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राष्ट्रीय राजमार्ग एवं अवसंरचना विकास निगम लिमिटेड

NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION LTD.

FINAL DETAILED PROJECT REPORT

APRIL 2020

CONSULTANCY SERVICES FOR PREPERATION OF DETAILED PROJECT REPORT AND PROVIDING PRE-CONSTRUCTION ACTIVITIES IN RESPECT OF THE FOLLOWING STRETCH ON NH-244 (OLD NH-1B) IN THE STATE OF JAMMU AND KASHMIR.

(1) SUDHMAHADEV- DRANGA TUNNEL OF APPROX. LENGTH 4.5 KM AND ITS APPROACH ROAD ON CHENANI - SUDHMAHADEV-GOHA ROAD PORTION.

(2) VAILOO TUNNEL OF APPROX. LENGTH 10.0 KM UNDER SINTHAN PASS AND ITS APPROACH ROAD ON GOHA-KHELLANI- KHANABAL ROAD PORTION.

(3) ROAD PORTION FROM 82.675 TO 82.925 AT KM 83 ON BATOTE-KISHTWAR ROAD SECTION OF NH-244.

(4) EXTENDED ROAD SECTION FROM GOHA TO KHELLANI OF 30 KM LENGTH

GOHA - KHELLANI ROAD
PACKAGE-IA (KM 12.850 to KM 20.300)
VOLUME - II - DESIGN REPORT (ROADS)

IN ASSOCIATION WITH

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Introduction

CHAPTER - 1

INTRODUCTION

1.1 The Project Road

The Ministry of Road Transport and Highways (MORT&H) is poised to develop all remote and strategically important roads in hilly terrains to perennial routes. In continuation to these developments National Highways and Infrastructure Development Corporation Limited (NHIDCL) has been appointed by MORT&H, to implement these projects.

NHIDCL has been assigned the work of Consultancy Services for Preparation of Detailed Project Report and providing Pre-Construction activities for the construction of a Road Tunnel and its approaches enabling all weather connectivity along the stretches on NH-244 in the State of Jammu and Kashmir. NHIDCL has entrusted TPF Getinsa Eurostudios SL in association with Rodic Consultants Private Limited, to carry out Consultancy Services for preparing **Detailed Project Report for Dranga – Khellani section from Sudhmahadev – Dranga Tunnel approach road to Khellani town including a tunnel (unidirectional twin tubes) named as Khellani tunnel to bypass the Khellani town** in the State of Jammu & Kashmir.

The Index Map showing the stretches of National Highways, described above as a part of project road, is presented in **Fig. 1.1** (enclosed).

Salient Features of Project Road

NHIDCL has been assigned the work of Consultancy Services for Preparation of Detailed Project Report and providing Pre-Construction activities for the Construction of a Road Tunnel and its approaches enabling all weather Connectivity along the stretches on NH-244 (Old NH1B) in the State of Jammu and Kashmir.

(i) Sudhmahadev – Dranga Tunnel of approx. length 4.5 Km and its approach roads on Chenani – Sudhmahadev – Goha road portion.

(ii) Vailoo Tunnel of approx. length 10.00 Km under Sinthan Pass and its approach roads on Goha – Khanabal road portion

NHIDCL has entrusted the M/s Getinsa-Eurostudios in association with Rodic Consultants Private Limited to carry out Consultancy Services for preparing Detailed Project Report for Dranga – Khellani section from Sudhmahadev – Dranga Tunnel approach road to Khellani town including a tunnel (unidirectional twin tubes) named as Khellani tunnel to bypass the Khellani town. This proposed section of Goha - Khellani falls on the newly proposed alternate route for the Jammu – Srinagar highway. It will divert the main traffic from NH-244 (old NH-1B) from Chenani town and traverses through newly proposed Sudhmahadev – Dranga Tunnel approch road and then through this project road section of Goha – Khellani tunnel road and finally terminates again at NH-244 (old NH-1B). This entire proposed road is very shorter in length and access through many untouched villages and towns in its stretch. This road also traverses through a tunnel, so, it would very convenient to travel through it.

Also, it has proposal of a link road through the main stretch. It is proposed to connect Goha town from junction of the Sudhmahadev - Daranga Tunnel approach road. This link road will allow the people of Goha and beyond to access the proposed road from Sudhmahadev to Khellani. The total length of this link road is 2.016 km.

This Project Corridor is divided in two packages:

Package	Chainage		Length (Km)	Remarks
	From	To		
I A	12+850	20+300	7.450	Road, Bridges/Vaiduct and Link road to Goha
	0+000	2+016	2.016	
I B	20+300	29+030	8.730	Road, Bridges & Tunnel
II	29+030	31+449	2.419	Road, Bridges & Tunnel

This report deals with Package I A and I B.

Proposed improvement under the project

The project road is to be reconstructed to 2 Lane carriageways with paved shoulder configurations. The geometric designs would be as per recommendations of IRC: SP:73-2018 & IRC: 48 Hill road Manual.

1.3 Reporting Requirement and Structure of the Report

1.3.1 Reporting Requirements

Project preparation activities are planned for a three-stage completion as mentioned below.

Stage 1 - ***Inception Report***

Stage 2 - ***Feasibility Study Report***

Stage 3- ***Detailed Project Report (DPR)***

Stage II is completed till date. This is stage **III.**

1.3.2 Structure of the Report

This report constitutes Volume – II of the DDPR and Comprises of the Design Report.

Part – 1 : *Roads & Highways*

Part – 2 : *Tunnel, Bridges and CD Structures*

Part –1 comprises the following chapters:

Chapter – 1 : Introduction

This chapter provides the location and salient features of the project road and structure of the report.

Chapter – 2 : Design Criteria and Standards

Deals with the design standards propose for the project road and provides the typical cross-sections adopted under different situations.

Chapter – 3 : Geometric Design

Deals with the geometric design of the road proper resulting from the application of the design standards.

Chapter – 4 : Drainage Design

Deals with drainage of the road and road side.

Chapter – 5 : Toll Plaza and Toll Collecting System

Deals with Toll Traffic, Toll Lanes and Toll Revenues collection assessments.

Chapter – 6 : Design of Traffic Control and Other Facilities

Deals with Traffic Signs and Road Markings and other Appurtenant.

Chapter – 7 : Pavement Design

Deals with the design of new pavement for widened carriageway, reconstructed carriageways, strengthening, overlays for existing pavement, pavement for service road, etc.

Design Standards

CHAPTER – 2

DESIGN STANDARDS

2.0 General

The proposed section of Goha - Khellani falls on the newly proposed alternate route for the Jammu – Srinagar highway. It will divert the main traffic from NH-244 (old NH-1B) from Chenani town and traverses through newly proposed Sudhmahadev – Daranga Tunnel approach road and then through this project road section of Goha – Khellani tunnel road and finally terminates again at NH-244 (old NH-1B). This entire proposed road is very shorter in length and access through many untouched villages and towns in its stretch. This road also traverses through a tunnel, So, it would very convenient to travel through it.

The cross-section elements have been adjusted to far extent to accommodate within the minimize width of PROW and topographic barriers.

Also, it has proposal of a link road through the main stretch. It is proposed to connect Goha town from junction of the Sudhmahadev - Daranga Tunnel approach road. This link road will allow the people of Goha and beyond to access the proposed road from Sudhmahadev to Khellani. The total length of this link road is 2.016 km.

The improvement point of view two types of standards has been adopted, namely:

- The desirable standards, which could be adopted as a rule.
- The minimum standards in fact a compromise between safety and the operational freedom, which could be accepted for difficult stretches where application of the desirable standards, would lead to high costs.

Accordingly, design standards for geometric elements have been proposed under “desirable” and “minimum” categories. These proposed standards are consistent with the fall within the parameters recommended in the related standards of the Indian Roads Congress (IRC). Considering the practicability of work the adopted values has been listed in the **Table 2.1**.

Table 2.1 Adopted Design Values

(i)	**Design Speed (Km/hr.)**		
	Mountainous Terrain	:	60 (Ruling), 40(Minimum)
(ii)	**Level of Service**	:	B
(iii)	**Roadway Widths (m)**		
	Mountainous Terrain	:	11 m for 2-lanes with paved shoulders/ Earthen Shoulder
(iv)	**Roadway Elements**		
	Mountainous Terrain		
	With Retaining wall and parapet	:	Carriageway 2-lane- 2x3.5 m
			Paved Shoulder 2x1.5 m
			Earthen Shoulder 1.0 m (Valley Side)
(v)	**Camber**		**Carriageway**
			Flexible- 2.50%
			Rigid - 2.00 %
			Paved Shoulder
			Flexible- 2.50%
			Rigid - 2.00 %
			Unpaved Shoulder
			Flexible- 3.50%
			Rigid - 3.00 %
(vi)	**Right of Way**		As per Plan and Profile
(vii)	**Embankment/ Cutting Slope**		
	Fill height, up to 3.0 m		In filling- 1V: 2 H
	Fill height from 3.0 m to 6.0 m		In filling- 1V: 1.5 H
	Fill height exceeding 6.0 m		To be designed based on soil parameters, (IRC:75-1979) In cutting- 1V:1H
(viii)	**Stopping Sight Distance**		20 m for design speed of 20 km/hr.
			25 m for design speed of 25 km/hr.
			30 m for design speed of 30 km/hr.
			40 m for design speed of 35 Km /hr.
			45m for design speed of 40km/hr.
			60 m for design speed of 50km/hr.
	Intermediate sight distance		40 m for design speed of 20 km/hr.
			50 m for design speed of 25 km/hr.
			60 m for design speed of 30 km/hr.
			80 m for design speed of 35 Km /hr.
			90 m for design speed of 40km/hr.
			120 m for design speed of 50km/hr.
(ix)	**Super-elevation**		

	Mountainous Terrain (As per IRC: SP:48-1998) Clause No-6.8.2.2		With snow bound area Maximum 7% Without snow bound area Maximum 10% **Adopted maximum 7%**
(x)	**Radii for Horizontal Curves**		
	Mountainous Terrain		Ruling Minimum 150 m
			Absolute minimum 75 m
(xi)	**Gradient (As per IRC: SP:73-2018) Clause 2.9.7.2**		
	Mountainous Terrain		
	Ruling		5.00%
	Limiting		6.00%
	Steep Terrain		
	Ruling		6.00%
	Limiting		7.00%
(xii)	**Minimum k factor**		
	Summit Curve		
	Mountainous Terrain		Desirable: 8
			Minimum: 5
	Valley Curve		
	Mountainous Terrain		Desirable: 10
			Minimum: 7
(xiii)	**Bridge Clearance**		
	Vehicular underpass		5.5 m
	Cattle and Pedestrian		3.0m
(xiv)	**Design Flood Frequency**		
	Bridges		More than 50 years
	Sewers and Ditches		60 years

2.2 Terrain Classification

The following terrain classification recommended by IRC-38:1988 is proposed to be adopted:

Terrain Classification	Percentage cross slope of the country
Plain	0 – 10
Rolling	10 – 25
Mountainous	25 – 60
Steep	> 60

2.3 Deign Speed

Design speed is the basic parameter, which determines geometric features of the road. The proposed design speeds for different terrain categories are as follows:

Terrain Classification	Design Speed (km/h)	
	Desirable	Minimum
Plain & Rolling	100	80
Mountainous & Steep	60	40

For road stretches passing through built-up areas, the speeds corresponding to rolling terrain are proposed.

2.4 Cross-Sectional Elements

2.4.1 Lane Width

As per IRC: SP:73-2018, the standard lane width of the project highway shall be 3.5 m.

2.4.2 Paved Shoulders

Full strength pavement for paved shoulders is proposed. Width of these shoulders will be 1.5 m. This will provide better traffic operation conditions, lower maintenance cost and will be useful at the times of routine/periodic maintenance.

2.4.3 Earthen Shoulders

It is proposed to have 1.0 m wide earthen shoulders which will provide sufficient space for installing road appurtenant such as traffic signs, crash barriers (where required) etc., and in combination with the paved shoulders for parking of stalled vehicles.

2.4.4 Median

Shall be as per IRC: SP:73-2018 if applicable.

2.4.5 Side Slopes

The slope of embankment is linked with its height. In accordance with the Manual for Safety in Road Design (MoRT&H publication), 2H: 1 V has been proposed for the entire stretch.

2.4.6 Typical Cross-section

For application to different situations, a number of typical cross-sections have been prepared and these are listed in the **Table 2.2**. Figures of different typical cross sections showing following different types of road features have been presented in **Volume-IX: Drawings.**

Table 2.2 Type of Cross Section

Summary of TCS for Package I A (Main Road)				
Sr. No.	**Detail**	**TCS**	**Length**	
			(m)	**Kms**
1	Two lane carriageway with paved shoulder in mountainous terrain with both side fill with left retaining/toe wall	**TCS-1**	321	0.321
2	Two lane carriageway with paved shoulder in mountainous terrain with both side fill with left side gabion wall	**TCS-2**	96	0.096
3	Two lane carriageway with paved shoulder in mountainous terrain with left side fill with retaining/toe .wall & right side revetment wall/breast wall. (height of cut < 15m)	**TCS-3**	3523	3.523
4	Two lane carriageway with paved shoulder in mountainous terrain with left side fill & right side revetment wall/breast wall. (height of cut < 15m)	**TCS-4**	190	0.190
5	Two lane carriageway with paved shoulder in mountainous terrain with both side revetment wall/breast wall (height of cut < 15m)	**TCS-5**	2780	2.780
6	Two lane carriageway with paved shoulder in mountainous terrain with both side cut (height of cut on right side > 25m)	**TCS-6**	240	0.240
7	Two lane carriageway with paved shoulder in mountainous terrain with left side fill with retaining/toe wall (height of cut on right side > 25m)	**TCS-7**	40	0.040
8	MAJOR BRIDGE		150	0.150
9	MINOR BRIDGE		110	0.110
TOTAL DESIGN LENGTH			**7450**	**7.450**

Summary of TCS for Package I A (Link Road)				
Sr. No.	**Detail**	**TCS**	**Length**	
			(m)	**Kms**
1	Two lane carriageway in mountainous terrain with both side fill with right side gabion wall	**TCS-8**	450	0.450
2	Two lane carriageway in mountainous terrain with left side fil l with retaining/toe wall & right side revetment wall/breast wall (height of cut <10 m)	**TCS-9**	580	0.580
3	Two lane carriageway in mountainous terrain with left side fill with retaining/toe wall right side cut (height of cut <25 m)	**TCS-10**	760	0.760
4	Two lane carriageway in mountainous terrain in left side fill & right side revetment wall/breast wall (height of cut<10 m)	**TCS-11**	60	0.060

Summary of TCS for Package I A (Link Road)				
Sr. No.	**Detail**	**TCS**	**Length**	
			(m)	**Kms**
5	Two lane carriageway in mountainous terrain in left side revetment wall/breast wall (height of cut< 10 m.)	**TCS-12**	166	0.166
TOTAL DESIGN LENGTH			***2016***	***2.016***

Summary of TCS for Package I B				
Sr. No.	**Detail**	**TCS**	**Length**	
			(m)	**Kms**
1	Two lane carriageway with paved shoulder in mountainous terrain one side cut & one side fill with protection as applicable (new construction)	**TCS-1A**	2700	2.700
2	Two lane carriageway with paved shoulder in mountainous terrain with one side cut & one side fill with protection as applicable (reconstruction)	**TCS-1B**	260	0.260
3	Two lane carriageway with paved shoulder in mountainous terrain with both side fill & with protection on either side as applicable (new construction)	**TCS-2**	870	0.870
4	Two lane carriageway with paved shoulder in mountainous terrain with both side cut (new construction)	**TCS-3A**	3820	3.820
5	Two lane VUP approach with 5.5m SR on both side with right side cut & left side fill with protection as applicable	**TCS-4**	120	0.120
6	Two lane carriageway with paved shoulder in mountainous terrain with both side cut & with rock bolting on right side (new construction)	**TCS-5A**	730	0.730
7	Two lane carriageway with paved shoulder in mountainous terrain with right side cut with rock bolting & left side fill with protection as applicable (new construction)	**TCS-6**	80	0.080
8	Minor Bridge		90	0.090
9	Viaduct		40	0.040
10	VUP		20	0.020
TOTAL DESIGN LENGTH			**8730**	**8.730**

2.5 Sight Distance

Safe stopping sight distance, both in the vertical and horizontal directions will apply in design. The sight distance values as per IRC recommendations are as follows:

Design Speed	IRC SP 23:1993	
Km/h	Stopping Sight Distance (m)	Intermediate Sight Distance (m)
20	20	40
25	25	50
30	30	60
35	40	80
40	45	90
50	60	120
60	90	180
80	120	240
100	180	360

2.6 Horizontal Alignment

This proposed section of Goha - Khellani falls on the newly proposed alternate route for the Jammu – Srinagar highway. It will divert the main traffic from NH-244 (old NH-1B) from Chenani town and traverses through newly proposed Sudhmahadev – Daranga Tunnel approach road and then through this project road section of Goha – Khellani tunnel road and finally terminates again at NH-244 (old NH-1B).

