IWAI)

For Scour

The stipulations of IRC-78:2000 have been adopted for estimating the scour depth. Foundation has been designed on the basis of Q_{50} multiplied by suitable factor as stipulated.

The following table summarizes the return period adopted for design:

Sl. No.	Design Parameter	Adopted Return Period Flood
1.	Waterway for bridges/culverts	100 Years (with 50 Year base flood)
2.	HFL for Bridges	100 Years
3.	Foundation design	100 Year Flood multiplied by suitable factor.

7.2.8 Design Afflux

Maximum Permissible Afflux under the bridges, as estimated from Orifice Formula (IRC SP-13:2004) or from stipulations of HDS1, FHWA has been considered as 300 mm. As the rivers are expected to be flowing under outlet control, the bridges shall definitely be high level ones. Excessive affluxes i,e additional fluming would entail even more height for the bridges apart from unnecessarily increasing the velocities under the bridges.

7.2.9 Vertical Clearance

The minimum vertical clearances for bridges and slab culverts have been provided on the basis of stipulations of IRC 5: 2015.

For bridge across river Narmada, the Inland Waterways Authority of India vide memo no. IWAI/PL-13(2)/2001/GEN/NW-4 dated 8th July, 2009 has suggested that the vertical clearances be kept 10 m above HFL / HTL.

The IRC – 6, 2014 stipulates that the vertical clearance for navigational channels shall be 10m above the Navigational HFL (HFL corresponding to 20-year flood or HTL whichever is higher).

7.2.10 Design Velocity through Bridges / Culverts

During reconnaissance survey of the Expressway, information regarding measured flood velocities was collected from three GD Stations of CWC. The maximum velocities, as measured by float were in the range of 3.5 m/sec to 4.28 m/sec. A maximum design velocity of 3.5 m/sec under the major bridges seems to be acceptable and has been adopted in design. However, for minor bridges of the Ghat areas, the maximum design velocity considered has gone upto 3.8m/sec.

For culverts, a minimum velocity of 0.9 m/s has been adopted as a self cleansing velocity.

7.2.11 Determination of Linear Waterway of Bridges

IRC SP:13-2004 stipulates methods for determining the linear waterway for Alluvial streams, Quasi-Alluvial streams and streams with rigid boundaries. For Alluvial streams, Lacey's Regime equation (W = 4.8*(Q)^(1/2)) provides a guideline for fixing the linear waterway for a bridge. The only decision variable used in this equation is the design discharge. For Quasi-Alluvial streams and streams with rigid boundaries, anticipated flow boundaries (bed and bank) are required to be taken into consideration. For streams crossing the proposed alignment, the Lacey's regime condition does not seem to be applicable in toto, as it appears from the type and nature of river boundaries of the study area.

Annexure 7.6 compares, for a number of existing bridges on NH8, Lacey's Regime Widths with actual widths of waterway provided. The table shows that the extent of fluming varies widely between 1.16 and 0.22. Excepting Narmada, nowhere in the reach, the actual waterway provided is near Lacey's Regime Width.

CWC Flood Estimation Report for Sub zone 3(a) provides a guideline for fixation of Linear Waterway for bridges in this Sub zone. The formula relates the Linear Waterway with the cube root of discharge unlike Lacey's formula which relates Linear Waterway with the square root of design discharge. The Report suggests not using Lacey's equation of regime width for determination of Linear Waterway for bridges in the Mahi and Sabarmati Sub zone 3(a). Flood Estimation Reports for Sub zones 3(b) do not suggest any guidelines for fixation of waterway.

The Linear Waterway for the bridges has been, therefore, derived on the basis of anticipated flow hydraulics under bridges (Weir-Orifice Formula) as detailed in IRC SP:13-2004. It has been assumed, for keeping afflux within limit, that the downstream depth shall be more than 80% of the upstream depth. The Drowned Orifice Formula has, therefore been used to pass the design discharge through a chosen set of trial opening widths (linear waterways). The corresponding affluxes and velocities under the bridges were checked against permissible affluxes and velocity under the bridges. An optimum linear waterway (net effective waterway perpendicular to flow direction) has been recommended for adoption from a set of

trial values. The initial trial value has been chosen as 60 to 70% of the top water width at HFL (assumed as waterway corresponding to Q_{50}) of unobstructed natural stream. The corresponding afflux and velocity under the bridge have been estimated corresponding to 50 Year return period flood. If the estimated afflux and velocity were found to be acceptable for Q_{50}, Q_{100} has been used as the design discharge and the afflux and velocity under the bridge has been estimated for Q_{100} also. If these parameters are within the permissible extreme values the trial value has been accepted. In case, the estimated parameters are beyond the permissible extreme values, "L" has been increased i.e. the extent of fluming reduced, for the next trial and the corresponding effects have again been studied. The adopted "L" has thus been optimized for acceptable afflux and velocity under the bridge.

For major rivers, stipulations and guidelines of Hydraulic Design Series No. 1 of Federal Highway Administration (FHWA) have been followed.

The gross waterway (length of bridge between the abutments) has been fixed with due considerations regarding angle of crossing, span arrangement and end contractions. While fixing the waterway of the proposed bridges, the stream order at the crossing point vis a vis at the crossings with NH-8 has been studied. It has been ensured that for all the major bridges, the individual proposed openings are not less than those provided for the existing bridges for streams of the same order.

Annexure 7.7 provides a comparison between bridge openings provided on NH-8 and openings recommended for the proposed bridges of Main Expressway.

The National Transport Policy Committee (NTPC), 1980 and Inland Waterways Authority of India (IWAI), vide memo no. IWAI/PL-13(2)/2001/GEN/NW-4 dated 8th July, 2009 have identified, inter alia, river Narmada as potential waterways which may eventually be declared as National Waterways. IWAI recommends the following guidelines while designing bridge across river Narmada:

a) Minimum horizontal clearance between piers should be 100 m.

b) Minimum vertical clearance over 20-Year HFL or HTL, whichever is higher should be 10 m.

As such, the individual spans and vertical clearances for the proposed bridge over River Narmada, has been designed in line with the stipulations of IWAI and IRC-6 : 2014.

For local nallahs for which catchment areas could not be reasonably found, linear waterways have been determined by assigning prime importance to the existing cross sections of the nallahs (channel conveyance capacity) near proposed crossing points.

7.2.12 Design Flow Control

The rivers, owing to their vicinity to sea, have been assumed to flow under outlet control condition because of tidal and storm effect. As such, the flow condition shall not be governed solely by the longitudinal bed slope (apart from roughness coefficient and hydraulic radius) of the rivers, but also by the actual flood slope. Under flow condition of low tide and no major storm, the bed slopes of rivers control the flow whereas under hydro-meteorologically adverse condition, the flatter flood slope governs the flow through bridges.

7.2.13 Determination of Flood Slope / Water Surface Profile

Flood slopes govern the flow under adverse hydro-meteorological condition (high tide and heavy rainfall). Flood slopes have been determined on the basis of known values of HFLs at different known locations on the same river at the same instant of time.

Field survey shows that the River Narmada has a very flat longitudinal bed profile at the proposed crossing point. Flow through it shall, therefore, be governed by the flood slope available at any particular point of time.

The water surface profile of Mahi (corresponding to 2005 flood) has also been estimated from the following HFL data collected from different Govt agencies and local enquiry:

- Mahi HFL at NH8 : 29.3m GTS (Local enquiry and Flood Mark)
- Mahi HFL at Umeta Bridge : 20.6m GTS (Irrigation Deptt., Vadodara, Gujarat at Kuber Bhawan)
- Mahi HFL at Singrot Weir : 19.8m GTS (Irrigation Deptt., Gujarat at Kuber Bhawan)

The vertical profile of the proposed expressway and the protection measures on riverside slope of the embankment has been designed on the basis of these water surface profile and existing soil profile at the locations concerned.

7.2.14 Design Approach for Embankment Slope Protection

General

The proposed stretch between km 365+400 and km 387+700 seems to run through an area having deep gorges, erosive soil properties and seems to require protection with the help of suitable retaining wall and / or other means.

The height of embankment in the stretch between Km 365+400 and km 387+700 is generally more than 4 m. The sloping length of the embankment with a side slope of 2H: 1V, comes to about 9 m. As such, the slope requires protection against rain wash on both sides.

Slope Protection against rain wash

A break in slope length is generally provided in the form of berms to check rain water flowing in sheet from accelerating and culminating into formation of gullies along the slope. But provision of berms widens the base of the embankment requiring additional land. An alternative may be thought in the form of providing Geotextile (Geo cell) materials to check soil erosion on slope. These materials are very strong and effective in checking soil erosion. Though they appear to be costly, they can be designed and utilized in an environment friendly and cost effective manner.

The Vadodara Mumbai Expressway embankment shall have shoulder drains at road levels collecting high velocity runoff from the paved area, discharging into chutes which will eventually carry the same to suitably designed drains / pits alongside the toe of the embankment. The side slopes of the embankments will therefore be subject only to the precipitation impinging on the sloping surface and gradually moving in sheet flow down to reach the ground. The provision of the shoulder drains and chutes shall ensure that the slopes do not carry accelerating discharges of harmful magnitude. However slope protection design is carried out in the following paragraph.

Methodology for Design

At the outset, stretches having existing ground level below HFL (100 years) have been identified and depth of overbank flow or depth of inundation have been calculated as the difference between the HFL and existing Ground Level. From the observed HFL values for the year 1998, flood slope for different stretches has been calculated.

Design of slope and toe protection has been done on the basis of following two approaches:

Permissible Velocity Approach

Velocity at toe has been calculated by using Manning's formula over a wide rectangular channel. Manning's "n" has been assumed as 0.05 for overbank flow. Hydraulic radius has been approximated to the depth of flow. The flood slope has been assumed to be the bed slope of flow.

For each stretch, the toe velocity has thus been calculated. These estimated velocities have been increased by 150% to take care of the obliquity of flow. Thus the design toe velocities have been arrived at.

Permissible velocities for grass lined channels have been taken from "Natural Resources Conservation Service-Illinois, US Department of Agriculture as these are not available in Indian Standards. Local grass is conservatively assumed to be equivalent to tall grasses which can withstand a maximum velocity of 3.3 ft/sec. Assuming erodible top soil, this velocity has been decreased by 25% to reach an acceptable permissible velocity of 2.5 ft/sec or 0.76 m/sec. This velocity seems to be a reasonable one.

Whenever the design velocity is greater than 0.76 m/sec, hand placed riprap has been proposed. Otherwise, grass lining has been proposed for the remaining stretch.

Tractive Force Approach

The tractive force approach pivots on the shear stress tolerance of the lined surface. The equation for critical shear stress, as proposed by Swamee, P.K and Mittal, M.K (1976), published in the CBIP Journal of Irrigation and Power has been relied upon for arriving at the permissible shear stress for the bare soil.

The applied equation is below:

Tcb = 0.155 + (0.409 ds^2 / sqrt (1 + 0.177 ds^2))

Where Tcb is critical shear stress (n/m2) at bed and ds is the grain size of the bed materials in mm.

The critical shear stress for the slope material shall be naturally less. Depending on the angle the embankment makes with the horizontal (18 deg) and the internal angle of friction of the slope material (32 deg), the critical shear stress for the slope has been calculated using the following equation:

Tcs = Tcb * Cos 18 * sqrt (1- (tan 18)^2 / (tan 32)^2)

Where Tcs is the critical shear stress (N/m2) of slope material.

For arriving at the permissible shear stress for the soil vegetation matrix, "Vegetative Lining and Bare Soil Design" principles described in "Design of Roadside Channels with Flexible Lining", Hydraulic Engineering Circular Number 15 (HEC 15), Federal Highway Administration, US Department of Transportation has been relied upon.

A good grass cover factor of bunch growth form, giving Cf value of 0.5 has been assumed. This value seems to be conservative on a scale of Excellent – Very Good – Good – Fair – Poor.

An overall grass roughness coefficient (n) of 0.04 and soil grain roughness (ns) of 0.016 (for fine materials) have been assumed for calculation.

The equation used for arriving at the permissible shear stress (on slope) is as follows:

Tp = Tp(soil) / (1- Cf) * (n/ns)^2

Where Tp is the permissible shear stress (N/m2) on the vegetative lining and Tp(soil) is the permissible shear stress (N/m2) on the slope material.

Applied unit shear on bed has been calculated with the help of the equation T = Y R S Where T is the applied unit shear (N/m2), Y is the unit weight of water (9810 N/m3), R is the Hydraulic radius equal to the depth of overbank flow (m) and S is the slope of the water profile. Applied unit shear on slope has been computed as 75% of that on bed.

Where ever the applied unit shear exceeds the permissible one for the vegetative lining, hand placed riprap has been proposed. Otherwise grass lining has been proposed.

Design of Riprap and Filter

Hand placed riprap has been proposed instead of dumped stone as the latter requires a minimum of two layers and dumping does not ensure proper interlocking between stone components. On the other hand, hand placed riprap can be placed with interlocking arrangement conforming to designer's specifications.

On slope

The weight of stone has been calculated on the basis of equation given in IS 10751:1994 and IS 14262: 1995. One man stone of 40 Kg (minimum) weight has been recommended for hand placed riprap. The thickness of stone pitching has been checked for negative head and a minimum thickness of 300 mm has been recommended on the basis of IS:8237-1985.

The top level of slope protection has been recommended as HFL + 0.5 m.

Two layers of filter materials (coarse and fine) each having thickness of 150 mm has been recommended on the basis of IS 8237 - 1985.

Toe Protection

Based on the maximum anticipated toe velocity and depth of overbank flow, unit discharge for every stretch has been calculated. Applying Lacey's theory, maximum depth of scour below HFL has been calculated with a scour factor of 1.5. Depth of scour below bank has then been calculated by subtracting the depth of overbank flow from the maximum scour depth. An apron length of 1.5 times the scour depth below bank subject to a minimum of 3 m has been recommended. The minimum width of 3 m has been recommended in line with the stipulations of IS 12094:2000.

The thickness of the apron has been recommended as a minimum of 1.25 times that of slope pitching.

Two layers of filter materials (coarse and fine) each having thickness of 150 mm has been recommended on the basis of IS 8237 - 1985.

Extent of Riprap protection

The extent of riprap cover has been calculated on the basis of permissible velocity approach. A linear interpolation has been made to arrive at the point where the design velocity reduces down to the permissible velocity of 0.76 m/sec. The figure detailing the slope protection works is given in **Fig 7.1** and stretch-wise provisions of the abovementioned protection works are detailed in **Annexure 7.12** for Main expressway.

7.2.15 Manning's "n"

The Rugosity Coefficients for use in design have been taken from Table 5.1, SP:13-2004. The same table is reproduced below for ready reference:

Rugosity Coefficients, "n"

Sl. No.	Surface (Natural Streams)	Manning's N-values.			
		Perfect	Good	Fair	Bad
1.	Clean, straight bank, full stage, no rifts or deep pools	0.025	0.0275	0.030	0.033
2.	Same as (1), but some weeds and stones	0.030	0.033	0.035	0.040
3.	Winding, some pools and shoals, clean	0.035	0.040	0.045	0.050
4.	Same as (3), lower stages, more ineffective slope	0.040	0.045	0.050	0.055
5.	Same as (3), some weeds and stones	0.033	0.035	0.040	0.045
6.	Same as (4), stony sections	0.045	0.050	0.055	0.060
7	Sluggish river reaches, rather weedy or with very deep pools	0050	0.060	0.070	0.080
8	Very weedy reaches	0.075	0.100	0.125	0.150

Suitable "n" values have been taken for different bed / bank conditions and for deep channel and flood plains of rivers.

7.2.16 Determination of HFL for the bridges

HFLs at the proposed crossing points have been determined on the basis of provisions of IRC-5:2015. The design HFL is the highest value amongst

- HFL ever recorded
- HFL on the basis of design discharge
- HFL anticipated (for tributaries) on the basis of backwater effect of main river. HFLs for 2 (two) bridges near Mahi have been decided on the basis of backwater effect of the main rivers.

For the navigational river Narmada, HFLs have been determined with due consideration of the stipulations of IWAI and latest amendments of IRC:6-2010.

7.2.17 Design Scour Depth

For determination of the scour depth, Lacey's regime equations as stipulated in IRC-78:2014 have been used for all the bridges having sandy bank and beds.

Lacey's equations generally give conservative values for scour depth. Although Flood estimation Report for Sub zone 3(a) suggests not to use Lacey's Regime Equation for fixing linear waterway for the bridges, it recommends Lacey's scour formula to be used for estimating the scour depth, as given in IRC-78:2014.

Upstream and downstream protections / cut off walls have been provided for culverts to take care of scour and under piping.

7.2.18 Selection of Hydraulic Structure

The type of hydraulic structure at any particular location has been primarily selected on the basis of type of water body, estimated discharge and existing cross section of the water body concerned.

For a canal, the hydraulic structure has been spanned across the banks with sufficient headroom ensuring safe passage of inspection vehicle and without disturbing the existing waterway and existing / anticipated inspection road on the bank of the canal.

For a drainage channel, economic considerations and design requirement have governed the selection of the hydraulic structure. A minor bridge has been thought of only when it is justified that a culvert cannot economically serve the purpose fulfilling all the design requirements.

7.3 METHODOLOGY FOR DESIGN OF BRIDGES

Hydrological and Hydraulic Design of bridges / culverts require

- Hydrological analyses for estimation of Peak Design Flood
- Hydraulic calculation for determination of corresponding HFL under unobstructed condition
- Hydraulic calculation for fixing linear waterway, afflux, flow velocity through bridge opening and estimation of scour depth

7.3.1 Methodology adopted for estimation of Design Flood

The following methods have been used to calculate flood discharges:

A) Catchment Area Methods

Two Empirical Methods namely Inglis Formula and Dicken's Formula have been used to estimate flood discharges from a single parameter, catchment area. Flood discharges calculated from these formulae cannot be assigned with any Return Period.

Inglis Formula

$$Q = \frac{125A}{\sqrt{A+10}}$$

Where A = catchment area in Sq.km

Dicken's Formula

$Q = C_1 A^{0.75}$

Where: A = Catchment area in Sq. km.

C_1 is Run-off coefficients which depend on the topography, type of the soil, vegetation, ground slope, climate of the region, etc. Due to varying topography and catchment characteristics C_1 values vary and have been determined based on the available catchment area and peak flood discharges of 50/100 years of return period as given in the flood estimation reports for sub zone 3a, 3b and 5a.

Discharges calculated by this formula cannot be assigned any return period.

CWC Quick Estimate Method

The flood estimation Report for Sub zone 3(a) provides guidelines for a quick estimate of 50 / 100 Year Flood.

Q50 = (1.164*(A)^0.947*(s)^0.242*(R50)^1.143) / (L)^0.566

And

Q100 = (1.161*(A)^0.96*(s)^0.241*(R100)^1.126) / (L)^0.568

Where

Q50 / Q100 = 50 / 100 Year flood in cumec

A = Catchment area up to outfall point in SqKm.

L = Length of longest stream in Km

S = equivalent stream slope in m / Km

R50 / R100 = Design Storm Point Rainfall in cms for the design storm duration (TD)

TD = TB = 5.452*(L / s^0.5)^0.36 in hrs.

Rational Method

Unlike the Empirical Formulae, Rational Method takes into account the Rainfall and other catchment characteristics. Flood discharges estimated by Rational Formula can be assigned a Return Period.

Rational Formula

Q= 0.028 PfAIC

Where:

Q = Maximum runoff in cumecs

A = Catchment area in hectares

Ic = Critical intensity of rainfall in cm/ hr.

P = Coefficient of run-off for the given catchment characteristics.

f = Spread factor for converting point rainfall into areal mean rainfall.

Ic = (F/T)*((T+1) / (Tc+1))

F = Total Rainfall of T hours duration (24 hrs.) in cm corresponding to 50 / 100 yrs return period.

T = Duration of total rainfall (F) in hours= 24 hrs.

Tc= Time of concentration in hour.

Time of Concentration

Time of concentration (Tc) has been determined from the following Empirical Formula:

$Tc = [0.87(L^3/H)]\ 0.385$

Where, L is the length of catchment in km and H is the elevation difference in meter in length L.

Point rainfall values are adjusted for aerial mean value using recommended spread factor as per IRC: SP-13 and CWC report. Total rainfall in 24 hrs is adjusted corresponding to Tc for finding critical rainfall intensity Ic from the rainfall distribution curve (Duration vs. conversion ratio) of CWC report.

B) Estimation of Flood Discharge by Synthetic Unit Hydrograph (SUH) Method as suggested in the Flood Estimation Reports of CWC for different Sub zones.

The steps followed for estimation of Flood discharges are as follows:

B.1 Derivation of Synthetic Unit Hydrograph (SUH)

The steps associated are

- Delineation of Catchment Area with the help of ArcGIS Software
- Measurement of Longest Stream Length (L), stream Length (Lc) between the centroid of the catchment and the outfall point, Segmental Stream Length with corresponding elevations with the help of ArcGIS Software.
- Estimation of Statistical Mean slope / Equivalent Stream Slope of the river by spreadsheet calculation
- Derivation of raw 1-hr Synthetic Unit Hydrograph (SUH) from the physiographic parameters estimated from ArcGIS output and stream slope.
- Smoothening of the SUH by adjusting the receding limb and making the depth of runoff for the SUH equal to 1 cm. (Spreadsheet calculation)
- Tabulation of 1-hr ordinates of the SUH.

B.2 Rainfall Analysis (Spreadsheet Calculation)

The steps associated are

- Estimation of Design Storm Duration (TD) from the physiographic characteristics of the catchment.
- Estimation of 24-hr_T-Year point rainfall from judicious study of Isopluvial maps, site information regarding maximum daily rainfall and information collected from publications regarding maximum daily rainfalls of the area concerned.
- Conversion of 24-hr design rainfall to TD hr point rainfall.
- Conversion of TD hr point rainfall to TD hr aerial rainfall.
- Time distribution of Aerial Rainfall to get 1-hr rainfall increments.
- Estimation of hourly effective rainfall by deducting hourly estimated losses from the hourly rainfall increments
- Tabulation of hourly rainfall excess

B.3 The Convolution Process (Spreadsheet calculation for peak flood determination)

The steps associated are

- Arranging the hourly rainfall excesses against the hourly ordinates of the SUH in such a manner as to produce the maximum runoff. The maximum ordinate should be multiplied by the maximum hourly rainfall excess and so on.
- Summation of each hourly products to get the Peak Direct Runoff.

B.4 Estimation of Base Flow

The base flow is estimated from the empirical formula suggested by CWC for different sub zones.

B.5 Estimated Design discharge

The estimated design Discharge is arrived by adding estimated base flow to the estimated Peak Direct Runoff value.

C) Estimation of Design Flood by Flood Frequency Analysis

Annual maximum flood series for the following sites are being collected from Central Water Commission, Tapi Division, Surat:

1. River Narmada at Garudeswar
2. River Narmada at Chhanwada

Frequency analyses of these annual series shall be done by Gumbel Extreme Value / Log Pearson Type III Method to estimate 50 / 100 Year Frequency Flood for these sites.

The catchment area of River Narmada downstream of Stations Garudeswar and Chhanwada have been split into two sub basins each having area less than 5000 SqKm. The 50 / 100 Year discharges from these two sub basins have been estimated with the help of SUH Method of CWC. These estimated values shall be added to the 50 / 100 Year estimated discharges (to be estimated by Flood Frequency Analyses of observed annual series of peak discharges) of Garudeswar and Chhanwada to arrive at the estimated 50 / 100 Year discharges for River Narmada at the proposed crossing point.

Method and Design Flood adopted

For catchment areas greater than 25 Sq.Km, flood estimation by SUH Method has been adopted for design as it is the most detailed method of estimation. Observed discharges, wherever available, have been given priority to be adopted, with due adjustment, as the design flood.

Rational Formula has been used for estimation of Design Floods for catchment areas less than 25 SqKm.

Floods estimated with the help of Empirical Catchment Area Methods have been considered as the upper limit of the discharge from the concerned catchments.

Estimated floods have been checked with the help of Slope Area Method wherever reliable information regarding HFL could be obtained from local enquiry.

Annexure 7.8 tabulate proposed major bridges alongwith adopted rainfall and adopted design discharges for Expressway.

7.3.2 Methodology adopted for estimation of Design HFL (unobstructed condition) of Bridges

Before assessing the effect of constructing the bridge, it is necessary to estimate the HFL at the bridge point in natural condition when the adopted Design Flood passes through the bridge section. HFL corresponding to Design Flood in unobstructed condition has been estimated by equating the Design Flood with the Carrying Capacity of the channel.

The conveyance factor in unobstructed condition has been estimated with the help of Manning's equation with a trial depth of flow. Discharge corresponding to the trial depth have been calculated and compared with the Design Discharge.

With the help of Spreadsheet calculation, level of water required to pass the design discharge has been taken as the HFL in unobstructed condition.

As the natural drains generally have irregular cross sections having varying roughness coefficients in deep channel portion and flood plain, varying roughness coefficients, areas and wetted perimeters for sub sections have been considered for determining conveyance factor (K) of each sub section. Discharge passing through each sub section has been found as

$Q_n = K_n\sqrt{S}$ (n =1, 2, 3 ….)

Where Kn = Conveyance Factor for the nth sub section = (1/ n)*An*Rn^(2/3), n being the Roughness Coefficient for the nth sub section.

Where S is the energy slope based on average flood slope and longitudinal bed slope of the channel. Average discharge for the cross section of the channel has been found by adding discharges passing through each sub section.

Three cross sections, one each at upstream and downstream of the proposed bridge crossing and one at the crossing itself, have been studied for each bridge point to arrive at the carrying capacity of the channel at the proposed crossing point.

While determining the carrying capacity of the channel, the Geometric Mean of the Conveyance Factors of three cross sections has been used.

i,e

$Q = K\sqrt{S}$

Where, $K = (K_1 \times K_2 \times K3)^{1/3}$

7.3.3 Methodology adopted for estimation of afflux, velocity through bridge and fixation of Linear Waterway

While determining the HFL in natural condition the unobstructed waterway was found out. Trial values of clear effective waterways normal to flow (L) were assumed and the effect of the assumed L on the afflux, velocity under bridge were studied by the Orifice Formula as explained in IRC-SP:13 : 2004. Optimum L ensuring permissible afflux and velocity through the bridge has been recommended for adoption. The affluxed HFL, after considering the effect of the bridge, has been found by adding the estimated afflux with the HFL under natural condition of flow. To assess the effect of bridge construction on the natural river regime for small rivers, the Orifice Formula, and not the Weir Formula, has been used with the assumption that the afflux should be less than 20% of the downstream depth. This assumption seems to be reasonable as an afflux value more than 20% of the downstream depth of these deep channels would not be acceptable to the upstream region.

Orifice formula

$$Q = C_o\sqrt{2g}LD_d\left[h + (1+e)\frac{u^2}{2g}\right]^{1/2}$$

h = Afflux = (Du – Dd)

u = Upstream velocity

Dd = Downstream depth

L = Clear Effective Waterway

Co and e are coefficients to account for losses of head and recovery respectively

Values of e and Co are taken from Fig 5.13 and Fig 5.14 of IRC-SP13, respectively. The above formula is valid for h < ¼ Dd

However, for major rivers, stipulations and guidelines of Hydraulic Design Series No. 1 of FHWA has been followed.

Methodology adopted for Design HFL

The Design HFL is the highest of the following:

a) HFL determined analytically

b) HFL ever recorded (comparing flow depth as per CWC record)

c) HFL determined after considering the backwater effect of a main river on its tributary.

7.3.4 Methodology adopted for Scour Analysis

Lacey's Regime equations, as recommended by IRC-5: 1998 and IRC-78:2000 have been adopted for determination of scour Depth for design of foundation. The equations are as follows:

Mean Scour Depth

$d_m = 1.34 (q^2/f)^{1/3}$

Where dm is the mean scour depth measured below HFL, q is the design discharge intensity under bridge in cumecs per meter and f is the silt factor given by the equation

$f= 1.76 (d_{50})^{1/2}$

Where d_{50} is the mean sediment size in mm.

Scour at rocky bed and banks are not governed by Lacey's equations.

For computing scour depth, enhancement of flood flow to the maximum extent of 30% (depending on the catchment area) has been considered as per stipulations of IRC-78:2000. Maximum scour levels for pier and abutment have been calculated using a factor of safety by 2 and 1.27, respectively as stipulated in IRC-78:2000.

A minimum depth of foundation equal to 2 m below bed level has been adopted for design of foundation.

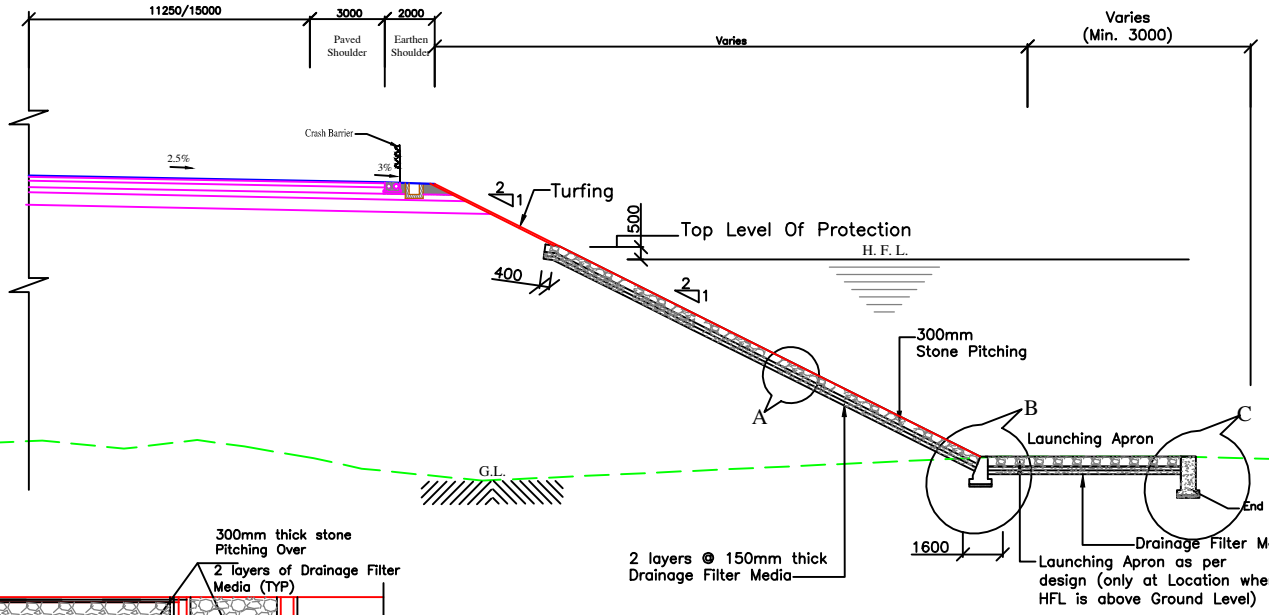
Annexure 7.9 provide an account of proposed major bridges over streams for the Expressway.

Annexure 7.10 provide an account of proposed minor bridges over streams for the Expressway.

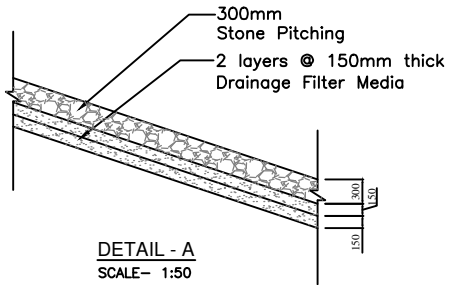
Annexure 7.12 provides summary sheets tabulating, for individual bridges, adopted design flood, design HFL, afflux, velocity through bridges and recommendations.

• • •

Fig 7.1

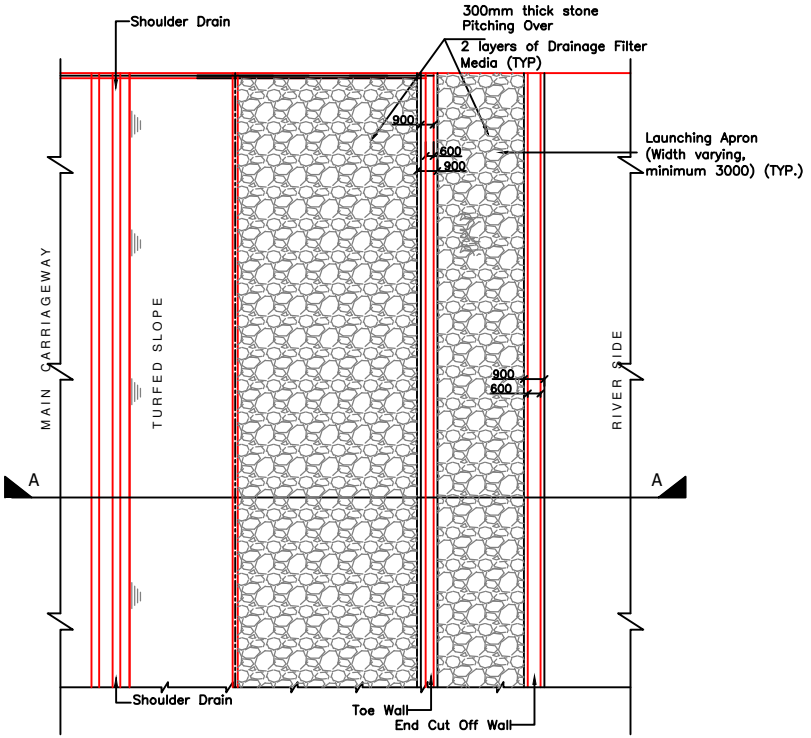


River Side

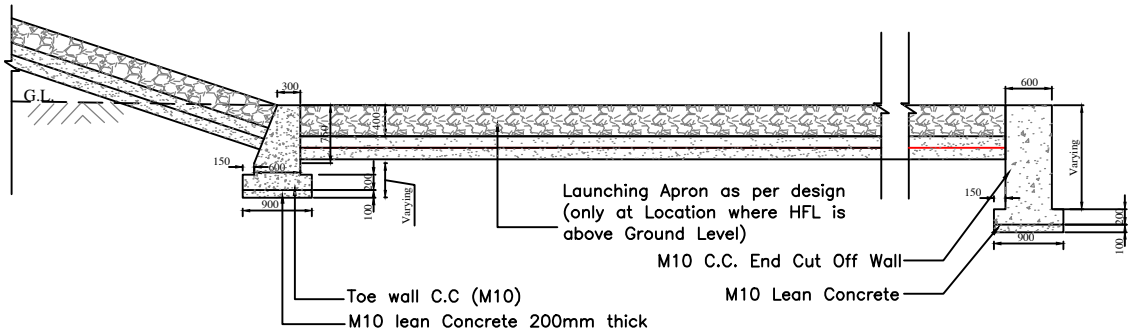


DETAIL - A
SCALE– 1:50

TYPICAL CROSS SECTION A-A
DETAILS ON STONE PITCHING AND LAUNCHING APRON



SCHEMATIC PLAN OF RIVERSIDE EMBANKMENT PROTECTION
SCALE– 1:300



DETAIL - B & DETAIL - C
SCALE– 1:50

Note:- All Dimensions are in mm unless otherwise Specified.

NATIONAL HIGHWAYS AUTHORITY OF INDIA	Scale : As Shown	Consultancy Services for Preparation of Detailed Engineering Design of Vadodara - Mumbai Expressway including Spur to JNPT under NHDP Phase-VI	Detailed Project Report Details of Stone Pitching, Launching Apron	Intercontinental Consultants & Technocrats Pvt.Ltd, A-8, Green Park, New Delhi - 110016 Ph : 2686-3000, Fax 2685-5252	DRAWING No:-NHAI/VME/SP/01/R0

Revisions	Date	Description	Checked by
R1	March-2016	As per NHAI Instruction	
R0	Nov. 2012	INITIAL PLAN	

ARTI ROY	B.K SWAIN	DEEPAK KUMAR	ASEEM PRABHAKAR
Prepared by	Designed by	Checked by	Approved by

File Name :

DRAINAGE STUDIES AND DESIGN OF CULVERTS

8

8. DRAINAGE STUDIES AND DESIGN OF CULVERTS

8.1 INTRODUCTION

This alignment passes through plain terrain and hydro-meteorological region of state of Gujarat. Hydrological investigations of this alignment have been carried out by devoting independent time and human resources. Findings of the detailed investigations and design reports have, thereafter, been presented into this comprehensive write up.

The construction of Expressway embankment will unavoidably obstruct the natural overland flow and to some extent distort the natural flow regime of the local channels. Suitable bridge / culvert openings have, therefore, been proposed across natural drainage channels with a view to pass the discharges with minimal disturbances caused to the natural flow regime. In addition to these bridges / culverts, localized drainage arrangements consisting of longitudinal drains and additional culverts are required to be developed to divert the overland flow (which would otherwise meet the natural stream at some downstream point) intercepted by the expressway embankment into the nearest natural drainage channel. Moreover, these local drainage arrangements have been designed to carry the runoff from the surface of the proposed expressway, too.

As such, development of a drainage system on micro area basis and integration of the same with the overall natural drainage network of the area shall ensure effective drainage of the whole area upstream of the proposed embankment of the expressway.

In developing the localized drainage systems, the issues which have been addressed are as follows:

1. Identification of local depressions / channels crossings the proposed alignment and naturally attracting overland flow towards them
2. Assessment of flow direction at those localized areas
3. Identification of local ridges - natural or manmade, canals etc.
4. Distances between local depressions and nearest local ridges and corresponding land slope
5. Identification of natural storage areas like ponds, lakes etc.
6. Nearest human habitation / property, places of worship, places of strategic importance etc.
7. Permissible head up of water upstream of proposed embankment assessed on the basis of type, nature and elevation of upstream area.
8. Height of proposed embankment

8.2 COMPONENTS OF ROAD DRAINAGE SYSTEM AND DESIGN METHODOLOGY

The road drainage system shall consist of the following:

8.2.1 Drainage of Embankment

It is mandatory to design a system to carry runoff from top of embankment safely into the carrier channel. The system shall ensure safe disposal of surface runoff without erosion of earthen shoulder / slope / embankment toe.

The basic design principles for avoiding accumulation of water on the road surface are:

a) Provision of suitable longitudinal slope

b) Provision of suitable cross slope (both-sides or unidirectional as applicable for the road stretch under consideration i.e. straight, curved, super elevated etc.

c) Provision of GSB layer with sufficient permeability extending up to embankment slope for all sections and provision of horizontal cut-off in waterlogged areas depending on the duration and extent of waterlogging.

d) Provision of shoulder drain (along the edge of shoulder in high embankments) which will empty into chute drains

e) Provision of pipe drains to carry accumulated water from catch pits on medians up to the carrier channels / chutes.

f) Provision of chute drains with energy dissipation arrangement in high embankments to safely discharge runoff from embankment top into toe channels.

g) Provision of turfing with native vegetation / stone pitching / geotextile for protecting embankment slope from formation of gullies by rain wash.

8.2.2 Shoulder Drains / Chute Drains

Since the project road passes through high rainfall area and the height of embankment is more than 5m at most of the places, shoulder drains have been recommended for the entire stretch. Chute drains have been provided at 100 m c/c to discharge the shoulder drain to toe drain.

Typical cross sections of the proposed road embankment provide other details of these drain section.

8.2.3 Roadside Toe Drains

Roadside toe drains shall be provided to receive discharge from embankment surface and ROW of the embankment and carry it safely to the nearest outfall point ensuring safety to the embankment toe, which is the area most vulnerable to erosion / failure.

Roadside drains shall generally be provided on both sides of the embankment to safely carry the discharge from the embankment without jeopardizing the safety of the toe. For limited stretches, particularly near the approaches to rivers where the existing ground slope is steep enough to carry the upstream discharge up to the rivers, roadside drains may be discontinued. Otherwise, these drains shall be carried on both sides of the embankment.

The alignment of the drains shall depend on the topography of the area and the type of drain selected. For stretches, where the natural ground slope is towards the embankment toe, the drain shall be provided at the toe point and lined suitably. For stretches, where the ground slope is away from the embankment toe, the drains may be provided at the edge of ROW and these drains may not be lined. IRC: SP-42: permits construction of unlined drains beyond a point where an imaginary line drawn from the shoulder edge at a slope of 4(H): 1(V) intersects the natural ground. However, maintenance of unlined drains is difficult. Unlined Drains are, therefore, not considered for recommendation.

The shape and size of the roadside drains shall be decided on the basis of length of embankment being served by the drain up to the nearest outfall point.

For stretches passing through urban areas, rectangular covered drains shall be recommended for safety reasons.

For rural areas, the drains shall be open, lined and trapezoidal with 1:1 side slope. As the topography in general is quite flat in Gujarat Section, optimization of

the length of drain, bed width and depth of flow shall be necessary to reduce the top width of the drain (land width required for construction of drain). To reduce the length of drain up to nearest outfall and consequently the section, intermediate balancing culverts shall be provided at suitable locations. These drains may also terminate at local roadside ponds, if feasible. The minimum bed width and depth of flow at starting section shall be 500 mm and 300 mm respectively. The sections shall be gradually increased, if necessary, in terms of bed width and depth of flow up to the outfall point.

The section shall be designed to ensure a non-silting / non-scouring velocity in drains.

8.2.4 Methodology for Design of Drains

The design discharge (25 Year Return Period) for the shoulder drains at high embankment sections and the roadside drains has been estimated on the basis of Rational Formula while the hydraulic design has been done with the help of Manning's Formula.

Steps involved for design of shoulder drains and roadside drains are as follows:

a) Computation of the Average coefficient of runoff (Pav) for composite surfaces.

   Pav = (P1*A1+P2*A2)/ (A1+A2)

   Where, P1, A1 and P2, A2 are the respective runoff coefficients and contributing areas applicable for paved road portion and adjacent built up / agricultural areas.

b) Computation of the Time of Concentration (Tc) has been done taking adjacent land width of 100m beyond the extreme edge of ROW as the remotest point.

   Tc = Inlet time (from adjacent land) + Flow time in the drain.

c) Computation of the Catchment area (At) contributing flow to the drain.

   At = (width of paved surface + width of adjacent land) * length of road under consideration.

   Though runoff from adjacent land has been duly catered while estimating discharge for the bridges and culverts, it is necessary to ensure passage of runoff from adjacent land upto the outfall points. Roadside drains shall intercept such sheet flow and carry the same upto the nearest outfall.

   As the width of adjacent land increases, the time of concentration increases and consequently the design rainfall intensity decreases. This results in a gradually decreasing rate of increase in discharge with increasing width of adjacent land. A land width of 100m beyond the ROW edge has been considered for estimating the discharge of the roadside drains.

d) Rainfall analysis – 25 year, 24-hr point rainfall has been taken from the Isopluvial Map of the area, as given in CWC Flood estimation reports.

e) Computation of rainfall intensity (It)

   The design intensity of rainfall for duration equal to the time of concentration (Tc) and 25 Year Return Period has been estimated by the equation:

   It = (F * (T + 1)) / (T * (t +1))

Where,

F = Total rainfall in a storm in cm falling in duration of storm of 'T' hrs.

t = Smaller time interval in hrs taken as time of concentration.

f) Computation of Design discharge using Rational formula i.e.,

Q = 0.028 * Pav * It * At

Where, It is in cm/hr, At is in hectare and Pav is the composite runoff coefficient.

g) Once the Design Discharge has been determined, Manning's equation has been used to determine the bed width, flow velocity and depth of flow required to pass the design discharge.

$Q = (1/n) * A * R^{2/3} * S^{½}$

$V = (1/n) * R^{2/3} * S^{1/2}$

Where

Q = Design Discharge in cumec

V = mean velocity in m/s

n = manning's roughness coefficient

R = hydraulic radius in m

S = energy slope of the channel, which is roughly taken as the bed slope of the drain.

A = area of flow in m^2.

h) The flow velocity is checked to ensure a non silting / non scouring velocity in the subcritical regime.

i) A Free board of 150 mm has also been added to the depth of flow to get the depth of channel section.

Annexure 8.1 shows the design rainfall considered for estimating discharge for the drains.

25-year, 24 hour point rainfall values considered for design of drains are as follows:

From km 254.430 till end of Main Expressway : 220mm

Annexure 8.2 provides sample calculations for roadside drains.

8.2.5 Culverts

Type and shape of Culverts

Culverts have been recommended for

- passing drainage discharges carried by small streams of the area , wherever feasible,
- passing minor canal / field channel supplies
- intermediate outfall points to receive and safely pass the discharges carried by the longitudinal drains (Balancing culverts)

Box / Slab culverts have been generally preferred to pipe culverts due to the general shortcomings (number of joints inviting weak points, difficulty in maintenance etc.) of a pipe culvert structure.

The choice between Box Culverts and Slab Culverts has been made on the basis of the water depth required to pass the design discharge and embankment height

decided at that particular location from geometrical considerations. Typical cost associated with submerged box culvert with low height embankment over it, headwall, cut off wall and protection of slope has been compared with the option of an RCC slab supporting vehicular movement over it with necessary abutment structures. The economically effective option has been recommended for adoption.

During the public consultation process and the joint measurement surveys most of the villagers have raised the demand for providing culverts for the continuity of their field channels. NHAI has raised this issue in the comments on the draft DPR. Though most of the cattle underpasses and most of the box culverts provide continuity to field channels, however to cater to the public demand 1.2m diameter pipe culverts have also been provided with chamber at the edge of the ROW for continuity of existing and future field channels. These can also be used for utility crossover. The location of these culverts marked in drawings is tentative and shall be finalized in consultation with local people during execution.

Minimum size of Culverts

Taking width between the earthen shoulders as 46m (8–Lane) and an average embankment height of 4m with 2H:1V slope, the toe to toe width of embankment comes to 62m. If the size of the culvert is determined on the basis of hydraulic requirements only (which may necessitate pipe sections smaller than 900 mm dia.), periodical clearing of the culvert barrels may become a serious problem. The minimum size of the culverts has, therefore, been recommended to be 2m for ease of routine maintenance.

8.2.6 Approach and Methodology for Design of Culverts

The 24 Hour maximum rainfall of 25 Year return Period has been taken as the design rainfall. 100 year discharge has been used as check flood for the culvert structures.

The section of the proposed road passing through the western ghats is expected to experience cloud burst and short duration – high Intensity rainfall.

Annexure 8.1 shows the design rainfall considered for estimating discharge for the culverts.

Annexure 8.3 shows the range of estimated discharge of culverts proposed to be located in hydro-meteorologically different zones within the project area.

The hydraulic calculations for culverts have been done with the help of Hydraflow extension software of Autodesk, Inc which follows the methodology of hydraulic design of culverts as set forth in Hydraulic Design Series Number- 5 - Hydraulic Design of Highway Culverts that is prepared for the U.S. Federal Highway Administration (FHWA).

The maximum downstream velocity (corresponding to check flood i,e 100 year flood) for the culverts has been considered as 4 m/sec with rip rap / concrete protection.

In no case, the Hw/d ratio (governing head water elevation) has been considered more than 1 for the safety of the pavement layers.

The minimum size of culvert has been considered to be 2m X 2m for ease of maintenance.

The estimated carrying capacity of culverts for optimum longitudinal slopes is tabulated below:

Culvert Capacity

Size	Capacity (cum/sec)	Longitudinal Slope
2 X 2	8.50	0.3% to 0.5%
3 X 2	13	0.3% to 0.5%
3 X 3	19	0.3% to 0.5%
4 X 3	26	0.3% to 0.5%
5 X 3	32	0.30%
6 X 3	39	0.30%

Note : 1. Limiting downstream velocity : 4 m/sec (check flood) with riprap protection.
2. Hw / D Ratio =< 1, for safety of embankment

No calculation of design discharge shall be required for culverts carrying canal supplies. The Design Discharge and the Full Supply Levels of the canals have been collected from the Irrigation Department, Government of Gujarat, for finally fixing the height of structure above the canals. Canal network drawings for a part of the project area have been collected from the Office of the EE, Surat Canal Division (Ukai-Kakrapar Project) and from NPCQC & P&D DN 1, Vadodara, Sardar Sarovar Narmada Nigam Limited.

For balancing culverts, the culverts have been designed on the basis of length of roadside drains emptying into the culverts. Many of the culverts of the study area are of balancing type.

Annexure 8.4 reflects the conveyance capacities of different types of balancing culverts passing discharges contributed by roadside drains of varying lengths.

Annexure 8.5 provides sample hydraulic design calculation of culvert by Hydraflow Software.

Annexure 8.6 list of culverts (drainage as well as culverts over canal) recommended for the Expressway.

Annexure 8.7 provides list of pipe culverts for field channels for the Expressway.

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GEOMETRIC DESIGN STANDARDS FOR EXPRESSWAY

9

9. GEOMETRIC DESIGN STANDARDS FOR EXPRESSWAY & NH-8

9.1 INTRODUCTION

An Expressway is a type of road where there is complete access control to this road and no cross traffic is allowed. Access is allowed only through well designed interchanges/grade separators. This is also known as a 'Freeway' in some parts of U.S.A, 'Motorway' in U.K and 'Autobahn' in Germany. The expressways provide unhindered speedy movement of vehicles due to full control of its access. This category of road is therefore designed to carry large volumes of traffic at high speeds at the same time being safe.

Already beginning has been made for construction of expressways in the country. Mumbai-Pune Expressway and Ahmedabad – Vadodara Expressway are already in operation. The Government of India has taken up construction of 1000 km of expressways under National Highway Development Project (NHDP) Phase VI. The proposed peripheral roads around Delhi are also being constructed as per expressway standards. It has also been proposed for development of an expressway network and also acquisition of land for expressways during 11^{th} Plan Period. Several State Governments have also taken up construction of expressways under the program of the respective State Governments. Constructions of Taj (Yamuna) Expressway and Ganga Expressway in Uttar Pradesh have been taken up by the State Government.

Construction of Vadodara-Mumbai Expressway is included in the NHDP Phase VI and is being executed by National Highways Authority of India (NHAI). This Expressway will be constructed under Public Private Partnership (PPP) through Design Build Finance and Operate (DBFO) system. The consultancy work for 'Preparation of Feasibility cum Preliminary Design Report for Vadodara- Mumbai Expressway' has been awarded to M/s Intercontinental Consultants and Technocrats Private Limited (ICT) by NHAI.

The basic objective of design of expressway is to resolve the inherent conflicts between high speed and safety, even at higher level of traffic. With this objective, the expressway should have following design attributes;

a) There should be lane separation. This means that expressway will have dual carriageway with each carriageway having minimum two lanes.

b) There should be grade separation. The cross traffic is not allowed at the same level. The cross traffic is taken through grade separated structures either as underpasses or over bridges.

c) There should be access control. This implies that entry to and exit from the expressway shall be only at the designated points. The expressway shall also be fenced throughout its length to prevent any illegal entry in it.

The geometric design of expressways needs special consideration due to provision of full access control, high speed, increased safety requirements as well as huge cost of construction. The Terms of Reference (TOR) for the study under consideration specifies only the design speed for the proposed Expressway which is 120 km/hr. The proposed expressway between Vadodara and Mumbai is passing mainly through plain/rolling terrain in Maharashtra and plain terrain in Gujarat. The geometric design standards for the proposed expressway have therefore been developed considering the design speed of 120km/hr which is commensurate with this terrain.

9.2 REVIEW OF DESIGN STANDARDS

The MoRT&H has issued "Guidelines for Expressways" in April 2010. The geometric design standards for Vadodara – Mumbai (VM) Expressway are being finalized taking into consideration these guidelines. The international standards like "A Policy on Geometric Design of Highways and Streets" by AASHTO, the standards prevalent in U.K have also been studied in formulating the design standards for VM expressway. In this connection, it has also been kept in view that Vadodara – Mumbai Expressway is in continuation of Ahmedabad – Vadodara (AV) Expressway. Therefore, the standard of AV Expressway is an important consideration for finalizing the standards of this Expressway.

To finalize the design standards for VM expressway a literature review on the geometric design standards of Expressways of few developed countries as well as for the Expressways constructed/planned in the country has been done. Now the specifications are revised in the present submission according to IRC: SP: 99 (2013).This is presented in **Table 9.1**.

9.3 DESIGN OF CROSS SECTION

9.3.1 Right of Way (ROW)

The VM Expressway is passing through plain/rolling fertile cultivated land. This is a 'Greenfield Project' and land is to be acquired for the entire project. The requirement of land has to be decided keeping in view the requirement of accommodating the expressway and the amenities. At the same time the high value of land in this area as well as social implication of such large scale acquisition will also be a factor.

The Guidelines for Expressways issued by MoRT&H recommends a minimum Right of Way (RoW) of 90m for expressways in plain/rolling terrain. It further states that the need for wider RoW for toll plazas, service roads for connecting cross roads, high embankments/deep cuts, future widening shall also be kept in view.

Due to provision of high level bridges & underpasses, the expressway will be running on an embankment of more than 5m in substantial length. The RoW for the expressway shall be 100m in general. But for locations of high embankment, service roads etc. the RoW shall be 120m. This is as per the minutes of the meeting with secretary MoRT&H held on 02.01.2012 issued vide NHAI letter no. NHAI/NHDP-V/MC-II/BOT/FR/AV/14 dated 18.01.2012. The guidelines recommend fencing of the RoW to avoid encroachments hence the RoW shall be fenced.

Table 9.1: Geometric Design Standards of Expressway

Sl. No	Parameter	Unit	AASHTO	Guidelines for Expressways by MoRTH	Mumbai-Pune Expressway	AV Expressway	Ganga Expressway	Taj Expressway	As approved by NHAI at Inception Stage	As adopted in Design	Remarks
1	Design Speed (Maximum)	km/ hr	110	120	120	100	120	120	120	120	The design speed of any road is the fundamental parameter which determines all other parameters for providing mobility and safety on the road. Expressways are designed for high speed travel. For plain terrain, in international as well as Indian standards the design speed for expressways are taken as around 120km/hr. This standard is also in line with the modern technology vehicles which is also capable of travelling at a high speed. The TOR also specifies design speed as 120 km/hr.
2	ROW (Minimum)	m	25m-45m on each side as outer separation beyond the travelled way	90	90 (desirable minimum) 100	90	110	100	100	100m general and 120m Maximum	Optimum width of ROW has been considered considering high value of fertile land and requirement of the expressway. Sufficient margin beyond the Road way is required from the consideration of safety as well as environment. It has been assessed that width of 76.5m is required to accommodate eight lane expressway and 12m wide median with an embankment height of 4m. The balance land will be required to accommodate utility duct, plantation, and also service road if reqd. IRC:SP:99 also specifies 90m to 120m for Rural Area.

Sl. No	Parameter	Unit	AASHTO	Guidelines for Expressways by MoRTH	Mumbai-Pune Expressway	AV Expressway	Ganga Expressway	Taj Expressway	As approved by NHAI at Inception Stage	As adopted in Design	Remarks
3	Lane Width	m	3.6	3.75	3.75	3.75	3.5	3.75	3.75	3.75	The lane width of carriage way in India for roads other than expressways has been standardized as 3.5m. Considering high speed of travel and driving behavior slightly larger width of 3.75m are being provided in expressways of India. The same width has been proposed for uniformity, comfort level of driver and also from safety consideration**. Lane width of 3.75m is also recommended in IRC: SP: 99**
4	Shoulder Width										
	Paved Left Side	m	3.6	3	2.5 (Hard Shoulder) +0.5m Edge Strip	2.5	2.5	3.75	3	3	For safe accommodation of a stranded vehicle particularly a truck and to facilitate unhindered movement along the expressway 3m width proposed. **Same is also recommended in IRC: SP: 99**.
	Paved Median Side		1.2-2.4, 3m-3.6m for six lane expressway	0.75	0.7 (Edge strip)	0.7	0.7	0.7	0.75	0.75	The lane adjacent to the median is a fast lane. Sufficient width of shoulder on the median side has ben proposed to decrease the shyness, to facilitate increased speed and to accommodate edge line. **Same is also recommended in IRC: SP: 99**
	Earthen	m	--	1.5	1.5	1.5	1.5	1.5	1.5 min	3	Minimum width of 3.0m is required to provide lateral support, to accommodate sign boards, safety barrier and side drain. **Now revised to 2.0m as per IRC: SP: 99.**

Sl. No	Parameter	Unit	AASHTO	Guidelines for Expressways by MoRTH	Mumbai-Pune Expressway	AV Expressway	Ganga Expressway	Taj Expressway	As approved by NHAI at Inception Stage	As adopted in Design	Remarks
5	Median Width	m	15-30	12 (without barrier) 4.5 (with barrier)	9 (without curb) & with barriers for < 9m	6	6	6	12 --	19.5 (For Six Lane Section) 12 (For Eight Lane)	In a high speed facility wide median will reduce the head light glare of vehicles of opposite side, provide recovery area of out of control vehicles as well as space for median plantation. The wider median in six lane section will be used for inside widening in future. **Now provided 6.0m wide flush median as per NHAI's advise, so that earth work can be reduced.**
6	Side Slope		6:1 or flatter Steeper Slope with guard rail for high fills --	2:01 Desirable 4:01	2.5:1 (Up to 3m High) and 3:1 (3m-5m High)	2:01	3:01	2.5:1	-- 2:1 (General) or flatter as desirable --	1 3:1 --	Keeping in view the ability of traversing of an out of control vehicle, availability and cost of land, provision of turfing and to reduce erosion side slope of 3:1 is adopted. **The side slopes are revised to 2H:1V as per directions of NHAI.**
7	Cross fall/Camber										
	Pavement	%	1.5-2 2.5 for heavy rainfall area	2-2.5	2.5 3.5	2.5	2.5	2	2.5	2.5	The proposed camber/crossfall is for efficient surface drainage in consideration of the type of pavement as well as high rain fall area

Sl. No	Parameter	Unit	AASHTO	Guidelines for Expressways by MoRTH	Mumbai-Pune Expressway	AV Expressway	Ganga Expressway	Taj Expressway	As approved by NHAI at Inception Stage	As adopted in Design	Remarks
	Shoulder (earthen)	%	1% greater than pavement with a range of 2-6%	3	4	3	3.5	3.5	3	3	The proposed crossfall is for efficient drainage in consideration of the earthen surface and slope provided for the pavement **The cross-slope of earthen shoulder shall be 1% more than the carriageway cross slope hence adopted 3.5% (IRC:SP:99)**
8	Super elevation (maximum)	%	Maximum 8-12% rate is applicable if snow & ice condition is not a factor	7	7	--	5	6	7	7	Maximum rate of super elevation of 7% proposed based on the design speed and also Indian standards. **Now revised to 7% if the radius is less than the desirable minimum and 5% if radius is more than equal to the desirable minimum (IRC:SP:99)**
9	Stopping Sight Distance	m	220	250	250	--	250 180 (abs Minm)	250	-- 250 --	-- 250 --	**Desirable minimum sight distance (500m) is proposed, if site constraints are there then minimum safe stopping sight distance of 250 m is proposed. (IRC:SP:99)**
10	Decision Sight Distance at critical locations										
	Stopping	m	235	265	--	--	--	305	265	265	It is required at critical location like interchanges, toll plaza and lane drops. The distance has been calculated for pre-maneuver time of 3 sec. As for stopping but for a pre-maneuver time of 10.2-11.2seconds **360m is proposed for both the cases as per IRC: SP: 99.**
	Speed/ Path/ Direction change	m	330	360	--	--	--	375	360	360	

Sl. No	Parameter	Unit	AASHTO	Guidelines for Expressways by MoRTH	Mumbai-Pune Expressway	AV Expressway	Ganga Expressway	Taj Expressway	As approved by NHAI at Inception Stage	As adopted in Design	Remarks
11	Radius of Horizontal Curve										
	Absolute minimum	m	501	670	450	--	700	760	670	800	The minimum radius has been calculated for the maximum allowable super elevation and side friction factor of 0.10. **IRC: SP: 99 is recommending 670m.**
	Desirable minimum	m	--	1000	600	--	--	--	1000	1000	The calculated radius is for Super elevation of 7% & 50% of the friction value i.e. 0.05. **1000 m is adopted.**
12	Minimum Length of Transition Curve	m	--	100		--	--	--	100	100	
13	Minimum radius of horizontal curve to eliminate transition curve		--	4000	4000	--	2600	2000	4000	4000	Calculated from the basic formula corresponding to the value of speed of 120km/hr.
14	Gradient										
	Ruling	%	3 (Maximum)	3	2	--	2.5	2.5	3	3	Based on the design speed of 120km/hr and for plain terrain the ruling gradient has been proposed **Now revised to 2.5% as recommended in IRC: SP: 99.**

Sl. No	Parameter	Unit	AASHTO	Guidelines for Expressways by MoRTH	Mumbai-Pune Expressway	AV Expressway	Ganga Expressway	Taj Expressway	As approved by NHAI at Inception Stage	As adopted in Design	Remarks
	Minimum	%	0.5	0.5	0.5	--	--	--	0.5	0.5	For drainage purpose
15	Vertical Clearance (Minimum)										
	Vehicular under-passes	m	4.9	5.0	5.5	--	5.5	5/5.5	5.5	5.5	--
	Light Vehicular Under-passes	m	--	-	--	--	-	-	-	3.5	--
	Pedestrian/ Cattle crossing		--	3.0	--	--	4	3	3.5	3.5	**In IRC: SP: 99, it is 3.0m but NHAI has advised to provide 3.5m.** **In reference to MORT&H circular no. RW/NH-35072/04/2004-S&R(R)**
	Elephant / Camel crossing	m	--	4.5	--	--	--	--	4.5	4.5	--

9.3.2 Number of Lanes

As explained in Chapter 4 (para 4.6.3) the section from km 254+430 to km 287+385 should be developed to 8 lane and section from km 287+385 to km 378+740 should be developed to 6 lane facility at the opening year. Further, to accommodate acceleration lane and declaration lane, 8 lane has been extended from 287+385 to km 287+700. Hence it is concluded that the section from km 279+000 to km 287+700 to be developed to 8 lane and from km 287+700 to km 292+000 should be developed to 6 lane facility of Package IV.

