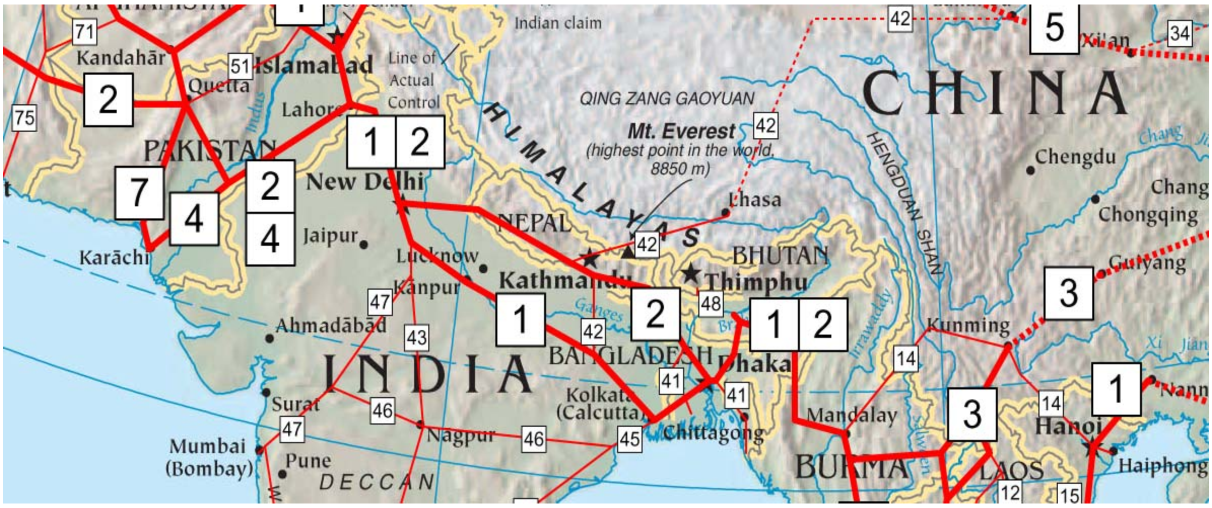
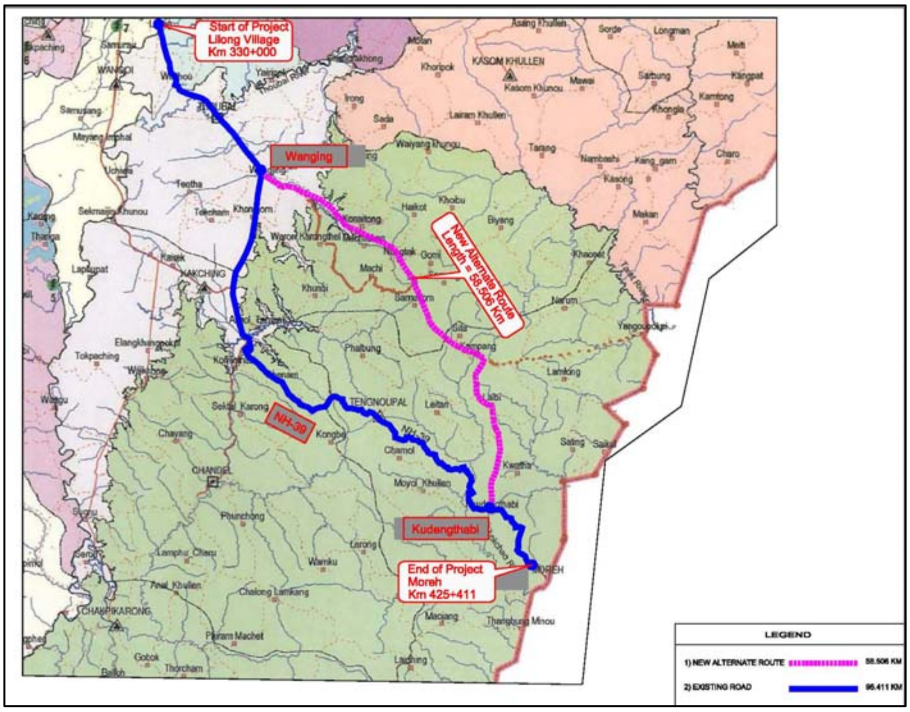
ADB TA No. 8116-IND

**INDO MYANMAR ROAD SECTION FROM IMPHAL TO MOREH ON NH-39**




*Funded by:*

*Asian Development Bank*

Implementation Agency:

**MORT&H / PWD Govt of Manipur**

# Detailed Project Report

## Volume - II Design Report

SHELADIA ASSOCIATES, INC.

April, 2015

**SHELADIA Associates Inc. USA**

# Abbreviations

| | |
|---|---|
| **AASHTO** | American Association of State Highway Transport Officials |
| **AADT** | Annual Average Daily Traffic |
| **ADB** | Asian Development Bank |
| **ADT** | Average Daily Traffic |
| **AH** | Asian Highway |
| **ASTM** | American Standard Testing Methods |
| **BC** | Bituminous Concrete |
| **BOQ** | Bill of Quantities |
| **BS** | British Standards |
| **CBR** | California Bearing Ratio |
| **DP** | Displaced Person |
| **DPR** | Detailed Project Report |
| **EA** | Executing Agency |
| **EMP** | Environment Management Plan |
| **GSB** | Granular Sub Base |
| **GOWB** | Government of West Bengal |
| **IPP** | Indigenous People Plan |
| **IRC** | Indian Roads Congress |
| **LCS** | Land Customs Station |
| **LTP** | Lead Technical Professional |
| **MDD** | Maximum dry density |
| **MORT&H** | Ministry of Road Transport and Highways |
| **NH** | National Highway |
| **NPV** | Net Present Value |
| **NRRP** | National Rehabilitation and Resettlement Policy |
| **NSDP** | Net State Domestic Product |
| **PWRD** | Public Works (Roads) Department |
| **QAP** | Quality Assurance Program |
| **QAR** | Quality Assurance Reviewer |
| **SH** | State Highway |
| **SHELADIA** | Sheladia Associates Inc |
| **TAC** | Technical Assistance Cluster |
| **TOR** | Terms of Reference |
| **VDF** | Vehicle Damage Factor |

# Chapter 1 Part-1–GEOMETRIC DESIGN

## 1.1 Introduction

The overall process whereby the road alignment (horizontal and vertical) in different terrain condition be designed in such as way to meet the need of the road users is generally known as geometric design. The main geometric features are:

- Horizontal alignment;
- Vertical alignment; and
- Road Cross Section

Geometric design standards shall fulfil the following three main objectives:-

1. it shall ensure safety and comfort of road users;
2. it shall ensure that the road is designed economically; and
3. It must ensure uniformity of the alignment.

Thus, geometric design must aim at combining various geometric design elements to produce an economic geometric form for a road. These elements have important bearing on how the road will function, its capacity, behaviour and safety of road users. The traditional approach in geometric design considers the three views of layout plan, longitudinal section and cross-section. The road user sees the road as a constantly changing continuum as he drives along, and the appearance of the road influences the driver's behaviour. It is therefore important for the Consultant to provide the motorist with reasonable clues as to provide the motorist as to what to expect as he drives along the road; such clues should be clear messages, which are unlikely to mislead him.

Applying standard and practice without considering the prevailing circumstances is no substitute for judgment, and brings no assurance of acceptable end product. Equally, design prepared without referring to general accepted standard and practice are not likely to serve the travelling public as intended. Design based on a combination of sound professional judgment, applicable standards and current practices will generate the most effective road.

Highway design standards are intended to provide comfort, safety and convenience for the travelling public.

Generally, the main objectives of the Geometric Design Standards are to adopt a limit to the design in order to:

- Optimize the level of safety through the provision of adequate sight distance, gradient, super elevation and curve widening.

- Ensure uniformity of alignment and maximum level of safety and comfort for drivers using the road within the given economic and environmental constraints.
- Ensure horizontal and vertical curvature combination to enhance the safety and operational efficiency of the road, and
- Cost optimization

With the above general objective, the consultant has carried out detailed assessment of the existing road alignment and geometric design standards have been established. The principal geometric design elements of a road are the horizontal & vertical alignment and the cross section.

The designer has attempted to provide an appropriate design standard that confirms to the existing road terrain condition and combinations of these elements should be defined in relation to the following controls factors:

1. Topography and land use
2. Road function
3. Traffic volume
4. Design speed and other speed controls
5. Road safety considerations
6. Environmental considerations
7. Economic and financial considerations

The above design controls were considered during the design. In particular the economic and financial considerations may justify a relaxation in some of the controls and criteria for upgrading and rehabilitation projects as the investment in the existing road pavement and structures should not be ignored.

Thus the Consultant highly emphasized and attempted to arrive at a final design, which:

- Fits into the existing natural condition, terrain by making a balance with the physical and social environment,
- Fulfils the projected traffic requirements, and
- Encourages consistency and uniformity of operation.
- Economical for implementation

## 1.2 Horizontal Alignment Condition of Existing Road

With a view to make the necessary recommendation for the project road to match with standard of Asian highway, it was fundamental to evaluate the existing road standard in relation to the current standards in use. During the draft DPR design stage the TA Consultant has analysed the geometric condition of the existing road to identify the substandard road geometry of the road sections in relation to the recommended design standard.

It is observed that the project highway predominantly has a straight alignment and traverses through almost in plain terrain for its entire length. However, there are a few sharp curves present in the Project road alignments. The details are presented in Table 1.1a and 1.1b. The factors contributing to road safety are engineering, education and enforcement. However, it must be appreciated that these factors interact, and different combinations of factors are likely to have different impacts. The engineering factors responsible for accidents are substandard geometric design as presented, road surfaces, road markings and delineation, road signs, streetlights and other road furniture, traffic management.

**Table 1.1a Sharp curve Locations on NH-39**

| S. No | Chainage | Remarks | S. No | Chainage | Remarks |
|---|---|---|---|---|---|
| 1 | 334+450 | S-Curve | 23 | 390+100 | Left hand curve |
| 2 | 335+450 | S-Curve | 24 | 391+800 | S-Curve |
| 3 | 335+750 | Left hand curve | 25 | 392+300 | Left hand curve |
| 4 | 336+550 | Left hand curve | 26 | 394+000 | Right hand curve |
| 5 | 367+000 | Right hand | 27 | 399+800 | S-Curve |
| 6 | 369+100 | Left hand curve | 28 | 400+100 | Right hand curve |
| 7 | 370+900 | Left hand curve | 29 | 400+300 | S-Curve |
| 8 | 373+600 | Right hand | 30 | 401+200 | Left hand curve |
| 9 | 375+800 | S-Curve | 31 | 401+700 | S-Curve |
| 10 | 377+100 | S-Curve | 32 | 402+500 | S-Curve |
| 11 | 377+400 | Left hand curve | 33 | 403+000 | Left hand curve |
| 12 | 379+100 | Left hand curve | 34 | 403+200 | Right hand curve |
| 13 | 381+400 | Left hand curve | 35 | 405+500 | Right hand curve |
| 14 | 383+000 | S-Curve | 36 | 405+800 | S-Curve |
| 15 | 384+000 | S-Curve | 37 | 406+800 | Right hand curve |
| 16 | 386+600 | S-Curve | 38 | 408+400 | Left hand curve |
| 17 | 387+100 | Right hand | 39 | 411+100 | Left hand curve |
| 18 | 387+200 | Left hand curve | 40 | 414+050 | Left hand curve |
| 19 | 387+800 | S-Curve | 41 | 415+300 | Left hand curve |
| 20 | 388+000 | S-Curve | 42 | 421+100 | Left hand curve |
| 21 | 388+800 | Left hand curve | 43 | 421+800 | Left hand curve |
| 22 | 389+000 | S-Curve | 44 | 422+200 | S-Curve |

The existing project road can generally be classified as NH/ SH standard bitumen surfaced road. It is currently in fair condition (owing to the recent maintenance). The condition and geometric elements of this road is assessed to identify the benefits, the deficiencies (sub standard geometric elements), the gaps and constraints.

The geometric elements are compared against NH standard as required by ToR.

The topographical surveying data of the existing road corridor is found useful for the assessment of the existing road geometric features. The topo survey data has adequate information and representation of the existing road and its corridor which include

- The centreline of the existing road
- The pavement edges, ditches, and catch points of the existing road
- Stream lines, river centreline and bank lines
- Urban and rural area features such as buildings, houses, electric poles and other existing features

The consultant has used **MX-Road roadway design software** to analyse the topo survey data. The topo data in AutoCAD format is first imported into MX media and converted into MX- 3D objects. These 3D objects are then used to generate the digitized terrain.

Generation of Ground Model

The 3D data is analyzed using Surface Analysis options of MX-Road to generate triangulated surface model. The triangulated surface model is further analysed.

The existing horizontal alignment of the project road is represented by a line in the DTM. This centreline is traced with tangents and appropriate horizontal curves using the horizontal alignment design options in MX-Road. This has enabled us to have:

- Tangent information
- Horizontal curve information
- Station information of the existing road

This information is reported as MX-outputs and analyzed using EXCEL spreadsheets as provided herein below.

The existing horizontal alignment is analyzed for the main geometric features: the tangent and the curves. The horizontal alignment information including PI-stations, deflection angles, horizontal curve radii are summarized and compared with NH standard limiting values as provided in the standards has been verified.

## 1.3 Vertical Alignment Condition of Existing Road

The existing ground profile along the existing alignment is extracted from the ground model. Then, the existing ground profile is traced with gradients and appropriate vertical curves using the vertical alignment design options in MX Road. This has enabled us to have

⇒ Gradient Information

⇒ Vertical curve information of the existing road

This information is compared with the limiting design values (minimum or maximum for design standard) of plain terrain.

In the overall, most of the gradient is gentle and is within the allowable maximum gradient. We therefore can conclude that the gradient of the project road is significantly within the standard requiring the least improvement. But there are some locations in both corridors near the bridge location where vertical alignment needs to be improved from safety point of view.

## 1.4 Formation width and Cross- Section of Existing Road.

"No feature of a highway has a greater influence on the safety and comfort of driving than the width and the condition of the surface." (AASHTO - 1990: p 333).

From the collected inventory of NH-39, only 17 % is in valley and balance in hills and hilly/mountain terrain. The minimum existing formation width is 5.5m.

It was observed that the type of pavement is bituminous pavement 5 m for 500m length, 9 to 12 m for 3500m length, 12.5 m to 14m for 3600m length, 16.5 m for 400m length and rest is with 7 m

The existing shoulder on either side of the carriageway is of earthen type with a width varying from 0.5 m to 1.0 m for a majority road section of 96900 m length, Hard Shoulder of 3.5m from 341+900 to 342+500 and at some stretches for a length of about 2900 m paved shoulders width varying from 0.5 to 2.0 m mostly in urban sections are observed. From the above it is reported that there is an urgent need to provide a uniform standard cross section for the entire project as required by the design traffic.

Road width should be minimized so as to reduce the costs of construction and maintenance whilst being sufficient to carry the traffic loading efficiently and safely.

Accordingly, various cross-sections are proposed, each addressing a specific need along that portion of road traversed. Proposals are listed for 2 lane sections in Urban / rural areas for plain terrain and 4 lane carriageway for Large Towns with or without service road as described later.

## 1.5 Pedestrians and Slow moving vehicles, Cyclists

The following special characteristics of pedestrians need to be taken into consideration during the design as required by Asian Highway Standards Annex II that pedestrians, bicycles and other slow moving traffic should be separated from through traffic by provision of frontage roads and sidewalks where smooth traffic is impeded by the existence of such local mixed traffic: The design has to consider the following needs of pedestrians

- Select the shortest path between two points.
- Have resistance to changes in gradient or elevation when crossing roadways and
- Avoid using inconvenient sections of roadway facilities such as muddy walkways

Pedestrian volume and activities are high to moderate in urban towns than rural areas. In rural areas of the project pedestrian volume and activities are found significant. Accordingly, pedestrians as one of the major road users are considered in Town and village areas only.

Cyclist volume and activity is also significant in town and village areas only.

The existing height of embankment for both Nh-39 are presented in Table 1.2 below.

There is no embankment observed in between Lilong and Pallel except at the cross drainage structures. The existing heights on valley side in ghat section from Pallel and Moreh.

**Table 1.2 – Height of Embankment**

| Embankment Height (m) | Project Length (%) (NH-39) |
|---|---|
| 0-1 | 26 |
| 1-2 | 9 |
| 2- 4 | 4 |
| 4- 6 | 9 |
| 6-12 | 17 |
| >12 | 35 |

It is noted that 26% and 35% of NH 39 are having an hill slopes height of less than 1m and greater than 12m (ghat section). Also road embankment may need to be raised to provide adequate clearance above the pipe culverts where needed.

## 1.6 Recommended Geometric Design Standards

The project roads are named as Asian Highways and it enable connectivity to three neighboring countries Bhutan, Nepal and Bangladesh. This warrants for a project with geometric design standard that is comparable with International geometric design standards. The selection of design standards is related to road function, volume of traffic and terrain. As per international practice, the criteria that need consideration for deciding design standards are Design speed, Lane width, Shoulder width, Bridge width, Structural capacity, Horizontal alignment, Vertical alignment, Grade, Stopping sight distance, Cross slope, Super elevation and Vertical clearance. In practice, design speed is used as an index which links road function, traffic flow and terrain to the design parameters of sight distance and curvature to ensure that a driver is presented with a reasonably consistent speed environment.

The Design Speed is a selected speed which correlates with the terrain conditions and the classification of the road to determine the various design elements of the roadway. It may be defined as the maximum safe speed that can be maintained over a given section of the road where conditions are so favourable that the design features of the road govern. Design elements such as lane and shoulder widths, horizontal radius, super elevation, sight distance and gradient are directly related to design speed. Thus all of the geometric design parameters of a road are directly related to the adopted design speed. The Asian Highway classification and design standards provide the minimum standards and guidelines for the construction, improvement and maintenance of Asian Highway routes. These standards do not apply to built-up areas as per Annex II of Design Standards. The secretariat introduced the provision of Asian Highway design standards, which were developed in 1993. A comparison was made between the Asian Highway design standards, the national standards of the participating countries and the European arterial road standards, as they were reflected in the European Agreement on Main International Traffic Arteries, 1975. A similar comparison of design speeds recommended by different authorities including Asian Highways Standards in relation with plain terrain and similar road function is presented in the Table 1.3 below for assisting appropriate decision on built up areas.

**Table 1.3 Design speeds recommended by different agencies for Terrain**

| Terrain Classification | Asian Highways Class I & II Km/hr | National Highway as per IRC SP 73 Km/hr | TRRL ORN 6-Arterial Class B Km/hr | AASHTO Arterial Rural Section M/Hr | AASHTO Arterial Urban Section M/Hr |
|---|---|---|---|---|---|
| Plain / Level | 100-80 | 100-80 | 100 | 100 -120 | 50-100 |
| Mountainous/Steep | 60-40 | 50-30 | 40 | 60-30 | 30 |

As per ToR section 4.10.2, the Consultants shall evolve Design Standards primarily based on IRC publications, MORT&H Circulars and relevant recommendations of the international standards (American, Australian, British, Canadian, Japanese) for approval by PWRD. Based on Annex II of Asian Highway Standards (AHS) and IRC SP 73/ 2007 the Design Consultant recommends a design speed of 50-30 km/hr in mountainous/steep sections. The project road corridors pass through urban and built-up areas for significant length and bypassing these built up areas is desirable but the large land acquisition requirements make this option unviable and therefore the only option is to reduce the design speed to reasonable levels to minimize the impact and provide safe roads. A design speed of 30km/hr is recommended for urban/built-up sections in Mountainous/Steep terrain which is comparable with International standards. The Geometric design standards recommended for the project road improvements are presented in Table 1.4 primarily based on IRC, MoRT&H circulars and Asian Highways Standards.

**Table 1.4 Recommended Geometric Design Standards**

<table>
<tr><th>Sl. No.</th><th>Element</th><th>Rural (Non Urban)</th></tr>
<tr><td></td><td>Highway Classification (Annex II – AHS)</td><td>Class I for 4 Lane & Class II for 2 Lane</td></tr>
<tr><td>1.</td><td>Right of Way- Plain<br>Right Of Way- Mountainous/Steep (ROW) (Table 2.6 –IRC 73)</td><td>16m-Urban&30m-Rural<br>10m</td></tr>
<tr><td>2.</td><td colspan="2">Two Lane cross section configuration
<table>
<tr><td>Plain and Rolling section</td><td>ROW</td><td>Normal Carriageway (m)</td><td>Paved Shoulder (m)</td><td>Unpaved Shoulder (m)</td><td>Roadway width (m)</td></tr>
<tr><td colspan="6">Rural (IRC SP 73/2007)</td></tr>
<tr><td>Cross Sectional Details</td><td>30m</td><td>3.25</td><td>2 x1.5</td><td>2 x1.0</td><td>12.5</td></tr>
<tr><td colspan="6">Urban (IRC 86/1993)</td></tr>
<tr><td></td><td>ROW</td><td>Normal Carriageway (m)</td><td>Paved Shoulder (m)</td><td>Footpath cum Drain (m)</td><td>Roadway width (m)</td></tr>
<tr><td>Cross Sectional Details</td><td>16m</td><td>3.5</td><td>2x2.25</td><td>-</td><td>11.5</td></tr>
<tr><td colspan="6">Hilly Terrain</td></tr>
<tr><td></td><td>ROW</td><td>Normal Carriageway (m)</td><td>Paved Shoulder (m)</td><td>Footpath cum Drain (m)</td><td>Roadway width (m)</td></tr>
<tr><td>Cross Sectional Details</td><td>10m</td><td>5.5</td><td>-</td><td>2x1.5</td><td>8.5</td></tr>
</table>
Note - ROW shall be restricted to minimum construction width to avoid fresh land acquisition.<br>
AHS Annex II - Pedestrians, bicycles and animal-drawn carts should be separated from through traffic by the provision of frontage roads and/or sidewalks for the sections where smooth traffic is impeded by the existence of such local mixed traffic.</td></tr>
<tr><td>3.</td><td colspan="2">Four Lane cross section configuration</td></tr>
</table>

The right of way requirement is 60 m and a minimum of 45 m. However, in order to minimize the social impact, ROW shall be restricted to minimum construction width to avoid resettlement and fresh land acquisition. Different cross sections have been developed for open and built up area with a minimum of 35 m ROW.

4 Lane Main Carriageway Configuration without Service Road

| Reference | ROW (m) | Required Construction Width | Space for Services | Embank Slope, & Drain | Earthen Shoulder | Paved Shoulder | Main Carriageway | Shyness | Median | Shyness | Main Carriageway | Paved Shoulder | Earthen Shoulder | Embank Slope, & Drain | Space for Services |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 Lane Main Carriageway Configuration without Service Road<br>All values in meters | | | | | | | | | | | | | | |
| | 45 | 44 | 2 | 7 | 2 | 1.5 | 7.0 | 0.25 | 4.5 | 0.25 | 7.0 | 1.5 | 2 | 7 | 2 |

4 Lane Built-up cross section configuration

| Reference | ROW (m) | Required Construction Width | Drain Cum Footpath | Service Road Carriageway | Separator | Paved Shoulder | Main Carriageway | Shyness | Median | Shyness | Main Carriageway | Paved Shoulder | Separator | Service Road Carriageway | Drain Cum Footpath |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 Lane Main Carriageway Configuration with Service Road<br>All values in meters | | | | | | | | | | | | | | |
| Fig 2.2 of SP 73 | 45 | 44 | 2.0 | 7.0 | 1.5 | 2.0 | 7.0 | 0.25 | 4.5 | 0.25 | 7.0 | 2.0 | 1.5 | 7.0 | 2.0 |
| | 40 | 39.5 | 2.0 | 6.0 | 1.5 | 2.0 | 7.0 | 0.25 | 2.0 | 0.25 | 7.0 | 2.0 | 1.5 | 6.0 | 2.0 |
| | 35 | 34.5 | 1.5 | 5.0 | 1.0 | 1.5 | 7.0 | 0.25 | 2.0 | 0.25 | 7.0 | 1.5 | 1.0 | 5.0 | 1.5 |

Suitable cross section shall be adopted based on the available ROW.

| | | | | |
|---|---|---|---|---|
| 4. | Camber/Cross Fall – Table 2.4 -IRC SP 73 Table 4 ( AHS) | Cement Concrete : 2.0%<br>Bituminous : 2.5%<br>Earthen shoulder : 4.0% | | |
| 5. | Design Speed (km/h) | Level & Rolling : 80-100 for rural/open sections & 50 for built-up sections<br>Rolling : 65- 80<br>Mountainous : 40 - 50<br>Steep : 40 - 30 | | |
| 6. | Sight Distance | Stopping Sight Distance (m) | Intermediate Sight Distance | Overtaking Sight |

| | | | (m) | Distance(m) |
|---|---|---|---|---|
| | Speed (Kmph) | | | |
| | 100 | 180 | 360 | 640 |
| | 80 | 120 | 240 | 470 |
| | 65 | 90 | 180 | 340 |
| | 60 | 80 | 160 | 300 |
| | 50 | 60 | 120 | 235 |
| | 40 | 45 | 90 | 165 |
| | 30 | 30 | 60 | 120 |

| | | | |
|---|---|---|---|
| 7. | Super Elevation | Limited to 7%(Two lane Carriageway)<br>Limited to 5%(Four lane Divided Carriageway) | |
| 8 | Minimum radii of horizontal curves (m) | Design speed (km/h) | Desirable Min radius, R min (m) (Plain Terrain) |
| | | 100<br>80<br>65<br>50 | 360<br>240<br>150<br>90 |
| | Minimum radii of horizontal curves (m) | Design speed (km/h)<br>40<br>30 | Desirable Min radius, R min (m) (Mountainous/Steep Terrain)<br>40<br>30 |
| 9 | Minimum Length of Transition Curve (m)<br>*NA: Not applicable*<br>NR: Not required | (see table below) | |

| | Design Speed (kmph) | | | |
|---|---|---|---|---|
| | Plain and Rolling | | | |
| Curve Radius (m) | 100 | 80 | 65 | 50 |
| | Transition Length (m) | | | |
| 90 | | | | 75 |
| 100 | | | NA | 70 |
| 150 | | | 80 | 45 |
| 170 | | | 70 | 40 |
| 200 | | NA | 60 | 35 |
| 240 | | 90 | 50 | 30 |
| 300 | NA | 75 | 40 | 25 |
| 360 | 130 | 60 | 35 | 20 |
| 400 | 115 | 55 | 30 | 20 |
| 500 | 95 | 45 | 25 | NR |
| 600 | 80 | 35 | 20 | |
| 700 | 70 | 35 | 20 | |
| 800 | 60 | 30 | NR | |

| | | | | |
|---|---|---|---|---|
| 900 | 55 | 30 | | |
| 1000 | 50 | 30 | | |
| 1200 | 40 | NR | | |
| 1500 | 35 | | | |
| 1800 | 30 | | | |
| 2000 | NR | | | |

Minimum Length of Transition Curve (m)
*NA: Not applicable*
NR: Not required

| Curve Radius (m) | Design Speed (kmph) Mountainous/Steep | | | |
|---|---|---|---|---|
| | 40 | 30 | 25 | 20 |
| | Transition Length (m) | | | |
| 14 | | | NA | 30 |
| 20 | | | 35 | 20 |
| 25 | | | 25 | 20 |
| 30 | | NA | 25 | 15 |
| 40 | NA | 30 | 20 | 15 |
| 50 | 40 | 25 | 15 | 15 |
| 55 | 40 | 20 | 15 | 15 |
| 70 | 30 | 20 | 15 | 15 |
| 80 | 25 | 15 | 15 | NR |
| 90 | 25 | 15 | 15 | |
| 100 | 20 | 15 | 15 | |
| 125 | 15 | 15 | NR | |
| 150 | 15 | 15 | | |
| 170 | 15 | 15 | | |
| 200 | 15 | NR | | |
| 250 | 15 | | | |
| 300 | 15 | | | |
| 400 | NR | | | |
| 500 | | | | |

Note

Transition curves are required to connect curves with radii less than 1500m for Class I roads and 900m for Class II roads as per AHS Annex II.