The horizontal alignment of a road usually compromises a series of straights (tangents) and circular curves which has been connected by transition curves. The following section outlines design criteria which have been considered when developing the horizontal alignment.

Further it has been ensured that the alignment would enable consistent, safe and smooth movement of vehicles operating at the design speed.

Super elevation and side Friction details

Super elevation is the cross fall this is provided on the pavement on a horizontal curve in order to assist a vehicle to maintain a circular path, and partially compensate the centrifugal force.

For normal values of super elevation, side friction and radius, the following formula is adopted

$$e + f = \frac{V^2}{127R}$$

e = pavement superelevation (m/m)

f = coefficient of side friction force developed between the vehicle tyres and the road pavement. This is taken as positive if the frictional force on the vehicle acts towards the centre of the curve.

R = curve radius (m)

Maximum side friction of 0.15 is adopted for the project road as per IRC: 73

Considering the high-speed characteristics of the project road, the maximum super elevation is limited to 7%.

Super elevation has been developed by rotating the carriageway about edge.

Minimum rate of change for attainment of super elevation is adopted as **1 in 150** in maximum condition.

Positioning of super elevation development in transitions is kept so that 0 % cross fall corresponds to the start of the transition and full super elevation for the curve (e %) is attained at the end of the transition. In circular curves, 2/3 of the super elevation is achieved on the tangent i.e. at the start of the curve 2/3 e% is achieved. In case of compound curves (curves in same direction) where proper super elevation runoff length is not available, full super elevation on sharper curve is retained on the common tangent.

Transition curves

Transition curves have some advantages which can be summed up into the following:

- To introduce gradually the centrifugal force between the tangent point and the beginning of the circular curve, to provide smooth entry to curve.
- To enable gradual introduction of the designed super elevation and extra widening of pavement at the start of the circular curve.
- To improve the aesthetic appearance of the road.

Almost all curves in the project road are provided with transition except at larger radius where transition is not required as per requirement of IRC Code.

Set Back Distance

It is the clear distance between the centreline of a horizontal curve to an obstruction on the inner side of the curve. This is considered in design so that adequate sight distance is available while negotiating the curve.

Recommended Elements of Horizontal Alignment:

Study of the limiting values for various elements of horizontal alignments recommended by various international standards reveals that, besides the general factors described above, conditions specific to the country have also a role to play in determining the boundaries of the standards. The standards proposed to suit the project road, are presented below:

Horizontal Radii Criteria

Type of Terrain	Minimum Radii of Horizontal Curve	
	Desirable Minimum	Absolute Minimum
Mountainous	150	75
Plain	400	250

Adopted Horizontal Radii

Speed (km/h)	Absolute Minimum Radius (m)
50	80
40	50
35	40
30	30
25	20
20	14

The value of 7% for maximum super elevation has been adopted as a general rule to provide for better operational conditions for heavy trucks which generally move at lower speeds.

2.7 Vertical Alignment

The vertical alignment has been designed to be generally compatible with the horizontal alignment and consistent with the topography to achieve a free-flowing profile. The following criteria shall in general be followed while designing vertical curves:

- Generally vertical curve is designed based upon SSD

2.7.1 Gradient

As per IRC: SP:73- 2018 the gradient to be followed is as given below.

Vertical Gradient

Terrain	Ruling (%)	Limiting (%)
Plain	2.5	3.3
Mountainous	5.0	6.0
Steep	6.0	7.0

2.7.2 Summit or Crest Curves

According to AASHTO (2001) design guidelines, the minimum K values for stopping sight distance requirements are 52, 26 and 7 for design speeds of 100 km/hr, 80 km/h and 50 km/hr respectively.

According to TAC (1999) design guidelines, the minimum K valves for stopping sight distance requirements are 45 to 80, 24 to 36 and 6 to 16 for design speeds of 100 km/hr, 80 km/hr and 50 km/hr respectively.

The Consultants propose minimum summit curve K values of 75, 35 and 15 for design speeds of 100 km/hr, 80 km/hr and 50 km/hr respectively.

2.7.3 Valley or Sag Curves

The minimum K values for valley or sag curves, in accordance with AASHTO (2001) design guidelines are 45, 30 and 13 for design speeds of 100 km/hr, 80 km/hr and 50 km/hr respectively. The minimum K values for valley or sag curves, in accordance with TAC (1999) design guidelines are 37 to 50, 25 to 32 and 7 to 16 for design speeds of 100 km/hr, 80 km/hr and 50 km/hr respectively.

The Consultants propose minimum summit curve K values of 42, 30 and 15 for design speeds of 100 km/hr, 80 km/hr and 50 km/hr respectively.

Terrain Categories	K -Value of Summit Curves		K- Value of Valley Curves		Minimum Length of curve
	Desirable	Minimum	Desirable	Minimum	(m)
Plain	74	38	42	28	60
Rolling	38	18	28	18	50
Mountainous	8	5	10	7	30

2.8 Cross-fall

In case of 2-lane road, for Package I A (main road) TCS-1, 2, 3, 4, 5, 6 and 7 each lane will have unidirectional cross fall, for link road-1 TCS-8, 9, 10, 11 and 12 each lane will have unidirectional cross fall and for Package I B (main road) TCS-1A, 1B, 2, 3A, 4, 5A and 6 each lane will have unidirectional cross fall. For effective drainage consideration the cross-fall for the pavement and paved shoulders will be 2.5%. For earthen shoulders, the corresponding value will be 3.0%.

2.9 Geometric Design Control

Geometric design relates to design of all visual elements of the road. For the project road, this includes:

- Design of horizontal alignment which considers improvement of sub-standard curves, removal of kinks, realignment due to improvement of geometrics, considering the upgrading proposal to 2 Lane Carriageway with paved shoulder. The geometric designs would be as per recommendations of IRC: SP: 73-2018 & IRC 48-1998 Hill Road Manual.
- Design of vertical profile which considers flattening of steep and impermissible grades, provision of adequate sight distance and removal of dangerous dips and profile irregularities as per pavement design.

2.10 Roadway Width at Cross-Drainage Structures

2.10.1 Culverts

The culverts will be built/widened to the same width as the flanking roadway.

2.10.2 Bridges

The bridges will be built/widened as per guidelines of IRC: SP:84-2014.

2.11 Loading Standards for Bridge Structures

These will be according to IRC standards for bridges on National Highways.

2.12 Standards for At-Grade Intersections

The standards proposed in IRC SP: 41 "Guidelines for the Design of At-Grade

Intersection in Rural and Urban Areas" will be applied.

2.13 Drainage

Earthen/Natural soil cut to Trapezoidal shape will form the open drain in general connected to natural out fall. Wherever required, lined drains with suitable locally available materials will be provided to accommodate higher discharge. The drain will be lined with suitable material. These are:

Earthen Trapezoidal drain	:	This will generally apply for stretches with low to medium discharge
Lined drain with or without cover	:	This will apply in urban areas. Covers will be provided at places involving high pedestrian activities or where pedestrian footpath is desired.

At high embankments (height exceeding 5 m) a system of kerb and chute at edge of paved shoulders will be provided at 10 to 20 m intervals, as required for safe disposal of surface water without erosion.

For intra-pavement drainage, it is proposed to extend the sub-base layer up to edge of embankment slopes.

Geometric Design

CHAPTER – 3

GEOMETRIC DESIGN

3.1 General

Geometric design relates to design of all visual elements of the road. For the project road, this includes:

- ❖ Design of horizontal alignment which considers improvement of sub-standard curves, removal of kinks, realignment due to improvement of geometrics, considering the upgrading proposal to 2 Lane Carriageway with paved shoulder. The geometric designs would be as per recommendations of IRC: SP: 73-2018 & IRC 48-1998 Hill Road Manual.
- ❖ Design of vertical profile which considers flattening of steep and impermissible grades, provision of adequate sight distance and removal of dangerous dips and profile irregularities as per pavement design.

3.2 Design of Horizontal Alignment

The topographic survey data from total station survey equipment have been downloaded into computer to prepare Digital Terrain Model (DTM). Based on the decision taken on the side of widening, the centre line of the carriageway was finalized in the light of the design standards in the form of smooth flowing line compromising tangents and curves. A template of the cross section appropriate to the location was then superimposed to develop all other lines such as kerb lines, pavement/roadway lines etc. MX software was used to prepare the design.

3.3 Design of Vertical Profiles

Vertical alignment has been carried out at the centre line where it is proposed to be 2 laning with paved shoulders. It has been properly designed based on the vehicle speed, acceleration, deceleration, stopping distance, sight distance and comfort in vehicle movements at high speeds.

The following criteria in general were followed while designing the vertical profile.

i) The Project stretch is two-lane with Paved shoulder so Stopping sight distance are provided wherever possible.

ii) For the new carriageway, the levels have been decided based on requirement due to combination of spans, which results in increase in girder depth and any other hydrological requirement. A maximum super elevation of 7% has been provided after giving rotation at median edges.

iii) Gradients in accordance with the adopted standards were maintained considering SSD.However, to avoid any additional cutting and filling on proposed alignment due to adherence of recommendations of IRC-73, some minor compromise has been made.

iv) Grade compensation is considered in adherence to IRC: SP:23 which states “Since grade compensation is not necessary for gradients flatter than 4%, when applying grade compensation correction, the gradients need not be eased beyond 4%”.

3.4 Service/Slip Roads

Following criteria has been adopted for service roads

- Design speed : 40 KMPH
- Camber : 2.5 % (outward unidirectional)
- Carriageway Width : 7.0 m

However, no slip/service road has been proposed in the project road.

3.5 Hair Pin Bends

The following criteria should be followed for their design:

- Minimum Design Speed: 20kmph
- Minimum Roadway width with apex: NH/SH -11.5 for double lane & 9.0 m for single lane
- Minimum radius for inner curve: 14.0 m
- Minimum Length of transition Curve: 15.0 m
- Gradient: max-2.5%, min- 0.5%

- Super elevation :7%

3.6 Sample Calculation

The entire project road has been designed with the use of windows-based software package MX.

Two numbers of sample designed examples of horizontal and vertical curves for the project road by the MX package have been taken up for validation as detailed below:

Sl. No	Design Element	Curve Details	Description
1	Horizontal Curve	HIP NO-2, Chainage 12+923	Centre line of road
2	Vertical Curve	PVI Chainage 19+689	Summit Curve
		PVI Chainage 13+071	Valley Curve

The detailed design calculations for the above horizontal & vertical curves are given in **Annexure 3.1**.

Annexure: 3.1

SAMPLE DESIGN CALCULATION FOR HORIZONTAL ALIGNMENT AND VERTICAL PROFILE

A. Abbreviations

1)	Shift	S
2)	Tangent Length	T_s
3)	Apex distance	E_s
4)	Deviation angle of transition curve	Δ_s
5)	Total Deviation angle	Δ
6)	Central deflection angle of Circular Curve	Δ_c
7)	Length of Circular Curve	L_c
8)	Total Length of Curve	L_{total}
9)	Centrifugal Acceleration	C

B. Design Calculation for Horizontal Curve

i) HIP NO-2, Chainage 12+923

<u>Design Parameters</u>

R = 55 m
Δ = 46°49’35.04”
V = 40 Km/h.

<u>Design Calculations</u>

Since Radius is less than 1800 m we must provide transition.

a) <u>Calculation of transition length(Ls)</u>

i) According to the change of centrifugal acceleration (Refer IRC: 73 – 2018)

$$C=\frac{80}{75+V} \quad =\frac{80}{75+40} \quad = 0.6957$$

Since c<0.8, we take c = 0.640

$$L_s=\frac{0.0215\ V^3}{CR}$$

$$=\frac{0.0215\ (40)^3}{0.6400\times 55}$$

=35.96 m ---------------------------------------(i)

According to the rate of change of super elevation:

L_s = Super elevation X rate of change of super elevation X carriageway width.

$$e=\frac{V^2}{225\ R}$$

$$= 0.129$$

Adopted value e = 0.070

Therefore, $L_s = 1.0X\ V^2/R$

= 29.09 m -----------------------------(ii)

Therefore, L_s taken as maximum of the above two equation and Table 17 of IRC: 73 – 2015.

Therefore, L_s taken as 40 m

b) Check for the friction

$$e + f = \frac{V^2}{127\ R} \qquad = \frac{(40)^2}{127\ (55)} \qquad = \frac{1600}{127 \times 40} \qquad = 0.197$$

$$0.07 + f \qquad = 0.229$$

f = 0.15 = 0.15 (coefficient of friction should be less than or equal to 0.15) ...Hence safe

c) Features of the Curve

$$s = \frac{{L_s}^2}{24\ R} \qquad = \frac{(40)^2}{24 \times 55} \qquad = 1.212\ m$$

$$T_s = (R + s)Tan\ \frac{\Delta}{2} + \frac{L_s}{2}$$

$$E_s = (R + s)Sec\ \frac{\Delta}{2} - R$$

$$L_c = R\ \times\ \Delta_c$$

$$L_{Total} = L_c + 2\ L_s$$

$$\Delta = 0.817\ Rad$$

$$\Delta_s = \frac{L_S}{2\ R}$$

$$= \frac{L_S}{2\ R} \qquad = \frac{40}{2\ \times 55} \qquad = 0.3636\ \text{Rad}$$

$$\Delta_c = (\Delta - 2\Delta_s)$$
$$= 0.090\ \text{Rad}$$

Therefore,

$$T_s = (55 + 1.212)Tan\ \frac{(46°49'35.04")}{2} + \frac{40}{2}$$
$$= 44.341$$
$$L_c = 55\ \times 0.090$$
$$= 4.95\ \text{m}$$
$$E_s = (55 + 1.212)\ Sec\ \frac{(46°49'35.04")}{2} - 55$$
$$= 6.26\ \text{m}$$
$$L_{Total} = 4.95 + 2\ \times 40$$
$$= 84.952\ \text{m}$$

C. Design Calculation for Vertical Curve

i) PVI Chainage 19+689 (Summit Curve)

Design Parameters

Grade in, N_1 = 6.347 %
Grade out, N_2 = -5.280 %
Grade difference, N = 11.627 %

Design speed V = 50 Kmph.

PVI Level = 1430.029 m

Stopping Sight Distance (I.S.D.), S = 125.74 m
Type of curve: Summit curve.

Calculations

Assuming, $L > ISD$

$$L = \frac{NS^2}{9.6} = \frac{0.11627 \times (125.74)^2}{9.6} = 191.498 \text{ m} > \text{ISD} \ldots\ldots\ldots \text{ OK}$$

Length of curve provided =200 m

Chainage at the start of curve = PVI. Chainage – L/2
= 19689.104– 200/2
= 19589.104 m

Chainage at the end of curve = PVI. Chainage + L/2
= 19689.104 + 200/2
= 19789.104 m

Level at start of curve: = Level of PVI - (N_1 X L/2)
= 1430.029 – (0.06347 X 200/2)
= 1424.749 m

Level at end of curve: = Level of PVI +(N_2 x L/2)
= 1430.029 + (-0.0528 X 200/2)
= 1427.122 m

ii) PVI Chainage 13+071 (Valley Curve)

Design Parameters

Grade in, N_1 = -5.000 %
Grade out, N_2 = 6.751 %
Grade difference, N = -11.751 %

Design speed V = 50 kmph.

PVI Level = 1391.987

Stopping Sight Distance (S.S.D.) S = 62.87 m
Type of curve: Valley curve.

Calculations

Assuming, L > SSD

$$L = \frac{NS^2}{(1.5 + .035\ \times \mathrm{S})} \qquad = \frac{0.11751 \times (62.87)^2}{(1.50 + 0.035\ \times 62.87)} \quad = 125.523 \text{ m} > \text{SSD} \ldots\ldots\ldots \text{ OK}$$

So, provide the minimum valley curve
Length of curve provided = 200 m

Chainage at the start of curve = PVI. Chainage – L/2
= 13070.725– 200/2
= 12970.725 m

Chainage at the end of curve = PVI. Chainage + L/2
= 13070.725+ 200/2
= 13170.725 m

Level at start of curve: = Level of PVI - (N_1 X L/2)
= 1391.987 – (-0.05 X 200/2)
= 1396.987 m

Level at end of curve: = Level of PVI + (N_2 x L/2)
= 1391.987 + (0.06751 X 200/2)
= 1398.738 m

Drainage Design

CHAPTER – 4

DRAINAGE DESIGN

4.1 General

Road section either in cut or fill inevitably suffers from risk of erosion by runoff resulting from rainfall. The runoff has therefore to be channelized and damage to any element of the road and/or adjoining properties. This is done by properly designing the drainage structures, which includes drains, discharging structures and transfer structures.