9.3.3 Lane Width

In accordance to IRC:SP:99, the lane width has been proposed as 3.75m.

9.3.4 Shoulder

In accordance to IRC:SP:99, the paved shoulder has been proposed on each carriageway.

9.3.5 Median

A median is the portion of a highway separating the traffic of opposite directions. The basic requirement of an expressway is to have a median to provide lane separation for opposing traffic. The median minimize headlight glare, provide width for future lanes and can create green space for pleasant environment. It also provides a stopping area in case of emergencies and a recovery area for out of control vehicles. Median as wide as possible needs to be provided on expressway from the consideration of safety. Economic and social factors like increased cost of construction and maintenance of expressway, requirement of additional land and its consequent effect restricts the median width.

The guidelines for expressways issued by MoRT&H recommend depressed median for expressways. It recommends a minimum median width of 10m and a desirable width of 15m without median barrier.

On consideration of all the above factors it has been proposed to provide 12m wide median on the 8 lane dual carriageway cross section. In 6 lane sections the median width is proposed to be 19.5m. Widening to 8 lanes in future for these sections will be done inside median, reducing it to 12m and making a uniform width of 12m throughout the expressway.

However, now to reduce the earthwork quantities 6m wide median is adopted in this submission as per NHAI instructions.

9.3.6 Camber/Cross Slope

Camber/Cross slope is required to be provided on the roadway for drainage of surface water. A steep lateral slope is desirable to minimize ponding of water on pavements with flat longitudinal grade. On the other hand, steep cross slopes are undesirable on tangents because of the tendency of vehicles to drift toward the low edge of the traveled way. The rate of cross slope also depends on the type of the surface from the drainage consideration. Further, higher rate of cross slope is required in a road passing through high rain fall area compared to that in a road in a dry area. The guidelines for expressways issued by MoRT&H recommend a crossfall of 2.5% for both rigid and bituminous surface in areas with rainfall more than 100cm. It is thus proposed to provide 2.5% cross slope/camber for bituminous and concrete surfacing and 3.5% on earthen shoulders.

9.3.7 Side Slopes

The proposed expressway will be on embankment. Side slope of the embankment are to be provided keeping in view of the stability of the embankment and to provide a reasonable opportunity for recovery for an out of control vehicle. 4(H):1(V) side slope is minimum requirement from safety

consideration for recovery of out of control vehicle. Flatter side slopes will involve increased right of way and cost of construction.

The guidelines for expressways issued by MoRT&H recommends a desirable slope of 4(H):1(V) and a steepest slope of 2(H):1(V). To keep and balance between safety and cost a minimum side slope of 3(H):1(V) has been adopted. Flatter side slopes will be provided in the sections where it is required from stability point of view.

However, now to reduce the earthwork quantities 2H:1V side slope is adopted in this submission as per NHAI suggestions.

In the cut section, a slope of 4(V):1(H) has been adopted as per Guidelines for expressway issued by MoRT&H.

9.4 HORIZONTAL ALIGNMENT

9.4.1 Horizontal Curve

The expressways are designed for high mobility and high-volume traffic. Therefore, these expressways should have free flowing horizontal curves and smooth grades. Safety and aesthetics should also be prime consideration for developing the horizontal and vertical layouts. The design speed for the expressway is 120 km/hr as recommended in the TOR. As per the guidelines for expressways issued by MoRT&H, the maximum limit of super elevation has been considered as 7% and a friction factor of 0.1 has been taken. The minimum value of the radius for a side friction factor of 0.1 works out as 670 m. However, as it is a high speed facility the desirable minimum radius has been calculated on the basis of maximum value of super elevation of 7% and side friction factor as 50% of 0.1 i.e. 0.05. The minimum desirable radius thus obtained is 1000m. The alignment of Phase IA (Km 254.430 to Km 378.740) of VM expressway has been designed with radii more than the desirable radius of 1000m.

Super Elevation

The Guidelines for Expressways issued by MoRT&H recommend a maximum super elevation of 7% for expressways in plain/rolling terrain. AASHTO recommends maximum value of 12% as super elevation in an expressway. For this expressway based on the standard and practices in India and abroad maximum value of super elevation has been adopted as 7%.

Now revised to 7% if the radius is less than the desirable minimum and 5% if radius is more than equal to the desirable minimum (IRC:SP:99)

The Guidelines for Expressways issued by MoRT&H recommends a radii of 11400m beyond which super elevation is not required for a cross slope of 2.5%. This appears to be much on the higher side as compared to other international standards and the standards for national highways i.e. IRC38:1988. AASHTO recommends a curve radii of about 3000m beyond which no super elevation is required for a cross slope of 2.4%. The standards for national highways stipulate a radius of 1800m beyond which no super elevation is required for a speed of 100kmph and a cross fall of 2.5%.

In a curve with a radius of 4000m and an adverse cross fall of 2.5% a vehicle at 120kmph speed would require a coefficient of friction of 0.053 to counter act the centrifugal force which is half of the 0.1 recommended coefficient of friction. Hence no super elevation is to be provided for curves with radius more than 4000m on VM expressway.

9.4.2 Transition Curve

Transition curves are provided on both ends of the circular curve for comfortable and gradual change to attain super elevation, sufficient time to manipulate

steering and gradual change of centrifugal force. Spirals are provided as transition curves. The minimum length required for transition curve for a design speed of 120 km/hr is 100m. The length of transitions has been calculated on the basis of the radius of the curve. Transition curve will not be required for curve with a radius equal to or more than 4000m.

9.4.3 Sight Distance

9.4.3.1 Stopping Sight Distance

The stopping sight distance (SSD) is the sum of two distances namely the distance traveled by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied known as break reaction distance and the distance required to stop the vehicle from the instant brake application begins termed as breaking distance. Break reaction distance is calculated on the basis of break reaction time of 2.5 second and breaking distance is calculated on the basis of coefficient of friction between tyres and road surface as 0.35. The stopping sight distance on this basis works out as 250m. The Guidelines for Expressways issued by MoRT&H and AASHTO standards recommend an SSD of 250m and the same is adopted for VM expressway.

The IRC: SP: 99 was published in 2013, it specifies that minimum desirable sight distance of 500m for design speed 120 km/hr. shall be adopted unless there are site constraints, hence we have revised the design with desirable sight distance.

9.4.3.2 Decision Sight Distance

Decision sight distance is required when the driver is required to make complex or instantaneous decisions, when information is difficult to perceive, or when unexpected or unusual maneuvers are required. The avoidance maneuvers can be in the form of stopping or in the form of speed/direction/path change. In case of stoppage the break reaction time has been considered as 3.0 seconds as per AASHTO standard. In case of speed/path/direction change maneuver with pre-maneuver and maneuver time varies from 10.2seconds to 11.2 seconds as per recommendation of AASHTO. For design speed of 120 km/hr, the decision sight distance for the cases of stopping and speed/path/direction change maneuvers have been taken as 360m as specifies in IRC:SP:99.

9.5 VERTICAL ALIGNMENT

9.5.1 Vertical Gradient

As mentioned above, the expressways should have smooth flowing vertical alignments for high volume and high speed operation. Therefore gentle grades suiting to topography are to be provided. The proposed expressway is passing primarily through plain terrain. The maximum allowable gradient on expressways in plain terrain as per the Guidelines for expressways issued by MoRT&H as well as the U.K and AASHTO standards is 3%. The ruling gradient, which governs the design, of 2 to 2.5% has been provided for the expressways in India. Considering all these, ruling gradient of 2.5% has been proposed for this expressway.

A minimum longitudinal gradient in addition to camber/cross fall is to be provided to facilitate surface drainage. 0.5% gradient has been proposed as a minimum gradient.

9.5.2 Vertical Curve

The IRC: SP: 99 was published in 2013, it specifies that minimum desirable sight distance of 500m for design speed 120 km/hr. shall be adopted, hence the summit curve is also to be designed for desirable sight distance of 500m.

9.6 VERTICAL CLEARANCE

The Guidelines for expressways issued by MoRT&H recommend a minimum clearance of 5m for the Vehicular Underpass and 3m for the Pedestrian Underpass.

Following vertical clearances are proposed at various underpasses for safe passage as per IRC: SP: 99.

Flyovers/Vehicular underpasses	:	5.5m
Light Vehicular underpasses	:	3.5m
Pedestrian/Cattle crossing	:	3.5m (As per NHAI's instructions)
Vehicular Overpass	:	6.0m
Elephant/ Camel crossing	:	4.5m

9.7 EMERGENCY/MAINTENANCE CROSS OVERS

Emergency/maintenance crossovers will be provided by median opening so that emergency, maintenance and law enforcement vehicles and can avoid long distance of travel. This facility will also be required for clearance of long traffic jam. The median opening will be provided where the spacing of interchanges is more than 5 km. As per the Guidelines for Expressways issued by MoRT&H median openings shall be provided with detachable crash barrier at every 2.5 km spacing. However it is felt that 2.5 m is too close a spacing on an expressway with design speed of 120 kmph. It will create safety and maintenance issues. IRC: SP: 99 is also recommending a spacing of 5 Km. Hence a spacing of 5 km for emerging/maintenance crossover has been adopted. The maintenance crossovers shall generally not be located closer than 450m to the end of speed-change taper of a ramp or any structure. These crossovers shall generally not be provided at the location of horizontal curves and where stopping sight distance of 450m and above is not available. The width of the opening shall be 35m.

9.8 RECOMMENDED DESIGN STANDARDS FOR EXPRESSWAY

Therefore the geometric design standards for Phase IA of VM Expressway have been finalized based on the literature review and other factors as mentioned above. NHAI has approved the geometric design standards of the expressway with minor modifications. The adopted design standards for this submission have also been indicated in **Table 9.1**.

9.9 DESIGN STANDARDS FOR THE INTERCHANGES

The interchanges comprise of grade separation structures for straight movement and combination of ramps for direct and semi direct connections and loops to accommodate turning movements. A literature survey on the geometric design of ramps and loops as per various standards and used in different expressways was made. The findings are tabulated in **Table 9.3**. The recommended standards for design of ramps and loops for the Phase I A of Mumbai–Vadodara Expressway are also indicated in the same table. NHAI approved these design standards with the comments of increase of design speed for loops to 60 km/hr and consequent increase in its radius of 130m. It was found that that an interchange with a loop of radius of 130m requires substantial land beyond the ROW of 120m. It was considered to restrict the radius of the loop to 85m in urban areas to minimize the acquisition of land. The proposed design standards are also in **Table 9.3**.

Table 9.3: Geometric Design Standards for Interchange Elements

Sl. No	Design Element	Unit	AASHTO	UK	Guidelines for Expressway by MoRT&H	Mumbai-Pune Expressway	Ganga Expressway	Taj Expressway	Proposed Standard	As approved by NHAI	As Adopted	Remarks
1.	Design Speed	Km/hr	--	--	--	--	--	--	--	--	--	--
	Loop	--	50	--	60	50	60	50	50	80	60	Ramp design speed above 60 km/hr for loops require much longer length and larger areas which are expensive and require additional travel distance.
	Ramp	--	Between 60 to 100	85 (Interchange Link)	80	90	80	80	80	80	80	Higher speed has been proposed as ramp provides direct connectivity
2.	Stopping Sight Distance	M	--	--	--	--	--	--	--	--	--	The distances have been calculated for the adopted design speed.
	Loop	--	65	--	80	--	60	--	65	80	65	The distances have been calculated for the adopted design speed.
	Ramp	--	85-185	--	130	--	130	--	130	130	130	The distances have been calculated for the adopted design speed.
3.	Radius of Curvature	M	--	--	--	--	--	--	--	--	--	The radius is based on the design speed and super elevation

Sl. No	Design Element	Unit	AASHTO	UK	Guidelines for Expressway by MoRT&H	Mumbai-Pune Expressway	Ganga Expressway	Taj Expressway	Proposed Standard	As approved by NHAI	As Adopted	Remarks
	Loop	--	73	75	130	85	130	85	95	130	130	--
	Ramp	--	113-394	--	230	300	230	235	230	230	230	--
4.	Maximum Super elevation	%	--	--	--	--	--	--	--	--	--	--
	Loop	--	--	--	--	--	7	7	7	7	7	--
	Ramp	--	--	--	--	--	6	6	6	6	6	--
5.	Longitudinal Gradient (Max)	%	On upgrades 3-5% to 4-6% depending on the speed	--	--	--	--	--	--	--	--	--
	Desirable	--	--	--	4	4	4	4	4	4	4	--
	Absolute	--	--	--	6	--	6	6	6	6	6	--
6.	Summit & Valley Curves	M	--	--	Minimum Length= 0.6V	--	0.6V	As per codal provision	Min 0.6V	Min 0.6V	Min0.6V	--
7.	Acceleration Lane Length	M	--	--	--	--	--	--	--	--	--	--
	Loop	--	340	--	400	450	400	230 (For loop speed of 55 km/hr and expressway speed of 100 km/hr)	450	460	460	--

Sl. No	Design Element	Unit	AASHTO	UK	Guidelines for Expressway by MoRT&H	Mumbai-Pune Expressway	Ganga Expressway	Taj Expressway	Proposed Standard	As approved by NHAI	As Adopted	Remarks
	Ramp	--	290-125	115 (Nose Length)	300	300	300	245 (for ramp speed of 45 km/hr and expressway speed of 120 km/hr)	300	300	300	--
8.	Deceleration Lane Length	m	--	80 (Nose Length)	--	160	--	--	--	--	--	--
	Loop	--	150	--	150	125	150	127.5 (for loop speed of 55 km/hr and expressway speed of 100 km/hr)	170	170	170	--
	Ramp	--	140-105	--	130		130	120 (for ramp speed of 55 km/hr and expressway speed of 120 km/hr)	130	130	130	--
9.	Taper Length	m	--	--	--	--	--	--	--	--	--	--
	Loop	--	--	--	--	--	75	112.5	75	90	90	--
	Ramp	--	--	205 (Entry Taper)	--	--	90	246.75	90	90	90	--

Sl. No	Design Element	Unit	AASHTO	UK	Guidelines for Expressway by MoRT&H	Mumbai-Pune Expressway	Ganga Expressway	Taj Expressway	Proposed Standard	As approved by NHAI	As Adopted	Remarks
10.	Carriageway Width	m	Single or two lane	--	7.5 for two way		7.5	--	7.5 (one way)	7.0 (one way)	7.0	--
11.	Shoulder Width	m	--	--	2m each	--	2	--	2	2 (left), 0.5 on RHS	2 (left) and 0.5m RHS	--
12.	Clear Zone	m	--	--	--	--	--	--	--	7.0	7.0	--

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PAVEMENT DESIGN

10

10. PAVEMENT DESIGN

10.1 INTRODUCTION

This chapter pertains to the design of pavement of the proposed Phase IA, Package IV of Vadodara Mumbai Expressway.

The report deals to the following scheme to present the pavement recommendations.

1. Analysis of traffic including homogeneous sections, VDF, evaluation of design traffic, etc.
2. Pavement type options based on homogeneous sections as per design traffic and design CBR.
3. Pavement Recommendations on new initial construction and future rehabilitation measures.

The additional topics covered for the main corridor include:

1. Life Cycle Cost Analyses for the various options.
2. Recommendation on the preferred option with associated benefits.
3. Technical accessories for the preferred option.

10.2 HOMOGENEOUS SECTION BASED ON TRAFFIC

The geometric cross section includes both 6 lane and 8 lane configuration for the Main Expressway. **Table 10.1** presents the anticipated lane scheme to be adopted for the project.

The detailed traffic surveys for the entire project road were conducted in March – May 2009 and updated in July 2017. Based on the traffic data and the tentative interchange locations, the entire project road (Vadodara to Surat) is divided into one homogeneous section and presented in **Table 10.1.**

As explained in Chapter 9 (para 9.3.2) 8 lane facility has been extended upto 287+700.

Table 10.1: Homogeneous section as per Traffic Survey on Main Expressway

Homogeneous section	Chainage (km)		Length (Km)	Proposed carriageway	
	Start	End		2021	2035
IV(a)	279.000	287.700	8.700	8L	8L
IV(b)	287.700	292.000	4.300	6L	8L

Based on the traffic survey conducted by the Consultant, the commercial traffic likely to ply on the main expressway is given in **Table 10.2**.

Table 10.2: Mode-wise Commercial Traffic on Main Expressway

Homogeneous section	LGV	Bus & Mini-Bus	2 Axle	3 Axle	MAV	Container
IV(a)	1403	798	3478	4217	1871	1544
IV(b)	988	420	2080	2114	1543	1434

10.3 HOMOGENEOUS SECTIONS BASED ON SUBGRADE STRENGTH

Borrow area soil CBR are found in the range of 4-7 % and hence not meeting minimum design CBR value of 8%. Hence stabilization of soil is proposed to improve CBR of subgrade. Based on test results of borrow areas available and traffic, the entire project stretch can be broadly divided into following homogeneous sections as mentioned in **Table 10.3**.

Table 10.3: Homogeneous Sections based on Subgrade Strength

Homogeneous section	Chainage	Designed CBR (%)
IV(a)	Km 279.000 to Km 287.700	10
IV(b)	Km 287.700 to Km 292.000	

10.4 VEHICLE DAMAGE FACTOR (VDF)

Based on the data obtained from axle load survey carried out by the Consultants at four locations on existing NH-8, VDFs of vehicles with various axle configurations (details furnished in Traffic Report) are computed for legal axle loads as well as for 10% and 15% overloading on legal axle loads with respect to standard axle load. The VDFs are also determined by converting one truck/vehicle pass into equivalent standard axle passes and computed as follows:

VDF = (Total axle loads of vehicle / Maximum Gross Vehicle Weight) ^{4}

Where, Maximum Gross Vehicle Weight (GVW) is the weight specified by Ministry of Road Transport and Highways, Government of India vide notification no. S.O.728(E), dated 18.10.1996. These computed VDFs are furnished in the **Table 10.4.**

Table 10.4: Values of VDF

Vehicle Type	Estimated VDF for NH-8	VDF for legal axle load	VDF, if legal axle limit is increased by,		VDF range based on GVW
			10%	15%	
LGV	0.21 to 1.72	2.00	2.93	3.50	0.16 – 1.52
Bus	0.8 to 1.1	0.8	0.8	0.8	0.6 – 1.02
2-Axle	1.95 to 5.18	3.26	4.77	5.69	0.8 – 5.2
3-Axle	3.37 to 9.68	3.10	4.53	5.41	1.4 – 8.5
4-Axle	6.12 to 11.22	5.24	7.67	9.16	0.92 – 3.67
5-Axle	9.25 to 20.46	6.45	9.45	11.29	1.02 – 5.54
6-Axle	16.52 to 22.83	6.19	9.06	10.82	3.41 – 5.5
*7 & more Axle	16.39	9.28	13.58	16.23	12

** Only one sample was surveyed.*

Generally, the axle load survey provides data to enable the assessment of the damaging effect of the heavily loaded vehicles on the pavement. The fourth power law stated in IRC: 37 indicate that VDF increases sharply with increase in overloading. Since the expressway will have more access control compared to

National Highways, will be closely monitored for overloaded vehicles and will follow stringent criteria of maintenance programme, overloading scenario on expressway will be different from that on NH. It is very likely that there will be much less percentage of overloaded axles on the proposed expressway. Previous studies on VDFs suggest that the same pavement stretch when designed for legal axle load results in less VDF value and more design life as compared to the pavement designed for standard axle load. Considering all these aspects and the VDFs determined above on the basis of standard axle loads as well as permissible maximum GVW, a more reasonable VDF values are assigned for the expressway to compute the traffic load for designing the pavement and the same is furnished below in **Table 10.5**.

Table 10.5: Adopted VDF

Vehicle Type	Assigned VDF to determine Design Traffic
LCV	3.50
Bus	0.80
2-Axle	5.69
3-Axle	5.41
4 to 6 Axle	4.5
*7 & more Axle	4.0

10.5 LANE DISTRIBUTION FACTOR

A realistic assessment of distribution of commercial traffic by direction and by lane is necessary as it directly affects the total equivalent standard axle load application used in the design. The *following* IRC: 37-2012 recommendation has been considered in the pavement designing.

Expressway – 60 % of the one directional traffic for 6 lane Express way

10.6 DESIGN PERIOD

As per IRC:SP:99 2013, The design period of the proposed Main Expressway is considered as 20 years for Flexible Pavement and 30 years for rigid pavement.

10.7 DESIGN TRAFFIC

10.7.1 Main Carriageway

Based on the traffic projection given in the Traffic Report and the Vehicle Damage Factor (VDF) assigned as above for various types of commercial vehicles, Cumulative standard Axles (CSA) during the period of design life are computed for flexible pavement of main carriageway and are given in **Annexure 10.1A**. The summarized design traffic data for the project corridor is shown in **Table 10.6**.

As explained in Chapter 9 (para 9.3.2) 8 lane facility has been extended upto 287+700.

Table 10.6: Design Traffic – Main Carriageway

Chainage (km)		Length (Km)	Design Year (20 Years)	Traffic in MSA (Calculated)	Adopted Traffic (MSA)
Start	End				
279.000	287.700	8.700	2021- 40	175.5	175
287.700	292.000	4.300	2021- 40	150.4	150

10.7.2 Connecting Roads

Since the connecting roads are to cater the local traffic, design traffic of 10 msa is considered for flexible pavement.

10.7.3 Ramps/Loops of Interchanges

Since toll plazas are also been proposed on Ramps/Loops of Interchanges, rigid pavement has been recommended in all the ramp sections. The detailed calculations of design traffic are provided in **Annexure 10.1B**.

The adopted design traffic (30 years design period) for the ramps is summarized below:

Chainage		Adopted Traffic (Million Axle Repetition)
Start	End	
279.000	292.000	15

10.8 PAVEMENT TYPE OPTIONS FOR MAIN EXPRESSWAY

In designing the pavements, a total of four options have been considered. These are:

- Option 1 - Conventional flexible pavement as per the provision of IRC: 37 – 2012,
- Option 2 - Flexible pavement incorporating a semi-rigid layer like Cement Treated Base (CTB) (*henceforth referred as Semi-Rigid option*),
- Option 3 – Flexible pavement incorporating a reinforcing layer of 3-D Geocell (*henceforth referred as Reinforced option*), and
- Option 4 - Rigid pavement.

Note: *For underpasses and service lanes of toll plaza, rigid pavement is suggested and designed accordingly.*

10.8.1 Option - 1

10.8.1.1 Flexible Pavement Design for Main Carriageway of Expressway

Thicker bituminous layer can be used provided the top 40 mm to 50 mm is milled and replaced with a fresh bituminous wearing course or a hot in-situ recycled mix periodically to remove the cracked and deformed spots and restore the riding quality.

Hence for the project single stage construction for project road is adopted keeping in view the periodic maintenance of road. The flexible pavement is designed as per IRC 37-2012. The design of pavement is done by using 90% reliability fatigue and rutting equations.

The estimated flexible pavement composition is shown in **Table 10.7** below:

Table 10.7: Pavement Composition for Expressway - Main Carriageway

Homogeneous Section	Chainage	Design CBR (%)	Design Traffic (msa)	Adopted Composition (mm)			
				BC	DBM	WMM	GSB
HS IV(a)	279.000 to 287.700	10	175	50	130	250	200
HS IV(b)	287.700 to 292.000		150	50	120	250	200

Note: BC – Bituminous Concrete, DBM – Dense Bituminous Macadam, WMM – Wet Mix Macadam, GSB – Granular Sub-Base

10.8.1.2 Flexible Pavement Design – Connecting Road Along Expressway

Connecting road is designed for 10 msa traffic and CBR of one homogeneous section (10%). Accordingly, the pavement composition for connecting road is determined as per design chart of IRC: 37 – 2012 and given in **Table 10.8.**

Table 10.8: Pavement Composition - Connecting Road

Sl. No.	Range of Chainage	Subgrade Strength (CBR in %)	Pavement Composition (mm) 2017-2037			
			BC	DBM	WMM	GSB
1	279+000 to 292+000	10	40	50	250	200

Functional Overlay

In general, an overlay of 30 mm BC + 50 mm DBM will be laid on the connecting road in 10th year assessing the condition and roughness of the road at that time.

10.8.1.3 Rigid Pavement Design – Ramps of Interchanges

Only rigid pavement is considered for the ramps. Since the axle load spectrum on the ramps is considered same as that on main carriageway, the rigid pavement details designed for the interchange ramps is the same as the main carriageway under Option – 4 and thus following composition as given in **Table 10.9** below is recommended :

Table 10.9: Pavement Composition – Ramps of Interchanges

Sl. No.	Range of Chainage	Pavement Composition (mm)		
		PQC	DLC	GSB
1	Km 279.000 to Km 292.000	300	150	150

10.8.2 Option - 2

Design of Semi Rigid Pavement with Cement Treated Base (CTB)

General:

Keeping in view the high intensity of design traffic, incorporation of Cement Treated Base (CTB) may be considered as an alternative to the conventional granular base like Wet Mix Macadam (WMM). CTB is a suitably designed mixture of crushed aggregate, Portland cement and water, which is compacted and cured to form a strong and durable paving layer introduced as the base layer of the designed pavement structure.

The semi rigid pavement with cement treated Base (CTB) is designed as per Clause 10.5 of IRC 37-2012. The design methodology in IRC 37-2012 is based on the structural analysis of a multi-layered pavement subject to traffic loading. In this multi-layered pavement structure, CTB is being contemplated to be laid over Granular Sub-base with a crack relief layer of 100 mm of aggregate interlayer over it. Finally Dense Bituminous Macadam (DBM) and Bituminous Concrete (BC) will be provided. Following three types of pavement distress at locations of critical strains are considered:

- Horizontal tensile strain at bottom of asphalt
- Horizontal tensile strain at bottom of CTB layer
- Vertical compressive strain on top of sub-grade

While analyzing the pavement's performance in respect of the above mentioned critical strains, following equations as provided in IRC 37-2012 has been taken into considerations in designing the pavement:

a) Fatigue Criteria of bituminous layer as per IRC:37 – 2012

$N_f = 2.021 \times 10^{-4} \times [1/\varepsilon_t]^{3.89} \times [1/E]^{0.864}$

where,

N_f = Number of cumulative standard axles to produce 10 percent cracked surface area for traffic more than 30 msa.

ε_t = Tensile strain at the bottom of bituminous layer

E = Elastic modulus of bituminous surfacing (MPa) is taken as 3000 MPa.

b) Fatigue Equation of CTB layer as IRC 37-2012

$N = ((113000/E^{0.804}+191)/ \varepsilon_t)^{12}$

Where,

N = Fatigue life of cementitious material

E= Elastic modulus of cementitious material

ε_t = tensile strain at the bottom of CTB layer (micro strain)

c) Rutting criteria as per IRC:37-2012

$N_R = 1.41 \times 10^{-8} \times [1/\varepsilon_Z]^{4.5337}$

where,

N_R = Number of cumulative standard axles to produce rutting of 20 mm for length of 10 %.

ε_Z = Vertical subgrade strain

Design Inputs:

Elastic Modulus of sub-grade (also its CBR), sub-base, cement treated base, dense bituminous macadam and bituminous concrete are the major inputs required for the design. Poisson ratio of these layers and estimated design traffic also form a part of the inputs.

As per guidelines of IRC: 37-2012 , following values (as presented in **Table 10.10**) of elastic modulus and poisons ratios of different pavement layers are considered in the pavement design.

Table 10.10: Design Inputs for Structural Pavement Design

Sl. No	Pavement Layer Description	E value (MPa)	μ
1	BC	3000 (VG-40)	0.40
2	DBM	3000 (VG-40)	0.40
3	Aggregate Interlayer	450	0.40
4	CTB	5000	0.30
5	GSB	$E_2 = E_1 * 0.2 * h^{0.45}$	0.40

Sl. No	Pavement Layer Description	E value (MPa)	μ
6	Sub-grade	E1 = CBR * 10 , CBR ≤ 5 and = 17.6 * $(CBR)^{0.64}$ > 5	0.40

Design Traffic

Design traffic (estimated for 20 years design period) as considered in the first option of pavement design is taken as the traffic load input for this option. **Table 10.6** is referred to in this regard.

Design CBR

Design sub-grade CBR as considered in the first option of pavement design is considered in this option .

Design Output

Based on the above design inputs, the pavement structure is designed and the recommended pavement composition is furnished here below in **Table 10.11**.

Table 10.11: Pavement Composition for Expressway - Main Carriageway (Option 2)

Homo-geneous Section	Chainage	Design CBR (%)	Design Traffic (msa)	BC mm	DBM Mm	AIL mm	CTB mm	GSB mm
HS IV(a)	279.000 to 287.700	10	175	50	50	100	175	250
HS IV(b)	287.700 to 292.000		150	50	50	100	170	250

** BC – Bituminous Concrete, DBM – Dense Bituminous Macadam, GSB – Granular Sub-Base, CTB – Cement Treated Base.*

In order to maintain the riding quality of the Expressway as per client's specified requirement during the entire design period it is recommended to provide a functional overlay at an interval of every 5 to 7 years. A tentative maintenance schedule is summarized in **Table 10.12.**

Table 10.12: Maintenance Schedule for Main Carriageway of Expressway – Option 2

Chainage	Overlay scheduled
km 279.000 to km 292.000	Yr 2025 – Functional Overlay Yr 2030 – Functional Overlay Yr 2035 – Functional Overlay

10.8.3 Option - 3

Design of Reinforced Pavement

10.8.3.1 Design Traffic

Design traffic (estimated for 20 years design period) as considered in the first option of pavement design is taken as the traffic load input for this option. **Table 10.6** is referred to in this regard.

10.8.3.2 Pavement Design for Main Carriageway

The pavement design philosophy for the reinforced option is similar to that of Option 1. Here, a layer of 3-D geocell infilled with granular materials is introduced to increase the stiffness of the base and sub base layers thus reducing the DBM component of the pavement composition recommended in Option 1. In this case, the base layer shall constitute of 100 mm of WMM along with a reinforcing layer of 125 mm 3-D geocell filled with select granular material and 25 mm of cover by the same granular fill. The combination of reinforced and unreinforced base layeris assumed to exhibit a stiffness of 460 Mpa for subgrade CBR of 10% .

The reinforced section is compared with the conventional section (Option 1) in terms of Fatigue and Rutting life. The Reinforcement layer provides improved modulus for fully and partially confined zones. In this design case, a Modulus Improvement Factor (MIF) for the affected layer of 2.5 was applied. This factor is far smaller than found in multiple research and tests conducted using Neoweb system combined with various infill types. However, we have adopted a conservative value of 2.5 subject to the type and characteristics of geocell used in execution. The stress and stains were calculated from using the IIT PAVE as recommended in IRC- 37: 2012. Before using the software, the input parameters like tire contact pressure, wheel spacing, axle spacing, constants of rutting and fatigue equations are considered in accordance with IRC 37-2012.

The pavement composition for different homogeneous sections is calculated at design traffic and it's tabulated in **Table 10.13.**

Table 10.13: Pavement Composition for Expressway - Main Carriageway

Homogeneous Section	Chainage (km)	Design CBR (%)	Design Traffic (msa)	Pavement Composition			
				BC	DBM	Reinforced WMM	GSB
HS IV(a)	279.000 to 287.700	10	175	50	75	250	200
HS IV(a)	287.700 to 292.000		150	50	75	250	200

** BC – Bituminous Concrete, DBM – Dense Bituminous Macadam, WMM – Wet Mix Macadam, GSB – Granular Sub-Base*

In order to maintain the riding quality of the Expressway as per client's specified requirement during the entire design period it is recommended to provide a functional overlay at an interval of every 5 to 7 years unless strengthening overlay is planned around the same time. The overlay required for different sections are summarized in **Table 10.14** below.

Table 10.14: Summary of Overlay for Main Carriageway of Expressway – Option 3

Sl. No.	Chainage	Overlay scheduled
1	Km 279+000 to Km 292+000	Yr 2025 – Functional Overlay Yr 2030 – 40 mm BC / SMA + 50 mm DBM Yr 2035 – Functional Overlay

10.8.4 Option - 4

Design of Rigid Pavement

10.8.4.1 Design Traffic

The rigid pavement has been designed to withstand the cumulative effect of the axle load repetitions of different commercial vehicles applied over the design life of 30 years. Only 25% of the cumulative repetitions of commercial vehicles in predominant direction for 30 years are taken as the design traffic for computing the expected axle load repetitions for design.

Based on the base year traffic volume data and the growth factors, the cumulative repetitions of commercial vehicles for 30 years design life and the design traffic computed for different traffic sections of the project road package are given in **Annexure 10.2** and summarized in **Table 10.15.**

Table 10.15: Cumulative Repetition of Commercial Vehicles

Homogenous Section	Chainage (km)		Length (Km)	Total Cumulative Axle Repetitions (Millions)	25% of Cumulative Axle Repetitions in predominant Direction (Millions)	Adopted Design Traffic (million Axle repetitions)
	From	To				
HS IV(a)	279.000	287.700	8.700	343	43	45
HS IV(b)	287.700	292.000	4.300	221	28	30

10.8.4.2 Axle Load Spectrum

Axle load spectrum was obtained from axle load survey data carried out at four representative locations along the project corridor. Axle Load Spectrum obtained from Axle Load Survey conducted at Narmada Toll Plaza (km.192.3) was adopted as representative spectrum data for rigid pavement design purposes.

Axle load spectra as given in **Table 10.16** .

Table 10.16: Expected Axle Load Spectrum (279.000 km to 292.000 km)

Axle Load Class, tons			Load, L (tons)	Percentage of Axle
Single Axle Loads				
0	-	9	4.5	17.31
9	-	11	10	11.06

Axle Load Class, tons			Load, L (tons)	Percentage of Axle
11	-	13	12	6.73
13	-	15	14	6.73
15	-	17	16	1.92
17	-	19	18	3.37
19	-	21	20	0.48
21	-	23	22	0.00
Tandem Axle Loads				
0	-	14	7	5.29
14	-	18	16	4.33
18	-	22	20	12.02
22	-	26	24	19.71
26	-	30	28	2.88
30	-	34	32	2.40
34	-	38	36	3.37
38	-	42	40	2.40

10.8.4.3 Pavement Design Details

The design calculations are given in **Annexure 10.3**. The pavement design details so obtained are summarized below:

Strength Properties of Subgrade

CBR 10%

Note:

To provide the pavement with a foundation of adequate and uniform support, it is suggested to provide 15 cm thick lean cement concrete sub-base directly under the concrete pavement. Table-4 of IRC:58-2002 shows k-values of 41.1 kg/cm^2 /cm against CBR 10 and for concrete slab over 15 cm of Dry Lean Concrete sub-base. However, k-values of 30 kg/cm^2 /cm has been adopted for design.

Strength Properties of Cement Concrete

Modulus of Elasticity, E	3 x 105 kg / cm^2
Poisson's Ratio, μ	0.15
Flexural Strength	45 kg/cm^2

Other Parameters

Tyre Pressure, p	8 kg / cm^2
Coefficient of Thermal Expansion, D	0.00001/ ^{0}C
Temperature Differential, d_t	15.8 ^{0}C (Gujarat km 114 to km 378.740)
Contraction Joint Spacing, L	400 cm
Load Safety Factor, LSF	1.2

Pavement Thickness

- Thickness of Cement Concrete Pavement 300 mm
- Thickness of Dry Lean Cement Concrete Sub-base 150 mm
- GSB Layer (Drainage Layer) 150 mm
- Selected Subgrade 500 mm

Types of Joints

- Contraction Joints @ 4.0 m c/c
- Longitudinal Joints to be provided between adjoining slabs of 3.50 m width
- Construction Joints, wherever necessary, such as at the end of day's job or preferably should meet at the contraction joints.

Load Transfer Devices

i. Dowels for Transverse contraction and construction Joints
   - Diameter 32 mm
   - Length 500 mm
   - Spacing 180 mm

ii. Tie Bars for Longitudinal Joints
   - Diameter 12 mm
   - Length (deformed bars) 650 mm
   - Spacing 590 mm

A summary of the rigid pavement composition and design considerations are presented in **Table 10.17.**

Table 10.17: Summary of Rigid Pavement Composition

Chainage		Length (Km)	2021	2035	Total Cumulative Repetitions (Millions)	25% of Total Cumulative Repetitions Predominant Direction (Millions)	Adopted Design Traffic (Million)	Rigid Pavement Composition						Remarks
Start	End							PQC (mm)	DLC (mm)	GSB (mm)	Dowel Details	Contraction Joint Spacing (mm)	Tie Bars	
279.000	287.700	8.700	8L	8L	343	43	45	300	150	150	Spacing @ 180 mm Dia 32 mm	4000	Length 640 mm; Diameter 12 mm at a spacing of 590 mm c/c	CBR = 10; Adopted K = 30 kg/cm^2/cm
287.700	292.000	4.300	6L	8L	221	28	30							

10.9 LIFE CYCLE COST ANALYSIS FOR MAIN EXPRESSWAY

10.9.1 General

In the preceding sections, the methods followed for designing the various alternatives of flexible, semi-rigid, reinforced and rigid pavements have been illustrated.

The choice of the appropriate economically advantageous pavement type, flexible, semi-rigid, reinforced or rigid, is made by carrying out Life Cycle Cost Analysis (LCCA), which includes the initial investment cost as also the maintenance / rehabilitation costs over the design life of the structure. Life cycle cost analysis is a tool to select a pavement design alternative that will provide a satisfactory level of service at the lowest cost over time. The economic analysis methods used most commonly for this purpose include present worth, annualised cost, and rate of return. The analysis is most sensitive to the factors of inflation, discount rate, and analysis period.

In the subsequent paragraphs, the long-term economic viability of pavement types using *Present-Worth method* of analysis has been studied. In this regard, the following two alternatives have been considered:

10.9.2 Parameters Considered

Design Parameters

- **Flexible Pavement**

The pavement compositions relevant to all the sections and subsections have been presented in **Table 10.7** for conventional flexible pavement section, **Table 10.11** for the semi-rigid section with CTB, and **Table 10.13** for the geocell-reinforced section.

The structural and functional overlays adopted for the Homogeneous Sections for stage-construction are also contained in earlier sections for the flexible, semi-rigid, and reinforced options respectively. .

- **Rigid Pavement**

The pavement composition relevant to all the sections has been presented in **Table 10.17**.

Design Life consideration

Flexible pavements have been designed for a life of 20 years whereas the rigid pavements have been designed for a period of 30 years according to the standard codal provisions. However, for comparison at par, for rigid pavements, we have considered Present Worth Value of maintenance work standards up to the end of the 20^{th} year only. Hence, the LCCA for rigid pavements shall represent the Present Worth up to the 20^{th} year and an additional pavement life of 10 years.

Other Comparison Parameters

The various parameters as Input to LCCA model are described as follows:

Capital Cost : Capital Cost consisting of the initial cost of construction for the three types of black top and white top (rigid pavement) based on above design given in **Table 10.7, 10.11, 10.13** and **10.17**.

Maintenance Cost : *Case 1*

For Flexible Pavement

- Routine maintenance in the form of patching, pothole repair, sealing of cracks etc. as per IRC-82.
- Periodic Rehabilitation / Maintenance by way of strengthening and / or Functional overlays.

Case 2

The regime of maintenance on semi-rigid pavement has not yet been established in India. It is still in the study phase. In absence of appropriate codal provisions, we have assumed the same maintenance regime as applicable for the flexible pavement.

For Semi-rigid Pavement

- Routine maintenance in the form of patching, pothole repair, sealing of cracks etc. as per IRC-82.
- Periodic Rehabilitation / Maintenance by way of strengthening and / or Functional overlays.

Case 3

The regime of maintenance on reinforced pavement has not yet been established in India. It is still in the study phase. In absence of appropriate codal provisions, we have assumed the same maintenance regime as applicable for the flexible pavement.

For Reinforced Pavement

- Routine maintenance in the form of patching, pothole repair, sealing of cracks etc. as per IRC-82.
- Periodic Rehabilitation / Maintenance by way of strengthening and / or Functional overlays.

Case 4

For Rigid Pavement

- Routine maintenance in the form of sealing of cracks, mud jacking of settled slabs, etc.
- Periodic Rehabilitation / Maintenance by way of sealant renewal. Joint sealing, *etc.*

The cost of annual routine maintenance of pavement component is taken to be as follows:

(a) Flexible Pavement (Conventional)

Rs. 16, 23,861 / km for 6-lanes

Rs. 20, 10,495 / km for 8-lanes

(b) Semi-rigid Pavement (CTB Base)

70 % of the cost mentioned above in conventional.

(*c) Reinforced Pavement (Geocell incorporated)*

60 % of the cost mentioned above in conventional. We have conducted literature review of domestic, international and research-based project applications and found that a conservative value of 60 % would be appropriate for this type of pavement.

(d) Rigid Pavement

Rs. 9, 69,525 / km for 6-lanes

Rs. 12, 00,364 / km for 8-lanes

Note: The costs are based on Total M&R costs for Zone IV Urban NH as given in Clause 6.14.1.1 of "Report of the Committee on Norms for Maintenance of Roads in India" published by IRC.

Costs to be considered for the pavement types for the flexible, semi-rigid, and reinforced pavement sections are reported below:

(i) Flexible pavement designed for 20 years and strengthened with 1st overlay at the indicated intervals and routine maintenance applied every year (except the strengthening year) over the analysis period.

(ii) Semi-rigid pavement designed for 20 years and routine maintenance applied every year over the analysis period.

(iii) Interim functional overlays applied with reasonable gaps and / or between the strengthening as the case may be for the flexible and semi-rigid pavement. Functional overlay is considered to include a bituminous surfacing of 30 mm thickness.

Costs to be considered for the pavement types for the two rigid pavement sections are reported below:

(i) Rigid pavement designed for 30-year period but, routine maintenance costs evaluated and discounted up to the end of the 20th year only. Routine maintenance costs have been considered annually except the years of prevailing major rehabilitation.

(ii) Sealant renewals and diamond grinding considered in the 10th year only within the considered period of the initial 20 years.

10.9.3 Cost Estimate

The unit rates used for the cost analyses are presented below in **Table 10.18**.

Table 10.18: Unit costs for the materials of pavement sections

Sl. No.	Item	Unit	Package IV
1	BC	cum	7730
2	DBM	cum	6761
3	WMM	cum	1749
4	CTB	cum	2479
5	Geocell	sqm	480
6	GSB	cum	1400
7	Subgrade	cum	336
8	PQC	cum	6149

Sl. No.	Item	Unit	Package IV
9	DLC	cum	2861
10	Diamond Grinding	sqm	300

Note: The rates are tentative and are subject to change. These rates prevailed at the time of formulation of this report.

Based on the above design and maintenance concept, the costs for the four options have been computed. An interest rate of 8 % has been considered along with a Discount rate of 12 %. Cost estimate for each of the sections have been computed separately based on their customized improvement standards.

Table 10.19 shows the cost of initial construction in crores per km for the four options for the various homogeneous sections.

Table 10.19: Capital Cost for the four options for 8-laning / 6-laning

Sl. No	Length (km)		Homo-geneous Section	Option 1 - Capital Cost per km (Conventional BT pavement) (Rs crores)	Option 2 - Capital Cost per km (CTB section) (Rs crores)	Option 3 - Capital Cost per km (Reinforced section) (Rs crores)	Option 4 - Capital Cost per km (Rigid section) (Rs crores)	Length
	From	To						
1	279.000	287.700	H S IV(a)	7.12	6.06	7.48	9.39	8.700
2	287.700	292.000	H S IV(b)	6.90	6.02	7.48	9.39	4.300

It is apparent that Option 2 (Semi-rigid Pavement incorporating CTB) scores the lowest for cost of initial construction (capital cost) per km.

10.9.4 Construction and Maintenance

The maintenance schemes for the various options are presented below in **Tables 10.20a, 10.20b** and **10.20c.**

Table 10.20(a): Maintenance Scheme for Option 1 and Option 3

Sl. No	Length (km)		Routine Maintenance	1st Strengthening	Functional Overlay
	From	To			
1	279.000	292.000	√	√	Twice

Table 10.20(b): Maintenance Scheme for Option 2

Sl. No	Length (km)		Routine Maintenance	Functional Overlay
	From	To		
1	279.000	292.000	√	Thrice

Table 10.20(c): Maintenance Scheme for Option 4

Sl. No	Length (km)		Routine Maintenance	Diamond Grinding	Sealant Renewal
	From	To			
1	279.000	292.000	√	Once	Once

Note: "Once" implies once in 20 years of period considered.

10.9.5 Economic Analysis

The details of economic analysis based on present-worth method, i.e. present value of total of construction and maintenance costs over the analysis period of 20 years are provided in Annexure 17.2 (Chapter 17).

10.9.6 Conclusion and Recommendations

In the Life Cycle Cost Analysis, the present values of all the costs for each of the alternatives have been computed. The alternative giving the lowest present value of the costs has to be taken to be the most advantageous option from economic angle. The final recommendations about the pavement option to be adopted will however take into account specific locational and environmental features, constructability, comfort level, etc.

Taking into consideration the above parameters, the net present value for the four options are tabulated in **Table 10.21**.

Table 10.21: Comparative Cost Comparison of the various Options

Sl. No	Stretch		Initial Capital Cost (Total in crores Rs.)				Life Cycle Cost (Total in crores Rs.)			
	From	To	Option 1	Option 2	Option 3	Option 4	Option 1	Option 2	Option 3	Option 4
1	279.000	287.700	60	51	63	79	108	80	95	110
2	287.700	292.000	32	28	35	43	53	41	49	57
Total Cost			92	79	97	122	161	121	144	168

Thus, looking in terms of the investments required for initial construction of the pavement for the new carriageway for the project road, Option 2 of semi-rigid pavement with CTB turns out to be attractive and advantageous from both economic angle and initial construction cost. However, the performance of semi-rigid pavement and reinforced pavement does not have a track record in India due to very limited use till date. In a project of this magnitude, it is not advisable to adopt semi-rigid or reinforced pavement type for the entire project corridor. However, we strongly recommend that a test section along a desirable designated stretch be constructed with semi-rigid type and / or reinforced pavement and the performance be monitored for any future use in a large scale.

Table 10.22 portrays discussion on the pros and cons of each option.

Recommendation

Based on the above considerations, we strongly **recommend Option 4** as the best pavement type for the project corridor. It may appear that the traffic noise impact from rigid pavement may pose a problem. However, diamond grinding is a solution to it and is discussed in detail in the following section.

Also, the aspect of the VOC has not been captured in the life cycle cost analyses. According to the study conducted by CRRI in 1992, it has been seen that there is a fuel consumption savings of 14 % on concrete surfaces for gross truck weight of 20 T and the savings progressively increase as the vehicle weight increases.

Table 10.22: Advantages and Disadvantages of the Pavement Alternatives

Aspect	Option 1		Option 2		Option 3		Option 4	
	Advantages	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
Constructability	Conventional Construction			"Out of the box" construction technique			Practiced and used technology	Diamond Grinding part is "out of the box" and a new technology
Capital Cost	Medium		Lowest		Higher than Option 1			Highest
Life Cycle Cost		Highest	Lowest		Almost equal to Option 4		Medium	
Remaining Life / Salvage Value at the end of 20 years		Pavement is used up 100%		Performance yet to be judged in Indian scenario		Performance yet to be judged in Indian scenario	10 years of service life	
			Residual strength of base, subbase and subgrade persists after design period and may form good foundation for future		Residual strength of base and subbase persists after design period and may form good foundation for future		During widening / upgradation in 2035, the pavement section holds good and requires no strengthening	
Other Environmental Aspects		Depleting sources of bitumen	Save bitumen	Depleting sources of bitumen	Save bitumen	Depleting sources of bitumen	Ample sources of cement	
	Noise pollution is less compared to rigid type of pavement		Noise pollution assumed to be less compared to rigid type of pavement.		Noise pollution assumed to be less compared to rigid type of pavement			Noise pollution is an issue. To minimize noise pollution, diamond grinding is recommended and discussed below.

Aspect	Option 1		Option 2		Option 3		Option 4	
	Advantages	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
Vehicle Operating Cost (VOC) and Road User Cost (RUC)		High		Not yet studied in India		Not yet studied in India	According to CRRI study conducted in 1992, it has been seen that there is 14 % savings in fuel costs for heavy vehicles and this aspect is an added advantage and has not been taken into consideration in **Annexure 10.4** calculations.	

10.9.7 Effect of Traffic Noise

While recommending the option of rigid pavement, the effect of traffic noise and the cost towards its mitigation measures have been taken into consideration in the life cycle cost analysis.

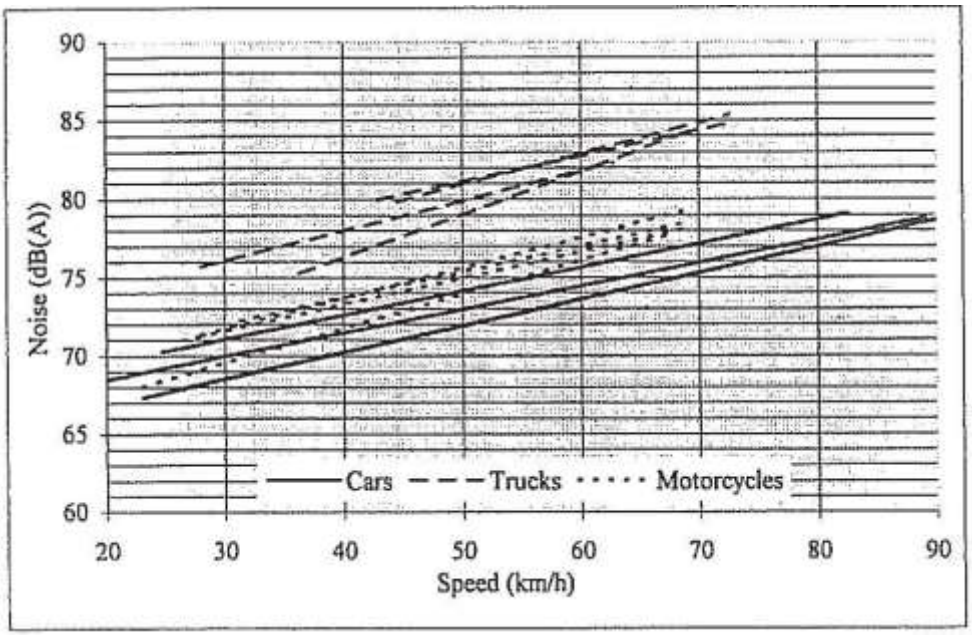
There are many sources of road traffic noise, which affect the environment. It has been established that there are two major sources which contribute to road traffic noise. These are:

- Engine Noise, which tends to be dominant at low operating speeds (below 50-60 km/h).
- Interaction between vehicle tires and road surface, which dominates at high operating speeds (70-150 km/h).

Since the project road will primarily have traffic running in the speed range of 80-120 km/h, the major contributor to overall sound levels would be tire-road noise. The source and magnitude of noise from tire and pavement interaction are primarily related to surface texture and surface smoothness, which are measured in terms of Roughness Value (mm/Km) for different types of pavement surface. IRC:SP:99 2013 specifies the maximum permissible roughness values of bituminous concrete surface of flexible pavement and cement concrete surface of rigid pavement as 1800 mm/km (IRI = 2.55 m/km) corresponding to 'Good' condition of road surface. Various past studies on the evaluation of traffic noise suggest that with this difference in unevenness index value (roughness value), the noise generated by vehicles traveling on concrete road can emit 3 to 5 dB(A) more noise than vehicles traveling on an asphalt surface. Outcome of one of such study reports on the evaluation of Traffic Noise in Arterial Road with different road roughness carried out in Indonesia (refer to Proceedings of Eastern Asia Society for Transportation Studies, Vol. 4, October 2003) is stated here below:

1) The noise generated by vehicles traveling on concrete road can emit up to 3 Db (Decibels) more noise than vehicles traveling on Asphalt surface.
2) On flexible pavements, trucks produced higher SPL (Sound Pressure Level) than cars.
3) Like flexible pavements, on rigid pavement also, trucks produced higher SPL than cars.
4) A rigid pavement with IRI (International Roughness Index) higher than flexible pavement did not always produce higher SPL.
5) Under free flow conditions and speed of 80km/h, the noise level may increase by 5-Db (A) for a 30% increase in commercial traffic.

A comparative study of SPL of cars, trucks and motorcycles on rigid pavements as well as flexible pavements was also made and the same are reproduced here in **Figures 10.1 & 10.2**.



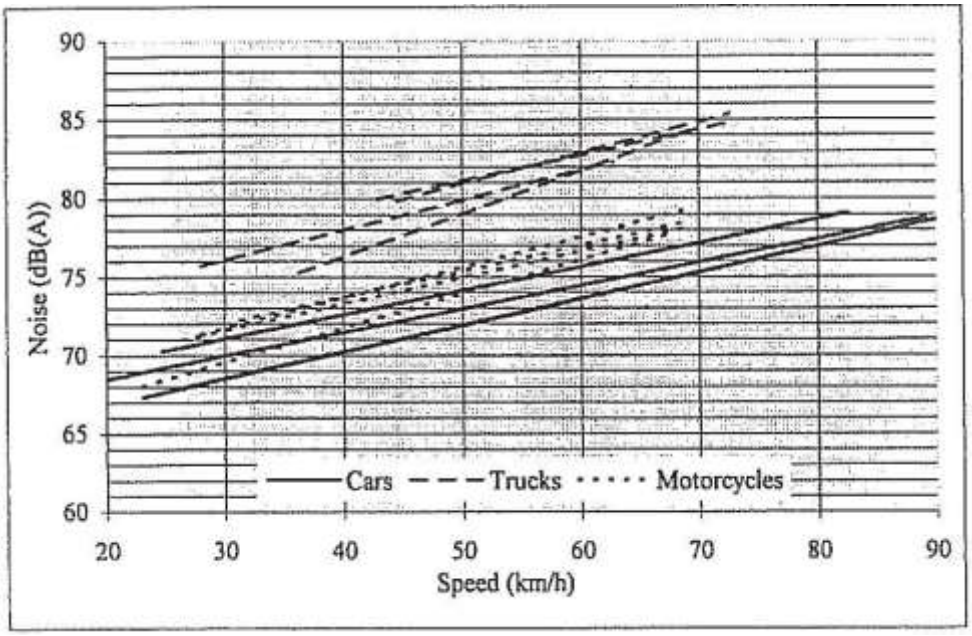


Figure 10.1: Comparison of SPL of cars, trucks and motorcycle on concrete roads

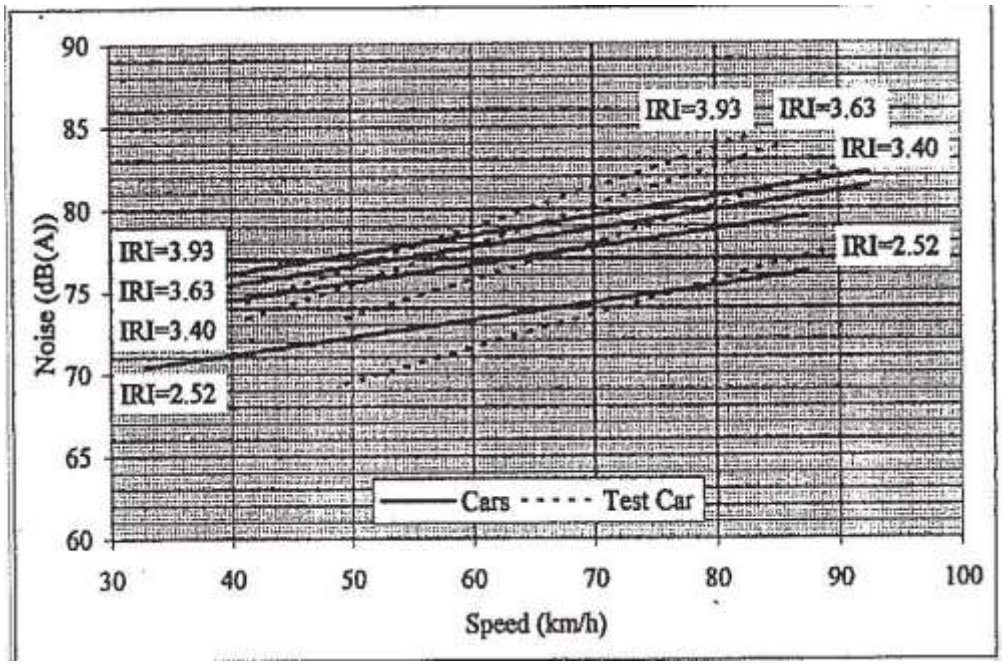


Figure 10.2: Comparison of SPL of cars, trucks and motorcycle on flexible roads

From comparison between SPL of vehicles on flexible and rigid pavements, it is seen that the IRI of 3.4 on flexible pavements produce sound pressure levels more than that at IRI 5.35 & 5.31 at rigid pavements.

An attempt has been made to calculate the approximate traffic noise on the section of maximum peak hourly traffic, which is Section-5 of the project road and the same has been calculated as 76 dB(A) for asphalt road surface in the first year of the design period. For concrete road surface, the likely noise level on the same section would therefore be in the range of 79 dB – 81 dB. It has also been found that pavement texture does not remain constant over the time due to increase in traffic, commercial traffic in particular and hence, affects the tire pavement noise levels. To keep the pavements quiet, preventive maintenance technique is recommended to be employed. Therefore, in carrying out the life cycle cost analysis of various pavement options, the cost of maintenance has been considered accordingly.

10.9.8 Recommendations on Noise Mitigation Measures considered in Pavement Design

Currently the most commonly adopted solution to reduce the noise generated by traffic is installation of sound barriers. While the construction of sound barriers impedes the sound transmission path between vehicles and the neighboring development alongside the highways resulting in noise abatement, they tend to be extremely costly and not practical for expressways. Other methods of reducing pavement noise are pavement grinding or providing a thin overlay of asphalt concrete. Our recommendation for the project road would be as follows:

1) On newly constructed concrete pavements, diamond grinding is recommended for correcting the initial roughness that are likely to occur due to construction problems and this will ensure to have uniform skid resistance and appearance of the newly constructed concrete road service. The expected reduction of noise would be approximately 2 dB to 5 dB at the pure tone frequencies that generate the tire whine noise. At closer distances to the travel lanes, reduction in the same frequencies may be as much as 7 dB.

2) Past experience and various studies suggest that estimated life of diamond grinding can be 10 to 15 years, depending on traffic and environmental conditions. In this case, in our life cycle case analysis, it has been considered that diamond grinding will be used as a part of the preventive maintenance technique at an interval of every 10 years throughout the design life (30 years) of the rigid pavement.

3) It has been experienced that uniformly spaced transverse tined concrete pavement results in the most irritating tire/pavement noise when compared to longitudinal tine concrete pavement textures. It is therefore recommended to adopt the technique of diamond grinding which will give the surface a longitudinal oriented structure.

10.9.9 Recommendation on Heated Tire issue on Concrete Pavement

Cement concrete roads are harder than bituminous roads, which results in lesser rolling resistance of the tires. While this means that the friction is more as it is a rigid pavement, it also means that there is slightly more chance of heating of tires. The nylon threads inside radial tires heat up due to friction, especially on long journeys at a high speed. The first safeguard against tire heating is to adhere to the tire manufacturers' specifications and maintain speed limit.

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DESIGN OF BRIDGES / STRUCTURES

11

11. DESIGN OF BRIDGES / STRUCTURES

11.1 GENERAL

As per approved alignment the following types of bridges and structures are being provided depending upon hydraulic considerations, traffic need and site requirements.

- Major / Minor bridges across rivers, nalas, creeks, canals and drains
- Bridges across oil pipe line crossings
- ROBs / RUBs
- Flyovers and Interchanges
- Vehicular Underpasses / Vehicular Over Bridge
- Light Vehicle Underpasses / Pedestrian / Cattle Underpasses

11.2 AVAILABLE DATA FROM SECONDARY SOURCES

Before conducting field surveys all concerned authorities were approached to ascertain the availability of any past reports including subsurface geotechnical data, hydraulic data and other relevant information. Since the proposed Expressway is on green field alignment the above information was not available except pre-feasibility study report carried out by M/s. SECON Pvt. Ltd. in October 2008 for the proposed Expressway.

11.3 FIELD SURVEY AND SITE INVESTIGATION

After reconnaissance survey of the project stretch of VM Expressway by the Team Leader and the Team of experts, the detailed investigation and survey for bridges / structures were carried out at site to identify the location of bridges, fixing waterway, span arrangements, type of structure and protection measures. Thereafter detailed site investigations, field studies and topographic surveys were carried out for the total project length as per provisions of IRC: 5-2015 and IRC: SP-13.