The super-elevation shall be attained gradually over the full length of the transition curve so that the design super-elevation is available at the starting point of the circular portion. In case where transition curve cannot be provided for some reason, 2/3 of the super elevation may be attained on the straight section before start of the circular curve and the balance 1/3 on the curve.

<table>
<tr><td></td><td colspan="4">In developing the required super-elevation, it should be ensured that the longitudinal slope of the pavement edge compared to the centre-line (i.e., the rate of change of super-elevation) is not steeper than 1 in 150 for roads in plain and rolling terrain.<br><br>When culverts fall on a horizontal curve, the top surface of the wearing course of culverts should have the same profile as the approaches. The super-elevation may be given to the abutments keeping the deck slab thickness uniform as per design. The level of the top of the slab of the culverts should be the same as the top level of the approaches so that undue jerk while driving on the finished road is avoided.</td></tr>
<tr><td>9</td><td>Extra width of pavement at Horizontal Curves (for two lane)</td><td colspan="3">
<table>
<tr><td>Radius of Curve (m)</td><td>Extra Widening (m)</td></tr>
<tr><td>Up to 20 m</td><td>1.50 m</td></tr>
<tr><td>21 – 40 m</td><td>1.50 m</td></tr>
<tr><td>41 – 60 m</td><td>1.20 m</td></tr>
<tr><td>61 -100m</td><td>0.90m</td></tr>
<tr><td>101 – 300 m</td><td>0.60 m</td></tr>
<tr><td>Above 300 m</td><td>Not Required</td></tr>
</table>
</td></tr>
<tr><td rowspan="4">10.</td><td>Vertical Alignment (Max Gradient ) Table 4 ( AHS)</td><td>Ruling</td><td>Limiting</td><td>Exceptional</td></tr>
<tr><td>Plain and Rolling Terrain</td><td>4 %</td><td>5 %</td><td>NA</td></tr>
<tr><td>Mountainous terrain and steep terrain more than 3000m above MSL</td><td>5%</td><td>6%</td><td>NA</td></tr>
<tr><td>Steep terrain up to 3000m above MSL</td><td>6%</td><td>7%</td><td>NA</td></tr>
<tr><td>Note</td><td colspan="4">General notes on Vertical Alignment<br>Broken-back grade lines, (i.e. two vertical curves in the same direction separated by a short Tangent) shall be avoided and preferably replaced by a single long curve.<br>Decks of small CD structure (i.e. culverts & bridges) should follow the same profile as the flanking road section, with no break in the grade line.<br><br>The grade compensation at curves should be calculated by the following formula – Grade compensation (%) = (30+R) / R subject to maximum value of 75/ R where R is the radius of curve. Grade compensation is not necessary for gradient flatter than 4%, when applying grade compensation correction, the gradient need not be eased beyond 4%</td></tr>
<tr><td>11.</td><td>Minimum length of Vertical Curve</td><td colspan="3">Design speed 100 kmph – 60m<br>Design speed 80 kmph – 50m<br>Design speed 65 kmph – 40m<br>Design speed 50 kmph – 30m</td></tr>
<tr><td>12.</td><td>Maximum grade change not requiring a vertical curve</td><td colspan="3">Design speed 100 kmph – 0.5 %<br>Design speed 80 kmph – 0.6 %<br>Design speed 65 kmph – 0.8 %</td></tr>
</table>

| | | |
|---|---|---|
| | | Design speed 50 kmph – 1.0 % |
| 13. | Length of Vertical Curve for different speeds | |

| Design Speed | K Value for Summit Curve | | | K Value for Valley Curve |
|---|---|---|---|---|
| | SSD | ISD | OSD | |
| 50 | 8.2 | 15 | 57.5 | 10 |
| 60 | 14.5 | 26.7 | 93.7 | 15 |
| 65 | 18.4 | 33.8 | 120.4 | 17.4 |
| 80 | 32.6 | 60 | 230.1 | 25.3 |
| 100 | 73.6 | 135 | 426.7 | 41.5 |

Length of curve = K* A where A is algebraic difference in grades expressed as percentage

It is desirable to provide vertical curves meets the requirement OSD for two lane two way carriage way and ISD for the 4 lane divided carriage way.

| | | | |
|---|---|---|---|
| 14. | Drainage Criteria<br>The minimum depth of open side drain, measured from the top of subgrade, be 1.0m in a normal formation and be provided on either side depending upon the cross slope of road. | | |
| 15. | Side Slopes<br>(hf □ height of shoulder edge above the natural ground level)<br>(hc : Height of cut) | a. fore Slope<br>hf ≤ 1m : 1 : 2<br>1m<hf≤3m : 1 : 2<br>hf – 3 to 4 m : 1 : 1.5<br>Above 4m, retaining structures recommended | b. back Slope<br>hc ≤ 1m – 1 : 2<br>1 to 3 m – 1 : 1.5 to 2<br>> 3m – 1 : 1.5 |

| | | |
|---|---|---|
| 16. | Overhead Utilities | |
| | 1) Vertical clearances (min) | |
| | ROB | 6.525 m |
| | Flyover | 5.5 m |
| | Vehicle Underpass | 5.5 m |
| | Elephant Underpass | 6.0 m |
| | For ordinary wires and lines carrying very low voltage up to 110 volts e.g. telecommunication lines. | 5.5 m |
| | For electric power line carrying voltage up to and including 650 volts | 6.0 m |
| | For electric power line carrying voltage exceeding 650 volts | 6.50 m |
| | b) Horizontal Clearances | |
| | Poles carrying overhead power and telecommunication lines, except in urban areas<br><br>Poles erected for street lighting | 10.0 m & a minimum distance of 5.0m from nearest line of avenue trees |

| | | |
|---|---|---|
| | For roads with raised kerbs<br><br>For road without raised kerbs | Minimum 300 mm from the edge of the raised Kerb and 600 mm being preferable.<br><br>At least 1.5 m from the edge of carriageway subject to a minimum of 5.0 m from the centre line of carriageway |
| Note | Guard cradle or screen should be provided for electric power carrying voltage exceeding 110 volts while crossing the highway. The cradle should be extended desirably over the full right-of-way. However, guards may be omitted in the case of extra high voltage lines strung on self supporting towers designed with adequate factor of safety<br>As per AHS, Overhead clearance should be not less than 4.5 m and Railway intersections should be at different levels | |

## 1.7 Recommended Cross Sectional Elements

Road width should be minimized so as to reduce the costs of construction and maintenance whilst being sufficient to carry the traffic loading efficiently and safely.

Accordingly, various cross-sections are proposed, each addressing a specific need along that portion of road traversed. Typical cross sections and the schedule of cross section is presented in Appendix 1.1 A and B.

Travel Way Width:

As per AASHTO, no feature of a highway has a greater influence on the safety and comfort of driving than the width and the condition of the surface. It can be seen from the following Table 1.5 that different standards specify or use a range lane width.

**Table 1.5 – Travel way width or Lane width of Carriageway for different standards**

| Design Standard | Lane Width (m) |
|---|---|
| AHS Class I & II | 3.5 |
| IRC SP 73 Section 2.4 | 3.5 |
| TRL Arterial, Design Class A | 3.25 |
| AASHTO | 3.0 – 3.6 |

The capacity of the road is highly dependent on the width of traffic lane that will govern the safety and convenience of traffic. The carriageway widths do also have a profound influence on the capacity of the road section. For the project roads, a lane width of 3.5 m is recommended. Lane width should be at least 3.5 m on straight sections of road as per AHS. This guarantees adequate clearance for any vehicle having a width 2.55 m which is the maximum specified in EU directive 96/53/EC and 2.6 m specified by some countries.

For the 2 lane rural sections, in plain terrain, a normal carriageway width of 7.0 m with 1.5 m of paved shoulders and 1.0 m of earthen shoulders is recommended. In built up urban 2 lane sections a carriageway of 7.0m, 2 x 2.25m frontage lanes for slow moving traffic with 1.5m footpath and in village sections a carriageway of 7.0m, 2 x2.0m for slow moving with 0.5m shoulder are recommended as given in Table 1.4.

For the 4 lane rural sections, in plain terrain, a carriageway width of 2x 7.0 m and paved shoulders 2 x1.5m, earthen shoulder 2x2m with a median of 4.5m are recommended as presented in Table 1.4 without service road. In built up urban 4 lane sections with service road, a carriageway width of 2x 7.0 m and paved shoulders 2 x1.5m, separator 2x1m with a median of 2.0m and service road on either side with a carriageway of 5.5 to 7.0 are recommended as presented in Table 1.4.

## 1.8 Proposed Geometric Design

### 1.8.1 General

The project road alignment has been studied thoroughly based on recommendations of the feasibility study, field reconnaissance and detailed topographic survey. The project road traverses through plain terrain and have a fairly good horizontal alignment. Poor geometry is observed at isolated locations and some of them in built up areas. The right of way available is generally good in rural open areas but there is either limited right of way or extensive encroachment in built up/urban areas limiting the capacity expansion and improvement options. The Imphal-Moreh Project corridor has been surveyed in detail covering all items in the scope of work using the sophisticated Survey Equipment such as ORTHOPHOTO, GPS, Total Station, Auto Level and drawings to be produced as AutoCAD drawing in DWG/DXF format.

### 1.8.2 Capacity Augmentation

The existing road has a two-lane carriageway all through. Detailed traffic studies have been carried out to identify the capacity augmentation needs of the project road sections., the engineering solutions that emerged from the capacity augmentation requirement and the condition of the existing roads considered over a 30-year life cycle period The capacity augmentation recommended based on traffic, engineering and social assessment is presented in Table 1.6

**Table 1.6Capacity Augmentation for NH-39**

| Sl.No | Homogenous Section Details | Recommendation on Capacity Augmentation |
|---|---|---|
| 1 | HS 1: Lilong to Thoubal (km 330 to km 342+600) | 4 Lane with Paved shoulder and service road on built up location. |
| 2 | HS 2: Thoubal to Pallel (km 342+600 to km 365+900) | 4 Lane with paved shoulder and service road on built up location. |
| 3 | HS 3: Pallel to Khudangthabi (365+900 to km 417) | 2 Lane with Paved shoulder. |
| 4 | HS 4: Khudangthabi to Moreh (km 417 to km 425+411) | 2 Lane with Paved shoulder. |
| 5. | Alternative Alignment from Wangjing to Khudangthabi (km 0+000 to km 59+359) | Intermediate Lane Configuration |

In the course of the design, maximum effort was made to achieve design consistency, to meet road user expectations and perceptions of the designed road and its environment by limiting speed changes throughout the project road. The alignment in general allows design to be carried out to the selected minimum standard. In addition, where constraints are not severe, the road is designed to higher standards. Where constraints are severe like heavily built up areas and forest areas, project design has deviated from design standards as presented in Departure/ Variation section. Service roads are provided in some built-up sections and new grade separated crossings where buildings are abutting the road alignment.

### 1.8.3 Proposed Horizontal Alignment

The project road is predominantly located in plain& Hilly terrain. The horizontal alignment is designed to provide best possible radius greater than the minimum radius required in most of the locations to have a comfortable ride .

The total length of the project roads is estimated to be 59.359 km for Alternative Route and 95411 km(i.e. from Km 33000 to 425411) for NH-39 along main road as derived after detailed design. The summary of horizontal curves is presented in Appendix 1.4 (a) and (b) and Plan and Profile Drawings are presented separately along with final alignment drawings. The summary of designed horizontal alignment are presented in Table 1.4(a)&1.4(b) for Nh-39 and Alternative route

**Table 1.8 Horizontal Alignment Details of NH-39 and Alternative Route**

| Description | NH-39 | | Alternative Route |
|---|---|---|---|
| Lane configuration | 2-Lane | 4-Lane | Intermediate lane |
| Total Length of Sections (Km) | 8900 | 58500 | 59.359 km |
| Minimum Horizontal Curve Radius in Hill section | 20m | | 20m |

| | | |
|---|---|---|
| Number of horizontal curves | 674 | 799 |
| Total length of Horizontal Curve & transition | 52% of Project Length | 70% of Project Length |
| Total Length of Straight Portion | 48% of Project Length | 25 % of Project Length |

### 1.8.4 Proposed Vertical Alignment

The profile of the project road has been finalized on the basis of DTM data collected during the topographic survey and based on the adopted design standards.

The project road is substantially located in plain& hilly terrain. The vertical alignment of the project road is generally designed for a design speed of 65 kmph for built up &30 Kmph in hill areas.

**Table 1.10: Summary of Vertical Curves**

| NH-39 | | Alternative Route | |
|---|---|---|---|
| Sag Number of Sag Curves | 147 | Sag Number of Curve | 43 |
| Number of Hog Curves | 140 | Hog Number of Curves | 43 |
| Total Curve Length | 23120 m | Total Curve Length | 10591 m |
| Total Tangent Length | 72791m | Total Tangent Length | 50680 m |

The details of vertical curves are presented in Appendix 1-6(a) & 1.6(b) for both Nh-39 & Alternative Route. The vertical profile summary is presented in Table 1.11 below. There are steep gradient along the project roads.

**Table 1.11: Vertical profile distribution of NH-39 and Alternative Route**

| Vertical Profile of NH-39 | Length( m) |
|---|---|
| Tangents on gradient 5 to 10 % | 315m |
| Tangents on gradient 0.0 to 5% | 666.98m |

| Vertical Profile of Alternative Route | Length( m) |
|---|---|
| Tangents on gradient 5 to 10 % | 238.6m |
| Tangents on gradient 0.0 to 5 % | 152.3m |

As a design philosophy, short sag vertical curves are generally employed to limit the drainage problem associated with long sag vertical curves. For hog curves in general, the design with K value for ISD will enhance the aesthetics and safety characteristics of the road.

Besides, wherever possible, phasing of horizontal and vertical curves is matched by phasing the start and end of the horizontal and vertical curves at approximately same points.

In general, profiles are set to follow the existing tracks and RoW wherever possible with adjustments made to satisfy sight distance, flood level, bridge approach and culvert clearance needs.

### 1.8.5 Service Road Locations

Service roads on both sides are envisaged in congested towns / villages locations to segregate the slow moving local traffic from the high speed highway traffic. This will also cater to the need of the local pedestrians and vehicles to travel without hindering the high-speed highway traffic. In view of social aspects and density of population of Manipur, consultants feel that such built-up locations need to be provided with service road. But when considering the economy of the project, proposal of service roads are restricted at unavoidable locations. However service roads are provided on all built-up areas where raising of embankment is required due to over topping. All together service roads provided for a length of 8.5 km split in 4 stretches and its details are given in Table 1.12

**Table 1-12: Location details of service roads proposed**

| SL No | Chainage ( km) | | Length (m) | Side | Name of Village/Town |
|---|---|---|---|---|---|
| | Start | End | | | |
| 1 | 330+600 | 332+300 | 1700 | B/S | Lilong Bazar |
| 2 | 332+800 | 333+200 | 400 | B/S | LilongHangamthobi |
| 3 | 334+000 | 334+300 | 300 | B/S | Ushopokpi |
| 4 | 338+400 | 339+850 | 1450 | B/S | Thoubal Town |
| 5 | 340+700 | 342+240 | 1540 | B/S | Thoubal Town |
| 6 | 342+240 | 342+930 | 690 | B/S | Thoubal Town |
| 7 | 343+600 | 345+100 | 1500 | B/S | Khangbok Town |
| 8 | 345+600 | 346+000 | 400 | B/S | Wangbal Village |
| 9 | 348+090 | 349+300 | 1210 | B/S | Wangjing Town |
| 10 | 352+300 | 353+300 | 1000 | B/S | Khongjom Town |
| 11 | 357+600 | 358+100 | 500 | B/S | Sora Village |
| 12 | 359+610 | 360+530 | 920 | B/S | KakchingLamkhai |
| 13 | 364+600 | 366+200 | 1600 | B/S | Pallel Town |

### 1.8.6 Design of Junctions

The main objective of intersection design is to facilitate the convenience, ease, and comfort of people traversing the intersection while enhancing the efficient movement of motor vehicles, buses, trucks, bicycles, and pedestrians. Intersection design should be fitted closely to the natural transitional paths and operating characteristics of its users.

The basic elements considered in intersection design are human factors, traffic considerations, physical elements and economic factors. The basic types of intersections are the three-leg or T, the four-leg, and the multi-leg. At each location, the intersection type is determined primarily by the number of intersecting legs, the topography, the character of the intersecting highways, the traffic volumes, patterns, and speeds, and the desired type of operation. The junctions are designed to allow all turning movements and taking into consideration the heavy articulated vehicular traffic. Safety will be the main focus while designing the junctions. Depending on the cross road flow the traffic is channelized to avoid merging and diverging conflicts. All cross roads are designed to a length of 100m from the junction.

All junctions in the project are at grade junctions. Turning movement counts were carried out at all major junctions along the project road. There are 2 major junctions in NH-39 and 1 Major junction in Alternative Route situated along the project corridor as presented in Appendix 1.7(a). The traffic analysis and forecast concluded that there are no junctions that require grade separation as per the criteria specified in IRC SP 41-1994.

Minor Junctions:

All approach roads at minor junctions are designed to a suitable length. The junction radii are designed for safe negotiation of vehicles to and from service road/cross road. Where minor roads form junctions directly with the main carriageway in the absence of service road and VUP’s/PUP’s, the entry/exits are provide with acceleration/deceleration lanes.

The 21 minor junctions in Nh-39. Details are given below

**Table 1-13 Details of Major/Minor Junctions**

| | Existing | Type of junction | Classification |
|---|---|---|---|
| 1 | 342+600 | + | Major |
| 2 | 360+000 | T | Major |
| 3 | 365+850 | + | Major |
| 4 | 322+900 | Y | Minor |
| 5 | 328+600 | T | Minor |
| 6 | 331+450 | T | Minor |
| 7 | 333+050 | T | Minor |
| 8 | 334+200 | T | Minor |
| 9 | 348+550 | Y | Minor |
| 10 | 351+700 | T | Minor |
| 11 | 352+550 | T | Minor |

| | Existing | Type of junction | Classification |
|---|---|---|---|
| 12 | 352+600 | T | Minor |
| 13 | 353+050 | T | Minor |
| 14 | 353+650 | T | Minor |
| 15 | 353+100 | T | Minor |
| 16 | 354+400 | T | Minor |
| 17 | 357+550 | T | Minor |
| 18 | 357+750 | T | Minor |
| 19 | 360+150 | T | Minor |
| 20 | 365+850 | T | Minor |
| 21 | 416+750 | T | Minor |
| 22 | 424+750 | T | Minor |
| 23 | 426+850 | T | Minor |
| 24 | 428+800 | + | Minor |

### 1.8.7 Via Duct

Due to steeper slope, it is difficult for the vehicle to mount the road. Hence viaduct has been provided at Km-397.960 on Nh-39 for easier mounting of vehicle.

### 1.8.8 Pedestrian crossings, Bus bays & Truck Lay byes

Pedestrian crossings are suitably integrated with the overall design of the intersection.

The following criteria shall be followed regarding selection of pedestrian crossings:

(i) At-Grade Pedestrian crossings are recommended at all important intersections and such other locations where substantial conflict exists between vehicular and pedestrian movements. The pedestrian crossings are designed at right angles to the carriageway and properly marked so that the pedestrians are subjected to minimum inconvenience and not substantially increase the walk distance of pedestrians. Adequate visibility, freedom from obstructions and sufficient space for waiting are the other important requirements.

At-grade pedestrian crossings are controlled whether at signalized intersection or pedestrian actuated signal. The details are presented in the drawing volume.

The buses are strictly be allowed to stop for dropping and picking up passengers only at the

Bus bays for safety reasons. The location of the bus bays are fixed on the basis of following principles: (i) the bus stops shall be sited away from bridges and other important structures and embankment sections more than 3 m high. (ii) As far as possible, bus bays shall not be located on horizontal curves or at the summit of vertical curves. (iii) The location shall have good visibility, not less than the safe stopping sight distance. (iv) The bus bays shall not be located too close to the road intersections.

One bus bay is recommended in towns and major villages on each side in each location. There are 10 bus stops in NH-39. The typical section is presented in drawing volume along with the schedule for NH-39. The details are presented in Appendix 1.9 a and b.

### 1.8.9 Recommendations on High Embankments

The high embankment approaches (height> 6m) are generally made with the introduction of the retaining walls in the form of Gabion walls where ROW is limited. The following summarizes the design recommendations:

1. Fill slope 1(V): 2(H) is found safe at all locations of high embankment and thus the slope may be maintained throughout the road stretch of this package with balancing berm when the maximum height > 6m. Gabion walls are recommended where ROW is limited.
2. In order to minimize post construction settlement, the top layer of the sub-grade (about 500 mm thick) is recommended to be laid only 2-3 months after placing of the lower - in locations where the height of embankment is > 6 metres.
3. Unsuitable material on the top layer of original ground, if any, shall be removed. The original ground shall be scarified and compacted before placing subsequent fill soil.
4. The embankment fill shall be taken from selected borrow areas with superior material as embankment is build up. The slopes of the embankment shall be protected with stone pitching up to high flood level + 1m above and by providing appropriate positive drainage with chutes at 10 to 15m intervals.
5. Guard rail shall be provided along the approaches of embankments of height > 6 m to ensure safety.

The shoulders in high embankment locations (i.e. of height more than 10m) are to be fully paved to reduce the moisture variation in road prism and psychological widening for easy crossing.

The schedule of high embankment are presented in Appendix 1.11(a)&(b) for both NH-39 & Alternative Route.

### 1.8.10 Retaining walls / Toe walls / Gabion walls

Retaining wall / toe / Gabion walls are recommended for main link and alternative alignment, or in High Embankments as presented in Appendix 1.11(a)&1.11 (b).

### 1.8.11 Road Safety Barrier

Highway engineering safety is usually assumed to be optimised by linking geometric elements to a design or operating speed, so that the resulting geometry has a consistency which reduces the likelihood of a driver being presented with an unexpected situation. This concept of driver expectation forms the basis of this set of design standards.

But it is not always be practical or economical to provide safe slopes and curves within the standard in all section of a road. In these instances safety barriers will be required and used. Where appropriate as per guidelines, provision will be made to construct safety barriers using steel guardrails made of steel beam as per IRC 103 with strong post as per MoRTH specification 810. Following modified criteria is recommended in addition to provisions of IRC SP 73 as per international standards.

For roads where cars travel in excess of 50 km/h:

- Sections with embankment height >3 metre on sharp curve and where the side slope is steeper than 1 in 2
- Where there is a risk that vehicles could fall into a body of water deeper than 1 m or onto a rail track;
- Safety barriers recommended to be installed on bridge approaches at least for 30m on approaching side and 15m on the leaving sides on both ends.
- Safety barriers are recommended at RoB approaches with free slope on either side.

The guard rail shall confirm to AASHTO M 180, type I, zinc coated 550g/m2, minimum single post, Class A- Base metal nominal thickness 2.67mm and W beam 2.74mm with standard end units or to MoRTH Specification 810. The total requirement and schedule is presented in the drawing volume and in Appendix 1.11.

### 1.8.12 Road Furniture

As per Asian Highway Standards (AHS), the project highway route numbers begin with "AH", standing for "Asian Highway", followed by one, two or three digits. Single-digit route numbers from 1 to 9 are assigned to major Asian Highway routes, which cross more than one sub region. Two- and three-digit route numbers are assigned to indicate the routes within sub regions, including those connecting to neighbouring sub regions, and self-contained highway routes within the participating countries.

The letters and numbers are printed in the Latin script and Arabic numerals. The highway routes with a single digit are supposed to cross the whole of Asia while three digit routes are used within a single region of the states - the routes with two digits are longer regional routes that may or may not cross country borders.

The actual design of the signs has not been standardized by AHS, only that the letters and digits are in white or black, but the colour, shape and size of the sign being completely flexible. Accordingly retro-reflective sheeting (high intensity grade type) is recommended in accordance with MORTH standards. The colour (white letters and numerals) and locations shall be as per IRC 67 and as per section 800 of MoRTH specification as it matches with AHS.

The highway corridors are also State or National Highways with its own route numbers. It is recommended that AHS numbering be followed in all major junctions with overhead destination boards green signs with white numbers are recommended as practiced by International routes and NH/SH numbering be followed continuously to meet both needs.

### 1.8.13 Road Signs and Road Markings

The colour, configuration, size and location of all traffic signs is in accordance with the Code of Practice for Road Signs, IRC: 67 and presented in the drawings volume.

Steel posts shall be made of pipes as shown on the drawings. Steel posts shall be galvanised. The signs will be reflectorized as shown on the drawings and made of encapsulated lens type reflective sheeting vide Clause 801.3, fixed over aluminium sheeting as per these Specifications.

Road markings recommended are according to section 803 of the Technical Specification. Road marking with hot applied thermoplastic material marking paint and road studs are recommended in sections where safety at night needs to be enhanced. Paint shall be white or yellow traffic paint suitable for paved surfaces conforming to the requirements of Technical Specification 803. The colour, width and layout of road markings shall be in accordance with the Code of Practice for Road Markings with paints, IRC : 35, and as specified in the drawings or as directed by the Engineer. Hot Applied Thermoplastic Road Marking paint will have homogeneously composed of aggregate, pigment, resins and glass reflectorizing beads.

Cats Eyes studs shall be installed at junctions or non overtaking zones as directed by the Engineer. The stud anchor shall be of aluminium approximately 60mm long and 30mm in diameter. Each stud shall have 2 reflecting surfaces with colour white and red. The colour white to be used to delineate the centreline with intermittent markings and the red faces are to be used at locations of continuous lines where overtaking is prohibited. Cats eyes type pavement studs shall be approximately 100mm square by 10mm high.

# Chapter 2 TOPOGRAPHICAL SURVEYS

The proposed Project Roads i). Imphal to Moreh –Lilong, Thoubal, Khangabok, Wangjing, Khongjom and Pallel -are being surveyed in detail covering all items in the scope of work using the sophisticated Survey Equipment's such as GPS, Total Station, Auto Level and drawings to be produced as AutoCAD drawing in DWG/DXF format. The traverse and survey are conducted along the selected alignment. The survey data is processed to develop the digital terrain models of the road corridors for the final roadway design.

A detailed topographic survey is being carried out along the proposed alignments using GPS, Total Station and Auto Level to collect sufficient topographic information to prepare 60m wide detailed digital terrain model – maps showing existing physical features and location reference along the alignment. The surveys are being undertaken by the internationally approved methods and prevailing conditions.

## 2.1 Terrain Classification

Project corridor is passing through plain and Hilly terrain sloping towards north to east, elevation is 780 above MSL.

## 2.2 Datum

The datum used for establishment of primary horizontal control station DGPS survey was Universal Transverse Mercator (UTM) zone 45 North (87E) and Geoid EGM2008 (Global) 2.5'x2.5' grid is adopted.

Vertical datum is adopted for NH-39 and Alternative Route is supplied by SOI has given below.