4.2 Principle

The drains collect the runoff from the road surface, embankment slopes and adjoining lands. Geographical characteristics, soil condition and rainfall intensity are some of the main factors which influence the shape, location and capacity of drains. The drain should have sufficient capacity to carry natural peak runoff without scouring embankment or any part of the road.

Based on the calculation of discharge to be transferred through the drain and considering the drain characteristics, it should be necessary to find critical length for the drain at which discharge of the flow is required.

There will subsequently be a choice between several possibilities based on the topographical conditions.

- Protect the drain by lining
- Choose another type of drain
- Discharge the drain flow into a natural outlet, via a transfer structure (divergent drain or culvert)
- Provision of catch pit drain at the outlet of the culvert. Thus, also assists to maintain the grade of the longitudinal drain.

4.3 Selection of Drains Sections

The choice of cross-section of open drains is generally limited to 3 types; triangular, trapezoidal and rectangular. Each of the cross-section type has its be met suitable from traffic consideration, but this form of cross section has the disadvantage of lesser flow capacity. Rectangular section is well suited for roadside drains when large discharge is required but unless they are covered or kept sufficiently away from traffic, they may prove to be greater traffic hazard. Trapezoidal section is a compromise between triangular and rectangular section. However large top width of trapezoidal drain may also prove to be a traffic hazard.

4.4 Type Adopted

The drain has to collect the flow from the road surface, embankment slopes and adjoining lands and carry to the nearest available cross-drainage work. The longitudinal slope of the road alignment is generally varying in direction with respect to the countryside slope. Keeping this in view, it is proposed to locate the drain close to the toe of the road embankment on both sides in the rural area. In urban stretches, lined rectangular drains have been provided.

The chainages where the drain has been provided is as under:

Drainage Detail of Package I A (Main Road)						
Sr. No.	Design Chainage (Km)		Length (Km)	TCS Type	Drain	Side
	From	To				
1	12+920	13+005	85	TCS-3	PCC Drain	One Side
2	13+045	13+080	35	TCS-3	PCC Drain	One Side
3	13+080	13+120	40	TCS-5	PCC Drain	Both Side
4	13+120	13+170	50	TCS-3	PCC Drain	One Side
5	13+170	13+190	20	TCS-5	PCC Drain	Both Side
6	13+190	13+220	30	TCS-3	PCC Drain	One Side
7	13+250	13+330	80	TCS-3	PCC Drain	One Side
8	13+450	13+470	20	TCS-3	PCC Drain	One Side
9	13+470	13+650	180	TCS-6	PCC Drain	Both Side
10	13+650	13+690	40	TCS-7	PCC Drain	One Side
11	13+690	13+750	60	TCS-6	PCC Drain	Both Side
12	13+750	13+800	50	TCS-5	PCC Drain	Both Side
13	13+800	13+830	30	TCS-4	PCC Drain	One Side
14	13+830	14+000	170	TCS-5	PCC Drain	Both Side
15	14+000	14+030	30	TCS-3	PCC Drain	One Side
16	14+030	14+200	170	TCS-5	PCC Drain	Both Side
17	14+200	14+230	30	TCS-3	PCC Drain	One Side
18	14+230	14+320	90	TCS-5	PCC Drain	Both Side

Drainage Detail of Package I A (Main Road)						
Sr. No.	Design Chainage (Km)		Length (Km)	TCS Type	Drain	Side
	From	To				
19	14+320	14+360	40	TCS-3	PCC Drain	One Side
20	14+360	14+395	35	TCS-5	PCC Drain	Both Side
21	14+405	14+490	85	TCS-5	PCC Drain	Both Side
22	14+490	14+590	100	TCS-3	PCC Drain	One Side
23	14+590	14+920	330	TCS-5	PCC Drain	Both Side
24	14+920	15+050	130	TCS-3	PCC Drain	One Side
25	15+050	15+130	80	TCS-5	PCC Drain	Both Side
26	15+130	15+150	20	TCS-4	PCC Drain	One Side
27	15+150	15+430	280	TCS-3	PCC Drain	One Side
28	15+430	15+680	250	TCS-5	PCC Drain	Both Side
29	15+680	15+850	170	TCS-3	PCC Drain	One Side
30	15+930	16+150	220	TCS-3	PCC Drain	One Side
31	16+150	16+260	110	TCS-5	PCC Drain	Both Side
32	16+260	16+388	128	TCS-3	PCC Drain	One Side
33	16+600	17+120	520	TCS-3	PCC Drain	One Side
34	17+120	17+750	630	TCS-5	PCC Drain	Both Side
35	17+750	17+775	25	TCS-3	PCC Drain	One Side
36	17+810	17+870	60	TCS-3	PCC Drain	One Side
37	17+870	17+920	50	TCS-5	PCC Drain	Both Side
38	17+920	17+980	60	TCS-3	PCC Drain	One Side
39	18+050	18+170	120	TCS-3	PCC Drain	One Side
40	18+170	18+370	200	TCS-5	PCC Drain	Both Side
41	18+370	18+420	50	TCS-4	PCC Drain	One Side
42	18+420	18+500	80	TCS-3	PCC Drain	One Side
43	18+500	18+530	30	TCS-5	PCC Drain	Both Side
44	18+530	18+820	290	TCS-3	PCC Drain	One Side
45	18+820	18+900	80	TCS-5	PCC Drain	Both Side
46	18+900	19+189	289	TCS-3	PCC Drain	One Side
47	19+199	19+450	251	TCS-3	PCC Drain	One Side
48	19+450	19+660	210	TCS-5	PCC Drain	Both Side
49	19+660	19+690	30	TCS-4	PCC Drain	One Side
50	19+690	19+720	30	TCS-3	PCC Drain	One Side
51	19+720	19+760	40	TCS-4	PCC Drain	One Side
52	19+760	19+830	70	TCS-5	PCC Drain	Both Side
53	19+830	19+920	90	TCS-3	PCC Drain	One Side
54	19+920	19+950	30	TCS-5	PCC Drain	Both Side
55	19+950	19+970	20	TCS-4	PCC Drain	One Side
56	19+970	20+170	200	TCS-3	PCC Drain	One Side
57	20+170	20+200	30	TCS-5	PCC Drain	Both Side
58	20+200	20+280	80	TCS-3	PCC Drain	One Side
59	20+280	20+300	20	TCS-5	PCC Drain	Both Side

Drainage Detail of Package I A (Link Road)

Sr. No.	Design Chainage (Km)		Length (Km)	TCS Type	Drain	Remarks
	From	To				
1	00+000	00+180	180	TCS-9	PCC Drain	Both Side
2	00+180	00+220	40	TCS-11	PCC Drain	One Side
3	00+220	00+260	40	TCS-10	PCC Drain	One Side
4	00+460	00+480	20	TCS-10	PCC Drain	One Side
5	00+480	00+560	80	TCS-9	PCC Drain	Both Side
6	00+680	00+710	30	TCS-10	PCC Drain	One Side
7	00+710	00+800	90	TCS-9	PCC Drain	Both Side
8	00+850	00+870	20	TCS-10	PCC Drain	One Side
9	00+870	00+890	20	TCS-11	PCC Drain	One Side
10	00+890	00+920	30	TCS-10	PCC Drain	One Side
11	00+920	00+980	60	TCS-9	PCC Drain	Both Side
12	00+980	01+000	20	TCS-10	PCC Drain	One Side
13	01+030	01+050	20	TCS-10	PCC Drain	One Side
14	01+050	01+100	50	TCS-9	PCC Drain	Both Side
15	01+100	01+130	30	TCS-10	PCC Drain	One Side
16	01+130	01+170	40	TCS-9	PCC Drain	Both Side
17	01+170	01+470	300	TCS-10	PCC Drain	One Side
18	01+470	01+490	20	TCS-9	PCC Drain	Both Side
19	01+490	01+510	20	TCS-10	PCC Drain	One Side
20	01+510	01+550	40	TCS-9	PCC Drain	Both Side
21	01+550	01+730	180	TCS-10	PCC Drain	One Side
22	01+730	01+750	20	TCS-9	PCC Drain	Both Side
23	01+750	01+770	20	TCS-10	PCC Drain	One Side
24	01+820	01+850	30	TCS-10	PCC Drain	One Side
25	01+850	02+016	166	TCS-12	PCC Drain	Both Side

Drainage Detail of Package I B (Main Road)

Sr. No.	Design Chainage (Km)		Length (Km)	TCS Type	Drain	Remarks
	From	To				
1	20+300	20+350	50	TCS-3A	PCC Drain	Both Side
2	20+350	20+460	110	TCS-1A	PCC Drain	One Side
3	20+460	20+480	20	TCS-6	PCC Drain	One Side
4	20+480	20+580	100	TCS-5A	PCC Drain	Both Side
5	20+580	20+640	60	TCS-6	PCC Drain	One Side
6	20+640	20+850	210	TCS-5A	PCC Drain	Both Side
7	20+850	21+040	190	TCS-3A	PCC Drain	Both Side

Drainage Detail of Package I B (Main Road)						
Sr. No.	Design Chainage (Km)		Length (Km)	TCS Type	Drain	Remarks
	From	To				
8	21+040	21+085	45	TCS-1A	PCC Drain	One Side
9	21+130	21+310	180	TCS-3A	PCC Drain	Both Side
10	21+370	21+405	35	TCS-1A	PCC Drain	One Side
11	21+445	21+520	75	TCS-3A	PCC Drain	Both Side
12	21+520	21+650	130	TCS-5A	PCC Drain	Both Side
13	21+650	21+880	230	TCS-3A	PCC Drain	Both Side
14	21+880	21+940	60	TCS-1A	PCC Drain	One Side
15	21+940	22+000	60	TCS-3A	PCC Drain	Both Side
16	22+000	22+100	100	TCS-5A	PCC Drain	Both Side
17	22+210	22+340	130	TCS-3A	PCC Drain	Both Side
18	22+340	22+540	200	TCS-1A	PCC Drain	One Side
19	22+540	22+605	65	TCS-3A	PCC Drain	Both Side
20	22+645	22+740	95	TCS-3A	PCC Drain	Both Side
21	22+740	22+840	100	TCS-5A	PCC Drain	Both Side
22	22+840	23+050	210	TCS-3A	PCC Drain	Both Side
23	23+140	23+180	40	TCS-1A	PCC Drain	One Side
24	23+180	23+460	280	TCS-3A	PCC Drain	Both Side
25	23+460	23+520	60	TCS-1A	PCC Drain	One Side
26	23+520	23+640	120	TCS-3A	PCC Drain	Both Side
27	23+750	23+810	60	TCS-3A	PCC Drain	Both Side
28	23+810	23+900	90	TCS-5A	PCC Drain	Both Side
29	23+900	23+960	60	TCS-3A	PCC Drain	Both Side
30	24+030	24+230	200	TCS-3A	PCC Drain	Both Side
31	24+320	24+490	170	TCS-3A	PCC Drain	Both Side
32	24+590	24+870	280	TCS-3A	PCC Drain	Both Side
33	24+870	25+010	140	TCS-1A	PCC Drain	One Side
34	25+010	25+210	200	TCS-3A	PCC Drain	Both Side
35	25+210	25+320	110	TCS-1A	PCC Drain	One Side
36	25+320	25+490	170	TCS-3A	PCC Drain	Both Side
37	25+560	25+670	110	TCS-1A	PCC Drain	One Side
38	25+760	25+880	120	TCS-3A	PCC Drain	Both Side
39	25+880	26+020	140	TCS-1A	PCC Drain	One Side
40	26+020	26+150	130	TCS-3A	PCC Drain	Both Side
41	26+150	26+300	150	TCS-1A	PCC Drain	One Side
42	26+300	26+370	70	TCS-3A	PCC Drain	Both Side
43	26+445	26+480	35	TCS-1A	PCC Drain	One Side
44	26+480	26+605	125	TCS-3A	PCC Drain	Both Side
45	26+615	26+770	155	TCS-1A	PCC Drain	One Side
46	26+770	26+910	140	TCS-3A	PCC Drain	Both Side
47	26+910	27+930	1020	TCS-1A	PCC Drain	One Side
48	27+930	27+990	60	TCS-3A	PCC Drain	Both Side

Drainage Detail of Package I B (Main Road)						
Sr. No.	Design Chainage (Km)		Length (Km)	TCS Type	Drain	Remarks
	From	To				
49	27+990	28+160	170	TCS-1A	PCC Drain	One Side
50	28+160	28+510	350	TCS-3A	PCC Drain	Both Side
51	28+510	28+630	120	TCS-1A	PCC Drain	One Side
52	28+650	28+770	120	TCS-4	PCC Drain	One Side
53	28+770	29+030	260	TCS-1B	PCC Drain	One Side

4.5 Hydrological Design

Hydrologic analysis is a very important step prior to the hydraulic design of road drainage system. Such analysis is necessary to determine the magnitude of flow and the duration for which it would last. Hydrological data required for design include drainage area map, watershed delineation, direction of flow, outfalls, and drains, other surface drainage facilities, ground surface conditions and rainfall and flood frequencies. Factors that affect run-off are size and shape of drainage area, slope of ground, land use characteristics, geology, soil types, surface infiltration and storage.

The design of drains has been done according to the method suggested in IRC SP-42. The **rational method** is a universally accepted empirical formula relating rainfall to runoff and is applicable to small catchment areas not exceeding 25 Sq.Km.

The formula is: $Q = 0.028\, PAI_c$

Where:

Q = discharge (peak runoff) in cumec

P = coefficient of run-off for the catchment characteristics

A = area of catchment in hectares

I_c = critical intensity of rainfall in cm/hr for the selected frequency and for duration equal to the time of concentration

The suggested values of `P' for use in rational formula are adopted from Table 2 of IRC SP-42.

The primary component in designing drains is the design storm viz. rainfall value of specified duration and specific return period. As the extent of drainage system for roads is small, even intense rainfall of short duration may cause heavy outflows. Therefore, proper study of extreme values of rainfall of various short durations is required in designing road drainage systems. The storm duration chosen for design purpose is equal to time of concentration and is based on the assumption that the maximum discharge at any point in a drainage system occurs when the entire catchment is contributing to the flow. The time of concentration for any watershed is the time required for a given drop of water from the most remote bank of watershed to reach the point of study. It may have two components (I) entry time (II) time of flow. If the drainage point under consideration is at the entry of the drainage system, then the entry time is equal to the time of concentration. If, however, the drainage point is situated elsewhere, then the time of concentration is sum of the entry time and the time required by the raindrop to traverse the length of the drainage system to the point under study.

Once the time of concentration has been fixed, the next step consists in reading the intensity of rainfall from the appropriate rainfall map for storm duration equal to time of meditation and adopted design frequency. Unfortunately, rainfall maps of India for duration less than 1 hr are not yet available. A general equation given in IRC SP-42 is used for deriving intensity for shorter duration.

The equation is:

$$I = \frac{F}{T}\left(\frac{T+1}{t+1}\right)$$

Where

I = Intensity of rainfall within a shorter period of 't' hours within a storm

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

t = Smaller time interval in hours within the storm duration of 'T' hours

The available topographic sheets of the area have been studied to formulate an idea of the drainage pattern and determine the extent of the area on both sides of the road contributing to the flow to be carried by the roadside drains. Final bearings of the drains have been taken at site itself. The design frequency of the storm for roadside drain design has been taken as 25 year, as suggested in IRC SP-42.

4.6 Hydraulic Design of Drain

After determining the quantity of runoff, the design depth of flow in the drain for the adopted section has been calculated from the Manning's formula.

$$Q = A\,(1/n\; R^{2/3}\, S^{1/2})$$

Where A = Area of flow in m^2

n = Coefficient of rugosity

R = Hydraulic mean depth in m

S = Longitudinal Slope of Drain

In design of roadside drains, the flow of water is assumed as sub critical flow. The slope and velocity are kept below the critical level.

Values of `n' and maximum permissible velocity for various channel surfaces are adopted from Table 6 of IRC SP-42.

4.7 Outfall for Drains

The open drains will have their outfall in the depressions leading to the proposed cross-drainage works. The drains may also lead to the country side as per the contour. The levels of drainage channels have been fixed keeping in view the invert levels of cross-drainage structures.