11.4 SITE SELECTION FOR RIVER / NALA / CANAL BRIDGES

Site selection of proposed bridges over river / nala / canal has been done generally keeping in view the criteria and guidelines laid down in MOSRT&H Pocket Book for Bridge Engineers and IRC: 5–2015. Accordingly, the following criteria have been adopted:-

- **For Minor Bridges (Bridge length upto 60m)**

  The main consideration has been given to the geometrics and requirement of expressway and bridge location has been kept as per proposed alignment of Expressway.

- **For Moderate Bridges (Bridge lengths between about 60 and 300m)**

  Bridge locations have been decided after considering both, viz. the alignment requirements of expressway as well as the technical merits of the proposed bridge sites.

- **For Major Bridges (Bridge length exceeding 300m)**

  In deciding the siting of major bridges > 300m in length, the technical merits of the bridge site have been main consideration and approaches have been realigned to suit the location of the bridge site wherever required.

The following main factors have been considered in deciding site selection for bridges:

- Permanency of the channel
- Presence of high and stable banks
- Narrowness of the channel and large average depth compared to maximum depth
- Straight reach of the river towards u/s and d/s of the proposed site to the extent possible
- Freedom from islands or any form of obstruction both towards u/s and d/s
- Possibility of right angled crossings
- To ensure proper geometrics of approach roads

The sites for the proposed minor, medium and major bridges on the proposed Vadodara-Mumbai Expressway have been selected keeping in view the criteria / factors narrated above. However, several alternative sites were studied in the case of major bridges across Narmada. The merits / demerits of each alternative and recommendation for final location are given in **Annexure 11.1** of this Chapter.

11.5 HYDROLOGICAL SURVEYS & HYDRAULIC STUDIES

The collection of proper hydraulic data has got vital bearing in deciding the waterway of bridges, type of foundations and protective works and thus utmost care was exercised in ensuring that the data collected is realistic and accurate. All information about HFL, LWL and discharge was also collected by local enquiries and visible signs at bridge sites, wherever available.

A desk study was made from the available data on topography viz. topographic maps, storm duration, rainfall statistics, top soil characteristics, vegetation cover etc., so as to assess the catchment areas and hydraulic parameters for all proposed structures wherever required. The findings of the desk study were further supplemented and augmented by reconnaissance survey along the area and further investigation carried out thereafter.

Hydraulic data for all the proposed cross drainage structures was collected by a specialist team of experts dealing exclusively with the hydrology of the bridges. Detailed hydraulic calculations have been carried out to determine design discharge, HFL, scour depth, clear waterway and vertical clearance etc. for each bridge as per provisions of TOR. Accordingly hydraulic design of structure has been carried out for the maximum flood of 100 year return period.

After detailed topographical survey and finalization of the bridge locations detailed hydraulic analysis and computation have been carried out to fix hydraulic parameters required for design of river / canal / drain bridges. Details of hydraulic computations, approach and methodology adopted and analysis of hydraulic data are given in separate chapter of this report. A statement showing details of hydrological data i.e. discharge, HFL, waterway for major/minor bridges over rivers/drains/nalas are given in **Annexure 11.2** of this Chapter**.**

11.6 PROTECTION WORK

Based on hydrological studies and site investigations, suitable protection works have been proposed for bridges and structures and approach embankment as per provisions of IRC: 89-1997. These protection measures include:

- Protection of river banks
- Protection of approach roads
- Protection around abutment
- River bed protection in case of open/shallow foundation
- Special protection measures for bridges over major rivers of more than 300m length as per hydraulic and site requirements.

As per detailed study and investigation it has been found that no extensive protection works are required on most of the bridges except over river Narmada which has a wide flood plain and heavy discharge. Accordingly model study has been recommended by the Consultant and the same is being carried out at CWPRS, Pune as approved by NHAI. For some minor bridges the existing channel has been realigned or diverted due to site condition for smooth flow of water. In such cases the new channel shall be properly protected with slope pitching and launching apron as per requirement.

11.7 SPAN ARRANGEMENT

General

Span arrangement of the proposed bridges / other structures have been decided mainly based on hydraulic data, subsoil strata likely to be encountered at site and other site considerations. Out of the feasible structural alternatives, the main objective has been to select such a form, which will ensure provision of longer / continuous spans with lesser expansion joints for better riding quality and to meet the functional, structural and economic requirements and also to blend with the environment of the surrounding area keeping in view the aesthetic consideration and innovative designs. For choice of type of structure the main emphasis has also been given on fast track construction by adopting segmental / precast construction which can be easily constructed by the locally available material, resources, labour and equipments. In order to optimize the use of precast elements the number of spans have been standardized and kept to be the barest minimum.

Waterway & Vertical Clearance

a) *For Navigational Spans*

Inland Waterways Authority of India (IWAI) have intimated vide their letter No. IWAI/PL-13 (2)/2001/Gen/NW dated 8/7/2009 that National Transport Policy Committee 1980 has identified 10 potential waterways across the country, which include river Narmada, their techno economic feasibility including declaring them as National Waterway is under progress. IWAI have accordingly desired that for these bridges minimum horizontal clearance between bridge piers may be kept as 100m and minimum vertical clearance as 10m above HFL/HTL as a long term navigational requirement as these rivers fall in the highest class of waterway i.e. (Class-VII). Accordingly longer spans and higher vertical clearance for the above bridge has been provided keeping in view the navigational requirements as suggested by IWAI and specified in Clause 220 of IRC:6-2017.

b) *For other Bridges over Rivers / Nallas / Streams*

The minimum vertical clearance from lowest point of superstructure above HFL shall be based on design discharge of River / Nalla / Stream as stipulated in Clause 106.8 of IRC:5-2015 and reproduced below:

Design Discharge in cumecs	Minimum Vertical Clearance in mm
Upto 0.3	150
Above 0.3 & upto 3.0	450
Above 3.0 & upto 30.0	600
Above 30.0 & upto 300.0	900
Above 300.0 & upto 3000.0	1200
Above 3000.0	1500

c) For Canal Bridges

Service Road and Inspection path of adequate width has been proposed on either side of canal. The vertical clearance above service road upto lowest point of superstructure has been proposed as 3.5m, this has been increase to 5.5m as per road traffic / irrigation department's requirement for some of the canal bridges.

11.8 STRUCTURAL SYSTEM / TYPE OF STRUCTURES

In selection of type of structures there can be number of feasible alternatives for each bridge / structure depending upon the available data and site conditions. However, efforts have been made to ensure that the type of structures selected will be innovative, cost effective and suitable for construction by locally available material and technology in shortest possible time.

Keeping in view the above considerations, the following type of structures have been proposed for bridges/structures which may be simply supported, continuous or integral as per site requirement:-

Superstructure

Span upto 10m	:	RCC solid slab / RCC box
Span 10m to 20m	:	RCC voided slab
Span 15m to 25m	:	RCC precast beam and cast in situ slab
Span 24m to 45m	:	PSC Precast girder and cast in situ slab
Span 30m to 60m	:	Pre-cast post tensioned girder or steel plate girder with cast in situ RCC slab / PSC box girder
Span > 60m	:	PSC box girder cantilever type construction/ Extradosed type
Railway Over Bridge (ROB) Railway portion	:	Steel plate girder with RCC deck slab composite type superstructure as per Railways' Circular.
Vehicular Over Bridge (VOB)	:	RCC Integral Structure / PSC Precast Girder with cast in situ RCC deck slab composite type.
Vehicular Underpass (VUP)	:	RCC Box / Portal type
Light Vehicular Underpass (LVUP)	:	RCC Box
Pedestrian / Cattle Underpass (CUP)	:	RCC Box

Substructure

Abutment	:	RCC wall type
Pier	:	RCC circular/wall/ornamental type

Foundation

Major Bridges	:	Well / Pile / Open
Minor Bridges	:	Well / Pile / Open
R.O.B. / Flyovers / Interchanges	:	Open / Pile

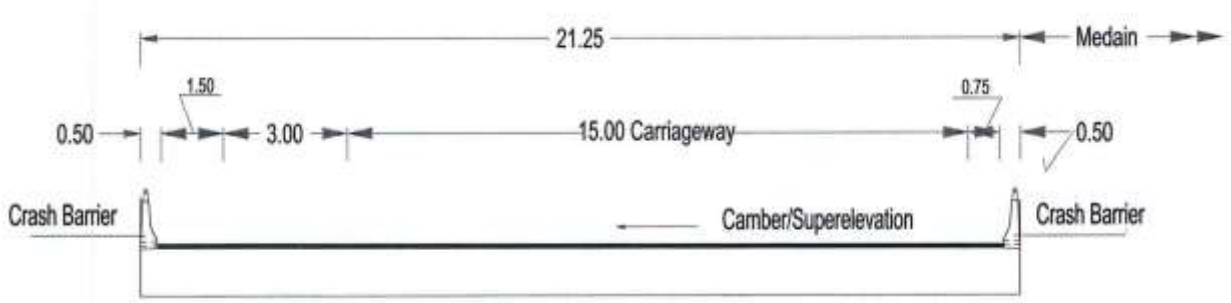
In deciding the span arrangement and selection of type of superstructure the following points have generally been taken into consideration:-

- Single span bridges of longer span lengths have been preferred. However in multi-span bridges with less than 30m individual span, deck continuity has been provided for better riding quality of the road.
- Effort has been made to provide long span or continuous superstructure wherever feasible.
- Long span cantilever type segmental PSC box girder have been proposed where long span due to navigational requirement are required or where depth of water is more / subsoil condition are suitable to reduce number of foundations.
- Steel girders with RCC deck slab composite type superstructure have been proposed on ROBs as per Railways' requirement.
- As far as possible precast RCC/PSC/girder and slab or segmental PSC box or pre-fabricated steel girder type superstructure have been adopted for fast track construction.
- In the case of bridge over Narmada river PSC box type superstructure with cantilever construction in modules of 75m + 3 x 120m + 75m for main river portion and 48m span PSC box with segmental construction have been proposed for viaduct portion.
- Effort has been made to provide single span bridge over canal with a provision of 7.5m wide service road on either side of canal with vertical clearance of 3.5m to cater for any future remodeling of channel and to avoid any cross traffic on the Expressway.
- Single span RCC/PSC girder type bridges have been provided at the gas pipeline crossings to keep ROW of gas pipeline free from the road embankment / structures.

11.9 DECK CONFIGURATION

Deck configuration of new bridges / structures has been kept as per proposed road cross section of Expressway. All bridges / structures shall have two independent carriageways of 4-lanes each with 3.5m wide open median between the two carriageways as per Typical Cross Section 6.5 (c) of 8-lane structures given in Manual of Specifications and Standards for Expressways. Overall deck width of each carriageway has been kept 21.25m to match with the width of approach embankment.

Typical Cross-section of 8-Lane (2x4 lane) Bridge and Grade Separated structures is shown in **Fig. 11.1.**



11.10 DESIGN LOADING

Each carriageway of proposed bridges and structures has been designed for live load as per provision of Clause 204.3 of IRC: 6-2017. Accordingly each 6-lane carriageway of proposed bridges / structures on Expressway has been designed for two lane of IRC Class-70R loading with two lane of IRC Class A loading or one lane of IRC Class-70R loading with four lane of IRC Class A loading or 6 lane of IRC Class-A loading whichever governs with appropriate lane reduction factor. However ROBs having each 5-lane carriageway have been designed for two lane of IRC Class 70R loading with one lane of IRC Class A loading or one lane of IRC Class-70R with three lane of IRC Class A loading or 5 lane of IRC Class A loading, whichever governs with appropriate lane reduction factor.

Bridges / Structures shall also be checked for Special Vehicle (SV) loading as per provision of Clause 204.5 of IRC:6-2017.

11.11 DETAILS OF PROPOSED BRIDGES / STRUCTURES

11.11.1 Proposed Bridges / Structures on Vadodara-Mumbai Expressway

As per approved alignment of the expressway, the following bridges and other structures have been proposed as per hydrological considerations and rail traffic requirement for ROBs and road traffic requirement for Road junctions of NH, SH, District / Village roads and local roads crossing the alignment.

S. No.	Structure type		No. Structures
A.	Major Bridges over Rivers	-	1
B.	Major Bridge over canal	-	1
C.	Minor Bridges over Rivers / Drains / Nalas	-	3
D.	Minor Bridges over Canals	-	1
E.	Interchanges	-	1
F.	ROBs	-	NIL
G.	Flyovers	-	1
H.	Bridges on Gas / Oil pipelines	-	NIL
I.	Vehicular Over Bridges	-	NIL
J.	Vehicular Underpasses	-	2
K.	Light Vehicular Underpasses	-	3
L.	Pedestrian / Cattle Underpass	-	7
	TOTAL	**-**	**20**

In addition to above, one LVUP have been proposed on Loops/Ramps of Interchanges.

A. Major Bridge over Rivers (More than 60m length) - 01 No.

The expressway alignment is crossing major / minor rivers, drains and nala at number of locations where major / minor bridges have been proposed as per hydraulic considerations. Details of major bridge over Narmada River are given below.

Table 11.1: Details of Major Bridge over Rivers / Drains / Nala

Sl. No.	Name of Bridge	Chain-age	Span Arrangement c/c exp. jt (m)	Total length F/F of Dirt walls (m)	Type of Superstructure	Type of Foundation	Deck Configuration (m)
1.	Major Bridge over Narmada River	284+428	16 x 48.00 + 2x(75+3x120 +75) + 9 x 48.00	2220.050	PSC box Balanced Cantilever construction type / PSC segmental box Girder	Well / Pile	2 x 21.25

B. Minor Bridges over Rivers/Drains/Nalas (Less than 60m length) - 03 Nos.

Table 11.2: Details of Minor Bridges over Rivers / Drains / Nalas

Sl. No.	Name of Bridge	Chainage	Span Arrangement c/c exp.Jt. (m)	Total length F/F of Dirt walls (m)	Type of Superstructure	Type of Foundation	Deck Configuration (m)
1.	Minor Bridge over Tributary of Narmada	280+632	Double cell box opening size 10m x 5.5m	24.000 *	RCC Buried Box	Raft	Deck width 46.0m Barrel length 66.000
2.	Minor Bridge over Tributary Narmada (Skew 30˚)L	281+549	Single cell box opening size 11 x 5.0m	14.000 *	RCC Buried Box	Raft	Deck width 46.0m Barrel length 79.44m
3.	Minor Bridge over Stream	288+863	1 x 15.850	15.900	RCC Girder & Slab	Open	2 x 21.25

** Length of RCC box type structure is between outer faces of RCC Box.*

C. Bridges over Canals (02 Nos.)

Since the expressway alignment is passing through fields and cultivated areas, canals, branch canals, distributaries and minors are crossing the alignment at several locations. Bridges at these locations have been provided as per data collected from site and obtained from Irrigation Department. Efforts have been made to provide single span bridge covering entire canal section, service road of width 7.5m and inspection road on either side of canal with a vertical clearance of 3.5m above service road has been proposed. Details of 2 Nos Canal bridges in this package have been tabulated in **Table 11.3** below.

Table 11.3: Details of Canal Bridges

Sl. No.	Name of Bridge	Chain-age	Span Arrangement c/c exp. (m)	Total length F/F of Dirt walls (m)	Type of Superstructure	Type of Foundation	Deck Configu-ration (m)
1.	Major Bridge over Gas Pipeline and Ambleswar Branch canal (Skew 60˚) L	290+085	2 x 62.40	124.900	Steel Plate Girder & RCC Slab	Pile	2 x 21.25
2.	Minor Bridge over Ambleswar Distributary canal (Skew 35˚) R	291+295	1 x 47.700	47.761	PSC Girder & Slab	Pile	2 x 21.25

D. Interchange - 01 No.

The expressway is an access controlled facility and therefore access is provided only entry/exit at specified locations through interchanges. Six number interchanges have been provided in this phase of the main expressway on that two falls in this package. In general, one obligatory span of 47.2m span over the cross-road with viaduct span on either side has been proposed as per site requirement. PSC box girder / PSC T-beam with cast in situ RCC deck slab composite type superstructure have been provided in obligatory span. In viaduct span PSC girder / RCC girder deck with RCC slab and RCC voided slab superstructure are proposed. The minimum vertical clearance under obligatory span has been kept as 5.5m. Length of viaducts has been provided as per site requirement to keep maximum height of earthen embankment in approaches upto 10m. In additional to main structure, one LVUP structures have also been proposed in ramps / loops of interchanges. The details interchange structure over Bharuch - Dahej (SH-6) in this package are tabulated in **Table 11.4** below:

Table 11.4: Details of Interchange

Sl. No.	Name of Bridge	Chainage	Span Arrangement c/c exp. (m)	Total length F/F of Dirt walls (m)	Type of Superstructure	Type of Foundation	Deck Configu-ration (m)
1.	Interchange at Crossing Bharuch-Dahej State Highway (SH-6)	287+385	1 x 49.200 + 2 x (25 + 25 + 27.788)	200.825	PSC Box Girder & 3 Span Cont. PSC Girder and Slab	Pile	2 x 28.75
			RCC Box (Clear Opening 10.5 x 3.50)	11.700	RCC Box	Open	1 x 10.5

E. Flyover - 01 Nos.

The alignment of proposed expressway is crossing National Highways / State Highways at a number of locations. At the junctions where interchanges are not required only flyovers have been proposed with main span of 30m and vertical clearance of 5.5m. There are 9 nos. locations in phase-1 where flyovers are proposed of that only one locations fall in this package, the details proposed flyover over Hansot Ankaleshwar Road (SH-6) are tabulated below.

Table 11.6: Details of Flyover

Sl. No.	Name of Bridge	Chainage	Span Arrangement c/c exp. (m)	Total length F/F of Dirt walls (m)	Type of Superstructure	Type of Foundation	Deck Configuration (m)
1.	Flyover over Hansot Ankaleshwar Road (SH-6) (Skew 20^0) L	279+353	17.687 + 34.203 + 17.687	69.630	PSC Girder & Slab / RCC Girder & Slab	Pile	2 x 21.25

Full details of the above proposed bridges / structures such as span arrangement, type of foundation, superstructure, substructure, deck configuration etc. are given in **Annexure 11.3.**

F. Vehicular Underpasses - 02 Nos.

For district and major roads Vehicular Underpasses (VUPs) of RCC box type / Integral Portal frame type structure with clear opening of 12 x 5.5m have been provided as per traffic requirement. Details of these VUPs are given below in **Table 11.9**.

Table 11.9: Details of Vehicular Underpasses

Sl. No.	Name of Bridge	New Chainage	Size of Opening (m)	Total length F/F of Dirt wall (m)	Type of Superstructure	Type of Foundation	Deck Configu-ration (m)
1 to 2	VUP (2 Nos.)	Refer Annexure - 11.4	12 x 5.5		RCC Box	Open	2 x 21.25

Full details of the above proposed VUP's such as location, span arrangement, type of foundation, superstructure, substructure, deck configuration etc. are given in **Annexure 11.4.**

G. Light Vehicular Underpasses - 03 Nos.

For minor village / local roads Light Vehicular Underpasses (LVUPs) have been provided with clear opening of 10.5m and vertical clearance of 3.5m. The details of these LVUP's are given below and in **Table 11.10.**

Table 11.10: Details of Light Vehicular Underpasses

Sl. No.	Name of Bridge	New Chainage	Size of Opening (m)	Type of Super structure	Type of Founda-tion	Deck Configu-ration (m)
1 to 3	LVUP (3 Nos.)	Refer Annexure 11.5	10.5 x 3.5	RCC Box	Open	2 x 21.25

H. Pedestrian/Cattle Underpasses (07 Nos.)

For movement of cattle and agricultural vehicles and labour, PUP / CUP's have been provided with clear opening of 7.0m and vertical clearance of 3.5m. The details of these PUP / CUPs are given below in **Table 11.11**.

Table 11.11: Details of Pedestrian / Cattle Underpasses

Sl. No.	Name of Bridge	New Chainage	Size of Opening (m)	Type of Super structure	Type of Foundation	Deck Configu-ration (m)
1 to 07	PUP / CUP (07 Nos.)	Refer Annexure 11.6	7.0 x 3.5	RCC Box	Open	2 x 21.25

Full details of the above proposed LVUP & PUP/CUP such as location, span arrangement, type of foundation, superstructure, substructure, deck configuration etc. are given in **Annexure 11.5 & 11.6** respectively.

11.12 DESIGN STANDARDS FOR BRIDGES / STRUCTURES

Design standards have been clearly identified and enumerated for evolving a comprehensive design philosophy, which covers all aspects of design for various components of the bridges/structures viz. superstructure, substructure, foundations and protection works. The design of bridges / structures shall be carried out as per relevant IRC codes of practice, IRC specifications, latest

guidelines and circulars of NHAI, Guidelines of Expressway published by MORT&H and relevant Bureau of Indian Standards (BIS). For aspects not covered by IRC and BIS Standards, the relevant recommendations of the International Standards like Euro Code, BS-5400, AASHTO or sound engineering practices have been followed. For ROBs / RUBs the standards / instructions issued by Ministry of Railways have been kept in view. The design philosophy includes but is not limited to the following:-

- Materials - concrete, steel etc.
- Live loads
- Width of carriageway and number of lanes
- Design speed
- Requirement of footpaths
- Temperature gradient and climatic data
- Wind effect
- Seismic effect
- Safe bearing capacity and soil parameters
- Navigational requirement
- Differential settlement
- Methodology for analysis and design
- Bearings, expansion joints and wearing coat
- Construction techniques
- Protection works
- Repair / rehabilitation techniques

11.12.1 Design Loads

The design loads on this project road considered generally shall be as per the relevant IRC Standards as well as design approach formulated for similar type of ongoing projects on NHs in the country.

a) Dead Loads

The unit weight of materials considered for the design shall be as per Clause-203 of IRC: 6-2017 as given below:

Item	**Unit Weight (kN/m³)**
Reinforced concrete	25.0
Prestressed concrete	25.0
Plain concrete	25.0
Structural steel	78.5
Water	10.0
Backfill soil (dry)	20.0
Submerged soil	10.0

b) Super Imposed Dead Loads

Wearing Coat

65mm thick wearing coat comprising of 40mm thick bituminous concrete over laid with 25mm thick bitumen mastic layer shall be adopted in conformity to section 500 of MORT&H specifications. Alternatively the cement concrete wearing coat with new materials like latex modified concrete or stone mastic asphalt wearing coat or alike as per international practice may be provided after approval of NHAI / MORT&H.

Accordingly weight of wearing coat considered in design including future overlay is 2 kN/m^2.

Crash Barrier

450mm wide (at base) and 1100mm high New Jersey type crash barrier is provided for flyovers, bridges without footpath. Weight of crash barrier works out to above 7.5 kN/m. **For ROB high containment type crash barriers as per provision of RDSO has been proposed.**

c) Live Load

Live load on bridges shall be considered as per provision of clause 204.3 of IRC: 6-2017. Live load combination for design will be as per Table-6 and Table-6A of IRC: 6-2017. In general, the following live load combinations are considered.

- Where carriageway width is > 5.3 and < 9.6m, 1 lane of IRC class 70R or 2 lane of IRC Class-A loading whichever is critical.
- Where carriageway width is > 20.1m & < 23.6m, 2 lane of IRC Class 70R + 2 lane of IRC Class A loading or one lane of IRC Class 70R + 4 lane of IRC Class A loading or 6 lane of IRC Class A loading whichever is critical.
- Where carriageway width > 23.6m and < 27.1m, 2 lane of IRC Class 70R + 3 lane of IRC Class A loading or one lane of IRC Class 70R + 5 lane of IRC Class A loading or 7 lane of IRC Class A loading whichever is critical.
- Where carriageway width > 27.1m and < 30.6m, 2 lane of IRC Class 70R + 4 lane of IRC Class A loading or one lane of IRC Class 70R + 6 lane of IRC Class A loading or 8 lane of IRC Class A loading whichever is critical.

Lane reduction factor for longitudinal effect of Live load shall be considered in accordance with clause 205 of IRC:6-2017. The above loads will be increased by appropriate impact factors as per provision of Clause - 208 of IRC: 6-2017.

Structures shall also be checked for Special Vehicle (SV) loading as per provision of Clause 204.5 of IRC:6-2017.

d) Wind loads

Wind load on structure shall be considered as per clause 209 of IRC: 6-2017.

e) Water current forces

Water current forces considered shall be as per Clause - 210 of IRC: 6-2017. Severe of the following two conditions is adopted for the design.

- Water current pressure acting at right angle to structure.
- Water current pressure acting at an angle of (+/-) 20 deg to structure.

In the case of bridges having pucca floor or having an inerodable bed the effect of cross current due to a difference of head of 250mm between the opposite faces of a pier shall be considered as per Clause 210.6 of IRC: 6-2017.

f) Longitudinal forces

Longitudinal forces arising from braking effect and frictional resistance of bearing shall be considered as per clause 211 of IRC: 6-2017.

- Braking force – 20% of first trainload + 10% of the succeeding trains or part thereof + 5% of loads on the lanes in excess of two. The force due to braking effect is assumed to act along a line parallel to the road way and 1.2m above deck level. While transferring the force to the bearings, the change in the vertical reaction at the bearings is taken in to account.
- Frictional resistance offered to the movement of bearings due to change in temperature or any other cause.

g) Centrifugal force

Centrifugal force shall be considered as per Clause 212 of IRC: 6-2017. Where a bridge or flyover is located on a horizontal curve or portion of structure in curve is subjected to Centrifugal force in addition to all other forces. This force will be considered as acting at 1.20m above carriageway level and no increase for impact will be allowed.

h) Earth pressure

Components of bridges and other structures required to retain the earth will be designed for earth pressure as per clause 214 of IRC: 6-2017. All abutments and return walls will be designed for live load surcharge equivalent to 1.2m earth fill.

In general, soil used for back filling behind abutment and return wall will have the following properties:-

ϕ $\geq 30^{o}$

δ $= 20^{0}$

r_d $= 20$ kN/m^3

r_{sub} $= 10$ kN/m^3

i) Temperature effects

Temperature effects will be considered as per provision of Clause 215 of IRC: 6-2017.

j) Seismic Forces

As per Fig. 11 of IRC:6-2017 the project corridor is falling in Seismic Zone-III of Seismic Map of India. Accordingly the following parameters shall be considered:-

Zone factor (Z)	-	0.16
Importance factor (I)	-	Importance factor for different bridge categories will be taken from Table-19 of modified clause 219.5.1.1 of IRC:6-2017
Response Acceleration Coefficient (Sa/g) (for 5% damping)	-	In accordance with figure-20 of IRC:6-2017 for the time period of structure
Response Reduction factor	-	Response reduction factor for different bridge components will be

taken from Table-20 of clause 219.5.5 of IRC:6-2017

k) Buoyancy / Rock

100% buoyancy shall be considered while checking stability of foundations resting on soil. However, the maximum base pressures shall also be checked without buoyancy effects. Pore pressure uplift limited to 15% shall be considered while checking stresses of the substructure elements.

In the design of substructure and foundation, the effects of buoyancy shall be considered assuming the fill behind abutments has been removed by scour.

11.12.2 Load Combinations

Basic loads considered in the design are as follows:

- Dead load (G)
- Live load (Q) + Vehicle impact Qim + Braking (F_b)
- Vehicle Collision load (V_c)
- Centrifugal force (F_{cf})
- Water current (F_{wc})
- Buoyancy (G_b)
- Earth pressure (F_{ep})
- Temperature effect (F_{te})
- Wind load (W)
- Seismic Force (F_{eq})
- Grade effect (G_e)
- Barge impact

The load combinations shown in Table 1 and Annex B in accordance with clause 202.3 of IRC: 6-2017 shall be adopted for working out stresses in members. For working out base pressure load combinations given in clause 706 of IRC: 78-2014 shall be followed.

11.12.3 Condition of Exposure

Since the expressway is running along the sea coast, the structure shall be designed for severe condition of exposure. Accordingly, cover to the reinforcement minimum grade of concrete minimum cement content and water cement ratio will be as per provisions for severe condition of exposure.

11.12.4 Material Specifications

Concrete

The concretes will conform to the requirements stipulated in IRC:112-2011. Minimum grades of concrete proposed for each component are listed below:

- PSC post tensioned Box / I girders = M45 / M50
- RCC Main & cross girders and deck slab = M35
- Pier, Pier cap, Abutment and Abutment cap = M35
- Pedestals on Pier / Abutment = M45
- Pile cap and Pile = M35

- Kerb, Bed block and dirt wall = M35
- Approach slab = M30
- Crash barrier over deck slab = M40
- Crash barrier in approach = M40
- PCC Leveling course below foundations and approach slabs = M15

Expansion Joints

Buried or filler type expansion joints will be provided for RCC solid slab bridges having spans upto 12m. In the case of RCC T beam and slab / PSC girder and slab / Steel plate girder and slab bridges where expansion requirement is upto 80mm, strip seal type expansion joints will be provided. In the continuous spans and large span bridges, where expansion requirement exceed 80mm, Modular type of expansion joints will be provided. Expansion joint shall be designed and manufactured as per provisions of IRC: SP-69-2005.

Bearings

Tar Paper bearings will be provided for RCC solid slab bridges having span less than 12m. Elastomeric bearings have not been proposed as their service life is short and shall need replacement after every 10 to 15 years and their frequent replacement shall be problematic and difficult due to heavy traffic on Expressway. PTFE / POT bearings will be provided for all bridges, flyovers and grade separators having spans above 12m. POT/PTFE bearing shall be designed as per provisions of IRC: 83 (Part-III) – 2015.

Untensioned Reinforcement

Corrosion Resistant TMT deformed bars of Grade Designation Fe-500D conforming to IS: 1786 is proposed to be used.

Prestressing Steel

High Tensile Steel Strands **:** Uncoated, stress relieved, low relaxation strands, conforming to IS: 14268, are proposed. It will avoid grouping of cables and also reduce the number of cables.

11.12.5 Approach Slab

Reinforced concrete approach slab 3.5 m long and 300 mm thick in M30 grade concrete at either end of the bridge has been proposed with one end supported on reinforced concrete bracket projecting out from dirt wall and the other end resting over the soil in accordance with the guidelines issued by MoRT&H. 100 mm thick levelling course in M15 grade concrete has been provided under the approach slab.

11.12.6 Drainage Spouts

Drainage spouts shall be provided in accordance with MoRT&H Standard Plans.

11.12.7 River Training and Protective Works

River training and protective works are required for ensuring the safety of bridges and their approaches on either side. The selection of the type of river training or protective work will depend upon terrain, overall behaviour of the river, location of the bridge vis-à-vis the areas of attack of the river, span arrangement, type of foundation, nearness of the approaches from the influence zone of the river etc.

The following types of river training works and protection are generally required depending upon the hydraulic consideration and site requirement.

1) River Bank Protection

For protection of river banks against the erosive attack of the river, the pitched slope may normally vary from 1.5(H):1(V), to 2(H):1(V). However, the embankment slope has been proposed as 3(H):1(V) for this project. Generally maximum depth of anticipated scour is assumed as 1.5 dsm. The thickness of the pitching and the details of the apron are worked out as for the guide bund.

2) Approach Road Protection

The approaches to high bridges located in the flood zones of rivers are susceptible to river attack, making it necessary to protect them for their safety. The design of the protective works depends upon the location of the approaches, their distance from the river, depth of low, velocity of attack etc.

3) River Bed Protection

For cases where adoption of shallow foundation becomes economical by restricting the scour, floor/bed protection has to be provided. Such protection has to be of adequate thickness as not to get washed away or disturbed by piping action, etc. Usually, performance of similar works are the best guide in finalizing the design of the new works.

Accordingly as per detailed reconnaissance as well as site inspection and hydrological investigation the following protective measures are proposed to be provided:

- **For bridges with open/shallow foundation**, bed protection in the shape of flooring with flexible apron/launching apron with slope pitching around abutment will be provided.
- **For bridges with deep foundation viz. pile / well foundation** protection around abutment with stone pitching and launching apron/toe wall will be provided along with protection of road embankment on either side upto required length as per site requirement.
- **For bridges over major river of more than 300m length** detailed hydraulic study shall be carried out for providing river training works if required.
- In general no major river protection works are required in most of the cases except in the case of major bridge across river Narmada.
- All the existing bridges across Narmada River in the vicinity of proposed expressway were inspected and it was found that except in case of bridge over Narmada River at Zadeshwar on NH-8 guide bunds have not been provided on other existing bridges. Therefore, provision has been made for a guide bund on left bank of the river. But the necessity and design of the same shall be reviewed on the basis of detailed hydrological studies and model studies. A typical design for the guide bund is enclosed in **Annexure 11.7.**

Design for all protective works shall be carried out as per provision of IRC:89– 1997.

11.12.8 Vertical and Lateral Clearance

Minimum vertical and lateral clearances for design of bridges / structures shall be as follows:

Vertical clearance above finished road level of lower road for vehicular underpasses	5.5m
Vertical clearance above finished road level of lower road for light vehicular underpasses/ PUP	3.5m
Vertical clearance above top of expressway for VOBs	5.5m
Vertical clearance above finished road level of lower road for flyovers / interchanges	5.5m
Vertical clearance for railway bridge over rails	6.525m
Vertical clearance for Railway Overhead Bridge over rail in Dedicated Freight Corridor (DFC)	8.05m
Vertical clearance for power telecommunication lines	6.0m
Electric power lines up to 650v	6.5m
Lateral clearance at railway tracks	As specified by Railway Code
Lateral clearance for bridge spans for bridges on National Waterways	100m (between piers)
Vertical clearance for bridges on National Waterways	10m above NHFL/ HTL

11.13 STANDARDS AND CODE OF PRACTICES

Design of all components of structures will be carried out in accordance with the provisions of the following Standards / Codes of Practices and MORT&H / NHAI guidelines and relevant recommendations of International Standards like Euro Code, BS-5400 and AASHTO.

Standards and Codes of Practice

Design of all components of structures shall be carried out in accordance with the provisions of the following Standards / Codes of Practices:

a) Foundations

- IRC:5-2015: Standard Specifications and Code of Practice for Road Bridges, Section I – General Features of Design
- IRC:6-2017: Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses
- IRC:112-2011: Code of Practice for Concrete Road Bridges
- IRC:78-2014: Standard Specifications and Code of Practice for Road Bridges, Section VII – Foundations and Substructure
- IS: 2911 (Part-I/ Sec-2) -2010: Code of Practice for Design and Construction of Pile foundation (Bored cast in-situ concrete piles)
- IRC:87-2011 - Guidelines for Formwork, Falsework and Temporary Structures (First Revision)

b) Substructure

- IRC:5-2015: Standard Specifications and Code of Practice for Road Bridges, Section I – General Features of Design
- IRC:6-2017: Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses

- IRC:40-2002: Standard Specifications and Code of Practice for Road Bridges, Section IV – Brick, Stone and Block Masonry
- IRC:78-2014: Standard Specifications and Code of Practice for Road Bridges, Section VII – Foundations and Substructure
- IRC:112-2011: Code of Practice for Concrete Road Bridges
- IRC:87-2011 - Guidelines for Formwork, Falsework and Temporary Structures (First Revision)

c) Superstructure

- IRC:6-2017: Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses
- IRC:22-2008: Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction (Limit States Design)
- IRC:24-2010: Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method)
- IRC:112-2011: Code of Practice for Concrete Road Bridges
- IRC:SP:64-2005: Guidelines for the Analysis and Design of Cast-in-Place Voided Slab Superstructure
- IRC:SP:73-2015: Manual of Standards & Specifications for Two lane of Highways with Paved Shoulder
- IRC:SP:84-2014: Manual for Specifications & Standards for Four Laning of Highways Through Public Private Partnership
- IRC:83-Part-II–2015: Standard Specifications and Code of Practice for Road Bridges, Section IX – Bearings, Part II: Elastomeric Bearings
- IRC:83-Part-III –2015: Standard Specifications and Code of Practice for Road Bridges, Section IX – Bearings, Part III: POT, POT-CUMPTFE, PIN and Metallic Guide Bearings
- IRC:83-Part-IV –2014: Standard Specifications and Code of Practice for Road Bridges, Section IX – Bearing (Spherical and Cylindrical)
- IRC:87-2011 - Guidelines for Formwork, Falsework and Temporary Structures (First Revision)

d) Expansion Joints

- IRC:SP:69-2011: Guidelines & Specifications for Expansion Joints
- MOST Interim Specification contained in letter no. RW/NH-34059/1/96-S&R, dated 31.03.1997 and 17.07.1997.

e) Protection Works

- IRC: 89-1997: Guidelines for Design and Construction of River Training & Control Works for Road Bridges

f) Special Publications

- IRC:SP:18-1978-Manual for Highway Bridge Maintenance Inspection
- IRC:SP:35-1990-Guidelines for Inspection and Maintenance of Bridges

- IRC:SP:37-2010-Guidelines for Evaluation of Load Carrying Capacity of Bridges (First Revision)
- IRC:SP:40-1993-Guidelines on Techniques for Strengthening and Rehabilitation of Bridges
- IRC:SP:47-1998-Guidelines on Quality Systems for Road Bridges (Plain, Reinforced, Prestressed and Composite Concrete)
- IRC:SP:51-2015-Guidelines for Load Testing of Bridges (First Revision)
- IRC:SP:64-2005-Guidelines for Analysis and Design of cast in place voided slab superstructure
- IRC:SP:65-2005-Guidelines for Design and Construction of Segmental Bridges
- IRC:SP:66-2005-Guidelines for Design of Continuous Bridges
- IRC:SP:67-2005-Guidelines for use of external and unbonded prestressing tendons in bridge structures
- IRC:SP:69-2011-Guidelines and Specifications for Expansion Joints (First Revision)
- IRC:SP:71-2006-Guidelines for Design and Construction of Pretensioned Girder of Bridges
- IRC:SP:74-2007-Guidelines for Repair and Rehabilitation of Steel Bridges
- IRC:SP:75-2008-Guidelines for Retrofitting of Steel Bridges by Prestressing
- IRC:SP:90-2010-Manual for Grade Separators and Elevated Structures
- IRC:SP:99-2013-Manual of Specifications and Standards for Expressways.
- IRC:SP:104-2015-Guidelines for fabrication and erection of steel bridges
- IRC:SP:109-2015-Guidelines for design and construction of small diameter piles for road bridges

g) Other references

- MoRT&H Specifications for Roads and Bridge Works 2013 (Fifth Revision)
- TOR for Consultancy Contract Agreement
- Client's Requirement in addition to TOR if any
- Guidelines and Circulars issued by MoRT& H and NHAI issued time to time.
- MoRT& H Specifications / Circulars / Other Documents
- MoRT& H Pocket Book for Bridge Engineers
- Relevant Provisions of IS/BIIS/IRS/International Design Codes as applicable

11.14 DESIGN METHODOLOGY

11.14.1 Superstructure

Design of superstructure will be carried out as per following codes of practice.

1. IRC: 6-2017 : Loads and stresses
2. IRC:112-2011 : Concrete Road Bridges
3. IRC: 22-2015 : Composite construction
4. IRC:24-2010 : Steel bridges
5. IRC:SP:64-2005 : Guidelines for the analysis and design of cast in place voided slab superstructure
6. IRC:SP:65-2005 : Guidelines for design and construction of segmental bridges
7. AASHTO LRFD Bridge Design Specification 4th Edition 2007.
8. AASHTO Guide Specification for design and construction of segmental concrete bridges.
9. Euro Codes and BS-5400

11.14.2 RCC Slab Type Superstructure

The slab type superstructure will be analysed for Dead load by conventional method and for Live Load by effective width method as per Annexure B3 of IRC: 112 – 2011.

11.14.3 RCC / PSC Girder-Slab Type Superstructure

Transverse Analysis

Deck slab will be assumed as a continuous beam of unit width supported at girder locations and analyzed by using STAAD PRO software. The nodes will be chosen on the centre-line of the deck slab members. Member properties will be calculated based on average thickness of member. Self-weight will be calculated based on the member thickness and applied as uniformly varying load. Wearing coat load will be applied as uniformly distributed load and Crash barrier load will be applied as concentrated load at appropriate locations.

Live Load analysis is carried out for maximum axle load of the following:-

One Lane of Class A (2 – 11.4 t axle)

Two Lanes of Class A (2 x 2 – 11.4 t axle)

One lane of Class 70R Wheel type l, m, n (40 t Bogie axle load)

One lane of Class 70R Track

Three lanes of Class A (3 x 2 - 11.4 t axle)

One lane of Class 70R l, m, n (40 t Bogie axle load) + 1 lane of Class A (2 – 11.4 t axle)

One lane of Class 70R Track + 1 lane of Class A (2 – 11.4 t axle)

Four lanes of Class-A (4 x 2 -11.4 t axle)

Two lanes of Class-70R, l, m, n (40 t Bogie axle lanes)

Two lanes of Class 70R track

Five lanes of Class-A (5 x 2 – 11.4 t axle)

Two lanes of Class 70R, l, m, n (40 t Bogie axle lane + one lane of Class A (2-11.4 t axle).

Two lanes of 70R track + one lane of Class-A (2-11.4 t axle).

For Live Load analysis, the 1st wheel is placed nearest possible location to the crash barrier. The axle load is then moved at 0.5 m interval to generate all possible load cases. For two axle loads, 1st axle load is maintained at particular location and the 2nd axle is moved at 0.5 m interval. This process is repeated for all the possible locations of 1st axle at the interval of 0.5 m interval. Intensity of wheel loads are calculated as per Annexure B3 of IRC: 112 – 2011 and applied as distributed load. The structure is analysed for DL + SIDL + LL combination.

Longitudinal Analysis

Longitudinal Analysis is done by Grillage method using the STAAD PRO Software. The deck is idealized as a grid consisting of longitudinal and transverse members. Section properties of all members are calculated and given as input. The members are idealized as the beam elements connected at centroid level.

Dead loads such as weight of crash barrier, wearing coat etc., and self-weight are applied as uniformly distributed loads on the members. Live load is applied as moving loads and impact factors are adopted as per IRC: 6 – 2017. Analysis is done by moving entire wheel loads from one end to another end of deck in longitudinal direction.

Three standard positions of wheel loads are considered in the analysis, namely, Position (i) when the wheels are placed with minimum distance from kerb, Position (ii) when one wheel is placed on centre on main girder and Position (iii) when the wheels are placed symmetric to carriage way. Each load position is taken as a live load case and the structure is analysed for that load. Maximum BM and SF at various points along the length of deck are calculated and used in the design.

11.14.4 PSC Box Type Superstructure

Transverse Analysis

Box girder is modeled as a plane frame having unit with and supported at bearings and analyzed by using STAAD PRO software. The nodes are chosen on the centre-line of the all member of box section.

Rest of the procedure is same as explained in the section above

Longitudinal Analysis

Single beam analysis is done for DL, SIDL and LL to get BM and SF at various sections. LL effects will be increased by 5% to cater for longitudinal warping effects due to torsion. Analysis for Temperature gradient will be carried out as per the provisions of clause 215.3 of IRC: 6 – 2017. For cracked section the condition of maximum shear with co-existent bending moment and maximum bending movement with co-existent shear shall be considered.

Loss of prestress at different sections due to elastic shortening, relaxation of steel, Creep, Shrinkage, friction and seating of anchorages etc. will be calculated as per provision of IRC: 112 – 2011.

The load combinations shown in Table I of IRC: 6 – 2010 shall be considered for working out stresses in various components of box girder. Permissible stresses in concrete and steel at various stages will be worked out as per provision of IRC: 112 – 2011.

(Note: - Initial prestressing force in the cable will be limited to 72.8% of UTS)

11.14.5 RCC Voided Slab Type Superstructure

Design of RCC voided slab type superstructure will be carried out as per provisions of IRC:SP:64-2005 – Guidelines for analysis and design of cast in place voided slab superstructure.

11.14.6 Steel Plate Girder

Design of steel plate girders will be carried out as per provision of IRC:24-2010.

11.14.7 Cantilever Construction type Segmental Bridges

Narmada River has wide waterway and large depth of water which require navigational spans of 120.0m. It is proposed to provide Modules of 510m length (75.0m+3x120.0m+75m) each. The construction of such long spans has been proposed by using Balanced Cantilever Construction Method, which is widely accepted all over the world. Deep valleys are crossed without high and expensive centering and shuttering and also without the risk of same being washed away during floods. Moreover for spans over 70m cantilever construction is virtually the only method which is economical and is quite competitive with steel superstructure.

The balanced cantilever may be either cast in situ or precast segmental. Considering the large deck plan area of proposed bridge, it is preferred to go in for precast segmental construction as the cost of casting yard and launching girder / Segment lifter is well compensated by repeated use of moulds. Adoption of Precast Segmental Construction offers inherit merits of:

- Speedy construction as the precast segments can be cast in casting yard simultaneously during sinking of well foundations at site. This overlap of two independent activities allows for substantial reduction in construction time, which is main essence of any BOT Projects.
- Superior Quality Control-In casting yard, water sprinkler System for curing, assembly of prefabricated reinforcement Cages etc help achieving superior finish and graceful deck.

The segments are to be cast near approaches or nearby casting yard and are transported to the site by over barges in river / or by road on Trailer depending on site requirement.

Analysis & Design of System

The sizing of deck and substructure has been achieved through preliminary design calculations.

The construction stage analysis of a balanced cantilever bridge is as critical as service stage analysis it involves cable by cable and segment by segment stresses calculations and associated creep, shrinkage distribution. After casting of closure pour near mid span, the hyperstatic moments due to creep redistribution makes the situation even more complex.

The detailed design is proposed to be carried out through sophisticated structural modeling using two softwares STAAD PRO, ADAPT and MIDAS. ADAPT and MIDAS are specific purpose software to analyze Stage by Stage construction of bridges along with prestress losses and associated stresses.

11.14.8 Substructure

Design of substructure shall be carried out as per provisions of IRC: 112 – 2011, and IRC: 78 – 2014.

11.14.9 Piers

Piers will be designed for all load combinations given in Table 1 of IRC: 6–2017.

Piers of solid circular / rectangular shape with cut water and portal type will be proposed for all bridges flyover and grade separator. Piers in the viaduct portion will be proportioned in such a way that it will not be an obstacle to the movement of cross traffic. Sizes will be fixed based on the structural and aesthetic requirements. Piers will be designed as per provision of clauses 710.2 and 710.3 of IRC: 78-2014 and IRC: 112-2011.

When the length of solid pier is more than four times its thickness, it will also be checked as a wall pier and designed as per clause 710.3 of IRC: 78-2014.

11.14.10 Pedestal and Abutment / Pier cap

On the top of **Abutment** and Pier cap, Pedestals will be provided to facilitate the positioning of jacks for lifting the deck during bearing replacement. Pedestals will be designed as per clause 306 and bearing stress in concrete will be checked as per provisions of IRC: 112-2011.

The width of Pier cap will be dimensioned to accommodate the following:-

- Bearing leaving an offset of 150mm beyond them.
- Ballast / dirt wall.
- Space for jacks to lift the superstructure for repair/replacement of bearing.
- Equipment for prestressing operations where necessary.
- Drainage arrangement for the water on the cap.

Abutment and pier caps will be designed and provided as per provisions of clauses 710.8 to 710.9 of IRC: 78-2014.

11.14.11 Abutments

Bridge abutments will carry superstructure from one side and retain earth from the approach embankment. Abutments will be designed to withstand earth pressure in normal condition in addition to the loads and forces transferred from superstructure. Abutments will also be designed for live load surcharge equivalent to 1.2m height of earth fill. No earth retaining structure will be designed to withstand horizontal pressure less than that exerted by a fluid weighing 480 kg/m^3, in addition to the live load surcharge. In case of flyovers, end pier will be modified into abutment pier and suitably integrated with reinforced earth retained embankment. Abutments will be designed as a member subjected to axial load and moment as per provisions of IRC: 112 – 2011 and clauses 710.4, 710.5, 710.6 and 710.8 of IRC: 78 - 2014.

11.14.12 Foundations

Design of foundation will be carried out as per provisions of IRC: 6 – 2017, IRC: 78-2014 and IRC: 112-2011.

The foundation will be designed to withstand the worst combination of loads and force discussed in section – 6 above. Minimum depth of foundation will be decided from the consideration of scour, bearing capacity, settlement, stability and suitability of strata at founding level and sufficient depth below it.

In case of river bridges, maximum scour depth calculated as per clause 703.3.1.2 of IRC:78-2014 will be reduced by multiplying factor of 0.9 for the load combination of flood with seismic effect. For low water level (without flood

conditions) combined with seismic effect maximum scour depth calculated as per Clause 703 of IRC: 78 – 2014 will be reduced by multiplying factor of 0.8.

Open / pile / well foundations will be provided depending upon the type of founding strata met with and safe bearing capacity of the soil at proposed foundation level.

Open Foundations

Open foundations will be proposed for bridges / flyovers / grade separators where a good bearing strata is available at shallow depth otherwise pile foundations will be proposed. Design of open foundation will be carried out as per provision of clause 707 of IRC: 78 – 2014. In the case of ROBs pile foundation will be proposed.

Pile Foundations

Where open foundations are not feasible, pile / well foundations will be proposed. Pile foundations will be designed as per provisions of Clause-709 of IRC:78-2014. Piles will be designed to transmit the load of a structure to competent subsurface strata by resistance developed from bearing at the toe or skin friction along the surface or both. Capacity of piles passing through any soil and resting on soil / rock will be calculated as per provision of Appendix–5 of IRC: 78–2014.

Piles if founded on rock will be socketed into soft/weathered rock by a minimum of 3.0m and in hard rock by 1.50m. Minimum spacing of end bearing piles will be 2.5 times the diameter of piles and for friction piles will be 3.0 times the diameter of piles.

Well Foundations

This foundation is provided where there is deep depth of water and other type of foundations cannot satisfy the requirements economically. Design of well foundation is carried out as per provision of Clause 708 of IRC:78-2014.

11.14.13 Reinforced Earth Approaches

Reinforced earth retaining walls on both side approaches and behind abutments of ROBs / flyovers / grade separators will be provided. Cast-in-situ anti crash barrier-cum-friction slab in approach portion will be provided at outer edges of the retaining structure. Design of RE wall will be carried out by the supplier as per provisions of BS: 8006 and guidelines issued by NHAI.

11.14.14 Protection Works

Protection works wherever required for bridges will be designed and provided as per provision of IRC: 89 - 1997.

11.15 SUBSOIL INVESTIGATION REPORT

As per Terms of Reference the boring has to be carried out on each bridge / structure location to assess the geotechnical conditions for design of foundation. However, criteria for number of bores to be taken at each bridge / structure location is not given in TOR. One bore hole for each bridge / structure up to length of 30m, 2 bore holes for each bridge / structure of length between 30m to 100m and 4 bore holes for each bridge / structure of more than 100m length have been got carried out for Vadodara-Mumbai Expressway as approved by NHAI. The copy of sub soil investigation report has been submitted with Final Feasibility cum Preliminary Project Report.

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DESIGN OF EXPRESSWAY

12

12. DESIGN OF EXPRESSWAY

12.1 GENERAL

The proposed Vadodara- Mumbai Expressway and the Spur are to be built as access controlled expressways with access allowed only at the interchanges. The design standards have thus been accordingly formulated and applied in the preliminary design.

The main expressway alignment is about 379 km long and passes through mostly plain terrain with small sections lying in rolling terrain. The influence area of the expressway has got a well-developed network of National and State Highways with NH8 being a major carrier of traffic in the region. The expressway also crosses some major rivers like Narmada, Tapi and there are numerous streams and canals in its path. The preliminary design of the expressway for the purpose of feasibility study has been done taking into account the terrain, topography, design standards, soil conditions and traffic safety.

As per the advice of NHAI , Vadodara Mumbai Expressway from Km 26.320 to Km 378.740 including Spur is repackaged in to two phases and based on preconstruction progress Phase I is again divided in to 2 Phases (i.e. Phase IA and IB). Further, in reference to NHAI letter no NHAI/NHDP-V/MC-II/BOT/FR/AV/100901 dated 6th June 2017, Phase IA has been further sub-divided in 5 packages for execution on EPC mode (details are given in Chapter 1 ; Introduction of Main Report).

This report is for Phase IA- Package IV: Km 279.000 to Km 292.000 of Vadodara Kim Expressway.

12.2 CROSS-SECTION

Based on the design standards enumerated in **Chapter 9** and the result of the traffic assignments the following options for the cross-section for the main expressway and spur have been considered and Final DPR was submitted:

Option 1: Six lane divided carriageway with 19.5m wide depressed median was proposed. This option is for stage construction to eventual eight lane divided carriageway. The wider median in this option will be used for future widening to eight lanes and the median will be reduced to 12m as proposed in the design standards. The carriageway width is 11.25m with 3.0m wide paved and 3.0m wide earthen shoulder. The inside edge strip is 0.75m wide with a 0.8m rounding further inside. The outer edge strip is 0.3m (included within paved shoulder) and inner edge strip of 0.75m has been proposed.

Option 2: Eight lane divided carriageway with 12m wide depressed median was proposed. The carriageway width is 15m with 3.0m wide paved and 3.0m wide earthen shoulders.

NHAI has asked reduction in the median width, advised to provide 6m wide median, so that earth work quantities can be reduced.

Considering the above facts & IRC: SP: 99, following options for cross section for the Expressway have been revised.

Option 1: Six lane divided carriageway with 6.0m wide flush median. This option is for stage construction to eventual eight lane divided carriageway. The future widening to eight lanes is considered on outer side of the paved shoulder. The carriageway width is 11.25m with 3.0m wide

paved and 2.0m wide earthen shoulder. The inside edge strip is 0.75m wide is proposed.

Option 2: Eight lane divided carriageway with 6m wide flush median. The carriageway width is 15m with 3.0m wide paved and 2.0m wide earthen shoulders. The inside edge strip is 0.75m wide is proposed.

It is proposed to build connecting roads along the expressway at some locations to facilitate movement of local traffic across expressway. The typical cross-section with one side service road and both side service roads has been developed.

Since the GAD's for all ROB have been approved by the Railway Authority as per previous proposed cross section (12m & 19.5m median), the section falling on the approaches of ROB including ROB has been considered with 12m/ 19.5m median. Further, on structure approaches, RE wall and retaining walls has been proposed and Typical cross section these sections has been developed for 6/8 lane divided carriageway. The details of typical cross section proposed for this package are as follows;

Sl. No.	Cross Section Type	TCS No.
1	8-lane divided carriageway without connecting road	1
2	VUP / Grade Separator / ROB Approaches	4
3	VUP / Grade Separator / ROB Approaches with left side connecting road	6
4	6-lane divided carriageway without connecting road	8
5	8-lane divided carriageway with depressed median and without connecting road	13

The above typical cross sections are given at the end of this Chapter.

During the draft feasibility study it was proposed to adopt a ROW of 100m for the expressway. However during subsequent discussions with NHAI officials it was decided to adopt an ROW of 120m to give adequate space for utilities, for plantation of trees and to avoid construction of retaining walls in high embankment areas. The Guidelines for expressways issued by IRC recommend a minimum RoW of 90m.

A meeting was held in the office of secretary MoRTH on 2nd January 2012 to discuss the various issues relating to the expressway. It was decided in the meeting that the ROW for the expressway will be 100m in general. However wherever there is requirement of additional ROW due to design considerations like locations of high embankment, service roads etc the ROW shall be 120m. The detail of ROW is given in **Annexure 12.1.**

The influence area of the expressway experiences heavy rainfalls during the monsoon season and the rain cuts in the embankment are quite common on existing roads. The embankment cuts have been noted at number of places on the existing NH8. Since the expressway will be largely running on an embankment of 4-5m, so to take care of this damage, a surface drain has been proposed on the earthen shoulder in all the above options. Chutes have been provided at an interval of 100m in the embankment slope to take the surface runoff to the ground level drain without damaging the embankment. The top width from edge of the earthen shoulder is 46m and a side slope of 2:1 is proposed.

Thrie-beam crash barriers are proposed on the earthen shoulders. A 0.6m wide utility duct is proposed in the earthen shoulder for the cables of the HTMS system to be installed along the expressway.

Trapezoidal side drains at the ground level near the edge of the Right of Way on both sides of the embankment will be provided for drainage of the area at the ground level. These drains will be connected to the nearest culvert/CD structures for draining out of water. The top and bottom width of the drain will be 3.5m and 1.2m respectively with a depth of about 1m. These drains will be lined with 100mm thick M10 cement concrete.

Fencing on both sides and along the entire length of the expressway will be provided to protect the Right of Way and prevent entry of animals on to the expressway. GI chain links steel posts (angle section) fencing will be provided.

It is recommended that section from Km 254.430 to Km 287.385 is to be built as eight lane & from Km 287.385 to Km 378.740 is to be built as six lane divided carriageway. However all structures are proposed to be eight lane from the opening year.

12.3 DESIGN OF ALIGNMENT

The selection of the alignment has been dealt with in Chapter 3- Route Alignment Selection. The selected alignment has been designed using the design standards enumerated in Chapter9 – Geometric Design Standards. The geometric features of alignment have been designed using MX ROAD software. The alignment has been designed to a design speed of 120kmph. Since it is a greenfield expressway, the alignment has been designed as a free flowing alignment with transition curves preceding and succeeding a circular curve. Since a corridor of 600m had already been frozen for the main expressway in Gujarat in 1993-94, the alignment follows this corridor to a large extent.

The Phase IA, Package IV of the Expressway has 5 numbers of horizontal curves in a length of 13 Km. All these curves are of radius more than 2000m except at one location having 1500m. There are about 29 vertical curves proposed in this package.

12.4 DESIGN OF INTERCHANGES

Interchanges are required on expressways for transfer of traffic from the expressways to other intersecting roads/expressways or vice versa avoiding any conflict. The objective of provision of interchanges is to allow safe and uninterrupted travel for expressway users. This is attained by providing movement of traffic between two or more roads at different levels. This allows greatest efficiency, safety and capacity for the expressways. The type of interchanges and their geometry should be adequate to accommodate safe and unhindered movement of all anticipated traffic including turning traffic without any conflict. The location, type and layout of interchanges have maximum influence on the safe and smooth operation of the expressways. Therefore, these are to be decided on the basis of the classification and number of the intersecting road/highway, character and composition of traffic, design speed, degree of access control, and availability of land and its use, terrain and economic consideration. The proposed expressway will be a tolled road and closed system of toll collection will be adopted. Therefore, the toll plazas will be located at the interchanges to avoid interference with the main line traffic. This aspect has also been considered while deciding the type, layout and design of the interchanges.

12.4.1 Location of Interchanges

The number/spacing of the interchanges will have a bearing on the cost of the expressway, operation of traffic and utilization of the expressway. Closely spaced interchanges will affect the flow of the through traffic due to shorter available weaving length as well as it will be costlier. The interchanges at a long interval will lead to long detour and the expressway may not be able to capture enough traffic for its justification and the users will not be able to avail the facility of fast movement corridor. Therefore, the locations of the interchanges are to be optimized based on these considerations.

There is only one interchange in this package and the location given in **Table 12.1.**

Table 12.1: Location of Interchanges

Sl. No.	Chainage (km)	Type of Crossing
Package IV		
1.	287.385	Dahej-Baruch (SH-6)

12.4.2 Configuration and Layout

The type of configuration to be used will depend on the following factors

a) Number, geometry and category of intersecting roads.

b) Expected volume of straight traffic and turning traffic

c) Topography

d) Land use

e) Availability of land

f) Safety during movement.

g) Operation of toll booth

The layout of all the interchanges that have been developed based on the above consideration are given in **Table 12.2**.

Table 12.2: Configuration of Interchanges

Sl. No.	Location (km)	Connecting Road	Type of Interchange	Remarks
Package IV				
1	287.385	Dahej-Baruch (SH-6)	Full Cloverleaf	The expressway at this location intersects the road connecting Dahej Port on west and the Bharuch city on the west. Therefore, full cloverleaf has been proposed to provide conflict free movements for all turning movements.

The drawings indicating layouts of the interchanges are given in **Volume II: Drawings.**

12.5 FLYOVERS

The expressway is access controlled facility and therefore access will only be provided at the interchanges. All other road crossings therefore will be provided either with a flyover or with a vehicular underpass with no access to the expressway. Flyovers are proposed on all major State Highways (SH) crossing the expressway. There is only one flyover proposed on Package IV. List of proposed flyovers is as given in **Table 12.3.**

Table 12.3: List of Proposed Flyovers

Sl. No.	Chainage (km)	Structure	Type of Crossing	Span (m)
Package IV				
1	279+353	PSC Girder / RCC Girder & Slab	Hansot Ankaleshwar Road (SH-6)	17.687 + 34.203 + 17.687

12.6 VEHICULAR UNDERPASSES

Vehicular underpasses of size 12mx5.5m have been proposed on Major District Roads (MDRs) and Other District Roads (ODRs). There are 2 number of Vehicular Underpasses proposed on expressway. A list of proposed VUPs is given in **Table 12.4**.