The geographical area of the state 22.327 sq km constitutes less than 0.70% of the entire country. It lies between latitude of 23°83’N – 25°68’N and longitude of 93°03’E – 94°78’E. the State capital, Imphal is located at an elevation of 790 m above mean sea level. Geographically the state is bounded on all sides by ranges of hills and particularly land blocked

## 2.3 Installation of Primary Control Stations

A pair of inter-visible Primary control stations had been installed at intervals not more than 5 km using Global positioning systems (GPS) and the entire survey co-ordinate system is based on the Global coordinate system such as UTM/WGS84.

- DGPS observations were taken in STATIC mode and Post Processing of data is done using the Trimble Geo Office Software. Primary survey controls were established using Differential Global Positioning System (DGPS) as detailed below:
- Fixing of Horizontal control grid by using Differential Global Positioning System (DGPS) at every 5 Km radically on a pair of Primary Control Stations. The DGPS UTM WGS 84 co-ordinates converted as TM co-ordinates to use for establishing the secondary control station along the project roads.

- The primary control Points are located on the edge of the right of way (ROW) at inter-visible locations at every 5km and as far as possible on either side of 5-km stone so that it can be identified easily on the field. The stations selected were ensured to be obstruction free towards sky at an angle of 15º with horizontal plane.
- The primary control station pillars were established with steel bar of 10 mm diameter, fixed in M20 RCC pillar of size 30 cm X 30 cm X 45 cm embedded in M10 concrete (50 mm all around) up to a depth of 30cm and the balance 15 cm above the ground is painted yellow. Pair of such pillars is located at 5 km intervals along the project road.
- The primary control stations were observed for a minimum of 1 hours and at reference stations for 30 minutes to eliminate the possible projection and time errors in the signals received from various satellites being observed at respective locations in order to ensure high accuracy in the positioning of control station within +3cm.

The general methodology adopted for GPS survey is as follows:

Install a pair of points at each location such that the positions are along the alignment and near to our proposed intersections. All these points are connected by triangulation during which the observation time is 1 hours for each position. These are the primary points which are having a secondary point for each. In the next stage these primary and secondary positions are observed for more accuracy.

Care is taken to see that all the primary points are within 5 Km from at least one other primary point and all the secondary points are about 50 to 200 m and inter visible to their respective primary points.

Proper precautions such as ensuring the availability of minimum of 4 and maximum of 12 satellites during the observations are taken care.

The output data is presented in three formats namely:

a) Lat & Long

b) UTM as per WGS 84 in Zone 46N.

All data collection has been done using field computer/data logger. The integrity of data was checked every day on the day of survey. The horizontal and vertical alignments were also checked on the screen and any problems with the raw data are rectified the next day. The two rover stations took common points several times a day to verify the operations of each other as the survey is in progress. For any problems discovered during the survey, corrective measures were taken immediately.

## 2.4 Installation of Secondary Control Stations

Secondary control station points were installed at an interval not exceeding 250m. A traversing survey was carried out using total station and auto level for transferring precise Northing, Easting and altitudes. Two rounds of angle measurements were taken on both left and right face. The angle spread between observed round will not be more than 5 sec. The secondary control stations were fixed by closed traverse and the traverse corrections were applied-based on Bowditch method.

## 2.5 Detailed Survey

The topographical surveys for longitudinal and cross sections covered the following

- Longitudinal section levels along the finalized centre line at 25m intervals to comply with TOR, at the locations of curve points, intersections and at the locations of change of elevations.
- Cross section elevations at 10m interval in full extent of survey for sufficient width covering sufficient number of spot levels on the ground.
- Levelling is being carried out with Auto Level with reference to the Benchmarks and Temporary Bench marks established.

The SHELADIA team also collected details of all-important physical features along the arms of the intersections at the cross roads for a length as per IRC standard. The following details were collected by topographic survey in detail:

- Trees with girth greater than 0.3m, electrical poles, telephone lines, OFC lines, water / oil / Gas pipe lines, manholes
- Building lines, type of buildings (shops or houses), Right of Way boundary if available at site by presence of boundary stones.
- Existing road edge, centreline, be recorded at an interval not exceeding 25 m
- Location of existing features within ROW.
- Special emphasis was made in identifying all religious places – temples, churches, mosque, locations, boundary lines and clear dimensions of compound walls and entrances.
- Locations of roadside drain clearly identifying the type (open / closed), width of drain including the beginning and end of drain.
- Roadside land use viz., residential, mixed residential, commercial, shops and business established areas etc.

The Topographical Survey work was monitored full time by Consultant's Survey Engineer to maintain high precision in picking up maximum number of details in the limited time frame.

## 2.6 Survey Equipment's Used

- Electronic Digital Total Station "Trimble" model M3 - with one-second precision, calibrated to specification was presented to the Engineer-in-charge for verification. Angle measurement, standard deviation 1". Laser plummet accuracy: maximum rotation dia meter of laser spot ± 0.8mm/1.5m. Compensator 1.5 seconds.
- SOKKIA AUTO LEVEL C320 (No: - 10356)
- Accuracy: Automatic compensation for horizontal bubble cantering.
- LEVELING STAFF
- Accuracy to read 5mm least count.
- COMPUTER for survey data processing

## 2.7 Methodology of Error Distribution:

In Traversing: Linear correction of error = Closing error X Measured length for

arithmetical check Perimeter

Horizontal angles: (2n-4) 90° for interior angled traverse (2n+4) 90° for exterior angled traverse.

Levelling:Proportionate distribution of error to the station.

Arithmetical check.

$\sum$ BS - $\sum$ FS = $\sum$ RISE - $\sum$Fall = Last R.L – First R.L. The Permissible error in levelling is 5mm / Km.

## 2.8 Survey Accuracy

Linear measurement accuracy will be 5 cms per Km. i.e 20000 accuracy. Since the bearing distance of the observed points are known by the Total Station, Co-ordinates X, Y, Z are calculated with computer using Auto CADD 2000.

These points whose co-ordinates are to be plotted and joined are presented in the map of the area surveyed. Survey plotting is being carried out in the office simultaneously with the fieldwork. The plotted sheets are taken to the site for verification to ensure that no detail or structure is left out. Necessary modification to the drawings if any is made and then final prints are taken to the desired scale.

Scale of the Survey drawings adopted is 1:1000, for site verification so as to carryout proper checking. The corrections are to be incorporated in the final drawings. All Topographic features in the AutoCAD drawings are coded as per code list.

## 2.9 BMs and Boundary Pillars

After completing the horizontal alignment design, the road centre line is laid on ground and TBM pillars installed.

Care is taken in carrying out the topographic survey for the structural components to adhere to the requirements set in IRC: SP-19-2004, IRC: 5-1998 and IRC-SP-50-1999. Temporary benchmarks are established as pillars at the edges of ROW.

## 2.10 Topographic Survey Data

The data is being processed to build a digital terrain model of the road corridors and is presented in graphical form along the alignment design drawings. The complete data set after processing will be submitted along with the survey report presented in Design Report.

## 2.11 Field topographical Surveys and DTM processing

This was carried using the Leica Total station, Topcon Total stations, and Sokkia Auto Levels.

A corridor of 60m was considered for sections in rural areas while in urban centres (trading centres) a 45m corridor was generally covered. All the details required for the assessment of the junctions including the width of the existing roads, traffic islands, obstructions to traffic, adequate detail for generating the Digital Terrain Model (DTM) in form of spot heights and others were picked.

All features were coded for example CL for centreline, RE for road edge, FE for fence, DR for drains, EP for electricity poles and others.

All the total stations used were self-recording and therefore no post processing of the data was required. Only analysis of the data using advanced features of Microsoft excel was done to check for any inconstancies.

Data was processed into files transferrable into various software used for generating DTMs and processing topographical maps. For this project, AutoCAD land Development software was used to process the data into topographical maps and generating Digital terrain models. These topographical maps were used for design purpose by highway design team.

# Chapter 3 UTILITIES SHIFTING

The guide lines for location / Level requirements of utilities are presented in IRC 98/ 1997 and a summary is presented in Table3.1 below.

**Table3.1 Location Requirements of Utility Lines as per IRC 98/1997**

| Description | Location | Level (Min depth 0.6m) |
|---|---|---|
| Trunk Sewer & Drainage Lines | Outside CW, flow by gravity, | 2-6mm depth |
| Trunk Water Supply Lines<br>Service Water Supply Lines | WS in one side | 1 to 1.5m H<br>0.6 – 1m H |
| HT Electricity Cable<br>LT Electricity Cable | HT,LT not close to WS, tele lines<br>0.7-1.1 W | 1.5-2m H<br>0.6 – 1.0m H |

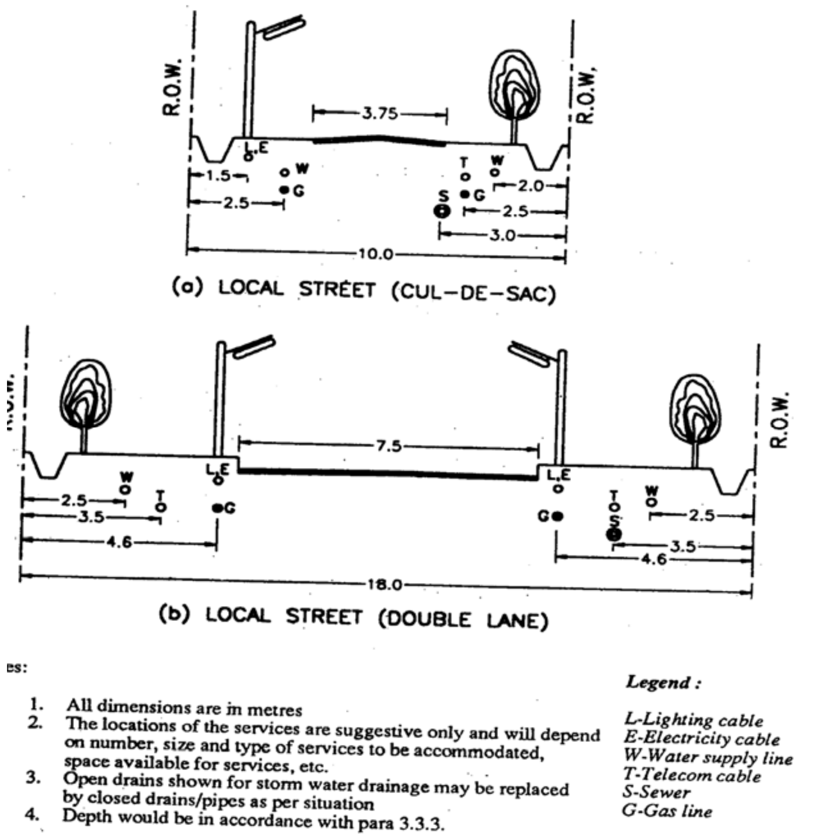
| | | |
|---|---|---|
| Telecommunication cables Direct<br>Telecommunication cables ducted | Unspecified, under foot path or extreme end of RoW | 0.6 -1m H<br>2 – 3m H |
| Duct / Subway for crossing | 3.6.3 -Annular space sealed to not act as drainage path. This shall be adopted for AH as separate ducts are not available<br>Casing Pipe from drain to drain in cut / toe-toe on fill at least 1.2 m below Road Level & 0.3m min from drain inverts | |
| Typical Casing Pipe Under Road | If depth of fill > 450mm below crust, lower 450mm with coarse sand FM>2. If <450mm, fill by granular material with plate compactor or frog hammer. Duration of trenching & reinstatement barest minimum as it leads roads pavt in weakest condition esp when traffic allowed. All works shall be responsibility of road dept, cost of such works be met by utility owner | |

While citing Utility along/across Bridge Structures, the following considerations need to be adopted as per IRC guidelines

- Provision of Water, sewage, Gas Pipes Utility along Important bridges be avoided
- If inevitable, utility be supported in substructure than superstructure. Seamless pipes with welded joints. CI pipes with S&B joints won't be allowed
- Pipeline should be so aligned that it is taken out of the approach embankment as quickly as possible. Thrust block should be inside the culvert for easy mace. Where change in elevation, air valves be provided
- All new bridge structures- consult public utility authority for needs &requirements
- Bank of reference plans showing all utility plans, their location & Depth

The indicative utility locations for Electric cable, water supply, telecom cable as per IRC 98 is presented in Figure 3.1 below

**Figure 3.1 - Indicative utility locations for Electric cable, water supply, Telecom**




**cable:**

The details of impacted utility installations, which may need to be shifted, are collected during Road Inventory data. This data is further updated during topographic survey. . Mostly utilities are present in urban sections.

The above utility details are updated by directly contacting the utility owners along the corridor and a utility shifting needs assessment and utility plan are presented in the draft report. The summary is presented in this report and details are presented in Volume II Design Report. Currently NH-39 utility data presented is based on discussions with utility owners and the final assessment on NH-39 will be presented in Final DPR.Shifting of water pipelines of PHED is a major task both physically and financially and hence major water supply pipes will be checkedbefore Final DPR submission after joint verification/discussion with PHED..

# Chapter 4 PAVEMENT DESIGN

## 4.1 General

The general design procedure is based on the prevalent practices in the country. The design of pavement structure has been carried out as per IRC Guide lines and TOR. The design of new pavement and overlays on existing pavement shall be based on IRC-37:2012 and IRC-81: 1997 for flexible pavement and IRC-58: 2011 for rigid pavement.

## 4.2 Pavement Design Parameters

### Design Period (for flexible and rigid pavements):

The design life of pavement has been considered in accordance with IRC-37:2012 guide. The year of opening for the traffic has been considered as 2016. As the project roads falls in the category of National Highway and keeping in view of IRC guide lines, design life for the flexible pavement is considered 15 years and in case of rigid pavement it is 30 years. The design loading in case of flexible pavement is computed for both 15 years and 20 years.

## 4.3 Pavement Investigation

The project road has been investigated subjectively as well as objectively, for their structural and functional performance. The various surveys/investigations of the pavement are discussed below:

- Pavement Condition Survey
- Benkelman Beam Deflection Survey
- Test Pit Investigations

### 4.3.1 PAVEMENT CONDITION SURVEY

One of the most important activities of feasibility study on highway improvement project is assessment of the existing pavement condition. Detailed field studies were carried out to collect pavement, shoulder and drainage condition. The pavement condition data for the project stretch from Km 330+00 to 425+411 is presented in Annexure 4.1 &4.2.

The visual condition survey has been carried out recording the data every 100 m intervals. This included information on visible deficiencies in terms of pavement deterioration, riding quality, cracking, rutting, incidence of potholes and patches, edge break, ravelling, shoulder materials, embankment conditions etc. and ongoing/recent improvements; the visual condition survey represents the state of the pavement and has some bearing on the decision on type of rehabilitation to be adopted. The condition survey has been prepared by considering the following details:

1. Length of the section : Minimum of 100 m section
2. Surfacing Description : BT/CC/GR/ER
3. Rut Depth : in mm
4. Cracks : % of Area
5. % Area Covered by : Potholes, Ravelling, Patching
6. Shoulder Condition : Good/Fair/Poor/Very Poor
7. Remarks : If any

Cracking: Visual distresses in the form of cracks have been recorded on every 100 m interval, with the % area.

Ravelling: Ravelling which indicates disintegration of the pavement from the surface downward due to the loss of aggregate particles has been noticed.

Rutting: Rutting is the deformation of pavement layers under the movement of loads along the wheel path.

The criteria considered for classification of pavement sections is according to IRC 81-1997 as, no cracking or rutting less than 10 mm is classified as Good, rutting observed between 10 mm to 20 mm is classified as Fair, and rutting more than 20 mm or cracking exceeding 20 percent is treated as Poor.

The pavement condition survey was conducted in July 2013 for NH 39 the summary of overall pavement condition is presented in Table 4.1

**Table 4.1 Overall Pavement condition along NH 39**

| Pavement Condition | Length (m) | Percentage of Length |
|---|---|---|
| Good | 23900 | 24 |
| Fair | 44600 | 45 |
| Poor | 31900 | 31 |

#### 4.3.3.1 Homogenous Sections

Pavement Condition along the project Corridor has been recorded for the divided four homogeneous sections for better analysis and understanding of the project. Homogeneous sections are listed below:.

i) Lilong village –Thoubal junction (km 330+000 to km 342+600)

ii) Thoubal Junction to Pallell Junction (km 342+600 to km 365+900)

iii) Pallell Junction to Khudengthabi (km 365+900 to km 417+00)

iv) Khudengthabi to Moreh(Barma Border) (km 417+000 to km 425+411)

(a) Lilong Village –Thoubal Town (km 330+000 to km 342+600)

The overall condition from Lilong to Thoubal Junction on NH-39 for a length of 12600m is presented in Table 4.2 and the distresses such as cracking, patching, potholes and rutting percentages are presented below in Figure 4.1 in which “Good” indicate the portion of pavement with no distress observed.

**Table 4.2 Pavement Condition Rating- Lilong to Thoubal Section**

| Pavement Condition | Length (m) |
|---|---|
| Good | 4300 |
| Fair | 4700 |
| Poor | 3600 |

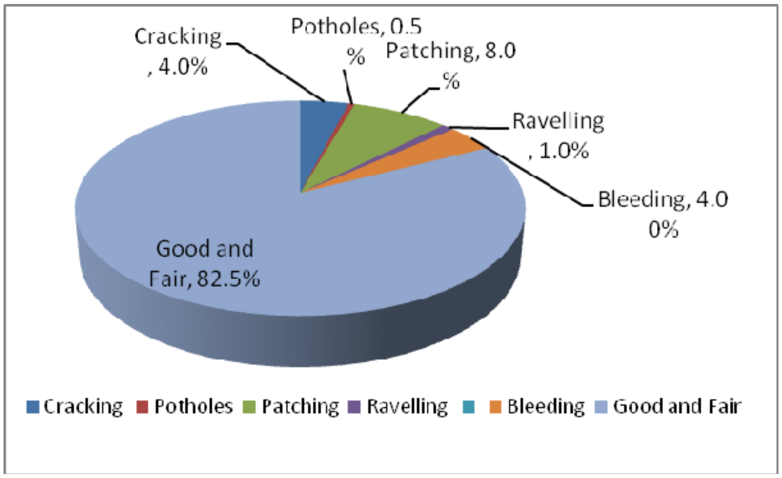



**Figure 4-1 Pavement distress along Lilong to Thoubal Section**

(b) Thoubal Junction to Pallel Junction (km 342+600 to km 365+900)

The overall condition from Thoubal Junction to Pallel Junction for a length of 23300 m is presented in Table 4.3 and the distresses such as cracking, patching, potholes and rutting percentages are presented in below in Figure 4.2

**Table 4.3 Pavement Condition for Thoubal to Pallel Section**

| Pavement Condition | Length (m) |
|---|---|
| Good | 9600 |
| Fair | 10400 |
| Poor | 3300 |

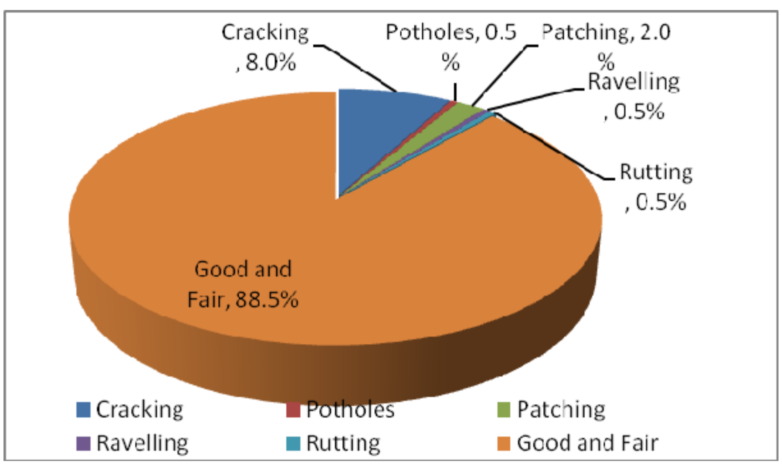



**Figure 4.2 Pavement distress along Thoubal to Pallel Section**

(c)Pallel Junction to Khudengthabi (km 365+900 to km 417+000)

The overall condition from Pallel to Khudengthabi for a length of 51100 m is presented in Table 4.4 and the distresses such as cracking, patching, potholes and rutting percentages are presented in below in Figure 4.3

**Table 4.4 Pavement Condition rating along Pallel to Khudengthabi Section**

| Pavement Condition | Length (m) |
|---|---|
| Good | 9200 |
| Fair | 24200 |
| Poor | 17700 |

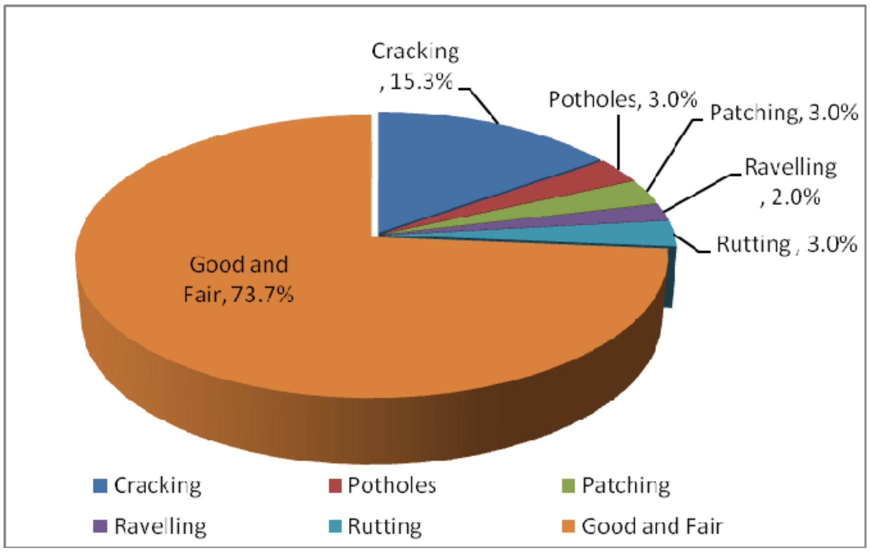



**Figure 4.3 Pavement Distress along Pallel to Khudengthabi Section**

(d)Khudengthabi to Moreh (Project End) (km 417+000 to km 425+411)

The overall condition from Khudengthabi to Moreh for a length of 8411 m is presented in Table 4.5 and the distresses such as cracking, patching, potholes and rutting percentages are presented in below in Figure 4.4

**Table 4.5 Pavement Condition rating along Khudengthabi to Moreh Section**

| Pavement Condition | Length (m) |
|---|---|
| Good | 800 |
| Fair | 5300 |
| Poor | 7300 |

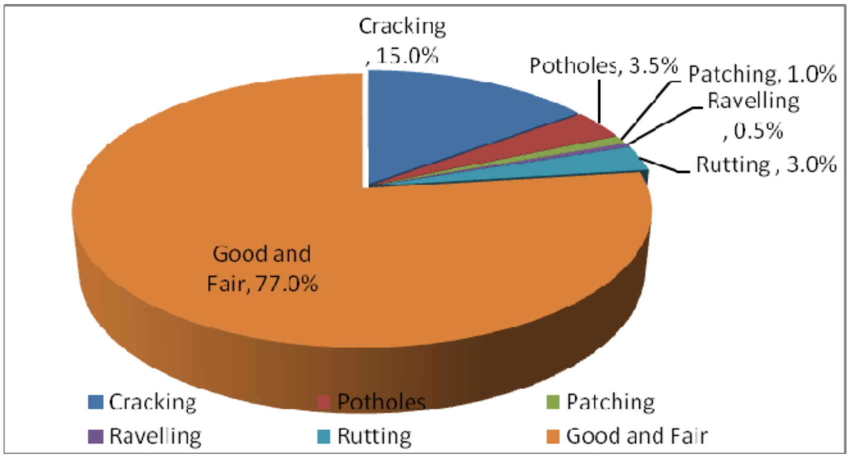



**Figure 4.4 Pavement Distress Khudengthabi to Moreh Section**

#### 4.3.3.2 Summary of the Pavement Condition Survey

From Pavement Condition survey it was found that out of 100.4 km road, about 23+900 km Road length in good condition, 44+600 km length is in fair condition, 31+900 km Road length in poor condition. The details of pavement condition survey are presented in Annexure 4.2 for NH 39. Summary of the overall pavement condition with chainages are presented in below Table 4.6 to 4.7&4.8