4.8 Maintenance of Drainage System

The drainage system is at best when it is maintained as properly as designed. For this purpose, it is necessary that the drains keep their shape and slope in the designed manner during their lifetime. It is also necessary that drains retain their full cross-section, particularly for the monsoon. Three categories of maintenance are required for the drains:

(a) Continuous regular maintenance

(b) Periodical maintenance

(c) Special maintenance / Repair for improvement

Continuous regular maintenance is important aspects pertaining to maintenance programs. It is very essential that maintenance unit have all the drawings of new proposed drains showing all the technical details on the ground.

Periodical maintenance and inspection is also very necessary as failure of drains may occur due to deficiency in maintenance rather than defect in design. The principal activities may be

(a) Desilting

(b) Cleaning of weeds

(c) Cleaning of obstruction, debris and blockage

(d) Repairing of lining immediately at the commencement of damage or deterioration

It should be a common practice that all the drains are desilted thoroughly before onset of monsoon. All un-lined roadside drains require dressing and deepening before monsoon. In case of pipe drains, if it is not possible to desilt it manually, suitable mechanical devices such as sectional sewer rods, flexible sewer rods, bucket machine, roding machine with flexible rods, scraper and hydraulically propelled rubber rods etc., should be employed. Success of such operation can be ensured only through proper inspection by all field officers rather than leaving it only to maintenance unit. Outfall structure and the cross-drainage structure also require similar treatment.

Special maintenance/repairs are required during rains, especially after heavy shower all cross-drainage should be inspected to observe any blockage due to debris, log of wood and other such material. A watch on the deficiencies in the drainage system should be kept and problem locations should be identified, and proper record should be kept. Necessary corrective measures should be adopted immediately after heavy rains. A watch on missing manhole covers and broken covers is also required to be kept and replacement / repairs should be carried out on priority to avoid accident.

4.9 Hydrological and Hydraulic Study for Bridges

Design Engineers essentially need the design flood of a specific return period for fixing the waterway vis-à-vis the design HFL of bridges depending upon their size and importance to ensure safety as well as economy. The committee of engineers headed by Dr. A.N. Khosla had recommended that design discharge should be the maximum flood on record for a period not less than 50 years. This was accepted by IRC. IRC: 5-1970-Section-I General Features of Design specifies that the waterway of a bridge is to be designed for a maximum flood of 50 years return period.

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

- Empirical Formulae
- Rational Method
- Hydro-meteorology model
- Statistical method based on recorded discharge
- Area-Velocity Method or Slope Area Method

These methods have been discussed in detail in Appendices to Design Report Volume-II, Part-2 (Bridges).

Toll Plaza and Toll Collection System

CHAPTER –5

TOLL PLAZA AND TOLL COLLECTION SYSTEM

5.1 General

Financial analysis of the Project stretch suggests that the Project stretch is not viable on BOT Basis. The Project is financially viable on EPC Basis. Provision of Toll has not been provisioned now. If required provision shall be made accordingly.

However, the general details of Toll collection system is being incorporated hereby for information only.

5.2 Toll System

The location and number of toll plazas depend on the type of toll system. The two alternative systems for consideration are a 'closed' or an 'open' one.

Closed Toll System

This system consists of isolating the tolled stretch of the highway. Barriers are set up across the highway next to each end point and additionally at all entry and exit points within the section. Anyone driving on the highway section pays a fee, which is related to the distance travelled. The driver gets an entry ticket which registers point, date and time of entry and he pays at the exit according to the distance traveled.

Open Toll System

In an open toll system, flat toll fees are levied at certain points on the highway. Toll fees do not necessarily reflect a consistent rate per kilometer as they may relate to different trip lengths. Also, an open system often leads to short intervals between barriers inconveniencing long distance traffic.

Open system is best suited for partially access controlled highways where local traffic cannot be completely isolated. They are less costly and less complicated to operate than a closed toll system.

5.3 Toll Plaza Location

The location for the toll plaza on any project road has been suggested on the basis of travel pattern and taking into account the following considerations:

- Capture maximum tollable traffic
- Have minimum interference of non-tollable local traffic
- Ensure minimal possibility of revenue leakage

However, no toll plaza is proposed for this road section.

5.4 Toll Collection System

There are three commonly used operations for toll collection, viz, manual collection system, semi-automatic system and fully automatic system.

Manual Collection System

In this system, all the operations, viz. Toll collection, ticket printing, record maintenance, lane control and accounting system, etc., are performed manually. This could result in poor supervision of toll plaza operations, least efficiency of vehicle throughout and more manpower requirements. However, this method can be a better alternative for the open system for an isolated highway section with low traffic volumes. It is, however, not suited for adoption for catering to high volumes of traffic.

Semi-Automatic System

In this system, only toll collection is operated manually and all other operations like vehicles classification, ticket printing, lane controlling, accounting system and monitoring the plaza operation are computerized. Thus, this system offers a well co-ordinate and more efficient toll plaza operations coupled with high vehicle handling capacity over conventional operation system. This system is well suited for Indian conditions particularly for the present study corridor for providing a high level of customer service.

Automatic System

In this system, the toll is collected electronically through automatic vehicle identification system. Toll is calculated by the system itself based on the vehicle type, which is detached automatically when a vehicle passes through the system.

Proposed Toll Collection System

Semi-automatic system is cost effective for operation in India. Therefore, a semi-automatic system is proposed.

5.5 Tollable Traffic

The local traffic shall be given exemption by issuing monthly passes as per the Concession Agreement. Monthly passes are issued based on trip length. Similarly, frequent users would prefer return passes, which will entitle the specified vehicle to undertake a return journey on the same day as the outward journey. The share of monthly passes and return journey trips are estimated from OD survey conducted at the respective locations based on trip length and frequency.

Since, no toll plaza is proposed so no tollable traffic is calculated.

5.6 Details of Proposed Tolling System

The Semi-Automatic Post Classification Toll Collection System is proposed for the project road. The equipment in the proposed semi-automatic post classification system will have following:

a) Lane Controller

b) Operator Display

c) Operator Console

d) Patron Fare Display

e) Lane Open/Closed Signal

f) Traffic Control Barrier Gate

g) Classification Sensor - Four Contact Treadle Sensor

h) Vehicle Presence Sensor - Loop Detector

i) Gate Open/Closed Traffic Signal

j) Receipt Printer

k) Intercom Units

l) Plaza Computer system

m) Software & Hardware

5.7 Design Principles of Toll Plaza

Lane Width

As per Manual of Specifications and Standards (IRC: SP: 73:2018) for Two-laning of Highways through PPP, width of each toll lane shall be 3.2 meters. For over dimensional vehicles, 4.5 m wide lane is proposed on each direction.

Lane Separator Island

The length for the separator islands has been worked out based on the average queue length and size of toll booth. The width of median is recommended 1.9 m for accommodating toll booths as per Manual of Specifications and Standards (IRC: SP: 73-2018) for two-laning of Highways through PPP.

Each end of toll plaza is tapered to the approaching road width. A taper of 1 in 10 has been recommended.

Office Building

The office building is proposed to be constructed for toll plaza. The office building would include administrative office and minimum services viz. toilets, bath, stores, etc. A built-in safe deposit vault attached to the office would be provided for safety of cash collected during the day.

Traffic Control

CHAPTER – 6

DESIGN OF TRAFFIC CONTROL AND OTHER FACILITIES

6.1 General

The up-gradation and widening of the project road, would transform it into a high-speed corridor for which an efficient traffic control system is essential. The main purpose of traffic control system is to provide the road users a smooth, hazard free passage, together with ensuring adequate safety to all concerned, including the pedestrians. Since the project roadway crosses many populated villages and towns, the designing of traffic control measures assumes paramount importance.

The various traffic control measures adopted for the project road are described in the succeeding paragraphs. These comprise the designs of:

(i) Junctions

(ii) Traffic Signs and Road Markings

(iii) Bus bays, Truck Lay bye and Parking lanes

(iv) Street Lighting

(v) Other Appurtenant

6.2 Junctions

6.2.1 Major & Minor Junctions

There are total of 2 major junctions and 1 minor junction on the project road. The junctions have been designed as per IRC guidelines.

The detailed layout of junction is presented in Volume IX – Drawings of Detailed Project Report.

6.3 Traffic Signs and Road Markings

6.3.1 Traffic Signs

The traffic signs on the project roads have been provided in accordance with the IRC Code of Practice for Road Signs (IRC 67-2010).

The various types of road signs as presented in the above-mentioned standard and introduced in the project roads are described below. The main categories of road signs are;

- Mandatory or Regulatory Signs (MS)
- Warning or Cautionary Signs (WS)
- Informatory Signs (IS)

Mandatory Signs /Regulatory Signs and Compulsory Signs

The Mandatory Signs are meant to convey to road users a definite instruction they must follow e. g. octagonal 'STOP' sign, circular signs for speed or other restrictions etc. Compulsory signs such as "Keep Left" compel the drivers to follow a definite route.

Warning Signs

The Warning Signs are meant to convey to road users a warning about dangers/hazards ahead. These are triangular signs warning about 'School Zone', 'cross road' and other hazards lying ahead.

Informatory Signs

The Informatory Signs are provided to convey to road users' information on places of interest, services and facilities etc. This also includes other signs which are useful to the drivers like Direction signs, parking signs etc.

Design and Siting

The road signs shall be of the retro-reflectorized type and made of high intensity grade with encapsulated lens type reflective sheeting fixed over aluminium sheets. The sign post would be of aluminium alloy posts or steel posts or hollow section of cast or sheet metal.

Locations of signs have been marked on plan and profile drawings of the project road as also in the individual intersection drawings.

All the road signs selected are proposed to be erected on a refuge or on an island or on earthen shoulder of the road and will be mounted on ground. Orientation and siting of signs with respect to the carriageway will be carried out conforming to IRC standard with due care to adjoining land use on urban and semi urban areas.

Clearances with respect to carriageway

1. Section with shoulders and verges	2-3 m lateral clearance of nearest point of sign plate from carriageway edge.
	1.5 m vertical clearance of the lowest point of the sign plate from the crown of the carriageway.
2. Section with footpath or separator	0.6 m lateral clearance of the lowest point of the sign plate from kerb edge.
	2.0 m vertical clearance of the lowest point of the sign plate from top of footpath/separator.

Care would have to be taken in selecting locations of signs posts, particularly in urban stretches, that the sign post is not lost amidst other sign or advertising posts, and the siting distances will be adjusted for better visibility.

6.3.2 Road Markings

It will be essential to provide suitable carriageway markings for conveying to traffic on roads warning, a requirement or information of the descriptions necessary for smooth and hazard-free movement. These are provided also to ensure safety and orderly use of the carriageway in accordance with traffic regulations, to define lanes and guide/regulate vehicles at junction and to complement the traffic signs. IRC standards have been followed in general.

The carriageway markings as suggested should be simple, clear to purpose and type, hard wearing and skid resistant in both dry and wet weather conditions.

Provisions have been made for Road Marking on the entire length of the project road which, inter alia, includes centre line, carriageway edge-lines, lane line, pedestrian crossings etc.

Hot applied thermoplastic Materials (Superimposed Type) has been proposed for road marking purpose to be applied with the help of marking machines after trials.

Carriageway Edge Line

Carriageway Edge lines are specifically required to define edges of the carriageway wherever there are paved shoulders or slow/parking lanes. Carriageway edge lines recommended are 150mm wide, white in colour and continuous along both sides of the carriageway except at junctions where a broken edge line is used to provide continuity in case of minor junctions and discontinued across major ones. Edge lines have also been provided around directional traffic islands and rotary islands.

Centre Lines

The Centre Line has been suggested to be 100mm wide in broken or continuous-single or twin lines depending upon the zonal restriction requirements as mentioned below:

- Broken single line will indicate that crossing centre-line is not hazardous and permitted to do so with adequate caution. This type has been normally provided in rural straight stretches of 2-lane roads.
- Continuous single line provided at all sharp curves and on all bridge structures, will indicate crossing is permitted only for right turning vehicles.

Other Markings

Other markings such as Directional Arrows, Chevron and Diagonal markings, Lane markings, Pedestrian crossing, Zebra Control areas and other related signs required for smooth operation of traffic have been provided in accordance with IRC standard code of practice (IRC 35-1977) or as per other recommendations.

6.4 Bypasses & Realignments

No bypass is proposed in the Project stretch. Few realignments have been proposed.

6.5 Service Roads/Slip Roads

Slip road is provided on the approach of grade separated structures. However, there is no slip road proposal.

6.6 Street Lighting

Adequate lighting is important for safe operation and making proper manoeuvres at those locations where the road passes through urban stretches. At such locations due to higher share of local traffic, slow traffic and large pedestrian movement, the drivers need to take correct decisions avoiding sudden braking and swerving. Need for adequate street lighting exists at such urban locations along the project corridor.

However, electric light posts have already been provided locally in these urban stretches which would be suitably relocated.

6.7 Other Appurtenances

6.7.1 Guard Posts

Standard Guard posts made of M 20 grade concrete resting on M15 Grade concrete foundation have been proposed on approaches to structure, high embankment area where height of embankment is more than 3m and in sharp curve locations. These guard stones shall be painted with alternate black and white stripes and placed at intervals of 1.5m with an offset of 2m from carriageway edge.

6.7.2 5th Kilometre, Kilometre and 200m stones

These have been proposed as per the required provision in IRC 8 and 26 and as per standard practice in the country. These should be made of precast concrete and lettering/numbering shall be as per IRC codes mentioned above.

6.7.3 Roadside Safety Barriers

There are two types of safety barriers viz. longitudinal road side safety barriers and median safety barriers. There are broadly three types of longitudinal road side safety barriers.

Type of Crash Barrier	Location Provided
a) Flexible type	Not Provided
b) W Beam Type	(i) Package I A (Main Road): In TCS – 1, 2 and 4 Link Road: In TCS – 8 and 11 (ii) Package I B (Main Road): In TCS – 1A, 1B, 2, 4 and 6
c) Rigid type (like concrete crash barrier)	Not Provided

These safety barriers will be provided on embankment height more than 3 m, sharp curves, approaches of bridges, cut slopes etc.,

6.7.4 Delineators

Delineators provide visual assistance to drivers about the alignment of road ahead, particularly at night. This is particularly useful at curves.

Two types of delineators have been proposed on the project road, namely:

(i) Triangular red reflectors as object markers provided at the heads of medians and directional islands

(ii) Circular red reflectors fixed on guard posts at prescribed spacing to delineate the alignment in sharp curves and high embankments.

The guidelines of MC-79 have been followed in selecting the types and locations.

6.8 Environmental Aspect

The project road passes through hilly terrain and the proposed alignment does not pass through any ecologically sensitive area. Environmental impacts caused by a highway upgrading project are expected to be limited in extent. The impact on land resources would mainly be on account of earthwork and quarrying operation. Nevertheless, some of these concerns due to high speed traffic on the corridor have been given due consideration in design as a matter of principle. The measures adopted in design to mitigate these potential impacts are:

a) Plantation of trees along the road that will result in partial noise attenuation and act as sink of air pollutants.

b) Bus bays at required locations will facilitate a healthy environment for the road users by ensuring a smooth traffic flow and reduction in air and noise pollution.

c) Provision of pedestrian facilities, system of sign and markings suitable lighting have been provided at suitable locations to safeguard against hazards which may result from higher vehicle speed.

The positive impact of the project includes improvement of economy, reduction in travel time and enhancement to the landscape along the road.

Pavement Design

CHAPTER – 7

PAVEMENT DESIGN

7. PAVEMENT DESIGN REPORT

7.1 Introduction

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the subgrade. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements. This chapter gives detail design of flexible pavement. Improper design of pavements leads to early failure of pavements affecting the riding quality.

The project road will be provided with paved shoulders, and it has been proposed that these will be constructed as per IRC specification.

7.2 Pavement Design Objective

Pavement is the most significant component of a road and therefore its design strengths must be assured to support the projected traffic loading throughout the design period. The Objective is to determine the total thickness of the pavement structure as well as thickness of individual structural layer components. Design strength of pavement must be adequate to support the projected traffic loading throughout the operation period.

For the project, pavement design is required for the following cases:

- Pavement for new carriageway

The Consultant has worked out the designs for the above case based on result of survey/investigations regarding traffic, axle load spectra, pavement condition and strength, sub-grade/material properties etc.

As mentioned in TOR, the overlay as well as new pavement has been designed primarily as per IRC guidelines.