Table 12.4: Proposed Vehicular Underpasses

Sl. No.	Chainage (km)	Structure	Type of Crossing	Skew	Span
Package IV					
1	289+860	RCC Box Str.	Manubar–Bharuch		12 m X 5.5 m
2	290+920	RCC Box Str.	Manubar – Kanthariya	30	12 m X 5.5 m

12.7 LIGHT VEHICULAR UNDERPASSES

The expressway crosses many small village roads of single lane/intermediate lane size in rural areas. To serve the purpose of connectivity for these small roads, Total 3 numbers light vehicle underpasses of size 10.50m x 3.5m have been provided at these locations. A list of proposed Light Vehicle underpasses is given in **Table 12.5**.

Table 12.5: Proposed Light Vehicular Underpasses

Sl. No.	Chainage (Km)	Structure	Type of Crossing	Span
Package IV				
1	282+320	RCC Box Str.	Sakkarpore - Khalpiya	10.5 m X 3.5 m
2	282+885	RCC Box Str.	Sakkarpore - Khalpiya	10.5 m X 3.5 m
3	286+755	RCC Box Str.	Dehgam-Dehgam	10.5 m X 3.5 m

In addition to above one LVUP has been proposed in ramp of interchange.

12.8 PEDESTRIAN/CATTLE UNDERPASSES

Since the expressway is a green field alignment and is access controlled therefore it will be bifurcating the communities and farming land on either side. Since it is passing mainly through rural belt the farming communities on either side need to be provided with suitable connection. To serve this purpose, pedestrian/cattle underpasses of size 7mx3.5m have been provided at regular interval. These will not only serve as passage for field canals for irrigation purposes but also serve as balancing culverts in the rainy seasons. A list of proposed pedestrian/cattle underpasses is given in **Table 12.6**.

Sl. No.	Chainage (in Km)	Type of Crossing	Type of Structure	Span
1	281+034	Cart Track	RCC Box	7 m X 3.5 m
2	282+109	Cart Track	RCC Box	7 m X 3.5 m
3	285+784	Cart Track	RCC Box	7 m X 3.5 m
4	286+409	Cart Track	RCC Box	7 m X 3.5 m
5	288+284	Cart Track	RCC Box	7 m X 3.5 m
6	289+334	Cart Track	RCC Box	7 m X 3.5 m
7	291+184	Cart Track	RCC Box	7 m X 3.5 m

12.9 CONNECTING ROADS

The Expressway is an access controlled facility with access and exit only at the interchange locations. The Expressway alignment is cutting through many of the existing roads and it would be very expensive to provide underpass at all the cross roads. Therefore the roads where underpasses have not been provided have been connected to the nearest underpass by service roads so that the movement of local traffic across the expressway is not hindered. The list of service roads proposed along the expressway is given in **Table 12.7**.

Table 12.7 : Details of Connecting Road

Sl. No.	Stretches(Km)		Length (in Km)	Width (in Meter)
	From	To		
Left side Connecting Road (Main Expressway)				
1	279+335	279+735	0.400	7.0

12.10 DESIGN OF HIGH EMBANKMENT

12.10.1 General

High embankments are required in flood prone area; embankments are also raised for approaches to bridges, under passes, flyovers etc. Earthen embankments of height more than 6m are required to be designed for a safe side slope. Even embankment of lesser height may have to be designed if ground soil is poor in strength and / or good soil is not available for embankment construction.

12.10.2 Design Considerations

Basic requirements for slope stability analysis are engineering properties like c, ϕ, γ of embankment soil & ground soil, flood level, seismic zone, proposed height and side slope, stratification of ground soil layers, if any, with engineering properties of such layers are required. For these, a detailed geotechnical investigation along the alignment of the project road is required. The slope-stability analysis can be carried out based on the various soil investigation reports of the ground soil and properties reported for the borrow soil for different height of embankment.

12.10.3 Allowable factor of safety

The factor of safety against slip circle failure based on shear strength charactertics of the soil shall be more than 1.25. as per IRC:75.The embankment is required to be safe against excessive settlement also which become critical for locations where the embankment is high and ground soil just below the embankment consists of clay layers of large thickness. Also the embankment near structure is required to match the settlement of the structure to have less differential settlement.

The post construction settlement of embankment of 0.3m to 0.6m is considered reasonable provided the same is uniform and does not result in large differential settlement adjoining structures.

12.10.4 Conclusions

To achieve required FOS of embankment slope the slope cannot be flattened as it would require additional ROW. Therefore, either ground soil replacement can be resorted to or stone column can be provided. Stone column shall be cheaper and easier to provide and can therefore, be adopted for this work.

12.11 EXPRESSWAY LIGHTING

The expressway under consideration has been provided with lighting system in grade separated structures with interchanges, flyover/ continuous flyover structure, under-decks of the grade separators, VUPs, PUPs/ CUPs etc.

The average illumination level of the designed lighting system has been taken as 30 Lux as prescribed in IS:1944 (Part I, II & V). For most of the grade separators & its interchanges, 30 meter High Masts with 2x400 watts & 1x400 watts HPSV flood light luminaries have been proposed. However for some grade separator and their interchanges, while 30 meter high masts along with 10 meter octagonal poles fitted with 1x250 watts single HPSV luminaries have been proposed for toll plaza complex and their connecting loops ramps, the Expressway proper has been provided with single 400 watts HPSV luminaries on 12m octagonal poles to be placed on earthen shoulders on either side of the MCWs. No light poles have been proposed on the median of the expressway so as to allow future widening of the expressway. For the lighting of the under decks of the expressway at crossings with SH, local roads, cattle under passes etc., 150 watts/ 70 watts flood light fittings have been proposed for their illumination.

The lighting system designed will be energized through underground Aluminium cables, of XLPE type. Power to the system will be obtained from State Electricity Board/ local Electricity Company. An electrical sub- station of required capacity have been proposed in Toll Plaza complexes, wherever required as per norms of the Electricity Board/ Company.

Two Stand- by Diesel Generators of capacity equal to that of the sub-station have been proposed to be provided and integrated with the sub-station, in addition to

capacitor panels, HT/LT voltage stabilizer etc., Further a solar photo-voltaic system to generate energy of 50% capacity of the sub-station has been proposed to be provided and integrated with the system to generate pollution free power to the system. The lighting and power supply design thus has attempted for a green field system.

Design of all the light fittings, poles, cables and other electrical equipments has been made as per relevant I.S. Code of practice. Where Indian Standards are not available, C.I.E. codes have been followed. Design of high mast structure has been made conforming to Technical Report No. 7 of Association of Public Lighting Engineers. U.K. All electrical equipment's/ switch gears to be used in the sub-station has been designed as per norms of National Building Code (NBC) of India, 2005 edition amended up to date and as per specifications of CPWD General Specifications for Electrical works- part-I (Internal) and Part-II (External) amended up to date.

A sample lighting design calculation has been done for interchange and the same in shape of a design report has been enclosed as **Annexure 12.2**.

NHAI has advised to provide solar lighting system in the project. Solar energy is renewable energy have following benefits and disadvantages

Benefits

i. Power from the Sun is clean, silent limitless & free.

ii. Free from CO2, SO2 or NO gases which are normally associated with burning finite fossil fuel reserves and do not contribute to global warning.

iii. It is a clean energy system and Environment friendly and better for the public living nearby.

iv. No fuel is required for generation, so fuel cost of power generation is zero.

v. It can install on land as well rooftop converting non utilized rooftop space in to a profit center.

vi. No moving parts and therefore no wear & tear – very low operation and maintenance cost.

vii. The maintenance associated with solar lights are very less as compared to the other street lights.

viii. Unlike the conventional street lights, there are no wires associated with the solar street lights and so there is less risk of accidents.

Disadvantages

i. This system works only when the Sun light is available, when there are clouds, the battery shall not be charged and in turn there will not be illumination on the highways.

ii. Requires higher initial investment.

iii. Rechargeable batteries must be replaced a few times within the lifetime of the fixtures.

However two types of systems are proposed for the project highway.

1. Rooftop system at Way side amenities, Rest area, Toll Plaza etc.
2. Single pole with fixtures & solar panel etc.

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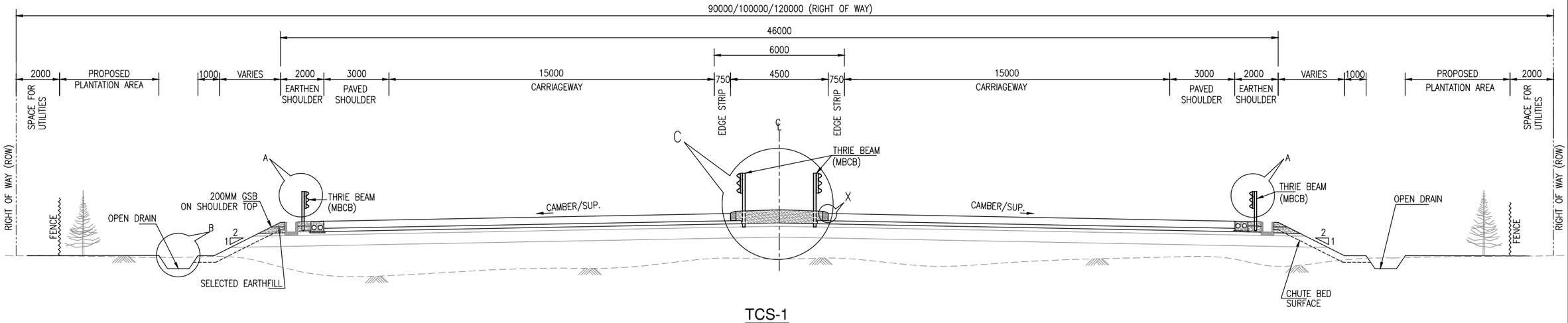
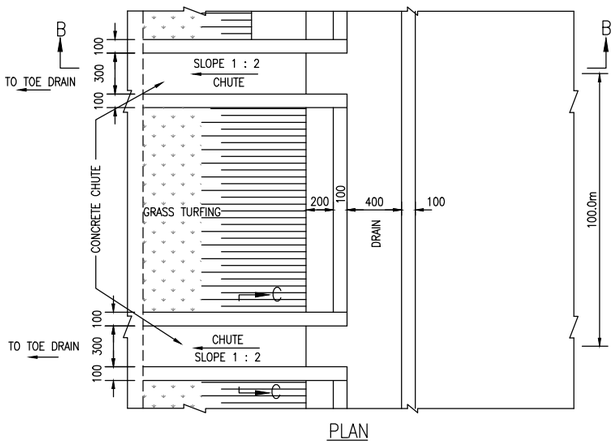


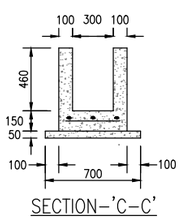
TCS-1

TYPICAL CROSS SECTION OF EXPRESSWAY
8-LANE DIVIDED C/W WITHOUT CONNECTING ROAD

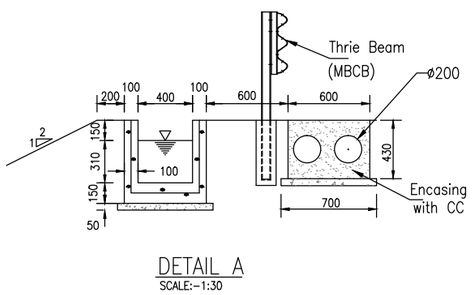
SCALE:–1:125



PLAN

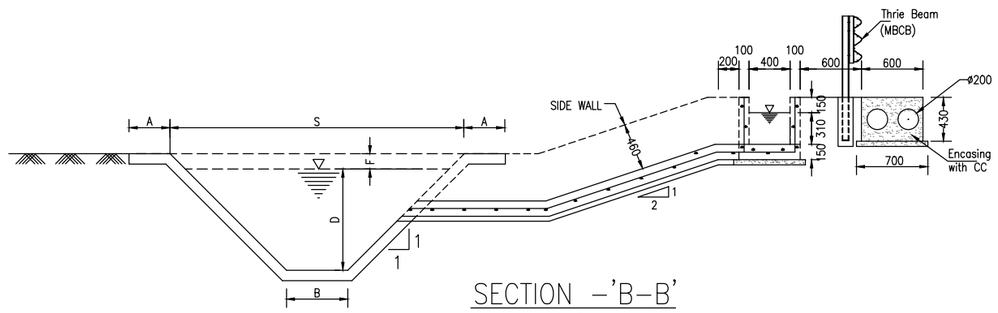


SECTION–'C–C'



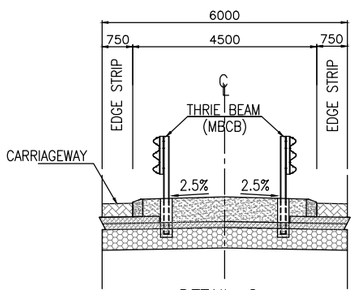
DETAIL A

SCALE:–1:30



SECTION –'B–B'

SCALE:–1:40



DETAIL–C

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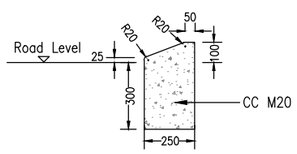
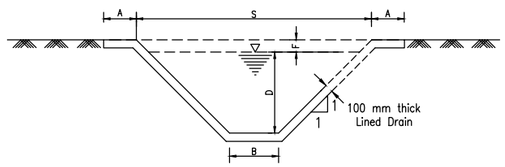


DETAIL X

Details of Mountable Kerb



DETAIL B

SCALE:–1:50

Detail of Drain – "B" (Toe Drain)

S. No.	Dimensions(in mm)				
	A	B	D	F	S
1	400	600	790	150	2480

MAIN EXPRESSWAY

Notes:
1. All Dimensions are in mm unless otherwise specified.

NATIONAL HIGHWAYS AUTHORITY OF INDIA	Scale : AS SHOWN	Consultancy Services for Preparation of Detailed Engineering Design of Vadodara - Mumbai Expressway including Spur to JNPT under NHDP Phase-VI	Phase - IA Package IV	TYPICAL CROSS SECTION OF EXPRESSWAY 8-LANE DIVIDED C/W WITHOUT CONNECTING ROAD	Intercontinental Consultants & Technocrats Pvt.Ltd, A-8, Green Park, New Delhi - 110016 Ph : 4086-3000, Fax 2685-5252

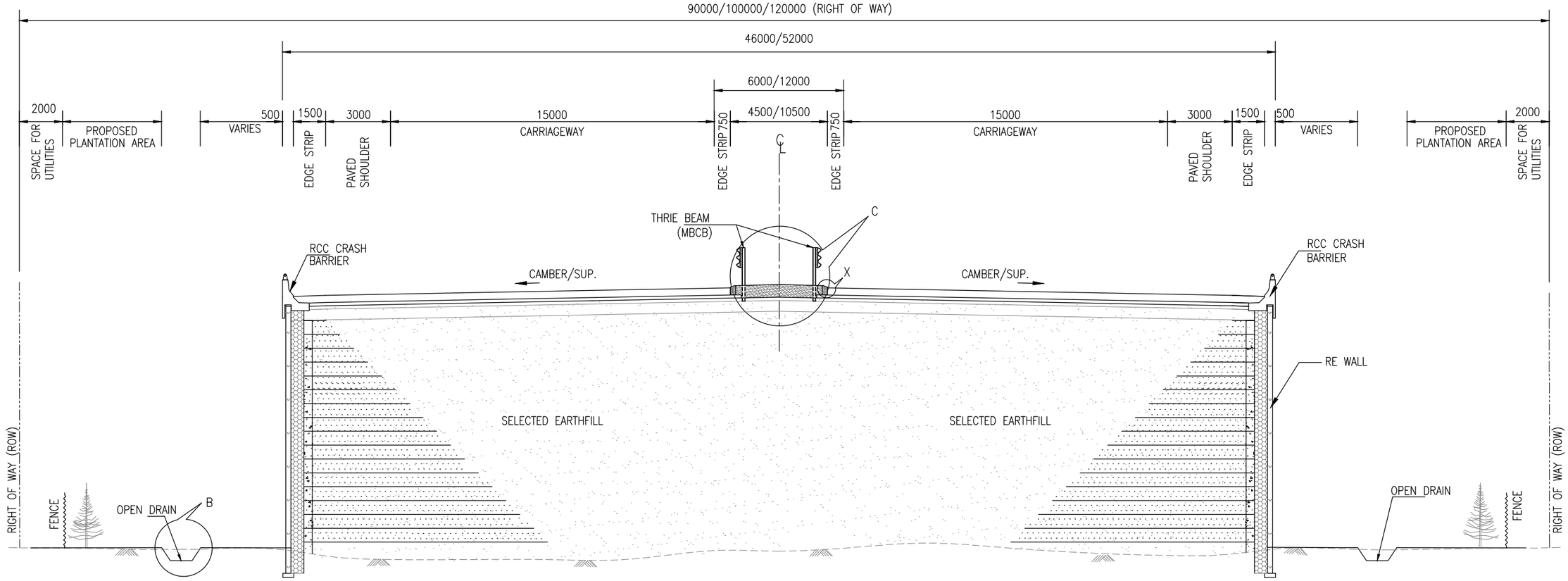
Revisions	Date	Description	Checked by
R0	Aug. 2017	INITIAL PLAN	

Revisions

ARJIT ROY	B.K SWAIN	DEEPAK KUMAR	ASEEM PRABHAKAR
Prepared by	Designed by	Checked by	Approved by

DRAWING No:- NHAI/VME/TCS/01/R0

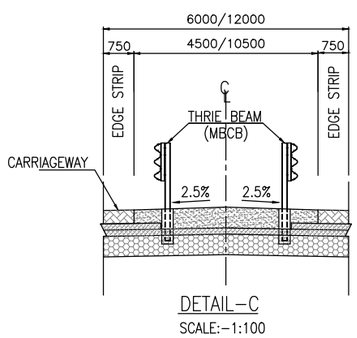
File Name :



TCS-4

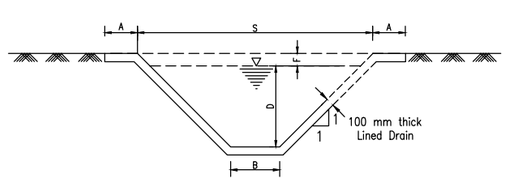
TYPICAL CROSS SECTION FOR VUP/GRADE SEPARATOR / ROB APPROACHES

SCALE:–1:135



DETAIL–C

SCALE:–1:100



DETAIL B

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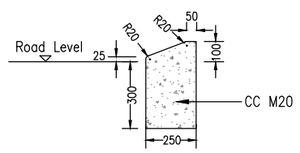

DETAIL X

Details of Mountable Kerb

Detail of Drain – "B" (Toe Drain)

S. No.	Dimensions(in mm)				
	A	B	D	F	S
1	400	600	790	150	2480

MAIN EXPRESSWAY

APPLICABLE CHAINAGES (MAIN EXPRESSWAY)						
Sl. No.	Chainage (Km)		Length (Km)	Pavement Composition (Rigid)		
	From	To		PQC (mm)	DLC (mm)	GSB (mm)
1	279+000	279+335	0.335	300	150	150
2	279+735	279+800	0.065	300	150	150

Notes:

1. All Dimensions are in mm unless otherwise specified.

NATIONAL HIGHWAYS AUTHORITY OF INDIA	Scale : AS SHOWN	Consultancy Services for Preparation of Detailed Engineering Design of Vadodara - Mumbai Expressway including Spur to JNPT under NHDP Phase-VI	Phase - IA Package IV	TYPICAL CROSS SECTION OF EXPRESSWAY 8-LANE DIVIDED C/W FOR VUP/GS APPROACH	Intercontinental Consultants & Technocrats Pvt.Ltd, A-8, Green Park, New Delhi - 110016 Ph : 4086-3000, Fax 2685-5252

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Prepared by	Designed by	Checked by	Approved by

Revisions	Date	Description	Checked by
R0	Aug. 2017	INITIAL PLAN	

Revisions

DRAWING No:- NHAI/VME/TCS/02/R0

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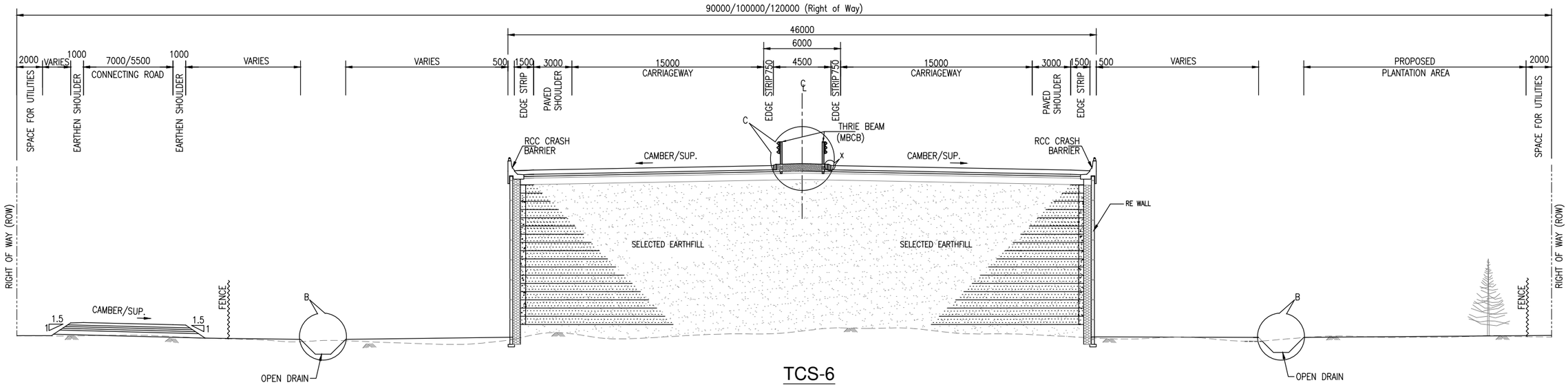

TCS-6

TYPICAL CROSS SECTION FOR VUP/GRADE SEPARATOR / ROB APPROACHES WITH LEFT SIDE CONNECTING ROAD

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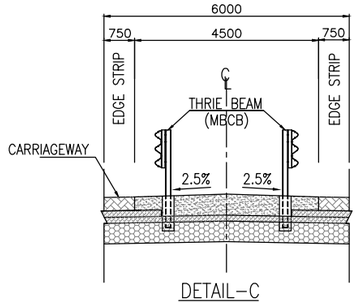
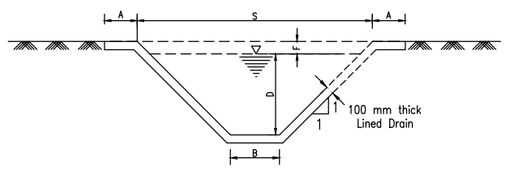


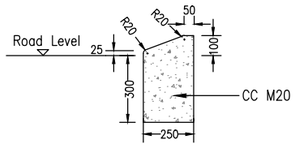
DETAIL–C

SCALE:–1:100



DETAIL B

SCALE:–1:50



DETAIL X

Details of Mountable Kerb

Detail of Drain – "B" (Toe Drain)

S. No.	Dimensions(in mm)				
	A	B	D	F	S
1	400	600	790	150	2480

MAIN EXPRESSWAY

Pavement Layers for Connecting Road						
S. No.	Chainages(km)		Pavement Composition			
	From	To	BC	DBM	WMM	GSB
1	279.000	292.000	40	50	250	230

MAIN EXPRESSWAY

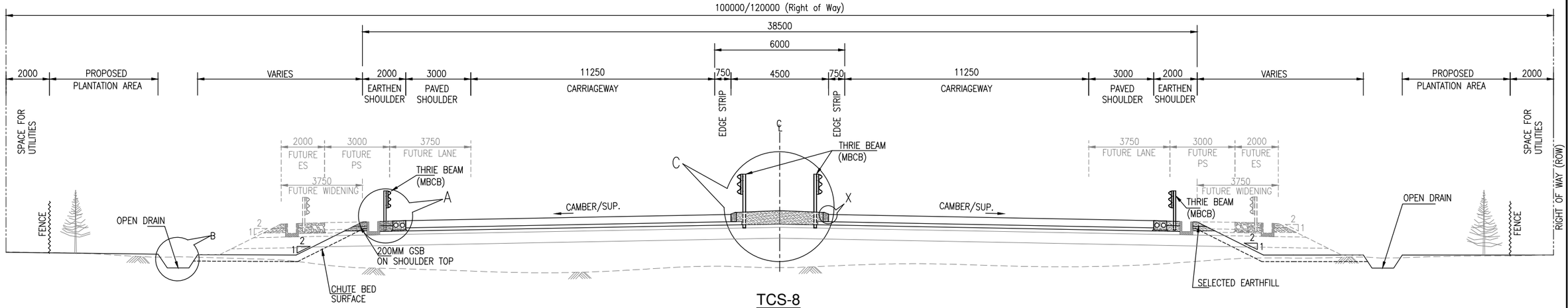
APPLICABLE CHAINAGES (MAIN EXPRESSWAY)						
Sl. No.	Chainage (Km)		Length (Km)	Pavement Composition (Rigid)		
	From	To		PQC (mm)	DLC (mm)	GSB (mm)
1	279+335	279+735	0.400	300	150	150

Notes:

1. All Dimensions are in mm unless otherwise specified.

NATIONAL HIGHWAYS AUTHORITY OF INDIA	Scale : AS SHOWN	Consultancy Services for Preparation of Detailed Engineering Design of Vadodara - Mumbai Expressway including Spur to JNPT under NHDP Phase-VI	Phase - IA Package IV	TYPICAL CROSS SECTION OF EXPRESSWAY 8-LANE DIVIDED C/W FOR VUP/GS APPROACH	Intercontinental Consultants & Technocrats Pvt.Ltd, A-8, Green Park, New Delhi - 110016 Ph : 4086-3000, Fax 2685-5252	R0 | Aug. 2017 | INITIAL PLAN DRAWING No:- NHAI/VME/TCS/03/R0

ARIT ROY (Prepared by) · B.K SWAIN (Designed by) · DEEPAK KUMAR (Checked by) · ASEEM PRABHAKAR (Approved by)



TCS-8

TYPICAL CROSS SECTION OF EXPRESSWAY 6-LANE DIVIDED C/W WITHOUT CONNECTING ROAD

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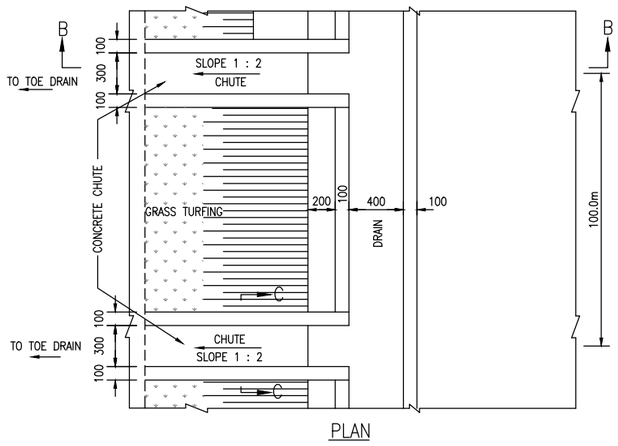
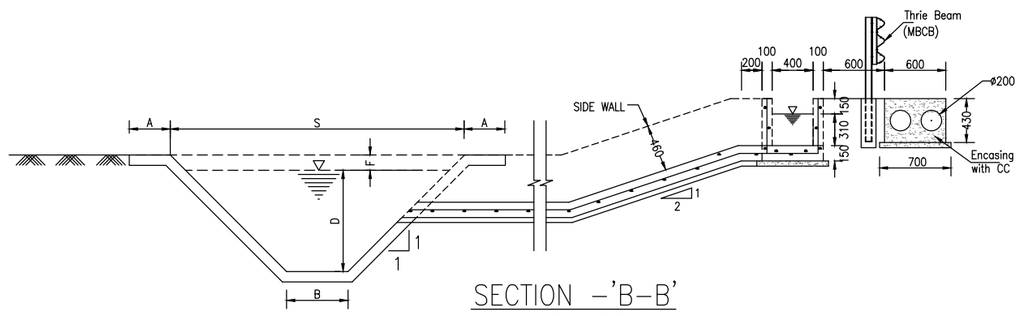
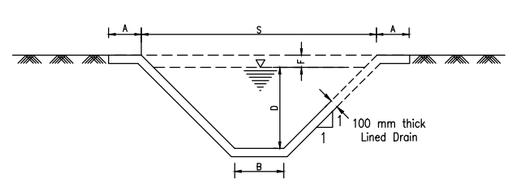


PLAN



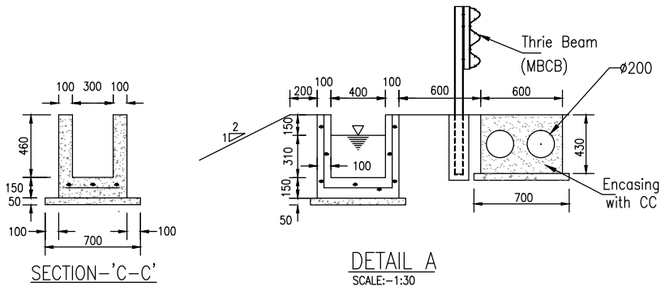
SECTION –'B–B'

SCALE:–1:40



DETAIL B

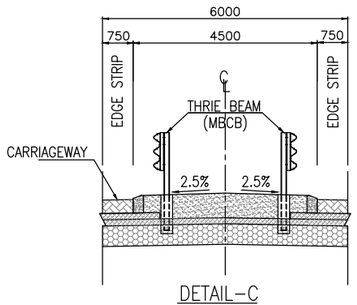
SCALE:–1:50



SECTION–'C–C'

DETAIL A

SCALE:–1:30



DETAIL–C

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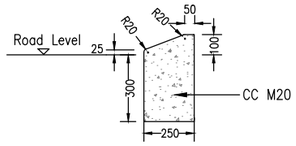


DETAIL X

Details of Mountable Kerb

MAIN EXPRESSWAY

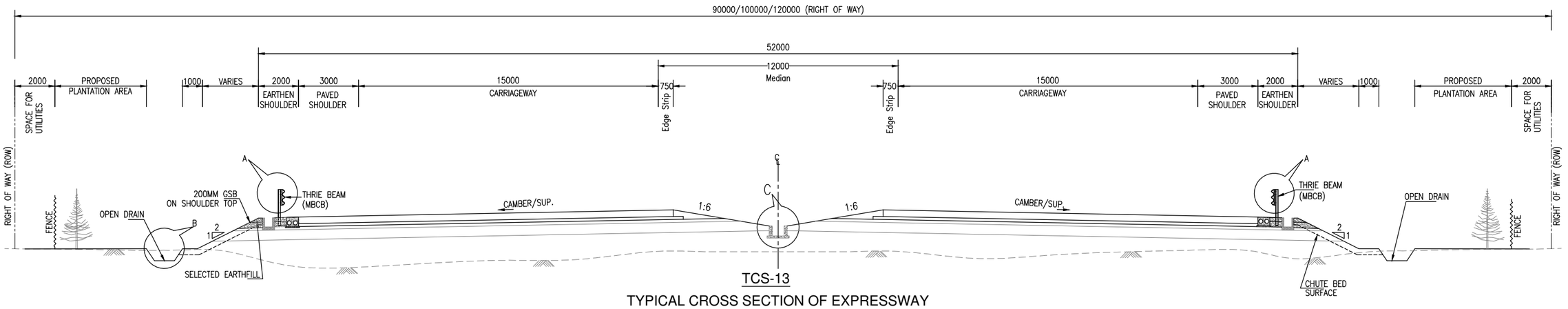
APPLICABLE CHAINAGES (MAIN EXPRESSWAY)						
Sl. No.	Chainage (Km)		Length (Km)	Pavement Composition (Rigid)		
	From	To		PQC (mm)	DLC (mm)	GSB (mm)
1	287+700	288+000	0.300	300	150	150
2	288+000	292+000	4.000	300	150	150

Detail of Drain – "B" (Toe Drain)

S. No.	Dimensions(in mm)				
	A	B	D	F	S
1	400	600	790	150	2480

Notes:
1. All Dimensions are in mm unless otherwise specified.

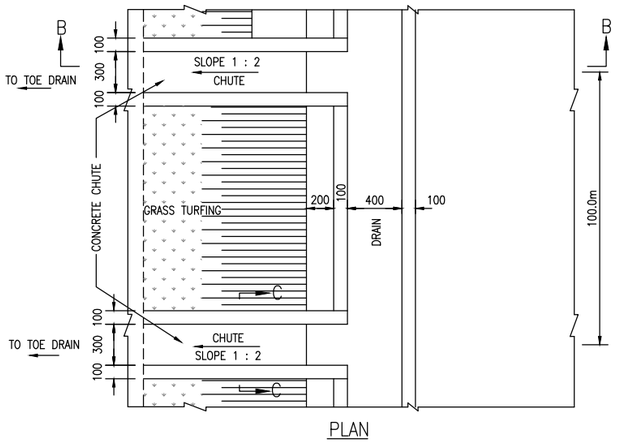
NATIONAL HIGHWAYS AUTHORITY OF INDIA	Scale : AS SHOWN	Consultancy Services for Preparation of Detailed Engineering Design of Vadodara - Mumbai Expressway including Spur to JNPT under NHDP Phase-VI	Phase - IA Package IV	TYPICAL CROSS SECTION OF EXPRESSWAY 6-LANE DIVIDED C/W WITHOUT CONNECTING ROAD	Intercontinental Consultants & Technocrats Pvt.Ltd, A-8, Green Park, New Delhi - 110016 Ph : 4086-3000, Fax 2685-5252	R0 | Aug. 2017 | INITIAL PLAN Revisions | Date | Description | Checked by Revisions ARJIT ROY (Prepared by) | B.K SWAIN (Designed by) | DEEPAK KUMAR (Checked by) | ASEEM PRABHAKAR (Approved by) DRAWING No:- NHAI/VME/TCS/04/R0 File Name :



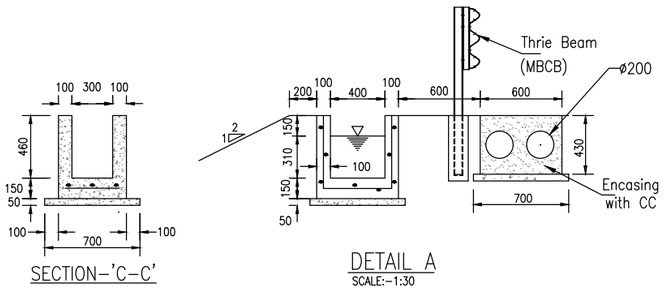
TCS-13

TYPICAL CROSS SECTION OF EXPRESSWAY
8-LANE DIVIDED C/W WITH DEPRESSED MEDIAN & WITHOUT CONNECTING ROAD

SCALE:–1:125



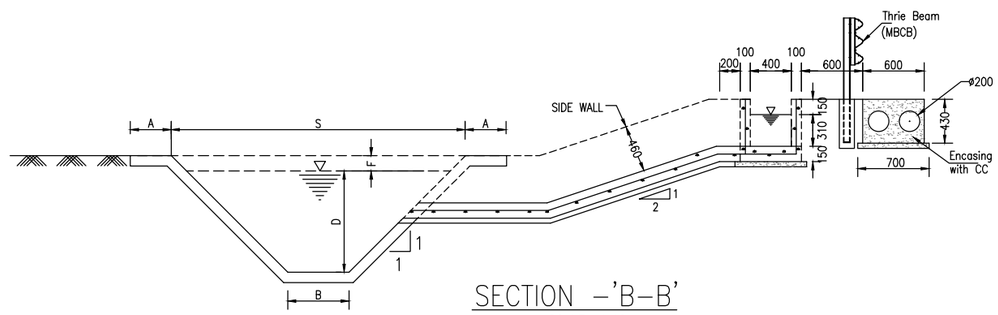
PLAN



SECTION–'C–C'

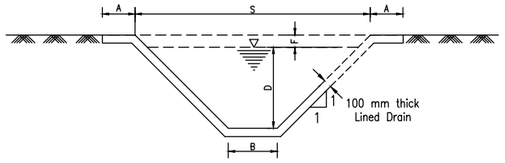
DETAIL A

SCALE:–1:30



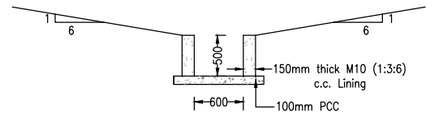
SECTION –'B–B'

SCALE:–1:40



DETAIL B

SCALE:–1:50



DETAIL C

SCALE:–1:50

Detail of Drain – "B" (Toe Drain)

S. No.	Dimensions(in mm)				
	A	B	D	F	S
1	400	600	790	150	2480

MAIN EXPRESSWAY

APPLICABLE CHAINAGES (MAIN EXPRESSWAY)						
Sl. No.	Chainage (Km)		Length (Km)	Pavement Composition (Rigid)		
	From	To		PQC (mm)	DLC (mm)	GSB (mm)
1	283+050	283+200	0.150	300	150	150
2	283+200	285+600	2.400	300	150	150
3	285+600	285+750	0.150	300	150	150

Notes:
1. All Dimensions are in mm unless otherwise specified.

NATIONAL HIGHWAYS AUTHORITY OF INDIA

Scale : AS SHOWN

Consultancy Services for Preparation of Detailed Engineering Design of Vadodara - Mumbai Expressway including Spur to JNPT under NHDP Phase-VI

Phase - IA Package IV

TYPICAL CROSS SECTION OF EXPRESSWAY 8-LANE DIVIDED C/W WITH DEPRESSED MEDIAN & WITHOUT CONNECTING ROAD

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Revisions	Date	Description	Checked by
R0	Aug. 2017	INITIAL PLAN	

Revisions

DRAWING No:- NHAI/VME/TCS/05/R0

File Name :

TOLLING STRATEGY AND PLANNING OF TOLL PLAZAS

13

13. TOLLING STRATEGY AND PLANNING OF TOLL PLAZAS

13.1 TOLLING STRATEGY

13.1.1 Introduction

The following tolling strategy elements are proposed considering suitability to Indian conditions and future plans.

1. The document shall follow Guidelines for Expressway (Part I & II) published by IRC on behalf of MoRT&H.
2. The document shall follow IRC:SP:99-2013 manual of specifications and standards for Expressways published by IRC on behalf of MoRT&H.
3. The tolling system proposed for the V-M expressway shall be “Closed Toll System”. The user can enter and exit the expressway only from toll plazas.

All toll collection points on closed system toll roads are either at the system end-points, or at every interchange between those endpoints. Every vehicular movement on the system must pass through an entry toll lane and an exit toll lane. In case of consolidated toll plaza design, all interchange traffic is brought to a single point to minimize plaza and building construction costs, and minimize the cost and complexity of cash-handling operations. Entry lanes can be operated in either an attended or an unattended fashion using ticket-issuing machines. Because the toll amount varies with each vehicle, automation of cash collection is not possible, and all “exit” lanes are built as attended lanes.

The salient features of tolling system are presented below.

1. For Standard Lanes (cash) the road user shall be issued a ticket at the entry and shall be required to pay at the exit. For Electronic Toll Collection (ETC) lanes, designated as FASTag lanes by NHAI, the vehicles shall be allowed to drive through non-stop. Alternately, toll fee can be collected at entry based on information of intended exit point provided by user. Though payment-at-exit is operationally simpler, but the O&M Operator/Concessionaire may favour payment-at-entry to deal with issues related to non-payment by some users and also discourage violations/run-throughs at exit.

   However, as per IRC:SP:99-2013 Clause 12.5 “payment need to be made only at the exit” and this shall be used as guideline in following chapters.
2. If payment-at-exit is chosen, Automatic Vehicle Classifier (AVC) is not required in the entry lanes. However, most of the Toll Collection Equipment (TCE) vendors supply AVC as a standard integrated component and may require to alter the system software. For them, providing an AVC would be simpler. It is suggested that to maintain standardization and flexibility and to improve auditability, AVC is installed at all lanes (entry or exit). It shall also help in times when one plaza is running on manual mode. The design suggested shall be focused on improving auditability and reducing pilferage even though it shall be at some increased cost.”
3. The computer systems at each toll plazas shall be interconnected by two communication links – one main link (optic fiber) and the other as fallback link (wireless). The toll plazas shall share information in real time over the communication link.
4. Any transaction not requiring manual intervention shall be treated as ETC.

5. RFID tags shall be the only method for ETC for electronic payment through long life media The free flow ETC technology shall be the one approved by NHAI/GoI(i.e. ISO 18000-C RFID).
6. It is recommended that all discounts/exemptions be vehicle specific and implemented through the nationwide interoperable FASTag being implemented by NHAI. The use of smart card and any local RFID card for local discounts be discarded (as per letter NHAI/13013/CO/2014-15/ETC/FASTag Lane/70613 dated 20.08.2015).
7. Number of ETC Express lanes is recommended to be at least two per direction per toll plaza. The ETC lane location shall be centermost lanes - this is to allow the vehicle to pass at high speeds. Further, location of ETC lanes shall be the as per NHAI guidelines (DO letter no. NHAI/13013/CO/ETC implementation/2015 dated 20.06.2015, Point No 3 – Segregation Traffic Island for ETC lane). There shall be no reversible lanes.
8. Non-ETC vehicles shall not be allowed on ETC lanes and shall be penalized as per NHAI guidelines of recovering twice the fee (Gazette Notification GSR 831(E) dated 21st November, 2014). In such case, need for eject lane is obviated. As eject lane is not required, the island length may be same as other lanes (as per current NHAI guidelines, island length is 70m, to accommodate eject lane).
9. Weight enforcement (Weigh in Motion) shall not be part of toll plaza but shall be installed in the main expressway between entry to the expressway and next toll plaza. This may be implemented as a standalone Ramp Sorter System and not part of the tolling activity or system.

   As per current NHAI guidelines WIM is to be installed in each toll lane. This may be relooked into by NHAI.
10. The system shall allow for various classes of vehicles discussed in this volume. Not all classes of vehicles shall be allowed on the expressway.
11. The tolling system shall allow for different discount schemes discussed in this volume.
12. Various methods of payments defined in this chapter shall be supported by the tolling system. It shall be possible to have a combination of such methods in certain defined lanes (e.g. mixed lane).
13. The final fee chargeable to a road user shall be dependent of the vehicle class, distance between entry and exit plazas and discount availed.
14. The plaza operations shall allow for manual operation in case the Toll Collection Equipment is inoperable.
15. Concessionaire / Operator shall follow the defined service levels and non-conformance shall invite penalties.
16. There shall be no U-turn for any vehicle except emergency vehicles. U-turn for such emergency vehicles shall be provided at suitable place away from toll plaza.

13.1.2 Vehicle Classes

As per the tolling policy and notifications of Government of India, toll rates are notified for various types of vehicles, and the toll charges are revised from year to year based on WPI index and procedure given in GOI notification. The details of these vehicle classes, as notified by GOI are given hereunder.

1. All vehicles shall be divided into classes.
2. The vehicle class shall be one of the basis of calculating chargeable fee.
3. The following shall be the classes (As per GOI notification No. 12037/19/2010/SP (W.Bank)/P-9 dated 27th December 2010, and subsequent Notification issued on 12th January 2011) :
   - Tollable classes (allowed on Expressway)
   - Class 1 – Car/Jeep/Van/LMV (Light Motor Vehicle) means any mechanical vehicle the GVW of which does not exceed 7,500kg OR the registered passenger carrying capability does not exceed 12 (excluding driver).
   - Class 2 – LCV/LGV/Minibus – means any mechanical vehicle with GVW>7,000kg but <12,000kg or registered passenger carrying capability >12 but <32 (excluding driver)
   - Class 3 – Bus/Truck (2 Axles) means any mechanical vehicle with a GVW >12,000kg but <20,000kg OR registered passenger carrying capability exceeding 32 (excluding driver)
   - Class 4 – means any mechanical vehicle having three-axles (inclusive of the axle of the trailer, if any with a GVW <=25,000kg)
   - Class 5 – Heavy Construction Machinery, Earth Moving Machinery or Multi-axle vehicle means heavy construction machinery or earth moving equipment or mechanical vehicle including a multi-axle 6 vehicle with 4-6 axles or vehicle (inclusive of the axle of trailer, if any) with a GVW>25,000kg but <60,000kg
   - Class 6 – any mechanical vehicle with 7 or more axles or vehicle with GVW>60,000kg
   - Vehicles not allowed on expressway
     - Non-motorized vehicles
     - Vehicles having less than four wheels
     - Vehicles without registration number plate
     - Tractors
4. The list of Exempt Vehicles shall be as per NHAI norms/Government notification.

13.1.3 Discounts

The type of discounts permitted under the Government Notifications are described here under.

Types of Discount

As per GOI notification No. 12037/19/2010/SP (W.Bank)/P-9 dated 27th December 2010, the following discounts are allowed:

a) For any road user:

The discounted toll fee available for any user is given in **Table 13.1**.

Table 13.1: Type of Discounts in Toll Fee for Any User

Amount Payable	Maximum number of one way journeys allowed	Period of validity
One and a half times of the fee for one way journey	2	24 hours from time of payment
Two thirds of the amount of the fee payable for 50 single journeys	50	One month from date of payment

b) For local users owning non-commercial vehicles

This discount is applicable if the following conditions are fulfilled:

- The vehicle owner resides within a distance of 20km from the toll plaza
- The vehicle is registered for non-commercial use
- provided that the discount shall not be applicable at the next toll plaza

In such case the discounted rate shall be Rs. 150 per calendar month (for base year 2007-2008 and revised annually)

The above indicates that a user can have multiple vehicles and is allowed to use the same pass for all his vehicles. Such discount would be "person specific" rather than "vehicle specific". To cater to such type of scheme, a pass which can be transferred from one vehicle to the other is required. So, a smart card is recommended for this discount scheme.

Also note that if the discount is intended to be "vehicle specific", RFID based ETC tag /pass shall be more appropriate and the transactions shall be treated in the same manner as other ETC passes.

c) For owners of commercial vehicles plying within same district

As per GOI (Ministry of Road Transport and Highways) Notification dated 12th January, 2011, the discount is applicable if the following conditions are fulfilled:

- the user owns a commercial vehicle
- this vehicle is registered within the same district
- this commercial vehicle is not plying under National Permit
- this commercial vehicle plies within the district

In such cases,

- the discount shall be applicable at all toll plazas within that district
- the discount shall be at the rate of 50% of the prescribed rate of fee

13.1.4 Considerations for this Expressway

The above discounts are appropriate for an open toll system. The following modifications in the discount schemes are recommended to make the discount more suitable for this expressway (**Table 13.2**):

a) for any road user

Table 13.2: Type of Discounts Possible for Any User of Expressway

Amount Payable	Maximum number of one way journeys allowed	Period of validity
One and a half times of the fee for one way trip with defined entry and exit plaza (specific entry-exit plaza combination)	2	24 hours from time of exit *plus some variable time depending on trip distance.*
Two thirds of the amount of the fee payable for 50 single defined trips (specific entry-exit plaza combination)	50	One month from date of payment

For 50 trip monthly pass, it is recommended that the road user be allowed to use the prepaid trip for a distance less than he has paid for. For example, if he has purchased trips from Plaza A to Plaza C, and if Plaza B falls in between Plaza A & C, the road user be allowed to exit from Plaza B as well.

b) for local users owning non-commercial vehicles

This discount is applicable if the following conditions are fulfilled:

- the vehicle owner resides within a distance of 20km from a toll plaza
- The vehicle is registered for non-commercial use
- provided that the discount shall be applicable for trips only *between this "home toll plaza" and nearest toll plaza on either side (if toll plazas exist on either side)*

In such case the discounted rate shall be Rs. 150 per calendar month (for base year 2007-2008 and revised annually)

c) for owners of commercial vehicles plying within same district

The discount is applicable if the following conditions are fulfilled:

- The user owns a commercial vehicle
- this vehicle is registered within the same district
- This commercial vehicle is not plying under National Permit. *Discount may be extended to all commercial vehicles.*
- this commercial vehicle plies within the district *on toll plazas operated by the same Concessionaire*

In such cases,

- the discount shall be applicable at all toll plazas on the expressway provided they fall within that district
- the discount shall be at the rate of 50% of the prescribed rate of fee

Treatment of National Permit

National permit means a permit granted by a competent authority to a goods carriage to operate through-out India / the Territory of or in such contiguous States not being less than four in number including the states in which the permit

is issued as may be specified in such permit in accordance with the choice indicated in the application.

It would be difficult for the TC to determine whether the vehicle has a National Permit or not. Even if the vehicle is registered for National Permit, the driver may choose not to disclose the same to avail of the above mentioned discount.

For this, some suggestions are given below:

a) The road user provides a declaration at the time of issue of such discount pass that the vehicle is not registered for National Permit, and, if in future the vehicle gets registered, the owner of such vehicle shall promptly inform the Concessionaire.

b) The Concessionaire shall periodically check with competent authority if the vehicle is registered for National Permit and if the owner has given a wrong declaration, his pass may be allowed to be blacklisted for one year.

c) The database of other Concessionaires having similar clause is made sharable by NHAI.

d) The database of authorities issuing National Permit is made sharable with Concessionaires

e) The above clause is re-examined to include all commercial vehicles irrespective of them having a National Permit or not.

Further, the following may be noted:

a) The above clause shall be for all commercial vehicles including taxis and buses.

b) There shall be some kind of understanding between different Concessionaires in the same district so that the district pass is made interoperable at all toll plazas. Alternately, each Concessionaire shall have to issue a separate pass and the user shall have to carry multiple passes.

c) Penalties

In case the road user loses the ticket issued at the entry toll plaza, he shall be required to pay the higher of the following:

- Fee between his exit toll plaza and the mainline plaza at one end
- Fee between his exit toll plaza and mainline plaza at other end

Methods of payment

The summary table of relevant Methods of Payment (MOP) for consideration is given in **Table 13.3**. All have been discussed in brief below but not all are recommended to be used on the Expressway.

Table 13.3: Methods of Payment for Toll Fee in Expressway

MOP	Description	Media	Payment	Remarks
Cash	Payment in Indian currency	Paper/ coins	-	Recommended
ETC	Used by any road user for as per defined discount policy	RFID tag	Prepaid &Post paid	Recommended for 50 trip monthly pass

MOP	Description	Media	Payment	Remarks
Fleet Card	Special category of Smart Card used to grant discount to transporters having more than specified number of vehicles.	RFID tag	Prepaid & Post paid	Discretion of Concessionaire
E-purse card	Special category of Smart Card. It is like a debit card and can be used to pay for goods and services apart from toll within the Expressway (like restaurants, petrol pumps etc.)	Plastic card	Prepaid	Not recommended
ETC (Interoperable)	Transponder-tag based electronic collection system for discounted transactions – can be used nationwide (as per NHAI policy yet to be implemented)	Plastic tag	Prepaid &Postpaid as per NHAI policy	Recommended for free flow ETC lanes
Daily Pass	Allows vehicle to pass defined number of times through designated toll plazas by paying one-time fee	Paper	Prepaid	Recommended for 24 hour pass
Credit granted	When the toll collector grants credit (allows road user to go for free). Credit is granted from a selectable list (e.g. operator vehicles)	-	-	Discretion of Concessionaire
Insufficient funds	When the toll collector accepts only part of the money. The road user does not have full amount. He may give the balance later	-	-	Discretion of Concessionaire
Exempt	For vehicles under the Exempt list issued by the NHAI	preferably RFID tag	-	Recommended as per GOI notification

MOP	Description	Media	Payment	Remarks
Violation	This happens when there is an AVC class but no Operator Class	-	-	Recommended
Convoy	The toll collector allows a convoy to pass. Cash is paid by last vehicle in the convoy for all preceding convoy vehicles	-	-	Not recommended as difficult to handle operationally especially if vehicles in convoy exit from different plazas.

Method of operation of each type recommended above is defined in detail under the section dealing with toll collection operation.

13.1.5 Toll Rate for Proposed Expressway

The toll is generally fixed based on three considerations as follows:

(i) The first basis is the Willingness to Pay for the better services provided to the road users. The survey conducted has abundantly provided the clue that the road users are willing to pay toll, but surely not as required for recovery of cost of the road (expressway in this case). But, the general conditions of the existing highways in the influence area of the proposed expressway, which will be actually providing traffic base for virgin alignment of the expressway through diversions, are very poor in terms of their general maintenance, riding quality, level of congestion and safety due to the mixed traffic. Thus, in some cases the road users have expressed willingness to pay much higher than what is required to be paid for using the expressway, just because of frustration on their existing routes. Thus, it is quite clear that there is demand for higher level of service as well as willingness to pay for use of such toll expressway.

(ii) User benefit principle is an established technique, and according to theory 35 to 50% of the benefits derived by the user from the VOT and VOC savings are always offered for using the higher level of services. In case of the users of Vadodara – Mumbai Expressway the long distance traveler will have very significant saving on time, especially for those O-D pairs located close to the immediate influence area of the expressway (i.e. close to the interchanges). Similarly, even for shorter travel, there can be significant savings if the O-D pairs are close to the expressway.

(iii) The third basis is the maximization of revenue, which has a limit to which the traffic will accept the toll rates. If a high toll rate is implemented, then many users are likely to be deterred from using the system and revenue falls below the optimum level. Similarly, if the toll rate is low then revenue is lost from motorists who would have paid higher for use of the facility. Moreover, the low toll rates may invite traffic to such an extent that the deterioration of facility becomes faster.

The toll rate applicable for Vadodara – Mumbai Expressway has been determined both through a compilation of various toll rates applicable as per the Govt. of India toll notification for NH and those being charged on some state highways of Gujarat and other Expressways operational in Gujarat and Maharashtra. The toll rates proposed for Ganga Expressway and as those operational on Mumbai-Pune Expressway have also been looked into. The toll

rates obtained from the WTP survey have also been considered for different modes. The toll rate analysis has shown that there are lot of variations in the toll charged on various roads. The WTP analysis, on the other hand, showed that users have shown an inclination to pay higher toll rates when asked in terms of travel time savings, while for actual payment of toll on per km basis, the acceptable toll rate value is observed to come down by 25-30%. The truck drivers were generally observed to avoid the tolled routes unless the benefit from time savings is significantly higher in the choice of a tolled route. The WTP survey has brought out that trucks have already started avoiding the Bharuch – Vadodara section of NH-8 after the opening of new toll plaza at Km 157.000 near Karjan. The toll rate for expressway facility shall be 1.25 times of Govt. notified toll rates as specified in toll fee notifications dated 16.12.2013 issued by MoRT&H. Accordingly, the toll rate has been adopted as 1.25 times of the rate provided in the Govt. Notification. Since, there are many structures on the VME the effective toll rate for VME is about 1.8times that of NH-8.

The sensitivity analysis shown in the **Chapter 4 - Traffic Survey and Analysis** also had established that 25% extra toll is the optimum for maximization of revenue.

As per the GOI Toll Notification, the toll fee will be increased or revised upward at a rate of 5% per year in the future years. The patronage of traffic was evaluated with variations in toll rate from the toll rates based on the Notification and its hundred percent variation. The results of this analysis were shown in the **Chapter 4 - Traffic Survey and Analysis**, where the sensitivity of traffic estimates and toll revenue with variations in toll rates was shown.

13.1.6 Toll Plaza Lane Requirements

The analysis to determine the number of toll lanes or toll booths in each toll plaza has been done on the basis of Queuing Theory. The input data, level of service requirements and results are described in this chapter. The calculation has been done by assuming the closed system of tolling on the expressway (i.e. every vehicle to be tolled based on exact distance traveled). The Model selected is M/M/s model in which there can be more than one toll lanes or toll booths. The model selected has been explained in detail below.

The M/M/S Model of Queuing Theory

M/M/s model is a queuing model that contains more than one departure channels (i.e. number of toll lanes), where the first 'M' represents the distribution of arrival rate (i.e. poisson in this case), the second 'M' represents the distribution of service rate (which is also poisson in this case) and 's' represents the number of servers (or toll booths, which is to be determined).

The following parameters describe the operational characteristics of *M/M/s* model.

a) Vehicle arrival rate and its distribution

b) Service rate and its distribution

c) Expected time spent by each vehicle in the system based on number of servers (toll booths)

The detail formulation for the model is as per the following equation:

1. Probability of having no vehicles in the system, is given by equation (1).

$$P_0 = 1 \Big/ \sum_{n_c=0}^{N-1} \frac{\rho^{n_c}}{n_c!} + \frac{\rho^N}{N!\left(1-\rho/N\right)}$$

(1)

Where,

ρ = Utilization Factor = $\frac{\lambda}{\mu}$

λ = Arrival Rate of Vehicles

μ = Service Rate of Toll Booth

N = Number of Toll Booths

n_c = Number of vehicles in the Queue.

And, ρ/N = System Utilization Factor

2. Average Length of Queue in the toll booths is given by equation (2).

$$\overline{Q} = \frac{P_0 \rho^{N+1}}{N!N}\left[\frac{1}{\left(1-\rho/N\right)^2}\right]$$

(2)

3. Average time spent in the system is comprised of the time spent in the queue and also in obtaining the service (i.e. service time). This is given by equation (3).

$$W = \frac{\overline{Q}+\rho}{\lambda}$$

(3)

As Queuing Theory is applicable only for steady state condition, the System Utilization Factor (ρ/N) must be less than 1, however the Utilization Factor for a single booth (ρ) can be greater than 1.

The vehicle arrival rate (λ) and service rate (μ) are to be given as inputs in the model. To estimate the expected waiting time, the numbers of toll booths are also given such that the utilization factor (ρ) becomes less than 1. The output, expected waiting time, was compared with the required level of service for the toll plaza type (i.e. main plaza or link plaza). With several trials the least number of toll lanes or toll booths required were selected in case of different interchanges.

Tolling System Service Rate

Based on the payment method described above in the chapter, service rates of the tolling system may vary. However, the ToR suggests service time to be limited to 10 seconds per vehicle which amounts to service rate of 360 vehicles per hour. The toll lane estimation has been done by adopting this service rate.

Vehicle Arrival Rate (Interchange Traffic)

The assigned traffic on entry and exit lanes of each interchanges were converted into peak hour traffic by adopting peak hour proportion of 6% of the AADT. The peak hour traffic of entry and exit lanes, given as input in the queuing model as vehicle arrival rate, for various horizon years is shown in **Table 13.6**.

Level of Service at Toll Plaza

The level of service for traffic, i.e. the maximum permissible waiting time of 45 sec has been considered. For the queuing impact, maximum permissible queue length of 4 vehicles, in any toll lane, has been adopted. The number of toll lanes required has been estimated by considering the above mentioned requirements in the Queuing model.

Estimation of Toll Lanes

Each toll plaza will have separate toll lanes for ETC system (the inner most lanes), manual/semi-automatic system (lanes in the middle) and one lane (the outer most) for extra wide vehicles. Provision of ETC lanes in the toll plaza requires being in continuation with the interchange ramp lanes, so that the ETC user passes through toll plaza with least maneuvering. Hence, minimum number of ETC lanes required in the toll plaza is equal to the number of lanes on the interchange ramp or number of lanes in one direction on the expressway in case of main line toll plaza.

Based on the above mentioned requirements, vehicle arrival rate and service rate described earlier, the toll lanes requirement has been worked out for revised traffic in the horizon years 2035 and 2045.

A list of interchanges with their type and number of toll plazas on each of them is given in **Table 13.5.**

Table 13.5: List of Interchanges, their Types and Number of Toll Plazas

Interchange No.	Chainage (Km)	Type of Interchange	Number of Toll Plazas at the Interchange	Package
Phase IA				
9	254+430	Partial Cloverleaf	2	Package V
10	287+385	Full Cloverleaf	4	Package IV
10A	323+087	Diamond Type	4	Package II and III
11	353+690	Partial Cloverleaf	4	Package II
12	374+355	Partial Cloverleaf	4	Package I
13	376+235	On Main Express	1 (Main Line Toll Plaza)	Package I

The results obtained from the computations based on queuing theory using the volume of incoming and outgoing interchange traffic in two horizon years are given in **Table 13.6**. It may be noted that the toll lane requirements in the opening year has been estimated from the traffic that will be using the interchange in the

year 2035. For visual representation of the toll lane requirements refer to **Annexure 13.1**.