**Table 4-6 Locations where pavement is in Good Condition**

| Existing Chainage | | Length (m) | Rem-arks | Existing Chainage | | Length (m) | Rem-arks |
|---|---|---|---|---|---|---|---|
| From | To | | | From | To | | |
| 334+600 | 335+100 | 500 | Good | 374+00 | 374+20 | 200 | Good |
| 335+200 | 335+700 | 500 | Good | 374+40 | 374+60 | 200 | Good |
| 336+100 | 336+200 | 100 | Good | 374+80 | 374+90 | 100 | Good |
| 336+300 | 336+500 | 200 | Good | 375+20 | 375+30 | 100 | Good |
| 336+600 | 336+800 | 200 | Good | 375+50 | 375+60 | 100 | Good |
| 336+900 | 337+000 | 100 | Good | 375+80 | 375+90 | 100 | Good |
| 337+800 | 338+000 | 200 | Good | 376+50 | 376+60 | 100 | Good |
| 338+200 | 338+400 | 200 | Good | 376+70 | 376+80 | 100 | Good |
| 338+600 | 338+700 | 100 | Good | 377+10 | 377+20 | 100 | Good |
| 338+800 | 338+900 | 100 | Good | 377+70 | 377+80 | 100 | Good |
| 339+000 | 339+300 | 300 | Good | 377+90 | 378+00 | 100 | Good |
| 339+400 | 339+500 | 100 | Good | 378+30 | 378+40 | 100 | Good |
| 339+800 | 339+900 | 100 | Good | 378+70 | 378+80 | 100 | Good |
| 340+000 | 340+200 | 200 | Good | 379+20 | 379+30 | 100 | Good |
| 340+400 | 340+800 | 400 | Good | 381+50 | 381+70 | 200 | Good |
| 340+900 | 341+300 | 400 | Good | 381+80 | 382+10 | 300 | Good |

| Existing Chainage | | Length (m) | Rem-arks | Existing Chainage | | Length (m) | Rem-arks |
|---|---|---|---|---|---|---|---|
| From | To | | | From | To | | |
| 341+400 | 341+500 | 100 | Good | 382+20 | 382+50 | 300 | Good |
| 341+600 | 341+700 | 100 | Good | 382+60 | 382+70 | 100 | Good |
| 341+900 | 342+200 | 300 | Good | 382+80 | 382+90 | 100 | Good |
| 342+500 | 342+700 | 200 | Good | 383+60 | 383+70 | 100 | Good |
| 342+900 | 343+100 | 200 | Good | 384+40 | 384+60 | 200 | Good |
| 343+400 | 344+000 | 600 | Good | 384+70 | 384+80 | 100 | Good |
| 344+400 | 344+700 | 300 | Good | 385+10 | 385+20 | 100 | Good |
| 345+000 | 345+700 | 700 | Good | 385+30 | 385+40 | 100 | Good |
| 346+100 | 346+600 | 500 | Good | 385+60 | 385+70 | 100 | Good |
| 346+700 | 347+300 | 600 | Good | 385+80 | 385+90 | 100 | Good |
| 347+500 | 348+200 | 700 | Good | 386+10 | 386+20 | 100 | Good |
| 348+400 | 348+600 | 200 | Good | 387+10 | 387+20 | 100 | Good |
| 348+700 | 348+800 | 100 | Good | 387+50 | 387+60 | 100 | Good |
| 348+900 | 349+200 | 300 | Good | 387+90 | 388+00 | 100 | Good |
| 349+300 | 349+600 | 300 | Good | 388+60 | 388+70 | 100 | Good |
| 349+700 | 350+000 | 300 | Good | 389+00 | 389+20 | 200 | Good |
| 350+100 | 350+300 | 200 | Good | 389+30 | 389+70 | 400 | Good |
| 350+400 | 350+600 | 200 | Good | 390+40 | 390+50 | 100 | Good |
| 350+700 | 351+100 | 400 | Good | 390+70 | 390+80 | 100 | Good |
| 351+200 | 351+300 | 100 | Good | 393+60 | 393+70 | 100 | Good |
| 351+400 | 351+500 | 100 | Good | 393+90 | 394+00 | 100 | Good |
| 351+700 | 351+800 | 100 | Good | 394+50 | 394+60 | 100 | Good |
| 352+200 | 352+300 | 100 | Good | 395+00 | 395+20 | 200 | Good |
| 352+400 | 352+700 | 300 | Good | 395+30 | 395+40 | 100 | Good |
| 352+800 | 352+900 | 100 | Good | 395+60 | 395+80 | 200 | Good |
| 354+900 | 355+100 | 200 | Good | 396+00 | 396+10 | 100 | Good |
| 359+200 | 359+600 | 400 | Good | 396+20 | 396+50 | 300 | Good |
| 359+700 | 359+800 | 100 | Good | 396+60 | 396+90 | 300 | Good |
| 361+300 | 361+500 | 200 | Good | 397+00 | 397+10 | 100 | Good |
| 361+600 | 361+800 | 200 | Good | 397+30 | 397+40 | 100 | Good |
| 361+900 | 362+000 | 100 | Good | 397+50 | 397+70 | 200 | Good |
| 362+100 | 362+300 | 200 | Good | 397+80 | 397+90 | 100 | Good |
| 362+400 | 362+500 | 100 | Good | 398+10 | 398+20 | 100 | Good |
| 362+600 | 362+700 | 100 | Good | 398+40 | 398+60 | 200 | Good |
| 362+800 | 362+900 | 100 | Good | 398+70 | 398+80 | 100 | Good |
| 363+000 | 363+200 | 200 | Good | 398+90 | 399+00 | 100 | Good |
| 363+300 | 363+400 | 100 | Good | 399+10 | 399+20 | 100 | Good |
| 363+500 | 363+800 | 300 | Good | 399+60 | 399+80 | 200 | Good |
| 363+900 | 364+200 | 300 | Good | 401+10 | 401+20 | 100 | Good |
| 364+400 | 364+600 | 200 | Good | 401+30 | 401+50 | 200 | Good |
| 364+700 | 364+900 | 200 | Good | 401+90 | 402+10 | 200 | Good |
| 365+300 | 365+400 | 100 | Good | 402+20 | 402+30 | 100 | Good |
| 365+900 | 366+000 | 100 | Good | 403+00 | 403+10 | 100 | Good |
| 366+800 | 366+900 | 100 | Good | 426+80 | 426+90 | 100 | Good |

| Existing Chainage | | Length (m) | Rem-arks | Existing Chainage | | Length (m) | Rem-arks |
|---|---|---|---|---|---|---|---|
| From | To | | | From | To | | |
| 367+400 | 367+600 | 200 | Good | 427+10 | 427+20 | 100 | Good |
| 367+800 | 367+900 | 100 | Good | 427+50 | 427+60 | 100 | Good |
| 368+200 | 368+300 | 100 | Good | 427+80 | 427+90 | 100 | Good |
| 368+500 | 368+600 | 100 | Good | 428+40 | 428+50 | 100 | Good |
| 373+100 | 373+200 | 100 | Good | 428+60 | 428+70 | 100 | Good |
| 373+400 | 373+500 | 100 | Good | 429+90 | 430+00 | 100 | Good |
| 373+600 | 373+700 | 100 | Good | 430+10 | 430+20 | 100 | Good |

**Table 4.7 Locations where pavement is in Fair Condition**

| Existing Chainage | | Length (m) | Rem-arks | Existing Chainage | | Length (m) | Rem-arks |
|---|---|---|---|---|---|---|---|
| From | To | | | From | To | | |
| 330+300 | 330+400 | 100 | Fair | 375+400 | 375+500 | 100 | Fair |
| 330+700 | 330+800 | 100 | Fair | 375+600 | 375+800 | 200 | Fair |
| 331+000 | 331+100 | 100 | Fair | 375+900 | 376+500 | 600 | Fair |
| 331+100 | 331+200 | 100 | Fair | 376+600 | 376+700 | 100 | Fair |
| 331+500 | 331+600 | 100 | Fair | 376+800 | 377+100 | 300 | Fair |
| 331+800 | 331+900 | 100 | Fair | 377+300 | 377+700 | 400 | Fair |
| 334+200 | 334+600 | 400 | Fair | 377+800 | 377+900 | 100 | Fair |
| 335+100 | 335+200 | 100 | Fair | 378+000 | 378+300 | 300 | Fair |
| 335+700 | 336+100 | 400 | Fair | 378+400 | 378+700 | 300 | Fair |
| 336+200 | 336+300 | 100 | Fair | 378+800 | 379+200 | 400 | Fair |
| 336+500 | 336+600 | 100 | Fair | 379+800 | 380+000 | 200 | Fair |
| 336+800 | 336+900 | 100 | Fair | 380+200 | 380+300 | 100 | Fair |
| 337+000 | 337+800 | 800 | Fair | 380+700 | 380+800 | 100 | Fair |
| 338+000 | 338+200 | 200 | Fair | 381+100 | 381+500 | 400 | Fair |
| 338+400 | 338+600 | 200 | Fair | 382+100 | 382+200 | 100 | Fair |
| 338+700 | 338+800 | 100 | Fair | 382+500 | 382+600 | 100 | Fair |
| 338+900 | 339+000 | 100 | Fair | 382+700 | 382+800 | 100 | Fair |
| 339+300 | 339+400 | 100 | Fair | 382+900 | 383+200 | 300 | Fair |
| 339+500 | 339+800 | 300 | Fair | 383+300 | 383+600 | 300 | Fair |
| 339+900 | 340+000 | 100 | Fair | 383+700 | 384+400 | 700 | Fair |
| 340+200 | 340+400 | 200 | Fair | 384+600 | 384+700 | 100 | Fair |
| 340+800 | 340+900 | 100 | Fair | 384+800 | 384+900 | 100 | Fair |
| 341+300 | 341+400 | 100 | Fair | 385+000 | 385+100 | 100 | Fair |
| 341+500 | 341+600 | 100 | Fair | 385+200 | 385+300 | 100 | Fair |
| 341+700 | 341+900 | 200 | Fair | 385+400 | 385+600 | 200 | Fair |
| 342+200 | 342+500 | 300 | Fair | 385+700 | 385+800 | 100 | Fair |
| 342+700 | 342+900 | 200 | Fair | 385+900 | 386+100 | 200 | Fair |
| 343+100 | 343+400 | 300 | Fair | 386+200 | 387+100 | 900 | Fair |
| 344+000 | 344+400 | 400 | Fair | 387+200 | 387+500 | 300 | Fair |
| 344+700 | 345+000 | 300 | Fair | 387+600 | 387+700 | 100 | Fair |

| Existing Chainage | | Length (m) | Rem-arks | Existing Chainage | | Length (m) | Rem-arks |
|---|---|---|---|---|---|---|---|
| From | To | | | From | To | | |
| 345+700 | 346+100 | 400 | Fair | 387+800 | 387+900 | 100 | Fair |
| 346+600 | 346+700 | 100 | Fair | 388+000 | 388+600 | 600 | Fair |
| 347+300 | 347+500 | 200 | Fair | 388+700 | 389+000 | 300 | Fair |
| 348+200 | 348+400 | 200 | Fair | 389+200 | 389+300 | 100 | Fair |
| 348+600 | 348+700 | 100 | Fair | 389+700 | 389+900 | 200 | Fair |
| 348+800 | 348+900 | 100 | Fair | 390+000 | 390+400 | 400 | Fair |
| 349+200 | 349+300 | 100 | Fair | 390+500 | 390+700 | 200 | Fair |
| 349+600 | 349+700 | 100 | Fair | 390+800 | 390+900 | 100 | Fair |
| 350+000 | 350+100 | 100 | Fair | 391+100 | 393+600 | 2500 | Fair |
| 350+300 | 350+400 | 100 | Fair | 393+700 | 393+900 | 200 | Fair |
| 350+600 | 350+700 | 100 | Fair | 394+000 | 394+200 | 200 | Fair |
| 351+100 | 351+200 | 100 | Fair | 394+400 | 394+500 | 100 | Fair |
| 351+300 | 351+400 | 100 | Fair | 394+600 | 395+000 | 400 | Fair |
| 351+500 | 351+700 | 200 | Fair | 395+200 | 395+300 | 100 | Fair |
| 351+800 | 352+200 | 400 | Fair | 395+400 | 395+600 | 200 | Fair |
| 352+300 | 352+400 | 100 | Fair | 395+800 | 396+000 | 200 | Fair |
| 352+700 | 352+800 | 100 | Fair | 396+100 | 396+200 | 100 | Fair |
| 352+900 | 353+600 | 700 | Fair | 396+500 | 396+600 | 100 | Fair |
| 354+500 | 354+800 | 300 | Fair | 396+900 | 397+000 | 100 | Fair |
| 355+400 | 355+500 | 100 | Fair | 397+100 | 397+300 | 200 | Fair |
| 356+200 | 356+300 | 100 | Fair | 397+400 | 397+500 | 100 | Fair |
| 357+000 | 358+300 | 1300 | Fair | 397+700 | 397+800 | 100 | Fair |
| 358+500 | 358+600 | 100 | Fair | 397+900 | 398+100 | 200 | Fair |
| 358+700 | 359+200 | 500 | Fair | 398+200 | 398+400 | 200 | Fair |
| 359+600 | 359+700 | 100 | Fair | 398+600 | 398+700 | 100 | Fair |
| 359+800 | 360+300 | 500 | Fair | 398+800 | 398+900 | 100 | Fair |
| 360+400 | 360+500 | 100 | Fair | 399+000 | 399+100 | 100 | Fair |
| 360+700 | 361+300 | 600 | Fair | 399+200 | 399+600 | 400 | Fair |
| 361+500 | 361+600 | 100 | Fair | 399+800 | 401+100 | 1300 | Fair |
| 361+800 | 361+900 | 100 | Fair | 401+200 | 401+300 | 100 | Fair |
| 362+000 | 362+100 | 100 | Fair | 401+500 | 401+900 | 400 | Fair |
| 362+300 | 362+400 | 100 | Fair | 402+100 | 402+200 | 100 | Fair |
| 362+500 | 362+600 | 100 | Fair | 402+300 | 403+000 | 700 | Fair |
| 362+700 | 362+800 | 100 | Fair | 403+100 | 403+500 | 400 | Fair |
| 362+900 | 363+000 | 100 | Fair | 403+600 | 403+700 | 100 | Fair |
| 363+200 | 363+300 | 100 | Fair | 411+200 | 411+300 | 100 | Fair |
| 363+400 | 363+500 | 100 | Fair | 412+900 | 413+000 | 100 | Fair |
| 363+800 | 363+900 | 100 | Fair | 415+100 | 415+200 | 100 | Fair |
| 364+200 | 364+400 | 200 | Fair | 417+200 | 417+400 | 200 | Fair |
| 364+600 | 364+700 | 100 | Fair | 417+900 | 418+000 | 100 | Fair |
| 364+900 | 365+300 | 400 | Fair | 419+600 | 419+700 | 100 | Fair |
| 365+400 | 365+900 | 500 | Fair | 419+900 | 420+000 | 100 | Fair |
| 366+000 | 366+600 | 600 | Fair | 423+000 | 423+300 | 300 | Fair |
| 366+700 | 366+800 | 100 | Fair | 423+500 | 423+600 | 100 | Fair |

| Existing Chainage | | Length (m) | Rem-arks |
|---|---|---|---|
| From | To | | |
| 366+900 | 367+400 | 500 | Fair |
| 367+600 | 367+800 | 200 | Fair |
| 367+900 | 368+200 | 300 | Fair |
| 368+300 | 368+500 | 200 | Fair |
| 368+600 | 370+700 | 2100 | Fair |
| 370+800 | 371+100 | 300 | Fair |
| 372+500 | 372+600 | 100 | Fair |
| 372+700 | 372+800 | 100 | Fair |
| 373+000 | 373+100 | 100 | Fair |
| 373+300 | 373+400 | 100 | Fair |
| 373+800 | 374+000 | 200 | Fair |
| 374+200 | 374+400 | 200 | Fair |
| 374+600 | 374+800 | 200 | Fair |
| 374+900 | 375+200 | 300 | Fair |

| Existing Chainage | | Length (m) | Rem-arks |
|---|---|---|---|
| From | To | | |
| 423+800 | 423+900 | 100 | Fair |
| 424+000 | 424+400 | 400 | Fair |
| 424+600 | 424+700 | 100 | Fair |
| 424+900 | 425+300 | 400 | Fair |
| 426+100 | 426+800 | 700 | Fair |
| 426+900 | 427+100 | 200 | Fair |
| 427+200 | 427+500 | 300 | Fair |
| 427+600 | 427+800 | 200 | Fair |
| 427+900 | 428+100 | 200 | Fair |
| 428+200 | 428+400 | 200 | Fair |
| 428+500 | 428+600 | 100 | Fair |
| 428+700 | 429+900 | 1200 | Fair |
| 430+000 | 430+100 | 100 | Fair |
| 430+200 | 430+400 | 200 | Fair |

**Table 4.8 Locations where pavement is in Poor Condition**

| Existing Chainage | | Length (m) | Rem-arks |
|---|---|---|---|
| From | To | | |
| 330+000 | 330+300 | 300 | Poor |
| 330+400 | 330+700 | 300 | Poor |
| 330+800 | 331+000 | 200 | Poor |
| 331+200 | 331+500 | 300 | Poor |
| 331+600 | 331+800 | 200 | Poor |
| 331+900 | 334+200 | 2300 | Poor |
| 353+600 | 354+500 | 900 | Poor |
| 354+800 | 354+900 | 100 | Poor |
| 355+100 | 355+400 | 300 | Poor |
| 355+500 | 356+200 | 700 | Poor |
| 356+300 | 357+000 | 700 | Poor |
| 358+300 | 358+500 | 200 | Poor |
| 358+600 | 358+700 | 100 | Poor |
| 360+300 | 360+400 | 100 | Poor |
| 360+500 | 360+700 | 200 | Poor |
| 366+600 | 366+700 | 100 | Poor |
| 370+700 | 370+800 | 100 | Poor |
| 371+100 | 372+500 | 1400 | Poor |
| 372+600 | 372+700 | 100 | Poor |
| 372+800 | 373+000 | 200 | Poor |
| 373+200 | 373+300 | 100 | Poor |
| 373+500 | 373+600 | 100 | Poor |
| 373+700 | 373+800 | 100 | Poor |
| 375+300 | 375+400 | 100 | Poor |

| Existing Chainage | | Length (m) | Rem-arks |
|---|---|---|---|
| From | To | | |
| 380+000 | 380+200 | 200 | Poor |
| 380+300 | 380+700 | 400 | Poor |
| 380+800 | 381+100 | 300 | Poor |
| 383+200 | 383+300 | 100 | Poor |
| 384+900 | 385+000 | 100 | Poor |
| 387+700 | 387+800 | 100 | Poor |
| 389+900 | 390+000 | 100 | Poor |
| 390+900 | 391+100 | 200 | Poor |
| 394+200 | 394+400 | 200 | Poor |
| 403+500 | 403+600 | 100 | Poor |
| 403+700 | 411+200 | 7500 | Poor |
| 411+300 | 412+900 | 1600 | Poor |
| 413+000 | 415+100 | 2100 | Poor |
| 415+200 | 417+200 | 2000 | Poor |
| 417+400 | 417+900 | 500 | Poor |
| 418+000 | 419+600 | 1600 | Poor |
| 419+700 | 419+900 | 200 | Poor |
| 420+000 | 423+000 | 3000 | Poor |
| 423+300 | 423+500 | 200 | Poor |
| 423+600 | 423+800 | 200 | Poor |
| 423+900 | 424+000 | 100 | Poor |
| 424+400 | 424+600 | 200 | Poor |
| 424+700 | 424+900 | 200 | Poor |
| 425+300 | 426+100 | 800 | Poor |

| Existing Chainage | | Length (m) | Rem-arks |
|---|---|---|---|
| From | To | | |
| 377+200 | 377+300 | 100 | Poor |
| 379+300 | 379+800 | 500 | Poor |

| Existing Chainage | | Length (m) | Rem-arks |
|---|---|---|---|
| From | To | | |
| 428+100 | 428+200 | 100 | Poor |
| | | | |

### 4.3.2 Benkelman Beam Deflection Survey

Benkelman Beam Deflection Survey (BBD) has been carried out to assess the residual strength of the existing flexible pavement and there by assessing the requirement of structural strength overlay for rehabilitation of the same. The BBD survey was carried out in accordance with IRC-81 1997 with provisions as per Canadian Good Roads Association (CGRA) method; Deflection readings were carried out at every 50 m staggered on the project road except the Ghat section. The collected deflection data was analyses along with the corrections required in accordance with requirement of IRC-81 1997. The corrections were carried out for:

- Leg Correction
- Pavement Temperature
- Seasonal Correction
- Sub grade Moisture Correction
- PI of Subgrade

Leg correction factor: While measuring the deflection there is every chance of deflection bowl extending up to supporting legs of the Benkelman beam. The deflection of legs is revealed by the difference in differential reading between initial, intermediate and final reading. If the differential reading between initial and final and intermediate and final differ by more than 0.025 mm then leg correction needs to be applied.

The true deflection is computed as

- $X_T = X_A + 2.91\ Y$
- Where,
- $X_T$ = True pavement deflection
- $X_A$ = Apparent pavement deflection i.e. 2X (Final – Initial reading)
- Y = Vertical movement of the front legs i.e., twice the difference between the final and intermediate reading.

Correction for Temperature:

The stiffness of bituminous layers changes with temperature of the bonder and consequently the surface deflection of bituminous pavement will vary depending upon the temperature of the constituent bituminous layers. Therefore it is necessary that the measured deflection be corrected to a common standard temperature for tropical climate of India. The standard temperature is taken as 35°C. Correction for temperature variation on deflection for values other than those measured at 35°C shall be 0.01 mm for each degree of change from the standard temperature of 35°C. The correction will be positive for pavement temperatures lower than 35°C and negative for pavement temperature higher than 35°C.

<u>Correction for seasonal variation:</u>

Since the pavement deflection is dependent upon change in climate/season of the year, it is always desirable to take deflection measurements during the season when the pavement in its weakest condition. In India this condition occurs immediately after the raining season. When deflection measurements are taken during dry months, they will require correction factor, which is defined as the ratio of maximum deflection immediately after the monsoon to that of deflection in the dry months.

Correction for seasonal variation depends upon the type of the sub-grade soil; its field moisture content (at the time of deflection testing) and average rain fall in the area. For this purpose sub-grade soil has been divided into three broad categories namely sandy/gravely clayey with low plasticity (PI <15) and clayey with high plasticity (PI >15). Similarly rainfall has been divided into two categories namely annual low rainfall (< 1300mm) and annual high rainfall (>1300mm).

<u>Characteristic Deflection:</u>

The statistical analysis involves calculation of mean deflection value, standard deviation and characteristic deflection. The design calculations are us under.

Mean deflection $\bar{\chi} = \frac{\sum x}{\eta}$

Standard deviation $\sigma = \frac{\sum (x \quad \bar{x})^2}{\eta \quad 1}$

Characteristic Deflection = Mean deflection+ 2 * Standard deviation

Where,

X =Individual deflection, mm

χ- = Mean deflection value mm

n = number of deflection measurements

σ = Standard deviation

Dc = Characteristic deflection

Benkelman Beam Survey carried from km 330 to 365 only that is plain area and the section from km 365 to 430 is not carried out as this hill section is recommended

for reconstruction. The deflection survey data and analysis is given in the Annexure 4.3. Brief Summary of BBD is given below:

Length of stretch with Characteristic deflection

0.5 to 0.75 mm – 18 Km

0.75 to 1.0 mm – 7 Km

Average characteristic deflection for homogeneous 1 and 2 is in the order of 0.705 and 0.753 respectively. Graphical representation for the characteristic deflection for the two homogeneous sections from km 330 to 342 and 342 to 365 is shown below.

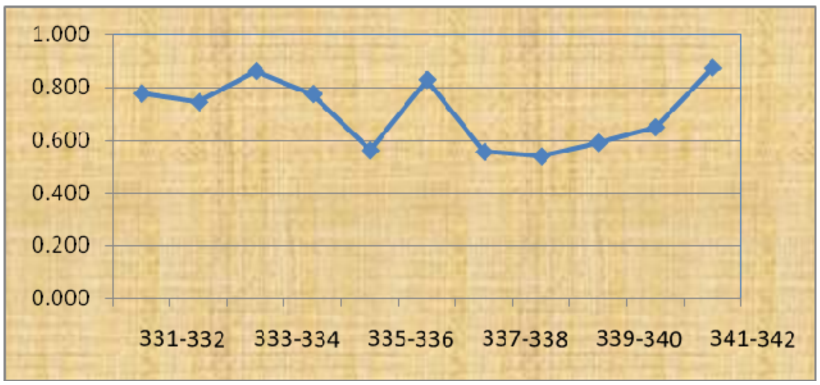



**Figure 4-5 Characteristic Deflection from Km 330 to 342**

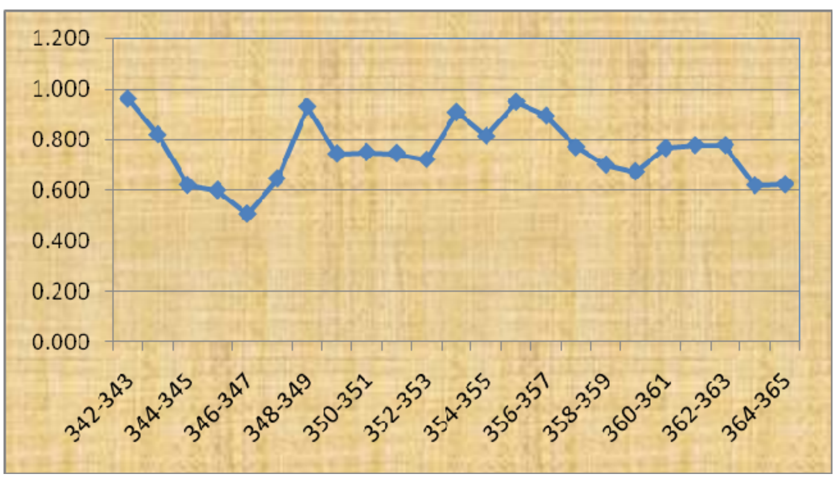



**Figure 4.6 Characteristic Deflection from Km 342 to 365**

Characteristic deflection values for each kilometres is set out in Annexure *5-3.*

### 4.3.3 Test Pit Investigations

#### 4.3.3.3 Test Pits Methodology

Investigations have been carried out by digging test pits to assess the adequacy of existing pavement layers including sub-grade soil properties to establish the strengthening/ reconstruction requirement to cater for design traffic during service life.

#### 4.3.3.4 Test Pits (1m X 1m X 1m)

Test pits were dug at 5 km interval at the pavement-shoulder interface extending through the pavement layers excluding the proposed bypass locations. Pits were made in such a way that one third of the pit (20 cm) was within the carriageway and the remaining two third (80 cm) in the shoulder, ensuring minimum damage to the original pavement and disruption to the traffic. The pits were backfilled and compacted after completion of work .The sequence of operations for large pits was as follows:

Manual excavation of 1.0 m X 1.0 m pit down to subgrade level. After reaching the subgrade level the thickness of the different pavement layers were measured and type of material examined. Subgrade soil samples were collected and the soil collected in containers for determining the field moisture content by oven-dried method.

- Field (in-situ) dry density using Sand Replacement method as per IS2720 Part 28 was carried out at the subgrade level.
- A Dynamic Cone Penetration (DCP) test as per ASTM method was carried out at subgrade level.
- One sample of 40 kg subgrade soil was collected from sub-grade for the laboratory test.

Photographs of the pavement layers were obtained at a few test pits:

#### 4.3.3.5 Pavement Composition

For each test pit, the following information was recorded

- Test pit reference (Identification number and location):
- Pavement compaction (material type and thickness)
- Subgrade type (textural classification) and condition(dry, wet)

Broad variation in pavement thickness was observed along the project road. However the pavement composition of the existing pavement is generally same composed of bituminous layers, WMM or WBM base and Sub-base. The Bituminous layer various from 40 mm to 180 mm: Base course various from 80 mm to 470 mm and sub-base various from 130 mm to 390 mm. The pavement composition and thickness are presented in Figure.5.9. From the pavement composition it is clear that there is no drainage layer in plain/low laying areas.

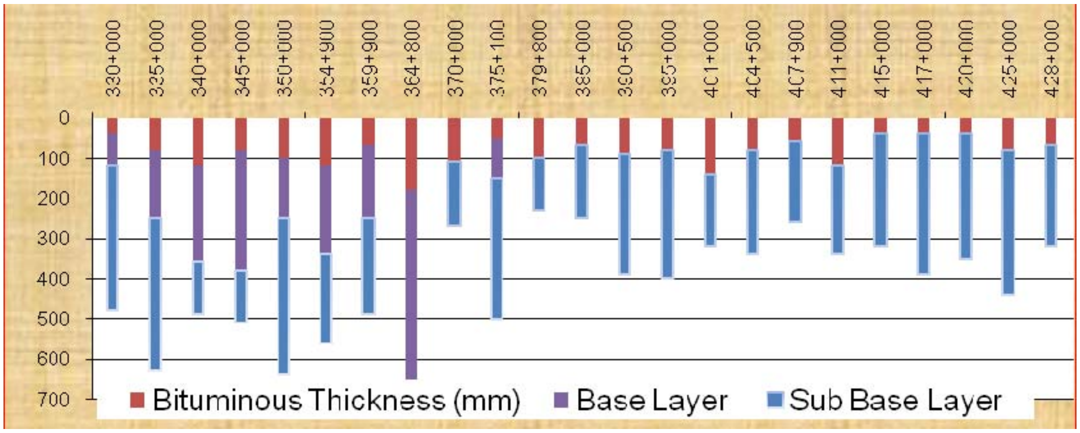



**Figure 4.7- Pavement Composition of Existing Road**

### 4.3.3.6 In-situ –density and moisture content

Sand Replacement method was adopted for obtaining the field density. Representative soil samples were also taken from the pit to establish moisture content. Table 4.9 shows the test result of field density and field moisture content. The field density and moisture content various from 1.578 gm/cc to 1.867gm/cc and 8.54% to 21.41% respectively.