7.3 General Design Guidelines

A. New pavements shall be designed in accordance with IRC: 37-2018 or any other international standard method/guidelines, subject to the condition that the overall pavement composition shall not be less than the minimum requirement specified in IRC: 37-2018

B. Clause 5.3, IRC: SP. 73-2018 states that "Flexible pavement design shall be designed in accordance with IRC:37. Guidelines for the Design of flexible Pavements". Strengthening of existing pavement shall be designed based on procedure outlined in IRC: 81. Rigid Pavement shall be designed in accordance with the method prescribed in IRC:58. "Guidelines for the Design of Plain Jointed Rigid Pavements for Highways"

- Clause 5.4. I of IRC: SP: 73-2018, states that "Flexible pavement shall be designed for a minimum design period of 15 years, subjected to the condition that design traffic shall not be less than 20 msa. Stage construction shall not be permissible. Rigid Pavements shall be designed for a minimum design period of 30 years. The stage construction shall not be permitted.

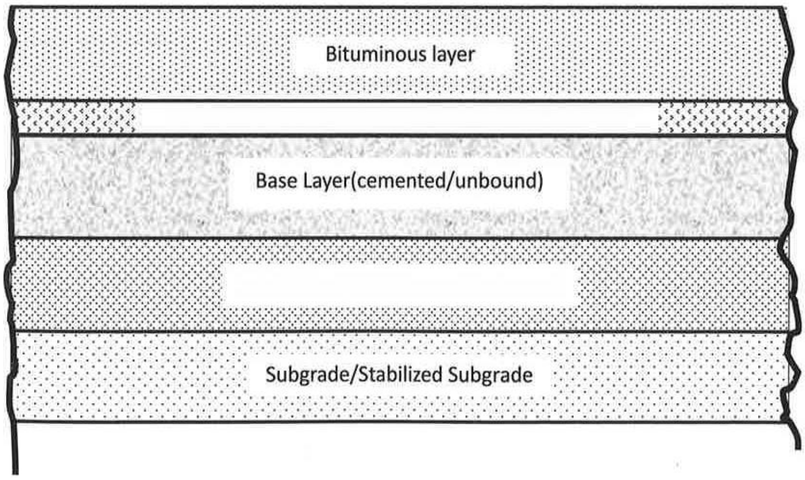
C. The whole pavement design concept has been divided into two parts:

- Flexible pavement design for new two-lane carriageway.
- Future overlays to be provided (after 10, 15 & 20 years) by component analysis method using the residual strength of the pavement material.

7.4 Pavement Composition

As per the guidelines of IRC: 37-2018, five different combinations of layers of pavement options are available for classified traffic and various material properties. The combinations contain layers of sub base, base, binder and surface courses.

Each combination of layers has been suggested for different environmental conditions and traffic. A flexible Pavement covered in these guidelines consist of different layers as shown in fig. below-



The Sub-base and the base layer can be unbound (e.g. granular) or chemical stabilized with stabilizer such as cement, lime, fly ash and others Cementous stabilizer. Flexible Pavement with unbound Sub-base and base layer has been proposed here to adopt in the project.

7.4.1 Bituminous Pavement with Unbound Base and Sub Base Layer

7.4.1.1 Sub-base Layer- Unbound

The sub-base material may consist of granular material or as confirming to MORTH specification for Road and Bridge Works. The sub-base should have sufficient strength and thickness to serve the construction traffic.

7.4.1.2 Base layer- Unbound

The base layer may consist of wet mix macadam, water bound macadam, crusher run macadam etc. Relevant specification of IRC/ MORTH are to be adopted for the construction.

7.4.1.3 Bituminous Layers

Bituminous layers consist of Dense Bituminous macadam and Bituminous Concrete which thickness varying as per design stipulation.

7.5 Recommended Pavement Option

7.5.1 Flexible Pavement:

Design of flexible pavement applies to the new carriageway. The new pavements have been designed following guidelines of IRC: 37-2018.

7.5.2 Rigid Pavement:

No rigid pavement is proposed. However, in tunnel portion length PQC shall be provided.

7.6 Parameters for Design

7.6.1 Design Life

The design life adopted in the analysis is 15 years for flexible pavement.

7.6.2 Traffic Homogenous Sections

The following stretch has been adopted for traffic homogenous sections:

- Goha – Khellani, Near Khellani on NH-244

7.6.3 No. of Lanes for Proposed Carriageway

The homogenous sections as mentioned above will be designed and constructed as two-lane carriageway with paved shoulders.

7.7 Functional and Structural Overlay

The requirement of structural and functional overlays is discussed in the following sections.

7.7.1 Functional Overlay

It may be noted that due to the high ambient temperature as a result of exposure to sun, the bitumen from top surface of the BC layer of pavement gets gradually oxidized with passage of time. Rain also causes the stripping of bitumen from the pavement surface gradually. The process of oxidation and stripping makes the top BC layer of the pavement bitumen hungry, which may lead to ravelling, potholes & other defects in the pavement, thereby affecting the function of the pavement in the form of poor riding quality.

It is proposed that during the design life period, functional overlay will be provided on the pavement after every 5 years (approx.) from the date of the opening of road to traffic. Minimum 25 mm SDBC functional overlay must be provided for the case of no requirement of structural overlay. The pavement will be provided with 25 mm thick functional SDBC surfacing.

7.7.2 Structural Overlay

If the pavement is not strengthened before the expiry of its design life (15 years) for the future traffic loading, then the underlying layers of the pavement will be overstressed. The over stressing of pavement layers including sub grade will damage the physical condition of the pavement in the form of occurrence of cracks, faulting, ravelling, rutting or other conditions, which would affect the load carrying capabilities of the pavement structures.

So, in order to ensure the desired level of structural strength and riding quality of the pavement after the expiry of design life, it is essential to provide a structural overlay on the pavement as a part of rehabilitation.

Since there is no IRC design standards/methodology/manual for the design of future overlay on the pavement beyond its design life, the future structural overlay design has been carried out by Component Analysis Method described in AASHTO Guide for Design of Pavement Structures 1993. Since, it is difficult to assess the deflection values at the design life of 10, 15 and 20 years; whereas the structural coefficients can be assessed to a fair degree of reliability. Therefore, the component analysis method has been used.

7.8 Preliminary Investigation

7.8.1 TRAFFIC

7.8.1.1 Commercial Vehicles:

The base year traffic has been assessed by carrying out traffic surveys at Location – Khellani. For pavement design purpose, commercial vehicles of laden weight more than 8 tonnes have been considered.

Such vehicles consisted of buses, LCVs, 2 Axle trucks, 3 Axle trucks and Multi Axle trucks. The summary of AADT (No.) of commercial vehicles is given in **Table below:**

Traffic Data 2018-2019	Location	Direction (Up & Down)	BUS	LMV/ LCV	2-Axle Trucks	3-Axle Trucks	Multi Axle	Total
7-days	Khellani on NH-244	Average	114	370	358	308	36	1186

The details of Traffic Volume Count, AADT and commercial Vehicle Calculations of the

Project Stretch is attached in Annexure 1.

7.8.1.2 VDF:

VDF has been calculated on the basis of Axle Load Survey carried on various types of vehicles. The VDF Calculations are given in Annexure 2.

The summary of the Calculated VDF location wise is shown in below table:

Khellani on NH-244	Summary	LCV	Bus	2-Axle	3-Axle	Multi Axle
	Average V.D. F	0.46	0.62	4.93	0.76	3.93

7.8.1.3 Cumulative Million Standard Axle:

Based on the commercial vehicles per day (CVPD) for the project road and VDF, Cumulative Million Standard Axle of the Project road has been calculated with a growth rate of 5.0% to 10 % for 15 years design period time, distribution factor is taken as 0.40. The Calculation of the MSA is as follows:

Location	MSA				
	10 Years	15 Years	20 Years	25 years	Adopted design MSA for 15 years
Khellani on NH-244	5.468	9.448	14.562	21.127	20 MSA

The Calculation Sheet of MSA is attached in Annexure 3.

As per clause 5.4 of IRC: SP:73-2018, Flexible pavement shall be designed for a minimum design period of 15 years subject to the condition that design traffic shall not be less than 20 msa.

7.9 Design CBR:

For new constructions, the soil support value pertains to the strength of the subgrade in terms of CBR. Materials from borrow areas will be used for constructing the subgrade, and accordingly, the engineering characteristics of these materials are relevant. For this purpose, as a part of the soils and materials survey, the Consultants have identified possible borrow areas all along the project road and have carried out laboratory tests on representative samples from these, including 4-day soaked CBR on specimens compacted at 97% MDD (heavy compaction). Besides these, suitable material available from roadway excavation for widening the road formation may be also used, subject to fulfilment of requirement of the soil parameters.

Based on the material investigations carried out on the project road, it is found that the existing ground is within the range of 9.7% - 11.8 % CBR at majority of locations. Hence, keeping in view the availability of material within the permissible leads, However for the safety measures and on conservative basis of design, the CBR value of 10% has considered for the Pavement design. The details of the CBR along with the 90th Percentile are attached in the Annexure-4 of the Report.

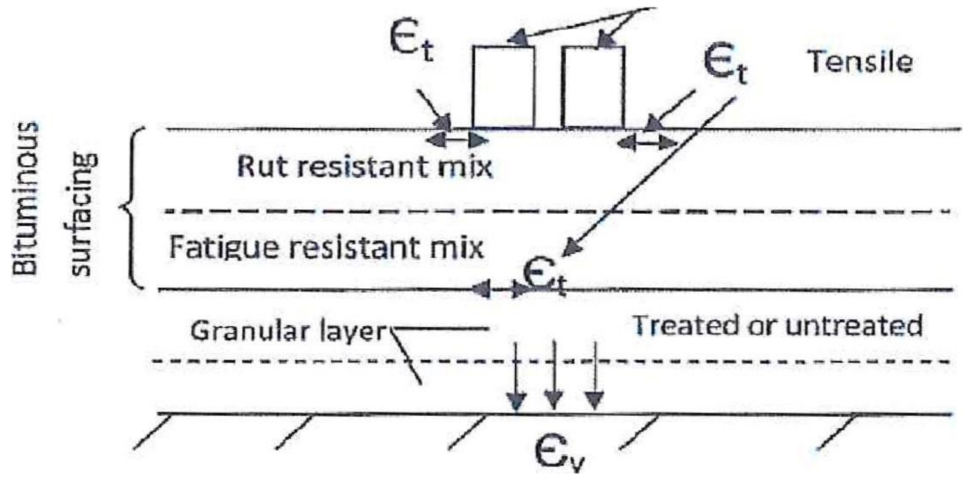
7.10 Design of Flexible Pavement by IRC Method

7.10.1 Pavement Model

The flexible pavement is modelled as an elastic multilayer structure. Stresses and strains at critical locations (fig. showing below) are computed using linear layered elastic model. The stress - strain analysis software IITPAVE has been used for the computation of stress and strain in flexible pavements as mentioned below.

i. Tensile Strain (€$_t$) at bottom of bituminous layer, which can cause cracking in the bituminous layer.

ii. And Vertical Compressive Strain (€$_v$) at the top of sub grade, which can cause rutting failure of pavement layers.



7.10.2 Fatigue in Bottom Layer of Bituminous Pavement and Fatigue Life

With every load repetition, the tensile strain developed at the bottom of the bituminous layer develops micro cracks, which go on widening and expanding till the load repetitions are large enough for the cracks to propagate to the surface over an area of the surface that is unacceptable from the point of view of long-term serviceability of the pavement. The phenomenon is called fatigue of the bituminous layer and the number of load repetitions in terms of standard axles that causes fatigue denotes the fatigue life of the pavement.

Fatigue Model- Fatigue model has been calibrated in the R-56 (54) studies using the pavement performance data collected during the R-6 (57) and R-19 (58) studies sponsored by MORTH. Two fatigue equations were fitted, one in which the computed strains in 80 per cent of the actual data in the scatter plot were higher than the limiting strains predicted by the model (and termed as 80 per cent reliability level in these guidelines) and the other corresponding to 90 per cent reliability level. The two equations for the conventional bituminous mixes designed by Marshall method are given below-

$N_f = 1.6064 * C * 10^{-04} \times [1/€_t]^{3.89} * [1/M_{Rm}]^{0.854}$ ………. (80 percent reliability)

$N_f = 0.5161 * C * 10^{-04} \times [1/€_t]^{3.89} * [1/M_{Rm}]^{0.854}$ ……….. (90 percent reliability)

Where,

$C = 10^M$, and $M = 4.84 \{[V_{be}/(V_a + V_{be})] - 0.69\}$

V_a = percent volume of air void in the mix used in the bottom bituminous layer;

V_{be} = per cent volume of effective bitumen in the mix used in the bottom bituminous layer;

N_f = fatigue life in number of standard axis;

$€_t$ = Maximum tensile strain at the bottom of the bituminous layer;

M_R = Resilient modulus of the bituminous layer.

The flexible pavement has low flexural strength and hence layers reflect the deformation of the lower layers/subgrade on to the surface layer after the withdrawal of wheel load. To control the deflections in the subgrade so that no permanent deflections results the pavement thickness is so designed that the stresses on the sub grade soil are kept within its bearing power. Loading of bituminous pavement requires the stiffest layers to be placed at the surface with successive weaker layers down to sub grade.

For structural design, only the number of commercial vehicles of laden weight of 8 tonnes or more and their axle loading will be considered.

7.11 Sub Base Layer

The sub-base layer serves three functions like to protect the sub-grade from over stressing, to provide a platform for the construction traffic and to serve as drainage and filter layer.

7.11.1 Unbound Sub-Base Layer:

Material passing through 0.425mm (425 micron), LL & PI shall not more than 25 and 6 %. Material shall have a minimum 10% fines value of 50 KN when tested in compliance with BS:812. The water absorption value (as per IS 2386) of the coarse aggregate shall be less than 2%, if not soundness test shall be carried out as per IS 383. 100% sample should pass through 75mm sieve and only 3-10% sample should pass through 0.075mm sieve for all the three grades. When coarse graded sub base is used as a drainage layer, Loss Angels abrasion value should be less than 40, so that there is no crushing during the rolling and the permeability is retained. The sub-base should be composed of two layers, the lower layer forms the separation/filter layer to prevent intrusion of sub grade soil into the pavement and upper layer forms the drainage layer to drain away any water that may enter through surface cracks.

Strength Parameter: Resilient Modulus (M_{Rgsb})

$M_{Rgsb} = 0.2 \times h^{(0.45)} \times M_{R\ subgrade}$, where h is thickness of subbase layer in mm.

MR value of subbase is dependent on MR value of subgrade since weaker subgrade does not permit higher modulus of the upper layer because of deformation under loads.

$M_{R\ subgrade} = 10 \times CBR$ if Subgrade CBR is <=5

$M_{R\ subgrade} = 17.6 \times (CBR)^{0.64}$ if subgrade CBR is >5

7.12 Base Layer:

7.12.1 Unbound Base Layer:

Base layer consists of WMM, WBM, Crusher run macadam, reclaimed concrete etc. Relevant specifications of IRC/MORTH are to be adopted for the construction.

When both sub-base and base layers are made up of unbound granular layers, the composite resilient modulus of the granular subbase and base are as follows:

$M_{R\ granular} = 0.2 \times h^{0.45} \times M_{R\ subgrade}$,

where 'h' is combined thickness of subbase and base layers in mm.

Poisson's ration of granular bases and sub-base is recommended as 0.35.

7.13 Bituminous Layers (Binder and Surface)

Binder layer consists of DBM and BM are to be adopted for construction. It is act like as load distribution and supporting layer.

Surface layer consists of BC, SDBC and PC are to be adopted for construction.

Strength Parameter: Resilient Modulus (MRBC/DBM)

The strength of bituminous mix based on extensive laboratory testing of Resilient Modulus Test. Based on the study data of India, IRC: 37-2018 recommended resilient modulus (in MPa) for different mix types and temperatures are given below.

Mix Type	Temperature ^{0}C				
	20	**25**	**30**	**35**	**40**
BC and DBM for VG 10 bitumen	2300	2000	1450	1000	800
BC and DBM for VG30 bitumen	3500	3000	2500	1700	1250
BC and DBM for VG 40 bitumen	6000	5000	4000	3000	2000
BC and DBM for Modified bitumen	5700	3800	2400	1650	1300
BM with VG 10 bitumen	500 MPa at 35^0 **C**				
BM with VG 30 bitumen	700 MPa at 35^0 **C**				
WMM/RAP treated with 3 percent bitumen emulsion/foamed bitumen	600 MPa at 35^0 **C** (laboratory values vary from 600 to 1200 MPa for water saturated samples				

7.14 Pavement design as per IRC 37:2018:

Pavement design is carried out in accordance with IRC: 37:2018 for the following base and sub-base options.

- Unbound - Granular base and sub-base

Table - 1: Inputs for the Pavement Design

Design Inputs	Total Construction
Design Life	
	15 years
Design MSA	
	20
Design CBR	
CBR for entire Stretch	10 %

7.15 Methodology for Pavement Sections with Design CBR Of 10 %

Pavement design procedures for the total stretch were accomplished using the principles of mechanistic design and were in general accordance with the postulates of IRC: 37-2018. The IITPAVE software was used for this evaluation.