Table 13.6: Peak Hour Traffic on Toll Plaza and Estimated Number of Toll Lanes

Interchange No. & Chainage in Km	Toll Plaza	Direction (Entry: to expressway, Exit: from expressway)	Year 2035		Year 2045	
			Peak Hour Traffic (Vehicles)	No. of toll lanes (normal + ETC + extra wide)	Peak Hour Traffic (Vehicles)	No. of toll lanes (normal + ETC + extra wide)
Package V						
Int. 9 (254+430)	TP-1	Entry	112	(1+2+1)	141	(1+2+1)
		Exit	510	(2+2+1)	623	(2+2+1)
	TP-2	Entry	350	(2+2+1)	400	(2+2+1)
		Exit	145	(1+2+1)	189	(1+2+1)
	Package IV					
Int. 10 (287+385)	TP-1	Entry	152	(1+2+1)	149	(1+2+1)
		Exit	106	(1+2+1)	140	(1+2+1)
	TP-2	Entry	475	(2+2+1)	603	(2+2+1)
		Exit	0	(1+2+1)	0	(1+2+1)
	TP-3	Entry	57	(1+2+1)	74	(1+2+1)
		Exit	137	(1+2+1)	135	(1+2+1)
	TP-4	Entry	0	(1+2+1)	0	(1+2+1)
		Exit	427	(2+2+1)	566	(2+2+1)
	Package III					
Int. 10A (323+087)	TP-1	Exit	157	(1+2+1)	194	(1+2+1)
	TP-2	Entry	50	(1+2+1)	56	(1+2+1)
	Package II					
	TP-3	Exit	158	(1+2+1)	192	(1+2+1)
	TP-4	Entry	60	(1+2+1)	65	(1+2+1)
Int. 11 (353+690)	TP-1	Entry	0	(1+2+1)	0	(1+2+1)
		Exit	33	(1+2+1)	38	(1+2+1)
	TP-2	Entry	221	(1+2+1)	271	(1+2+1)
	TP-3	Entry	0	(1+2+1)	0	(1+2+1)
		Exit	0	(1+2+1)	0	(1+2+1)
	TP-4	Entry	65	(1+2+1)	70	(1+2+1)
		Exit	232	(1+2+1)	291	(2+2+1)
	Package I					
Int. 12	TP-1	Entry	702	(3+3+1)	854	(3+3+1)

Interchange No. & Chainage in Km	Toll Plaza	Direction (Entry: to expressway, Exit: from expressway)	Year 2035		Year 2045	
			Peak Hour Traffic (Vehicles)	No. of toll lanes (normal + ETC + extra wide)	Peak Hour Traffic (Vehicles)	No. of toll lanes (normal + ETC + extra wide)
(374+355)	TP-2	Entry	0	(1+2+1)	0	(1+2+1)
	TP-3	Exit	673	(3+3+1)	826	(3+3+1)
	TP-4	Exit	0	(1+2+1)	0	(1+2+1)
On Main Exp. (376+235)	TP-1	Entry	1070	(4+2+1)	1427	(5+2+1)
		Exit	977	(3+2+1)	1245	(4+2+1)

**TNA: Ramps or loops where no turning traffic could be predicted by RTDM, as it is not a microscopic model and locally generated traffic may not be completely represented. Thus, the minimum configuration of toll plaza with one normal and one extra-wide lane has been provided for such ramps/loops.*

13.2 TOLL PLAZA FACILITIES

13.2.1 Introduction

The Toll Plaza is the place where the following activities take place:

a) Collection of road use fees

b) Interaction with stakeholders including road users.

c) Monitoring and audit activities

It shall house the following:

a) Staff - Managerial staff, toll operations staff (toll collectors & supervisors), maintenance staff, audit staff, ATMS control room staff, security guards, public relations office and other support staff HR, Finance etc. It may also house route operations personnel

b) It shall also have public facilities like restrooms, first-aid room etc...

c) Vehicle maintenance facilities and laboratories may be housed at the Toll Plaza.

d) Other facilities like generator room, parking etc.

e) Toll booths

This is where the cash is collected from the road user and transferred to the designated facility (like bank).The Toll Plaza is face of the company where maximum interaction with the road user takes place. This area must be aesthetically built, maintained clean, must allow efficient operations and be safe for tolling staff and road users. Various equipment like Toll Collection Equipment, surveillance system communication system and electrical systems (UPS and DG sets, air-conditioning, ventilation etc.) are installed at the plaza.

This section discusses the requirements of the toll plaza area consisting of

- Toll Plaza building
- Lane area
- Flare area and Queuing/Recovery zones zone

- Tunnel

13.2.2 Toll Plaza Building Area Requirement

This section discusses only the building where back-end operations take place. The building may be located on either side of the lane area. The building shall comply with latest National Building Code. The building shall also have to pass the safety audit conducted independently by external agency.

Entry and Exit

The toll plaza shall have the following entry/exit points

a) For general public

The entry for the general public shall lead to a reception area. Reception shall be connected to rest of the building through an access controlled door so that members of the general public do not enter staff area in an uncontrolled manner.

b) For staff

The staff shall have a separate entry provision. The staff that handles cash shall enter the Locker Room where they shall keep their belongings before proceeding to start operations.

c) For cash transfer from lanes

Cash shall be transferred from booths in the Lane Area to the cash up area in the Toll Plaza by Toll Collectors/ cashiers/supervisors or other designated persons through an underground tunnel. All access in the booth (except emergency exit) shall be through the entry/exit door in the toll plaza which opens in the tunnel.

d) For banking vehicle

There shall be a separate entry/exit point from where the daily cash collections shall be transferred to the banking vehicle. The banking vehicle transports the cash to the bank and may be outsourced or in-house. There shall be separate passageway for the banking vehicle to access and park close to the point of cash transfer (vault room).

e) Emergency exit

There shall be exits provided in the building for employees in case of any mishap (e.g. fire) occurring.

Reception Area

The reception area shall have adequate seating, drinking water facilities and shall be adequately cooled/heated. This area shall also have a public relations officer to address the concerns and suggestions of the stakeholders. The complaint/feedback book shall also be made available here along with other notifications required to be made available to the public.

The Operator may house the POS desk here at his option.

Toll Control Room (TCR)

There shall be a TCR to monitor and control toll operations activities. The TCR shall be located such that it shall be possible to view all the lanes clearly (possibly on the first floor but below canopy height).It shall house

a) The equipment to monitor Toll Plaza activities (walkie talkies, intercom, panic alarm etc.).

b) The computers to monitor, validate, audit and print toll collection data.

c) Monitors/screens and other equipment to monitor plaza activity as part of CCTV surveillance system.

Parking

The Toll Plaza building shall have adequate parking for visitors and staff. The parking should be such that entry from the highway/flare area into the parking and exit out of the parking into the highway/flare area is safe. Care should be taken to design the merging traffic.

Toll Plaza building shall also have adequate space for parking of vehicles of visitors and staff.

The following vehicle space is recommended as a minimum:

a) Visitors – 6 vehicles

b) Concessionaire/NHAI staff – 6 vehicles and a separate 2 wheeler parking for at least 10 vehicles

c) Parking for Emergency Response Vehicles – at least 2 ambulances, two route patrol vehicles and one crane and recovery vehicle.

Canteen/Eating Area

It is recommended that the Plaza Building have a dedicated eating area and proper waste disposal systems put in place.

UPS Room

The UPS room shall house the UPS and the batteries required for the toll plaza equipment. This room shall be adequately ventilated and air-conditioned.

a) Air Conditioning Plant / Fresh Air Blower Area

All toll booths shall be air conditioned .The plaza shall area provide for AC plant or fresh air blower. Ducts shall carry fresh air into tunnel and booths. The air conditioning plant shall provide cool as well as hot air to maintain comfortable working temperature in booths and tunnel area. In case stand-alone air-conditioners are installed in each lane and the air intake is from the lanes where vehicles are generally idling, Carbon Dioxide and Carbon Monoxide levels shall be monitored inside the booth so that it does not become unsafe for the toll collector who has to operate for a prolonged period of time.

b) DG Room

The DG room houses the Diesel Generators. It shall have provision for storing fuel (if required) as well as electrical panels. The DG room shall have adequate provision for exhaust and shall be lockable to prevent pilferage of diesel. It shall have sufficient fire extinguishers. There shall be sufficient space between the generators to provide for maintenance. The DG room shall be sufficiently protected against rain and water.

c) Electrical Room

The Electrical Room shall have provision to install Electric Meter (State Electricity Board) and mains electrical panel. The room shall be compliant with local SEB rules (e.g. for access).

d) Cash-Up, Cashier and Vault Room

The cash-up room shall have sufficient stations so that all the toll collectors quickly cash up their respective proceeds and deposit it with the cashier.

The Vault Room houses the vault where all cash is kept till the time it is banked. The vault room walls shall be made of thick reinforced concrete and its door shall be made of thick steel.

e) Systems Room

The Systems Room or the ITS room or System Administrator room shall house the server and may also house the ITS maintenance staff. The server room (if separate) shall be lockable and air-conditioned and relatively dust free.

NHAI / Auditor Room

There shall be provision for a small room for housing NHAI staff and a large room for auditors designated by it. There shall be monitoring station in the NHAI room which shall display images from the CCTVs as well as reports from toll collection system

Other Rooms

Following other rooms shall also be constructed:

Any room / space deemed fit by concessionaire to increase operational efficiency or safety. Any other room in compliance with IRC:SP:99 (Manual of specification and standards for expressway section – 12).

Plumbing and Drainage

The plumbing and drainage system shall include the following:

a) Rain water drainage system

b) Sanitary drainage system

c) Potable water

The rainwater drainage system shall gather water from building roof and canopy and merge it with rod drainage system.

The operational building shall be served with water main sized for total plumbing demand.

The sanitary system shall include drainage piping from plumbing fixtures to the nearest sanitary disposal system or cesspit.

The building shall have provision for filtering water if direct potable water is not available. A water treatment plant shall be established for this.

Other Building Facilities

The following shall be the other required building facilities:

a) Maintenance area for vehicle maintenance

b) Warehouse for storing tools and spare parts.

c) Locker room where the operations staff involved in cash handling shall be required to keep their belongings before start of shift.

d) Time office for attendance

e) Restroom – separate restrooms shall be provided for male and females and for staff and members of public

f) Janitor room to store cleaning and housekeeping consumables.

g) Auditor’s room

h) Room for IDB

i) Meeting/conference room

j) Rooms for managerial and supervisory staff like General Manager, Plaza Manager, Traffic & Safety (route operations) Manager, Maintenance Manager,

k) Security officer room with designated lockable area/almirah to keep guns (if gunmen are deployed).

l) Rooms for support staffs (HR, Finance, IT etc.)

General Note

Care shall be taken to design all areas to have provisions for persons with disabilities. The toll plaza POS, customer support desk, parking and other areas which may be accessed by road users shall be designed to have ramps. Compliance to IRC:SP:99 shall be ensured.

13.2.3 Toll Plaza Area Requirement

Booths

There shall be one toll collection booth per lane with the following dimensions

a) Booth width = 1.8m

b) Minimum internal width (working space) = 1.2m.

c) Booth height = 3.6m

- The booth shall have glass front so that the TC can see the oncoming traffic. The booth shall have a table on which the required toll collection equipment shall be placed.
- If the booth has air-conditioners, care should be taken that it should not draw excessive smoke into the booth. For this the carbon monoxide level inside the booth shall have to be monitored.
- It is recommended that provision be made for fresh air ventilation and air-conditioning/cooling be made through ducts. The central blower/chiller unit is placed away from the smoke area, near the toll plaza and draws fresh air from a minimum height of 3m. This shall reduce carbon monoxide levels and maintain positive air pressure within the booth.
- The booth table shall be at a height of 0.9m from the road level. The toll collector shall be provided with an ergonomically designed chair so that he can work comfortably for the whole shift.
- The booth shall have two level sliding glass windows to process both low and high vehicles.
- The booth shall adequate lighting for the toll collector to work.
- Each booth shall have two doors. One entry/ exit shall have a staircase leading down to the tunnel. The other exit shall be at the rear or in the middle . It shall swing open to the inside and the exit shall open on the lane; this door shall strictly be used for emergency exit and
- The center booth shall be “double booth” and shall have two collectors sitting on either end catering to both sides of traffic. The passage to the tunnel shall be from the middle of the booth. The center booth shall be

used for manual collection only in emergency situations when a non-ETC user enters the center ETC lanes.

- Reversible lanes are not recommended.
- The booths shall have adequate guard rail protection on sides and over the top so that the toll collector does not get hurt in case of a vehicle straying from its path in the lane.

Lanes

There shall be adequate number of lanes to process the traffic as per service times required. All lanes shall be concrete.

The lane width shall be as follows:

a) Normal lane – the lane shall be 3.2m wide.

b) ETC (Center) lanes - lane width 3.5m

c) Extra wide lane - lane width 4.5m,

d) 2/3 wheeler lane - none

The lane configuration is as follows:

- Express Lanes (ETC only, free flow, for non-oversize vehicles) – number of ETC lanes shall be equal to number of approach roads (of ramp or mainline , as the case may be)
- Express Lanes should appear to the driver as a simple continuation of the mainline through the tolling zone or point, not requiring any change in driving pattern
- Express lanes should not restrict usage by particular vehicle types, such as “cars only,” or “trucks only,” beyond those restrictions in force on the approach and departure roadway or the roadway facility in general.
- The Express lanes are the centermost lanes and should include the number of express lanes equal to the number of approach roadway lanes, including provisions for widening if the approach roadway is configured for future widening.
- This provision assures that a given toll plaza will never require future modifications or lane conversions to meet customer demand for non-stop lanes. This design guideline is important for several reasons:
  a) The appearance of a wide-open path “through the plaza” is a very effective marketing tool
  b) Once constructed, future changes are not required to accommodate higher ETC demand at the toll facilities, assuming the mainline is not widened. This eliminates additional express lane design and construction along with the risk of reduced revenue resulting from delays caused by reconstruction.

Fig 13.1: Dedicated free flow ETC lanes

Toll collectors shall not be required to walk across ETC dedicated lanes (but through an underground tunnel or overhead walkway) **Fig 13.1**.

- Standard Cash lanes – balance all lanes including extra-wide lane
- Reversible lanes - none

Canopy

The canopy is required to provide shelter to the toll booths and lane staff from rain and sun. It also provides structural support to lighting and some ITS equipment is fixed.

The canopy should have good aesthetics and adequate drainage provision.

Island

The toll island, used for physical lane separation and protecting toll booth and toll collection equipment within the conventional plaza, is usually constructed of Portland cement concrete. It provides a foundation for the canopy and toll booth, conceals wire ways and duct ways, and protects and helps form access to either a tunnel or overhead walkway. In addition, the toll island provides the foundation for equipment used in lanes operating in manual and automatic collection modes. This equipment includes an automatic ticket issuing machine, along with the associated traffic control equipment, including the island traffic signal, lane use signal, and automatic barrier gate and display equipment such as the patron toll display, any changeable message sign and any speed display sign. Crash protection on the island approach end of a Standard lane is provided to protect the attendant, toll booth and equipment, along with any stairs from either an overhead walkway or tunnel. The crash protection generally includes the following items, listed from the furthest to the closest to the tollbooth: crash cushion/impact attenuator, rampart, and crash block(s). Impact attenuators will not reduce the number of accidents, but rather the severity of an accident. The rampart and crash block(s) are intended to protect the attendant, toll booth and toll collection equipment.

Island Design Issues and Guideline for Development

Some of the significant issues to consider when designing a toll island and recommendations for resolving these issues include the following:

- The island design needs to be capable of supporting a tollbooth, a canopy whose load is transferred to the island through columns and toll collection equipment; conceal unsightly conduit runs; and provide protection for a stairwell to an access tunnel Cast-in-place reinforced concrete provides a durable foundation that can be formed to achieve various shapes and contours around openings and conduits can easily be embedded to route wires and cable to the tollbooth and island equipment.
- The island design must provide a means of securely anchoring the tollbooth and provide a positive means of clearance from the edge of travel way. A concrete blackout allows the bottom edge of the tollbooth to be anchored below the surface of the island. This prevents the displacement of the booth into a lane if the anchor bolts are sheared as the result of a vehicle collision. A minimum one foot ledge from the tollbooth wall to the outside edge of island is recommended to protect the tollbooth from damage by passing vehicles.
- When staff and visitors must cross multiple lanes to get to their desired island location, provisions for an island refuge prior to crossing lanes should be provided. It is recommended the tollbooth be installed in juxtaposition to canopy supports and toll equipment so that there is an access-way in a straight alignment across all islands in a particular direction of travel. If the access way is installed behind the tollbooth, line of sight to approaching vehicles should not be obscured by the booth when standing near the edge of the island.
- Although an impact attenuator is expected to absorb a significant portion of an errant vehicle's momentum, the island design must incorporate feature(s) to prevent all vehicles from a head-on collision with the tollbooth. The commonly used solution consisting of ramparts and crash blocks that satisfies the following criteria is recommended:

  a) Capable of sustaining vehicular impacts,

  b) Does not block the vision of the attendant,

  c) Consistent with any plaza architectural theme,

  d) Does not launch a vehicle when impacted,

  e) Designed to be monolithic with or securely anchored to the island to prevent any displacement as a result of a vehicle collision, and

  f) Requires minimal maintenance.

     - The island design shall provide appropriate clearances and accommodate the strategic placement of toll collection and traffic control equipment and devices, displays, and signs to meet functional requirements while avoiding the appearance of clutter and information overload. . The island width shall be a minimum of 1.8m, based on a tollbooth width of 1.2m. All plaza islands shall be of the same length in a particular direction of travel even though automatic lanes usually require a smaller island than manual or attended lanes. From a safety perspective, the toll island should be a minimum height of 15 cm,. However, added protection is warranted for the safety of the collector and protection of the agency's investment in equipment and the

tollbooth installed on the toll island. This is particularly relevant with the addition of ETC capability that commonly results in higher speeds through the lane.

- The location of the island needs shall be clear to all approaching traffic under all lighting and weather conditions. To assure visibility of the toll island the design shall incorporate a beacon/fog light mounted on the bull nose on the approach end of the island and installed at a height that is visible to all approaching traffic.

Each island shall have a faucet installed which shall draw water from the toll plaza through adequate plumbing. This shall be used for washing the lane area.

Each island shall have a bull nose at the entry end. The bull nose shall be chevron painted with reflective paint.

The islands shall be at least 25m in length.

13.2.4 Toll Plaza Approach and Exit Area Requirements

Queuing Zone and Flare (Approach Zone)

The Approach Zone is the area from where the main carriageway ends to the start of the lane island. It consists of the flare area and the queuing area. The queuing area shall be straight (parallel to the main carriageway median) and shall have the length to accommodate at least four vehicles. The area between the main carriageway and end of start of queuing shall be flared in the ratio of 1:10 for mainline plaza and 1:10 for interchange ramp.

Recovery Zone and Flare (Exit Zone)

The other side of the pay axis shall be the Exit Zone. It consists of Recovery Zone and exit flare area. The Recovery Zone is the straight area (parallel to the main carriageway median) from end of island to the beginning of flare area. The area between the end of Recovery Zone and main carriageway is the exit zone flare area which merges the exiting traffic into the main carriageway. The recovery zone shall be at least one vehicle long and the flare shall be 1:15 for mainline plaza and 1:10 for interchange ramp. Both approach and exit areas shall be concreted.

13.2.5 Toll Plaza Tunnel Requirements

The toll plaza shall have an underground tunnel connecting the booths to the toll plaza building for the following purposes:

- Safe passage of toll collectors and other staff
- The tunnel shall house part of the Toll Collection System
- The tunnel shall also carry data and power cables between plaza building and lane area

The tunnel shall have the following:

- Dimensions large enough so as to allow free movement of people after positioning of equipment, utility ducts as well as staircases. The minimum recommended dimensions are

  Height – 3m

  Width – 2.4m

- The tunnel shall be well ventilated by fresh air and positive air pressure shall be maintained at all times. It shall have a blower at one end and at exhaust fan at the other. Small branch air ducts shall rise from the main tunnel duct to all booths to adequately ventilate them at constant at equal pressure.
- It shall have adequate lighting for passage and maintenance activities (of equipment in the tunnel)
- It shall have a provision for faucet and janitor room for storing housekeeping material.
- The tunnel shall connect to the main drain or to the sump through a pump. It shall have a cross slope of 2%.

13.2.6 Other Requirements

Signages

The entire toll plaza area shall have correct signage including the following:

- Toll fee shall be displayed as per NHAI norms as well as in each lane. The fare table at each entry (exit) shall display the fares for each entry/exit combination for every class of vehicle.
- Canopy shall have correct signage showing the type of lane below (e.g. extra wide lane, ETC lane, Exempt Vehicle lane, cash/card lane) so that it is easy for the road user to make decision.
- The character size of the signage shall be such that it can be easily read from a distance where the vehicle driver is.

Safety

- Bull nose shall have proper chevron marking
- If cones/bollards/other barriers are temporarily used for lane delineation at the toll plaza, the first barrier shall have light lamp indication to advise the road user in situations of poor visibility.

Lighting

Lighting Design Issues

Where there are concentrations of pedestrians and roadside intersectional interferences, fixed-source lighting tends to reduce crashes. . Due to the amount of activity from traffic weaving, diverging, merging and stopping in the approach and departure zones, and the presence of fixed objects mounted in front of and to the toll island(s) adjacent to the toll lane, properly designed luminaries are critical to maintaining safety and operational efficiency through the plaza.

Some of the significant issues that should be addressed when designing toll plaza lighting include the following:

- Design should strive to eliminate harsh glare on approaching and departing motorists,
- Reduce lighting spillover into adjacent properties, especially residential areas,
- Provide a smooth transition from toll lane lighting to departure zone lighting,
- Maintain uniform lighting through a toll lane,
- Minimize the quantity of plaza approach and departure lights standards and poles, that effectively pose a roadway hazard,

- Conceal conduit to canopy mounted luminaries,

The following shall be followed as per Guidelines *for Expressway*:

a) Inside the toll booth : 200 to 300 lux as per IS:3646 Part II

b) Canopy lighting : 100 lux

c) High mast lighting : min 30 lux to illuminate road surface

d) Street lights on both side approaches for a minimum length of 500m beyond toll plaza on each side.

e) Highway lighting : lighting in 1km length beyond approach areas

13.2.7 Toll Collection Equipment (TCE)

This section covers the specifications of TCE as well as other related equipment like electrical equipment, surveillance equipment, communication equipment and other equipment not directly integrated into the TCE.

The TCE shall be designed to include all discount schemes and methods of payment. These guidelines include hardware and software functionalities. Alternately, some guidelines are available in "Specifications for Road and Bridge Works (Fifth Revision) published by IRC" – also called Orange Book, Section 815.

Plaza Equipment

a) Control room – LSDU/Lane monitor, discrepancy resolution computer, report computer printers, intercom (master), violation alarm, software (application and operating).

b) POS - computer, tag/card charger & printer

c) ITS System Admin room – server with software (application, OS, database)

d) UPS and Network switches, cables and accessories

Lane & Booth Equipment

AVC sensors, Incident detection camera, Toll collector's screen, manual booth controller, customized keyboard/touchscreen, card and tag readers, bar code reader (if applicable), AVC controller, Toll Lane Computer (TLC), Automatic Lane Barrier (exit), Manual Lane Barrier (entry), Vehicle Class Indicator (VCI), Traffic light, OHLS, Fog light, Intercom slave, UPS (if required), network switches, cables and accessories.

a) Central / HO – monitoring/report computer, printer and UPS

Electrical Equipment

a) Diesel Generator

b) UPS for office computers

c) Electrical panels

Security & Surveillance Equipment

a) Plaza, lane & booth area - CCTV surveillance cameras

b) Plaza – monitoring screens, joystick, DVR

c) Vault

Communication Equipment

a) Intercom – connect all rooms within a plaza and all plazas among themselves.

b) Walkie-Talkie – connect lane staff to plaza

Other Equipment

a) Access control equipment

13.2.8 Standards/ Environmental Requirements

All equipment provided shall comply with requirements of environmental standards as given in **Annexure 13.2**, unless otherwise stated.

13.2.9 Equipment Functional Overview

This section explains the functional requirements of the systems installed at the toll plaza. As per the Tolling Strategy, the equipment shall have the following functionalities:

On the Entry Side

a) The mixed lane shall have equipment to print an “entry ticket”. A toll collector sitting in the booth shall issue a system printed bar- coded paper ticket to the road user if he intends through pay through cash or avails “monthly non-commercial district discount “The smart card user shall touch the card on the SCR, the card is validated and the vehicle allowed to pass. No TC intervention is required. A camera captures image of each vehicle.

b) The ETC express lanes shall not have a booth or ticket issue. The transponder shall read and register the vehicle details.

c) There shall be no AVC mandated.

d) The vehicle information shall be sent to all toll plaza servers and then to all exit toll booth TLCs via communication backbone.

On the Exit Side

a) In the mixed lane – The system shall read the “entry ticket” and the TC shall request the road user for appropriate fare. The road user shall pay through card. System logic shall allow for appropriate discount schemes. The smart card user shall touch his card on the SCR, card is validated and user allowed to pass. Fare deduction is automatic.

b) The ETC Express lanes shall have no TC. The ETC system shall calculate the exact fare based on information stored in its toll plaza server database. The appropriate fare shall be deducted after applying discount schemes.

c) AVC shall be installed in each lane and shall classify exiting vehicle.

13.2.10 Equipment Component Functionalities & Specifications

The following **Figure 13.2** is the overview of data connection diagram of the toll plaza

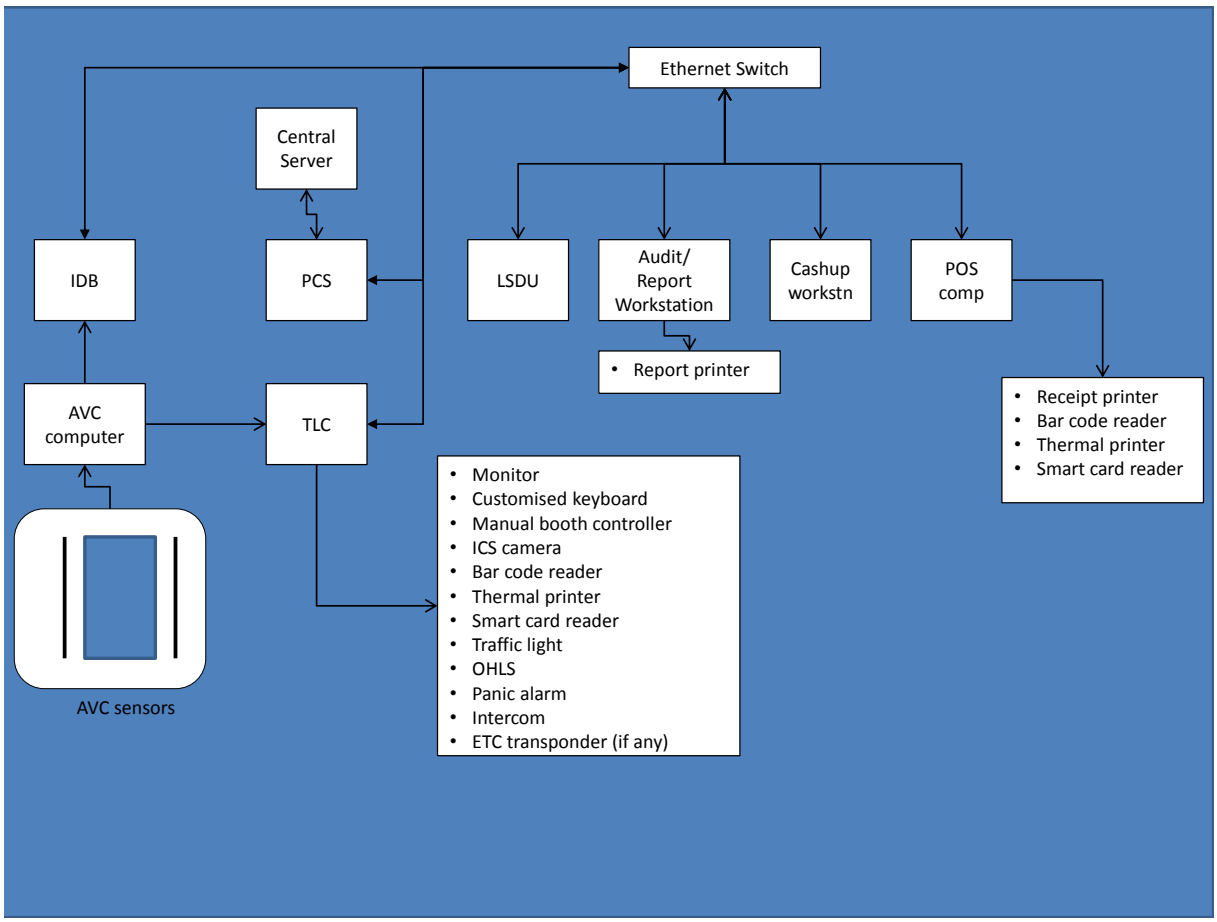

Fig 13.2: Equipment Specifications

13.2.10.1 Central Server

a. Purpose - Purpose of the Central Server is to receive and distribute data from/to all Plaza Servers.

b. Location - Any of the Expressway Toll Plazas

c. Requirements

i. The Server shall be with keyboard, monitor, mouse and UPS

ii. It shall receive and transmit data to/from all toll plaza servers. This data shall include vehicle transaction data, vehicle time of entry/exit, vehicle image at entry, toll fares, smart card/ETC data (blacklist/whitelist/grayish, card balance), and return journey data.

iii. It shall synchronize time between all plaza servers

The server supplied shall be of the latest configuration at the time of installation. However the minimum specifications are as follows:

- OS : Windows Server (Enterprise) preloaded
- Processor : Quad Core,3 GHz, 2x4MB shared cache, 1333MHz FSB
- Memory : 8GB DDR2 , 800MHz

- Drive controllers : Integrated serial ATA controller with RAID 0, 1, 5 and 10, removable boot drive option.
- Hard drive : minimum 5 SATA drives of 500GB each With RAID5
- Network adapter : Dual embedded gigabit Ethernet NIC & PCI NIC
- Optical drives : DVD/CD RW combo
- Database : Oracle, MySQL or equivalent
- Monitor : 19 inch TFT included
- Keyboard and mouse : included
- Mounting : 19" rack mountable

13.2.10.2 Plaza Computer System (PCS)

a. Purpose - The purpose of the plaza server is data storage and communication to/from Toll Lane Computer (TLC) as well as Central Server.

b. Location - Each Plaza shall have a Plaza Server, preferably located in the System Administrator/ITS room

c. Requirements

i. The PCS shall have an operating software, database software and application software. The application software shall present various screens to the computer user and shall be GUI based.

ii. The Plaza server communicates continuously with all TLCs in that plaza.

iii. It downloads fare tables from the Central Server and updates TLCs.

iv. It shall manage discount schemes in consultation with central server.

v. It shall store images of discrepant transactions.

vi. It shall check for data completeness at end of shift (i.e. all transaction data from all lanes shall be uploaded on the computer and there shall be no missing records)

vii. It shall keep a record of all system events and shall be able to display and print the same (if printer is provided).

viii. It shall be time synchronized with central server and shall synchronize other computers in toll plaza

ix. Technical specifications -Same as Central Server

13.2.10.3 IDB (Independent Database) Server

a. Purpose - The purpose of the IDB server is to store vehicle classification data independently. This data can be used as an audit on the PCS as the access to this server data shall be with NHAI. Also the IDB server shall continue to record data even if the TLC/PCS and other equipment are not working.

b. Location - Each Plaza shall have an IDB server, located preferably in the System Administrator/ITS room.

c. Requirements

- The IDB server shall receive vehicle data from the AVC computer.
- It shall store vehicle data (class) along with time
- It shall be time synchronized with the PCS.
- It shall not record revenue or images.

Technical specifications.

Same as Central Server

13.2.10.4 LSDU computer/Lane monitor

a. Purpose – The Lane Status Display unit (LSDU) computer shall display real time lane data to the Control Room supervisor/manager.

b. Location – Toll Control Room. One at each Plaza

c. Function requirements- The LSDU or Lane Monitor is a desktop computer installed in the Plaza Toll Control Room (TCR). It displays real time lane data to the supervisor in the TCR.

The LSDU shall display the following in real time for each lane:

- Operator class
- Vehicle class
- Barrier gate status (open/close)
- Violation alarm status (visual and audio alarm in case of violation)
- Class wise vehicle count (shift start till current time)
- Traffic light status (Red/Green)
- OHLS status (Lane open / Close)
- Network break (visual and audio alarm)
- Equipment health check status (loop failure, AVC sensor failure etc.) – visual and audio alarm in case of failure

Technical specifications

- Computer
- Processor: Intel Core 2 Duo Processor E8400 (3GHz, 6M, 1333MHz front side bus)
- Operating System: Windows XP Pro
- Memory: 2GB, DDR2 Non-ECC SDRAM, 800MHz (2 DIMMS)
- Boot Hard Drive: 160GB SATA 3GB/s and 8MB Data Burst Cache
- Optical Storage Device: DVD+/-RW
- Ethernet
- Display – 17” TFT screen
- Mouse – wireless
- Application software – shall be

1. GUI based
2. Access controlled

13.2.10.5 Audit Workstation

a. Purpose – This computer performs two functions – performing audit as well as printing of reports.

b. Location – Toll Control Room. One at each Plaza

c. Requirements - Functional requirements

- Shall be used by the supervisor/APM/manager to resolve discrepancies
- All intercom calls and violation alarms are logged in it and have be resolved by end-of-shift
- It shall have an application software which shall have the following

  Shall be access controlled

  GUI based

  Shall pull required information from the PCS
- Shall present to the Supervisor/Manager the information on discrepancies along with the vehicle image. He should be able to sort the transactions by shift, time, class or any other user defined parameter.
- It shall print required reports on the Report Printer
- No report shall take more than one minute to print from the time of giving report generation request to the system operator

Technical specifications

- Same as LSDU

13.2.10.6 Cashup Workstation

a. Purpose – This computer shall be used by staff to cash-up the money collected in the shift. The staff may include toll collectors, supervisors, POS clerk or any other staff member accepting toll related money.

b. Location – Toll Control Room. One at each Plaza

c. Requirements- Functional requirements

- Shall be used by the plaza staff to cashup – declare collected money in system before physically depositing the same with the cashier.
- The number of cashup computers shall be sufficient to handle all relevant staff in a manner that the entire cashup operation for all staff does not take more than 5 minutes.
- It shall have an application software which shall have the following

  a) Shall be access controlled

  b) GUI based
- Shall pull required information from the PCS
- Shall present to the Supervisor/Manager the information on discrepancies along with the vehicle image. He should be able to sort the transactions by shift, time, class or any other user defined parameter.

- It shall print required reports on the Report Printer Technical specifications

  Same as LSDU

13.2.10.7 Printers

a. Purpose – Printers shall be used to print reports and/or receipts. Either a network printer or standalone printers may be used.

b. Location – Audit/report workstation, cashier, POS.

c. Requirements

- There shall be one network printer in the Toll Control Room for reports. The printer supplied shall be of the latest configuration at the time of installation.
- Alternately separate printers or a combination may be used as per convenience.

Technical specifications

The minimum specifications are as follows:

Print speed	:	up to 52ppm letter; up to 50 ppm A4
Speed	:	first page out < 9sec
Resolution	:	min 1200x1200 dpi

13.2.10.8 Intercom

a. Purpose

The intercom shall facilitate communication between the toll collector in the booth and supervisor in the Toll Control Room (TCR).

b. Location

- the intercom master - shall be located in the TCR and
- the slave units – one in each booth

c. Requirements

- The communication allowed shall be two way
- The slave unit in the booth shall operate in hands free mode i.e. it shall have a microphone and a loudspeaker.
- The slave unit shall have a push button feature to initiate or receive a call.
- The master stations shall have Push to talk function as well as with a Voice Operated Handset.
- The person at the master station shall be capable of observing the alarm and shall be able to speak hands free and any time can origin the call to any slave unit.
- Depressing the slave unit switch will activates an Intercom master unit and respective Booth shall illuminate an LED with ringer. The ringer will continue until the response at the master station. Under this situation, the master station operator will have the option of listen only to the Toll Collector.

- A power LED shall indicate incoming power to the master station. Compatible Toll booth locations shall include surface or flush mount styles, outdoor stations, and vandal proof stations (surface or flush mounted, indoor or outdoor models).
- The push/talk button in slave unit which can origin the call to the master unit.
- All slave unit/booth can be programmed so that the master unit can listen any voice conversation for the period of 5-90 seconds without any interruption and knowledge of toll operator. Meanwhile if there shall be call from any booth, can be attended simultaneously.
- The intercom system may or may not be integrated into the TCE. Integrated system is preferred.
- If it is integrated into the Toll Collection Equipment, all calls shall be logged in the system as events (including unanswered calls). The supervisor shall be required to enter the call purpose and action taken ("event close") in the application software at the audit/report workstation. The shift shall not close till all such events are closed.
- If it a standalone system, then all calls shall be recorded on in a voice logger for future reference. The logger must have sufficient memory to store one year of voice call data; must have provision for audio playback selectable by date and time and must allow for printing of logs.
- Operator should able to take from the distance of Max. 2 meter from slave unit.

13.2.10.9 Intercom Masters / Slaves System Case

- The Intercom masters / Slaves System case shall be encased in Steel housing with metal cabinet finished in powder coated grey texture, Sturdy & compact plastic body and M.S. with powder coated.
- The Intercom masters / Slaves System case shall be provided with flexible mounting with a single door and provide simple access for servicing intercom masters / Slaves System and wiring.
- The Intercom masters / Slaves System case and all components within shall be protected from moisture, rain, sun radiation, dust, dirt and salt corrosion found in a highway and coastline environment.
- The Intercom masters / Slaves System case shall be cleaned, treated with chemical conversion coating, or with a paint primer suitable to case material, and finished with two coats of prime quality enamel. Alternatively, anodized aluminum or electro statically applied powder coats acceptable. The finish shall be of prime quality substantially free of flow lines, paint washout, streaks, blisters and other defects that would impair serviceability or detract from the general appearance.

Audio

- The voice should be without any noise interruption, should be sound clear if slave distance from Mater is from 20 to 200 meter.

Mounting

- The Intercom Substations shall be wall mountable (internal to the building, internal to the toll booth and external to the toll booth) or desk mountable and the Master Stations shall be desk mountable.

Communication

- The system shall be capable of being connected using standard Category 5e or category 6, four pair UTP / 5 Core cable between the booth locations and the master station controller.
- Wiring distances of at least 500 meters shall be supported without any amplifiers or other active devices between the sub-station and the master station location.

13.2.10.10 Panic Alarm1

a. Purpose - The panic alarm system is used by the Toll Collector to discreetly alert the TCR of any incident in the lane e.g. a rowdy road user or a threat.

b. Location - The panic button is located in the toll booth in such a way that it is not visible from outside and the TC has easy access to it while performing his normal duties.

c. Requirements

Panic Alarm Master Station shall have selector button with associated LED indicators for toll booths.

At the Toll booth location, a foot switch shall be provided. Panic Alarm shall trigger by press of foot switch which shall be available close to toll operator's foot and hidden.

The person at the master station shall observe the alarm.

Pressing the foot switch shall activate an emergency buzzer in the plaza and shall illuminate an LED associated with the Panic Alarm System. The buzzer shall continue until the reset button is pressed manually to reset the alarm at the master station. The alarm shall automatically reset after few seconds (settable from 10-60s), if the master unit not reset manually. However, visual alarm shall continue(either LED shall continue to glow or the LSDU monitor shall continue to flash unanswered call message along with booth number).

- The panic alarm system shall be integrated into the toll software. The supervisor at the TCR shall be required to input his action in response to any event of panic alarm being pressed. The shift shall not close without this.
- Multiple booths generating panic alarm shall allow the system to place the alarms in queues (up to 6)
- There shall be two types of reset switches.
  - ❖ Reset switch corresponding to each booth LED/indicator.
  - ❖ Master reset switch.

13.2.10.11 Incident Capture System Cameras

a. Purpose - The purpose of the ICS is to record images of vehicles crossing the lane and link each image with a transaction. The ICS camera shall capture such images and sends the same to the TLC for processing. At the

Entry Lanes there shall be no incidents (as there is no AVC) and the camera shall only record image and link it to a transaction ID.

b. Location - One ICS camera is shall be installed per lane. The camera shall be connected to the TLC which shall process the image.

c. Requirements

- The camera shall be pole or booth mounted
- It shall capture clear picture of the vehicle during all light conditions.
- It shall capture still images which shall be watermarked with transaction ID and time information by the software.
- The housing shall be such that the camera shall work in toll conditions. It shall prevent unauthorized access, shall have heater and fan (if required) and sufficiently prevent water, dust and carbon particle ingress.
- The mounting shall be such that the possibility of it being hit by a vehicle is less.

13.2.10.12 Exit Lane Barrier / Automatic Lane Barrier (ALB)

a. Purpose - The purpose of the exit barrier is to control traffic at the toll lane.

b. Location - One ALB is installed in each toll lane after the pay axis. The location may be different for ETC.

c. Requirements

- It shall consist a housing installed on the island and a boom arm. The housing shall include the electronic control unit, motor and power supply.
- Boom arm length shall be sufficient to cover the width of the lane (including extra wide lane)
- Colour – Boom shall have red reflective stripes
- Boom Running Time shall be 0.9 s or less (open / close time)
- Manual Operation – There shall be provision to operate manually Up/Down by switch (which shall also be connected to the MBC).

13.2.10.13 Cash Drawer

a. Purpose - The cash drawer and tray shall be utilized by the toll collectors to store and dispense cash (bills and coins) during toll collection as well as transfer cash between toll booth and administration building.

b. Location - The cash drawer shall be mounted under the counter top in each toll booth for ease of access by the toll collectors.

c. Functional - The cash drawer shall consist of a manual drawer, removable tray, and lockable tray cover in order for toll collectors to store and dispense cash (bills and coins) during toll collection as well as transfer cash between toll booth and administration building).

- Material- The material for the cash drawer shall be rust proof and be made up of 16 and 18 gauge steel providing a durable metal chassis construction.
- Lock and Key -The cash drawer shall have a lock for maximum security. The lock position shall be controlled by a key. The key shall be required

to be fitted to the key lock in order to have the cash drawer in locked, open or controlled position.

- Screws and Bolts-For additional security there shall be no screws or bolts to be accessed from outside the cash drawer.
- Tray - The cash drawer shall contain one tray with bill slots suitable for use with Indian currency.
- Slots-The cash tray shall contain a minimum of 5 coins and 5 bills (adjustable) slots.
- High Impact Plastic- The cash tray shall be made of high impact polystyrene plastic or ABS thermoplastic
- Water Proof - The cash tray cover shall protect from water ingress.

13.2.10.14 Mounting

- The Cash Drawer shall be mounted under the counter top in each toll booth for ease of access by the toll collectors.
- The mounting rails and brackets required for installation under the toll counter shall be provided.
- The slides for the cash till shall have a dual raceway steel ball bearing or similar quality providing easy slide and longevity.

13.2.10.15 Customized Keyboard

a. Purpose - The customized keyboard inputs information punched by the TC into the TLC. It has specials keys made specific to toll operator's requirement so that the tolling operation is faster and easier. Alternately, the Concessionaire may use a touchscreen terminal instead of a hardware keyboard.

b. Location - Key board shall be placed at toll operator desk for the purpose of transaction/toll collection and to active all device.

c. Requirements - The keyboard shall be made of robust material to withstand heavy usage and an external environment where there is heavy traffic propagating exhaust and dust.

Keys

- The keyboard shall have keys printed with characters of the English (US) alphabet, which will be mapped to specific keys through software.
- All keys shall be fully programmable
- Key shall programmed in matrix format and have the alphabets and number (0-9).
- It shall have direct access keys sufficient to cater to the needs of the Toll Collector including separate keys for each MOP, journey type, vehicle class, print receipt, cancel transaction , alphanumeric keys (for login/password) etc.

External Port – There shall be at least one external keyboard port for programming key codes and connecting with another keyboard compatible device.

Performance requirement

- The keyboard shall have a minimum Mean Time between Failures (MTBF) of 100,000 hours.
- The keyboard shall have a key switch reliability of minimum fifty (50) million operations.

13.2.10.16 Toll Lane Computer (TLC)

a. Purpose - The purpose of the TLC is to store lane data, collect data from AVC controller, interchange data with PCS and control all lane peripheral devices.

b. Location - One TLC shall be provided per lane and shall be located in the tunnel.

c. Requirements - The Toll Lane Computer shall be an industrial grade rugged PC, located in the Toll booth to locally process and record toll transactions, provide a control or feedback interface to all other lane control equipment and provide communications with the Toll Plaza Server via the Local Area Network.

The hardware provided shall be latest at the time of procurement. However, the following are the minimum requirements:

• Processor	-	Core 2 Duo 2.2 GHz/800 FSB (2 MB Cache)
• System Chipset	-	Intel
• Digital I/O	-	8 bit digital I/O
• RAM	-	1GB RAM, Expendable up to 4 GB
• Ports	-	2 X RS 232, 1 X VGA, 4 X USB ports, 2 PS/
• Serial Ports	-	12X EIA- 232 asynchronous capable of up to 38.4K (with external connector box, 25 pin DTE male connectors)
• Digital I/O	-	Adapter Card with 24 digital I/O lines and cable
• Operating System	-	Windows XP Professional or equivalent.
• Hard Drive	-	1 X 100 GB SATA HDD
• CD-ROM	-	None
• Dual Network Interface Card	-	10/100 Mbps NIC PCI interface
• Chassis	-	Ruggedized with protection against ingress of dust and against water with an IP65 and protection against condensation, industrial grade wall mount.

Communications - The Toll Lane Computer shall have dual Local Area Network Interface Cards. It shall communicate with the Toll Plaza Server via fiber optic cable (using a media converter) or Cat-6 cable. The two media converters per toll lane computer shall be supplied.

13.2.10.17 AVC Controller

a. Purpose - The purpose of the AVC controller is to gather information from the AVC sensors and generate vehicle class data.

b. Location - There shall be one AVC controller per lane installed in the tunnel

c. Requirements - The AVC controller hardware shall be mounted in an AVC cabinet. The controller shall be an industrial grade rugged computer. One output of the AVC controller shall be inputted to the TLC. Another parallel stream of data shall go to the IDB server.

The hardware provided shall be latest at the time of procurement. However, the following are the minimum requirements:

Processor	-	Dual Core 3.2 GHz (2 X 2M 800FSB
RAM	-	1GB RAM
Video	-	Graphics Video Adapter
Ports	-	2 X RS 232, 1 X VGA, 2 X USB ports
Serial Ports	-	12X EIA- 232 asynchronous capable of up to 38.4K (with external connector box, 25 pin DTE male connectors)
Digital I/O cable	-	Adapter Card with 24 digital I/O lines and
Operating System	-	Windows XP Professional or equivalent
Hard Drive	-	1 X 100 GB SATA HDD
CD-ROM	-	None
Dual Network Interface Card	-	10/100 Mbps NIC PCI interface
Chassis	-	Ruggedized with protection against ingress of dust and against water with an IP54 and protection against condensation, industrial grade wall mount. It shall have passive backplane with 3 PCI and 3 ISA slots

Communications - The Lane Controllers shall have dual Local Area Network Interface Cards. It shall communicate with the Toll Plaza Server via fiber optic cable using a media converter. The two media converters per toll lane controller shall be supplied.

13.2.10.18 Loop Cable and Sealant

a. Purpose - These specifications of the loop cable and loop sealant are designed for the application of inductive loop installation. The purpose of the loop installation is to detect vehicle presence in toll lane for vehicle audit, barrier gate operation, camera activation or lane control signal.

b. Location - Each toll lane (in-road)

c. Technical

d. Loop Cable

- Wire Gauge - 14 AWG, 16 Strand Copper Wire
- Insulation - Insulation of XLPE (Cross Linked Polyethylene), the insulation has a high

resistance to water, heat, abrasions, oils and gasoline.

- Voltage Rating - 1100 V
- Conductor Maximum Resistance and Inductance -4.81ohms/1000ft. Resistance and 0.22 μ H per feet Inductance
- Insulation Resistance - 1500 mega ohms for 1000 ft.
- Insulation Wall Thickness - 0.03125 in
- Temperature- - 10 to 160 ° C
- Conductor Elongation - 15 %
- Insulation Elongation - 250 %
- Splicing in Cable - There shall be no splicing in cable up to 90 meter.

e. Loop Sealant

- Curing Time - 10 Hours
- Color - Recommended Black
- Insulation/Resist - Water / liquid after curing
- Depth of Stability - The compositions should stable in 40mm deepand6 mm wide groove and make composite with road material (bitumen/rigid).
- Performance requirement - The minimum life of loop should min. 10 years. No effect of temperature/ environment on loop cable, if not installed.

13.2.10.19 Barcode Scanner

a. Purpose - The barcode reader shall be used to scan unique identification barcodes imprinted on media such as paper and plastic medium such as smart cards etc. The barcode reader shall be used for several applications within the toll operations: toll collector activities in the toll booth, customer service activities in the customer service center, toll collector and supervisory activities within the administration building (if required).For this purpose the barcode reader shall interface with and be controlled by a Toll Lane Controller. The barcode reader shall have automatic scanning operation with custom configurable scan patterns

b. Location - One bar code scanner in each exit lane shall be provided.

c. Requirements - Coding and Decoding Capability- Barcode reader shall be able to read thermal, laser and color barcodes and decode all standard bar codes, including at least bar code 128 with 24 digit Code Length (and preferably 1D, RSS 14, RSS Limited and Expanded RSS).

Scanner State and Status LED and Beep

- The barcode reader shall be equipped with easily visible LEDs that indicate the scanner's state and the status (e.g. "Good Read") of the current scan when the unit is in operation.
- The barcode reader shall have an audible beep that indicates the status of the current scan when the unit is in operation.

- The barcode reader shall have the function to configure the audible beep enable and disable.

Barcode Reader Case

- The barcode reader shall be a compact hand held design with a firm grip for repeated use.
- The barcode reader shall have a rugged protective boot with an adjustable stand and be mounted to a countertop, wall or be left free standing for handheld scanning.
- High impact ABS plastic with rubber end piece.

Light Source

Light source for the barcode reader shall be Charged Coupled Device (CCD) Red Led Array or Laser.

Scanning Distance/Range

The scanning distance (depth of field) of the barcode reader shall be at least in the range of 25 mm to 275mm for low density barcode labels (5 mils).

- The barcode reader scan pattern shall be a single scan line.
- Depth of Field: 0.25mm(10mils) ~ 50 mm(2 inch)

Scanning Capability

Scan Repetition Rate	:	100 ± 10 scans/second
Window Length	:	75 mm (2.95 inch)
Reading Angle	**:**	10 degrees forward to 30 degrees backward

Communication/Interface

- The barcode reader shall have a PC keyboard wedge interface, RS232, USB, Undecided, Wand Emulation, and Synapse interface.
- All cabling shall be able to cover a minimum length of 8 m without signal loss or the introduction of undue noise/ interference. Cable length shall be confirmed with GPPL or its representative before order is placed.

Power Consumption - The barcode reader shall have a power transformer that is compliant to operating voltage of 230V, 50 Hz AC power, or have the possibility to be powered through the RS232/USB interface.

- Power Requirements Decoded **:** 5 VDC + / - 10%
- MTBF : The barcode reader Mean Time between Failure (MTBF) shall not be less than 100,000hours.
- Bar Code Formats : Code 39, Interleaved 2 of 5, Industrial 2 of 5,Matrix 2 of 5, Coda bar, EAN-13, UPC-A,EAN-8, UPC-E,EAN/UPC Add-on2/5, Code 128, Code11, MSI/Plessey, Telepen, China Postal Code, Code 93, Laetus Pham code.
- Design Life : 10 Years.

13.2.10.20 Fog Light

a. Purpose - A fog light is a lighting device that enhances visibility in conditions of fog, rain, or dust.

b. Location - One fog light shall be installed in each lane on the bull nose.

c. Requirements - The fog light shall be mounted on the rampart located upstream end of the concrete toll island. The Fog light shall have the inner amber LED core and outer white LED core/ring. The amber LED shall glow always and the outer white LED shall flash at specified frequency.

Size of lens - 200mm diameter

Luminance Intensity (Candela Density) - 8000 mcd.

Frequency - 20/30 cycle per minutes (adjustable)

Visibility - 100 meter under extreme fog condition

Display Module

- The LEDs used in the display module shall meet the nominal wavelength of 590 nm (amber color).
- The color of the pixels shall be uniform.
- The fog light shall provide the option of operating as a flasher with a configurable flash rate.
- The fog light shall be highly visible within a 20 degree cone centered about the optical axis.
- The individual LEDs shall be assemble such that a loss or the failure of one LED will not result in the loss any other LED.
- All components within shall be protected from moisture, rain, sun radiation, dust, dirt and salt corrosion found in a highway and coastline environment. Recommended that all the LED should be assembled on green oriented PCB (Glass epoxy). Soldering should be clean and without dryness and insulated.
- Conformal coating of acrylic or silicon on component solder side to protect from moisture and dryness and salt corrosion, dust etc..
- The fog light shall have auto dim feature. The photo sensors on the fog light shall be located so as to account for various directions of shade/ shadow/brightness requiring changes in the luminosity level during the 24 hour operation.

Fog Light Face Plate

- A black border of at least 50mm width shall be provided on all sides of the light “LEDs”. LEDs assembling process shall start from 50mm distance of the border of lens.
- The LED area of the sign face shall be protected by weather tight, non-glare polycarbonate sheet.
- The polycarbonate sheet(s) shall be securely mounted to the front face of the sign.
- Input Voltage Range:90-270 VAC, 45- 60 Hz

Power Supply - Power supply shall be with high surge suppression and all the components should be assembled with conformal coating on component solder side to protect from moisture and dryness and salt corrosion.

Operation Life-100,000 Hours for the LEDs

Fog Light Case

- The fog light case shall be encased in ABS housing. The LED and all components within shall be protected from moisture, rain, sun radiation, dust, dirt and salt corrosion found in a highway and coastline environment.
- The finish shall be of prime quality substantially free of flow lines, paint washout, streaks, blisters and other defects that would impair serviceability or detract from the general appearance. Colour shall be grey on all exterior surfaces except for the front face. All visible surfaces on the front face shall be entirely matt black.
- Any wiring running between the service access door and the main housing shall be designed so that repeated flexing does not damage the conductors. Cables shall be neatly trained, secured and protected to prevent abrasion of the insulation. The fog light housing, including service access door, shall be electrically grounded
- The fog light shall be supplied with provisions to support mounting on the concrete rampart at the upstream end of the concrete toll island. All fasteners and mounting hardware shall be stainless steel.
- Lens - The lens protecting the LED face shall be constructed of stabilized polycarbonate and hard coated for abrasion resistance.
- Performance requirement
- The units shall be designed such that the decrease in luminous intensity of any LED pixel under 24 hour continuous operation shall not exceed 30% after one year and 40% after five years.
- All components shall be capable of withstanding the extreme environmental conditions as specified above. The design shall be inherently temperature compensated to prevent abnormal operation. Circuit designs shall include compensation as is necessary to overcome adverse effects due to temperature in the specified environmental range.
- The lifespan of the equipment shall be a minimum of five (5) years without maintenance or servicing.
- The Fog light housing shall be a minimum IP65 rated.

13.2.10.21 Over Head Lane Sign (OHLS)

a. Purpose - The purpose of the OHLS is to indicate to the User whether the toll lane is open for the processing of vehicle or closed. Red full round shall be used to signal that the lane is closed, whilst a green Full Round shall be used to indicate that the lane is open to traffic.

b. Location - The Over Head Lane Sign (OHLS) is located on the leading edge of the canopy covering the toll lanes above the center of the lane

c. Requirements - There shall be two full round lights; one of Green colour and one of Red colour.

- Signs are sufficiently bright and directed to indicate to a motorist, approaching the toll plaza, at a distance of 300 m on a bright cloud free day that the lane is available for use.
- Size of lens-300 mm, flat for both green and red symbol
- Luminance Intensity (Candela Density)-600 CD.

Display Module - The LEDs used in the display modules shall meet the following nominal wavelengths:

- 630 nanometers (red color); and
- 526 nanometers (green color)
- The color of the pixels shall be uniform to ensure there is no degradation of the open and closed symbols when they are lit up.
- The display module assemblies shall be secured to sustain the shock and vibration that exists in highway condition.
- The individual LEDs shall be assemble such that a loss or the failure of one LED will not result in the loss of any other LED.
- The LED pixels shall be suitably housed for proper heat dissipation.
- All components within shall be protected from moisture, rain, sun radiation, dust, dirt and salt corrosion found in a highway and coastline environment. Recommended that all the LED should assemble on green oriented PCB (glass epoxy coated).

Input Voltage Range-120V (80~135V) / 220V (180~250V).Power supply shall be with high surge suppressions and both side of PCB should be glass epoxy coated to protect from moisture, dryness and salt corrosion.

Dimming Function- "Yes". OHLS shall have at least two (2) stage dimming control to reduce the glare of the display and maintain a sharp image.

Operation Life-70,000 to 100,000 Hours

The OHLS case shall be ABS.

- External mounting assemblies including clamps and brackets shall be high strength aluminum alloy. All fasteners and mounting hardware shall be stainless steel. Mounting brackets, associated cables and all relevant equipment necessary for installation on the canopy façade.
- Lens shall be made by polycarbonate material and shall be transparent.
- The units shall be designed such that the decrease in luminous intensity of any LED pixel under 24 hour continuous operation shall not exceed 30% after one year and 40% after five years.
- The OHLS housing shall be a minimum IP65 rated.

13.2.10.22 Smart Card Reader and Smart Cards

a. Purpose - The purpose of the Smart card Reader is to read the information encoded inside a smart card and output it to the connected computer for further processing. The SCR an the POS shall also be used to write information on the smart card. The smart cards are used on the Expressway as a prepaid method of payment of toll fees.

b. Location - The Smart Card Reader shall be placed in the customer service centre and on the counter within each toll booth or mounted outside the toll booth for processing toll transactions with contact less smart cards.

c. Requirements - The Reader shall interface with the TLC.

- The Reader shall comply with ISO/IEC 14443 Type A 13.56 MHz
- Read/Write Range-The Reader shall have operating card read/write range from 0 to 150 mm.
- Security Keys-The Reader shall be able store at least 16 security keys for support of 16 independent secure smart card applications.
- Card Acceptance Indication-The Reader shall have built in buzzer for audio indication and LED for visual indication of card acceptance/rejection.
- Power Consumption-Maximum 20 W
- Power Supply-The power supply to the Reader shall be 230V, 50Hz.The Reader shall also provide the option to be powered through the RS232 interface.
- Operation Life-400,000 MTBF, Service and Design life 10 Years
- Smart Card Reader Case/Mounting-The Reader shall be provided for indoor and outdoor use. The Indoor Reader shall be desk mountable.
- The Reader shall be IP65 compliant.

Smart Card

- Form factor shall be Standard Credit Card size (86mm x 54mm)
- Material shall be PVC

The smart card shall carry the following minimum printed information:

- Emergency helpline numbers
- NHAI logo
- Unique serial number – this shall be embossed on the card

13.2.10.23 Thermal Printer

a. Purpose - The thermal printers shall be installed at pay axis of toll booth and used to dispense receipts of toll payments to road user.

b. Location - At each toll booth and optionally at POS for printing receipts (POS alternately may have a laser printer).

c. Functional - The receipt printer shall interface with and be controlled by a Toll Lane Controller

c. Technology - The receipt printer shall use thermal fixed head technology to print receipts.

- Method-Direct Thermal
- Printer shall have “paper low” indication
- Printing Speed-150mm/sec
- Dot Intensity- Min. 180x180

- Effective Printing Width- Min. 72mm, 512 Dots
- Dot Pitch - 0.141x0.141
- Output Capacity- The printers shall be designed for a monthly duty cycle of up to 60,000 pages, have at least two paper trays, a total input capacity of 350 sheets, expandable to 600, and an output capacity of 250 sheets.

i. Paper

Type	:	Thermal paper
Width	:	50 - 82.5mm
Thickness	:	0.06 ~ 0.09mm

ii. Reliability

TPH	:	Life 100Km
MCBF	:	50,000,000Lines

iii. Data Buffer : Min. 4 kb

iv. Auto Cutter

Life	:	1,000,000 cuts
Cutting Method	:	Full/Partial

v. Performance requirements

- The receipt printer shall have a Mean Time between Failure (MTBF) of at least 360,000 hours.
- The receipt printer head shall have a Mean Cycle between Failure (MCBF) of at least 50 million print lines.
- The auto cutter shall have a reliability of at least 1.0 million cuts.

13.2.10.24 Traffic Light

a. Purpose - The purpose of a traffic light is to indicate to the road user at the pay axis that he can now proceed to exit the lane. The traffic light consists

b. Location - One traffic light is installed (pole mounted) in each lane after the pay axis.

c. Functional - There shall be two full round lights (red and Green) mounted on single pole with Red on the top.

- The lights shall be LED based.
- Size of lens-200mm diameter , convex for both Green and red lights
- Luminance Intensity (Candela Density)-The luminous intensity of Green and Red light shall be 200-300 CD. All signs shall be clearly visible at a minimum distance of min. 10m from the sign, under ambient lighting conditions ranging from direct sunlight on the display face to complete darkness and under all weather conditions.

Display Module

- The LEDs used in the display modules shall meet the following nominal wavelengths:630 nanometers (red color); and 526 nanometers (green color)
- The display module assemblies shall be secured to sustain the shock and vibration that exists in highway condition.

- The individual LEDs shall be assemble such that a loss or the failure of one LED will not result in the loss any other LED.
- The LED pixels shall be suitably housed for proper heat dissipation.
- The LED area of the sign face shall be protected by weather tight, non-glare transparent polycarbonate sheet
- Power Consumption-Maximum 6W
- Power Supply-Power supply shall be with high surge suppression and all the components should be assembled with conformal coating on component solder side to protect from moisture and dryness and salt corrosion.
- Dimming Function-The traffic light/lane control signal shall have at least two (2) stage dimming control to reduce the glare of the display and maintain a sharp image.
- Operation Life-70,000 to 100,000 Hours for the LEDs
- Mounting-External mounting assemblies including clamps and brackets shall be high strength aluminum alloy. All fasteners and mounting hardware shall be stainless steel which should be easily mountable on pole.
- Communication-The desired symbol shall be displayed by direct switching of 230 VAC / 50 Hz power to the device by the Toll Lane Controller.
- Lens-Lens should be made by polycarbonate material and should be transparent.
- Pole
  - Height : 300 cm
  - Diameter : 10cm
  - Material : MS painted
  - Type : Hollow
  - Base plate for fixing : 4 earthling bolts
  - Color : Black
  - The finish shall be of prime quality substantially free of flow lines, paint washout, streaks, blisters and other defects that would impair serviceability or detract from the general appearance.

