NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION LTD.
(MINISTRY OF ROAD TRANSPORT & HIGHWAYS, GOVT. OF INDIA)
3RD FLOOR, PTI BUILDING, 4-PARLIAMENT STREET, NEW DELHI – 110001

NHIDCL
BUILDING INFRASTRUCTURE • BUILDING THE NATION

Consultancy Services for Feasibility Study, Preparation of Detailed Project Report and providing Pre-Construction Services for upgradation to 2 lane with paved shoulder from (i) Km 44.500 to Km 142.000 of Chattroo Village & (ii) Km 235.000 (Vailoo Village) to Km 269.000 (Khanabal) of Khellani – Kishtwar – Chattroo - Khanabal Section of NH 244 in the state of Jammu and Kashmir.

DETAILED PROJECT REPORT

KHELLANI TO CHATTROO SECTION

Volume – II A: Design Report Highways

Package-I from Design CH. Km 31+449 to Km 51+700 =20.251 km

December 2020

Rodic

Rodic Consultants Pvt. Ltd.
In JV with
Monarch Surveyors and Engineering Consultants Pvt. Ltd

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Introduction

CHAPTER - 1

INTRODUCTION

1.1 The Project Road

National Highways & Infrastructure Development Corporation Limited (NHIDCL), **Ministry of Road, Transport & Highways, Govt. of India** has been assigned **M/S Rodic Consultants Pvt. Ltd.**, New Delhi in joint venture with **M/S Monarch Surveyors and Engineering Consultant Pvt. Ltd.** as Consultants to carry out the "Consultancy Services for Feasibility Study, Preparation of Detailed Project Report and providing Pre-Construction Services for upgradation to 2 lane with paved shoulder from

(i) Km 44.500 to Km 142.000 of Chattroo Village &

(ii) Km 235.000 (Vailoo Village) to Km 269.000 (Khanabal) of Khellani – Kishtwar – Chattroo - Khanabal Section of NH 244 in the state of Jammu and 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

The entire project road (Khellani - Chhatroo) lies in the UT of Jammu and Kashmir. The project road of Khellani - Chhatroo is part of NH-244 (Old NH-1B) which runs from Batote to Khanabal via Khellani, Thatri, Kishtwar, Sinthan-Top, Vailoo, Achabal and Anantnag. The Project Road is situated in Doda and Kishtwar districts located at southern part of newly formed UT of Jammu and Kashmir. The project road stretch goes towards east from Khellani and turns north from New Thathri and finally ends near Chhatroo traversing through Kishtwar.

As per contract, the Project Road starts from existing Km 44.500 near Khellani and passes through Gangalwar, Bhuta, Suigwari, Nai Basti, Premnagar, Thatri, Darabshalla, Kandiri, Kishtwar, Marwah, Kodia, Dhadhpeth, Mughal Maidan, and Udil Gurjan and terminates at existing Km 142.000 near Chhatroo in the UT of Jammu & Kashmir.

The project road of Khellani – Chhatroo coincides with the other two DPRs. One is at its starting and another at the end point. The project's starting point coincides with the end point of Goha – Khellani tunnel project i.e. Ex Ch. 44+500 and the project's end point coincides with the starting point of approach of Vailoo tunnel project i.e. Ex Ch. 140+870. So, we have considered these two locations as our starting and End Chainages, respectively.

In future these three projects will work as a single stretch and will facilitate the traffic going towards Vailoo/Anantnag side, instead of Sinthan Pass route which is closes for almost 3-4 months during winter season, so the traffic will divert from Chhatroo and reach Vailoo/Anantnag via Vailoo Tunnel.

DPRs of Goha - Khellani Tunnel project and Vailoo Tunnel project are under preparation and the project stretch of Khellani - Chhatroo will cater as link between these two tunnel projects.

Hence, the project of Khellani-Chhatroo starts from Ex Km. 44+500 near Khellani and ends at Ex Km 140+870 near Chhatroo and has a total existing length of 96.370 Km.

The proposed stretch of Khellani – Chattroo starts near Khellani from design Ch. 31+449 (At ex. Km. 44+500) and ends near Chhatroo at design. Ch. 111+086 (At ex. Km. 140+870). Project length is 78.367 Km {79.037-1.270} Excluding Ch. 83 Tunnel Length of 1.270 Km i.e. under execution stage.