The allowable strains in pavement layers were calculated in terms of two primary pavement distress criteria: **fatigue cracking and rutting**. The actual strains arising in the pavement layers due to traffic loading were then calculated, assuming suitable thickness values for different pavement layers. The assumed pavement crust was deemed to be safe for the design loads if the actual strains were less that the allowable strains.

7.15.1 Allowable Strains in the Pavement Structure

The allowable strains in the pavement layers were calculated primarily based on two pavement distress criteria: fatigue cracking and rotting. The distress of fatigue cracking is more critical in the bituminous layer in the pavement crust. This type of cracking is usually initiated at the bottom of the bituminous layer after repeated application of the axle loads. This initiation means that the actual horizontal tensile strain at the bottom of the bituminous layer has exceeded a certain limit, which is the allowable strain.

The allowable tensile strains were calculated using the fatigue criteria equation as outlined in the Appendix I of IRC: 37-2018. The equation is as follows.

$Nf = 1.6064 * C * 10^{-04} \times [1/€t]^{3.89} * [1/M_{Rm}]^{0.854}$ .... (80 percent reliability)

$Nf = 0.5161 * C * 10^{-04} \times [1/€t]^{3.89} * [1/M_{Rm}]^{0.854}$ .... (90 percent reliability)

Equation No. 1 is recommended for use for traffic up to 30 MSA where normal bituminous mixes with VG 40 bitumen can be used.

The distress of rutting is more critical in the subgrade under the pavement crust. This type of cracking is usually initiated at the top of the subgrade layer after repeated application of the axle loads. This initiation means that the actual vertical compressive strain at the top of the subgrade layer has exceeded a certain limit, which is the allowable strain.

The allowable compressive strains were calculated using the rutting criteria equation as outlined in the Appendix I of IRC:37-2018. The equation is as follows.

$N_r = 4.1656 X 10^{-8} X (1/E_z)^{4.5337}$-----------3 (80% Reliability)

$N_r = 1.41 X 10^{-8} X (1/E_z)^{4.5337}$---------------4 (90% Reliability)

N_r = Number of cumulative standard axles to produce 20 mm rutting.

E_z = Maximum Vertical subgrade strain (micro strain)

Equation No. 3 is recommended for use for traffic up to 30 MSA where normal bituminous mixes with VG 40 bitumen can be used.

7.15.2 Actual Strains in the Pavement Structure

The actual tensile strains were calculated using the various pavement design parameters as inputs in the IITPAVE programs. The actual strains are computed using various trial pavement structural layer combinations.

The average maximum and minimum temperature are noted as 35 °C and -5 °C in the project area respectively. An average pavement temperature of 30 °C has been considered for pavement design and selection of modulus of bitumen.

The tyre pressure used in the analysis was 0.56 MPa (560 K.pa). Standard axle used was dual type, having a mass of 8160 kg. This resulted in a single tyre load of 20,000 N. The Poisson's ratio of bituminous layer, granular layer and sub-grade layers is taken as 0.35.

The pavement layer thickness is derived for the traffic volume of 20 msa corresponding to 10 % CBR, the pavement crust thickness is tabulated below according to IRC: 37 - 2018 plate 6.

Table- 2: Pavement structural Analysis with 10 % CBR & 20 MSA as per IITPAVE

Sl. NO	CBR	MSA	Elastic Modulus			Thickness (mm)					Actual strain (micro)	Allowable strain (micro)	Actual Strains (micro)	Allowable Strains (micro)
			sub-grade	GSB/ WMM	BT layers	BC	DBM	WMM	GSB	Total	Tensile Strain	Tensile Strain	Vertical Strain	Vertical Strain
1	10	20	76.83	240.16	4000	40	70	250	200	560	193.5	323.1	319.4	577.73

The detailed output of IIT-Pave is attached in Annexure-5

IIT PAVE Analysis		
1	Design Life	15 Years
2	Design MSA	**20**
3	Design CBR	10%
4	CBR for entire Stretch	10%
5	Pavement Thickness as per Plate 6 (with Unbound base & Sub base)	
	BC	40
	DBM	70
	WMM	250
	GSB	200
6	Resilient Modulus of Subgrade	76.83
	$M_{R\ Subgrade} = 17.6 * (CBR)^{0.64}$ for CBR > 5	
7	Elastic Modulus of granular layers	240.163
	$(M_{R\ granular} = 0.2 * h^{0.45} * M_{R\ Subgrade})$	
8	Poisson's ratio for Subgrade	0.35
9	Poisson's ratio for granular & bituminous layers	0.35
10	Bitumen Grade	**VG 40**
11	Pavement Temperature	**30^0C**
12	Resilient Modulus of Bituminous layers	**4000**
13	Fatigue & Rutting Strain	
	As per IRC 37, since Design Traffic < 30 MSA - 80% Reliability	
(i)	Allowable Strains-	
(a)	Fatigue, Nf - $(2.21 * (10)^{-04} * [1/€_t]^{3.89} * [1/M_R]^{0.854}$	
	Allowable Fatigue Strain (€t)	323.1
(b)	Rutting, N - $4.1656 \times 10^{-08} [1/€_v]^{4.5337}$	
	Allowable Rutting Strain (€v)	577.7
(ii)	Actual Strains generated by IIT PAVE	
(a)	Fatigue Strain (€t)	193.5
(b)	Rutting Strain (€v)	319.4

As the allowable Strain is more than actual generated strains by IIT PAVE software, the pavement is safe

7.15.3 Recommended Pavement Crust Composition

The traffic volume of 20 msa and 10 % of CBR being considered as per the availability of material, The Actual strains are Less than the Allowable strains hence the Pavement Design is safe.

Table- 4: Recommended Pavement Composition

Project Road:	**Goha – Khellani Road**							
Flexible Pavement Composition	**CBR**	**MSA**	**VG**	**Pavement Crust Composition (mm)**				
				BC	**DBM**	**WMM**	**GSB**	**Total**
	10%	20	VG - 40	40	70	250	200	560

7.16 Conclusions

Recommendations for Pavement Design:

- The flexible pavement has been designed for design life of 15 years and projected traffic.
- The sub base and base courses are designed for 15 years and 20 MSA projected traffic and design CBR of 10 %.

Annexure 1

PCU Equivalents	0.5		1		1.5		3		1.5		3		3		4.5		4.5		1.5		Total Fast-Moving Vehicles		Total All Vehicles	
Vehicle Type	FAST MOVING VEHICLES																							
	2-Wheeler		Passenger Car		Bus				LCV		Truck						Agricultural Tractor							
					Mini Bus		Standard Bus		4 Tyre		2-Axle		3-Axle		Multi Axle		With Trailor		Without Trailor					
Direction	UP	DN	UP	DN	UP	DN	UP	DN	UP	DN	UP	DN	UP	DN	UP	DN	UP	DN	UP	DN	UP	DN	UP	DN
Day 1	445	463	392	369	27	29	27	23	184	195	171	176	146	156	18	12	31	37	16	19	1457	1478	1457	1478
Day 2	478	477	386	370	28	30	22	28	185	192	172	178	152	153	18	20	33	36	19	17	1493	1501	1493	1501
Day 3	463	461	370	358	27	29	28	26	175	194	182	189	149	156	16	18	36	32	14	19	1460	1482	1460	1482
Day 4	412	478	367	379	27	29	36	28	188	182	180	188	141	163	21	12	37	36	16	18	1426	1513	1426	1513
Day 5	453	464	360	379	24	30	31	36	184	182	172	175	160	145	20	21	36	35	17	18	1457	1486	1457	1486
Day 6	465	439	351	388	27	30	23	28	175	178	185	182	163	144	20	19	36	34	16	17	1462	1460	1462	1460
Day 7	461	438	371	358	29	25	28	26	192	182	175	181	160	166	19	17	33	35	18	16	1485	1444	1485	1444
Total	**3178**	**3219**	**2595**	**2600**	**191**	**204**	**197**	**197**	**1283**	**1307**	**1236**	**1269**	**1072**	**1083**	**131**	**117**	**243**	**246**	**113**	**121**	**10238**	**10363**	**10238**	**10363**
Total Up/Down	**6397**		**5196**		**395**		**394**		**2590**		**2506**		**2155**		**248**		**488**		**234**		**20602**		**20602**	
Average	**453**	**459**	**370**	**371**	**27**	**29**	**28**	**28**	**183**	**186**	**176**	**181**	**153**	**154**	**18**	**16**	**34**	**35**	**16**	**17**	**1458**	**1476**	**1458**	**1476**
AADT No.	**914**		**743**		**57**		**57**		**370**		**358**		**308**		**36**		**70**		**34**		**2947**		**2947**	
AADT PCU	**457**		**743**		**86**		**171**		**555**		**1074**		**924**		**162**		**315**		**51**		**4538**		**4538**	
Directional Distribution	**49.6**	**50.2**	**49.8**	**49.9**	**47.4**	**50.9**	**49.1**	**49.1**	**49.5**	**50.3**	**49.2**	**50.6**	**49.7**	**50.0**	**50.0**	**44.4**	**48.6**		**47.1**	**50.0**	**49.5**	**50.1**	**49.47**	**50.08**
Composition by Vol.	**31.01**		**25.21**		**1.93**		**1.93**		**12.56**		**12.15**		**10.45**		**1.22**		**2.38**		**1.15**		**100.00**		**100.00**	
Composition by PCU	**10.07**		**16.37**		**1.88**		**3.77**		**12.23**		**23.67**		**20.36**		**3.57**		**6.94**		**1.12**		**99.99**		**99.99**	

Annexure 2

VDF

LCV

Sl. No.	Commodity	Wheel Load (kg)		Axle Load (KN)		Equivalency Factors			Gross Vehicle Weight (GVW) in KN	Vehicle Damage Factor (VDF)
		1st	2nd	1st	2nd	SW-FSA	DW-SA	SW-RSA		
1	Bricks	1002	4926	19.66	96.65	0.008		4.888	116.307	4.896
2	Empty	401	1598	7.87	31.35	0.000		0.054	39.220	0.054
3	grocery	1922	3408	37.71	66.86	0.113		1.120	104.575	1.233
4	Goods	1155	4624	22.66	90.72	0.015	1.654		113.384	1.669
5	construction material	1893	2453	37.14	48.13	0.107		0.301	85.269	0.407
6	vegetables	1990	4321	39.04	84.78	0.130		2.894	123.822	3.024
7	sand	1837	2267	36.04	44.48	0.095	0.096		80.520	0.190
8	Goods	1025	4694	20.11	92.10	0.009		4.030	112.207	4.039
9	Bricks	2178	2576	42.73	50.54	0.187		0.366	93.273	0.552
10	electronic material	1255	3597	24.62	70.57	0.021		1.390	95.196	1.410
11	wheat	1996	4844	39.16	95.04	0.132		4.570	134.201	4.702
12	vegetables	1058	4555	20.76	89.37	0.010		3.574	110.127	3.584
13	grocery	1872	2087	36.73	40.95	0.102		0.157	77.676	0.259
14	Goods	1710	3748	33.55	73.54	0.071	0.714		107.086	0.785
15	Empty	421	1658	8.26	32.53	0.000		0.063	40.790	0.063
16	Empty	1112	1604	21.82	31.47	0.013		0.055	53.288	0.068
17	Empty	872	1424	17.11	27.94	0.005		0.034	45.048	0.039
18	Empty	912	1471	17.89	28.86	0.006		0.039	46.754	0.045
19	Empty	763	1715	14.97	33.65	0.003		0.072	48.618	0.075
20	Empty	647	1465	12.69	28.74	0.001		0.038	41.437	0.040
21	Empty	1034	1593	20.29	31.25	0.009		0.053	51.542	0.063
22	Empty	516	1653	10.12	32.43	0.001		0.062	42.556	0.063
23	Empty	546	1708	10.71	33.51	0.001		0.071	44.223	0.071
24	Empty	1149	1598	22.54	31.35	0.014		0.054	53.896	0.069
25	Empty	407	1478	7.99	29.00	0.000		0.040	36.984	0.040
26	Empty	721	1535	14.15	30.12	0.002		0.046	44.263	0.048
27	Empty	852	1612	16.72	31.63	0.004		0.056	48.344	0.060
28	Empty	587	1496	11.52	29.35	0.001		0.042	40.868	0.043
29	Empty	699	1446	13.71	28.37	0.002		0.036	42.085	0.038
30	Empty	799	1723	15.68	33.81	0.003		0.073	49.482	0.077
31	Empty	1230	1730	24.13	33.94	0.019		0.074	58.075	0.093
32	Empty	1181	1539	23.17	30.20	0.016		0.047	53.366	0.063
33	Empty	953	1517	18.70	29.76	0.007		0.044	48.461	0.051
34	Empty	888	1594	17.42	31.27	0.005		0.054	48.697	0.059
35	Empty	431	1622	8.46	31.82	0.000		0.057	40.280	0.058
36	Empty	481	1406	9.44	27.59	0.000		0.032	37.023	0.033
37	Empty	1089	1443	21.37	28.31	0.012		0.036	49.678	0.048
38	Empty	882	1713	17.30	33.61	0.005		0.071	50.914	0.077
39	Empty	648	1709	12.71	33.53	0.001		0.071	46.244	0.072
40	Empty	760	1664	14.91	32.65	0.003		0.064	47.559	0.066
41	Empty	940	1667	18.44	32.71	0.006		0.064	51.149	0.071
42	Empty	664	1460	13.03	28.65	0.002		0.038	41.673	0.039
43	Empty	1187	1638	23.29	32.14	0.016		0.060	55.427	0.076
44	Empty	643	1767	12.62	34.67	0.001		0.081	47.284	0.082

Sl. No.	Commodity	Wheel Load (kg)		Axle Load (KN)		Equivalency Factors			Gross Vehicle Weight (GVW) in KN	Vehicle Damage Factor (VDF)
		1st	2nd	1st	2nd	SW-FSA	DW-SA	SW-RSA		
45	Empty	1031	1618	20.23	31.75	0.009		0.057	51.973	0.066
46	Empty	651	1563	12.77	30.67	0.001		0.050	43.439	0.051
47	Empty	1172	1419	22.99	27.84	0.016		0.034	50.835	0.049
48	Empty	687	1745	13.48	34.24	0.002		0.077	47.716	0.079
49	Empty	1222	1712	23.98	33.59	0.019		0.071	57.565	0.090
50	Empty	649	1431	12.73	28.08	0.001		0.035	40.810	0.036
51	Empty	573	1514	11.24	29.70	0.001		0.044	40.947	0.045
52	Empty	899	1778	17.64	34.88	0.005		0.083	52.523	0.088
53	Empty	528	1510	10.36	29.63	0.001		0.043	39.986	0.044
54	Empty	653	1499	12.81	29.41	0.002		0.042	42.222	0.043
55	Empty	514	1418	10.08	27.82	0.001		0.034	37.906	0.034
56	Empty	864	1490	16.95	29.23	0.005		0.041	46.185	0.046
57	Empty	495	1743	9.71	34.20	0.000		0.077	43.910	0.077
58	Empty	761	1733	14.93	34.00	0.003		0.075	48.932	0.078
59	Empty	774	1480	15.19	29.04	0.003		0.040	44.223	0.043
60	Empty	498	1434	9.77	28.14	0.001		0.035	37.906	0.036
61	Empty	684	1609	13.42	31.57	0.002		0.056	44.989	0.057
62	Empty	833	1458	16.34	28.61	0.004		0.038	44.949	0.042
63	Empty	905	1778	17.76	34.88	0.006		0.083	52.640	0.089
64	Empty	1013	1794	19.88	35.20	0.009		0.086	55.073	0.095
65	Empty	401	1533	7.87	30.08	0.000		0.046	37.945	0.046
									VDF	**0.459**