**Table 4.9 Field Dry Density and Moisture Content**

| S.No | Chainage | Side | Field Bulk density(gm/cc) | Field Moisture content (%) | Field Dry density (gm/cc) |
|---|---|---|---|---|---|
| 1 | 329+000 | RHS | 1.880 | 14.670 | 1.639 |
| 2 | 335+000 | LHS | 1.932 | 12.890 | 1.711 |
| 3 | 340+000 | RHS | 2.089 | 11.930 | 1.867 |
| 4 | 345+000 | LHS | 1.847 | 10.250 | 1.675 |
| 5 | 350+000 | RHS | 1.950 | 13.210 | 1.723 |
| 6 | 354+900 | LHS | 1.944 | 14.330 | 1.700 |
| 7 | 359+900 | RHS | 2.090 | 15.390 | 1.811 |
| 8 | 364+800 | RHS | Test not done due old BT surface encountered at subgrade level | | |
| 9 | 370+000 | LHS | 1.955 | 12.380 | 1.740 |
| 10 | 375+100 | RHS | 2.062 | 11.670 | 1.846 |
| 11 | 379+800 | RHS | Test not done due to seepage of water | | |
| 12 | 385+000 | LHS | 1.894 | 12.150 | 1.689 |
| 13 | 390+500 | LHS | 1.977 | 8.540 | 1.822 |
| 14 | 395+000 | RHS | 2.040 | 17.430 | 1.737 |
| 15 | 401+000 | LHS | 1.911 | 21.100 | 1.578 |
| 16 | 404+500 | RHS | 1.982 | 21.410 | 1.632 |
| 17 | 407+900 | RHS | 1.962 | 18.240 | 1.659 |

| S.No | Chainage | Side | Field Bulk density(gm/cc) | Field Moisture content (%) | Field Dry density (gm/cc) |
|---|---|---|---|---|---|
| 18 | 411+000 | RHS | 1.972 | 19.650 | 1.648 |
| 19 | 415+000 | LHS | Test not done due to seepage of water | | |
| 20 | 417+000 | RHS | 1.956 | 16.210 | 1.683 |
| 21 | 420+000 | RHS | 1.947 | 14.540 | 1.700 |
| 22 | 425+000 | LHS | 1.951 | 13.220 | 1.723 |
| 23 | 428+000 | RHS | 1.945 | 15.320 | 1.687 |

#### 4.3.3.7 Field CBR using DCP

Dynamic Cone Penetration (DCP) tests were conducted at the bottom of the test pits i.e., on top of the sub-grade to assess in-situ CBR of existing sub-grade layer. The CBR value was calculated based on different layers encountered below the top of sub-grade level. 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 ASTM-D 6951-09 equation has been used to calculate the layer DCP-CBR value for each layer.

$$\log_{10}(CBR) = 2.465 - 1.120 * \log_{10}(mm/Blow)$$

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

The minimum, maximum and average values of in-situ DCP-CBR values have been found to be 1.63%, 29.9% and 8.61%.The field CBR values obtained from DCP tests are given in Table 4.10.

**Table 4.10 Field CBR values obtained from DCP Test**

| S No | Chainage | Side | Field CBR (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Layer-1 | Layer-2 | Layer-3 | Layer-4 | Combined |
| 1 | 329.000 | RHS | 8.02 | 7.13 | | | 7.55 |
| 2 | 335.000 | LHS | 5.91 | 4.11 | | | 4.79 |
| 3 | 340.000 | RHS | 15.49 | 9.39 | 7.19 | | 9.67 |
| 4 | 345.000 | LHS | 1.63 | | | | 1.63 |
| 5 | 350.000 | RHS | 3.42 | | | | 3.42 |
| 6 | 354.900 | LHS | 4.68 | 4.85 | | | 4.77 |
| 7 | 359.900 | RHS | 6.65 | 5.90 | | | 6.34 |
| 8 | 364.800 | RHS | Not Done | | | | |
| 9 | 370.000 | LHS | 24.90 | 66.39 | | | 29.99 |
| 10 | 375.100 | RHS | 18.04 | 19.40 | 21.39 | 22.08 | 20.43 |
| 11 | 379.800 | RHS | Not Done | | | | |
| 12 | 385.000 | LHS | 13.31 | 11.82 | 14.80 | | 13.80 |
| 13 | 390.500 | LHS | 13.27 | | | | 13.27 |

| S No | Chainage | Side | Field CBR (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Layer-1 | Layer-2 | Layer-3 | Layer-4 | Combined |
| 14 | 395.000 | RHS | 14.88 | 16.70 | 17.44 | | 15.83 |
| 15 | 401.000 | LHS | 5.27 | 5.64 | | | 5.44 |
| 16 | 404.500 | RHS | 4.68 | 4.98 | | | 4.85 |
| 17 | 407.900 | RHS | 6.78 | 8.40 | 6.23 | | 6.95 |
| 18 | 411.000 | LHS | 4.79 | | | | 4.79 |
| 19 | 415.000 | LHS | Not Done | | | | |
| 20 | 417+000 | RHS | 2.79 | | | | 2.79 |
| 21 | 420.000 | RHS | 8.30 | 5.89 | | | 7.07 |
| 22 | 425.000 | LHS | 5.23 | 4.38 | | | 4.70 |
| 23 | 428.000 | RHS | 3.75 | 4.42 | | | 4.11 |

Average CBR observed is 8.61 but the maximum CBR of 20 and 29 observed at locations at km 370 and km 375 respectively. Graphical representation of DCP-CBR values for test pit samples are shown in Figure-5.9.

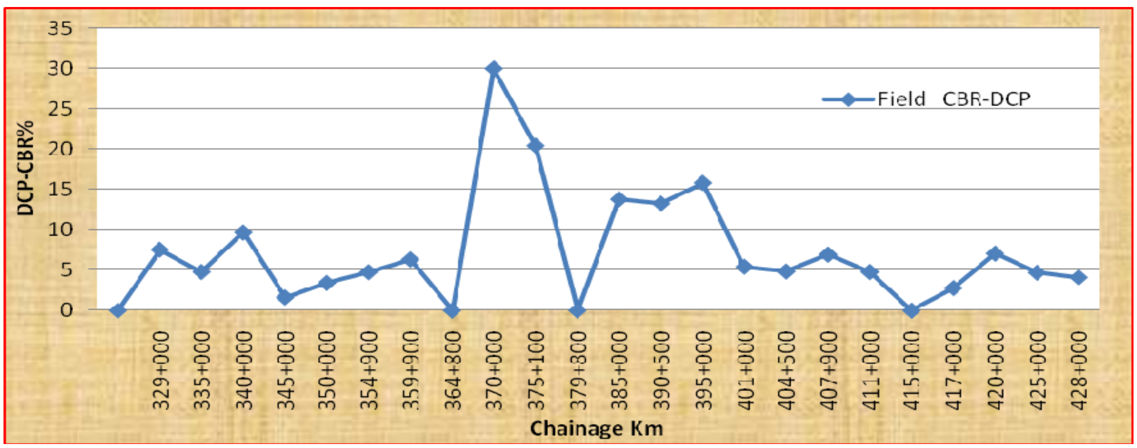



**Figure 4.8 Graphical representation of In-Situ CBR using DCP.**

### 4.3.3.8 Characterization of Sub grade

The following tests were conducted on each of the subgrade samples collected from test pits:

- Grain size Analysis
- Atterberge's Limits(Liquid limit and Plastic limit)
- Modified Proctor Density
- Four days soaked CBR at three energy levels

The methods of testing adopted for materials investigations are given in Table 4.11.

**Table 4.11 Method of Testing**

| Sl. No. | Type of Tests | Unit | Test Method |
|---|---|---|---|
| 1 | Moisture Content Determination | % | IS 2720(Part 2) |
| 2 | Grain Size Analysis(Wet Sieve) | % by wt | IS 2720 (Part – 4) |
| 3 | Atterberg's Limits(LL,PL,PI) | % by wt | IS 2720 (Part – 5) |
| 4 | Laboratory Moisture – Density Characteristics | g/cc and %by wt | Modified AASHTO Compaction(T-180-97) |
| 5 | Laboratory CBR (4 Days soaked compaction at three energy level | % | AASHTO T-193-99 |
| 6 | Free Swell Index | % | IS:2720 Part- 40 |
| 7 | Field Density by Sand Replacement Method | gm/cc | IS:2720 Part-28 |

The Summary of laboratory test results for subgrade is given in Table 4.9. The Consultants have collected base and sub base samples at an interval of 10 km to study the gradation and plasticity characteristics of the same. The collected samples further tested for Gradation and Atterberg Limits and it is found that all the collected samples gradations are out of envelope on finer fraction. However the road condition has not shown severe distresses.

**Table 4.9 Lab Test Results for Sub grade samples**

| S No | Location | Side | IS Classification | Sieve Analysis % by weight (IS : 2720 Part 4 - 1985) | | | Atterberg's Limit (IS : 2720, Part - 5-1985) | | | Free Swell Index % (IS : 2720 Part 40 - 1977) | Modified Proctor Test (AASTHO Modified T-180) | | Un Soaked CBR (%) | 4 days Soaked CBR (%) (AASHTO Method) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Gravel > 4.75 mm | Sand (4.75 - 0.075) mm | Silt+Clay< 0.075 mm | Liquid Limit (LL) % | Plastic Limit (PL) % | Plasticity Index (PI) % | | Max Dry Density gm/cc | OMC % | | 10 Blows | 30 Blows | 65 Blows | CBR at 97% of MDD |
| 1 | 329+000 | RHS | MH | 0.51 | 2.51 | 96.98 | 61.76 | 36.99 | 24.77 | 20.00 | 1.710 | 17.60 | 5.95 | 1.49 | 2.23 | 2.98 | 2.45 |
| 2 | 335+000 | LHS | MI | 1.17 | 7.59 | 91.24 | 43.46 | 30.12 | 13.34 | 20.00 | 1.840 | 15.30 | 6.94 | 1.49 | 2.48 | 3.97 | 2.99 |
| 3 | 340+000 | RHS | MI | 4.74 | 22.91 | 72.35 | 40.33 | | NP | 10.00 | 1.952 | 13.30 | 9.67 | 2.48 | 4.46 | 6.70 | 5.20 |
| 4 | 345+000 | LHS | MH | 4.32 | 12.44 | 83.23 | 53.93 | 34.14 | 19.79 | 20.00 | 1.748 | 15.50 | 7.44 | 2.48 | 3.97 | 5.95 | 4.64 |
| 5 | 350+000 | RHS | MH | 0.30 | 3.67 | 96.04 | 52.05 | 32.55 | 19.50 | 20.00 | 1.739 | 19.50 | 6.70 | 1.49 | 2.48 | 3.47 | 2.78 |
| 6 | 354+900 | LHS | MI | 3.03 | 14.82 | 82.15 | 42.08 | | NP | 10.00 | 1.789 | 17.50 | 8.18 | 2.48 | 4.46 | 6.45 | 5.03 |
| 7 | 359+900 | RHS | MI | 0.96 | 6.82 | 92.22 | 42.26 | 27.74 | 14.52 | 10.00 | 1.792 | 14.10 | 6.45 | 1.49 | 2.48 | 3.72 | 2.88 |
| 8 | 364+800 | Test Not Done | | | | | | | | | | | | | | | |
| 9 | 370+000 | LHS | SM | 19.25 | 40.05 | 40.70 | 39.56 | | NP | 10.00 | 1.945 | 15.30 | 15.63 | 4.46 | 8.18 | 12.65 | 9.64 |

| S No | Location | Side | IS Classification | Sieve Analysis % by weight (IS : 2720 Part 4 - 1985) | | | Atterberg's Limit (IS : 2720, Part - 5-1985) | | | Free Swell Index % (IS : 2720 Part 40 - 1977) | Modified Proctor Test (AASTHO Modified T-180) | | Un Soaked CBR (%) | 4 days Soaked CBR (%) (AASHTO Method) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Gravel > 4.75 mm | Sand (4.75 - 0.075) mm | Silt+Clay< 0.075 mm | Liquid Limit (LL) % | Plastic Limit (PL) % | Plasticity Index (PI) % | | Max Dry Density gm/cc | OMC % | | 10 Blows | 30 Blows | 65 Blows | CBR at 97% of MDD |
| 10 | 375+100 | RHS | MI | 9.15 | 35.21 | 55.64 | 41.23 | | NP | 20.00 | 1.940 | 13.50 | 11.16 | 2.98 | 5.21 | 8.43 | 6.33 |
| 11 | 379+800 | RHS | SC | 13.25 | 67.66 | 19.10 | 30.78 | 19.56 | 11.22 | 5.00 | 2.170 | 9.20 | 21.58 | 7.94 | 11.91 | 16.37 | 13.27 |
| 12 | 385+000 | LHS | SM | 11.49 | 52.10 | 36.40 | 45.10 | | NP | 10.00 | 1.950 | 13.20 | 17.86 | 6.94 | 9.92 | 12.65 | 10.70 |
| 13 | 390+500 | LHS | SM | 14.87 | 62.92 | 22.22 | 26.56 | | NP | 5.00 | 2.116 | 9.40 | 23.07 | 8.43 | 13.39 | 18.` | 14.95 |
| 14 | 395+000 | RHS | SM | 9.38 | 55.20 | 35.42 | 36.11 | | NP | 10.00 | 2.030 | 11.50 | 18.60 | 5.95 | 10.42 | 14.88 | 11.74 |
| 15 | 401+000 | LHS | MI | 14.31 | 35.52 | 50.17 | 38.32 | | NP | 10.00 | 1.872 | 15.50 | 13.39 | 2.48 | 5.46 | 8.93 | 6.59 |
| 16 | 404+500 | RHS | ML | 6.42 | 41.17 | 52.40 | 31.97 | | NP | 10.00 | 1.980 | 13.70 | 12.40 | 2.98 | 5.95 | 8.93 | 6.84 |
| 17 | 407+900 | RHS | SM | 9.29 | 57.88 | 32.82 | 24.32 | | NP | 5.00 | 2.110 | 9.70 | 19.35 | 8.18 | 12.40 | 16.37 | 13.47 |
| 18 | 411+000 | LHS | MI | 9.53 | 31.14 | 59.33 | 47.09 | 29.38 | 17.71 | 10.00 | 1.873 | 15.70 | 11.91 | 2.48 | 5.95 | 9.67 | 7.00 |
| 19 | 415+000 | LHS | SM | 10.24 | 44.40 | 45.36 | 47.83 | | NP | 10.00 | 1.989 | 13.20 | 14.88 | 3.72 | 6.94 | 10.91 | 8.13 |

| S No | Location | Side | IS Classification | Sieve Analysis % by weight (IS : 2720 Part 4 - 1985) | | | Atterberg's Limit (IS : 2720, Part - 5- 1985) | | | Free Swell Index % (IS : 2720 Part 40 - 1977) | Modified Proctor Test (AASTHO Modified T-180) | | Un Soaked CBR (%) | 4 days Soaked CBR (%) (AASHTO Method) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Gravel > 4.75 mm | Sand (4.75 - 0.075) mm | Silt+Clay< 0.075 mm | Liquid Limit (LL) % | Plastic Limit (PL) % | Plasticity Index (PI) % | | Max Dry Density gm/cc | OMC % | | 10 Blows | 30 Blows | 65 Blows | CBR at 97% of MDD |
| 20 | 417+000 | LHS | MH | 2.23 | 11.29 | 86.48 | 56.10 | | NP | 10.00 | 1.748 | 17.70 | 6.70 | 1.98 | 3.72 | 4.96 | 3.99 |
| 21 | 420+000 | RHS | SC | 17.05 | 35.87 | 47.07 | 47.91 | 31.57 | 16.34 | 30.00 | 1.970 | 13.50 | 14.14 | 2.98 | 7.44 | 11.91 | 8.75 |
| 22 | 425+000 | LHS | MI | 6.36 | 30.82 | 62.82 | 44.42 | 29.09 | 15.33 | 30.00 | 1.860 | 15.40 | 11.91 | 2.48 | 5.95 | 8.93 | 6.72 |
| 23 | 428+000 | RHS | MH | 0.63 | 8.44 | 90.93 | 50.70 | | NP | 10.00 | 1.675 | 23.20 | 6.70 | 2.23 | 2.98 | 4.46 | 3.57 |

The laboratory investigations of subgrade indicate that the existing subgrade varies and generally consists of SM, SC, MH, MI and ML along the road. The percentage of gravel, sand, silt and clay are in the range from 0.30% to 19.25%, 2.25% to 67.66% and 19.1% to 96.98% respectively. The liquid limit varies from 24.32% to 61.76% and plastic limit varies from 11.22% to 24.77%.The optimum moisture content and dry density varies from 9.2% to 23.2% and 1.675 gm/cc to 2.17gm/cc respectively. The soaked CBR values of existing Sub-grade varies from 2.45% to 14.95% at 97% of MDD. The average CBR for four homogenous sections are in the order of 3.55, 3.07, 9.39 and 6.35 respectively. Graphical representation of CBR is given below.

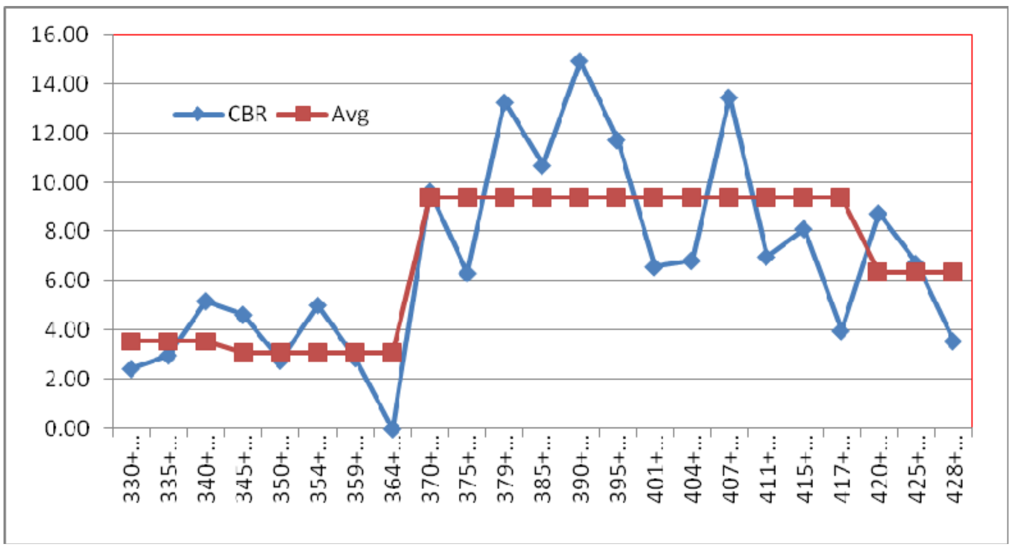



**Figure 4.9 Graphical representation of 4 days Soaked CBR.**

In case of section from Km 330+000 to 346+000, the Subgrade CBR values are very low and in hilly terrain the CBR value range up to 13% @ 97% MDD. However in both cases the pavement thickness is grossly in adequate for even minimum 10 MSA.

## 4.4 General

The material investigation for road construction has been carried out to identify the potential sources of construction material and to assess their general availability, properties and quantities. This is one of the most important factors for stable, economical and successful implementation of the road program within the stipulated time. For improvement work as well as for new carriageway/Alternative routes, the lists of material include the following.

- Grading V and VI crushed stone aggregate for sub-base-cum-drainage layer and crushed aggregates for base, surfacing & cement concrete works.
- Sand for filter material, concrete works, sub-base and filling material

- Borrow material for embankment, sub grade and shoulders
- Manufactured material like cement, steel, bitumen, geotextile, road appearances.

### 4.4.1 Information on Material Sources

The following information on material sources was sought:

- Source location, indicating places, kilometre age, availability and the status whether in operation or new source
- Access to source, indicating the direction and nature of the access road i.e. left/right of project road, approximate lead distance from the centre and type of access road.
- Ownership of land/quarries, either government or private.
- Test results, indicating the quality of materials along with their classification in details.

Probable uses indicating the likely use of materials at various stages of construction work i.e. fill materials, sub-grade, sub-base, and wearing course and cross drainage structures.

- During the processes of investigation, due consideration has been given to the locally available material for reducing the cost of construction. The samples from various identified sources have been collected for laboratory testing as per IRC/MORT&H/BIS standards.

### 4.4.2 Material for Embankment and Sub Base

Potential sources of earth for the construction of embankment and sub-grade (for reconstruction/new carriageway) were identified on either side of the project road. Borrow areas investigation is under progress and the details will be given in Detailed Project Report.

### 4.4.3 Stone Aggregates

The availability and quality of material as coarse and fine aggregate was explored and samples were taken from the quarry where large quantities of stone aggregates (boulders) were available. The details are given below.

**Table 4.10 Details of Test Results of Stone aggregate quarries**

| Source | Apparent Specific Gravity | Water Absorption (%) | Combined Flakiness and Elongation Index (%) | Aggregate Impact Value (%) ** | Suitability for Various Layers |
|---|---|---|---|---|---|
| Santosh Stone Crusher at km 307 on left side | 2.66 | 1.07 | 30.50 | 12.39 | 1. Crusher set-up has to be adjusted to meet the Gradation requirements.<br>2. Suitable for all the layers |
| Imphal River Boulders from km 309 with a lead of 1.0 km. | 2.70 | 0.66 | 0 | 13.35 | 1. Suitable for all layers |

Sufficient quantity of river boulders is available in the Imphal River at Km. 309+000 RHS and lead is 1.0 km. Representative samples from the above stone crusher samples were collected for testing in the laboratory. The following tests have been conducted on the samples collected.

| | |
|---|---|
| Aggregate Impact value | As per IS:2386(Part-6) |
| Combined flakiness and elongation indices | As per IS:2386(Part-7) |
| Water absorption | As per IS:2386(Part-3) |

MORT&H requirement of stone aggregates for their use in base / surfacing course of pavement are as follows:

- Aggregate Impact value <30%
- Combined flakiness and elongation indices <30%
- Water absorption <2%

### 4.4.4 Fine Aggregates

Only one source for fine aggregate has been identified which is near Yaripok village at km 342+200 on LHS and lead is about 18 km in length. The source of river sand is not suitable for cement concrete and masonry construction work due to the lab test results is out of specification limit as for IS codes. The details of quarry and properties are given in Table 4.11.

**Table 4.11 Details of Natural Sand Quarries.**

| Source | Gradation Zone | Apparent Specific Gravity | Water Absorption | Fineness Modulus | Silt Content by weight | Bulk Density | Suitability for Works |
|---|---|---|---|---|---|---|---|
| Thoubal River | II | 2.96 | 3.5 | 2.88 | 5.9 | 1.699 | Not Suitable |

### 4.4.5 Gradation Characteristics of Base and Sub Base Layers:

The consultants have planned for collection of base and sub base samples at 10 km intervals to study the gradation and plasticity characteristics of the same. Consultants collected 9 samples on the project corridor for Gradation and Atterberg Limits. All the collected samples gradation are out of envelope on finer fraction, however the road condition has not shown severe distresses.

The test results of the samples are presented in Annexure-4.4. DCP test results are set out in Annexure 4.5. Test results for stone aggregate are set out in Annexure 4.6. Lab test results for sub grade testing is set out in Annexure 4.7. Test results for fine aggregates are set out in Annexure 4.8.

#### 4.4.5.1 Inventory And Condition Survey of Bridges and Cross Drainage Structures

The inventory and condition survey of the CD structures along the project corridor are Carried out. Standard formats based on the guidelines as per IRC SP35, were prepared for inventory and condition survey. Instruments and tools such as GPS instrument, measuring tapes, plumb bob, small hammer, mirror, binoculars and camera were used for the survey. The location of the CD structure in this inventory is based on the chainage finalized for highway survey. Chainages of structures in this inventory is the chainage of alignment loaded in GPS instrument. The data collected was analyzed and strategy was tentatively proposed for treatment of each structure in terms of maintenance, rehabilitation or replacement during widening and improvement.

Inventory of the CD structures were in compliance with the guidelines contained in IRC SP: 35. The data were collected to the following attributes:

- Structure number
- Location and name of the stream/canal or river
- Name of the road crossing the stream/canal or river
- Year of construction of the structures
- Structure type and span arrangement

- Structure type for substructure and information on type of foundation
- Structure dimensions such as length, clear width, overall width, clear span, effective span, size of the vent, height from road level to existing bed level and height of parapet and railing,
- Type of construction materials used
- Alignment of structure viz. straight or skew
- Type and size of the bearing
- Type of expansion joint
- Gradient of the bridge (both longitudinal and transverse)
- Type of the protection provided for embankment at the approaches and the bed.

Structural condition of existing CD structures was assessed by visual inspection. Guidelines and recommendations given in IRC SP: 35, *Annex 5.6* was followed for condition survey. The following information was collected for the assessment:

## Hydraulic adequacy

- Previous flood scenario of the stream /River
- Previous overtopping record of the bridges and road have been collected from local enquiry and from the concerned departments
- Collection of FSL from irrigation department in case of irrigation canals
- High flood level and year of incident
- Low water level
- Type of vent and condition
- Condition of protection works to assess the existing scour condition

## Structural condition

- Condition of wearing coat, drainage spout and expansion joints
- Condition of handrail and parapet
- Condition of superstructure
- Condition of substructure
- Condition of bearing
- Condition of embankment protection work for the existing structure.

The survey data collected during the inventory and condition survey of bridges and culverts in tabulated form is given in Annexure.

# PART II – CHAPTER - 1 – HYDROLOGY AND DRAINAGE DESIGN

## 1.0 HYDROLOGY AND DRAINAGE DESIGN

## 1.1 HYDROLOGY AND HYDRAULIC STUDY OF CROSS DRAINAGE WORKS

The main objective of the hydrological and hydraulic study is to determine the required size of drainage structures to allow the estimated design flow of the streams to cross the road safely, and to check whether waterways of existing structures are sufficient to pass the flow without risk so that appropriate decisions could be taken concerning their rehabilitation.

The hydrological and hydraulic study for the project has been based on:

- Topographic survey data of cross drainage structures
- Generated topographical data and maps of streams for upstream and downstream, rainfall intensity, duration and its distribution.
- Rainfall pattern of the project site

### 1.1.1 Project Description

The project alignment is passing through 12 minor streams and 3 major streams. After extensive study of catchments, it has been found that most of the streams are originated at different ranges of hills and the toes of hills are thickly populated along both sides of banks of the streams. Maximum discharge of streams are vanished through irrigation canals for the domestic and agricultural requirements of local body.

The existing project road is hydraulically adequate and no overtopping of road was observed.

### 1.1.2 Data Collection and Data Analysis

Requirements for Hydrology and Drainage design

The hydrological study aims at estimating the peak discharge of the flood generated by the run-off of rainfall within the catchment area. The hydrological study requires:

- Knowledge of the characteristics of peak rainfall in the regions:
- Knowledge of the characteristics of the catchment areas:
- Topographic data about the stream, upstream and downstream:
- Survey of India topo maps to a scale of 1: 50,000 for identification of catchment area and its characteristics.
- Site study of the characteristics of the catchment areas, HFL from local enquiry.

Data Collection

Topographic surveys have been done at all the major and minor stream crossings with a view to obtain the cross section of the rivers at the proposed road crossing. As per IRC: SP: 13-2004 Clause 3.3, Table-1, approximate distances, upstream and downstream of the selection site of crossing at which cross sections should be taken are as under.

| **Catchment Area** | **Distance (u/s and d/s of the crossing) at which cross sections should be taken)** |
|---|---|
| Upto 3.0 sq. km | 100m |
| From 3.0 to 15 sq. km | 300m |
| Over 15 sq. km | 500m |

For major bridges and spans more than 30m and for the catchment area more than 15 square km the topographic surveys of about one and a half km or the width between the banks (whichever is more as per IRC 05-1998, clause 102.1.2.3) are yet to be carried out. But it is unable to perform the topographic surveys for the hilly regions of the stream and built up area. therefore the cross sectional area of such locations are taken as: cross sectional area of chord or cross sectional area of trapezoidal with an assumption of appropriate side slope, where top width equal to the proposed width of linear waterway and depth equal to depth of water as per inventory.