Performance requirement

- The units shall be designed such that the decrease in luminous intensity of any LED pixel under 24 hour continuous operation shall not exceed 30% after one year and 40% after five years.
- All components shall be capable of withstanding the extreme environmental conditions as specified above. The design shall be inherently temperature compensated to prevent abnormal operation. Circuit designs shall include compensation as is necessary to overcome adverse effects due to temperature in the specified environmental range.
- The traffic light shall have Mean Time between Failure (MTBF) of at least 100,000 hours.

13.2.10.25 UPS

a. Purpose -UPS (Uninterrupted Power Supply) being used at Toll plazas to support as a power back, surge protected synchronize power supply to all equipment.

b. Location - Central UPS for all toll equipment shall be provided in the UPS (and battery) room in the toll plaza building.

c. Functional - A central UPS shall be provided with redundancy option. This means that there shall be two UPS with separate battery banks working in redundant mode. Both shall work on 50% load sharing basis. In case one fails, then the other shall be able to take up the entire load. The power backup shall be 30 minutes on full load. The redundant UPS provided shall be dedicated for TCE only. Equipment other than TCE shall have separate standalone UPSs

UPS Technology

- On Line
- Corrects for frequency variations without switching to battery, resulting in longer battery life.
- Provides compatibility with backup generator — handles frequency variations and other power fluctuations that occur during generator operation.
- Allows selection of UPS features including input voltage, output voltage, auto-restart enable/disable, and other parameters.
- Assures continuity of power to critical loads during system maintenance or in case of internal fault with internal automatic and manual bypass.
  - Min. Back up : 30 Minutes on full load
  - Battery : User Replaceable battery
  - Output wave form on battery : Sine wave
  - Charging Time : Max. 5 hours 95%
  - Output Voltage : 220V AC
  - Communication : RS 232/ SNMP, Multilink software and Serial
  - Life of UPS : 10 years

13.2.10.26 POS Computer

a. Purpose – The purpose of the POS computer is to issue and recharge smart cards and ETC tags.

b. Location - The POS computer shall be located in the POS room.

c. Requirements – same as LSDU computer

13.2.10.27 LAN and Network Switches

a. Purpose – The purpose of LAN is to connect Ethernet devices through network switches and LAN cables.

b. Location - The network switches shall be located in suitable mounted in racks either in the toll plaza building or tunnel area. The term network switch includes switch, router, hub or any other device for connecting Ethernet devices and distributing network traffic.

c. Requirements -

- The LAN shall work on optic fiber or CAT6 cables.
- Connectivity – Ethernet
- Data transfer speed and interface type
  - 10/100/1000 Mbps Ethernet port with RJ-45 connector
  - 100/1000 Mbps Ethernet port with SFP connector
  - 10 Gbps Ethernet port with XFP connector
  - Power supply – hot swappable, redundant
  - Hot swappable SFP/XFP transceivers and fan tray
  - Rack mounted

13.2.10.28 ETC Equipment

a. Purpose -The purpose of ETC equipment is to facilitate free flow of traffic. It shall consist of transponder, tag, computer with software, tag recharge equipment.

b. Location - The transponders shall be located in ETC lane. The ETC lane computer shall be located in ETC booth. Tags shall be stuck on the vehicle windshield. Tag recharge equipment shall be at the POS.

c. Requirements -

- The lane transponder shall be able to read the tag from a minimum 10m distance at expressway speeds.
- The lane transponder shall not read tags on vehicles in adjacent lanes
- The frequencies shall not interfere with cellphone frequencies
- ETC shall be IS018000-C RFID based as per NHAI guidelines.

13.2.10.29 AVC Sensors

a. Purpose - The purpose of AVC sensors is to generate outputs during vehicle passage which are then processed by toll software to identify vehicle class.

b. Location - The AVC sensors shall be located in the lane after the pay axis. The sensors may be non- intrusive or buried in the road.

c. Requirements - The sensors may be of any of the following

- **Loop** – This type of sensor is buried in road and is used to detect presence of metal over it.
- **Pressure sensor** – resistive or optic. These are in-road sensors which prove a contact output (on/off) as a vehicle axle passes over it.
- **Light based** – laser or infra-red where vehicle cuts the light beams to record vehicle parameters (like length, axle spacing) or generate a vehicle profile. These are non-intrusive sensors.
- **Radio** – overhead radio scanners measure vehicle parameters by comparing transmitted and reflective radio wave.
- **Video/image** – These capture a video or image of the vehicle and classify it by eliminating background and then measuring pixels of the vehicle image.

- Although loop and pressure sensors are recommended, any other sensor type of proven technology as long as the accuracy parameters are met.

The AVC scheme shall be post classification

- The AVC sensors may be non- intrusive or buried in the road.
- The sensors are connected to the AVC controller
- Sensors shall be suitable for all lane types (stop-and-go traffic for Standard Lanes as well as for ETC lanes and extra wide lanes)

The AVC sensors shall generate output in a way that the following parameters are met, after being processed by toll software:

- Count accuracy : min 99.9%
- Class accuracy (@95% confidence level) :
  - Class 1 (Car/Jeep): >98%
  - Class 2 (LCV/Minibus) : > 95%
  - Class 3 (Truck/bus) : >99%
  - Class 4 (3-6axle truck) : >99.5%
  - Class 5 (>6 axles) : >99.5%
- The sensors shall count axles.
- The sensors shall not obstruct any vehicle.

13.2.10.30 Manual Booth Controller (MBC)

a. Purpose - The purpose of the MBC is to control three peripheral devices - barrier gate, traffic light and OHLS when the system is in manual mode (equipment not working)

b. Location - One MBC shall be located in each booth

c. Requirements -

- The MBC shall be lockable. The keys shall be with Plaza Manager/supervisor.
- The MBC shall directly connect to the said peripherals in case the system shuts down.
- MBC shall have three buttons to cover each operation
  i. Barrier gate – open and close function
  ii. Traffic light – green and red
  iii. OHLS – green and red

13.2.10.31 Manual Lane Barrier (MLB)

a. Purpose - The purpose of the MLB is to act as a physical barrier in a closed lane so that no vehicle enters the lane.

b. Location - One MLB is installed in each lane on the island just after the bull nose and as close to lane entry as possible.

c. Requirements - The boom shall be mechanical type boom and able to be positively locked in either open or closed position.

- The boom shall open horizontally. Care should be taken to install the barrier in such a manner that it does not touch any other equipment, booth or canopy column when fully open.
- The barrier arms shall rotate horizontally through 90 degrees and lock into position. Limit Switches are positioned at both the end to sense the open / close position of the Manual Entry barrier.
- Boom arm shall be made of aluminum and covered with red color reflective tapes of 75mm
- Barrier arm length shall be 3.5m for normal lanes and5.5m for extra wide lanes.
- The Lane entry boom shall be securely mounted using galvanized 12 mm chemical anchor bolts.
- Colour - White arm with red color reflective tapes/bands of a width no smaller than 75mm equally spaced along the boom
- A female connector with suitable lock shall be been provided to retain the barrier not to move in a fully open and fully closed condition.

13.2.10.32 WAN

a. Purpose - The purpose of the Wide Area Network (WAN) is to provide communication link between all plaza computers and Central Server.

b. Location - Plaza and route

c. Requirements - There shall be two backbones for data exchange – wireless and optic fiber

The OFC backbone shall be the same that carries ATMS data.

- A dedicated radio backbone (VSAT) shall be made available between the nodes.
- OFC shall be the primary backbone. In case of OFC backbone failure, the radio shall takeover automatically without any loss of data.
- The uptime of both backbones together shall be at least 99.999%.
- Each of the two networks shall have inbuilt redundancies. The OFC shall work even if one cable is cut. The wireless network shall be in form of a mesh and shall work in such a way that even if one link breaks, the system shall work (perhaps at reduced throughput).

Software (application, database and operating)

a. Purpose - The purpose of the software shall be data storage , computing and monitoring as well as interface. All computers shall be loaded with Operating Software (OS) to run the computer. Database software shall be provided to store toll data. Application software shall be provided in relevant computers to manage toll data and to interface with user.

b. Location - The software's shall be installed in relevant computers

c. Requirements -

- All software shall be valid for unlimited use for this project.
- All software shall be supplied with media license.

- Database shall
- Be of RDBMS type.
- Protect from server failure, site failure and human error
- Secure data and enable compliance with unique row-level security, fine-grained auditing, transparent data encryption, and total recall of data
- Shall be fast, have high-performance data warehousing, online analytic processing, and data mining.
- The OS shall be
- Real time
- Multi user
- Multi-tasking

The application software provided shall GUI based and shall be able to carry out all toll related activities including:

- Lane activities
- LSDU activities
- POS activities
- Cashier and cashup (operator clearance) activities
- Incident handling
- Report generation
- Event and exception handling
- Maintenance activities

13.2.10.33 Power - Diesel Generator

a. **Purpose** - The purpose of the DG is to provided power backup during power outages

b. **Location** - Toll plaza

c. **Requirements** –

- DG sets shall be provided as a backup power source wherever electricity from State Electricity Boards (SEB) is being used as a primary source. In other places, it shall be used as a primary source. DGs shall not be required wherever sufficient alternate power is available (like solar power).
- Use of sources of clean energy, like solar energy is appreciated, wherever possible.
- The power output of a DG (rating) shall be adequate to run intended equipment.
- It is recommended that the DGs shall be installed in pairs in areas of high power outages or no SEB power, during operation hours. This is because a DG is not recommended to run continuously for 6-8 hours.
- Toll plazas shall have DGs of different ratings to cater to day and night time demand.

- The outdoor DGs shall be of silent type or located in DG rooms so that its exhaust is away from staff and road users
- All DGs shall be self-start type.
- The maintenance waste and spillage from DGs (oil, soiled cloth etc.) shall be appropriately disposed as per law.

13.2.10.34 Plaza, Lane &Booth Area - CCTV Surveillance Cameras

a. Purpose - The purpose of such cameras is to have a monitoring of all sensitive plaza areas. This shall be a stand-alone system and not integrated with the toll collection equipment.

b. Location - The cameras shall be placed at least in the following areas: Each area where cash transaction or movement takes place e.g.

- Exit booth,
- cashup area,
- cashier,
- tunnel,
- vault

Each area where incidents can occur

DG room - Pole or canopy mounted PTZ cameras for overall plaza monitoring. Any other area deemed appropriate by Operator

c. Requirements –

- The cameras shall be able to work in low light conditions
- The cameras shall be able to be viewed on monitor by any authorized person (password controlled access).
- All camera images shall be recorded on a DVR (or dedicated PC)
- The recording capability of a DVR shall be at least 3 days of continuous recording.
- The recording shall be backed up regularly on appropriate media so that all video is backed up. Backup shall be produced to NHAI whenever requested.
- The viewing monitors shall be at least 17” wide.
- A joystick shall be provided to the person monitoring the video. It shall be possible to monitor up to 6 camera feeds on one screen. It shall also be possible to zoom any of these images by the joystick.
- One person shall monitor up to 6 cameras.
- Video shall be preferably transmitted uncompressed (from camera). If Ethernet cameras are used, it shall be on a separate LAN and not on the LAN used for toll collection equipment.

13.2.10.35 Intercom – Connect all Plaza Rooms

a. Purpose - The purpose of an intercom system is to connect all rooms in the toll plaza with each other. It may also be used for interconnecting plazas (if not provided as part of ATMS)

b. Location - Toll plaza building

c. Requirements - Intercom system shall be digital EPABX type.

- It shall consist of internal (station) and trunk lines.
- Appropriate number of telephones shall be installed.
- It shall be possible to print call reports.
- Emergency numbers shall not be routed through this system.

13.2.10.36 Walkie-Talkie – Connect Lane Staff to Plaza

a. Purpose - The purpose of having a walkie-talkie system at each toll plaza is to facilitate faster communication between lane staff (lane assistants, security guards) and toll plaza (control room, plaza manager)

b. Location - The walkie-talkie sets are hand held.

c. Requirements –

- The walkie-talkie sets are provided to all persons required to manage incidents.
- There shall be a charging station in the plaza building where the user shall be able to charge batteries.
- There shall be one battery charger for every two sets.

The frequency use shall be in compliance with WPC guidelines.

- The frequency used shall be different form the frequencies used for route operations (see chapter on ATMS)
- The system shall have one-to-all feature.
- This system shall be independent from TCE and shall not interfere with its operation.

13.2.10.37 Access Control Equipment

a. Purpose - The purpose of electronic access control equipment is to manage access of personnel in toll plaza areas.

b. Location - Toll plaza rooms, computer in TCR or ITS room

c. Requirements -

- The system shall include magnetic lock, identification reader and computer with software.
- Identification shall be smart card or biometrics based.
- Access to the IDB server room shall be restricted to NHAI personnel or any other person authorized by it.

13.2.10.38 Battery Operated Clocks

a. Purpose - The purpose of such clocks is to indicate time to toll collectors when all systems are down. This shall help them in issuing time based passes in manual mode.

b. Location - One such clock shall be located in each toll booth

c. Requirements -

- The clock shall be preferably digital type.

- It shall be located so that the TC can view it easily without interrupting his normal activities.
- It shall be calibrated at least once a week with the system time (time displayed by TCE on TLC monitor)
- All TCs shall be required to follow this time for issue of any time based pass in manual mode.

13.2.10.39 Fire Extinguishers

a. Purpose - Purpose of fire extinguishers is to douse fire.

b. Location - Fire extinguishers shall be located in any area deemed appropriate by Operator or recommended by NHAI but should be placed in at least the following areas:

- One in each toll booth
- One in every alternate lane
- Tunnel
- Toll plaza building – at least 3 per floor
- DG room
- All vehicles

c. Functional

- The fire extinguishers shall be of appropriate size and weight
- They shall be of ABC type
- It shall have a pressure indicator.

13.3 TOLL OPERATIONS

13.3.1 Toll Plaza Organisation and Staff

The principal function of Toll Operations is to perform the duties of accurate vehicle classification, toll collection, money handling, reporting, public relations and other tasks in such a way that passage by the user through the Toll Plaza is achieved in an efficient manner.

Each Operator/Concessionaire may deploy staff at his discretion and method of working so as to manage the operations in most efficient manner. The following is a broad guideline of the Toll Plaza hierarchy and functioning which the Operator may follow as a minimum:

13.3.2 Head Office

This is the higher most level of a Toll operation function. This level collects and compiles all necessary data from different plaza like traffic, revenue, sales, maintenance etc. on a periodic basis.

13.3.3 Public Relations Officer

Each Plaza shall have a person designated as a Public Relations Officer (PRO).The key functions of this level are

- Customer grievance handling,
- Managing feedback and suggestions

- To enhance revenue generation through sales of Smart Card, user awareness etc. (if possible)
- He may also be authorized for interaction with the press / news agencies.

13.3.4 Toll Plaza Manager

This is the higher most level of a toll plaza for toll operations and generally reports to General Manager or directly to Head Office.

Key functions of this level are:

a. To report head office about all toll operations - collection, traffic, sales, revenue, income, stock level, maintenance function, incidents, accidents etc. on a periodic basis.

b. At plaza level his/her responsibilities are to maintain manning level, preparing roaster, formats, handling user, plaza inspection, revenue leakage control by surprise checks etc.

13.3.5 Shift incharge/Assistant Plaza Manager (APM)

Reporting manager for Shift Incharge is Toll Plaza Manager. The Shift incharge acts as the Plaza Manager in shifts

The Shift Incharge is responsible for the traffic management, running the toll collection process during an allocated shift.

Shift Incharge Duties

a) To be completely familiar with all contractual requirements relating to toll collection.

b) To be completely familiar with all aspects of toll collection including computer systems (TCE).

c) To supervise the toll collection function, organise and control the duties of the toll collectors, toll cashier and lane incharge and be responsible for receipts transferred to the control of the shift incharge and the handling of these receipts in accordance with the prescribed procedure.

d) To ensure all reportable incidents are recorded and responded to as required.

e) To manage any abnormal incidents to the best of their abilities and sound judgment.

f) To complete the prescribed forms accurately and correctly during the shift and ensure that all the forms are filed for the administrative staff and in the correct order for further processing.

g) Sign responsibility for the completed shift and communicate information that requires further attention.

h) To perform regular checks on all equipment.

i) To ensure that security is maintained and that the security subcontract staff operates as required.

13.3.6 Lane Incharge/Supervisor/ Lane Assistant

The Lane Incharge reports directly to the Shift Incharge. His key responsibilities are:

a) Traffic management. Assist and attend to toll collectors who require assistance.

b) Handle incidents.

c) To control all activity of TC in lane. Work as a TC if required. Inspect TCs.

d) Monitor security personnel, if deployed on lanes

e) Communicate with the Plaza manager or TCR by a walkie-talkie.

f) To manage the issue of toll collector floats

g) To organize lane bleed off as and when required

h) To check cash declared form, filled by toll collectors

i) To check availability of Manual mode receipt.

j) To measure service time and queue length. Ensure that the road user has un-delayed service through the plaza

k) Attend to users where they have problems or who are causing delays

l) To ensure that the lane area is always neat, tidy and clean

m) Ensure that the security remain downstream and away from the booths

n) Ensure that no pedestrians, motorists or others stop or loiter in the lane and plaza area

o) Documents - Sign the shift data report, record all the Incident/Accident in incident log book., Maintain the complaint book, compile accident and equipment damage reports as required, assist with cash up and documentation checking

13.3.7 Toll Cashier

The Cashier reports directly to the Shift Incharge. His key responsibilities are:

a) Responsibility for cash management, which includes cash collection, cash safekeeping and cash transfer to the collection agents (for banking).

b) The Cashier has no subordinates and may not delegate the responsibility for cash management.

c) Lane money is to be kept as low as possible through regular bleed off.

d) Managing vault. Other money on the property is to be secured, wherever possible, in the vault and under the security of at least two separate key holders.

13.3.8 POS/Teller Operator

The POS Operator reports directly to the Shift Incharge. He is responsible for issue and recharge of smart cards and ETC tags

His key functions are:

a) Managing Smart card reader/encoder and ETC tag reader equipment

b) Manage stationary - Printed stationary i.e. Recharge Slips, Transfer/loss/surrender form, user guide, Application Form, Card Holder, Sticker, Cover Letter, envelope etc.

c) Managing fresh applications

d) Managing smart card / tags

- Issue of fresh application forms

- Receive, check, verify application and input in the system
- Perform transaction
  - Sale
  - Recharge
  - Refund
  - Replacement
  - Public relations (limited)
- Issue of receipt
- Online entry of data on system
- Recharge
- END OF SHIFT cash up and documentation

13.3.9 Toll Collector

The Toll collector reports directly to the lane Incharge. Key responsibilities are:

a) Accurate vehicle classification,

b) Dispensing Entry Tickets

c) To carry out the normal “cash” operations in the lane by classifying vehicles, accepting money for toll, validating the toll transactions, and issuing change and receipts when required.

d) Money handling,

e) Public relations (limited)

f) User interface - Toll Collector is the face of the organization and is an “Ambassador” for the NHAI by performing the public relations functions to the best of his /her abilities.

g) To declare all money collected in the lanes.

h) To carry out the normal “Unpaid” operations in the lane (where allowed) and authorised “exempt” vehicles whenever necessary.

i) To operate in the lane in Manual mode when required doing so by the Shift incharge.

j) To communicate with the Shift Incharge in circumstances such as the following:

- When an emergency vehicle needs to be given passage.
- When a vehicle obstructs the lane.
- When an extra wide vehicle needs to be processed through the extra wide lane.
- When a convoy is passing through a lane.
- When a run through Violation takes place.
- When needing to be “Bleed off” or when requiring small change.
- When a user has no money with which to pay toll.
- When it is necessary to refuse passage to a user.

- When the toll collection equipment is inoperable.
- When there are pedestrians in and around the lane area.
- All other circumstances that require the shift incharge's authority.

k) To be accountable for the safekeeping of the cash float, manual mode receipts and any face value stationery.

l) To keep the booth neat and clean and to pick up pieces of paper and other rubbish around the booth.

m) To operate and maintain all equipment in the correct manner and report any malfunction.

n) To perform the above tasks accurately and efficiently and in a friendly, polite and helpful manner.

o) To perform any other reasonable task that may be assigned to them by the Shift incharge.

p) Manual Mode – operate in Manual Mode under instructions from Plaza Manager/ Shift Incharge.

q) Documentation

- Shift Incident Log-Record all activity done during the shift like Shift take over, Lane allocation, Accident, Incident, User complaint, Shift hand over etc.
- Equipment Fault Record
- Record the entire equipment fault and damage occurred during the shift.
- Submit the above-mentioned document with signature to the shift incharge at the end of shift.

13.3.10 Other Staff

The following are the other staff which are recommended at the Toll Plaza for operations but may not be directly involved in collection :

i. Security

It is common practice for toll Concessionaires to subcontract security operations at toll plaza. The security guards not only help in guarding the lanes but also guarding buildings like toll plaza, ATMS sub-centres, operation/maintenance center etc.

ii. Safety Officer

It is recommended that the toll plaza have a designated Safety Officer. He shall be responsible for compliance of safety norms on the entire stretch as well as toll plaza.

He shall also be responsible for interaction with local road users (villagers) to advise them on safe driving and other safety issues. At least one meeting is recommended every month and is such a way that all neighboring villages are covered in a year.

iii. Liaising Officer

It is also recommended that a designated Liaising Officer be appointed by the collection agency who shall interact with the state administration and other external agencies (he shall have different function from a PRO who would

primarily interact with the road user). The objective of having a Liaising Officer is to have better interaction with local administration, police so that the involvement and participation of state bodies is to the full extent.

13.4 TOLL OPERATIONS METHODOLOGY

This section describes the toll transaction methodology for each type of journey.

Normal Transactions

The summary of different operations for each type of paid transaction is shown in **Table 13.7.**

Table 13.7: Summary of Transactions of Toll Payment

Category	Journey Type	Discount	MoP	Operation
1.	Normal	No discount	Cash	Entry Ticket at entry Exit Pay cash Surrender ticket
2	Up/Down or Return Journey	Yes, up/down trip at 1.5 times the normal fee	Bar coded ticket	Valid for 24 hours Entry Ticket at first entry Scan pass at re-entry Exit Issue of pass at exit Surrender of pass at re- exit
3	Monthly general	Yes, 50 trips at 2/3 rate	RFID	One month validity Entry Read Tag No ticket issue Exit Read Tag
4	Monthly local (non-commercial)	Yes, unlimited trips at Rs. 150 per month	RFID	For users within 20km of toll plaza for adjacent plazas Entry Read Tag No ticket issue Exit Read Tag
5	Monthly local (commercial)	Yes, 50% discount	Cash	For users in same district Smart card / laminated card for ID Entry Show ID at entry Ticket issued at entry Exit Show ID at exit (if reqd) Pay at exit by cash

It may be noted for Category 5 (monthly local commercial) discount, the Concessionaire may opt for a Smart Card instead of a District Discount ID. The Concessionaire may bear in mind that if Smart Card is to being used, it shall be in such a manner that it may be read at all toll plazas within the district (even if such toll plazas are operated by other operators/concessionaires).

The toll collection system shall assist in providing a user intuitive facility to direct all users towards the payment of toll for all vehicle types passing through any toll lane. The following is a step-by-step description of the process undertaken by the users when using the toll facility.

1. Transaction Methodology for Cash payment method (Category 1 & 5)

a. Entry

i. The user approaches the any open Standard Lane and stops at the pay axis.

ii. Driver announces if he has an ID card for monthly commercial discount.

iii. The TC classifies the vehicle. Enters in system if monthly local (commercial) discount is applicable

iv. A bar coded receipt (Entry Ticket) is generated which mentions at least the following details: Vehicle class, time of transaction, transaction ID, TC name or ID, Plaza name, discount (monthly local commercial). It may also contain company/NHAI logo, safety message, fare table etc.

v. TC hands over this Entry Ticket to the driver.

vi. Traffic light turns green, barrier gate opens and vehicle leaves (passes over exit loop).

vii. Barrier closes, traffic light turns green and TC is ready to process next transaction

b. Exit

i. The users shall approach the toll plaza and enters any open Standard Lane

ii. The driver stops at the Toll Booth. The traffic light is red and exit barrier gate is down. The UFD displays a greeting or a date/time message.

iii. The toll collector inside the tollbooth will visually classify the vehicle as it approaches and stops, and enter the vehicle's classification into the Toll Lane Computer (TLC) by pressing the appropriate classification key on the Customised Keyboard (or touchscreen) as well as the method of payment (cash).

iv. The TC scans the bar code on the Entry Ticket. If the classifications match, the system shall calculate and display applicable fare. As all toll plazas are interconnected on the dual communications backbone, the bar code scan of the Entry Ticket shall automatically recognize the discount. If required, the TC may see the discount ID (for monthly commercial local pass holder).

v. The fare shall be displayed to the user on the User fare Display (UFD) and to the toll collector on the TCT. A Key to "Cancel" a classification incorrectly entered into the TCT shall be available. Use of this key shall be reported and recorded on the Central Computer System (CCS) incident record. The toll collector shall also be allowed to cancel a

transaction with the use of this key. This course of action shall trigger a timer that will delay validating the following transaction. The period the delay shall be a settable parameter.

vi. The applicable toll tariff and blacklists list shall be available on the TLC at all times.

vii. He informs the driver how much he has to pay who then pays appropriate cash.

viii. Once the user has tendered the toll due, the toll collector accepts the fare validates the transaction.

ix. The transaction is processes and a receipt printed on the thermal printer. At the same time the exit traffic light goes red, barrier gate opens and the UFD displays vehicle class, amount paid and balance amount to the road user. The TC then hands over the receipt and the balance change to the road user. The road user leaves the booth.

x. As the road user leaves the pay axis , he drives over (or through) the AVC sensors. These sensors are connected to an AVC controller. The sensors automatically classify the vehicle and send the information to the AVC controller. At the same time, the ICS camera takes a picture of the vehicle and sends it to the TLC. The AVC controller sends one stream of vehicle class data to the TLC and other to the IDB in the plaza.

xi. If there is any discrepancy between entry /exit classification and the AVC, the captured image and transaction is presented on the plaza computer to the supervisor in the control room as “discrepancy”.

2. Methodology for Up/down journey with bar cod MoP (Category 2)

a. Entry

i. The user approaches the any open Standard Lane and stops at the pay axis.

ii. The TC classifies the vehicle.

iii. Rest of the methodology is same as that for cash payment (described above).

b. Exit

i. The users shall approach the toll plaza and enters any open Standard Lane

ii. The driver stops at the Toll Booth. The traffic light is red and exit barrier gate is down. The UFD displays a greeting or a date/time message.

iii. The toll collector inside the tollbooth will visually classify the vehicle as it approaches and stops, and enter the vehicle’s classification into the Toll Lane Computer (TLC) by pressing the appropriate classification key on the Customised Keyboard (or touchscreen) as well as the method of payment (cash).

iv. The driver announces that he intends to purchase an Up/down pass.

v. The TC scans the bar code on the Entry Ticket. If the classifications match, the system shall calculate and display applicable fare. As all toll plazas are interconnected on the dual communications

backbone, the bar code scan of the Entry Ticket shall automatically recognize the discount. If required, the TC may see the discount ID (for monthly commercial local pass holder).

vi. The fare shall be displayed to the user on the User fare Display (UFD) and to the toll collector on the TCT. A Key to "Cancel" a classification incorrectly entered into the TCT shall be available. Use of this key shall be reported and recorded on the Central Computer System (CCS) incident record. The toll collector shall also be allowed to cancel a transaction with the use of this key. This course of action shall trigger a timer that will delay validating the following transaction. The period the delay shall be a settable parameter.

vii. The applicable toll tariff and blacklists list shall be available on the TLC at all times.

viii. He informs the driver how much he has to pay who then pays appropriate cash.

ix. Once the user has tendered the toll due, the toll collector accepts the fare validates the transaction.

x. The transaction is processes and a receipt printed on the thermal printer. At the same time the exit traffic light goes red, barrier gate opens and the UFD displays vehicle class, amount paid and balance amount to the road user. Entry camera records vehicle image. The TC then hands over the receipt and the balance change to the road user. The road user leaves the booth.

xi. As the road user leaves the pay axis, he drives over (or through) the AVC sensors. These sensors are connected to an AVC controller. The sensors automatically classify the vehicle and send the information to the AVC controller. At the same time, the ICS camera takes a picture of the vehicle and sends it to the TLC. The AVC controller sends one stream of vehicle class data to the TLC and other to the IDB in the plaza.

xii. If there is any discrepancy between entry /exit classification and the AVC, the captured image and transaction is presented on the plaza computer to the supervisor in the control room as "discrepancy".

3. Methodology for journey with ETC tags

In any type of journeyall discounts except those mentioned above, shall be implemented through ETC tag. The vehicle with tag enters and exits non-stop at respective plazas at high speeds. The system automatically detects entry /exit details, applies best allowed discount (least fare), and deducts appropriate amounts. For example, a vehicle entering Plaza A and exiting at Plaza B shall have his account debited for distance between A and B. If the vehicle returns before 24 hours and Up/Down discount is applicable, the reduced fee (and not full fee) shall be deducted automatically. For detailed transaction process, see following section.

13.5 OTHER PAYMENT PROCESSES

i) Credit Granted Process

The toll collector shall press the Credit Granted key such is being used as the MOP. The toll collector's display (TCD) shall indicate (in menu format) a list of

authorities that are granted credit, from which the toll collector shall select an authorities that are granted credit, from which the toll collector shall select an authority. The toll collector shall then be prompted to enter the vehicle identification applicable to that authority. If the vehicle is registered in the credit granted database, a receipt with the relevant authority's information shall automatically be printed for the toll collector's records.

If the vehicle has not been registered in the credit granted database, the TCD shall return to the initial authority list, which shall include a menu item for Manual Voucher. An invoice (voucher) shall be written out the toll collector for input cash-up. A receipt shall automatically be printed once the Manual Voucher item is selected.

The toll collector shall at any stage be able to cancel the credit granted process and select another MOP.

A digital image shall be taken of all vehicles that are granted credit.

ii) Exempt Passage Process

The toll collector shall press the Exempt Passage key when such is being used as the MOP. The TCD shall indicate (in Menu format) a list authorities that are granted exempt passage from which the toll collector shall select an authority. The toll collector shall then be promoted to enter the vehicle identification applicable, a receipt with the relevant authority's information shall automatically be printed for the toll collector's records.

If the vehicle has not been registered in the exempt passage database, the TCD shall return to the initial authority list, which shall include a menu item for "Manual Voucher". A voucher shall be written out by the toll collector for input at cash-up. A receipt shall automatically be printed once the Manual Voucher item is selected.

The toll collector shall at any stage be able to cancel the exempt passage process and selected another MOP.

A digital image shall be taken of all vehicles that are granted exempt passage

Electronic Toll Collection (ETC)

i) ETC Overview

Although Electronic Toll Collection means any toll collection done without human intervention, which includes "card only" lanes, for the sake of clarity, for this document ETC shall mean only the transponder-tag based tolling where the road user does not have to stop or slow down.

Since the NHAI has adopted the ETC standards, no other technologies shall be discussed.

The technology selected by NHAI for ETC is RFID ISO 18000-C / EPC Gen-2. The following points must be ensured while implementing the same:

a. The transponder must be able to read the tag at expressway speeds.

b. The transponder must read the tag correctly from a distance and at the same time comply with WPC norms of radiated power (4W erp) and frequency (865-867 MHz). The minimum recommended read distance is 10m.

c. The RFID frequencies must not interfere with CDMA uplink (824-849MHz) downlink frequencies (869-889Mhz) even if a CDMA cellphone tower is located close to the toll plaza.

d. The RFID transponder should read only the tags in its lane i.e. should not read tags in adjacent lanes.

e. The transponders should not read the same tag more than once for the same transaction.

ii) Transaction Methodology In ETC Lanes

a. An On Board Unit (OBU) or ETC Tag is issued to the road user, which contains unique identification number. The tag is installed on windshield.

b. When the vehicle passes through the ETC lane this OBU (inside the vehicle) is detected by transceiver installed in the Lane and the toll transaction is done using the detected OBU ID.

c. All lanes that process ETC transactions shall ensure that only the correct vehicle E-ID is detected and processed. The system shall therefore ensure that the E-ID of any following vehicle or vehicles in adjacent lanes can never be assigned to the current transaction.

d. A valid E-ID shall be an identifier that:

- Is Registered on the TMS
- Balance sufficient for at least one trip
- Has not been blacklisted
- Has not expired
- Is not damaged

e. ETC lanes are recommended to be in the center.

f. At the entry, the vehicle shall be allowed to pass through the plaza at expressway speeds. The transponder shall detect the tag and the system shall check for tag validity. If the tag is valid the exit barrier remains open and the vehicle is allowed to pass. If the tag is not valid or if the vehicle enters without a tag, the exit barrier closes and the vehicle has to stop.

g. At the exit

- If a valid E-ID has been read, the system shall debit the User's ETC account for the value of a single passage corresponding to the vehicle class under which the E-ID has been registered. A unique sequential transaction number shall be allocated to each transaction. If the tag is invalid the exit barrier closes and the vehicle has to stop.
- Once the vehicle has passed the exit barrier, it shall cross the Automatic Vehicle Classification (AVC) system which will automatically classify the vehicle according to the defined vehicle classes
- The Toll Lane Computer (TLC) shall compare the AVC classification to the registered electronic identifier class and if different, send a class discrepancy message to the Incidents Computer (IC) located in the toll control room. Any class discrepancy shall trigger the incident recording system utilizing a Closed Circuit Television Camera (CCTV) situated in the lane. The camera shall record a digital image of the vehicle together with the details of the class discrepancy message, corresponding transaction number, date and time of the transaction and lane number for verification by the toll supervision personnel, thereby completing the

transaction. The IC incident resolution system shall in this case allow the option of debiting the value of the discrepancy to the user account.

- A User Fare Display (UFD) shall be located on the mainline pay axis. The UFD shall display any pre-programmed message as set by the toll supervisory staff. But default, the UFD shall indicate the remaining balance on the user's ETC account

h. If a vehicle without a valid tag drives into the ETC lane, it shall be stopped by the exit barrier. Further process may be handled in any of the following ways:

- Even in ETC lane, there shall be a booth having the capability of processing cash transactions.
- There shall be a Standard Lane adjacent to each ETC lane which also serves as an "ETC rejection lane".
- The vehicle is forced to reverse and enter a Standard Lane.

The following are recommended:

- Number of ETC lanes is equal to lanes in the main carriageway of expressway or ramp for respective plazas, subject to a minimum of two per plaza per direction.
- Each ETC lane also has a booth to process cash. In case the transponders are not working or the system as a whole is down, TC in such booths shall have a hand held RFID tag reader which shall read the tag and such information shall be uploaded to the plaza computer manually.
- ETC rejection lanes and reversing of vehicle in high speed lanes are not recommended.

13.6 TOLL MANAGEMENT SYSTEM (TMS) OVERVIEW

i) General Requirements

The toll management system (TMS) shall be responsible for processing the data received by the CCS into information that will be used to verify toll transaction, provide toll collector control and performance facilities, and shall include a host of management tools and reports for the effective administration of the toll operation. The TMS shall also assist in auditing the toll collection operation, it shall be a modular unit with the capability for various modules and functions to perform independently at the different levels of the toll collection operation.

ii) Manual Mode Data Capture

Data from manual mode operation shall be captured onto the TMS through administration terminals. Data consists of summarized cash transactions and itemized transactions for all other methods of payment. The input shall be a batch process, and the system shall provide validation of captured data in the same way as the TLC i.e. it shall provide warning when validating credit card transactions. The system shall allow an over-ride to accept unauthorized transactions already processed. The system shall ETC accounts for transactions manually processed.

iii) System Software Tools/Reports

a. User Hierarchy

The system shall offer complete flexibility of assigning roles and privileges to each roles. Configurable privileges shall be given to User Category of Manager, Toll Collector, Supervisor, POS operator, Maintenance user, Cashier/Accountant, System Administrator. Various User Privileges can be Master, Plaza Configuration, Shift Configuration, Lane Configuration, Vehicle Configuration, Tariff Scheme Configuration, Equipment Configuration, Fare Configuration, Menu Configuration, POS configuration, Transaction Review, Cash up,

iv) Operating Day

The operating day and the financial day is the same period. This is midnight to midnight. The financial month will close at midnight on the last day of the month. The system must automatically log every lane out and in at midnight. This includes inactive lanes. This will create a “virtual shift end”. It is imperative that End of Day is done properly at midnight and should be displayed accordingly in the TMS.

v) Data Incomplete

The system must recognize when data is incomplete from any lane and when a TMS user has not completed full cash up (voucher and cash declaration) for periods worked up to the end of the operating day. Once an operating day is complete then it must be flagged and no information can be changed (at any operating levels) for that day

vi) Cash Up Process

a. Local mode in lanes

It must be possible to draw a “mini shift” on the lane printer. The report shall be selected for a period of time worked in the lane and must disclose lane and collector details, each methods of payment by class and total, all ETC transactions with E-ID and discrepancies.

b. Virtual Cash Up

Virtual Cash Up will occur for all non-cashed up shifts up to the end of the operating day. When the collector next cashes up, the system must allocate sufficient cash to the pervious operating day to balance those shifts to zero. Any surplus or shortage will be brought forward into the next operating day and declared in that collector shift.

c. Money declaration

All personnel who have been logged into the lanes or have collected toll revenue (ETC exempt, violation, cards and credit granted) will do this , No information on “Required” money will be available to the collector before they have declared their money. Any changes in money must be logged.

d. Voucher input

Once money has been declared the system will automatically present a screen presenting the vouchers for violations, exempt and credit granted in sequential orders. These are to be completed. Where details are insufficient the voucher will be charged against the collector.

e. Sundry Payments

Amounts collected for toll revenue other than for cash – method of payment, are to be allocated as receipted amounts. The value and allocating must be available on the cash declaration screen.

f. End of Shift Document

This document must be printed automatically for each virtual and manual cash declaration. It will consist of at least:

- Declaration
- Heading (name, period etc.)
- Value declared
- Sundry payments processed
- Calculated lane cash
- Base Revenue
- Shortage / surplus (add/subtract discrepancies)
- Signature of collector and supervisor with date
- Manual input (voucher report)
- Voucher entered by method of payment
- Cards number captured manually
- ETC captured manually

g. Discounts

These are calculated at account level and not in the lanes. Provision must be made for discount based on criteria specified in this document under discount schemes

h. Fraud Detection

E-ID's may not be copied or transferred to other vehicles without prior approval. Exempt E-ID's will have an expiry date and be clearly identifiable as an exempt user. It must be possible to query the database.

There must be access control into the discount/rebate structures and adjustments. Changes are to be logged and reportable.

There must be a facility in the POS to test E-ID's without creating a financial transaction.

i. Invalidation

It must be possible to:

- Withdraw an E-ID
- Exchange/transfer
- Blacklist as stolen/lost
- Advise in lanes on UFD when balance has reached a settable minimum amount
- Reject passage with insufficient funds

j. Treatment Of Exempt Accounts

A database of exempt vehicle shall be maintained by operator in the Central Server and downloaded into the lanes. Collectors must be able to select, from a display in the lane, the appropriate exempt authority and specific requesting exemption of toll fees. These details will be recorded against the transaction and reported as if a manual voucher had been completed.

An image shall be captured for each exempt transaction and a suitable receipt shall be automatically printed for the collector use. Exempt passages are controlled in the debtors' control. Users who request exempt passage and are not in the lane exempt database are processed in the same manner as credit granted.

k. Sundry Payments

These are limited to payment of violations, credit granted, exempt vehicles, collector debts and ETC recharges and charges, fines, excess charges etc. All payments are entered into the debtor system as batch inputs. All batches are checked for being in balance and accurate prior to posting.

l. Points of Sale

POS shall be equipped to process both lane and administration functions. The Equipment supplier shall recommend the manner in which remote (not online) points of sale shall be integrated into the TMS. Remote points of sale are to administer sales, account credits, lost cards, stolen cards, queries etc. Thought should be given to an inexpensive remote POS system and the provide secure transaction and administration functions to the TMS.

m. Discrepancies

A difference between the collector classification or E-ID class and the AVC creates a discrepancy. All discrepancies will have the image captured. The image is sent 'real time' to the control room where the supervisor will correct the classification to that of the image. Under classifications will be added to any shortage or reduce any surplus. Over classifications will require surplus money from the collector.

- Surplus cash

Surplus cash reflected in the cash declaration will be deemed to belong to the concession and must be banked as such. This amount will include the value of over classifications corrected.

- Shortages

These amounts are reflected on the cash declaration and are to be paid by the collector at least once per month.

n. System Reporting

All reports must be available to view, print or in a file suitable for easy spreadsheet manipulation. Reports shall also be required in graphical form. The following is a list of minimum reports (required selectable time, shift wise, day wise, week wise, month wise and lane wise, plaza wise)

i. Equipment component failure
ii. Traffic count and class
iii. Operator efficiency
iv. AVC accuracy

v. AVC discrepancy report
vi. Equipment accuracy
vii. Equipment ageing
viii. Toll management System and Networked workstations failures
ix. Incident reports
x. Collector discrepancy
xi. Acknowledged incident report
xii. Manually captured E-ID
xiii. Payment reports
Exempt transactions
Concessions
Discounts
Rebates

o. System Auditability

The Toll System shall comply with the following :

i. Each and every transaction shall be uniquely identifiable and traceable unit, stored by the Toll System. The transaction record (or transaction) shall contain all data relating to the passage of a single vehicle through the lane.

ii. The Toll System shall ensure that the data supplied to the NHAI and AVC Independent Data Base (IDB) can be traced back and reconciled to the transaction data. Each and every vehicle passage over the AVC shall be uniquely identifiable and traceable unit, stored by the AVC system. The AVC transaction record shall contain all data relating to the passage of a single vehicle over the AVC area.

iii. The System shall utilise techniques for protecting data files and their integrity for any database structure or operating system within the Toll System. This shall include techniques for providing data integrity, overwrite protection and data security. Data security shall include protection against unauthorised users gaining access to data storage disks and files of the Toll System.

iv. The AVC System shall comply with the following:

v. The AVC system shall consist of individual AVC's installed in each lane as indicated and the Independent Data Base (IDB) that will collect, store, compress data and also be able to transmit data to the CLIENT.

vi. The AVC System shall comply with the following audibility criteria:

a. Each transaction recorded by the system shall be time – stamped and uniquely and sequentially numbered;

b. All status messages shall be uniquely linked to the Toll transaction in progress. Each status message shall be uniquely and sequentially numbered;

c. The IDB shall process hourly summaries that shall indicate the range of transaction and status message contained in the summary

vii. AVC shall detect Unusual Vehicle situations determination:

a. Wrong direction – vehicle travelling in the wrong direction through the toll lane;

b. Roll Back – vehicle travelling into the AVC area and then reversing back to the payment point. The AVC and TCC shall ensure that roll backs are accurately i.e. Ensure that only actual passages are reported.

c. Vehicle standing – standing – the vehicle presence sensing equipment stays active for longer than a pre-set time (usually 30 sec).

viii. The AVC shall count axles.

ix. The AVC shall store the following data from individual vehicles : Data & time of day; Entry plaza number, AVC sequential number; AVC sequential number at entry toll plaza, transaction value; Number of axles (and other classification parameters); Wrong direction; Roll back; Vehicle standing; AVC status; AVC / TLC communication status; AVC / IDB communication status.

The above vehicle information shall be maintained at AVC level for 4 weeks. Data shall automatically be copied to the IDB before deleting it at AVC level. The IDB shall include a daily backup process for all data.

x. The AVC shall be capable of operating in stand-alone mode. During stand-alone mode the AVC shall keep counting and registering the traffic in the case of a Toll System or network communication failure. When communication is restored, the AVC shall synchronize its message file with IDB.

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USER FACILITIES AND ROAD FURNITURE

14

14. USER FACILITIES AND ROAD FURNITURE

14.1 OPERATION AND MAINTENANCE CENTRE

There shall be dedicated Operation and Maintenance Centers along the expressway to accommodate spaces for office, vehicle parking, emergency medical facilities and restaurants etc. The TOR specifies that a dedicated operation and maintenance centre shall be planned at every 100km for accommodating the traffic control centre, offices for operation and maintenance staff, a trauma centre, a maintenance base or yard with equipment and material for carrying out emergency maintenance, parking for rescue vehicles (cranes etc), patrol vehicles, ambulances, rest places for personnel on night shift duty, a restaurant or canteen etc.

14.1.1 Provisions

The proposed centers will have following facilities for efficient operation and maintenance of the expressway.

a) Traffic Control Center and Administrative building,

b) Storage space for equipment and material for emergency maintenance and traffic signs are marking,

c) Workshop,

d) Trauma Centre,

e) Parking space for ten large sized vehicles,

f) Parking space for thirty cars,

g) Fuel station,

h) Space for helipad.

The 'Traffic Control Center and Administrative building' will be a single building and will accommodate, in addition to traffic control centre, the space for offices, laboratory, store rooms, record room, rest area for office personnel, canteen, toilets. The toll office of the inter change can also be accommodated in the same building.

14.1.2 Location

The proposed centers are to be located within the interchanges from the operational point of view. Therefore, the proposed locations of these centers are at Km 287.385 & Km 378.740 for Phase IA from Km 254.430 to Km 378.740.

14.2 SUB-CENTERS

It has been proposed, in addition to main traffic control centers, sub-centers at a 50 km interval. These sub-centers can be accommodated in the nearest way side amenity center.

14.3 TRAFFIC SIGNS AND PAVEMENT MARKINGS

The various considerations made for the safe design of expressway and different safety features included in the DPR are given hereunder. Indian Road Congress (IRC) codes and Design Manual for Roads & Bridges (DMRB, UK) guidelines and Manual for Uniform Traffic Control Devices (MUTCD, US Dept. of Transportation) have been followed in proposing and designing road safety features of the expressway. The expressway has been designed for same level of safety considerations throughout.

- General
- Alignment
- Interchanges
- Non-motorized User Provision
- Road Signs, Pavement Marking & Lighting
- Roadside Hazards
- Intersection Arrangements on Slip roads of Interchange
- Way Side amenities, Toll Plazas & Truck Lay byes

It may be worth mentioning that the expressway is designed as access controlled facility and 120 kmph speed has been kept for the design of main carriageway. The safety measures proposed for expressway are explained in the following subsections.

The expressway being a green field project, the development plan for enroute area, forecast traffic volumes and mix of traffic likely to be used and the physical constrains imposed by topography have been considered on road safety point of view. In addition, the cross sectional parameters such as width of lane, shoulder and median, and side slope also have been examined which have direct bearing with safety of the expressway. The flush median of 6m width is proposed with Thrie beam metal crash barrier on both side of median. Provision of antiglares is also recommended in median to reduce head light glare from opposite traffic. Direct access to the expressway has been avoided and lay byes have been provided to enhance the safety level of the expressway.

14.3.1 Alignment

The horizontal and vertical alignments have been designed to give sufficient forward visibility at the design speed. Safe overtaking opportunities have been provided throughout the reach. All curves have been provided with adequate transition and super elevation wherever required. The obstruction to sightlines by safety fences and other street furniture also have been verified.

14.3.2 Interchanges

The interchange arrangements provided at 5 locations on Phase IA (Km 254.430 to Km 378.740) of VME Corridor will safely transfer vehicles at these locations whereby possible accident risks due to at-grade conflicts have been avoided. The interchanges have been provided with adequate acceleration and deceleration lanes and ramps also have been designed for 80kmph/60kmph. The interchanges will be provided with gantry mounted signs and flag type direction signs apart from chevron signs for delineation of ramps and slip roads.

14.3.3 Non-motorized User Provision

All vulnerable road users like pedestrians and cyclists shall have no access to the expressway and are segregated from the exposure of fast moving traffic. They shall cross the expressway through underpasses. Service road has been provided to cater the slow moving and local traffic. Non-motorized users will not be allowed to use high speed expressway. Prohibitory signs will be installed at the start of all entry ramps to prevent the entry of cyclist and slow moving vehicles into the expressway.

14.3.4 Road Signs, Pavement Marking & Lighting

At all interchanges, shoulder and gantry mounted advanced directions signs will be provided. The font size for the design of direction and facility information signs has chosen for 120km approach speed on expressway and destinations will be given in two languages i.e. Hindi and English. The alphabets shall be with "Transport Medium" font. The signs shall be with retro reflective micro prismatic grade conforming to Type XI sheeting of ASTM standards for short, medium and long distance viewing to cater visibility requirement encountered by all road users in expressway. All curves shall be properly delineated with single chevrons signs which will be placed on outer edge of the curve, so as to view at least 2-3 chevrons from any given instance of viewing. Absolute speed limit signs and also compulsory "no parking" and "no stoppage" signs also have been proposed at regular interval. Also, variable message signs have been proposed for the expressway. Incorporating all these provisions, a sign schedule has been prepared and presented in **Volume II: Drawings.**

Pavement markings will be done for traffic lane line, edge lines and hatching. The marking will be with hot applied thermoplastics materials. The pavement markings will be reinforced with raised RR pavement markers and will be provided for median and shoulder edge longitudinal lines and hatch markings etc. Highway lightings including high masts will be provided at interchanges in order to improve the night time visibility.

14.3.5 Roadside Hazards

Road restrain systems will be provided to protect the road users from roadside hazard like signs, gantries, and abutments. Thrie beam metal crash barrier will be provided throughout on shoulder side of both carriageways. Also in median for both carriageways as flush 6m wide median is proposed. The metal beam crash barrier coming on either side of the approach will be continued with rigid beam crash hazard and will be illuminated with hazard markers to help an approaching driver to judge the structure/hazard locations. In order to help the road users to better align the curves, delineator posts will be provided on outer edge of the curves. The locations of Object Hazard markers and delineator posts which are designed as forgiving type for the expressway are also presented in **Volume II : Drawings**. Retro-reflective Type VI sheeting has been suggested for delineator post.

14.3.6 Way Side amenities, Toll Plazas & Truck Lay byes

At 4 locations bigger type way side amenities have been provided which would give parking, eating, fuel filling, public telephone, and toilets facilities. In another 4 locations, smaller type way side amenities have been provided to cater toilet and parking requirements and at 2 locations truck parking are also proposed. Gantry mounted signs provided well in advance of these facilities will guide the road users into these way side amenities. Likewise the gantry mounted truck lay by signs will lead the drivers safely. Series of Toll Plaza advance informatory signs supplemented with portal guide signs will guide traffic into Plaza both in main carriageway and also in ramps/slip roads.

Various safety elements considered in the geometric design of the expressway, and further the road safety features incorporated in the DPR will address the safety engineering aspect of the expressway. The road safety features are proposed in such way to make the expressway as a "forgiving highway".

14.3.7 Safety Barriers

The proposed expressway will be on embankment of height more than 4m with side slopes of embankment of 2(H):1(V). Longitudinal edge barriers (Thrie beam metal) will be provided on both the edges at the top of embankment throughout the length to protect any out of control vehicle from falling.

Properly designed edge barriers have been provided on entry/exit ramps and loops of interchanges. Thrie beam metal crash barriers have also been provided in the median on both sides throughout as warranted in IRC: SP: 99.

14.3.8 Emergency Crossovers

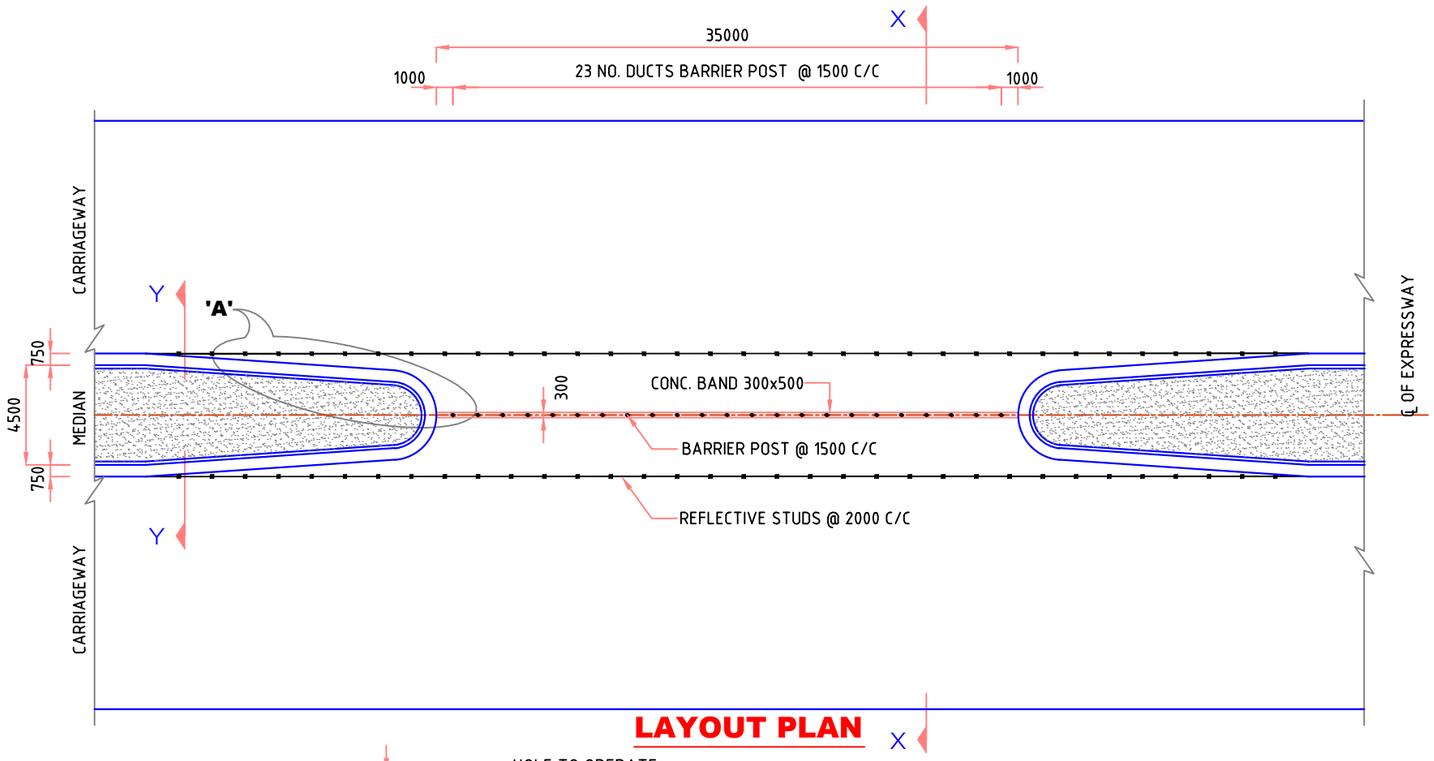
The emergency crossovers have been provided for emergency, law enforcement and maintenance operations. These crossovers have been provided at 5km interval. The cross over consists of a 35m wide median opening with barrier post. A typical layout of the emergency cross over is given in **Fig 14.1.**

14.3.9 Noise Barriers

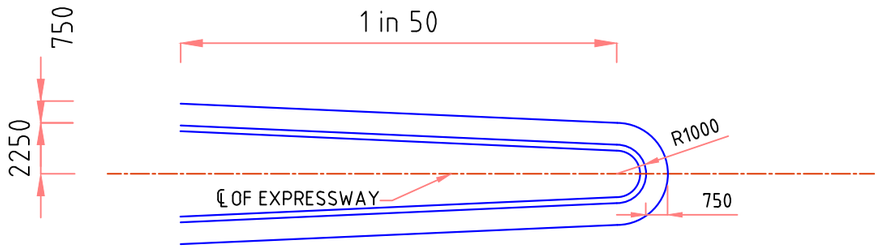
Noise barriers have been provided at urban location to reduce the decibels of the noise created by the vehicles in order to reduce the discomfort to the adjoining population.