BUS

Sl. No.	Commodity	Wheel Load (kg)		Axle Load (KN)		Equivalency Factors		Gross Vehicle Weight (GVW) in KN	Vehicle Damage Factor (VDF)
		1st	2nd	1st	2nd	SW-FSA	DW-SA		
1	Passenger	2622	3179	51.44	62.37	0.392	0.369	113.82	0.76
2	Passenger	2099	3453	41.18	67.75	0.161	0.514	108.93	0.68
3	Passenger	2329	3502	45.69	68.71	0.244	0.544	114.40	0.79
4	Empty	1634	2088	32.06	40.97	0.059	0.069	73.03	0.13
5	Passenger	2655	3616	52.09	70.95	0.412	0.619	123.04	1.03
6	Passenger	2235	3112	43.85	61.06	0.207	0.339	104.91	0.55
7	Passenger	2089	3657	40.99	71.75	0.158	0.647	112.74	0.81
8	Passenger	2209	3391	43.34	66.53	0.198	0.478	109.87	0.68
9	Empty	1444	2436	28.33	47.79	0.036	0.127	76.13	0.16
10	Passenger	2422	3337	47.52	65.47	0.286	0.449	112.99	0.73
11	Passenger	2610	3784	51.21	74.24	0.385	0.742	125.45	1.13
12	Passenger	2328	3188	45.68	62.55	0.244	0.374	108.22	0.62
13	Passenger	2074	3360	40.69	65.92	0.154	0.461	106.62	0.61
14	Passenger	2052	3073	40.26	60.29	0.147	0.323	100.55	0.47
15	Passenger	2458	3308	48.23	64.90	0.303	0.433	113.13	0.74
16	Passenger	2384	3494	46.77	68.55	0.268	0.539	115.33	0.81
17	Passenger	2473	3524	48.52	69.14	0.310	0.558	117.66	0.87
18	Empty	1336	2237	26.21	43.89	0.026	0.091	70.10	0.12
19	Passenger	2306	3183	45.24	62.45	0.235	0.371	107.69	0.61
20	Passenger	2562	3293	50.27	64.61	0.358	0.425	114.88	0.78
21	Passenger	2345	3786	46.01	74.28	0.251	0.743	120.29	0.99
22	Passenger	2274	3633	44.62	71.28	0.222	0.630	115.90	0.85
23	Empty	1414	2283	27.74	44.79	0.033	0.098	72.54	0.13

Sl. No.	Commodity	Wheel Load (kg)		Axle Load (KN)		Equivalency Factors		Gross Vehicle Weight (GVW) in KN	Vehicle Damage Factor (VDF)
		1st	2nd	1st	2nd	SW-FSA	DW-SA		
24	Passenger	2109	3685	41.38	72.30	0.164	0.667	113.68	0.83
25	Passenger	2086	3576	40.93	70.16	0.157	0.592	111.09	0.75
26	Passenger	2038	3713	39.99	72.85	0.143	0.688	112.83	0.83
27	Passenger	2681	3320	52.60	65.14	0.429	0.440	117.74	0.87
28	Passenger	2268	3629	44.50	71.20	0.220	0.627	115.70	0.85
29	Passenger	2239	3590	43.93	70.44	0.209	0.601	114.36	0.81
30	Passenger	2664	3772	52.27	74.01	0.418	0.732	126.27	1.15
31	Passenger	2647	3148	51.93	61.76	0.408	0.355	113.70	0.76
32	Passenger	2578	3108	50.58	60.98	0.367	0.338	111.56	0.70
33	Passenger	2069	3773	40.59	74.03	0.152	0.733	114.62	0.89
34	Passenger	2208	3293	43.32	64.61	0.197	0.425	107.93	0.62
35	Passenger	2681	3535	52.60	69.36	0.429	0.565	121.96	0.99
36	Passenger	2562	3366	50.27	66.04	0.358	0.464	116.31	0.82
37	Passenger	2476	3591	48.58	70.46	0.312	0.602	119.03	0.91
38	Empty	1555	2535	30.51	49.74	0.049	0.149	80.25	0.20
39	Passenger	1644	2173	32.26	42.63	0.061	0.081	74.89	0.14
40	Passenger	1398	2292	27.43	44.97	0.032	0.100	72.40	0.13
41	Passenger	1623	2436	31.84	47.79	0.058	0.127	79.64	0.18
42	Passenger	1508	2467	29.59	48.40	0.043	0.134	77.99	0.18
43	Passenger	1614	2419	31.67	47.46	0.056	0.124	79.13	0.18
44	Passenger	1379	2144	27.06	42.07	0.030	0.076	69.12	0.11
45	Passenger	1588	2272	31.16	44.58	0.053	0.096	75.73	0.15
46	Passenger	1664	2488	32.65	48.81	0.064	0.139	81.46	0.20
47	Empty	1677	2291	32.90	44.95	0.066	0.100	77.85	0.17
48	Passenger	2026	3644	39.75	71.50	0.140	0.638	111.25	0.78
49	Passenger	2296	3662	45.05	71.85	0.231	0.651	116.90	0.88
50	Passenger	2512	3195	49.29	62.69	0.331	0.377	111.97	0.71
51	Passenger	2573	3636	50.48	71.34	0.364	0.632	121.82	1.00
52	Passenger	2674	3297	52.46	64.69	0.424	0.427	117.15	0.85
53	Empty	1531	2136	30.04	41.91	0.046	0.075	71.95	0.12
								VDF	**0.619**

2 AXLE

Sl. No.	Commodity	Wheel Load (kg)		Axle Load (KN)		Equivalency Factors		Gross Vehicle Weight (GVW) in KN	Vehicle Damage Factor (VDF)
		1st	2nd	1st	2nd	SW-FSA	DW-SA		
1	Parcel	2345	3995	46.01	78.38	0.251	0.922	124.391	1.173
2	Sand	5005	8400	98.20	164.81	5.209	18.012	263.006	23.221
3	Goods	1950	1860	38.26	36.49	0.120	0.043	74.752	0.163
4	wheat	1890	1630	37.08	31.98	0.106	0.026	69.062	0.131
5	construction material	2050	1760	40.22	34.53	0.147	0.035	74.752	0.181
6	Empty	2340	1755	45.91	34.43	0.249	0.034	80.344	0.283
7	bitumen	3260	5490	63.96	107.71	0.938	3.286	171.675	4.224
8	grocery	2190	1670	42.97	32.77	0.191	0.028	75.733	0.219
9	goods	2190	1700	42.97	33.35	0.191	0.030	76.322	0.221
10	Empty	1660	2160	32.57	42.38	0.063	0.079	74.948	0.142
11	Oil	3570	5860	70.04	114.97	1.348	4.266	185.017	5.614
12	Chips	3250	3560	63.77	69.85	0.926	0.581	133.612	1.507
13	Grocery	3280	6740	64.35	132.24	0.961	7.466	196.592	8.427
14	Drum	3210	5000	62.98	98.10	0.881	2.261	161.080	3.142

Sl. No.	Commodity	Wheel Load (kg)		Axle Load (KN)		Equivalency Factors		Gross Vehicle Weight (GVW) in KN	Vehicle Damage Factor (VDF)
		1st	2nd	1st	2nd	SW-FSA	DW-SA		
15	Goods	3260	5490	63.96	107.71	0.938	3.286	171.675	4.224
16	Bitumen	2990	5385	58.66	105.65	0.663	3.042	164.318	3.706
17	Grocery	3360	6000	65.92	117.72	1.058	4.689	183.643	5.747
18	Foods	3390	4945	66.51	97.02	1.096	2.163	163.533	3.260
19	Goods	3575	6010	70.14	117.92	1.356	4.720	188.058	6.076
20	Bricks	3595	7090	70.53	139.11	1.387	9.142	209.640	10.528
21	Goods	3500	6010	68.67	117.92	1.246	4.720	186.586	5.966
22	Aggregates	3690	5930	72.40	116.35	1.539	4.474	188.744	6.013
23	Aggregates	3785	6390	74.26	125.37	1.704	6.032	199.634	7.735
24	fruits	3289	6749	64.53	132.42	0.971	7.506	196.946	8.477
25	electronic instruments	3219	5009	63.16	98.28	0.891	2.277	161.433	3.169
26	bitumen	3269	5499	64.14	107.89	0.948	3.308	172.028	4.256
27	reinforcement	3560	6075	69.85	119.19	1.333	4.927	189.039	6.261
28	goods	3369	6009	66.10	117.90	1.069	4.717	183.996	5.786
29	food items	3212	5002	63.02	98.14	0.884	2.265	161.159	3.148
30	cold drinks	3262	5492	64.00	107.75	0.940	3.291	171.753	4.231
31	poultry	2992	5387	58.70	105.69	0.665	3.047	164.396	3.712
32	animals	3362	6002	65.96	117.76	1.061	4.695	183.722	5.755
33	sand	3392	4947	66.55	97.06	1.099	2.167	163.611	3.266
34	goods	3577	6012	70.18	117.96	1.359	4.726	188.136	6.085
35	bitumen	3597	7092	70.57	139.15	1.390	9.152	209.718	10.542
36	vegetables	3502	6012	68.71	117.96	1.249	4.726	186.665	5.975
37	medical equipment	3692	5932	72.44	116.39	1.542	4.480	188.823	6.022
38	Aggregates	3787	6392	74.30	125.41	1.707	6.039	199.712	7.747
39	cement	3291	6751	64.57	132.45	0.974	7.515	197.024	8.488
40	fodder	3221	5011	63.20	98.32	0.894	2.281	161.512	3.175
41	animals	3271	5501	64.18	107.93	0.950	3.313	172.107	4.263
42	wheat	3562	6077	69.89	119.23	1.336	4.934	189.117	6.270
43	grocery	3371	6011	66.14	117.94	1.072	4.723	184.075	5.795
44	goods	3214	5004	63.06	98.18	0.886	2.268	161.237	3.154
45	animals	3264	5494	64.04	107.79	0.942	3.296	171.832	4.238
46	fruits	3005	5389	58.96	105.73	0.677	3.051	164.690	3.728
47	vegetables	3364	6004	66.00	117.80	1.063	4.701	183.800	5.764
48	medical equipment	3394	4949	66.59	97.10	1.102	2.170	163.690	3.272
49	drum	3579	6014	70.22	117.99	1.362	4.732	188.215	6.095
50	cylinder	3599	7094	70.61	139.18	1.393	9.162	209.797	10.555
51	sand	3222	5012	63.22	98.34	0.895	2.283	161.551	3.177
52	construction material	3272	5502	64.20	107.95	0.951	3.315	172.146	4.267
53	vegetables	3250	6078	63.77	119.25	0.926	4.937	183.015	5.863
54	aggregates	3372	6012	66.16	117.96	1.073	4.726	184.114	5.799
55	fodder	3215	5005	63.08	98.20	0.887	2.270	161.276	3.157
56	grocery	3265	5495	64.06	107.81	0.943	3.298	171.871	4.242
57	electronic instruments	3006	5390	58.98	105.75	0.678	3.053	164.730	3.731
58	food items	3365	6005	66.02	117.82	1.064	4.704	183.839	5.769
59	cold drinks	3395	4950	66.61	97.12	1.103	2.172	163.729	3.275
60	silk	3095	6015	60.72	118.01	0.762	4.736	178.738	5.497
								VDF	**4.932**

3 AXLE

Sl. No.	Commodity	Wheel Load (kg)			Axle Load (KN)			Equivalency Factors		Gross Vehicle Weight (GVW) in KN	Vehicle Damage Factor (VDF)
		1st	2nd	3rd	1st	2nd	3rd	SW-FSA	DW-TA2		
1	Empty	2978	1820	1730	58.43	35.71	33.94	0.653	0.049	128.079	0.702
2	grocery	2351	6690	6600	46.13	131.26	129.49	0.254	9.635	306.876	9.889
3	Goods	3431	6610	6250	67.32	129.69	122.63	1.150	8.447	319.629	9.598
4	construction material	3386	6250	6010	66.43	122.63	117.92	1.091	6.978	306.975	8.069
5	vegetables	2176	6240	5530	42.69	122.43	108.50	0.186	5.927	273.621	6.113
6	Empty	2343	1633	1465	45.97	32.04	28.74	0.250	0.028	106.752	0.279
7	Empty	2584	1700	1453	50.70	33.35	28.51	0.370	0.031	112.560	0.401
8	Empty	2238	1478	1410	43.91	29.00	27.66	0.208	0.021	100.572	0.230
9	Empty	2353	1542	1427	46.17	30.25	28.00	0.254	0.024	104.418	0.278
10	Empty	2447	1467	1465	48.01	28.78	28.74	0.298	0.023	105.536	0.320
11	Empty	2421	1685	1417	47.50	33.06	27.80	0.285	0.029	108.361	0.314
12	Empty	2384	1662	1473	46.77	32.61	28.90	0.268	0.030	108.283	0.298
13	Empty	2201	1429	1437	43.18	28.04	28.19	0.195	0.021	99.415	0.216
14	Empty	2421	1618	1451	47.50	31.75	28.47	0.285	0.027	107.714	0.313
15	Empty	2223	1442	1414	43.62	28.29	27.74	0.203	0.021	99.650	0.223
16	Empty	2130	1610	1475	41.79	31.59	28.94	0.171	0.028	102.318	0.199
17	Empty	2195	1668	1498	43.07	32.73	29.39	0.193	0.031	105.183	0.224
18	Empty	2221	1549	1451	43.58	30.39	28.47	0.202	0.025	102.436	0.227
19	Empty	2125	1489	1466	41.69	29.21	28.76	0.169	0.024	99.670	0.193
20	Empty	2354	1460	1454	46.19	28.65	28.53	0.255	0.022	103.358	0.277
21	Empty	2372	1439	1404	46.54	28.23	27.55	0.263	0.020	102.318	0.283
22	Empty	2598	1645	1471	50.97	32.27	28.86	0.378	0.029	112.109	0.407
23	Empty	2147	1578	1468	42.12	30.96	28.80	0.176	0.027	101.887	0.203
24	Empty	2458	1592	1410	48.23	31.24	27.66	0.303	0.025	107.125	0.328
25	Empty	2194	1699	1468	43.05	33.33	28.80	0.192	0.031	105.183	0.223
26	Empty	2327	1576	1449	45.66	30.92	28.43	0.243	0.026	105.006	0.269
27	Empty	2169	1614	1407	42.56	31.67	27.61	0.184	0.026	101.828	0.209
28	Empty	2110	1480	1430	41.40	29.04	28.06	0.165	0.022	98.492	0.187
29	Empty	2497	1628	1413	48.99	31.94	27.72	0.323	0.026	108.656	0.349
30	Empty	2323	1677	1466	45.58	32.90	28.76	0.242	0.030	107.243	0.272
31	Empty	2437	1420	1472	47.81	27.86	28.88	0.293	0.022	104.555	0.314
32	Empty	2150	1469	1474	42.18	28.82	28.92	0.177	0.023	99.925	0.201
33	Empty	2306	1566	1420	45.24	30.72	27.86	0.235	0.025	103.829	0.259
34	Empty	2513	1655	1475	49.31	32.47	28.94	0.331	0.030	110.716	0.361
35	Empty	2204	1483	1417	43.24	29.10	27.80	0.196	0.022	100.140	0.218
36	Empty	2418	1462	1466	47.44	28.68	28.76	0.284	0.023	104.889	0.306
37	Empty	2219	1446	1431	43.54	28.37	28.08	0.201	0.021	99.984	0.222
38	Empty	2481	1515	1400	48.68	29.72	27.47	0.315	0.022	105.870	0.337
39	Empty	2202	1557	1483	43.20	30.55	29.10	0.195	0.026	102.848	0.222
40	Empty	2308	1408	1481	45.28	27.62	29.06	0.236	0.022	101.965	0.257
41	Empty	2285	1462	1410	44.83	28.68	27.66	0.226	0.021	101.180	0.247
42	Empty	2377	1460	1430	46.64	28.65	28.06	0.265	0.022	103.339	0.287
43	Empty	2274	1565	1414	44.62	30.71	27.74	0.222	0.024	103.064	0.246
44	Empty	2286	1668	1444	44.85	32.73	28.33	0.227	0.029	105.909	0.256
45	Empty	2241	1629	1436	43.97	31.96	28.17	0.209	0.027	104.104	0.237
46	Empty	2354	1534	1499	46.19	30.10	29.41	0.255	0.026	105.693	0.281
47	Empty	2456	1591	1429	48.19	31.22	28.04	0.302	0.026	107.439	0.328
48	Empty	2481	1465	1401	48.68	28.74	27.49	0.315	0.021	104.908	0.335
49	Empty	2592	1686	1451	50.86	33.08	28.47	0.375	0.030	112.403	0.405
50	Empty	2532	1644	1425	49.68	32.26	27.96	0.341	0.027	109.892	0.369
51	Empty	2214	1427	1489	43.44	28.00	29.21	0.199	0.022	100.651	0.222
52	Empty	2380	1631	1412	46.70	32.00	27.70	0.266	0.026	106.399	0.293
53	Empty	2438	1574	1489	47.83	30.88	29.21	0.293	0.027	107.930	0.320
54	Empty	2147	1619	1423	42.12	31.76	27.92	0.176	0.026	101.808	0.203