The characteristics of the catchment areas have been ascertained from Survey of India topo sheets, to a scale of 1:250000/1:50000 from which, catchment area at the proposed bridge site, length of the stream and fall in elevation from originating point to the point of crossing, could be determined.

HFL data

The High Flood Levels (HFL) have been obtained from existing flood marks or ascertained from enquiry with local people.

### 1.1.3 Methodology of Discharge Calculations

Discharges for the major and minor bridges are worked out as per methodology described under various applicable standards of IRC, e.g. IRC: 5 -2000, pocket book of bridge engineers and SP-13-2004. The computed values are adopted through site validation and local inquiry with judgment.

The following methods have been used to estimate the peak discharge and waterway for bridge sites on major and minor streams.

- Area Velocity Method/Slope Area Method
- Catchment Area Method
- Rational formula
- Dicken's formula
- Synthetic Unit Hydrograph (as per CWC Manual-subzone 2b)

Paths of streams having nominal discharges of minor bridges at some locations could not identified on topo sheets. So, the calculation of discharges for that particular bridges have to be done as per Area Velocity method only.

For catchment areas not exceeding 50 sq. km, Rational method is an universally accepted empirical formulae relating rainfall to run-off as per clause 10.4 IRC SP 42-1994. If the catchment area is more than 50 sq. km the calculation of discharge has to be done as per Synthetic Unit Hydrograph method.

### 1.1.3.1 Area Velocity Method/Manning's Formula

This method has been utilised to calculate the discharge from the stream cross-section and stream slope/bed slope at the proposed bridge sites, for both major and minor bridges. After plotting the cross section of the river, and marking the observed HFL, the cross sectional area (A) and wetted perimeter (P) have been computed. The bed slope of the river has been estimated along its length.

The velocity and Discharge have been calculated using the Manning's formula:

$$V = 1/n \, R^{2/3} S^{1/2}$$

$$Q = A \times V$$

Where,

V = Velocity in m/sec

R = Hydraulic mean depth in m

S = Flood slope/bed slope

n = Co-efficient of rugosity

Q = Peak Discharge

A = Area of cross section

The value of 'n' has been adopted as per soil criteria and river bed characteristics, observed at site and are based on Table 5.1 of IRC SP-13: 2004 which has been tabulated below.

| Surface | Perfect | Good | Fair | Bad |
|---|---|---|---|---|
| **Natural Streams** | | | | |
| 1. Clean, straight bank, full stage, no rifts or deep pools | 0.025 | 0.0275 | 0.030 | 0.033 |
| 2. Same as (I), 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 and sections | 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 | 0.050 | 0.060 | 0.070 | 0.080 |
| 8. Very weedy reaches | 0.075 | 0.100 | 0.125 | 0.150 |

### 1.1.3.2 Catchment Area Method

a). Rational Formula

Pocket Book for bridge engineers, published by IRC or methodology available in IRC: SP-13:2004 has been adopted for computation of discharge by this method. In this method discharge is assumed to be proportional to the upstream catchments at the crossing and critical intensity of rainfall.

$Q = 0.028\ P\ f\ A\ I_C$

Where:

Q = Maximum runoff in cumecs

A = Catchment area in hectares

$I_C$ = 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 aerial mean rainfall.

$I_C = Io*[2/ (T_C +1)]$

$I_o$ = Intensity of one hour rainfall that occurs from the severest storm in the region. The intensity is chosen from Appendix – A of SP-13-2004.

$T_C$ = Time of concentration in hour.

**Table 4.1 Maximum Value of P in the Formula $Q = 0.028\ PAI_C$**

| | |
|---|---|
| Steep, bare rock and also city pavements | 0.90 |
| Rock, steep but wooded | 0.80 |
| Plateaus, lightly covered | 0.70 |
| Clayey soils, stiff and bare | 0.60 |
| -do- lightly covered | 0.50 |
| Loam, lightly cultivated or covered | 0.40 |
| -do- largely cultivated | 0.30 |
| Sandy soil, light growth | 0.20 |
| -do- covered, heavy brush | 0.10 |

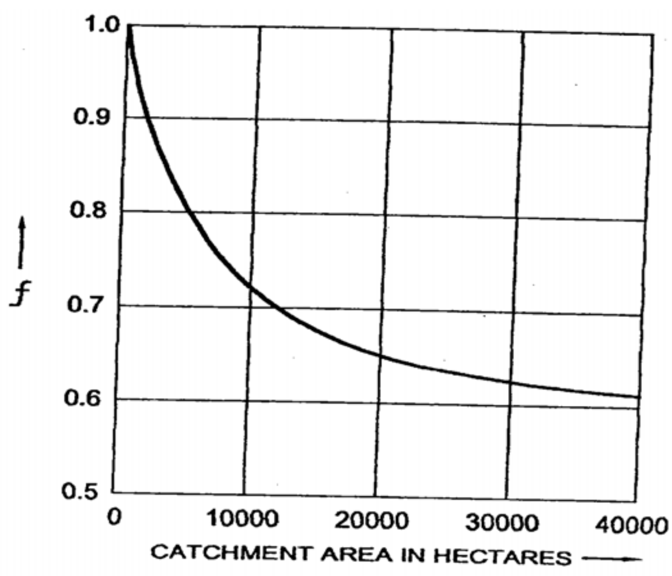



**Fig. 4.2 'f' curve**

Time of Concentration:

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

$$T_c = \left[\frac{0.87 * L^3}{H}\right]^{0.385}$$

Where, L is the distance of basin critical point to the outfall point/crossing 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, vide fig. 4.2, showing ‘f’ curve.

Maximum rainfall:

The alignment falls under flood estimation report of central water commission subzone (2c) which is under preparation by CWC. So, the calculation for discharge by SUH has been done by using CWC subzone (2b) since it lies between latitude of 24°43’N and longitude of 94°17’E and topography is also almost same.

The maximum 24 hour rainfall has been taken as 320 mm for 100 years return period as per flood estimation report of Central Water Commission, Subzone (2b)

b). Dicken’s Formula:

It has 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.

Discharge, $Q = C A^{0.75}$

Where, A = Catchment area in Sq. km.

C is Run-off coefficient, which depends on the annual rainfall. The max annual rainfall collected from various rain gauge stations within the project site is 1650mm. So, the value of C adopted is 17.

### 1.1.3.3 Synthetic Unit Hydrograph (as per CWC Manual-subzone 2b)

According to CWC Manual of sub zone (2b) the Synthetic Unit Hydrograph was computed by using the equations given below:

Basin Lag,

$t_p = 2.87(q_p)^{-0.839}$

Peak of the Unit Hydrograph, $Q_p = 0.905(A)^{-0.753}$

Peak of the Unit Hydrograph per Unit area in cumecs per sq.km,

$q_p = Q_p / A$

Width of Unit Hydrograph measured at 50% max. Peak discharge

$Q_p, W_{50} = 2.304(q_p)^{-1.035}$

Width of Unit Hydrograph measured at 75% max. Peak discharge

$Q_p, W_{75} = 1.339(q_p)^{-0.978}$

Width of Unit Hydrograph measured at 50% of Q p between the rising limb and $Q_p$, ordinate in hours, $W_{R50} = 0.814(q_p)^{-1.018}$

Width of Unit Hydrograph measured at 50% of $Q_p$ between the rising limb and $Q_p$, ordinate in hours, $W_{R75} = 0.494(q_p)^{-0.966}$

Base width, $T_B = 2.447 *(t_p)^{1.157}$

Time from start of rise to the peak of Unit Hydrograph, $T_m = t_p + t_r /2$

Max. Peak discharge, $Q_p = q_p \times A$

### 1.1.4 Design Discharge

The design discharge has to be considered according to IRC: 5-1998 in which the design discharge shall be adopted by considering the maximum discharge of all methods.

But, according to site investigation all structures are hydraulically adequate and maximum discharge of streams are vanished through irrigation canals for the domestic and agricultural requirements of local body. So, there has been a reduction of 30% to 40% in maximum total discharge taken as per site condition while fixing the design discharge and design HFL.

### 1.1.5 Design HFL

If the design discharge is obtained by area velocity method as governing case, then the design HFL has been taken as the observed HFL only. If not the design HFL has been obtained by back calculation, i.e., keeping the design discharge as constant, passing it through bridge site cross section and modify the HFL accordingly.

### 1.1.6 Linear Waterway

Linear water way is obtained by dividing the design discharge by velocity through vent, depth of flow and factor of safety which depends on shape of cross section of stream.

### 1.1.7 Afflux Calculation

If any of the bridges in the alignment have less clear waterway as compared to natural stream width. This causes afflux at bridge sites during flood. Afflux for the bridges has been calculated using Molesworth formula as described in IRC: 89-1997 and pocket book for bridge engineers. Value of afflux, h in meter, is given by the following expression:

$$\boxed{\left[\frac{V^2}{17.89}+0.015\right]\times\left[\left(\frac{Au}{Ae}\right)^2-1\right]}$$

Where, V = Average velocity of river prior to obstruction in m/sec

Au = Unobstructed sectional area of the channel in $m^2$

Ae = Sectional area of river at obstruction in $m^2$

### 1.1.8 Results

Design discharge = Q in 'cumecs'

Velocity = Vf in m/sec

Effective Linear water way = $L_{eff}$ in 'm'

Depth of flow (from the lowest bed level) = Actual depth of flow

Afflux = Afflux provided

Free Board = depends on the discharge(table 1)

Depth of Soffit = (HFL + Afflux + Free Board)

**Table: 1(Free Board)**

| Discharge (Cumecs) | Free Board(mm) |
|---|---|
| Up to 0.30 | 150 |
| 0.30 - 3.00 | 450 |
| 3.00 - 30.00 | 600 |
| 30.00-300.00 | 900 |
| 300.00-3000.00 | 1200 |
| >3000.00 | 1500 |

### 1.1.9 Scour depth

The scour depth is calculated according to the IRC SP: 13-2004. From the soil samples, recovered from the bore holes during soil investigation, grain size analysis are carried out and silt factors are calculated up to the depth of anticipated scour level in accordance with IRC-5.

The mean scour depth is calculated using the formula:

$d_{sm} = 1.34(D_b^2 / K_{sf})^{1/3}$

Where,

Ksf = silt factor

$D_b$ = ($Q_b$/ $L_e$) Design discharge in cumecs per meter width.

$d_{sm}$ = mean scour depth of scour level below HFL.

$L_e$ = effective linear water way.

$Q_d$ = Design discharge according to IRC 5 :1998

All the calculated hydrology and hydraulic data, scour calculations and recommendations for bridge structures have been summarized in Appendix – 1.1.

## 1.2 DRAINAGE DESIGN

A good drainage system is vital for the safety and longer life of any structure. This is more relevant in the case of highways. Proper drainage of road surface, pavement and the foundation layers is basic requirement for maintaining the structural soundness and functional efficiency of a road. Pavement structure including subgrade must be protected from any ingress of water. For this purpose, the following conditions have to be ensured.

- Saving the pavement structure from stagnation of water.
- Efficient dispersal and disposal of water.
- Quick disposal of sub-surface water away from the pavement.
- Interception of the surface runoff.
- Keeping the water flow duration on the pavement to a minimum.

Longitudinal gradient of minimum 0.3% is followed for better internal drainage of pavement layers. Camber of 2.5% is considered for flexible pavements as per IRC: SP: 84-2009 and IRC: SP: 42-1994 for quick surface runoff disposal from the pavement. Hence, it is considered enough to drain out the water from the pavement surface even with steepest longitudinal gradient of 5%, being ratio of longitudinal gradient to cross slope is 2.0.

Drainage design needs to be carried out for the following types of drainage situation:

a) Drainage at Urban/Built-up locations.
b) Drainage at Rural areas.
c) Drainage at High Embankments.
d) Median Drainage at Super Elevated Sections.
e) Drainage in Hill Sections

### 1.2.1 Drainage at Urban/Built-up Section

Concrete or Lined closed drains or pipe drains shall be used in Urban/Built-up Sections.

Minimum Section of Drain

As per IRC standards, It should be possible to clean the drains periodically using a spade. Accordingly, the minimum width of drain shall not be less than 250mm. In case of pipes drains, the minimum diameter is 600mm.

Minimum and Maximum Velocities:

The velocity values in excess of maximum permissible velocity will cause erosion in the drain which increases the maintenance cost and also weakens the road structurally. A minimum self cleansing velocity is also required to disperse floating debris conveniently. Clause 4.9.3.a of IRC: SP: 50- 1999 suggests minimum velocity for concrete drain is 0.75 m/sec and maximum velocity is 6.0 m/sec.

### 1.2.2 Drainage at Rural areas

Trapezoidal unlined open drains with minimum bed width of 0.5m and side slope 1:2 s shall be used in rural sections. Minimum velocity for open drain is 0.45 m/sec and maximum velocity is 1.2 m/sec shall be maintained as per codal provisions.

### 1.2.3 Drainage at High Embankments

In high embankment and bridge approaches if water is allowed to leave the carriageway at undefined spots, it may cause serious damage to embankment and pavement crust. This problem of erosion of slopes and shoulders is more pronounced in more than 3 m high embankments.

In such location where embankment height more 3m, rain water is collected in small manageable quantities through longitudinal kerb channel at the edges of roadway and brought down through chutes without damage. Drainage arrangement in such location is provided as per section 7 of IRC SP: 42.

### 1.2.4 Median Drains in Super Elevated Stretches

Clause 3.2.4 of IRC: SP: 50-2013 is reproduced here that “The provision of median openings (cuts) at super elevation and curves in divided carriageway shall be for and upto two lanes as shown in Figure 3.2.4(a) and 3.2.4(b) of the same code”. The same clause also says that “in locations where carriageway slopes towards median, as may be the case where road is in curve, necessary openings shall be provided in the median for smooth passage of water from one lane to other and to towards side drain”.

As per Fig. 3.2.C. of IRC: SP: 50-1999 or IRC: SP: 50-2013, if the finished road level of inner carriageway near median is less than or equal to that of the outer carriageway, the runoff shall be collected through the median cuts provided at the regular interval. If the finished road level of inner carriageway is more than that of the outer carriageway, the runoff shall be collected through the longitudinal median drains and the same shall be drained off into the nearby cross drain or can be taken out by providing cross culverts below the pavement.

### 1.2.5 Drainage in hill sections

Inadequate cross drainage on a hill road causes softening of the sub-grade and renders it too weak to take the load of moving traffic. Roadside drains are therefore necessary on a hill road. According to clause 8.4.1 of IRC: SP: 48-1998, they should be taken below the sub-grade of the road or in a kutcha road these are invariably taken about 300mm below the road surface.

Roadside drains should generally be of uniform section throughout irrespective of the location of road on the hill slope. They are generally constructed to parabolic, trapezoidal, triangular, V-shape, kerb and channel or U-shaped cross sections.

Minimum size of drain 60 cm x 60 cm and should have a gradient of 1:20 to 1:25 to develop self cleansing velocity to disperse floating debris conveniently. In continuous long stretches of road with steep grades, the road side drains should be stepped to break the velocity. A 0.60m high toe wall along the hill side will be required to prevent erosion of hill-slope-as an integral part of side drain.

### 1.2.6 Catch water drain in Hill section

Catch water drain, also known as intercepting drains, is provided on hill slope above cutting to collect and remove surface water runoff from upper reaches. As per Clause 6.5 of IRC: SP: 84-2009, these drains shall be trapezoidal shape and stone lined and cement pointed. The drains are designed for carrying the intercepted water to the nearest culvert or natural drainage channel. It is to be ensured that the catch water drains are provided in stable hill slopes outside the periphery of slide/unstable areas.

## 1.3 Culverts

To discharge runoff from hill side drain to valley side, 8 to 10 culverts or scuppers shall be provided. 3 culverts shall be provided in plain terrain. Almost from km. 352 to end of project stretch is rolling terrain. But some of locations in tolling terrain are falls on ridge alignment. So, an approximate number of culverts 5 per km has been provided based on site investigations. The list of proposed and existing culverts has been provided in Appendix -1.1.

## 1.4 DESIGN STANDARDS

The design of drainage structures is carried out in accordance with the following codes:

IRC: SP: 13 - 2004, “Guidelines for the design of small bridges and Culverts”.

IRC: 5 – 1998 “Standard specifications and code of practice for Road bridges”.

IRC: SP: 84 - 2009, “Manual of Specifications & Standards for Four laning of Highways through Public Private Partnership”.

IRC: SP: 42 – 1994, “Guidelines on Road Drainage”.

IRC: SP: 50 – 1999/IRC: SP: 50 – 2013, “Guidelines on Urban Drainage”.

IRC: SP: 48– 1998, “Hill Road Manual”.

# PART II - CHAPTER -2 BRIDGES DESIGN

## 2.1 Introduction - Overview of structures

The projects stretches falls in Zone V as per seismic zone map of IRC: 6-2010.

The bridge team carried out the inventory and condition survey of the existing structures in the two corridors main alignment and alternative alignment. As per inventory and condition survey, the details of structures in both the corridors are as follows:

**Table2. 1 Details of Existing Structures**

| Type of Structure | Main Alignment | Alternative |
|---|---|---|
| Minor Bridges | 12 | 0 |
| Major Bridges | 3 | 0 |
| ROB & RUB | 0 | 0 |
| Flyover | 0 | 0 |
| Level Crossings | 0 | 0 |

## 2.2 STRUCTURE DESCRIPTION

### 2.2.1 Minor bridges:

Minor bridges along the project road are of RCC solid slab type and RCC I girder superstructure with simply supported spans. There are two minor bridges with steel truss girder bridges with wooden deck superstructure observed. Most of the solid slab bridges are with tar paper bearings. Expansion joints are not visible and few of them are without approach slabs.

The existing minor bridges with solid slab super structure and the sub structure is with plain cement concrete or masonry piers are with open foundations. 7 minor bridges are situated in plain terrain and 5 minor bridges are in hilly terrain.

**Table2. 2: Details of Minor bridges**

| Sl. No. | Chainage | River/Bridge name | Superstructure Type | Span arrangement | Remarks |
|---|---|---|---|---|---|
| 1 | 334+330 | Ushoipokpi | RCC Solid slab | 5.6+6.0+5.6 | |
| 2 | 336+100 | Waithou | RCC girder | 3x13.2 | Poor condition |
| 3 | 344+150 | Arong Bridge | RCC T girder | 3x11.0 | |
| 4 | 347+600 | Khangabhok | RCC Solid slab | 2x7.0 | |
| 5 | 348+150 | Wangjing | RCC Solid slab | 8.8+8+8.8 | Poor condition |
| 6 | 349+900 | Uningkhom | RCC Solid slab | 2x5.8 | |
| 7 | 352+800 | Khongjom | RCC Solid slab | 2x5.8 | |

| Sl. No. | Chainage | River/Bridge name | Superstructure Type | Span arrangement | Remarks |
|---|---|---|---|---|---|
| 8 | 407+450 | Lokchao | RCC abutment with bailey super structure | 1x30.5 | |
| 9 | 409+000 | | RCC Solid slab | 1x10.0 | |
| 10 | 412+230 | | RCC Solid slab | 1x10.0 | |
| 11 | 428+180 | Khujairok | RCC T girder | 1x16.0 | |
| 12 | 430+400 | Border | RCC abutment with bailey super structure | 1x44.1 | This structure is on international border |

### 2.2.2 Major bridges:

Out of 3-major bridges, two are with PSC I girder simply supported type superstructure and one is RCC solid slab with Pier and abutment support. Following *Table 2.3* give the basic superstructure system and span arrangement of the Major bridges. All the major bridges are in plain terrain only. At one location i.e at Pallel town new bridge is under construction with the span of 3 x 24.0m with RCC I girders on realignment of the existing road.

**Table2. 3: Details of Major bridges**

| Sl. No. | Chainage | River/Bridge name | Superstructure Type | Span arrangement | Remarks |
|---|---|---|---|---|---|
| 1 | 330+150 | Lilong | PSC I girder | 1x48.5+1x48.5 | |
| 2 | 341+780 | Thoubal | PSC I girder | 2x34.5 | |
| 3 | 365+550 | Pallel Bridge | RCC Solid slab | 6x10.0 | New Bridge of 3x24.0m Span is under construction in realignment of the existing road |

Major bridges with PSC I girder type superstructures are with MS ROCKER CUM ROLLER bearings. Expansion joints at abutments and piers are of strip seal type. All the bridges are observed with well foundation and piers are of plate type.

### 2.2.3 VUP/PUP/CUP

There is one Pedestrian under Pass (PUP) situated on the project road which is in the approach of Thoubal Bridge and it is in fair condition.

### 2.2.4 Culverts

Culverts are of box/slab, pipe and brick arch type. Numbers of culverts in plain terrain are less when compared with the hilly terrain.

## 2.3 General guidelines for widening and improvement of existing structures

Bridges and culverts

- All structures along the project road were inspected for hydraulic adequacy, structural condition and loading for which those are designed. Structures are recommended for reconstruction if not satisfying the standards, else proposed for widening.
- Additional culverts will be proposed on existing road to ease the natural flow of water without causing damage to the embankment if required based on hydraulic calculations.
- Pipe culverts with diameter of the pipe below 900mm or not hydraulically functioning are recommended for replacement with new pipes of diameter 1.2m or box culverts with equivalent vent size depending up on the height of embankment.
- Culverts are recommended for reconstruction where the embankment needs to be raised and the culverts are not structurally sound enough to carry the load of extra fill.

## 2.4 Improvement Proposals

Based on the inventory & condition survey of structures, MoRTH & IRC circulars / codal provisions and keeping in view of ToR, the following improvement proposals are suggested.

The deck width configuration for 2 lane bridges in 2 lane sections is adopted vide MoRTH circular No: RW/NH/33044/2/88-S&R (B) dated 24.03.2009 and those in 4 lane sections are as per IRC: SP: 84-2009. Details are given in Section 5.6. For new bridges, the requirement is 12.0 to 12.9 m depending on with or without footpath and 2 or 4 lane section. These standards call for the paved width to carry through the bridges.

The minimum clear carriageway width for a 2lane bridge shall be 7.5m as per clause 112 of IRC: 5-1998. As per ToR section 4.10.6.4 - Dismantling/ reconstruction of existing structures will be avoided as far as possible except where considered essential in view of their poor structural conditions. Based on this all existing bridges which are structurally distressed shall be reconstructed as new bridges.

It will be ideal from safety point of view to have at least all minor bridges to have width as per MoRT&H circular No: RW/NH/33044/2/88-S&R (B) dated 24.03.2009. However, keeping in view of the clause 4.10.6.4 of ToR and Section 3.0 of MoRT&H circular, bridges that are in fair condition are retained with repair & rehabilitation with proper safety measures and sufficient information for safely negotiating these bridges (traffic shall be guided with the help of crash barriers in a transition of 1 in 20 on either side approaches). Feasibility report also suggested retain all the bridges except two locations where it is proposed for reconstruction. Bridges which can be widened will be widened to a cross section specified in Section 2.28. Bridges with well foundation cannot be widened but will be retained if they are in fair condition with repair and rehabilitation. Components like bearings, expansion joints, railings, crash barriers, wearing surface, stone pitching in slopes of quadrants and wing walls, etc., which are not in sound condition / damaged shall be replaced / repaired. Minor non-structural works shall be suitably repaired.

Based on the above, the improvement proposals in 4 lane section are as follows:

(i) All major bridges with well foundation which are in fair condition and having a carriageway width above 7.0m are proposed to retain with repair and rehabilitation and new 2lane bridge next to the existing bridge has to be constructed.

(ii) All Minor bridges with well foundation which are in fair condition having carriageway width above 7.0m are proposed to retain with repair and rehabilitation and new 2lane bridge next to the existing bridge has to be constructed.

(iii) All minor bridges with open foundation which are in fair condition are proposed to be retained with repair and rehabilitation and widening of solid slab bridge to the required future width and new 2lane bridge next to the existing bridge has to be constructed.

(iv) All bridges where the superstructure is in poor condition and substructure & foundation in fair condition is proposed for deck replacement.

(v) All bridges with substructure / foundation in poor condition are proposed for new / reconstruction based on the foundation type.

(vi) All bridges which are hydraulically deficient are proposed for re / new construction.

For the existing structures in 4 lane sections, all the criteria from (i) to (vi) will be followed along with new 2 lane bridge as per the proposed cross section.

## 2.5 Based on the above guidelines, the improvement proposals are given below

### 2.5.1 Major bridges on Existing alignment

The important major bridges on existing alignment that would be covered in this study are being addressed as described below.

#### 2.5.1.1 Lilong Bridge at chainage 330+150

PSC I-girder type superstructure with well foundations. Condition survey shows that this bridge is of structurally sound and hydraulically functioning good. The bridge is also met the carriageway requirement of 2lane improvement even though the total width of the bridge is less than that required. Considering these parameters, this bridge is proposed to be retained with minor repair and rehabilitation.

2.5.1.2 Thoubal bridge, at chainage 341+780, is PSC I-girder type superstructure with well foundations. Condition survey shows that this bridge is of structurally sound and hydraulically functioning good. The bridge is also met the carriageway requirement of 2lane improvement even though the total width of the bridge is less than that required. Considering these parameters, this bridge is proposed to be retained with minor repair and rehabilitation

2.5.1.3 Pallel Bridge at chainage 365+500 a new 2 lane bridge is under construction of the realignment of the existing road during inventory it is observed that super structure is casting.

### 2.5.2 Minor bridges

#### 2.5.2.1 Bridges on existing road

Minor bridges at chainage 334+330 are the RCC solid slab type, 344+240 is RCC T girder bridge. These bridges fall in 4 lane improvement stretch of the project corridor. Condition survey shows that these bridges are of structurally sound and hydraulically functioning well except the bridges at 336+100 is structurally distressed hence this can be reconstructed. Remaining bridges are structurally sound, hence these can be widened to 12.0m and a new 2 lane bridge is proposed parallel to the existing bridge.

Minor bridges at chainage 347+600, 348+150, 349+900, 352+800, 409+000 and 412+230 are solid slab bridges which fall in 2 lane improvement with paved shoulder. These bridges are structurally sound so they are widened to 12.9m concentrically. (Refer Annex 2.1)

Minor bridge at 344+240 is a 2 lane bridge with RCC T Girder and retained and widened to 12.9m

Minor bridge at chainage 348+150 is structurally in distressed condition and proposed for reconstruction to new 2 lane bridge with 12.9m deck width.

Bridge at chainage 407+450 is stone abutment with foundation on rock with bailey super structure; Separate DPR had been submitted to the bridge. Hence not in the scope of the present study.

Bridge at 428+150 is RCC Girder Bridge is structurally sound and comes in 2 lane improvement of the project and as it is meeting the 2 lane carriage way width, hence it is retained. Bridge at chainage 430+400 is across menar river with RCC abutment with bailey type super structure is on the international border hence not in the scope of the project.