• • •

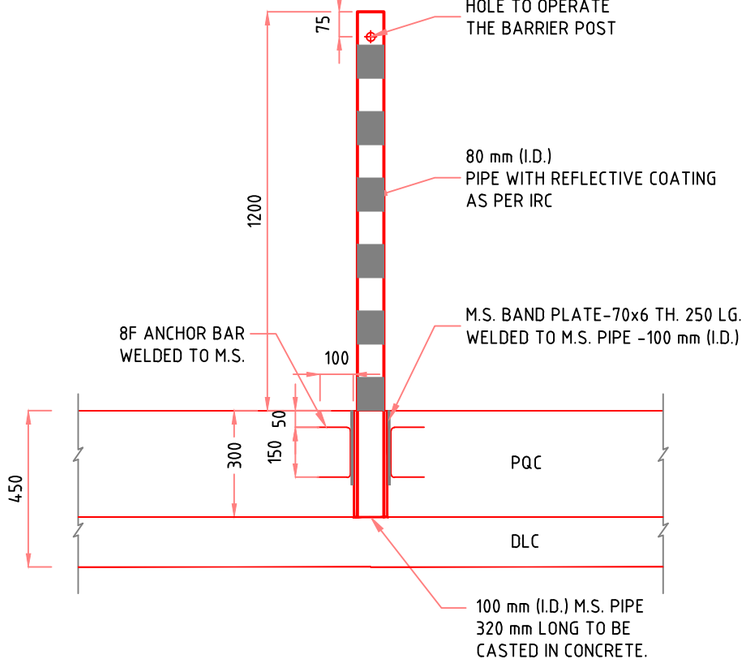
Fig. 14.1



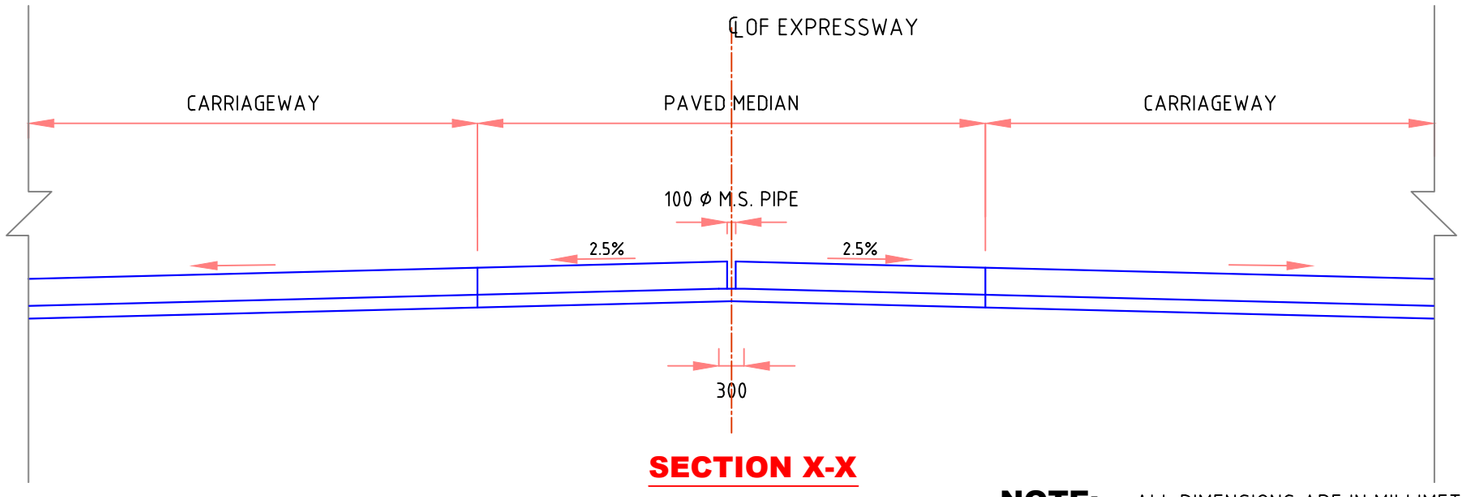
LAYOUT PLAN



DETAIL AT 'A'



DETAIL OF BARRIER POST

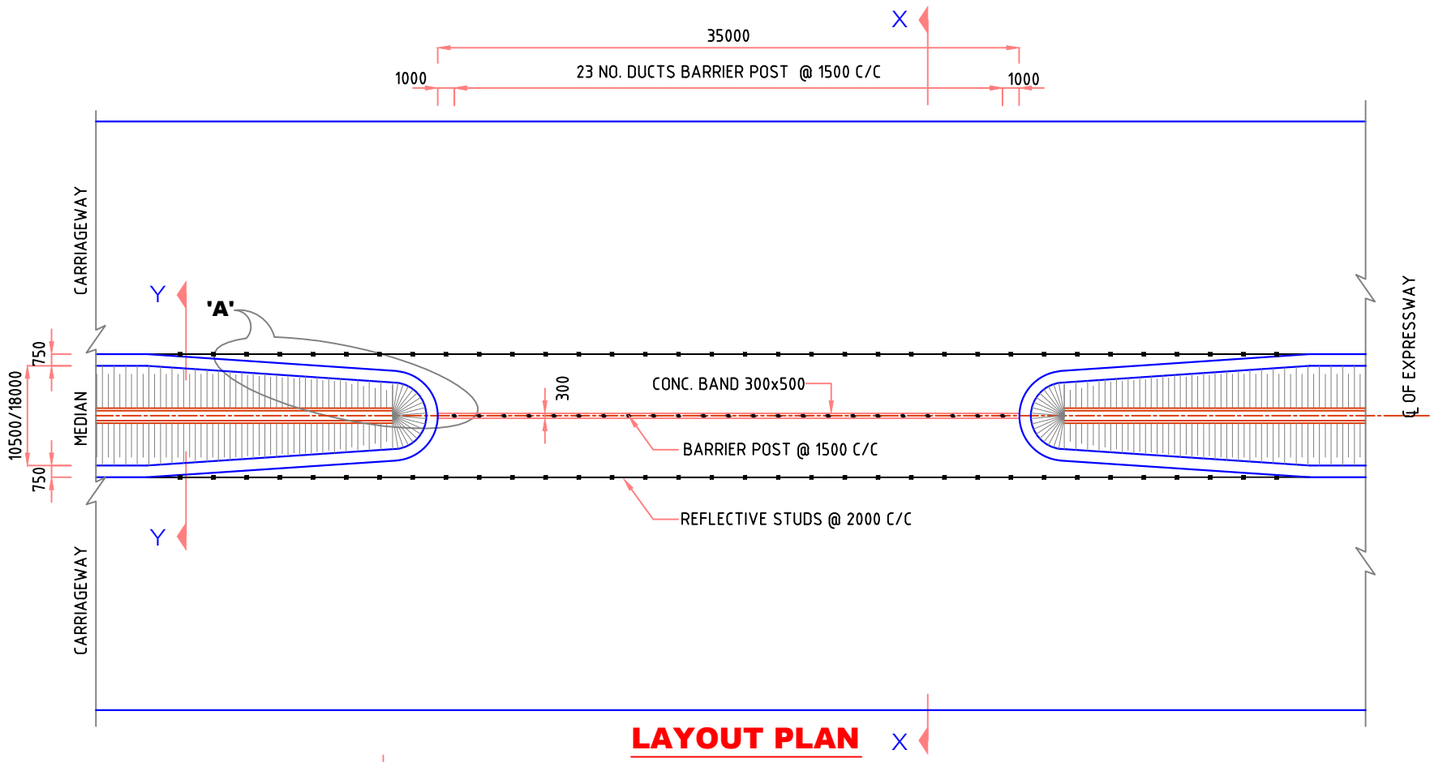


SECTION X-X

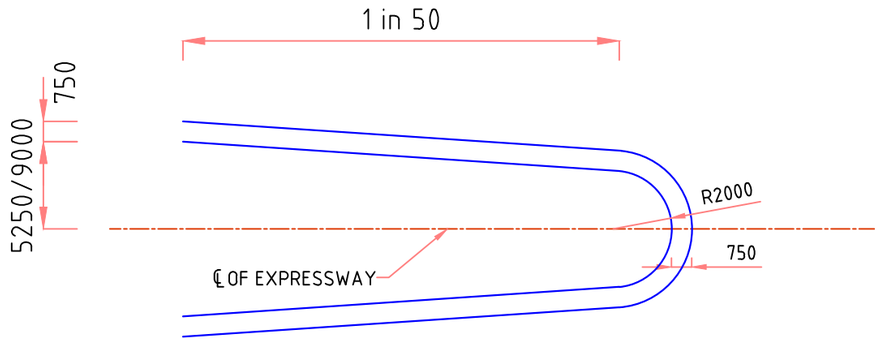
NOTE:- ALL DIMENSIONS ARE IN MILLIMETRES

NATIONAL HIGHWAYS AUTHORITY OF INDIA	Scale : Scale : Not to Scale	Consultancy Services for Preparation of Detailed Engineering Design of Vadodara - Mumbai Expressway including Spur to JNPT under NHDP Phase-VI (Phase-IA from Km. 254+430 to Km. 378+740)	Detailed Project Report Typical Details of Emergency Cross Over	Intercontinental Consultants & Technocrats Pvt.Ltd, A-8, Green Park, New Delhi - 110016 Ph : 4086-3000, Fax 2685-5252	R1 April. 2016 Modified Drawing R0 Nov. 2012 INITIAL PLAN Revisions Date Description Checked by Revisions DRAWING No:- NHAI/VME/ECO/01/R1 File Name :
				ARTI ROY Prepared by / B.K SWAIN Designed by / DEEPAK KUMAR Checked by / ASEEM PRABHAKAR Approved by	

Fig. 14.1



LAYOUT PLAN



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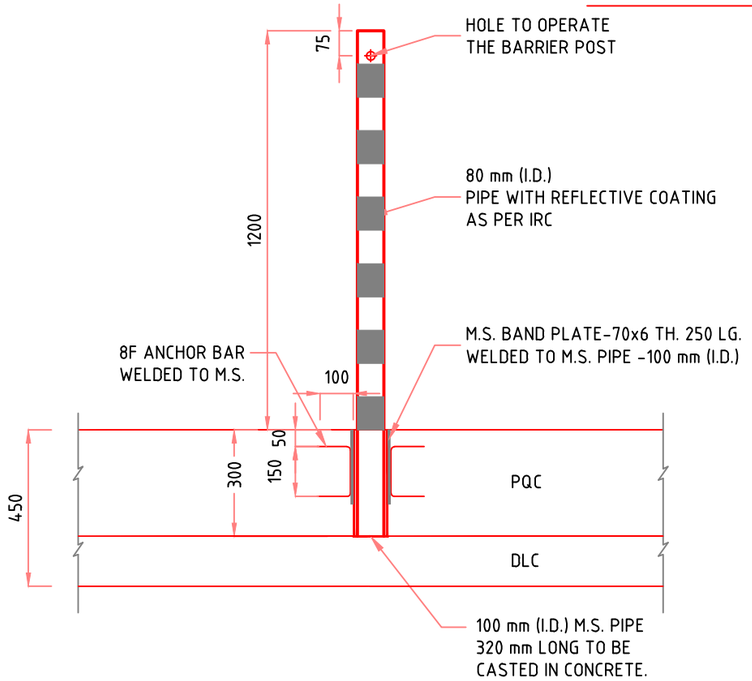
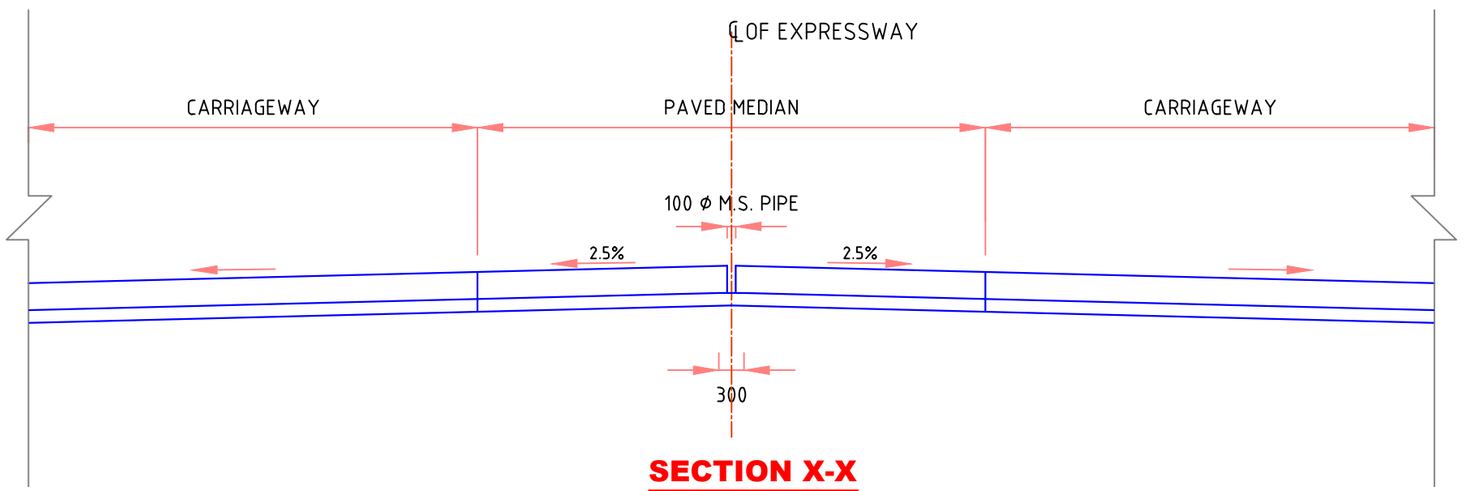


DETAIL OF BARRIER POST



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Revisions	Date	Description	Checked by
R1	April, 2016	Modified Drawing	
R0	Nov. 2012	INITIAL PLAN	

DRAWING No:- NHAI/VME/ECO/02/R1

File Name :

ADVANCED TRAFFIC MANAGEMENT SYSTEM (ATMS)

15

15. ADVANCED TRAFFIC MANAGEMENTS SYSTEM (ATMS)

15.1 ADVANCED TRAFFIC MANAGEMENTS SYSTEM (ATMS)

15.1.1 Introduction

The Expressway is expected to be provided with ATMS facilities to acquire data automatically and utilize the same for managing traffic as well as facilitate the travel through the corridor with least hazard, as the motorists will be informed in advance about the situation ahead. Basically, the ATMS will have the complete capability of incident management and to meet the requirements of the safety of users. ATMS will provide information to the users on real time basis for the traffic flow conditions, weather conditions and incidents ahead, and for this purpose, there would be a control centre and outdoor equipment located at strategic locations along the entire corridor and connected through a transmission medium.

15.1.2 System Requirement

ATMS shall provide the following facilities to Expressway users:

- Make emergency calls to Control Centre in case of accidents, breakdown, fire and ambulance.
- Pre-warn the Expressway users about unusual condition on the road.

ATMS shall provide the following information/data to traffic managers for efficient and effective handling of traffic.

- Information regarding location of any incident, incoming calls, help required and messages to be passed to third parties.
- Information regarding traffic congestion, speed and weather conditions.

ATMS shall provide the following controls to traffic managers:

- Change the variable message signs from the Control Centre.
- Mobilize the movement of ambulances, cranes & patrolling vehicles.

ATMS shall provide online recording and reviewing of the voice & visual information for record and analysis.

Value Added Systems in information dissemination to users of the Project, may be taken up in future. These shall include the following:

(i) Value Added Systems in the form of real time information on traffic conditions, unusual events, congestion levels, weather conditions etc.; to facilitate project users as also the operator.

(ii) Through relevant websites including that for the Project SPV/Concessionaire

(iii) Subscription based alert systems

(iv) Dedicated TV channels pertaining to traffic movement

(v) Tie ups with FM radio channels or creation of dedicated AM radio channel

(vi) Dedicated Toll Free Telephone Systems

Note: Local language is emphasized in above systems.

The ATMS shall among many things comprise following sub-systems:

i. Communication backbone

ii. Emergency Communication System
iii. Mobile Communication System
iv. Variable Message Sign System
v. Meteorological Data System
vi. Automatic traffic counter-cum-classifier system
vii. Video Surveillance System
viii. Video Incident Detection System (VIDS)
ix. Central Control Room (CCR)
x. Weigh in motion for axle load measurement
xi. Power Supply System

These systems shall have outdoor equipment consisting of ECBs, VMS panels, weather sensors, traffic sensors, video camera etc. The outdoor equipment shall be connected to the control centre through transmission system preferably comprising optical fibre cable, copper cable and interface equipment. There shall be one control centre per package and shall be located at any one of the toll plazas or administrative building and shall have monitoring equipment, on line information acquisition equipment, processing equipment etc. It shall also have graphic display board showing the highway and the locations of equipment and of incidents.

15.1.3 Emergency Call System

Purpose and General Information

This is a communication medium to be installed on the Expressway and to be used by the road users to make alarm call to the CCR in case of accidents & other problems on the expressway.

Location

ECB shall be installed every 2km on either side of the road with one unit directly across the road from the other i.e. two call boxes every 2km. It shall be placed along the left side of the carriage-way for each direction of travel on the verge adjacent to the hard shoulders. At each location one ECB shall be master and the other slave. The master ECB shall be equipped with fibre optic interface, solar panel, battery back-up and voice communication mechanism and shall also comply with all the requirements specified in this section for ECBS. The slave ECB shall be equipped at least with – activation button, vandal sensing mechanism, call progress indication LED, microphone, speakers – in a weather proof housing. To discourage motorists who break down near the start or finish of the expressway from leaving it to obtain assistance, no telephones should be provided within the first and the last 300meters.

To achieve maximum visibility, care should be taken to avoid siting telephones near structures (e.g. bridge piers), particularly where these are close to the hard shoulder on left hand bends.

Based on the above policy and the site condition, the location of the ECBs can be adjusted within 10% variation, however, only with the consent of the NHAI.

The optical fiber and splicing boxes shall be placed in the central median.

Major Components

Main components of the Emergency Call subsystem are:

1. Field components:
    a. Emergency Call Box – Master and Slave units
    b. (Solar) power supply
    c. Guard rail for protection
2. CCR components
    a. ECB server
    b. Headphone, speaker and microphone (Answering Unit)
    c. Voice recorder/logger
    d. Application software
    e. Database software

Functional Specifications

1. The system shall be connected to the CCR over the OFC backbone.
2. ECB shall have loud speaker, microphone, solar panel, and battery and activation button with LED indicating conversation. It shall be housed in vandal proof casing and operate in expressway noise levels with built in diagnostic features.
3. The road user just needs to press the push button on the ECB and shall be connected to the CCR. In case the CCR operator is busy, the user shall hear a recorded message and shall hold till he/she is connected. The Master unit shall be connected to the CCR over the communication backbone. The Slave unit shall be connected to the CCR through the Master unit.
4. The CCR can also call any specific ECB for testing/calling in which case the ECB shall ring. The ring shall go off when someone presses the push button and connects to the CCR.
5. The ECB shall have the following features :
    a. Vandal proof casing with tamper detection switch
    b. Push button
    c. Activation LED
    d. Loud speaker
    e. Microphone
    f. Two way communication between ECB and CCR
    g. Solar panel with batteries
6. ECB shall have hands free operation.
7. Each ECB shall have usage instructions in Hindi , English, Marathi and Gujrati pasted or printed on it along with graphical instructions.
8. Reflective stickers facing the motorist shall be pasted on the ECB indicating that it is a phone.
9. The CCR software shall manage the calls to and from the ECB.

10. The ECB shall have Ringing Tone to indicate progress of call when button is pressed; Confidence Tone to indicate call is still connected when on hold and recorded message if line is busy.
11. There shall be up to four programmable auto dial numbers associated with the push button. The ECB shall automatically dial subsequent numbers if the first number is busy or unavailable.
12. The ECB shall automatically end call when CCR telephone is disconnected.
13. All calls shall be recorded in the CCR voice logger/recorder along with date/time stamp. The voice recorder shall check for following minimum fault conditions :
    - Failure of recording electronics
    - Failure of storage media used for recording
    - Excessive recoverable errors on the storage medium
    - Lack of activity on a channel
    - Constant activity on a channel
    - Constant ringing on channel (answered calls)
14. ECBs shall be programmable from the CCR and from the field by laptop.
15. The system shall have in-built diagnostics and shall be able to detect activation of tamper switch, mic/loudspeaker faulty, line faulty, low DC voltage on line, cross talk and short circuit. Any diagnosed problem shall trigger an audio video alarm in the ECB server at CCR.
16. The diagnosed problems shall be stored in the system as events in the CCR. It should be possible to draw and print report of all such events on time and event category basis. ECB software at CCR shall allow recording and storing of maintenance and corrective action of each event when it is resolved.
17. ECB shall be powered by DC batteries which in turn shall be charged by solar panel. The battery shall support 7 days of operation (under normal circumstances) with minimum talk time of 90 minutes over 3 days in succession in case there is no sunlight for this period.
18. The ECB shall have tamper resistant screw bits on the outside and shall be security locked. It shall not be possible to open the ECB with normal tools or keys.
19. ECB foundation shall be concrete. Cables (communication/power) shall enter from the base of the ECB foundation.
20. Each ECB pillar shall be numbered.
21. The ECB mic/speaker shall be located 1-1.5m above ground.
22. The system shall not permit cancellation of any call before answering.
23. CCR Equipment
    a. The CCR equipment shall consist of an ECB server with large TFT display screen and voice logger for recording of all calls. It shall be possible to play back any call by time specified. Playback should not interfere with record function. The screen shall show the map of the

expressway with all Emergency telephones marked in accordance with their actual locations.

b. The GUI shall be user friendly. ECBs shall be displayed in grey colour icons on the screen. When a call is initiated, the icon shall turn green and blink. When the call is in progress, the icon shall be green and stationary. On-hold calls shall be displayed in orange blinking. Faulty ECBs shall be displayed in red, without blink.

c. The software shall have the following features:

   i. password protected & accessible only with relevant passwords

   ii. data logging with the currently logged user/ operator details

   iii. different levels of authorization for logging into the system

   iv. automatic Call location identification

   v. call disconnection by operator only

   vi. operator call back facility

   vii. automatic testing facility running in the background at operator selectable intervals

   viii. operator initiated ECB test facility

   ix. facility for holding at least 10 calls from ECB's

   x. Low battery and tamper alerts.

d. The following shall be recorded by the system software:

   i. Time of incoming call

   ii. Time of call answering

   iii. Time of call termination

   iv. Time of fault occurrence

   v. Time of happening of events

e. It shall be possible to :

   i. connect to any of the Calls on Hold

   ii. hang up the call

   iii. put on Hold the currently connected call

   iv. call back any of the ECB

   v. monitor faults and events

   vi. send e-mail to defined personnel intimating them about emergency

f. It shall be possible to draw the following minimum reports for each ECB as well as all/selected ECBs :

   i. Call count based on time period selection

   ii. Average call duration

   iii. Average waiting period for on-hold calls

   iv. Unanswered calls (count)

v. Fault and diagnostics report

vi. Incident category-wise report

vii. The reports shall be tabular as well as graphical.

24. The following technical specifications are advised for ECBs. However the system integrator/operator can choose any other technology as long as other requirements are met.

a) Working : work on VoIP

b) Communication : Ethernet type over optic fiber

c) Power : 12/24V DC, solar powered max 10W

d) Audio output : >95dB

e) Microphone : unidirectional, noise cancellation type

f) Wind speed resistance: 180kmph

g) Mean Opinion Score: Min 4.0

25. ECB shall connect to the Outdoor Technical Cabinet Switch on optic fiber port/copper port (Ethernet may also be used, wherever feasible).

26. The ECB shall be vandal resistant in construction. It shall be made of stainless steel/ Aluminum alloy/ FRP.

27. ECB components shall be corrosion resistant; PCBs shall be coated to prevent water, moisture and fungus.

28. Each ECB shall be protected against external EMI, lighting and static by adequate shielding and earthing. The enclosure shall be provided with a grounding lug for connection to ground wire.

29. ECB enclosure shall be IP65 rated and shall be vermin and rodent proof. Doors shall be with labyrinthine seal, butyl-rubber gaskets, security locks, and metal hinges in conformity with UNE20324 standard.

30. The ECB shall operate in full duplex mode and use signaling which is inaudible to the user.

31. It shall be possible to adjust the acoustic properties.

15.1.4 Variable Message Signs (VMS)

Purpose and General Information

Variable Massage Signs (VMSs) are to be installed for conveying the traffic conditions ahead to the drivers on real time basis as well as to display messages to support national road safety campaigns. It may also include the variable traffic speed limit depending upon the requirements.

Variable message signs (VMSs) shall provide traveler information for warning, regulating, routing, and managing the traffic in order to improve the overall traffic flow. The philosophy is to inform the driver of impending conditions with up-to-date information. The overall goal of VMS application is to provide permanently located signs that can be programmed remotely to communicate with the drivers the necessary information such that the driver can choose or be directed to the most appropriate route. The VMSs shall be controlled from the main CCR.

VMSs shall be used during the following conditions:

- Recurring Conditions

Mainly peak-period traffic congestion where demand exceeds capacity for relatively short periods of time.

- Non-recurring Conditions

Caused by random or unpredictable incidents. An "incident" is defined as any non-recurring event that causes a reduction of roadway capacity or an abnormal increase in demand. Such events include traffic crashes, disabled vehicles, spilled cargo, expressway maintenance and construction projects and adverse weather conditions.

VMS Usage Priorities

VMS should be used whenever pertinent messages will assist motorists to make helpful decisions. If, however, a situation arises, which requires the usage of a specific VMS for more than one ongoing condition, the following priority criteria should be used for displaying messages, in the order listed.

- Safety

Any VMS message that is necessary to provide safety to the motoring public has the highest priority. Examples include failure of an expressway bridge, roadway or any major incident. In general, safety messages should be kept current and relate to a specific safety campaign. The period of time that a specific message is displayed for a safety campaign should be limited to a few weeks. Motorists tend to ignore messages that are displayed for long periods of time.

- Roadway Closure

The VMS message shall include motorists regarding the roadway (particular carriageway, lanes of the expressway or cross road) closure is important because such a closure directly affects the route a driver would take.

- Minor Traffic Impact

A pre-warning message shall generally be used for planned full closures of carriageway of particular part of the expressway. The message shall be displayed no more than four days prior to the closure, and shall be immediately replaced with an appropriate message when the closure commences.

- Pre-Warning

This category includes construction lane closures, blocking-incidents, and delay information.

- Test

Test messages may be used to sign operation for testing the operating system and prior to placing a VMS into service.

- Public Service Information

Public service information messages do not require the drivers to make any unexpected maneuvers with regards to upcoming traffic conditions. Some examples include "Buckle Up," "Speed Kills," and "Don't Drink and Drive."

Various situations where VMS would be appropriate are as below:

- Incident signs as accidents, traffic diversions, incident management, monitor road work (men at work) adverse weather and road conditions and operation with lane control signals;
- Traveler information such as display of road construction activity in near future, messages for testing of the system and special events that effect the traffic flow;

- Public service announcements like messages relating to driver safety campaign.

Location

VMS shall be provided as per locations determined later. A general policy adopted for locating VMSs is to provide VMS at an average interval of 10km in each direction (not necessarily on the same gantry) to guide and forewarn the users about the traffic and weather conditions on the Expressway.

The most critical locations for installing permanent VMSs are in advance of interchanges or expressways where drivers can have the opportunity to take some action in response to messages displayed on VMSs. A VMS should not compete with existing roadway signs.

Drivers generally do not anticipate using a different route until they see and read a VMS message. Drivers who are traveling in the inside lanes need ample time to read the message and change lanes to exit.

In general, a VMS should be permanently installed at the following locations:

- Upstream from major decision points (e.g., exit ramps, freeway-to-freeway interchanges, or intersection of major routes that will allow drivers to take an alternate route).
- Upstream of bottlenecks, if any
- Where regional information concerning weather conditions such as fog, wind, or dust is essential.

The exact location shall be adjusted for the maximum utility to the users based on the site conditions, however, only with the consent of the NHAI .

Major Components

The design of the system will be modular except for the housing.

Main components of the VMS subsystem shall be:

- Field components – consists of the sign module having:
  a) VMS case
  b) VMS sign (display modules)
  c) Power supply
  d) Dimmer control (ambient light photo sensor system)
  e) Microcontroller
- CCR components
  a) VMS server
  b) VMS Application software
  c) VMS Database software

Specifications

1) VMS shall be able to display all colours.
2) The VMS shall be able to display the following:
   - English text
   - Hindi text

- Gujarati text
- Marathi text
- Numeric
- Punctuation marks
- Graphics
- Preset messages – at least 10 preset messages shall be displayed and shall be able to change automatically and sequentially in programmable intervals of 1-10 minutes

3) The mounting structure to be provided for the VMS units shall be sturdy, aesthetically designed and capable of bearing wind loads at least up to 200 kmph. The lowest hung part of the display board shall have vertical clearance of at least 5.5 m from the road level. It shall be provided with a walkway to allow at least 2 persons to carry out maintenance of the VMS without obstructing the carriageway. Safety barriers shall be provided at gantry support column (s) for their protection and for safety of road users. The concrete pedestal for support column should be flushed with ground but in no case should protrude for more than 15 cm.
4) The minimum distance of VMS on an expressway should be 1.5 km. prior to decision point. The signs should be visible from a distance of 300m.
5) There should be clear distance between existing road sign and VMS. The minimum distance between road signs and VMS should be at least 250m.
6) The average driver of motorized vehicle at high rate of speed can comprehend two message panels. Each panel should be complete phrase and each phrase should be independent of the other. The messages should consist of:

A problem statement	Road work/accident ahead
An effect statement	Delay/congestion
An attention statement for certain group	Motorist
An action statement	Take the next carriageway

7) Software – The VMS application software shall be installed in the CCR and shall have the following features:
   - GUI display
   - Login/password protected access
   - Database for storing messages and history
   - Reports for – preconfigured messages, login time and user, date/time of display, fault history.
8) Maintenance walkway shall be provided on the gantry at the rear of the sign-case. All component parts shall be easily and readily accessible by a single person for inspection and maintenance. There shall be room for a technician to work. The VMS should have in-built lighting to assist maintenance work during night.
9) Standards

   VMS shall be designed to comply to with the following protocols:

- EN 12966 parts 1,2 and 3

10) VMS shall be full matrix, true colour. It shall be made of modules and shall have equally spaced LEDs.

11) Text display - VMS shall be compliant to **EN 12966**. This includes the following for LED panel:

- Beam : B3
- Colour : C1
- Luminance : L3
- Temperature : T3
- Resistance to pollution : D3
- For wind pressure on enclosure refer EN 12899

12) Display specifications

Sign dimensions	:	Length 8000mm, height 2500mm
Pixel colour	:	True colour (36bit), text displayed in Amber colour
Pixel size	:	25mm
Pixel pitch	:	25mm
LED life	:	> 100,000 hours
Operating Voltage	:	AC 220V, 50Hz
Language	:	Hindi, English, Gujarati, Marathi
Character height	:	upto 450mm
Horizontal viewing angle	:	$>80^0$
Viewing distance	:	15-300m
Ingress protection	:	IP65 for front (LED face); IP55 for rear
Communication	:	Serial, Ethernet, OFC

13) The LED Cluster shall consist of individual LED's encapsulated in a resonated plastic housing proving protection to the elements under worst climatic conditions.

14) The modules shall be individually addressable and field replaceable.

15) Failure of one LED module should not affect the output of any other.

16) The system design shall be such so as the display is legible from a distance of between 15m to 300 m in all weather and lighting conditions.

17) Elaborate Fault diagnostics shall be provided as per EN12966 or other equivalent international standards. Each pixel shall be monitored and feedback shall be provided for the healthy status. Minimum of following shall be provided :

- Power Failure at VMS
- Processor PCB Failure
- LED Cluster Failure
- Loss of incoming message / data not properly received.
- Temperature monitoring

18) The VMS shall withstand shock and vibration existing on the expressway.

19) Controller functionalities

- The controller unit shall provide brightness control facility. The intensity of the VMS shall have at least six levels and it shall select the correct level automatically depending on ambient light conditions. For this, the VMS shall have photo sensor and dimmer control.
- The controller unit shall provide the monitoring of ambient temperature of the housing.
- The controller shall be provided with a test port for local diagnostics via laptop.

20) The VMS software should permit the following :

- Broadcast messages
- Specific address messages

21) It shall be possible to perform fault diagnostics from the central control room via the software.

22) Maintenance panels shall be provided on the rear of the housing

23) Maintenance walkway shall be provided on the gantry at the rear of the signcase. All component parts shall be easily and readily accessible by a single person for inspection and maintenance. There shall be room for a technician to work. Access shall be made by entering the side of the housing. The housing shall be weather tight, and compliant to the NEMA 3R Standard. The bottom panel of the housing shall have a minimum of four drain holes, with snap-in, drain filter plug inserts.

24) Ventilation - The ventilation system shall be forced air. The system shall be designed to adequately cool the pixels from all sides along with the front and rear of the display module and all other internal components. The ventilation system shall have the following properties:

- Positive pressure (exhaust fans are not acceptable).
- The fans shall have ball or roller bearings, shall be permanently lubricated and shall require no periodic maintenance. The fans are to be positioned in such a manner so as to provide a balanced air flow to the ventilation system in the event of failure of any fan.

a) Signcase

- All parts shall be made of corrosion resistant materials, such as plastic, stainless steel or aluminum. Painted steel is not acceptable. No self-tapping screws shall be used. The finish shall be matte black. The main body of the sign housing shall be constructed of aluminum with a natural mill finish. All exterior seams shall be continuously welded by an inert gas process, except for the coated fascia material. The signcase shall be constructed of non-ferrous material to avoid rusting. The VMS signcase shall have CFL lighting for maintenance during low light conditions.
- The performance of the sign, including the visibility and legibility of the display, shall not be impaired due to continuous vibration caused by wind, traffic or other factors.
- The angular alignment of the sign housing shall be adjustable in the

vertical direction from (0 to 10 degrees) down in one-degree increments to optimize the viewing angle.

- The housing shall be capable to withstand the following conditions for Vibration Test

  1. Frequency range : 10- 50Hz
  2. Vibration amplitude : 0.35mm
  3. Duration of endurance : 20 sweeps cycle
  4. Duration at resonant frequency : 30 min+ 1 min

  The Gantries for the VMS shall be designed and the design shall be got approved from the NHAI. It includes all civil works like foundations etc, and shall be done as per relevant standards.

15.1.5 Automatic Traffic Counter-cum-Classifier (ATCC)

Purpose and General Information

- This system shall be used for identifying and recording all types of vehicles on the Expressway for effective monitoring and data collection at Control Centre. The system shall be capable of detecting and recording all types of vehicles plying on the Expressway.
- Besides the above vehicle classes, the system shall be capable of classifying any other vehicle category as per need. Vehicle classification should be user selectable based on vehicle parameters.
- The system shall have interface with the ATMS software for central monitoring.

Location

- ATCC is proposed to be installed at at suitable location. The final location may be adjusted as per the site condition, only with the consent of the NHAI/Traffic and Transportation expert.
- The ATCC cabinet shall be installed in median or on the side of the expressway at a distance of 2 to 3 meters from the soft shoulder.

Major Components

Main components are:

a) Field components – consists of :
   a. ATCC roadside cabinet / electronics/data logger
   b. In-road/non-intrusive sensors and cables
   c. Field computer/laptop
   d. Power supply
   e. Lightning protection and earthing

b) CCR components
   a. ATCC server
   b. Application software
   c. Database software
   d. Report printer

Specifications

- The ATCC should be designed for 8 lanes of traffic i.e. one cabinet/data logging unit should be able to record data for at least 8 lanes (4 in each direction)
- System shall use a combination of loop and piezo sensors or any other sensor mechanism (intrusive or non-intrusive) for correctly counting and classifying vehicles.
- Piezo sensor installation shall be in concrete. ASTM 1318-02 recommends a concrete pavement of 90m (60m before sensor and 30m after) to ensure good accuracy.
- The ATCC shall detect all classes of vehicles as per toll classification scheme.
- . One or more of the following information shall be generated by the ATCC for each lane to correctly count and classify the vehicle:
  a. Vehicle length
  b. Vehicle speed
  c. Number of axles
  d. Axle spacing
  e. Axle load (WIM) and GVW
  f. Vehicle profile
  g. Vehicle image
  h. Any other proven technology with the consent of the Engineer and NHAI

2. The ATCC shall provide the following additional information:
   a. Occupancy
   b. Headway
   c. Gap
   d. Average Speed
   e. Flow rate

c) Data logger (roadside electronics): The requisite number of entry and exit ports to communication system shall be provided. The logic unit shall be micro-processor based. The system shall be able to count and classify vehicle in each lane. There shall be an indication to display vehicle detection .

d) Data logger shall have a Tamper Detection Alarm facility. Any effort to tamper with the data logger shall trigger an audio and visual alarm in the CCR.

e) Data collection: The system shall be capable of sending data to the ATMS Software which shall enable the Software to count and classify the vehicles, and provide other required information Data collection shall be by RS232, RS422 or RS485 interface or IP connection.

f) Data Storage: The system should be able to upload data to the system as it occurs. The unit shall store data of at least two weeks in event of communication failure.

g) System Accuracy (@95% confidence), whichever is applicable

   a. Vehicle length(m) : $\pm$ 5%

b.	Vehicle speed (kmph)	:	± 1.5%
c.	Vehicle count(nos.)	:	± 1%,
d.	Number of axles (nos)	:	± 2%
e.	Axle spacing (m)	:	± 2%,
f.	Vehicle class vehicles)	:	± 3% for Class Car/Jeep/Van (of detected
		:	± 5% for Class LCV
		:	± 3% for Class Truck/Bus (Two Axle)
		:	± 2% for higher classes
g.	Headway (msec)	:	± 7%
h.	Gap (cm)	:	± 8%
i.	WIM accuracy	:	± 15% on axle; ± 10% on GVW
j.	Vehicle speed	:	10-195 kmph

h) Coincidence detection (lane straddling): The ATCC shall be capable of determining and recording vehicles that straddle adjacent lanes. This reduces double counting of vehicles on sites where lane discipline is a problem.

i) Waether : The ATCC shall be capable of working with above mentioned accuracies , 24x7, in all weather conditions including heavy rain , dense fog and specified temperature range.

j) Reverse detection: The ATCC shall be capable of detecting and recording any vehicles traveling in reverse direction.

k) Data retrieval: The system shall be capable of data retrieval, direct data transfer through the Fiber Optic Network or locally through laptop.

l) Recording capability: The system shall have capability of recording vehicle counting and classification, speed, headway at set interval of 1-10 minutes.

m) Compatibility: The system shall have compatibility to transmit data over Optical Fiber Cable.

n) Fault monitoring : The system shall be capable of detecting and reporting the following fault events:

- Mains power failure
- Battery low voltage
- Modem communication error
- Laptop communication error
- CPU reset
- CPU failure
- Sensor fault (for each sensor)
- Door tamper

Software

The Application Software shall have the following features:

- It shall be GUI based
- The Opening Screen shall have password authentication

- Communications Parameters setting
- Configuration Parameters setting
- Raw and Binned data Retrieval
- Vehicle by vehicle Real Time Traffic Display
- Diagnostic Functions – Sensor Test
- Vehicle Classification Configuration & Weight Limits

Specifications for CCR equipment

- Server – The server supplied shall be the latest available in the market at the time of supply. However, the minimum specifications are given in subsection on “Servers” under section “Miscellaneous Equipment”.
- Application Software
  - Shall be a single software for all data loggers in each package
  - Shall be Windows based
  - Shall have unlimited period use license for each package
  - All upgrades shall be free of cost.
  - Shall communicate to each data loggers in the field and
  - Shall be GUI based
  - Password protected
- Database Software
  - Shall be password protected
  - records shall not be editable
  - Shall not be notepad, MS Word, Excel
- Reports – system shall be able to generate reports. All reports can be timewise, lanewise, locationwise or total summary reports for all data loggers. The reports shall be in tabular and graphic form. All reports shall be in metric units and dd/mm/yy time format. The following are the minimum reports :
  - Average Speed per Vehicle Category per Lane per Day
  - Traffic Volume per Vehicle Category per Lane per Day
  - Traffic Volume per Hour per Lane per Day
  - Axle Volume per Weight Band per Lane per Day
  - Volume (count) per Class per Lane
  - Average Speed per Class per Lane
  - Volume per Lane per Time Band
  - Volume per Speed Band per Lane
  - Overloaded Vehicles per Class per Lane
  - Average Speed per Category
  - Malfunction Management Report (fault report)

- Traffic Volume by Category by Lane (binned data)
- The reports shall be transferrable to MS Excel and Acrobat pdf format.
- Multiyear calendar adjusted for leap years

15.1.6 Video Surveillance System

Purpose and General Information

The purpose of the Video surveillance system is to monitor specific areas of the expressway remotely from the CCR by use of cameras installed at such critical junctions. This shall help in managing incidents.

The system shall also record and store video for analysis and future reference.

Major Components

Major components are:

- Field components :
  a) CCTV camera with housing
  b) CCTV pole
  c) Video transmission unit (encoder)
  d) PTZ control
  e) Power supply – solar panel
  f) Lightning protection and earthing
- CCR components
  a) Server with OS
  b) CCTV decoder/ switcher unit
  c) PTZ control/joystick
  d) Video Wall
  e) DVR
  f) Application software
  g) Database software

Functional Specifications

- Camera
  - The CCTV shall be PTZ type video camera.
  - The Video Camera shall be of dome type to avoid pilferage, be resistant to vandalism and weather-proof. The dome shall be of smoked glass so that it shall not be possible to see the camera (inside the dome) from roadside.
  - PTZ Cameras shall have 6 or more pre-defined positions.
  - The camera viewing distance of at least 1km in each direction. The horizontal rotation shall be 360^0 continuous pan and vertical tilt shall be 90^0 down to 0^0 horizontal.
  - The video camera shall transmit a clear video even in low light and night conditions.

- The camera and associated units shall be dust-proof and protected against water ingress.
- The CCTV video camera roadside cabinet shall house the power supply system and video encoding and transmission equipment.
- CCTV video camera shall preferably run on solar power.
- There must be a single encoder for each camera.

- Camera mounting
  - The camera shall be mounted on a properly designed pole of at least 10m height. The Video Camera mounting shall have easy accessibility for maintenance purposes while being protected from unauthorized access.
  - The mounting and equipment housing shall be able to withstand adverse weather conditions.
  - The camera mount should be of the same make as that of camera and suitable for the model number offered as specified by the manufacturer and should be an integrated unit.
  - Should support the weight of camera and accessories in a wind speed of 180kmph (min).
- Camera control & display
  - The camera images from all cameras shall be transmitted to the CCR for monitoring and storage.
  - All CCTV cameras shall be controlled by the CCR operator. Each camera shall be individually selectable and also the Pan , Tilt and Zoom functions for each camera.
  - The CCR shall have the facility to decode the video, record the video, display live and recorded video on a large video display and have PTZ controls.
  - The video from CCTV video cameras shall be viewed in the CCR on a video wall. The video wall shall be formed of expandable modules. The system shall allow CCR operator to blow individual images to fit the entire screen or any other size.
  - The CCTV video shall be recorded in the CCR in a DVR or computer.
  - Privacy Zone Masking: the camera software shall blocks scenes/areas that should not be displayed.
  - The CCR shall be designed in a way to ergonomically seat the CCR operators. There shall be one operator for every 6 video images.
  - System to have facility of additional camera installation beyond the originally planned capacity.
- CCTV software and recording
  - The CCR shall have a server with latest specifications for image processing, control and display.
  - System shall be triplex i.e. it should provide facility of Viewing, Recording & Replay simultaneously.
  - CCR shall have facility to record all videos from all simultaneously and store at least 30 days of video. This may be done by a separate DVR or

recording on the hard disk of the server. System shall have provision to automatically over-write the new information after the period of 30/31 days (First In First Out)

- The old recording shall be overwritten by new recording after 30 days
- The CCR Server shall have application software to control PTZ functions, select individual camera, playback video. It shall have access control (through password/login) so that no unauthorized person may view /edit any videos.
- The software should be able to control all cameras i.e. PTZ control, Iris control, auto /manual focus, and color balance of camera, Selection of presets, Video tour selection etc.
- The System should ensure that once recorded, the video cannot be altered, ensuring the audit trail is intact for evidential purposes.
- System must provide built-in facility of watermarking or Digital certificate to ensure tamperproof recording so that these can be used as evidence at a later date, if so desired. The recording shall support audit trail feature.
- The OS shall be off-the-shelf , preferably Windows.
- The offered system shall have facility to export the desired portion of clipping (from a desired date/time to another desired date/time) on CD or DVD. Viewing of this recording shall be possible on standard PC using standard software like windows media player etc.
- The software is required to generate reports of stored device configuration.
- The system shall provide User activity log (audit trail) with user id, time stamp, and action performed, etc.
- The administrator should be able to add, edit & delete users with rights. It shall be possible to view ability / rights of each user or the cameras which can be viewed & controlled as per the permission assigned by the administrator.
- The software for Employers should also be working on a browser based system for remote users. This will allow any authorized user to view the video of any desired camera on his monitor.
- Retrieval: The CCTV application should allow retrieval of data instantaneously or any date / time interval chosen through search functionality of the application software. In case data is older than 30 days and available, the retrieval should be possible. The system should also allow for backup of specific data on any drives like CD/DVD/Blu ray Recorders or any other device in a format which can be replayed through a standard PC based software. Log of any such activity should be maintained by the system which can be audited at a later date.
- Backup: Online backup should be maintained to protect against storage failure.

- Power
  - Surveillance CCTV System shall operate on 230 V, 50 Hz single -phase power supply.

- Power for all the equipment will be conditioned using on-line UPS with minimum 30minutes back up.
- If any equipment operates on any voltage other than the supply voltage and supply frequency, necessary conversion/correction device for supply shall be supplied along with the equipment

15.1.7 Mobile Radio Communication System

Purpose and General information

This Specification lays down the General, Functional and Technical requirements of Mobile Radio Communication System (MRCS) to be used as a sub-system of the Advanced Traffic Management System. All communication shall be to and from the CCR. The frequency band of operation is envisaged to be in the VHF band.

Mobile sets shall be installed in patrol vehicles, cranes and ambulances and shall communicate with CCR and also among themselves. The system shall use a pair of frequencies to be allotted to the concessionaire with the approval of relevant government bodies.

Major Components

The MRCS shall comprise of:

- Base Station Unit
- Repeater Unit
- Mobile Radio Unit
- Control Centre Equipment
- Rack

a) Base Station Unit:

- Transmitter
- Receiver
- Antenna with tower/mast
- Switch
- Radio Engineering terminal
- Radio Operator terminal
- Power Supply

b) Repeater Unit:

- Transmitter
- Receiver
- Antenna with tower/mast
- Repeater
- Power Supply

c) Mobile Radio Unit:

- Transmitter
- Receiver

- Antenna with tower/mast
- Control Unit
- Power Supply

d) Control Centre Equipment:

- Network Management System
- Headphone and microphone
- Voice recorder (optional)

Specifications

1) The system shall establish voice communication on radio between the Control Centre and the emergency mobile vehicles such as ambulances, cranes & patrolling vehicles.
2) The system shall cover the entire route.
3) The topology of the communication system shall cell centric (Repeater System).
4) All the Repeaters and Control Station shall be connected via Optical Fiber Cable (OFC) backbone on Ethernet port
5) There shall be minimum distortion in overlap areas of two towers.
6) All communication shall be half duplex
7) The system shall use one pair of VFH frequency allocated by WPC. In case two pairs are allocated, they may be reused in alternate sections.
8) The network shall be laid such that all the field mobiles are approachable to at least one Repeater.
9) The system design shall be modular in nature and easily configurable through on site programming.
10) The system shall have voice logger at the CCR to record all calls.
11) The system shall have Operator PC and microphone & speaker for the CCR operator.
12) The system design shall be modular in concept.
13) The radio base/repeater units shall be connected over OFC.
14) The system shall have the following features:
    - Operate in half or full duplex mode
    - Operate in VHF preferably using one pair of frequency (i.e. two frequencies- one RX and one TX) . If only one frequency is available, half duplex mode is acceptable.
    - Programmable VOX operation.
    - CCIR / DTMF tones for Mobile to Repeater Communications.
    - Mobile/handheld to mobile/handheld communication.
    - Mobile/handheld to CCR communication
    - CCR to Mobile/handheld communication.
    - Group call communication.

- Broad Cast Communication
- Call Limit Timer.
- Digital display on mobile units
- OFC connectivity. The mobile radio shall be integrated with the Fibre Optic Communication system.
- PTT (Push To Talk)

15) The system shall work satisfactorily under adverse conditions like storm, rain, and vandalism resistant. The system shall be compact & rugged in design having ease of maintenance.

16) The system shall neither affect functioning of other telecom equipment installed adjacent or along it, nor get affected by the presence of other equipment / systems.

17) The Mobile Radio shall have provision for mounting the mobile set on ambulances, cranes and patrolling vehicles.

18) The walkie-talkies shall work on re-chargeable batteries with 24 hrs. back-up. Mobile sets shall derive power from battery of the vehicle in which installed.

19) The equipment shall have facility to configure the network for individual, sub-group or broadcast mode of operation for both selective calling and group calling operation.

20) The system shall have the facility to terminate the mobile to mobile connection under the following conditions:

- One of the two parties hangs up
- One of the two parties receives a call from the Control Centre
- The duration of the conversation exceeds 5-minute limit

15.1.8 Meteorological Data System

Purpose and General Information

Purpose

The Meteorological Data System shall be capable of providing data regarding weather including Air Pollution parameters, atmospheric temperature, humidity, visibility, wind speed & direction. The information based on these data shall be made available to the road users through VMS so that they are forewarned of the weather conditions on the expressway.

Air Quality Index (AQI):

An Air Quality Index (AQI) has been developed by Central Pollution Control Board based on the dose-response relationship of various pollutants. This is called Indian AQI or IND-AQI (for India).

A minimum number of three pollutant parameters (Suspended Particulate Matter (SPM), Sulphur Dioxide (SO2) and Nitrogen Dioxide (NO2) are essential to calculate the AQI. Any additional information on other pollutants such as Respirable Particulate Matter (RSPM or PM 10), Carbon Monoxide (CO) and Ozone (O3) are included to calculate conclusive and complete value of AQI.

The developed index is classified in five categories: Good (0-100), Moderate (101-200), Poor (201-300), Very poor (301-400) and severe (401-500).

For this tender SPM, SO2 and NO2 shall be used and IND-AQI calculated.

Location

The Meteorological Data System shall be located at an interval of average 100km. However, required adjustment in the locations can be made only with the consent of the NHAI.

Major Components

The Meteorological Data System shall have following components:

a) Sensor for atmospheric temperature
b) Sensor for road surface temperature
c) Sensor for humidity
d) Sensor for visibility
e) Sensor for wind speed & direction
f) Sensor for air pollution parameters like SPM, NO_2 and SO_2.
g) Data Acquisition Unit / Logger
h) Control room computer
i) Software – application, OS, database

Specifications

1) The Meteorological Data System shall provide data regarding
   - atmospheric temperature
   - humidity
   - visibility,
   - wind speed & direction
   - air pollution parameters - SPM , NO_2 and SO_2.
2) The data from all sensors shall be fed into the data logger.
3) This information shall be made available to the users through the variable message signs as per requirement.
4) The Meteorological Data System shall have the facility to communicate through PIJF/Optical fibre cable.
5) The Meteorological Data System shall be compact, rugged in design and have ease of maintenance.
6) The software in the CCR shall be capable of processing sensor data, store and retrieve it and draw reports.
7) The software shall also calculate AQI and generate reports.
8) All reports shall be tabular as well as graphical.
9) The weather data shall automatically be fed to the VMS subsystem. The VMS may also be then capable of display these data at fixed time intervals.
10) Specification of Application Software (in the CCR)
    - The application software for continuous air monitoring shall be Windows based.
    - Provision of Calibration windows for analyzer calibration from computer.

- Main windows for real time display of all major parameters with status of all analyzers and sensors.
- Control Panel window for control of each analyzer.
- Alarm window for alarms of all analyzers and sensors
- Real time and multi curves / graphs for all parameters.
- Historic multi curves/ graphs over user selectable time period.
- Real time status & diagnostics for maintenance people.
- Programmable down loading of data from Analyser
- Report generation over user selectable time period.

15.1.9 Video Incident Detection System (VIDS)

Purpose and Geneal Information

The purpose of the VIDS is to sense, detect and record the incident. The system shall be an intelligent image detection using camera. The VIDS shall have inbuilt intelligence to ascertain when the image has meaningfully deviated from the standard image originally recorded. A pilot run for VIDS is suggested before implementation.

Location

VIDS is established at strategic locations.

Major Components

The major components are

- Field components :

a) VID camera with housing

b) Pole

c) Data transmission unit (encoder)

d) Power supply – solar panel

e) Lightning protection and earthing

- CCR components
  a) Server with OS
  b) Data analyzer
  c) DVR
  d) Application software
  e) Database software

Functional Specifications

The system shall capable to

- Measure traffic flow speed between 0 and design speed for up to 6 lanes
- Detect vehicles diving in wrong direction
- Detect stopped vehicles within 10 secs and for up to 16 detection zones
- Detect deceleration

- Detect fog/smoke
- Detect automatically types of traffic flow: normal, dense, delayed, congested and stop and go
- Monitor zone occupancy of the detection area
- Generate alarms for events: queue, stop, Inverse direction, speed drop, no video signal, fog/smoke and error,

15.1.10 OFC Backbone

Purpose and General Information

The purpose of the OFC backbone is to transport voice, data, LAN and video services between the field equipment and CCR.

As the transmission system would be used as a backbone network, the system shall have following characteristics:

a) High Availability

b) High Reliability

c) Dual ring configuration

d) Easy to install and operate

e) Scalability

f) High degree of flexibility with respect to the types of interfaces

Location

OFC shall be laid all through the expressway. It may be laid on RHS or LHS of the main carriageway or in the median. Lateral elements shall be connected on OFC or copper.

Major Components

The major components are

- Optic fibers
- Ducts
- Manholes/pulling chambers

Specifications

1) Number of cores shall be sufficient to carry all data with 100% spare data carrying capacity.

2) Topology

Each backbone shall consist of access nodes (see section on OTC) interconnected by a dual physical fiber optic ring for redundancy.

The standby ring shall take over automatically with minimum delay whenever a problem occurs on the active ring. If a complete cable break occurs, which means that both the active and standby rings are interrupted, the system shall automatically perform a loop-back operation, isolating the fault, and maintaining communications of all user equipment connected to the network.

After a power failure, a ring reconfiguration or when a new node is added to the ring, the complete network shall start up automatically.

1) The backbone OFC shall connect to field switches (in outdoor cabinets) which are further connected to field devices (cameras etc.). The ECBs may directly be connected with each other i.e. without external field switches.
2) The backbone OFC shall be single mode fiber.
3) Duct –HDPE ducts shall be used to carry OFC along the expressway. In areas where ducting is not possible , trenchless laying shall be done. Road crossovers shall be done using HDD.
4) All fiber optic cable runs installed shall be either main backbone cable or lateral cables. The main backbone cable shall be terminated in the Communications Node. The lateral fiber cables shall be terminated with a fan-out kit at the termination block in the field equipment cabinet.
5) Main backbone and lateral cables shall be suitable for conduit installation. Lateral cables that connect the main backbone cable to the equipment controller cabinets shall be completed with continuous runs of cable. All lateral cable shall include a maximum of three locations of appropriate strain relief within the field equipment cabinets.
6) All optical cables shall comply with International Telecommunications Union (ITU-T).
7) All optical cables shall be new, unused and of current design and manufacture.

15.1.11 Outdoor Technical Cabinet (OTC)

Purpose and General Information

There shall be data concentrators or integrator switches (also called “field switch” or simply “switch”) installed along the expressway which shall connect the field equipment to the OFC backbone. The purpose of the Outdoor Technical Cabinet (OTC) is to house these field integrator switches or data concentrators along with other necessary equipment and accessories.

The other purpose is to provide a secure and environment controlled surroundings to the equipment housed in it.

Location

The OTCs shall be located along the expressway on the central median.

Major Components

The OTC unit shall consist of:

a) Cabinet
b) Data Concentrator or integrator Switches
c) Power supply and UPS
d) Termination panels
e) Environmental controls

Specifications

The functional specifications are as follows:

1) Cabinet & environmental controls
    - The cabinet shall be mounted on concrete pads.

- It shall be lockable and shall have tamper proof lables affixed on it providing details of serial number, date of manufacture etc.
- It shall be weatherproof and shall not allow ingress of water and smoke. It shall maintain an internal temperature within the ambient range of all equipment housed in it. For this it shall have fans and heaters as necessary.
- It shall have a maintenance lamp which shall switch on automatically whenever the door is opened. The lamp shall be easily replaceable and shall be powered by the OTC's power supply.
- It shall be designed in such a manner that all the equipment mounted inside it are easily accessible. For this, it may have doors at the rear.
- It shall have two lifting eyes for lifting during installation.
- It shall have tamper switch and temperature sensors which give an alarm to the CCR if any tampering is being done or if the temperature goes out of the design limit. The sensors shall be connected to the CCR through the switch over NMS.
- The wires and connectors shall be neatly tied and harnessed through channels.
- It shall be properly earthed and have adequate protection from lightning.

2) Power Supply

- The power supply shall be suitable for all the equipment housed in the cabinet. It may be DC or AC or a combination of both.
- The power supply / UPS shall have adequate protection from noise, surge and lighting. For this it may have fuse, MOV and circuit breaker.
- It shall be online type with automatic voltage regulation.
- It shall include sealed maintenance free batteries with backup time of at least 30minutes.
- It shall have overvoltage and over current shutdown.
- The power supply shall have a port which shall connect to the Data Concentrator switch. The data from this port shall notify the CCR of the health of the power supply through NMS.
- It shall have LEDs/display/audio alarm or other indicators on its cabinet which shall indicate health and fault conditions including input voltage, overload, battery charging etc.

3) Termination panels

- The termination panels shall be housed inside the cabinet.
- The communication cables from field equipment shall terminate in this panel.
- Patch-chords shall be used to connect this panel to the Data Concentrator.

4) Data Concentrator or Integrator switches

- The switches shall connect to all field equipment and also to the OFC backbone.

- ECBs and other ATMS equipment shall not be connected on the same switch.
- The switches shall adequate number of ports to connect all field equipment. It shall also have 10% spare ports.
- The switch shall ports cable of handling all output types generated by the field equipment which may include analogue and digital - audio, video and data.

15.1.12 Power Management System

Functional specifications

1) Solar power shall be preferred over State Electricity Board (mains) and DG power.
2) Mains power shall be preferred over DG.
3) Wherever DG is used, it shall be used to power as many equipment as possible.
4) UPS with minimum 60 min backup shall be used wherever DG power is used. The DG shall be rated to at least twice the UPS rating.
5) The preferred power distribution is as follows :
   - ECB – solar power
   - CCTV/VIDS – solar
   - VMS – DG
   - ATCC – solar
   - Mobile radio - DG
   - Meteorological Data System – DG
   - Outdoor cabinet – solar / DG
   - CCR – mains / DG

15.1.13 Communication System

Purpose and General information

The purpose of the Communication System is to act as an interface between the field equipment and the CCR devices like displays and monitoring & control devices.

The communication system shall be “transparent” between field equipment and CCR i.e. it shall appear to the CCR device as if the remote field device is connected directly to it. The communication system shall be fast, reliable, support required data rates and have some built in redundancy.

Location

The communication system is located along the expressway and the CCR.

Major components

The communication system shall consist of:

- OFC (including termination panels, manholes, splicing, cables and connectors)
- OTC

- NMS
- Data concentrator at the CCR

Functional specifications

As defined in sections covering OFC, OTC and NMS

Technical specifications

As defined in sections covering OFC, OTC and NMS

15.1.14 Network Management System (NMS)

Purpose and General Information

The Fibre Optic Transmission System shall be equipped with a user friendly, Microsoft® Windows®-based Network Management System (NMS). The NMS shall allow the operator to manage and monitor multiple sub-networks in an efficient way.

The NMS shall have the following functionality: network configuration, configuration of services, monitoring, diagnostics, activation-deactivation of interface modules, bandwidth allocation, alarms and event logging and graphical network representation.

The network management hardware shall consist of a Personal Computer, which at the time of installation is the current industry standard. The NMS architecture shall be based on Employer-server technology. It shall be possible to connect multiple active Employers to the NMS server allowing network management from multiple and/or remote locations or by multiple users

Location

Software at CCR

Major Components

1) Personal computer
2) NMS software

Functional Specifications

1) It shall be possible to connect the NMS system to the network at any node via Ethernet.
2) Using the NMS, it shall be possible to configure the hardware modules that make up the network: nodes, network cards, interface cards and optical transceivers.
3) The Network Management System shall allow the user to activate or deactivate an interface module.
4) It shall be possible to create various services over the network.
5) The NMS shall allocate the transmission channels to virtual point-to-point or multi-point services in order to achieve an optimal bandwidth allocation. It shall be possible to configure the network and the services without being connected to the network, either via the Graphical User Interface (GUI) or via scripting.
6) NMS shall display a simple map of the network in form of a tree.
7) NMS shall provide Real Time Management Information Bases (MIBs).
8) Automatic reconfiguration

The management platform shall not be critical in the reconfiguration sequence of the system. It will only report the event in detail to the network operator.

Relevant configuration details shall be stored in the Random Access Memory (RAM) module of each node. After configuration, the network shall continue to work autonomously and shall reconfigure in error situations. It is therefore necessary that the reconfiguration algorithm resides in the nodes themselves.

9) NMS database

The NMS shall contain the network database containing all kinds of information: sub-network names, node names, and node configurations including installed network and interface cards. It shall be possible to make the following on-line changes: activation or deactivation of interface cards, addition or removal of interface cards, and addition, changing or removal of services. Each change shall automatically update the database on the hard disk of the network management PC and the RAM memory of the relevant node(s). It shall be possible to use the database to restore the network configuration in case settings in one or more nodes are lost due to a hardware defect.

10) Fault and Alarm Management

It shall be possible to easily monitor the operation of the different sub-networks that make up the network. During normal operation, the NMS shall continuously poll all the network nodes. It shall compare the status of the network with the information resident in its network database. If a fault or change occurs, the GUI screen on the NMS PC will display an alarm message indicating the nature and location of possible errors or changes. The alarm messages shall include at least the date, time, node, interface slot and/or interface port, alarm severity and description. Via the GUI, it shall be possible to register following events: loss of synchronization, network reconfiguration, node failure, interface card errors and external alarms. It shall be possible to store the events in the NMS database.

Errors and unexpected conditions shall be reported by the network management system in another color than the one used upon correct operation.

11) Internal alarm forwarding

The NMS shall be capable, via an alarm relay card, of forwarding the status of internal alarms to other devices such as beepers or lamps. It shall be possible to use this alarm relay card to convey network alarms to a third party umbrella alarm management system. An SNMP agent on the management system shall offer basic alarm forwarding and retrieval to an SNMP-based umbrella management system. It shall be possible to forward internal alarms to third party equipment via CORBA (Common Object Request Broker Architecture).

12) External event Management

It shall be possible to display the status of external events on the NMS system. It shall also be possible to forward this alarm information to an alarm relay card connected to the NMS PC.

15.1.15 Central Control Room (CCR)

Purpose and General Information

The purpose of the CCR is to monitor the expressway and to provide information to the road user. The CCR also houses the central servers and data processing equipment.

The CCR shall provide the real-time information and assistance to the Expressway users, collect data for the use of expressway authorities and to monitor and control the Traffic on the expressway as per the requirements.

The CCR shall be designed for round the clock operations of monitoring, on-line information acquisition and processing the same for decision making. The CCR shall be the repository of all the data acquired from the field and their processing, storing, and archiving. All the information for real time monitoring oh expressway shall be generated at the CCR and the relevant information shall be disseminated to the users through VMS, and to O&M teams through mobile radio.

Location

There shall be one CCR located in any toll plaza.

Major Components

- Emergency Call Operator Station (Emergency calls from ECB's)
- Mobile Call Operator Station (Mobile radio calls)
- Integrated Expressway Management / Traffic Manager station (Operating Variable Message Signs, Traffic Counting & Classifying System, Meteorological Data System, CCTV & Video Incident Detection)
- Video Wall
- Servers
- Switches
- Administration Computer and Network Printer
- Computer for NMS for fiber Optic Communication system.
- CCTV console equipment
- VIDS control equipment
- Computers for VMS, AVCC, Met, Traffic Control
- A network printer
- An office computer (administration terminal)
- A power supply and backup system

Functional Specification

The CCR shall have the following functions and capabilities:

1) Real time images of the expressway locations (from camera locations) to the control centre.
2) Emergency communication system for communication from the predefined ECB locations to the control centre.

3) Real time information to the users from control centre (about the route conditions, traffic situation, etc.) using variable message signs installed on gantries.
4) Real time monitoring of the traffic situation and collection of traffic data using traffic counting and classifying system
5) Monitoring of the weather conditions
6) Dedicated Mobile Radio system for communication between the control centre, ambulances, patrol vehicles, etc.
7) Traffic Control System at the interchanges
8) Monitoring and control of the expressway traffic from the main control centre using integrated expressway system
9) Compilation, recording, analysis, processing, storage of traffic information and data
10) Monitoring and control of the various sub-systems and devices installed on the expressway
11) The following shall be the servers at CCR:
    - Server for Emergency Call System
    - Server for Video Surveillance system, VIDS system
    - Common server for VMS, ATCC, Meteorological Data System
    - Server for Mobile Radio Communication System

15.1.16 Miscellaneous Equipment

Server

Servers shall be located in the CCR and run application software. The server supplied shall be of the latest configuration at the time of installation. However the minimum specifications are as follows:

1.	OS	:	Windows Server (Enterprise) preloaded
2.	Processor	:	Quad Core, 3 GHz, 2x4MB shared cache, 1333MHz FSB
3.	Memory	:	8GB DDR2 , 800MHz
4.	Drive controllers	:	Integrated serial ATA controller with RAID0,1,5 and 10, removable boot drive option.
5.	Hard drive	:	minimum 5 SATA drives of 500GB each with RAID5
6.	Network adapter	:	Dual embedded gigabit Ethernet NIC & PCI NIC
7.	Optical drives	:	DVD/CD RW combo
8.	Database	:	Oracle, MySQL or equivalent shall be included
9.	Monitor	:	19 inch TFT included
10.	Keyboard and mouse	:	included
11.	Mounting	:	19” rack mountable

Printer

There shall be one network printer in the CCR for reports. The printer supplied shall be of the latest configuration at the time of installation. However the minimum specifications are as follows:

1) Print speed : upto 52ppm letter; upto 50ppm A4
2) Speed : first page out < 9sec
3) Resolution : min 1200x1200 dpi

UPS

UPS shall be installed wherever necessary, for backup of all electronic equipment so that overall service levels and requirements mentioned in this document are met.