The project has been divided into five packages which are as follows:

- Package-I from Design CH. Km 31+449 to Km 51+700 =20.251 km.
- Package-II from Design CH. Km 51+700 to Km 66+535 =14.835 km.
- Package-III from Design CH. Km 67+805 to Km 80+675=12.870 km.
- Package-IV from Design CH. Km 80+675 to Km 95+550 (Kishtwar Bypass) =14.875 km.
- A Link Road (To connect the Kishtwar town) of length 1.871 Km.
- Package-V from Design CH. Km 95+550 to Km 111+066 =15.516 km.

This report deals with the **Package-I** of NH-244.

Proposed improvement under the project

The existing road shall be widening and reconstruction to a 2-lane carriageway with paved shoulder configuration. 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 DPR and Comprises of the Design Report.

Part – 1 : *Roads & Highways*

Part – 2 : *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 roadside.

Chapter – 5 : Design of Traffic Control and Other Facilities

Deals with Traffic Signs and Road Markings and other Appurtenant.

Chapter – 6 : 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 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 Design Values

Design Standards			
(i)	Design Speed (Km/hr) as per IRC SP:48-1998 Mountainous Terrain	:	50 (Ruling), 40(Minimum)
(ii)	Level of Service	:	B
(iii)	Roadway Widths (m) as per IRC SP:73-2018 Mountainous Terrain	:	11 m for 2-lanes with paved shoulders and earthen shoulder with one side hill and one side valley.
(iv)	Roadway Elements as per IRC SP:73-2018 Mountainous Terrain with Retaining wall and parapet	:	<u>Carriageway</u> 2-lane- 2X3.5m (Both Hill and Valley side) <u>Paved Shoulder</u> 2-lane- 2X1.5m (Both Hill and Valley side) <u>Earthen Shoulder</u> 1.0 m (Valley Side)

(v)	Camber as per IRC SP:73-2018	:	<u>Carriageway</u> Flexible- 2.50% Rigid - 2.00 % <u>Paved Shoulder</u> Flexible- 2.50% Rigid - 2.00 % <u>Unpaved Shoulder</u> 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
	To be designed based on soil parameters, (IRC:75-1979)		
	Fill height exceeding 6.0 m		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 45 m 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 as per IRC SP:48-1998 Mountainous Terrain	:	(Areas not affected by Snow) Ruling Minimum 80 m Absolute minimum 50 m (Snow Bound Area) Ruling Minimum 90 m Absolute minimum 60 m
(xi)	**Gradient** (As per IRC: SP:48-1998) Table 6.11		
	Mountainous Terrain		
	Ruling	:	5.00%
	Limiting	:	6.00%
	Steep Terrain		
	Ruling	:	6.00%
	Limiting	:	7.00%
(xii)	**Minimum k factor**		
	Summit Curve		
	Mountainous Terrain	:	Ruling: 15
		:	Minimum: 8.4
	Valley Curve		
	Mountainous Terrain	:	Ruling: 15
		:	Minimum: 6.6
(xiii)	**Vertical Clearance** as per IRC: SP:48-1998. (Clause no-6.7.2.1)	:	5.0 m
	Minimum Vertical Clearance of 5 mts should be given over the entire roadway at all underpasses and similarly at overhanging cliffs and semi tunnel sections.		
(xiv)	Design Flood Frequency		
	Bridges	:	100 years
	Sewers and Ditches	:	60 ears

2.1 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

2.2 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	50	40

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

2.3 Cross-Sectional Elements

2.3.1 Lane Width

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

2.3.2 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.

2.3.3 Earthen Shoulders

It is proposed to have 1 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.

2.3.4 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.

2.3.5 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

TCS Detail	TCS Type	Design Length in m
Two Lane C/W with PS & Both Side Fill & Protection as Applicable (New Construction)	TCS-1	287.5
Two Lane C/W with PS & Both Side Fill & Protection as Applicable (Reconstruction)	TCS-1A	1044
Two Lane C/W with PS and one side cut & other side Fill & Protection as Applicable (New Construction)	TCS-2	1335
Two Lane C/W with PS and one side cut & other side Fill & Protection as Applicable (Reconstruction)	TCS-3	15507
Two Lane C/W with PS and Both Side Cut & Protection as Applicable (New Construction)	TCS-4	1347.5
Major Bridge	1no.	90
Minor Bridge	9nos.	235
Viaduct	2 nos.	330
Bridge Cum Viaduct	1no.	75
Total Length in m		**20251**

2.4 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

2.5 Horizontal Alignment

To meet future traffic requirement, the existing carriageway is proposed for upgradation to 2 – lane with paved shoulder in its entire stretch.