Summary improvement proposals for all the bridges given in table 2.4

## 2.6 Standards for Design of New Structures and General Design Philosophy

Codes and References:

The design of various components of the structure, in general are based on provisions of IRC/IS Codes. The list of IRC Codes (latest revisions) given below will serve as a guide for the design of structures.

| | |
|---|---|
| IRC: 5-1998 | Standard Specifications and Code of Practice for Road Bridges, Section-I: General features of Design. |
| IRC: 6-2010 | Standard Specifications and Code of Practice for Road Bridges, Section-II: Loads and Stresses. |
| IRC: 22-1986 | Standard Specifications and Code of Practice for Road Bridges, Section-VI: Composite Construction. |
| IRC: 78-2000 | Standard Specifications and Code of Practice for Road Bridges, Section-VII: Foundation & Substructure. |
| IRC: 83-1987 | Standard Specifications and Code of Practice for Road Bridges, (Part II) Section-IX: Bearings - Part II: Elastomeric Bearings. |
| IRC: 83-2002 | Standard Specifications and Code of Practice for Road Bridges, (Part III) Section-IX: Bearings - Part III: POT, POT-cum-PTPE & Metallic guided Bearings. |
| IRC: 112-2011 | Code of Practice for Concrete Road Bridges. IRC: SP: 13-2004 |
| | Guidelines for Design of Minor Bridges & Culverts |
| IRC: SP: 35 | Guidelines for Inspection and Maintenance of Bridges |
| IRC: SP: 37 | Guidelines for Evaluation of Load carrying capacity of Bridges |
| IRC: SP: 40 | Guidelines for Techniques for Strengthening and Rehabilitation of Bridges |
| IRC: SP: 80-2008 | Guidelines for Corrosion Prevention, Monitoring and Remedial Measures for Concrete Bridge Structures. |
| IRC: SP: 84-2009 | Manual of Specifications and Standards for Four Laning of Highways through Public Private Partnership |
| IS: 2911 PI Sec-2 | Code of Practice for Design and Construction of Pile Foundations: Concrete Pile - Bored Cast-in-Situ |
| IS: 2911 PIV | Code of Practice for Design and Construction of Pile Foundations: Load test on Piles. |

## 2.7 International Codes and References:

Wherever IRC code is silent, following standards will be followed.

- American Association of State Highway and Transport Officials (AAHSTO) Standards.

- British Standards.
- Any other National or International Standard as considered suitable.

**Table 2.4 Improvement Proposals**

| SL.NO | Highway Chainage (Existing) | Chainage based on alignment marked(Design) | Bridge Name | Name of river / Road | Existing Span Arrangement | Bridge type | Carriage way width/ Total width (m) | Improvement Proposals |
|---|---|---|---|---|---|---|---|---|
| 1 | 330+150 | 330+380 | Lilong Bridge | Lilong Pool /NH 39 | 1X48.5+1X48.5 | MJB | 7.5/11.0 | 4-lane section. Existing bridge retained. New 2lane bridge is next to the existing bridge. |
| 2 | 334+330 | 334+640 | Ushoipokpi Bridge | NH 39 | 5.6+6+5.6 | MNB | 7.5/8.5 | 4-lane section. Existing bridge to be widened to 12.0m width and New 2lane bridge is next to the existing bridge |
| 3 | 336+100 | 336+289 | Waithou Bridge | NH 39 | 3X13.2 | MNB | 7.5/8.7 | 4-lane section. Reconstruction of existing bridge. New 4-lane bridge at same location of existing bridge |
| 4 | 341+780 | 341+857 | Thoubal Bridge | NH 39 | 2x34.5 | MJB | 7.50/11.0 | 4-lane section. Existing bridge to be widened to 12.0m width and New 2lane bridge is next to the existing bridge |

| SL.NO | Highway Chainage (Existing) | Chainage based on alignment marked(Design) | Bridge Name | Name of river / Road | Existing Span Arrangement | Bridge type | Carriage way width/ Total width (m) | Improvement Proposals |
|---|---|---|---|---|---|---|---|---|
| 5 | 344+150 | 344+240 | Arong Bridge | NH 39 | 3X11.0 | MNB | 7.5/8.4 | 2-lane section. Existing bridge to be widened to 12.9m width. |
| 6 | 347+600 | 347+900 | khangabhok Bridge | NH 39 | 2x7.0 | MNB | 7.0/8.0 | 2-lane section. Existing bridge to be widened to 12.9m width. |
| 7 | 348+150 | 348+475 | Wangjing Bridge | NH 39 | 8.8+8+8.8 | MNB | 7.0/10.6 | 2-lane section. Reconstruction of existing bridge. New 2-lane bridge at same location of existing bridge |
| 8 | 349+900 | 349+878 | Uningkhom Bridge | NH 39 | 2X5.8 | MNB | 7.5/8.5 | 2-lane section. Existing bridge to be widened to 12.9m width. |
| 9 | 352+800 | 352+863 | Khongjom Bridge | NH 39 | 2X5.8 | MNB | 7.5/8.5 | 2-lane section. Existing bridge to be widened to 12.9m width. |

| SL.NO | Highway Chainage (Existing) | Chainage based on alignment marked(Design) | Bridge Name | Name of river / Road | Existing Span Arrangement | Bridge type | Carriage way width/ Total width (m) | Improvement Proposals |
|---|---|---|---|---|---|---|---|---|
| 10 | 365+550 | 365+365 | Pallel Bridge | NH 39 | 6x10.0 (3x 24.0m Span Bridge under Construction Along The Realignment) | MJB | 5.5/6.0 | 2-lane section. Existing bridge retained. |
| 11 | 407+450 | 404+465 | lokchao Bridge | NH 39 | 1x30.5 | MNB | 2.5/3.0 | Separate DPR submitted |
| 12 | 409+000 | 405+540 | | NH 39 | 1x10.0 | MNB | 7.0/10.5 | 2-lane section. Existing bridge to be widened concentric widening |
| 13 | 412+230 | 408+465 | | NH 39 | 1x10.0 | MNB | 7.0/10.5 | 2-lane section. Existing bridge to be widened concentric widening |
| 14 | 428+180 | 423+470 | Khujairok Bridge | NH 39 | 1x16.0 | MNB | 7.0/10.5 | 2-lane section. Since this bridge is girder type bridge, concentric widening and also as built drawings are not available it is proposed |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | for retaining |
| **SL.NO** | **Highway Chainage (Existing)** | **Chainage based on alignment marked(Design)** | **Bridge Name** | **Name of river / Road** | **Existing Span Arrangement** | **Bridge type** | **Carriage way width/ Total width (m)** | **Improvement Proposals** |
| 15 | 430+400 | | Border Bridge | Menar River (Border) | 1x44.1 | MNB | 7.3/10.5 | Bridge is on International border not in scope |
| **ALTERNATIVE ALIGNMENT** | | | | | | | | |
| **SL.NO** | **Highway Chainage (Existing)** | **Chainage based on alignment marked(Design)** | **Bridge Name** | **Name of river / Road** | **Proposed Span Arrangement** | **Bridge type** | **Carriage way width/ Total width (m)** | **Improvement Proposals** |
| 1 | - | 6+020 | - | - | 2 x 20.0m | MNB | 12.90 | New 2 lane bridge |
| 2 | - | 7+390 | - | - | 1 x 24.0m | MNB | 12.90 | New 2 lane bridge |
| 3 | - | 11+900 | - | - | 2 x 18.0m | MNB | 12.90 | New 2 lane bridge |
| 4 | - | 15+866 | - | - | 1 x 12.0m | MNB | 12.90 | New 2 lane bridge |
| 5 | - | 16+600 | - | - | 1 x 21.0m | MNB | 12.90 | New 2 lane bridge |

## 2.8 Loadings

**Dead Load (DL):**

Unit weight of dead loads calculation shall be considered as per IRC: 6-2010 as below.

| | | |
|---|---|---|
| Materials | : | Unit |
| weight Plain Concrete& | : | 25 |
| KN/$m^3$ Reinforced Concrete | | |
| Pre-stressed Concrete | : | 25 |
| KN/$m^3$ Wearing Coat | : | 22 |
| KN/$m^3$ | | |
| Structural Steel | : | 78.5 KN/$m^3$ |

## 2.9 Super Imposed Dead Load (SIDL):

Unit weight of superimposed dead load shall be in conformity with IRC: 6-2010. For calculating the dead weight, 100mm thickness shall be considered including the future overlay.

The crash Barrier will be designed as per table 3 of IRC: 6 - 2010 under P-1 "Normal Containment" category. The crash barrier shall be provided as per IRC: 5.

## 2.10 Live Load (Carriageway (CWLL) + Footpath (FPLL)):

1 Lane / 2 Lanes / 3 Lanes of Class A / 1 lane of 70R in combination with 1 lane of class A with or without footpath whichever is critical for 2 Lane bridges in 2 Lane sections

1 Lane / 2 Lanes of Class A / 1 lane of 70R with footpath or 1 Lane / 2 Lanes / 3 Lanes of Class A / 1 lane of 70R in combination with 1 lane of class A without footpath for 2 Lane bridges in 4 Lane sections whichever is critical.

Reduction in Longitudinal effect for three lane loading shall be considered as per clause 211 of IRC: 6.

Footpath / Kerb loading shall be as per clause 206 of IRC: 6-2010 depending on the span.

## 2.11 Braking and Centrifugal Force:

Breaking and centrifugal forces are to be considered as per codal provisions mentioned in Cl. 211 & 212 of IRC: 6-2010.

## 2.12 Temperature Forces (Temperature Gradient):

Temperature forces considered for calculation of bearing movement and for the design of expansion joint shall be as per clause 215 of IRC: 6.The design is based on the range of effective bridge temperature at the site location of the structure. The temperature gradient considered for stress calculations of all structure members are as per the clause 215.3 of IRC: 6.

Minimum temperature = -2.5°C

Maximum temperature = 40°C

Mean = (2.5 + 40) / 2 =

Mean temperature +10 $^{o}$C or -10 $^{o}$C shall be considered as the Bridge temperature when the structure is effectively restrained.

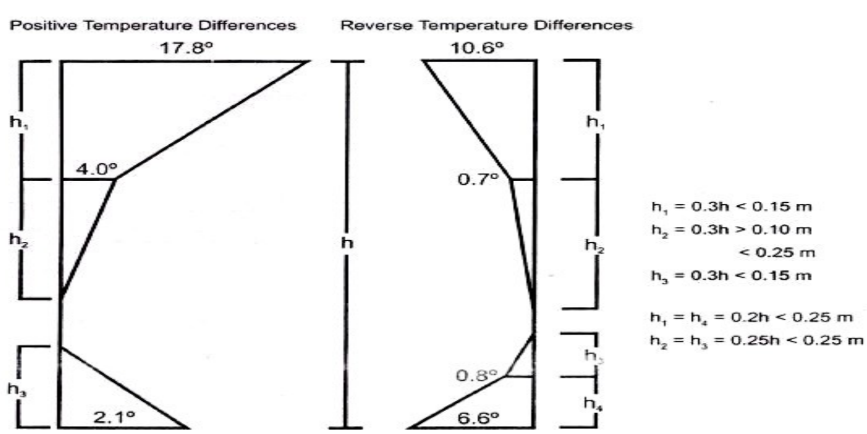
Temperature increase/ Decrease =40 - (21.25 - 10) = 28.75°C

Coefficient of Thermal expansion = 12 x $10^{-6}$ /°C (Cl. 215.4 IRC 6 2010)

For the calculation of shrinkage effect, the shrinkage strain of 2 x $10^{-4}$ has been converted into equivalent temperature fall as shown below:

Total temperature fall due to shrinkage = 2 x $10^{-4}$ / 117 x $10^{-7}$ = 17/°C

While considering the forces due to these strains, young's modulus of elasticity of concrete can be reduced to 50% of the original value to consider the long term effect.




*Temperature Gradient as per IRC 6: 2010*

## 2.13 Wind Forces:

Wind Forces shall be considered as per clause 209 of IRC: 6. Drag Coefficient, Gust factor and Lift Coefficient shall be calculated as per the above clauses. Basic wind speed considered as per IRC 6 is 47m/s for the bridge.

## 2.14 Water Current Forces:

Water Current Forces shall be considered as per clause 210 of IRC: 6.The structures shall be designed for a variation of 20 deg w.r.t to orientation of pier.

## 2.15 Buoyancy:

Buoyancy shall be considered as per clause 213 of IRC: 6 in the design of submerged structures, the buoyancy effect through pore pressure shall be limited to 15% of full buoyancy.

## 2.16 Earth Pressure:

Active pressure due to filling behind the retaining / abutment shall be evaluated by Coulomb's formula.

The Coefficient of active pressure (horizontal).

$$Ka = \frac{\sin^2(\alpha + \phi)\cos\delta}{\sin^2[\alpha \sin(\alpha - \delta)]\left[1 + \sqrt{\frac{\sin(\phi+\delta)\sin(\phi+\beta)}{\sin(\alpha-\delta)\sin(\alpha+\beta)}}\right]^2}$$

Following soil properties for filling behind abutment and between return walls shall be considered in the design.

| | | |
|---|---|---|
| Angle of Internal Friction | = | 30° |
| Angle of cohesion, c | = | 0 |
| Dry density of back fill material T/m3 | = | 2.0 |

The value for coefficient of active earth pressure, Ka is calculated using the above formula and design parameters, case by case. Passive earth pressure in front will be suitably accounted, case by case. For the Box structures, where uniform earth pressure act from both sides of the box, earth pressure at rest ($K_O$) shall be considered in the design.

$K_O$ = 1- sin cp =0.5

Surcharge live load, equivalent to 1.2m of earth fill shall be considered in the design.

## 2.17 Seismic Forces:

The project stretches falls under Seismic Zone V as per clause 219 of IRC: 6. The seismic coefficient shall be calculated for all new bridges considering the Importance factor (I) of 1.5 for locations where only 2 lane bridge is proposed and alternative routes are not available & 1.2 for locations where 4 lane bridge is proposed or 2 lane bridge with alternative route is available. Seismic reduction factor (R) is considered as 4 for Piers / Columns & 3 for Abutments with POT bearings for the design of substructure & foundation. Seismic reduction factor shall be 2.0 for bearings.

Bridges with length less than 10m are not required to be designed for seismic forces in all zones.

## 2.18Partial Safety Factors for various limit state:

Partial safety factor of 1.5 has been adopted for Concrete and 1.15 has been adopted for steel as per clauses 6.4.2.8 & 6.3.5 of IRC: 112 respectively.

Rectangular stress distribution has been considered for concrete as per Annexure A-2 of IRC: 112.

The partial safety factor for loads for different limit states has been adopted, as given in IRC:6 - 2010, shall be as per

- Table 3.1 for the verification of equilibrium
- Table 3.2 for checking the structural strength
- Table 3.3 for verification of serviceability
- Table 3.4 for base pressure & design of foundation

As per Notification 78 amendment to IRC6:2010, the factors shall be unity for base pressure and the factors shall be as per amendment for design of foundation with seismic.

## 2.19 Ultimate Limit State of Shear, Punching Shear and Torsion:

Ultimate Limit State of Shear, Punching Shear and Torsion shall be checked as per section of 10 of IRC: 112.

## 2.20 Serviceability of Limit State

Serviceability of Limit states of Stress levels, Crack width and deflection shall be carried out as per section of 12 of IRC: 112.

## 2.21 Proposed Bridge Type

**Table2. 5: Type of Superstructure**

| S No | Type of Superstructure | Span Range |
|---|---|---|
| 1 | Box Type Structure | Multiple Cells of 3 to 5m clear span |
| 2 | RCC Solid Slab/RCC Portal frame | > 7m &< 10m |
| 3 | RCC Girder with Slab | > 10m &< 24m |
| 4 | PSC Girder with Slab | > 24m &< 48m |

## 2.22 Type of Substructure:

RCC circular / column type structure with cantilever cap for pier and RCC wall type for full width of structure with cap for abutment is proposed.

## 2.23 Type of Foundation:

Considering the site condition and the type of soil strata and keeping in view of the existing foundations, open / pile foundations are proposed.

## 2.24 Bridge Location Selection

The cardinal principles to be kept in view at the time of selection of a particular bridge site including river training works are to provide a suitable crossing consistent with safety and economy and acceptable detour from the existing alignment.

## 2.25 Bridges up to a length of 60m

The location shall generally be governed by the approach alignment with minimum shifting for improvement of geometrics, if required, unless there are special bridge design problems

## 2.26 Bridges having total lengths between 60m and 300m

Requirement of a suitable bridge site and proper alignment of approaches should be considered together and the most suitable site shall be selected.

## 2.27 Bridges having total lengths in excess of 300m

The requirement of the most suitable site shall have over-riding consideration and the site is so selected shall regulate the approach alignments.

## 2.28 Bridge Deck Width

The width of New Bridge on 2 Lane National Highway with and without footpaths as per Ministry Circular No: RW/NH/33044/2/88-S&R (B) dated 24.03.2009 and the width of bridge on 4 Lane manual is as follows:

**Table2. 6**

| **Component** | **2 Lane with Footpath for 2 Lane Carriageway (Urban)** | **2 Lane without Footpath for 2 Lane Carriageway (Rural)** | **2 Lane with Footpath of 4 Lane Carriageway*** |
|---|---|---|---|
| Carriageway | 10.00m | 10.00m / 9.00m | 8.50m |
| Shyness | 0.25m on both sides | 0.25m on both sides | 0.25m on both sides |
| Safety Kerb | - | 0.75m on both sides | - |
| Crash Barrier | 0.45m on both sides | 0.45m / 0.50m on | 0.50m on both sides |
| Footpath | 1.50m on both sides | - | 1.50m on outer edge |
| Kerb + Railing | 0.20m on both sides | - | 0.50m on outer edge |
| Total Deck Width | 14.80m | 12.90m / 12.00m | 12.00m* |

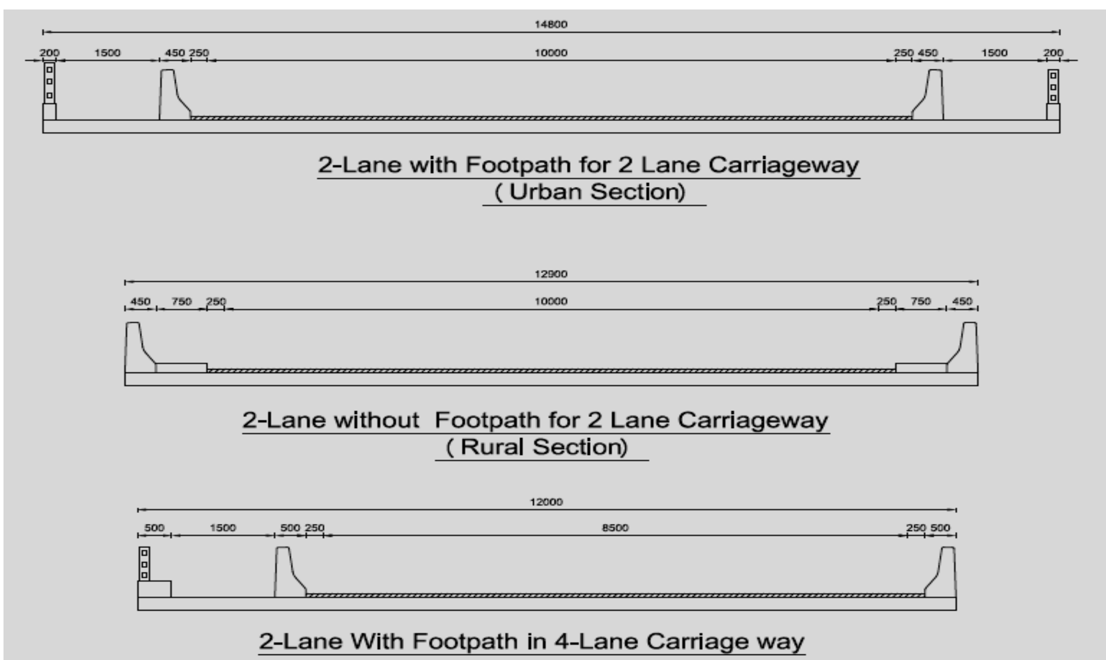



**Fig: 2.1 Bridge cross sectional Features**

## 2.29 Drainage Requirements

The high level bridges may preferably be built in longitudinal gradient with suitably designed cross drains at abutment locations to facilitate proper drainage.

Suitably designed drainage arrangement shall be provided for ROB / Flyover consists of rigid PVC pipes connecting downspouts below the deck with funnels and along the pier up to ground level and eventually joined to the road drainage system.

All carriageways and footpath surfaces shall have anti-skid characteristics.

## 2.30 Water Minimum Clearance above

Minimum vertical clearance shall be maintained above water to the soffit of superstructure as per clause 106.2.1 of IRC: 5-1997 based on the discharge through the bridge and is as follows:

Table2. 7

| **Discharge(m^3/sec)** | **Vertical Clearance(m)** |
|---|---|
| < 30 | 0.6 |
| 30 to 300 | 0.9 |
| 300 to 3000 | 1.2 |
| > 3000 | 1.5 |

As per clause 107.2 of IRC: 5-1987, the vertical clearance shall be increased suitably for the bridges in Himalayan foot hills, flood-prone areas of North-Eastern states and North Bengal.

## 2.31 Structural Analysis of Superstructure

### 2.31.1 Slab & Box type structures for Culverts, Minor Bridges and Vehicular Underpasses

All above are analyzed per meter width of strip for self-weight and superimposed loads. For live load analysis, effective width method recommended by IRC is used for calculating the dispersion. The section design is done for critical values of loads and combinations from the output of the analysis.

### 2.31.2 Analysis for Superstructures with RCC/PSC Girders for Bridges

Grillage analysis

Superstructure decks of slab on girder bridges are analyzed as a two dimensional grillage for the geometry by applying calculated grillage properties. Analysis is carried out for static as well as moving loads.

The analysis of the slab on girder bridges for longitudinal flexure shall be carried out using Grillage model on STAAD Pro on the following basis:

- Grillage model has been generated with longitudinal members along the C/L of the l-Girder and along the outer edges. Suitable transverse members along the cross beams have also been provided.
- Moment and shear force will be calculated separately for inner & outer girders by keeping the loading with minimum eccentricity to crash barrier.
- For the design of the longitudinal Girders shear and moments shall be determined at End of solid section, End of tapering section, and mid-section at suitable intervals for other locations.
- Transverse members of the grillage other than the Cross-diaphragm shall be modeled as slab elements.

## 2.32 Method of Analysis for Cross Diaphragm

The analysis of the Cross Diaphragm shall be carried out using Grillage model on STAAD Pro on the following basis:

The end cross Diaphragm shall be designed both as a continuous beam supported on the longitudinal girders and for the jack up condition.

Intermediate diaphragm shall be provided for span greater than 30.0m. It needs to be designed at service stage loads for the results of the grillage analysis.

## 2.33 Section properties

The effective flange width calculation for determination of sectional properties for the longitudinal girders and cross diaphragm shall be done in accordance with IRC: 112.

- The longitudinal members of bridges shall have negligible torsion carrying capacity. Torsion effect is accounted in bridges by assigning very small torsional moment of inertia for the members in the grillage model.

## 2.34 Method of analysis for deck slab

The deck slab shall be designed as a continuous one-way slab supported on the longitudinal girders with cantilever overhang beyond the girders. Live load effects shall be taken based on effective width method recommended in IRC: 112.

## 2.35 Prestressing details for PSC Superstructure

Maximum prestressing force, the losses in prestressing force and Partial factors for prestressing shall be as per clause 7.9 of IRC: 112.

Design parameters

- It is proposed to use 12T13/19T13 cables conforming to Class 2 of IS: 14268 (Low relaxation strands) with HDPE Sheathing for pre-stressing.
- Values of friction and wobble coefficient (μ and k) for pre-stressing strands shall be considered as μ = 0.17 and k = 0.002. (Ref. Table 7.1 of IRC: 112).
- Relaxation losses shall be computed as per clause 6.3.6 of IRC: 112.
- Ultimate resistance of the T-Girder in flexure shall be checked against yielding of steel and against crushing of concrete.
- Duct diameter is based on the number of strands in cable. Clear cover protecting cable from the nearest concrete surface is kept as 75mm as per clause 14.3.2 of IRC: 112.

Proposed Sequence of Pre-stressing

- The girder may be pre cast in the bed or in casting yard or in position.
- 1st stage pre-stressing shall be done after 7 days of casting of girder or after concrete has attained a strength of 70% of fck whichever is later.
- 2nd stage pre-stressing shall be done after 21 days of casting of girder or after concrete has attained full strength whichever is later.
- Launch the precast girders to the position in case the girders cast in bed or casting yard. For launching the girders, lifting arrangement will be done only on either ends at end diaphragm location.
- Erect staging and shuttering for slab by suitable supporting arrangement from web / bottom bulb of girders.
- Cast the top RC Slab together with end/Intermediate cross diaphragm.
- Cast the crash barrier and Kerb.
- Lay wearing coat.

## 2.36 Substructure and Retaining Walls

The pier has been designed for the vertical forces transferring from superstructure and for the biaxial moments developed in both longitudinal and transverse directions due to braking, LL eccentricity, seismic and other horizontal forces.

Conventional plate type abutment / counter fort type structure is proposed depending upon the height of the structure.

The abutment and pier is checked for both cracked and un-cracked condition and designed as per section 8 of IRC: 112.

Pedestals are provided under each of the girder. The pier cap is checked for bending and shears arising from vertical forces acting on bearings and torsion due to unbalanced vertical loads on bearings.

Seismic stoppers are proposed in longitudinal and transverse direction to prevent the dislocation of superstructure. Transverse stoppers of 4 no's on piers and 2 no's on abutments are provided with one on either side of longitudinal girder. Longitudinal stoppers of 2 no's are proposed monolithic along with dirt wall on abutments and 2 no's on piers between the outer end cross diaphragms in longitudinal directions.

The retaining walls shall be provided as per site requirement beyond the return walls of abutments where the height of structure above ground is more.

RE walls / Retaining walls are proposed for the approaches of ROB's and Flyover. Coulomb's theory is applicable for Earth pressure calculations as per IRC: 6 -2010.

## 2.37 Foundation

Type of foundation is based on the properties of sub grade soil strata. Foundation type as per the inventory of existing structures is well and open foundations. However, pile / well / open foundations are proposed.

The details of hydrology and hydraulic design parameters (Discharge, HFL, scour and afflux if any) for the bridges are adopted from the relevant sections of Hydrology and Hydraulics report presented in Chapter -1 of Part – 2 of Volume – II of Design Report.

Also details of geotechnical design parameters (Founding / Pile tip levels & SBC / Pile capacity) for bridges are adopted from the relevant section containing the geotechnical report presented in Chapter - 3 of Part – 2 of Volume – II of Design.

### Pile Foundation

Pile foundation is proposed in case of deep foundation as alternative to well foundation because of ease and faster construction. Bored cast-in-situ piles shall be adopted. Design of pile foundation shall be as per IRC: 112 & IS: 2911 (Part 4). Pile cap is designed as per bending theory. Unsupported length of pile and Length of fixity is calculated as per scour and soil properties.

### Open Foundation

Open foundation is proposed where good stratum will be available at shallow depths. Footing is designed as per bending theory.

## 2.38 Miscellaneous

### Drainage

Drainage Spouts shall be placed not greater than 5m centre to centre. Down-take pipes will be provided to dispose the water below soffit of the superstructure.

### Bearings

Pin / POT bearings are proposed. The design loads for POT– PTFE bearings are calculated as per the guidelines of IRC 83 (Part III).

The horizontal forces due to bearings shall be calculated as per clause 211 of IRC: 6. For Slab culverts tar paper bearing shall be used.

### Expansion Joints

Strip seal type of expansion joint is proposed.

### Cover

The minimum cover to reinforcement shall be determined from the recommendations of IRC: 112 table 14.2 taking into account the moderate environmental conditions.