Sl. No.	Commodity	Wheel Load (kg)			Axle Load (KN)			Equivalency Factors		Gross Vehicle Weight (GVW) in KN	Vehicle Damage Factor (VDF)
		1st	2nd	3rd	1st	2nd	3rd	SW-FSA	DW-TA2		
55	Empty	2559	1619	1456	50.21	31.76	28.57	0.356	0.028	110.539	0.384
56	Empty	2385	1594	1465	46.79	31.27	28.74	0.269	0.027	106.811	0.296
57	Empty	2532	1644	1425	49.68	32.26	27.96	0.341	0.027	109.892	0.369
58	Empty	2214	1427	1489	43.44	28.00	29.21	0.199	0.022	100.651	0.222
59	Empty	2380	1631	1412	46.70	32.00	27.70	0.266	0.026	106.399	0.293
60	Empty	2438	1574	1489	47.83	30.88	29.21	0.293	0.027	107.930	0.320
61	Empty	2147	1619	1423	42.12	31.76	27.92	0.176	0.026	101.808	0.203
62	Empty	2559	1619	1456	50.21	31.76	28.57	0.356	0.028	110.539	0.384
63	Empty	2385	1594	1465	46.79	31.27	28.74	0.269	0.027	106.811	0.296
64	Empty	2536	1648	1429	49.76	32.33	28.04	0.343	0.028	110.127	0.371
65	Empty	2218	1431	1493	43.52	28.08	29.29	0.201	0.023	100.886	0.223
66	Empty	2384	1635	1416	46.77	32.08	27.78	0.268	0.027	106.635	0.295
67	Empty	2442	1578	1493	47.91	30.96	29.29	0.295	0.027	108.165	0.323
68	Empty	2151	1623	1427	42.20	31.84	28.00	0.178	0.027	102.044	0.204
										VDF	**0.765**

MULTI AXLE

Sl. No.	Commodity	Wheel Load (kg)				Axle Load (KN)				Equivalency Factors			Gross Vehicle Weight (GVW) in KN	Vehicle Damage Factor (VDF)
		1st	2nd	3rd	4th	1st	2nd	3rd	4th	SW-FSA	SW-SA	DW-TA2		
1	Grocery	3520.00	2925.00	5832.00	3847.00	69.06	57.39	114.42	75.48	1.27	0.61	2.71	316.35	4.593
2	Rice	3890.00	4468.00	6550.00	6452.00	76.32	87.66	128.51	126.59	1.90	3.31	8.83	419.08	14.036
3	Empty	2406.00	1647.00	1406.00	1391.00	47.21	32.31	27.59	27.29	0.28	0.06	0.02	134.40	0.358
4	Empty	2483.00	1515.00	1461.00	1332.00	48.72	29.72	28.66	26.13	0.32	0.04	0.02	133.24	0.378
5	Empty	2269.00	1522.00	1484.00	1374.00	44.52	29.86	29.12	26.96	0.22	0.04	0.02	130.45	0.285
													VDF	**3.930**

Annexure 3

MSA

Year	Standard Bus	LCV	2 Axle	3 Axle	MAV	Yearly Design ESA	Cumulative Design ESA	MSA	Design Period
VDF	**0.62**	**0.46**	**4.93**	**0.76**	**3.93**				
2018	**114**	**370**	**358**	**308**	**36**	347906		**Base Year**	
2019	120	407	376	323	38	366541			
2020	126	448	395	340	40	386231			
2021	132	488	414	357	42	406742			
2022	139	532	435	374	44	428387	428387	**0.428**	**1-year**
2023	145	580	457	393	46	451232	879619		
2024	153	632	480	413	48	475347	1354966		
2025	160	689	504	433	51	500808	1855774		
2026	168	744	529	455	53	527233	2383007	**2.383**	**5-year**
2027	177	803	555	478	56	555090	2938096		
2028	186	868	583	502	59	584459	3522555		
2029	195	937	612	527	62	615426	4137981		
2030	205	1012	643	553	65	648081	4786062		
2031	215	1083	675	581	68	681841	5467903	**5.468**	**10-year**
2032	226	1159	709	610	71	717384	6185287		
2033	237	1240	744	640	75	754806	6940093		
2034	249	1327	781	672	79	794208	7734300		
2035	261	1420	821	706	83	835696	8569996		
2036	274	1505	862	741	87	878431	9448427	**9.448**	**15-year**

Annexure 4

Selection of Subgrade CBR for Pavement Design

The CBR values of the subgrade soil varies along a highway alignment even on a homogeneous section. 90th percentile CBR is recommended in guideline.

CBR Test Report				CBR Values in ascending order		
SL	Location	CBR		SL	Location	CBR
1	0.050	11.2			5.450	9.7
2	5.450	9.7			10.500	10.3
3	6.700	10.7			6.700	10.7
4	9.370	11			10.000	10.8
5	10.000	10.8			9.370	11.0
6	10.500	10.3			0.050	11.2
7	11.000	11.2			11.000	11.2
8	11.500	11.5			12.500	11.3
9	12.000	11.8			11.500	11.5
10	12.500	11.3			12.000	11.8

Calculation of percentage greater than equal to each of the values as follows-

For CBR of 09.7, Percentage greater than equal to 09.7 = 100

For CBR of 10.3, Percentage greater than equal to 10.3 = 90

For CBR of 10.8, Percentage greater than equal to 10.8 = 70

For CBR of 11.0, Percentage greater than equal to 11.0 = 60

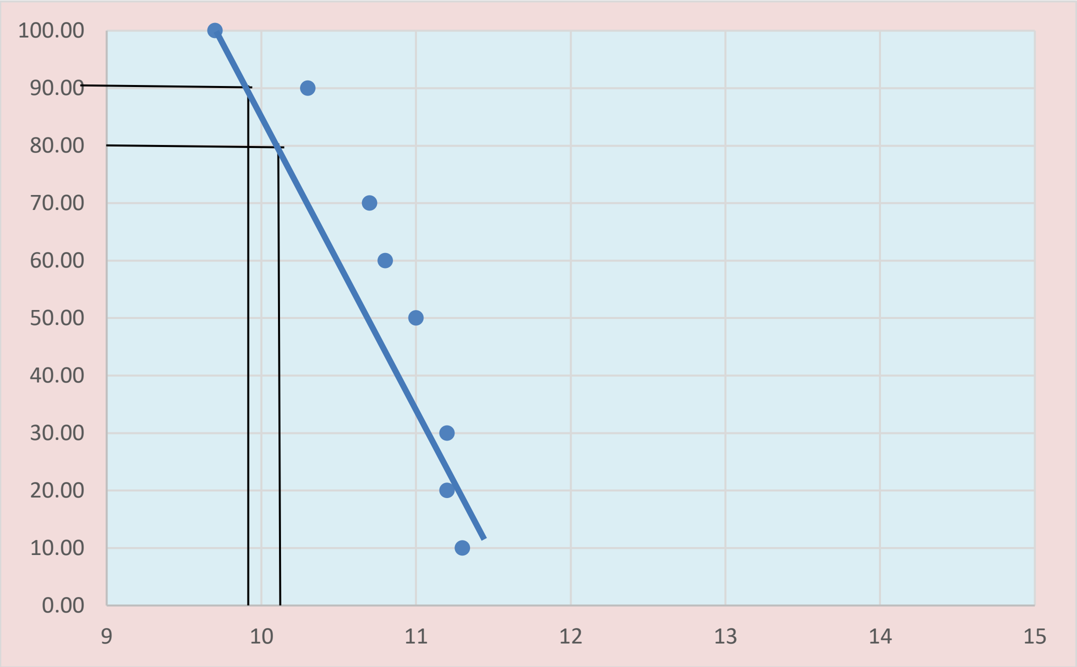
For CBR of 11.2, Percentage greater than equal to 11.2 = 50

For CBR of 11.3, Percentage greater than equal to 11.3 = 30

For CBR of 11.5, Percentage greater than equal to 11.5 = 20

For CBR of 11.8, Percentage greater than equal to 11.8 = 10

Selection of Subgrade CBR for Pavement Design



The 90th Percentile CBR value = 9.85

The 80th Percentile CBR = 10.15

The design CBR is = 10; Since the 90th percentile CBR value is less than proposed Pavement design CBR value, hence CBR value for pavement design will be 10.

Annexure 5

IIT - PAVE

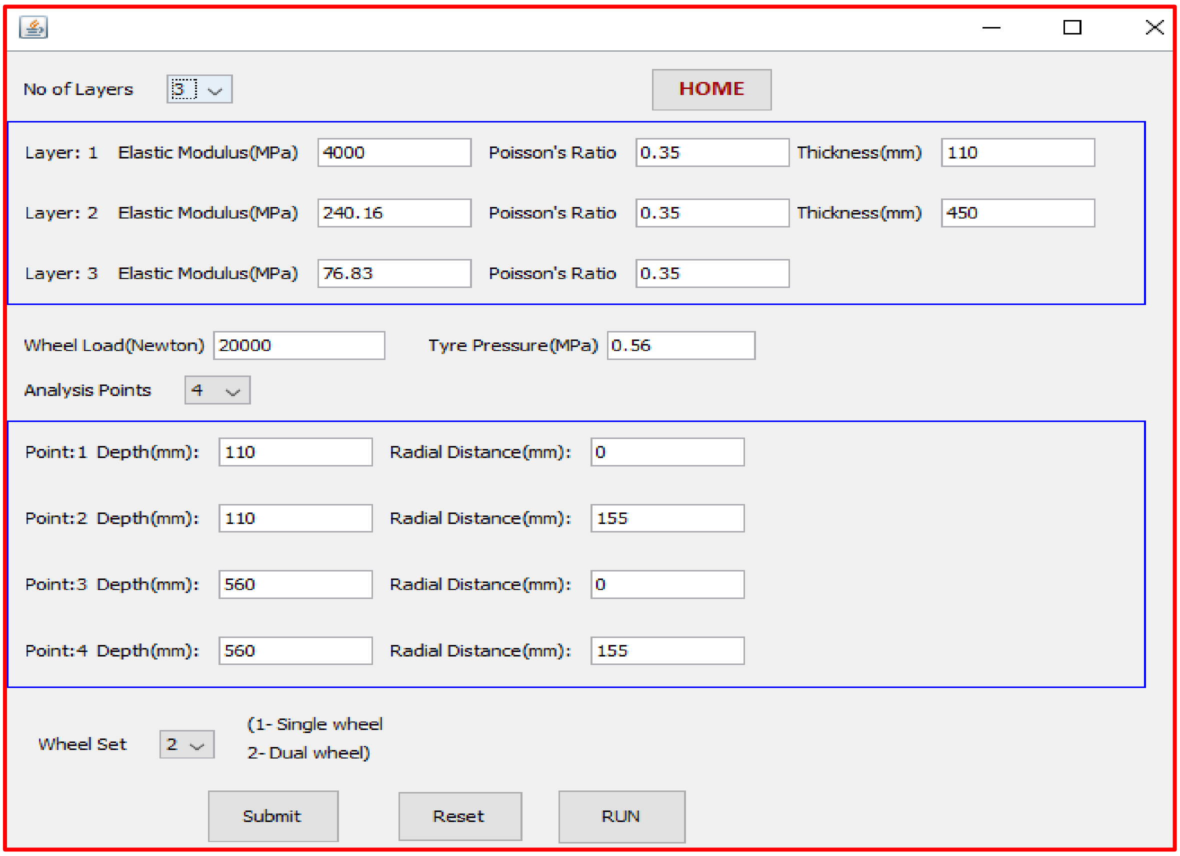


Figure- 01: Input to IITPAVE Software

IITPAVE - Notepad

File Edit Format View Help

```
No. of layers              3
E values (MPa)          4000.00   240.16    76.83
Mu values                  0.350.350.35
thicknesses (mm)         110.00   450.00
single wheel load (N) 20000.00
tyre pressure (MPa)        0.56
Dual  Wheel
  Z         R       SigmaZ       SigmaT      SigmaR      TaoRZ       DispZ       epZ         epT         epR
110.00     0.00-0.1438E+00 0.1006E+01 0.8065E+00-0.1729E-01 0.3876E+00-0.1945E-03 0.1935E-03 0.1262E-03
110.00L    0.00-0.1437E+00-0.1236E-01-0.2433E-01-0.1729E-01 0.3876E+00-0.5451E-03 0.1935E-03 0.1262E-03
110.00   155.00-0.1209E+00 0.8090E+00 0.2726E+00-0.6266E-01 0.3973E+00-0.1249E-03 0.1890E-03 0.7947E-05
110.00L  155.00-0.1209E+00-0.1263E-01-0.4484E-01-0.6266E-01 0.3973E+00-0.4198E-03 0.1890E-03 0.7947E-05
560.00     0.00-0.2186E-01 0.3148E-01 0.2737E-01-0.3609E-02 0.2661E+00-0.1768E-03 0.1231E-03 0.9993E-04
560.00L    0.00-0.2175E-01 0.2114E-02 0.7680E-03-0.3607E-02 0.2661E+00-0.2962E-03 0.1231E-03 0.9945E-04
560.00   155.00-0.2330E-01 0.3364E-01 0.3078E-01-0.4812E-02 0.2733E+00-0.1909E-03 0.1292E-03 0.1131E-03
560.00L  155.00-0.2330E-01 0.2225E-02 0.1322E-02-0.4796E-02 0.2733E+00-0.3194E-03 0.1291E-03 0.1132E-03
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Figure- 02: Output from IITPAVE Software

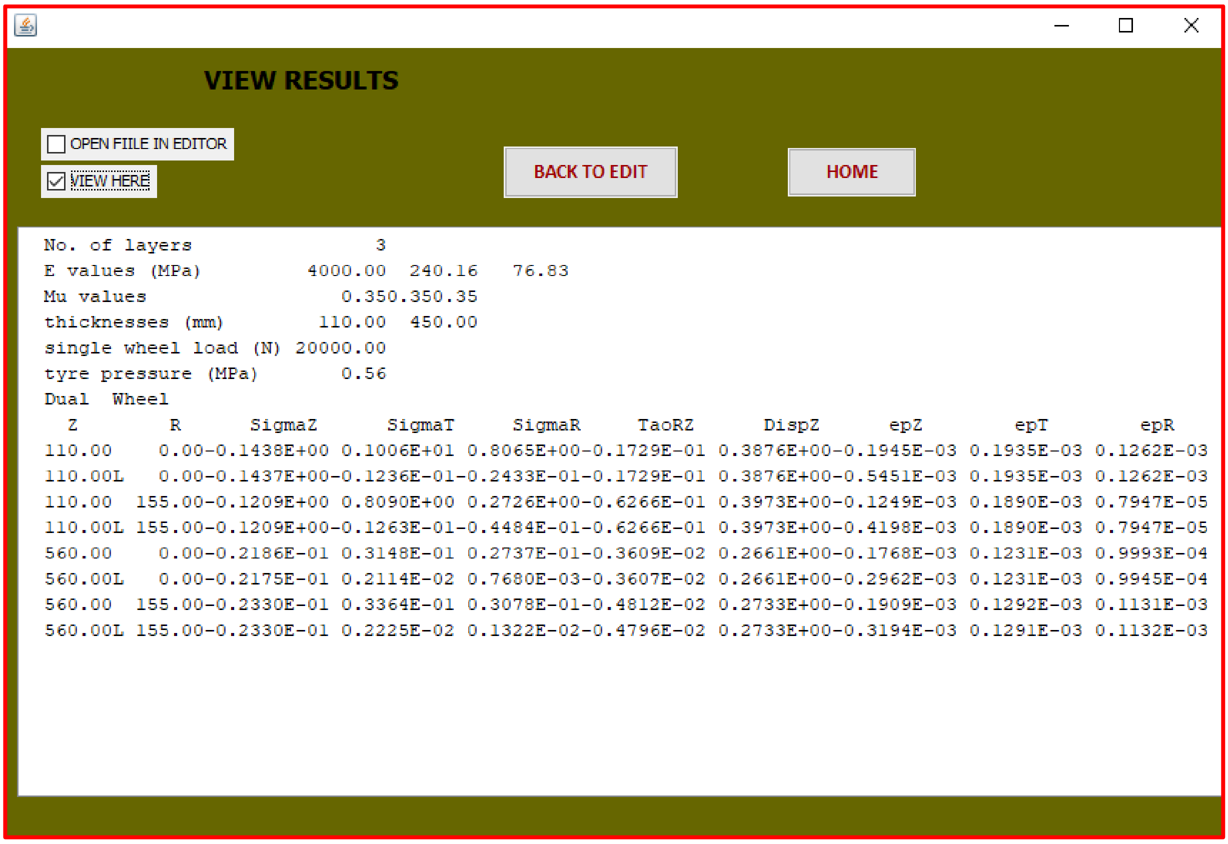

Figure- 03: Output from IITPAVE Software