UPS of adequate backup time shall be installed at least for

a) All CCR equipment's
b) Outdoor Technical Cabinets
c) All other equipment wherever power backup is required

Specifications

The UPS shall have the following specification:

1) Minimum backup time for UPS backed up by other power supply/DG shall be minimum 10 minutes. It shall be ensured by the vendor that power supply (combination of UPS, Solar, Generator , mains or any other supply) is provided in such a manner that all equipment is powered at all times , round the clock.
2) Input

Nominal Input Voltage : 220 V AC

Input Voltage Range : 140 V – 300 V AC on Full Load

Nominal Input Frequency : 50 Hz

Input Frequency Range : 45 – 55 Hz

Input Power factor : >0.97 at 220 V AC for full resistive

Modes of Operation

The UPS shall be designed to operate continuously at rated capacity as an on-line, automatic system in the following modes:

1) Normal - The inverter continuously supplies AC power to the critical load. The converter converts commercial AC power to regulated DC power which then serve as the inverter input and, simultaneously, as a float charge input to the storage battery.
2) Emergency - In the event of a commercial AC power failure, the inverter shall derive its input from the system battery, thus providing uninterrupted power to the critical load. This transition shall be accomplished without any switching or coupling, and with no interruption of power to the critical load from either a failure or restoration of the commercial AC power.
3) Recharge - Subsequent to restoration of commercial AC power, the converter shall automatically reactivate and provide DC power to the inverter,

simultaneously recharging the system battery. This occurs automatically and without interruption to the critical load.

4) Bypass - In the event that the UPS must be taken off line due to an overload condition or UPS failure, the critical load shall be transferred to the bypass source via the static switch without interruption of power to the critical load. The static switch shall only be utilized for automatic emergency transfers. A re-transfer from bypass to inverter shall be performed automatically in overload conditions. A re-transfer shall be inhibited if satisfactory synchronization of the inverter and bypass is not accomplished.

Diesel Generator

The contractor shall provide diesel generators wherever required (primarily for VMS and CCR). The rating of the DG set shall depend on the connected load, however DG of 10kVA single phase for VMS and 175kVA 3phase for CCR is suggested. The DG arrangement shall have the following requirements:

1) DGs shall be provided in pairs i.e. two DGs per site with each running continuously for maximum 6 hours.
2) It shall be self-start with 12V DC starter motor.
3) Battery charging Alternator.
4) It shall be silent type.
5) Conform to BS 5514 / ISO 3046
6) Output per phase 220V $\pm$1%, 50Hz
7) Instrument panel with starting switch & key, indication for battery voltage, water temperature, lube oil pressure, engine speed, engine hour counter, battery voltmeter, output voltage and frequency.

Solar Panel

The vendor shall provide Solar Panels of adequate capacity wherever required. The following are the minimum specifications.

1) Photo Voltaic (PV) cells shall be made of crystalline silicon
2) Cell encapsulation: ethylene vinyl acetate (EVA)
3) Mounting: pole mounted
4) Frame structure: Aluminum
5) Front side : Glass with thickness of min 3mm
6) Operating temp range ; -40 to +90 0C
7) Storage temp range ; -40 to +90 0C
8) Wind resistance: 60m/s

Rack

Equipment supplied at the CCR shall be rack mountable wherever possible. This includes servers, controllers, UPS, fiber patch panel etc.

CCR Software

The requirements of individual ATMS subsystems have been defined in relevant sections. The following are the integration requirements of application softwares of the ATMS subsystems:

Sl.	Subsystem	Requirements
1	ECB	• Separate Server with application software , OS and database
2	Video Surveillance System, VIDS	• Separate Server with application software , OS and database • Video may be recorded in Server or DVR
3	VMS, ATCC, Meteorological Data System, Mobile radio	• Common server and database for all these applications. • The relevant weather and ATCC data shall automatically be fed to VMS.
4	NMS	• Can be run on any server

Features

The following features are required from the ATMS software

1) The following shall be provided as option –
   - Although separate servers have been specified for separate applications, it shall also be possible to run any application from any server and all applications from one server in which case there shall be one common database.
   - One additional server to function as database server.
2) Alarm conditions of each subsystem shall triggered in respective application software.
3) The software shall have facility to send e-mail to pre-configured e-mails as per the following :
   - Breakdown events – to maintenance team
   - Emergency events – to concerned relevant external authorities like police and to designated internal staff. Emergency events shall be triggered by the personnel manning the ECB, CCTV and Radio stations.

     The “e-mail send” process shall be configurable to “manual” and “automatic”
4) The configuration as shown in the table above is suggestive. However, as all computers / servers are on the network, it shall be possible to run any application on any computer.

15.1.17 Availability Requirements

The inability to perform any required function, the occurrence of unexpected action or degradation of performance below the specifications shall be considered as a failure. The Mean-time-between-failure (MTBF) shall be the average operating time accumulated by the total population of identical items between failures. The system supplier/contractor shall submit MTBF and MTTR figures. The ATMS shall have an overall system availability of better than 99 percent. The ATMS shall be considered unavailable if any of its function cannot be properly executed and when any of the following conditions persist for more than 8 hours on the entire stretch.

i) Variable Message System Failure**:** No display/Improper Display of VMS or failure of their related transmission/control system which would render the VMS inoperative

ii) Emergency Call System Failure: Failure of any three consecutive Call boxes or failure of their related transmission system which would render the call boxes inoperative.

iii) ATCC Failure: Failure of more than one ATCC or failure of their related transmission system which would render the ATCC inoperative.

iv) Met Failure: Failure of more than one Met or failure of their related transmission system which would render the Met inoperative.

v) Video Surveillance System Failure: Failure of more than two Video Cameras or failure of their related transmission/control system which would render the cameras inoperative.

vi) Video Incident Detection System Failure: Failure of more than one Video Cameras or failure of their related transmission/control system which would render the cameras inoperative.

vii) Display at Control Centre: Whenever Control Centre is unable to get display of messages initiated by the Control Centre in-charge.

In addition to the above the system shall be considered unavailable when failure of the integrated ATMS Software or its hardware persists for more than 8 hours.

15.1.18 Maintainability Requirements

The Mean-Time-to-Repair (MTTR) of the ATMS to full normal operation following a failure shall be less than 8 hours all inclusive.

15.1.19 System Safety Requirements

All metal enclosures shall be provided with an earthing terminal and earthing of all equipment shall be carried out in accordance with overall earthing policy.

15.1.20 Environmental/Climatic Requirements

Indoor Equipment:

Temperature (Operating)	:	$0^{o}C$ to + $50^{o}C$
Relative Humidity	:	up to 95% (non-condensing)

Outdoor Equipment

Temperature (Operating)	:	$5^{o}C$ to + $60^{o}C$
Relative Humidity	:	up to 95% (non-condensing)

The system and the equipment used as a minimum shall meet the following climatic and environmental requirements as specified in IS:9000 :

Tests	**Severities**
Change of Temperature	(i) Low Temp 0°C + 3°C
(Temp cycling) as per	(ii) High Temp 60°C + 2°C
IS:9000 (part xiv/sec1)	
Rate of cooling and heating 1°C/m	(iii) Duration for each cycle 3 hours
	(iv) No of Cycles 3

These guidelines include hardware and software functionalities. Alternately, some guidelines are available in “Specifications for Road and Bridge Works (Fifth Revision) published by IRC” – also called Orange Book, Section 816.

15.2 EXPRESSWAY ROUTE OPERATIONS

15.2.1 Introduction

This section deals with Expressway Route Operations consisting of the following:

1) Expressway patrolling operations
2) Ambulance operations
3) Crane operations
4) ATMS Central Control Room (CCR) operations

Expressway Route Operations Strategy

The following shall be the strategy for route operations:

1) There shall be ERV stations built on the expressway. The purpose of such stations is :

- Providing parking space for the ERVs
- Provide amenities like water, electricity and shade.
- Act as space for installing equipment like DGs, field cabinets, radio tower equipment etc., if required.
- ERV Stations shall be located in such a way to allow for compliance of response times of ERVs. Existing facilities like toll plaza and wayside amenities shall be used wherever possible.

Expressway Patrolling

Expressway patrolling teams shall perform regular 24 hours patrolling/ surveillance of the ROW in respect of the Project/ Project Facilities. There shall be adequate number of dedicated patrolling vehicles for this. The team will monitor report and take actions against activities, such as, encroachments, unauthorized construction of road or entrance connections, structures, interference with drainage system etc., within 150 m of the Expressway corridor. Surveillance shall also include traffic operation and management of accidents / other incidents.

The Expressway Highway Patrolling Teams shall include a Route Patrol Officer (RPO)/Traffic Safety Officer, Driver, Assistant Route Patrol Officer (ARPO)/rescue man and a helper. These members shall

- have basic automobile and first-aid knowledge
- be provided with cellular phones and a wireless system and be connected to the ATMS Central Control Room (CCR)
- be equipped with cones, first-aid box, search lights, fire extinguisher, ropes, portable gas cutter and minor automotive accessories.
- be trained on route closure procedures
- be provided with a Digital Camera. If needed they will record any event immediately on reaching the spot for further assistance to the authorities.

The objective of the Expressway Patrolling team is to:

- Continuously monitor the expressway at a drive speed of not more than 30kmph.
- Reach the spot of accident or incident within a maximum of 45 minutes.

- Communicate the events to the higher-level officer and initiate corrective actions within the least possible time.
- Co-ordinate with police, fire, ambulance, crane and other relief facilities for completing the statutory requirements, relief/rescue operation, debris clearance operation.
- Keep strict vigil on the entire Project Highway at all hours so that no driver parks his vehicle on the carriageway. Parking shall be exclusively within shoulder with major store of the vehicle on earthen shoulder.
- Encroachment removal

Safety, Vehicle Breakdown and Accident

- In case of unsafe condition, vehicle breakdowns and accidents, the Concessionaire shall follow the relevant operating procedures, which shall include the setting up of temporary traffic cones and lights as well as the removal of obstruction and debris expeditiously.
- The Concessionaire shall ensure that any diversion or interruption of traffic is remedied without delay.

15.2.2 Emergency Response Protocol

The events of emergency can be classified into three levels as described below:

Common Event

Event that requires the closure of not more than one lane on a carriageway for mitigation and treatment of event:

- Traffic accident with or without fatality
- Prolong closure of one lane after an event
- Specialist or heavy machinery arrival for removal of obstructing source
- Recovery time to normalize road condition
- Unscheduled works for treatment of road

Non-Common Event

- Event that obstructs and requires the closure of one carriageway.
- Event affecting two consecutive sections that needs to be resolved.
- Event involving VIPs
- Event involving Concessionaire staff
- Major accident that may attract media attention
- Traffic jam / pile up (congestion) at toll plaza or mainline.

Major Non-Common Event

a) Closure of Project Highway due to :

- Major accident
- Flooding and other natural disaster
- Accident involving hazardous material

b) Event involving two Regions / Boundaries

c) Accident involving dignitaries / VVIPs

The decision making for the three categories will be as follows:

a) Common Event - ERP executive on duty

b) Non-Common Event - PRO / Maintenance Executive

c) Major Non-Common Event - Project Manager

The objectives of ERP team will be

1) Inform and co-ordinate with emergency and rescue services like police, hospital, ambulance, fire, crane etc.

2) Take precautionary measures to guide and regulate safe traffic movement.

3) Initiate measures to assure safety of other road users and public due to effects of toxic and inflammable materials if any.

4) Take precautionary measures to safeguard third party properties.

5) Co-ordinate with various agencies to clear the road of debris and resume normal operations at the earliest possible.

6) Report and exchange information among various team members for information and decision-making.

The Expressway Patrolling teams shall respond and try to reach the site to extend assistance within a maximum time of 30 minutes subject to traffic bottlenecks. The Patrolling teams shall generally be stationed at the Traffic Aid Posts close to or within the toll plaza complexes and report to the CCR. The Highway Patrolling teams and the ERP team will communicate with the emergency services for rescue and relief operations to accidents and other unsafe situations occurring on the project highway;

1) The following shall be called the Emergency Response Vehicles (ERV):

   - Ambulance
   - Crane
   - Towing vehicle
   - Route patrol vehicle

2) Ambulances, cranes, patrolling vehicles shall be available 24x7 and dedicated to this Expressway. Provision shall be made that if any ERV is off roads for any reason (breakdown, maintenance etc.), a replacement vehicle shall promptly be made available so that service levels are maintained at all times.

3) All above vehicles must meet the Vehicle Response Time (VRT). This is the time elapsed between the call made to the CCR and the vehicle reaching the destination (incident spot). For this purpose either the vehicles may be located at the toll plaza, wayside ameneties or suitable space/shed be made available on the Expressway.

4) The following are the VRTs defined for the Expressway:

   - Ambulance – 10 minutes
   - Crane/towing vehicle – 1 hour
   - Route patrol vehicle – 30 minutes

5) Adequate number of vehicles and drivers shall be made available to comply with defined VRT at all times.

6) Each ERV shall be fitted with a GPS device which shall at least provide the vehicle location. This shall be monitored at the ATMS CCR as well as by anyone authorized by the NHAI.

7) The route patrol personnel shall be provided with vehicles, safety attires (safety vest, rain coat and safety shoes) and a phone for communication purpose. The vehicle will be equipped with cones, blinkers, flag, beacon light, fire extinguisher, and baton light for traffic management purposes.

8) Tow-Truck / Cranes of capacity 30 metric tonne having all requisite arrangement of pulling and shifting accident / break down vehicles also will be made available by the Concessionaire.

9) Fire tender services from the fire stations available along the Expressway shall be extended to the project by the local authorities. The details of services shall be made available to NHAI before start of operations. It shall be updated every three months.

10) The Concessionaire will display the information about these emergency services at either end of the Project Highway.

11) Emergency helpline number(s) shall be displayed all along the Expressway through static signs and also be printed on the entry ticket and toll receipt. This number shall connect to the CRO at the ATMS CCR.

12) The users will be informed on an Emergency situation at the toll plazas as well as through the VMS.

Rescue Operation

In the event of accident, protest, public nuances, inform Police of the extent of crowd, situation likely to develop. In case of removal of debris, required JCB and labour for shifting shall be arranged with the assistance of local authorities to assure immediate operation.

Medical & Aid Services

First Aid shall be provided by paramedical persons. Further as per requirement, the injured shall be shifted to the local hospital by ambulances with the assistance from the local authorities. Necessary road closure, diversion shall be provided.

15.2.3 Management Information System

The Management Information System for Operations shall be established by the Concessionaire and its reports in text and graphic form provided to NHAI or anyone authorized by it.

1) Monthly Traffic Report (for each plaza):

   - Total traffic count by vehicle class for each day of the month (ATCC data)
   - Tollable traffic count by mode for each day of the month (Audited toll data).

2) Monthly Operations Report: This shall identify the following, at the minimum:

   - All the accidents or incidents on the Project Road during the month under report. This shall be in report as well as graphic form. The graphic form shall plot incidents/accidents vs chainages and shall be useful for Blackspot Analysis.

- Number and type of the complaints received from Users and others in respect of the Expressway and the conduct of Operations.
- Incidents of emergency de-commissioning of the Expressway during the month ended, if any.
- Incidents of lane-closure on the Expressway during the month ended, if any. The Concessionaire shall provide information on reason, time of such lane-closures.
- Incidents of encroachment removal
- All grounds for substantial dispute which have occurred or may reasonably be foreseen as likely to occur.
- The proposed measures to be taken by the Concessionaire to overcome such departures or to resolve such grounds for a dispute.
- Accident Reports: As soon as practicable and in any event no later than 7 days following the occurrence of any accident on the Expressway involving a fatality or serious personal injury or substantial property damage, the Concessionaire shall investigate the circumstances of such accident and submit to the NHAI and Independent Consultant a report setting out details of such accident and, to the extent they are known, the causes of such an accident, and the Concessionaire shall thereafter promptly report to the NHAI and/or Independent Consultant any additional details of such accident or its causes which become known to it.

15.3 WEIGHT ENFORCEMENT SYSTEM

15.3.1 Introduction

A Weight Enforcement System (WES) shall be deployed close to each entry to the Expressway. The purpose of such a system is ensuring that no commercial vehicles above the overload limit are allowed on the expressway.

The prevention of overloading, clause 12.4.13 of IRC:SP:99:2013 is recommended at Toll Plaza. However, a WES separate from weighing in toll lanes is recommended. This shall reduce operational issues and increase throughput.

The WES deployed shall be a combination of

- Presorting system - WIM Mainline system
- Sorting system - WIM Ramp Sorting Systems
- Weighing station - Static weighbridge (SWB)

1 & 2 above are used to pre-weigh and presort trucks prior to weigh stations. Only those trucks potentially in violation of weight regulations or other operating requirements are directed to the SWB.

Technology Overview

A typical WIM system consists of the following hardware:

- A scale or set of sensors on the mainline or installed on a ramp that records the impact of the passing vehicle;
- A roadside cabinet containing a processor that converts the downward force readings of the vehicle on the scale into data estimating the vehicle's gross weight and axle weights; and

- A communication system that transmits the weight data to the computers of enforcement personnel or to an enterprise-level WIM database management system. OFC or wireless technology is used to transmit data from WIM systems to users and to transmit real-time data and/or vehicle images.

The accuracy of the gross vehicle weight or axle weight estimate as computed by the roadside processor can be affected by the WIM scale technology in use. When installed on the mainline, more expensive WIM systems have less variance in their readings and may better compensate for filtering external factors that affect vehicle weight calculations. Conversely, less expensive WIM scales or sensors may not be as accurate at highway speed. When installed on a ramp, however, the quality of weight data uniformly improves and the difference in accuracy between less and more expensive WIM devices is not as great as under high speed conditions.

15.3.2 High-Speed WIM for Fixed Weigh Station Operations

WIM systems, as indicated above, are commonly used to screen vehicles on the mainline for weight compliance as they approach a weigh station. The WIM scale or sensor embedded in the pavement automatically weighs vehicles and provides an estimate of the vehicle's weight to station personnel for sorting purposes. Typically, weight screening is based on estimates from WIM sensors or scales on the mainline that are compared to a weight pass/fail threshold set to a percent of the legal weight. Thresholds are adjustable by station personnel. Trucks that exceed the threshold are directed into the weigh station to be weighed on more accurate static scales used to write citations. High WIM device accuracy results in low probability of incorrectly sorting a truck.

The data generated by a commercial vehicle passing over a WIM site includes information on number of axles and axle weights. Also, a digital photograph of the weighed vehicle is automatically recorded and transmitted to enforcement personnel, before the truck arrives at the static scale.

WIM provides real-time weight verification concurrent with safety and credentials verification for bypass eligibility. Vehicles cleared for bypass are not generally directed to pull into the weigh station. DSRC readers and WIM sensors are located far enough ahead of the station ramp to allow the screening system time to complete the necessary processing of the vehicle as it approaches. The driver is signaled to pull in or bypass via their transponder before it reaches the ramp.

Mainline weight screening produces a number of benefits. Weigh-in-motion significantly increases the capacity of weigh stations. In the absence of mainline WIM, queues may form and cause closure of weigh stations; as a result, compliance checks are not performed on the bypassed vehicles. WIM also reduces congestion within the fixed weigh station facility, focuses enforcement on high-risk operators, and provides time savings for safe and legal carriers, supporting more efficient movement of freight.

A VMS and a pass/fail traffic light located before the weighing area entry ramp directs trucks into the low speed WIM ramp station if their weights exceed established thresholds.

15.3.3 Low-Speed WIM (LSWIM) for Ramp Sorting

WIM scales are also installed on weigh station ramps to weigh and sort vehicles at low speeds. Vehicles that have left the main highway move to the approach ramp where they are weighed by a ramp sorter WIM. The ramp WIM sorts the arriving trucks based on a weight threshold set by weigh station personnel. Axle spacing, vehicle height, and vehicle classification also may be

determined. Vehicles that do not exceed the threshold are signaled by a message sign to move to the bypass lane for return to the main highway. Remaining vehicles are directed to the static scale for weighing. Compared to mainline WIM systems, ramp WIM systems weigh vehicles moving at lower speeds and provide a more accurate measure of a vehicle's weight.

15.3.4 Static Weigh Bridge (SWB)

As of now, an SWB is the only acceptable method of enforcement (in eyes of law). Any truck which is identified by the LSWIM as overloaded is directed towards the SWB. The truck is weighed here for GVW. Compliant trucks are provided a passage to merge back into the main carriageway (before the toll plaza). Overloaded trucks are directed to an access controlled parking bay and warehouse area. Here, the excess goods are offloaded for storage in the warehouse and the truck is weighed again at the SWB and if, found compliant, allowed to drive to the main carriageway.

Appropriate penalties may be imposed on the truck driver. However even though he pays the penalties, the overloaded truck shall not be allowed to pass till it offloads to within acceptable limits.

15.3.5 Requirements

The following requirements shall be met by the WES:

15.3.5.1 Mainline

a) HSWIM

- All LCVs/trucks shall be directed to be in leftmost lane by use of static signs.
- Approximately 800m before the LSWIM ramp, an HSWIM scale shall be installed in the road.
- The HSWIM scale shall have the following specifications:
  - It shall be able to measure the weight of the truck moving at speeds 30-120kmph
  - The accuracy of the HSWIM shall be at least 95% on GVW
  - The scale sensitivity shall be immune to braking action.
- As the truck drives over the HSWIM scale, a VMS and a red/green light shall indicate "pass/fail" to the truck driver.
- A roadside electronics cabinet shall house the necessary intelligence to manage this data. This cabinet shall also control VMS, lights, loops, piezos and any other associated peripherals.

b) Piezo

- In non-HSWIM scale lanes, piezo sensors of Class1 shall be installed.
- These shall detect passage of any commercial vehicle over it i.e. if vehicle tries to avoid the HSWIM
- The piezo shall have at least 80% accuracy on GVW
- It shall be connected to roadside electronics

c) Loops

- Loops shall be installed in leftmost lane after the HSWIM scale.

- These loops shall ensure that correct indication (VMS,light) is shown to each vehicle till it reaches the ramp.

d) Camera

- A pole mounted camera shall be installed which shall capture the image of every overloaded vehicle passing over the HSWIM.
- It shall also capture any commercial vehicle bypassing the HSWIM and passing over the piezo sensors.
- The camera shall be able to capture clear pictures during night time.

e) Lighting

- The areas from HWIM scale to ramp shall be sufficiently lit to facilitate night time operation.

15.3.5.2 Ramp

The ramp shall have an LSWIM scale installed

The LSWIM scale shall operate at speeds of 4 – 20 kmph

The LSWIM shall have an accuracy of at least 98% on GVW

The scale sensitivity shall be immune to braking action.

The scale shall be connected to roadside cabinet housing the LSWIM electronics. The electronics shall also connect to other peripherals like automatic barrier gate, loop, signal/display devices.

Any truck that is compliant shall be allowed to exit to the main carriageway. A non-compliant truck shall be directed to the SWB. The passage to main carriageway shall be normally blocked by an automatic barrier gate, which shall open only when it receives a signal from LSWIM electronics that the weight is within limits.

15.3.5.3 SWB

Any truck determined as overloaded by LSWIM shall be directed to the SWB.

The truck shall be weighed here for GVW.

The truck shall be parked correctly on the weighstation. If any of the wheels of the truck is outside the weighscale, the system shall give an audio/visual alarm.

Barrier Gates

After the truck is weighed, it shall proceed to exit to the main carriageway. This exit shall be normally blocked by a closed barrier (“normally closed” operation).

If the truck is compliant, the barrier shall automatically open and allow passage.

If the truck is non-compliant, the truck shall, on another branch road, be directed towards parking and warehousing facilities..

Parking and Warehousing

All overweight trucks shall be required to park in the parking area where they wait for their turn to be called for offloading.

Upon its turn, the truck shall move to the warehouse. The driver shall be required to declare the goods type that shall be offloaded.

The warehouse shall have facilities to store all types of goods including perishable goods (deep freeze facilities).

The driver shall pay for the warehousing facilities as per NHAI norms (depending on type, weight, dimensions, duration etc.)

After offloading excess goods, the driver shall be required to get his vehicle weighed again at the SWB before proceeding to the main carriageway.

It is recommended that the warehousing area have an independent secondary SWB for offloading. However, the truck still needs to be weighed on the primary SWB from where it shall be allowed to proceed to main carriageway.

Disputes / penalties

If the driver is not satisfied by the weight as displayed by the SWB, appropriate dispute resolution mechanism shall be implemented by NHAI. It is recommended that he be allowed to get his vehicle weighed by independent weighbridge operator.

Appropriate enforcement agencies need to be involved for imposing fines.

Operations

Manpower shall be deployed by the Concessionaire for WES operations.

An HSWIM booth shall be constructed on the roadside which shall house the HSWIM electronics and booth operator.

Any truck bypassing over the HSWIM shall be reported to the toll plaza through an intercom.

There shall be a booth next to the SWB. An operator shall man this booth and shall monitor the trucks and check if trucks are correctly placed for weighing. A computer and screen shall be provided for this.

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DETAILED COST ESTIMATE

16

16. DETAILED COST ESTIMATE

16.1 GENERAL

The lane configuration of Main Expressway is as below:

Phase- IA	Km 254.430 to Km 287.700, Length= 33.270 Km	Eight lane divided Carriageway
	Km 287.70 to Km 378.740, Length = 91.040 Km	Six lane divided Carriageway

For working out the cost the total stretch of Phase-IA is divided in to 5 packages. This cost estimate chapter has been prepared for Package IV.

Package-IV: Km 279.000 to Km 292.000. Length of the package is 13.00 km. The Expressway starts at Ankleshwar and ends at Manubar.

16.2 METHODOLOGY

- Computation of rates of the principal work items for Sections in Gujarat State based on State Schedule of Rates.
- Computation of earthwork and pavement as per computer calculation.
- Computation of detailed cost from detailed drawings and Cross sections.
- Computation of estimated cost of bridges from detailed drawings.
- Computation of cost for RCC box culverts and pipe culverts from their detailed drawings.
- Estimation of cost of Resettlement and Rehabilitation, utility relocation and environment mitigation measures on their detailed assessment basis.
- Estimation of provision of contingencies and supervision charges as percentage of total cost.
- Estimation of total detailed project cost.

16.3 UNIT RATES

For working out the rates the basic rates are taken from State Schedule of Rates for Bharuch Division, NH Circle, Vadodara for the year 2015-2016 and escalated to bring it to present year. The basic rate of Labour is taken from the minimum wages act for Gujarat state. For cement, steel and bitumen current market rates have been provided. For hire charges of Machinery the rates given in the Standard Data Book of the Ministry of Road Transport and Highways with escalation have been adopted since rates in the Standard Data Book for machinery are for the year 2001-2002 to bring it to present year. The component of labour, material and machinery has been adopted from the Standard Data Book. Borrow areas have been identified along the road for borrow area soil and average lead has been worked out. Similarly stone quarries have been identified and average lead has been worked out. For aggregate the rates have been worked out from State Schedule of Rates after adding the cartage cost from State Schedule of Rates.

The rates worked out for important items are given in the **Table 16.1**.

Table 16.1: Rate of Important Items

Sl. No.	Item	Unit	Km 279.000 to Km 292.000
1	Embankment from borrow areas	m^3	288
2	GSB	m^3	1400
3	WMM	m^3	1749
4	DBM with VG 40	m^3	6761
5	BC with VG-40	m^3	7730
6	DLC	m^3	2861
7	PQC	m^3	6149
8	HYSD Steel for bridges	T	76643
9	HT strands	T	129543
10	PCC M 15 for bridge foundations	m^3	5501
11	RCC M30 in superstructure	m^3	6923
12	PSC M 45 for superstructure	m^3	8088
13	Bored cast in situ piles M35 grade 1200mm dia.	m	15796

16.4 CONSTRUCTION QUANTITIES

For detailed estimate the quantities of earth work and pavement which have been calculated by using Computer software Mx Road.

16.5 PAVEMENT DESIGN OPTIONS

Rigid pavement has been provided for Main Expressway.

16.6 COST COMPONENTS

The estimated cost has been worked out under the following sub heads: -

- ***Site clearance and dismantling***

Under this sub head provision has been made for removing the roots of trees of girth more than 300 mm and dismantling the structures, which are proposed to be reconstructed.

- ***Earth Work***

This sub head provides for items of earth work in excavation, embankment, sub grade and shoulders.

- ***Sub Base and Base Courses***

The items of granular sub base and wet mix macadam base course have been provided under this sub head for flexible pavement.

- **Cement Concrete Pavement**

The items of Rigid have been provided under this sub head.

- **Bituminous Courses**

This sub head provides for items of bituminous courses for flexible pavement. For the Expressway at grade junctions are not proposed. For the important road crossings interchanges are proposed. Vehicular and pedestrian underpasses are proposed at suitable locations.

- **Culverts**

➢ **Main Expressway:**

The Express way is proposed on new alignment. It is proposed to provide new RCC box type culverts and pipe culverts for canal crossing. Total number of culverts provided in the cost estimate is given in **Table 16.2.**

Table 16.2: Number of Culverts

S. No.	Type of Culverts	Nos.
1	Box culverts	24
2	Pipe culverts	11

The estimated cost of culverts for Main Expressway is **Rs. 17.07 Crore**.

- **Bridges**

➢ **Main Expressway:**

The cost of bridges has been worked out from the detailed drawings. The total number of structures required to be constructed on the Main Expressway for Package-IV are given in **Table 16.3** below:

Table 16.3: Number of Structures

Sl. No.	Particulars	Total Nos.
1	Major Bridges	1
2	Minor Bridges	3
3	Canal Bridges	2
4	Interchanges	1
5	Flyovers	1
6	Vehicular Underpasses	2
7	Pedestrian/ Cattle Underpasses	7
8	Light Vehicular Underpasses	3

The cost above structures for Main Expressway comes out to **Rs. 794.00 Crore**.

- **Drainage and Protection Works**

Lined drains are proposed to be constructed on both sides of the road on shoulders. Drainage chutes with will be provided throughout the length irrespective of the height of the embankment. The other protection works such as river training work, canal diversion, Sand drains, RE wall, RCC Retaining wall and breast wall & Toe wall has been proposed at required locations. Also at the location of ravine, the special treatment is proposed. Metallic crash barriers are

also proposed on both sides throughout the length of the Expressway. Provisions of retro reflection stickers (red colour) on crash barriers (Thrie beam) have been proposed. For the protection of ROW fencing is provided on both sides.

- **Traffic signs, Markings and other Appurtenances**

Provision has been made for traffic safety features, road furniture and road markings as per details provided.

- **Miscellaneous**

Provision has been made for the following items under this sub head:

	Main Expressway
➢ Toll Plaza on loops of interchanges	4 Nos.

- **Horticulture**

Provision has been made for landscaping, plantation of Expressway and Interchanges.

16.7 CONTINGENCIES AND SUPERVISION COSTS

As this is an EPC project the following provision has been made for contingencies and supervision cost under this sub head: -

The following provision has been made for contingency and supervision cost:

- Contingency - 2.8%
- Supervision Charges - 2%
- Administrative charges - 1%
- Quality control charges - 1%
- Road safety cell audit charges - 0.5%
- Maintenance cost for 4 years - 5%
- Escalation @ 5% per year for 2 years - 10%

16.8 PROJET COST

	Cost of Civil Works including GST Rs in Crores		**Project Cost Rs in Crores**	
	Civil Cost	**Cost per km**	**Total Cost**	**Cost per km**
Phase IA, Package IV	1296.16	99.70	1760.95	135.46

Copy of General Abstract of cost is given in **Table 16.4**.

• • •

Construction of Six/Eight lane Vadodara Kim Expressway from Km 279.00 to Km 292.0 (Ankleshwar to Manubar Section of Vadodara Mumbai Expressway) in the State of Gujarat under NHDP Phase - VI on EPC mode (Phase IA-Package IV).

Package : 4 (km. 279.00 to km. 292.000)

Length = 13.000 km

TABLE 16.4: GENERAL ABSTRACT OF COST

S No.	Description	Amount (Rs)
1	Site Clearance and Dismantling	79,63,847.00
2	Earthwork	1,37,51,92,036.00
3	Granular Sub Base Course and Base Course	13,90,75,203.00
4	Cement Concrete Pavement	1,11,89,90,728.00
4	Bituminous Course	87,03,002.00
5	Culverts	17,07,18,624.00
6(A)	Major Bridges	6,01,97,21,700.00
6(B)	Minor Bridges, Canal Bridges and Gas Pipe Line Bridges	81,35,53,400.00
6(C)	Interchanges, Flyovers and ROB's	72,19,46,500.00
6(D)	Underpasses / Overpasses	38,48,70,100.00
7	Drainage and Protection Works	47,44,08,161.00
8	Traffic Signs, Markings and Other Appurtenances.	3,50,14,256.00
9	Miscellaneous	45,94,46,043.00
10	Horticulture	5,36,97,367.98
A)	**Total Civil Cost**	**11,78,33,00,967.98**
	Add tentative cost for GST@ 10% on (A)	**1,17,83,30,096.80**
B)	**Total Civil Cost including GST**	**12,96,16,31,064.78**
	Civil Cost in Crores	**1,296.16**
	Cost per Km (Length = 13.00 Km.) in Crores	**99.70**
C)	Add Contingencies @ 2.8% on (B)	36,29,25,670.00
	Sub Total (A+B+C) =	13,32,45,56,734.78
	Cost in crores	**1,332.46**
D)	Construction Supervision Charges @ 2% on (B)	25,92,32,621.00
E)	Administration Charges @ 1% on (B)	12,96,16,311.00
F)	Quality Control Charges @ 1% on (B)	12,96,16,311.00
G)	Road safety cell audit Charges @ 0.5% on (B)	6,48,08,155.00
H)	Maintenance Cost for 4 Years @ 5% on (B)	64,80,81,553.24
I)	Escalation @ 5% per annum for 2 years i.e. 10% on (B)	1,29,61,63,106.48
	Total (A+B+C+D+E+F+G+H+I) =	**15,85,20,74,792.49**
J)	Environment and Mitigation cost	75,89,277.00
K)	Land Acquisition ,Resettlement and Rehabilitation Cost	1,56,91,00,000.00
L)	Cost for Shifting of Utilities	18,07,65,879.00
	GRAND TOTAL	**17,60,95,29,948.49**
	Cost in crores	**1,760.95**
	Project Cost per km	**135.46 Cr**

ECONOMIC ANALYSIS

17

17. ECONOMIC ANALYSIS

17.1 ECONOMIC ANALYSIS

17.1.1 Introduction

This Chapter presents economic analysis for establishing viability of the proposed investments in constructing the proposed 6/8 lane access controlled expressway parallel to existing NH-8. The economic analysis identifies the expected tangible and intangible benefits of the above investment with the focus on the reduction in vehicle operating costs, time-savings and other benefits in the influence areas of the proposed project.

The economic analysis is based on the comparison of the total road agency costs and road users' cost under the two scenarios: (i) with project, i.e. construction of expressway; and (ii) without project, i.e. do minimum or no capital investment. The net benefits to the economy out of the investment in the proposed expressway development would be obtained by comparing the costs between two above-mentioned scenarios. In the present condition NH-8 are the existing major highways running parallel to the proposed expressway. Therefore existing 6-lane section (NH-8) of these roads is considered as base case. Alternatively in the "with project case" scenario there will be 6/8 lane expressway running parallel to NH-8, other nearby roads.

17.2 APPROACH AND METHODOLOGY

As stated before, the economic analysis is based on comparing the total costs to the road agency and the road users under with and without project situations. As recommended, after construction of Expressway with rigid pavement, it is expected that there would be considerable reduction in the vehicle operating costs, savings in travel-timing with higher speed, savings in existing maintenance cost, safe roads with stringent road safety audit while finalizing the road design, and other tangible and intangible benefits. All these are considered for determining the benefits of the investments in the said project.

The above exercise has been carried out using the latest version of the World Bank's HDM-4 software. Based on the outputs obtained through the HDM-4 analysis under two scenarios, i.e. with and without project, the cost-benefit analysis has been carried out following the yearly discounted cash-flow technique for the assumed project appraisal period.

The cost-benefit analysis of the investment in the project yields the results in terms of the Economic Internal Rate of Return (EIRR), and the Net Present Value (NPV) at the given discount rate, i.e. also termed as cut-off rate. The economic analysis is also supported with the sensitivity analysis to appreciate the robustness of the investments in the expressway development under different adverse conditions.

The economic analysis considers the total project costs, which include the capital cost of the project development option, routine and periodic maintenance cost to offer quality service to the road users after the provision of expressway, environmental and social mitigation costs, and resettlement and rehabilitation (R&R) to take care of the damages, if any due to the proposed interventions. The economic analysis has been carried out using all the inputs relating to the costs and benefits into the economic terms by using appropriate methods and the conversion factors to derive resource costs to the economy.

The costs and benefits associated with the project option have been developed on a yearly basis for the economic appraisal period of 20 years including the project implementation period of four years.

The economic appraisal is carried out by using the 'Highway Development and Management (HDM 4) Model'. The model is used to generate cash flow streams of VOCs, travel time and Accident costs to compute the net economic benefits, as inputs for the estimation of the IRRs and NPVs for project evaluation.

Phase IA has been divided in 5 packages and the expressway is a green field project. Hence package wise benefits could not ascertain for Economic analysis without exact comparison of NH 8 (competing road). Hence the analysis has been carried out for Phase IA (Kim to Vadodara).

17.3 PROJECT BENEFITS RATIONALE

The benefits of the proposed development of the Expressway with improvement of existing of NH-8 have been grouped into: (i) tangible, i.e. quantifiable benefits; and (ii) non-tangible, i.e. non-quantifiable benefits. For the exercise, the tangible benefits are incorporated in the HDM-4 analysis for undertaking the economic appraisal. The tangible benefits are mainly savings in the vehicle operating costs and travel time.

Although the benefits due to the improved accessibility and mobility are apparent and highly realized by the beneficiaries, due to several reasons, such as non-availability of proper data, resource constraints, conceptual clarity in estimation methods and selection of generally acceptable parameters, etc., the quantification of qualitative benefits becomes subjective. Therefore, the above exercise has been carried out on a limited scale with acceptable assumptions.

A brief note on the tangible and intangible benefits of the investment proposal in the Project Road is presented in the following sections.

17.3.1 Tangible Benefits

(i) Savings in Vehicle Operating Cost

Road development activities bring out several benefits to its users, but savings in Vehicle Operating Costs (VOCs) alone accounts for a higher share in the total benefits. It may also be noted that development of higher category roads such as expressway requiring higher investment, may yield much higher benefits to the road users in terms of higher savings in the VOCs as the incremental benefits of a higher category road would be higher compared to the other roads.

(ii) Savings in Travel Time

There would be significant savings in the travel time to its users, mainly on account of increased speed on the Expressway, timely delivery of the commodities under transportation, probably reduced waiting time for getting the transport for freight and passenger movement, higher utilization of vehicle and crew, etc.

This is mentioned here that proposed Expressway is designed at 120 kmph whereas the travel speed along NH-8 is being considered as 100/ 80 kmph, hence there would be considerable time savings while travelling on these highways.

Savings in travel time have been considered as tangible benefits for both freight and passenger movement and therefore incorporated in the HDM-4 Model for undertaking the economic analysis. The adopted value of proposed and existing

travel speeds along with pavement conditions on the Expressway and the Competing road (NH-8) for the analysis are given in **Table 17.1**.

Table17.1: Proposed Travel Speeds on the Project Roads

Phase -1A	Expressway		Competing Road (NH-8)	
	Avg. IRI* (m/km)	Speed (km/hr)	Avg. IRI (m/km)	Speed (km/hr)
Expressway (km 254.430 to km 378.740) & Competing road NH-8 (km 108.700 to km 233.000)	2.00	120	2.5-5.0	80/100

**in different homogeneous sections*

17.3.2 Intangible Benefits

In addition to the tangible benefits of the road improvement projects, there would be several intangible benefits, which are usually difficult to quantify and incorporate in the economic appraisal. However, these intangible benefits could be considered for broadening the base for decision-making process. The expected benefits of intangible nature are given as follows:

- There would be increase in general mobility of people residing in the influence area of the project for several socio-economic activities with an improved road transport infrastructure;
- Investments in road development activities create a variety job opportunities directly and indirectly for short-term to long-term;
- Well-engineered road with the proposed improvement, subject to the stringent road safety audit of design, ensures considerable reduction in the incidence of road accidents, particularly to the vulnerable road users;
- The project is serving a number of places of tourist attraction located in the catchment area of its influence providing links to the important tourist destinations, so more tourists would be visiting these places with comfort and convenience, and in turn, additional socio-economic activities would take place leading to increase in income of local people; and
- Other Exogenous Benefits, e.g. improved road would provide reliable and effective transport system for strategic and administrative purposes, logistics support in any emergency time, etc.

17.4 EXPRESSWAY DEVELOPMENT OPTION

Chapter 12 deals with the proposed engineering interventions on the two homogenous sections of the NH-8 and five traffic homogenous sections of Expressway in view of the level and structure of traffic – present and future with the project option.

The following Improvement Options for different homogeneous sections of the Expressway have been proposed.

The Competing Road (NH-8) is having 6 Lane configuration whereas, the proposed expressway is a combination of 6/8 Lane configuration based on the capacity augmentation as presented in Chapter 4.

Table 17.2: Recommended Lane Configuration

Traffic Homogenous Section	Chainage (km)		Length* (km)	Proposed Lane Configuration	
	From	To		2021	2035
Section-9	254+430	287+385	32.955	8 Lane	8 Lane
Section-10	287+385	323+087	35.702	6 Lane	8 Lane
Section-10A	323+087	353+690	30.603	6 Lane	8 Lane
Section-11	353+690	374+355	20.665	6 Lane	8 Lane
Section-12	374+355	378+740	4.385	6 Lane	8 Lane

Along with the above improvement options, timely routine and periodic maintenance has been proposed during the appraisal period in order to realize the expected economic benefits of the investment.

17.5 PROJECT COST

17.5.1 Economic Costing

For the purpose of economic analysis, the financial costs (i.e. based on the market prices) need to be converted into the economic costs, so that it could take care of the market imperfection, which usually exists in the financial cost of different project components. The economic costs also illustrate the resource cost to the economy, are generally estimated by taking out the taxes, duties, etc., which are merely transfer of payments, from the market prices.

For the purpose, the Consultants have used the Standard Conversion Factor (SCF) on the proposed intervention cost to convert into the economic cost, and for the components of the vehicle operating cost (VOC), such as fuel (diesel and petrol), vehicles, tyres and tubes, etc., the economic costs have been worked out separately by taking out the taxes, levies, etc.

As far as the application of SCF is concerned, different values have been used in road development projects in different states of the country, e.g. the World Bank used 0.90 as SCF in Uttar Pradesh, and 0.85 in Madhya Pradesh by ADB. It has been noticed that in most of the road development projects in the country, the SCF has been used either 0.85 or 0.90 to take care of the market imperfection in the financial cost of road projects. It is important to note that an SCF is used to avoid any subjectivity in the economic costing, and therefore it is usually not estimated at project level. It may also be noted that lower the value of SCF would reduce the project cost and yield higher EIRR of the investment. In view of the above, 0.90 has been applied as SCF on the cost of tradable goods to arrive at the project cost in economic terms.

17.5.2 Project Costs

The cost of the Project Roads (Expressway) has been worked out in Chapter 16 and summarized in **Table17.3**. The Project cost includes civil works with labor cess, contingencies (physical only), construction supervision and project administration, and provisional sums towards land acquisition, resettlement and rehabilitation, environmental mitigation and management costs, and shifting of utilities.

Table 17.3: Cost of Road Development / Improvement

Phase	Road development / Improvement Cost (Rs. Crore / km)	
	Financial	Economic
Phase IA	79.12*	71.21

**Total Project Cost including LA and R&R.*

17.5.3 Maintenance Strategy

In order to preserve both the project roads, i.e. an asset, a proper maintenance mechanism supported with adequate fund is highly desirable; otherwise the road asset will be deteriorated considerably, resulting in heavy losses. While undertaking the economic analysis, an adequate annual routine maintenance supported with periodic maintenance strategy has been considered in the HDM-4 Model, and the following expenditures on the timely maintenance have been considered:

(i) Routine Maintenance: Routine maintenance, for flexible pavement includes patch repairs, crack sealing, edge repair, cleaning of road side drains/cross drainage structures, repairing of shoulders, painting of highway signs and km stones, turfing, road markings, removal of litter, debris, replacement of damaged signs and maintenance of culverts, etc.; whereas for rigid pavement it, among others, includes sealing of cracks, mud jacking of settled slabs, etc.

(ii) Periodic Maintenance: In order to have the long-term benefits of the substantial capital investments in the Project Road with good riding quality to the users, and also to protect the assets, suitable periodic maintenance has been considered. Periodic maintenance cost for flexible pavement including strengthening of pavement has been considered once in every 5 years during the appraisal period, assuming the Project Road becomes operational after improvement in the year 2020; whereas for rigid pavement it requires diamond grinding and sealant renewals considered after every 10 years or as and when required.

Maintenance Cost

(a) For Existing National Highway (Flexible Pavement):

Routine maintenance cost (6 Lane) - Rs. 16,23,861 per km per year

Routine maintenance cost (8 Lane) - Rs. 20,10,495 per km per year

Periodic maintenance cost - Rs 680 per sq.m (5 year interval)

(b) For Proposed Expressway (Rigid Pavement):

Routine maintenance cost (6 Lane) - Rs. 9,69,525 per km per year

Routine maintenance cost (8 Lane) - Rs. 12,00,364 per km per year

Diamond Grinding - Rs 300 per sq.m (10 year interval)

Sealant Renewal - Rs 25 per meter (10 year interval)

17.5.4 Environment & Social Mitigation Costs

Any road improvement and rehabilitation works are termed as “interventions” on the existing physical situation of the specific areas. These interventions affect nearby inhabitants, physical and biological environment and hence need to be properly mitigated. The costs for various environment and social mitigation including resettlement and rehabilitation (R&R) have been estimated and

incorporated in the economic analysis after having adjusted for the economic costing.

17.5.5 Accident Cost Benefits

HDM-4 software, among others, requires inputs for estimating the benefits on account of reduction in accidents for the economic analysis. For determining the accident benefits, it is essential to determine the likely change/reduction in accidents by type that is expected after the road improvement with provision of road safety features in the design. This is a complex task, as it depends on the road user behavior, traffic volume and mix and several local factors. In India, there is no established research/evidence regarding likely change in road accidents when a road is upgraded or improved. Hence, it is difficult to say, the likely change in extent or nature of accidents before and after the interventions in the project. In view of the above accident reduction benefits have not been taken in to consideration for the economic analysis.

17.6 PROJECT BENEFITS

17.6.1 Basic Parameters & Assumptions

As stated earlier, the economic analysis has been carried out by using the HDM-4 Model. The Model conducts the economic analysis based on the life cycle cost analysis of different options. The analysis makes a comparison between the total transport costs including VOC and other costs for the existing road condition (without project option) and the improved road condition (with project option) on a yearly basis for the entire appraisal period including the construction period and the assumed benefit period. Basic parameters and assumptions used for undertaking the economic analysis of the development/improvement of the Proposed Expressway is given in **Table 17.4**

Table 17.4: Basic Parameters & Assumptions

Parameter	Assumption
Project Commencement Year	2018
Project Construction Period	2 years & 6 Month
Project Appraisal Period (including construction period)	20 years
Project Completion	2020 end
Project Opening Year	Early 2021
Project Terminal/End Year	2037
Discount Rate	12%
Standard Conversion Factor	0.90
Salvage Value for various road sections of Proposed Expressway	20%

17.6.2 Derivation of Economic Cost of VOC Components

Cost and performance operating behavior of the vehicles by type plying on the Project Road have been obtained and suitably used in the HDM-4 Model for the economic analysis. The major inputs required for estimating the VOCs are: costs of vehicles, tyres, petrol, diesel and lubricants, crew and maintenance labor, and vehicle utilization level. These VOC parameters in the analysis have been taken

from published government records updated with market inquiries and related information available.

The above information on the representative vehicles and the details of estimates including the unit cost for inputs in economic terms are presented in **Annexure 17.1**.

Similarly, consumption of fuel (petrol or diesel) is an important component of the VOC. The road users pay the market prices of petrol and diesel, as available at the pump stations in the country. The market or the petrol pump fuel price includes different taxes, duties, levies, etc.; and for economic appraisal, the cost of fuel is required in economic terms. The economic costs of the above products have been worked out based on the details available on the Indian oil Corporation Website (www.iocl.com).

The Consultants have also estimated the value of time (VOT) applicable in the country, using the prevailing standard method, which has been used in the economic analysis for considering travel time benefits. The steps and data used for the exercise are presented in **Annexure 17.1** .

17.6.3 Traffic Demand

Classified traffic volumes estimated for the Project Roads (present and future), presented in Chapter 4, have been considered for the economic analysis. For ready reference, the base year traffic (2016) and the projected traffic during the project appraisal period after interventions for all the three scenarios, i.e. total traffic on NH-8 in base case, traffic on the NH-8 with expressway and traffic on the proposed expressway are illustrated in **Table 17.5 to Table 17.8**.

Table 17.5: Total Traffic on NH-8 without Expressway (Present & Projected)

Year	2W	3W	Car	LGV	Bus / Mini bus	2-Axle Truck	3-Axle Truck	MAV	Tractor	NMT	Total
Section 1: Vadodara – Bharuch (km 108+700 to km 198+000)											
2016	4443	791	15723	2848	1281	5944	5135	7157	135	40	43497
2020	5143	915	20651	3680	1580	6923	6644	9285	155	45	55021
2025	6257	1114	27200	4817	1948	8155	8494	11860	179	42	70066
2030	7254	1291	33785	5871	2288	9278	10208	14234	198	58	84465
2035	8009	1425	39637	6917	2619	10386	11866	16429	208	61	97557
Section 2: Bharuch - Surat (km 198+000 to km 263+000)											
2016	10221	2562	17459	5978	1320	8774	8856	7345	52	44	62611
2020	11832	2965	22723	7483	1619	10251	11355	9517	60	49	77854
2025	14395	3608	29513	9592	1995	12186	14414	12174	69	58	98004
2030	16688	4183	36206	11508	2342	13967	17242	14626	77	64	116903
2035	18425	4618	41895	13159	2666	15635	19872	16733	80	68	133151

Table 17.6: Estimated Traffic on NH-8 with Expressway

Year	2W	3W	Car	LGV	Bus / Mini bus	2-Axle Truck	3-Axle Truck	MAV	Tractor	NMT	Total
Section 1: Vadodara – Bharuch (km 108+700 to km 198+000)											
2021	5143	915	13288	2245	1021	4902	4514	6120	155	45	38348
2025	6257	1114	14206	2312	1031	5035	4841	6654	179	52	41681

Year	2W	3W	Car	LGV	Bus / Mini bus	2-Axle Truck	3-Axle Truck	MAV	Tractor	NMT	Total
2030	7254	1291	15147	2413	1255	5405	5444	7589	198	58	46054
2035	8009	1425	16150	2518	1528	5802	6122	8655	208	61	50479
Section 2: Bharuch - Surat (km 198+000 to km 263+000)											
2021	11832	2965	9743	1762	1519	6747	7119	5877	60	49	47673
2025	14395	3608	10529	1834	1569	7027	7839	6530	69	58	53458
2030	16688	4183	11195	1954	1948	7680	9011	7720	77	64	60520
2035	18425	4618	11903	2082	2419	8394	10358	9127	80	68	67473

Table 17.7: Estimated Traffic on Expressway

Year	Cars/Jeep Van	Bus / Mini Bus	LGV	2 Axle Truck	3 Axle Truck	MAV	Total
Section-1 (km 254.430 to km 287.385)							
2021	8,141	798	1,403	3,478	4,217	3415	**21,452**
2025	12,389	940	1,999	4,059	5,288	4297	**28,972**
2030	17,187	1,420	2,731	5,025	6,866	5810	**39,039**
2035	20,198	1,609	3,134	5,598	7,856	6583	**44,978**
Section-2 (km 287.385 to km 323.087)							
2021	6,891	420	988	2,080	2,114	2977	**15,469**
2025	10,104	491	1,403	2,414	2,674	3681	**20,766**
2030	13,876	785	1,923	2,998	3,554	4819	**27,956**
2035	16,332	896	2,232	3,343	4,120	5534	**32,458**
Section-3 (km 323.087 to km 353.670)							
2021	6,546	407	958	2,018	2,050	2888	**14,867**
2025	9,598	476	1,361	2,341	2,593	3571	19941
2030	13,182	761	1,866	2,908	3,447	4675	26839
2035	15,515	870	2,165	3,242	3,996	5368	**31,157**
Section-4 (km 353.670 to km 374.355)							
2021	5,825	394	765	2,011	1,937	3077	**14,010**
2025	8,741	458	1,113	2,340	2,446	3786	**18,884**
2030	12,215	739	1,558	2,921	3,269	4923	25625
2035	14,107	834	1,764	3,230	3,749	5615	**29,300**
Section-5 (km 374.355 to km 378.740)							
2021	5,029	102	48	559	557	1218	**7,514**

Year	Cars/Jeep Van	Bus / Mini Bus	LGV	2 Axle Truck	3 Axle Truck	MAV	Total
2025	6,989	134	127	691	745	1530	**10,217**
2030	9,386	231	224	898	1,033	1991	**13,763**
2035	10,662	256	191	977	1,173	2281	**15,540**

17.7 ECONOMIC ANALYSIS RESULTS

17.7.1 Computation of EIRR and NPV

Based on the above-mentioned descriptions, the costs and the benefits of the improvement of the four homogeneous sections of the Expressway have been incorporated in the economic analysis for appreciating the viability of proposed investments in the development of the expressway including improvement of the existing NH-8. The results of economic analysis are presented in **Annexure 17.2** and summarized in **Table 17.8**.

Table 17.8: Results of Economic Analysis

Option	EIRR (%)	NPV (Rs. in million)
Phase-IA: Development of Vadodara Mumbai Expressway	30.8	154,105.02

The value of EIRR shows that the investment proposal in the said Project is economically viable, as the value is well above the benchmark rate of 12%, i.e. the cutoff point considered for viability analysis for similar projects. And the net present value (NPVs) at the discount rate of 12% shows positive, which also supports the viability of investments in the Project.

17.7.2 Sensitivity Analysis

Investment in any road development project, like any other investments, involves risks and uncertainties, such as cost overrun, time overrun, traffic development, level of benefit realization, etc. The sensitivity analysis is usually carried out for appreciating the robustness of the investment proposal whether it could stand under different adverse conditions of cost and time overruns and realization of the traffic projected. And the results of sensitivity analysis, among others, enable the decision makers for approving investment in the Project Roads under the Study.

In view of the above and following the requirements of the ToR, the sensitivity analysis has been carried out by an overall increase in the project cost by 15%, lowering benefits by decrease in traffic level by 15%, and considering both these conditions together as the worst situation, i.e. increase the project cost by 15% and decrease the project benefit by 15%.

The results of sensitivity analysis are illustrated in **Annexure 17.2**, and summary of the results in **Table 17.9** and **Table 17.10** under different situations. For comparisons, the Base Case as mentioned in these tables refers to the results obtained for the economic appraisal (Table 17.8).

Table 17.9: Sensitivity Analysis: Values of EIRR

Option	Base Case	Cost 15% up	Benefit down by 15%	Cost 15% up & Benefit down by 15%
Phase-IA: Proposed Expressway	30.8%	27.8%	26.8%	24.0%

Table 17.10: Sensitivity Analysis: Values of NPV (Rs. in million)

Option	Base Case	Cost 15% up	Benefit down by 15%	Cost 15% up & Benefit down by 15%
Phase-IA: Proposed Expressway	154,105.02	142,434.65	112,234.64	100,564.32

The figures obtained for the EIRRs and the NPVs under the sensitivity analysis showing different adverse situations for the economic appraisal of the investment in the Project Roads give acceptable results, i.e. the EIRRs are well above the cut-off rate of 12%, and the NPVs are positive at the discount rate of 12%.

Based on the above results, viability of investments in the Project Roads is established and the probable economic risk associated with the investment is negligible or not a risky proposition.

17.8 SUM UP

The results of economic analysis supported with sensitivity analysis considering the most adverse case show that the proposed intervention in the Project Roads is economically viable and highly desirable for the economic development of the region and macro level as well. Hence, development of the project roads, i.e. the Proposed Expressway should be taken up for implementation without any delay in view of full realization of benefits to the road users and the community along the Project affected area.

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CONCLUSIONS AND RECOMMENDATION

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18. CONCLUSIONS AND RECOMMENDATIONS

18.1 CONCLUSIONS

With rapid economic development taking place in the States of Gujarat there is a need to develop a high speed corridor wherein the movement of large volumes of passenger and goods vehicles can take place at a fast pace. The development of Delhi Mumbai industrial corridor is further going to increase the traffic in the region necessitating augmentation of capacity. The proposed 379km long Vadodara-Mumbai Expressway which is in continuation of Ahmedabad Vadodara expressway and the proposed 94 km long Spur to JNPT are envisaged to fulfill this objective. The Expressway together with the spur is expected to reduce the travel time between Vadodara and Mumbai/JNPT by 2-3 hours.

The proposed Package IIV (a part of Phase 1A) of VME passes through Gujarat generally follows the alignment fixed by the M/s Wilbur Smith in 1992 with some modifications depending on the ground conditions and is a green field project.

The existing NH8 is carrying daily traffic ranging from 93452 to 121908 PCUs and is not access controlled. The average journey speed in some sections of NH8 is as low as 50 kmph. The expressway will be a competing facility for NH8 and considerable traffic is expected to divert to the expressway apart from the generated traffic due to its better level of service as it is access controlled. The Consultants have carried out comprehensive traffic modeling of the project area taking into account the existing and future roads network, socio economic profile of the area, future development plans in the area and different toll rate scenario etc.

The Package IV of expressway is expected to carry a daily traffic volume about 35273 to 50453 PCUs in the opening year. Hence it has been recommended that, the Package IV of Phase IA should be built as 6/8lane facility at the beginning.

A total of 20 numbers of different structures comprising of One major bridge, 3 minor bridges,, 2 canal bridges, One Flyover, 2 vehicular underpasses, 3 light vehicular underpasses and 7 pedestrian/cattle underpasses have been proposed as per hydrological and traffic requirement for railway crossings, road junctions of NH, SH, District/Village roads and local roads crossing the alignment of the main Expressway.

The natural ground at its current level will hardly serve as the subgrade level thus necessitating that the entire roadway corridor be built on embankment structure. To support the sub-grade of CBR in the range of 10%, it is recommended to construct the embankment with soil of minimum 4 days soaked CBR of 4%. The design CBR for the main carriageway is 10%.

Four options have been considered in the design of pavement. However, it is recommended to provide rigid pavement in the entire length of the main expressway.

The expressway will be a tolled facility and a closed tolling system has been recommended with toll plazas at the entry and exit ramps of the interchanges. This will minimize delays to the through traffic. Mainline toll plazas have been recommended only at the start and at the end. Provisions have been made for the Automated Traffic Management Systems (ATMS) and user facilities like wayside amenities, truck lay byes and smaller car parking cum toilet facilities.

The civil cost of the project works out to about INR 1296.16 Crores (including GST) and per km cost is INR 99.7 Crores while the Total Project Cost including the cost of R&R, environment mitigation, Contingency and utility relocation works out to about INR 1760.95 Crores and per km Cost is INR **135.46** Crores.

The Economic Analysis of the Expressway (Phase IA) indicates that the project is economically viable in base case and worst case Scenario also. It means there will be considerable economic gains in terms of reduced VOC and travel time.

18.2 RECOMMENDATIONS

Based on the final revised design the following major recommendations are made

1) Based on the traffic estimates and the volume to capacity ratios it is recommended that this package be developed to Six/Eight lane facility in the opening year.
2) To minimize delays to the through traffic a closed type tolling system is recommended with toll plazas at the entry and exit of the interchanges. Mainline toll plazas are recommended only at the start and at the end.
3) Based on life cycle costing rigid pavement is recommended for the entire length of the Expressway.
4) The expressway gives us an opportunity to build innovative structures and the General Arrangement Drawings (GAD) presented with this report are recommended.
5) It is recommended that, the project be undertake on EPC mode for Implementation.

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