### Wearing Course

65mm thick wearing course is proposed consisting of 40mm thick bituminous concrete laid over 25mm thick mastic asphalt.

### Durability

Durability of structure depends on the materials used, mix proportions, workmanship achieved, design and detailing including minimum cover to steel. The grade of concrete, steel and cover to reinforcement given in Section 7 of this document is to be adopted.

## 2.39 Materials Used: Concrete:

Minimum grade of Concrete shall be:

- Leveling course : M15
- PCC members : M15
- RCC Deck Slab/Girder : M35
- RCC Solid Slab : M35

- PSC Girder (Precast) + Slab : M45 / M40
- RCC Pier Shaft, Abutment Shaft & footing : M35
- RCC Abutment cap & Pier cap : M35/M40
- RCC Retaining wall & median wall : M30
- RCC Approach Slab : M30
- RCC Box/ Slab Culvert : M30
- RCC Crash Barrier : M40
- Pedestals and Stoppers : M40 / M45
- Pilecap/ Well Cap : M35 / M40/M45
- Pile : M35/ M40 / M45
- Bottom / Intermediate / Top Plug : M15 / M20

## 2.40 Reinforcement (un-tensioned Steel as per Code IS: 1786):

Grade of HYSD bars shall be TMT bars Fe 500 & Modulus of elasticity 2.0 X $10^5$Mpa

Prestressing Steel:

Prestressing steel comprises uncoated stress relieved strands conforming to Cl.2 strands of IS.14268-1995.12T13/19T13 with HDPE Sheathing duct of 75mm / 90mm diameter respectively. Modulus of elasticity = 1.95 x $10^5$ $N/mm^2$.

Structural Steel

The following type of structural steel considered for the design of steel / composite superstructure. Fe 490 conforming to IS: 2062-1992: The basic permissible stresses for design of steel sections are taken from Table 6.2 of IRC: 24-2001.

## 2.41 Standards Adopted for Existing Bridges

Most of the bridges in the project stretches are more than 35 years old (as per local enquiry) except 4 to 5locations which are constructed in the recent years.

All the bridges which are in fair condition and retained as mentioned in Annexure 2.1 of Volume II of Part -2, are proposed with the necessary repair and rehabilitation measures as per IRC: SP: 35. For bridges which are retained and are in distressed condition as per visual condition survey, supplementary tests will be carried out as per IRC: SP: 35 & IRC: SP: 40 and the selection of tests will be as per the nature of distress in structure.

As the As-built drawings of the existing bridges are not available and the design live load is not known, the evaluation of load carrying capacity or rating of the bridge will be carried out by analytical and correlation method as per IRC: SP: 37. When it is not possible to determine the load carrying capacity of the bridges using analytical or correlation method the same will be carried out by load testing after the approval by client as the same is not envisaged in the scope of work.

The residual life of each retainable bridge or structure with and without the proposed strengthening and rehabilitation will be calculated as per acceptable standard practice.

## 2.42 Widening of the existing solid slab superstructure and abutment / pier substructure with open foundation

Based on the above, the bridges which are retained are proposed for widening by monolithic construction matching with the existing cross section of superstructure, abutment and pier along open foundation to the required width.

The widening of the existing solid slab superstructure will be done by chipping the edge 600mm on the widening side, the existing reinforcement will be exposed and new reinforcement will be lapped of the same diameter and same spacing and the same cross section of the existing slab will be extended to the required width.

Similarly the abutment and pier along with open / raft foundation will be widened by providing keying in the existing structure and constructing the widened portion to the required width, so that monolithic structure will be obtained.

The abutment and piers caps need to be widened for additional width to accommodate the transverse seismic stoppers to prevent the dislocation of superstructure.

## 2.43 Box and Pipe Culverts

There are 118 no’s of slab culverts and 192 no’s of pipe culverts exists in main alignment, 4 slab culverts and 19 pipe culverts in alternate alignment.

The existing pipe culverts having diameter less than 900mm or in distressed condition shall be replaced with 1200mm dia. NP4 pipes. The blocked pipe culverts will be proposed for reconstruction.

The diameter of the new pipe culverts shall be minimum 1200mm. The minimum cushion over the existing pipe culvert shall be 600mm and for the new culvert shall be 1000mm.

Box culverts both without and with cushion are proposed depending upon the location, size, Finished Road Level and Invert Level.

As per the drainage requirement, 36 no's of additional box culverts and 176 pipe culverts are proposed in alternate alignment.

The culverts which are structurally in fair condition are retained and proposed for widening to the full width of road approach. The improvement proposals for pipe culverts of main alignment are given in Annexure 2.2,and box culverts of main alignment are given in Annexure 2.3.Improvement proposal of culverts in alternate alignment are given in Annexure 2.4 of Volume II of Part -2.

## 2.44 Bridge Rehabilitation Proposals

- Epoxy grouting for the location of spalling for structures

Spalling of concrete shall be treated with epoxy or equivalent as approved at the locations soffit of the slabs / girders and other locations.

- Replacement of wearing course & Expansion joint for structures

Wearing course expansion joints shall be replaced after the construction of the whole stretch on the structures wherever the same has been damaged during the construction and / or which are in distressed condition.

## 2.45 Repair of Footpaths and Kerb with Railing

Damaged footpaths and kerb with railings shall be repaired / reconstructed for damaged portion of the bridges in project stretch.

## 2.46 Cleaning of bearings and debris

The bearings shall be cleaned for the dust and debris deposited along with clearing of dust, debris and bushes over the abutment and pier caps.

## 2.47 Stone pitching and filter material over quadrants of embankment slopes

The embankment slopes at quadrants at abutment locations are damaged at most of the bridge locations. Hence the quadrant slopes along with required stone pitching along with filter material has to be done. In addition to this, gabion protection works for slope and side protections are required at some locations.

## 2.48 ROB's

There are no level crossings and ROB in the project road.

## 2.49 Vehicular Underpasses (VUP)

Two Vehicular Underpasses are proposed in main alignment as detailed below.

**Table2. 8 LIST OF VEHICULAR UNDERPASSES**

| S. No | Design Chainage | Existing Chainage | Span (m) | Type of Superstructure | Type of Foundation | Deck Width |
|---|---|---|---|---|---|---|
| 1 | 342+535 | - | 20.0mx5.5 | RCC | Pile | 2x12.0 ; 4 Lane |
| 2 | 360+132 | - | 20.0mx5.5m | RCC | Pile | 12.0 ; 2 Lane |

## 2.50 Pedestrian Underpasses (PUP)

There is an existing Pedestrian underpass in Thoubal city beside Thoubal Bridge in main alignment. Details are given in the tabled below.

**Table2. 9 Pedestrian Underpass**

| S. No | Design Chainage | Span | Type of Structure |
|---|---|---|---|
| 1 | 341+914 | 5.0 x 3.0m | RCC Solid Slab |

## 2.51 Detailed Structure Design

The detailed designs are done for the sub structure and for super structure for all the major bridges, minor bridges, underpasses, Viaducts and culverts. The list of appendices has been mentioned in the table below.

**Table2. 10 Appendix List**

| Appendix No | Title of the design document |
|---|---|
| 2.2.1 | Design of PSC I beam slab superstructure (48.5m) for Lilang bridge @CH: 330+380 |
| 2.2.2 | Design of Abutment and Pile foundation for Lilang Bridge @ CH: 330+380 |
| 2.2.3 | Design of Pier and Pile foundation for Lilang Bridge @ CH: CH: 330+380 |
| 2.2.4 | Design of RCC T beam slab superstructure (18.0m) for Ushoipokpi bridge @CH: 334+640 |

| | |
|---|---|
| 2.2.5 | Design of Abutment and Pile foundation for Ushoipokpi Bridge @ CH: 334+640 |
| 2.2.6 | Design of RCC T beam slab superstructure (20.0m) for Waithou bridge @CH: 336+289 |
| 2.2.7 | Design of Abutment and Abutment foundation for Waithou bridge @ CH: 336+289 |
| 2.2.8 | Design of Pier and Pier foundation for Waithou bridge @ CH: 336+289 |
| 2.2.9 | Design of PSC I beam slab superstructure (34.5m) for Thoubal bridge @CH: 341+857 |
| 2.2.10 | Design of Abutment and Pile foundation for Thoubal Bridge @ CH: 341+857 |
| 2.2.11 | Design of Pier and Pile foundation for Thoubal Bridge @ CH: 341+857 |
| 2.2.12 | Design of PSC I beam slab superstructure (33.0m) for Arong bridge @CH: 344+240 |
| 2.2.13 | Design of Abutment and Pile foundation for Arong Bridge @ CH: 344+240 |
| 2.2.15 | Design of Portal frame for Wangjing bridge @ CH: 348+575 |
| **VUP** | |
| 2.2.20 | Design of RCC T beam slab superstructure (20.0m) for VUP's at Km 342+535 & 360+132 |
| 2.2.21 | Design of Abutment and Pile foundation for VUP's at Km 342+535 & 360+132 |
| **Viaduct** | |
| 2.2.22 | Design of PSC I beam slab superstructure (33.0m) for Viaduct @CH: 397+927 |
| 2.2.23 | Design of Abutment and Pile foundation for Viaduct @ CH: 397+927 |
| 2.2.24 | Design of Pier and Pile foundation for Viaduct@ CH: 397+927 |
| **Culverts** | |
| 2.2.25 | Design of Typical Box culverts for 1.5 m span |
| 2.2.26 | Design of Typical Box culverts for spans 2 and 2.5 m |
| 2.2.27 | Design of Typical Box culverts for spans 3 and 3.5 m |
| 2.2.28 | Design of Typical Box culverts for spans 4 and 4.5 m |

| | |
|---|---|
| 2.2.29 | Design of Typical Box culverts for spans 5.0m,5.5m and 6.0m |
| **Retaining wall** | |
| 2.2.30 | Design of Retaining wall |
| **Bridges in Alternative Alignment** | |
| 2.2.31 | Design of Abutment and Pile Foundation for Minor Bridge at 6+020<br>Span Arrangement : (2 x 20m) |
| 2.2.32 | Design of Pier and Pile Foundation for Minor Bridge at 6+020 |
| 2.2.33 | Design of RCC Superstructure for Minor Bridge at 6+020 |
| 2.2.34 | Design of POT bearing for Minor Bridge at 6+020 |
| 2.2.35 | Design of Abutment and Pile Foundation for Minor Bridge at 7+390<br>Span Arrangement : (1 x 24m) |
| 2.2.36 | Design of RCC Superstructure for Minor Bridge at 7+390 |
| 2.2.37 | Design of POT bearing for Minor Bridge at 7+390 |
| 2.2.38 | Design of Abutment and Open Foundation for Minor Bridge at 11+900<br>Span Arrangement : (2 x 18m) |
| 2.2.39 | Design of Pier and Open Foundation for Minor Bridge at 11+900 |
| 2.2.40 | Design of RCC Superstructure for Minor Bridge at 11+900 |
| 2.2.41 | Design of POT bearing for Minor Bridge at 11+900 |
| 2.2.42 | Design of Abutment and Open Foundation for Minor Bridge at 15+866<br>Span Arrangement : (1 x 12m) |
| 2.2.43 | Design of RCC Superstructure for Minor Bridge at 15+866 |
| 2.2.44 | Design of POT bearing for Minor Bridge at 15+866 |
| 2.2.45 | Design of Abutment and Open Foundation for Minor Bridge at 16+600<br>Span Arrangement : (1 x 21m) |
| 2.2.47 | Design of RCC Superstructure for Minor Bridge at 16+600 |
| 2.2.48 | Design of POT bearing for Minor Bridge at 16+600 |

# PART II- CHAPTER 3.0 GEOTECHNICAL INVESTIGATIONS

The Consultant devised a comprehensive Geotechnical and Subsoil exploration program, based on structural condition surveys of the existing bridges / structures where the existing structures require modification or reconstruction from the detailed design consideration. The investigation program also caters to encompass for the proposed new structures bridges / Road over bridges / Viaducts / Interchanges / Underpasses etc. along with the high embankments and any other location for proper design of the works. Deep borehole plans (BH Plans) for all such structure locations in accordance to IRC 78: 2000 and as per Clause 4.9.3.4 of the TOR have been prepared and submitted to PIU.

Detailed methodology of undertaking the Geotechnical and Subsoil Investigation being adopted is presented in following sub-sections.

## 3.1 Methodology and Specification for the Geotechnical and Subsoil Investigation

The sub soil investigations were be carried out to disseminate and characterize sub soil stratifications and engineering properties of different soil and rock strata encountered along the project site at the designate and proposed Bridges / Road Over Bridges / Viaducts / Interchanges etc. along the high embankment and any other location necessary for proper design of the works and conduct all relevant laboratory tests on soil and rock samples collected. Evaluation and knowledge of sub soil stratification and engineering properties of the soil / rock encountered during the exploration works is of major significance in order to design safe and economical foundations of the structures and embankments. Safe bearing capacity and pile / well foundation load carrying capacity of subsoil strata primarily depends on the type of sub-soil / rock sub-strata and their engineering characteristics and subsoil stratification in general.

Guidelines on the number of bore holes for Major and minor bridges are presented below based on the following criteria from IRC 78: 2000.

**Table 3. 1**

| SI. No | Length of Structure (m) | Type of Bridge / Pavement Conditions | No. of Boreholes |
|---|---|---|---|
| 1 | 0 – 30 | Minor Bridge | 1 |
| 2 | 30 – 60 | Minor Bridge | 2 |
| 3 | >60 | Major Bridge | One borehole at each and every support |
| 4 | Embankment / Retaining Structure of height more than 6m | Approaches to the Structures | 1 on Each side |

Apart from the above, additional boreholes / Test Pitsare required to be undertaken at locations of bridges / structures if significant variation in subsurface variability is such that explorations at the suggested spacing are found insufficient to adequately define the subsoil characteristics, else otherwise noted from those compared to the preliminary bore logs, available if any in consultation with the PWRD officials.

Additional BHs / Trial Pits, if required, to be undertaken at locations of major change in pavement conditions (deflection readings) observed or at 2 Km intervals whichever is less up to depths at least 2m below the base of the embankment or to rock level and shall be fully logged.

The termination criteria for the boreholes shall be as per IRC 78:2000 and MoRTH Specifications as follows.

In case of Soil:

| | |
|---|---|
| Open Foundation - foundation below the | minimum 1.5 times expected width of the proposed foundation level. |
| Pile Foundation - less than 15m | 1.5 times the estimated length of the pile but not beyond the probable length of the pile. |

While drilling through soil strata, the termination criteria of the boreholes at open foundation locations shall be, when a hard competent stratum is encountered and ensured within the zone of influence. The confirmation of the hard strata will be ascertained when Five consecutive SPT values (1.5m intervals) are found more than 50.

If a rock stratum is encountered within the zone of influence the depth of drilling / coring into the rock strata shall be limited to 3 to 6m length depending upon quality of the rock strata (percent core recovery and RQD values)

Subsoil investigation for the pile foundation locations shall be carried out up to and in to the rock stratum. Drilling / coring in to the rock stratum when encountered shall be governed by the quality of the rock cores (RQD and core recovery values). The length of coring into rock strata shall be up to 3 – 6m.

## 3.2 Program for Subsoil Investigation

The number of boreholes required for exploration on each of the proposed structures of the projects is presented in Appendix 3.1 to 3.3. All such locations proposed for investigations, RL and coordinates (related with the project datum and survey reference points) of the existing ground levels shall be recorded and the same shall be used while preparing the Geotechnical report and profile for the subsoil stratification.

## 3.3 Field and Laboratory Investigations

The subsurface investigation of soil or rock strata in the field involves three basic operations:

- Drilling
- Sampling (Disturbed / Undisturbed samples at the intervals of 1.5m or change of strata depending upon nature of strata encountered during the investigations )
- Conducting field tests (Standard Penetration Test 'SPT'), collecting disturbed and undisturbed samples followed by laboratory tests on soil/rock samples retrieved from the field.
- Monitoring and recording of water table in the boreholes and collecting samples for laboratory tests.

**Drilling Bore Holes:** In soils, boreholes of diameter 100mm to 150mm would be drilled with the help of auger. Initially the auger is pressed into the soil and twisted. As the borehole proceeds, extension rods are connected to the auger in order to increase the reach of the auger inside the borehole, up to the required depth. Any loose soil found will be carefully removed from the bottom of the borehole prior to undertaking standard penetration tests in order to ensure the tests are performed on undisturbed strata and representative disturbed sample is collected.

Water tables encountered were monitored and recorded from each borehole and samples collected for subsequent chemical analysis in the laboratory.

**Sampling:** The soil being flushed out during drilling from the boreholes would be continuously examined for any changes in the soil stratification at regular intervals and at levels where the change in soil type samples would be collected for further testing in the laboratory. Disturbed soil samples will also be collected during drilling operation where ever cohesive strata are encountered through thin walled samplers. Undisturbed soil samples were collected at required depth in thin wall samples tubes according to IS 2132-1986.

The sampling tube is pushed into soil by continuous and rapid motion. When full, the tube is turned at least for two revolutions to shear the sample off at the bottom. Sampling tubes are waxed and sealed at both ends and carefully labelled and transported to laboratory for testing.

**Standard Penetration Test & Collection of Soil Samples:** The standard penetration tests shall be conducted in boreholes (in soil) in accordance to the procedures laid down in IS 2131. The tests shall be carried out using the standard split spoon sampler to measure the number of blows 'N' and collecting representative samples at regular intervals.

Standard split spoon sampler is attached to 'A' rod. The rot at the top is driven into the soil up to a distance of 45 cm using a standard hammer of 63.5 kg falling freely from a height of 75 cm to the required depth. While driving, the number of blows required to penetrate every 15 cm are recorded. The total number of blows required for the last 30 cm is taken as 'N' value at that particular depth of the borehole. SPT "N" values are used to correlate different characteristics of the soil in order to analyse foundation and slope stability problems. Disturbed and Undisturbed soil samples collected from different depth in the Split-spoon sampler shall be properly stored and Tagged as per IS procedures for further laboratory tests.

**Drilling and Investigation at Water Logged / River Water Conditions:** Geotechnical Investigation through deep boreholes under water logged / river structure locations may require erection of suitable platforms / floating barges to carry out the drilling operations and collection of subsoil / rock samples. Suitable arrangements on case specific situations shall be worked out at the site during the investigation works, if an option of taking of suitable offset for the required borehole is not a viable option to consider working on the dry area. These shall be worked out considering the variability of the subsoil profile from the completed boreholes and the variability of subsoil stratification as noted from available data for the specific location of the structures.

**Laboratory Tests for Soil Samples:** Disturbed and undisturbed soil samples collected would be tested in the laboratory for determination of the following characteristics and properties. The entire laboratory tests would be conducted in accordance with the procedures laid-down in IS: 2720.

- Sieve Analysis (IS 2720 Part 4)
- Hydrometer Analysis (IS 2720 Part 4)
- Atterberg's Limit (IS 2720 Part 5)
- Specific Gravity test (IS 2720 Part 3)
- Shear strength (IS 2720 Part 11)
- Dry/Bulk Density
- Natural Moisture Content (IS 2720 Part 2)
- Free Swell Index (IS 2720 Part 40)
- Chemical Tests (Chloride and sulphate content, pH value)

## 3.4 Investigation Of Rocky Strata

Drilling through rocky strata shall be conducted using rotary drilling method, with diamond bits and Tungsten carbide bits. For better core recovery in hard rock like basalt and granites, use of diamond bits is recommended. NX sizes of bit are used in coring and NX size cores of Diameter of 53.975mm. The drilling operation is carried out by attaching bits to core barrels through reamer shells. Core barred tubes were deployed for better results on quality of core recovery.

Ample quantity of water is used as the drilling fluid; care is required while drilling observing water into the hole, be minimum, consistent with adequate removal of cutting from the hole and proper cooling of the bit.

Generally the core barrel is lifted after drilling through 1.50 m. There are two devices commonly used to retain the core as the core barrel is lifted. These are split ring core lifter and basket retainer. On removing the core from the barrel, all pieces of core are put in a partitioned wooden box specially built for the purpose. The ratio of total length of rock pieces collected to length drilled, expressed as percentage and known as core recovery is recorded. To obtain RQD, Rock Quality Designation, only those pieces of rock which were 10mm and longer were measured for their total length. The above length divided by length drilled, expressed as percentage, is recorded as RQD. Values of RQD were found to be less than the values for core recovery.

(a) Core recovery in % = Length of Core/ Length of run x100

(b) RQD in %= Length of core in pieces of 10 cm and above/ Length of run x100

If the core recovered is noticed broken by handling or during drilling (i.e. the fracture surface being fresh irregular breaks rather than natural joint surfaces), the fresh broken pieces were fitted together and counted as one pieces. Judgment is applied in the field in case of thinly bedded sedimentary rocks and foliated metamorphic rocks. The cores were logged almost immediately upon removing them from the core barrel before air slacking and cracking could begin. The core recovery is an indication of Soundness and degree of weathering of rock.

Laboratory Tests for Rocks: Rock samples recovered from various depths of strata are tested for the following properties.

(1) Water absorption (IS: 13030)

(2) Specific gravity (IS: 2720 (Part -3))

(3) Unconfined Compressive strength (IS 9143)

(4) Core Recovery (IS 11315 Part 11)

(5) RQD (IS 11315 Part 11)

## 3.5 Geotechnical Investigations and Sub-soil Exploration Report

A comprehensive Geotechnical and Subsoil-exploration report shall be prepared which included factual Field and Laboratory test results and relevant recommendations of the foundation of the structures and high embankment designs. Geotechnical report shall contain the followings:

- Plot of soil profile with depth including water table,
- Plot of soil strength (SPT),
- Table of soil index and classifications results thereof
- Recommendations on allowable bearing pressure
- Recommendations on expected settlement

From the laboratory and Field test data collected and analysed, all the design parameters for the recommended foundations (open, pile or well) shall be presented and accordingly the foundation bearing capacities shall be estimated for the structural designs (both under the normal and seismic conditions). Recommendations on High embankment (> 6m) slope stability analysis shall be made according to IRC requirements.

## 3.6 Sub-soil Stratification

As evident from the detailed Borehole Logs included in the reports (please refer to appendix 3.1 to 3.3 for AH 01, the subsoil strata at the structure locations comprises primarily Boulder Sand strata from the existing ground level / bed levels explored at all the locations.

Field Tests (Standard Penetration Tests 'N') collection of the soil samples at regular intervals have been undertaken at regular intervals during the investigations for each borehole locations as per standards. The standard penetration tests shall be conducted in boreholes (in soil) in accordance to the procedures laid down in IS 2131. The tests shall be carried out using the standard split spoon sampler to measure the number of blows 'N' and collecting representative samples at regular intervals. Standard split spoon sampler is attached to a 'A' rod. The rot at the top is driven into the soil up to a distance of 45 cm using a standard hammer of 63.5 kg falling freely from a height of 75 cm to the required depth. While driving, the number of blows required to penetrate every 15 cm are recorded. The total number of blows required for the last 30 cm is taken as 'N' value at that particular depth of the borehole. SPT "N" values are used to correlate different characteristics of the soil in order to analyse foundation and slope stability problems.

Laboratory Test results on soil / water samples are currently presented in appendix 3.1 to 3.3 for AH 01.

## 3.7 Foundation Recommendations:

Based on subsoil stratification encountered and their engineering properties ascertained from the results of field and laboratory tests undertaken on the strata / samples collected during the Geotechnical Investigations, assessment of the relevant engineering characteristics have been carried out and accordingly recommendations are made for the foundations for the design of structures.

For the structures which are land based, open foundations have been envisaged, except ROB structures and for the water / river based structures pile foundations of 1200mm diameter Bored-cast-in-situ RC piles are recommended by taking into accounts the structural loads and hydraulic parameters established through the investigations.

FOUNDING RECOMMENDATIONS FOR AH – 01 SECTION:

**Table 3. 2 Open Foundation Recommendations:**

| Si.No | Chainage | Proposed Span Arrangement | Location | Borehole Level (m) | Actual Scour level (m) | Founding Level (m) | Founding depth (m) | SBC (T/sqm) | Type of Foundation |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 336+100 | 2 X 20.0 | A1 | 773.480 | 767.000 | 765.000 | 8.480 | 30 | Open |
| | (Waithou) | | P | 770.480 | 765.980 | 764.480 | 6.000 | 80 | |
| 2 | 347+600 | 2 X 7.0 | A1 | 773.315 | | 766.815 | 6.5 | 28 | Open |
| | (Khabakong) | | P | 771.815 | | 766.815 | 5.0 | 28 | |
| 3 | 348+150 | 8.8+8.0+8.8 | A1 | 774.000 | 769.547 | 767.000 | 7.0 | 30 | Open |
| | (Wangjing) | | P | 772.000 | 765.981 | 767.000 | 5.0 | 30 | |
| 4 | 349+900 | 2 X 5.8 | A1 | 770.275 | - | 768.425 | 1.85 | 10 | Raft |
| 5 | 352+800 | 2 X 5.8 | A1 | 773.596 | 768.291 | 771.946 | 1.65 | 10 | Raft |

**Table 3. 3 Pile Foundation Recommendations**

| S.No | Chainage | Span | Location | BH Level (m) | Actual Scour level (m) | Type of Foundation | Pile Cap Top Level (m) | Pile Cap Bottom Level (m) | Pile Length (m) | Pile Tip Level (m) | Vertical Capacity (t) | Lateral Capacity (t) | Uplift Capacity (t) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Minor bridges** | | | | | | | | | | | | | |
| 1 | 334+330 Ushoipokpi | 1 x 18 | A1 | 773.720 | 767.235 | Pile | 773.220 | 771.420 | 17.2 | 754.220 | 300 | 20 | 10 |
| 2 | 344+150 (Arong) | 1 x 33 | A1 | 772.990 | Canal | Pile | 772.490 | 770.690 | 32.0 | 738.690 | 230 | 20 | 75 |
| **Major bridges** | | | | | | | | | | | | | |
| 1 | 330+150 (Lilong) | 2 x 48.5 | A1 | 779.270 | 768.983 | Pile | 778.770 | 776.270 | 32.0 | 744.270 | 200 | 18 | 65 |
| | | | P | 768.870 | 763.070 | | 770.870 | 768.370 | 42.0 | 726.370 | 360 | 20 | 140 |
| | | | A2 | 780.070 | 768.983 | | 778.770 | 776.270 | 32.0 | 744.270 | 200 | 18 | 65 |
| 2 | 341+780 (Thoubal) | 2 x 34.5 | A1 | 776.267 | 769.732 | Pile | 778.510 | 776.710 | 32.0 | 744.710 | 230 | 20 | 75 |
| | | | P | 771.267 | 763.250 | | 770.657 | 768.157 | 42.0 | 726.157 | 375 | 18 | 150 |
| 3 | 365+550 (Pallel) | 3 x 24 | A1 | 783.179 | 777.200 | Pile | 782.679 | 780.179 | 32.0 | 748.179 | 250 | 25 | 90 |
| | | | P | 781.179 | 772.062 | | 780.679 | 778.679 | 35.0 | 743.679 | 250 | 15 | 95 |

The detailed assessment and calculations for such recommendations for the foundation designs have been included in appendix 3.1 to 3.3 for AH 01.

For alternative alignment bridges, the geotechnical investigations are not carried out and the type of foundation & founding levels & SBC are taken based on the study of the similar bridges on existing alignment. The founding levels are considered as 5.5m below OGL for open foundation with SBC of 35 t/m^2 and 20m length of pile is considered for pile foundation.