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

Speed (km/h)	Absolute Minimum Radius (m)
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.

2.6 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

2.6.1 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

2.6.2 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.

2.6.3 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

2.7 Cross-fall

In case of 2- Lane road, TCS-1, 1A, 2, 2A, 3, 3A, 4, 4A, 5, A, B and C 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%.

2.8 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.

2.9 Roadway Width at Cross-Drainage Structures

2.9.1 Culverts

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

2.9.2 Bridges

The bridges will be built/widened as per guidelines of IRC: SP:73-2018.

2.10 Loading Standards for Bridge Structures

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

2.11 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.

2.12 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
RCC Covered Drain	:	This will be applied in urban areas. Covers will be provided at all the built-up areas use as footpath.
Catch Drain	:	This will be applied on Hill Side to protect the carriageway.

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:

- The proposed section is widening and strengthening to 2 lane with paved shoulder.
- 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 center 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 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-3, Chainage 31+601	Centre line of road
2	Vertical Curve	PVI Chainage 31+850	Summit Curve
		PVI Chainage 31+588	Valley Curve

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

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

1) HIP NO-3, Chainage 31+601

Design Parameters

R = 100 m
Δ = 38° 33'34.56"
V = 40 Km/h.

Design Calculations

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

a) Calculation of transition length (Ls)

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

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

Since c<0.8, we take c = 0.6957

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

$$= \frac{0.0215\ (40)^3}{0.6957 \times 100}$$

=19.78 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.

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

= 0.071

Adopted value e = 0.07

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

= 16 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 20 m

b) Check for the friction

$$e + f = \frac{V^2}{127\ R} = \frac{(40)^2}{127\ (100)} = \frac{1600}{127 \times 100} = 0.126$$

$$0.07 + f = 0.126$$

f = 0.056 < 0.15 (coefficient of friction should be less than or equal to 0.15)……..Hence safe

c) Features of the Curve

$$s = \frac{{L_s}^2}{24\ R} = \frac{(20)^2}{24 \times 100} = 0.167\ m$$

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

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

$$L_c = R \times \Delta_c$$

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

$$\Delta = 0.673\ Rad$$

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

$$= \frac{L_S}{2\ R} = \frac{20}{2 \times 100} = 0.1\ Rad$$

$$\Delta_c = (\Delta - 2\Delta_s)$$
$$= 0.473\ Rad$$

Therefore,

$$T_s = (100 + 0.167)Tan\ \frac{(38° \ 33'34.56")}{2} + \frac{20}{2}$$
$$= 45.039$$
$$L_c = 100 \times 0.473$$
$$= 47.30\ m$$
$$E_s = (100 + 0.167)\ Sec\ \frac{(38° \ 33'34.56")}{2} - 100$$
$$= 6.12\ m$$

$L_{Total} = 47.30 + 2 \times 20$
= 87.3 m

C. Design Calculation for Vertical Curve

1) PVI Chainage 31+850 (Summit Curve)

Design Parameters

Grade in, N_1 = 6.25 %
Grade out, N_2 = -4.746 %
Grade difference, N = 10.996 %

Design speed V = 50 Kmph.

PVI Level = 1116.234 m

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

Calculations

Assuming, L > ISD

$$L = \frac{NS^2}{9.6} = \frac{0.10966 \times (125.74)^2}{9.6}$$ = 181.105 m > ISD..............OK

Length of curve provided = 200 m

Chainage at the start of curve = PVI. Chainage – L/2
= 31850.429 – 200/2
= 31750.429 m

Chainage at the end of curve = PVI. Chainage + L/2
= 31850.429 + 200/2
= 31950.429 m

Level at start of curve: = Level of PVI - (N_1 X L/2)
= 1116.234 – (0.0625 X 200/2)
= 1109.984 m

Level at end of curve: = Level of PVI +(N_2 x L/2)
= 1116.234 + (-0.04746 X 200/2)
= 1111.488 m

2) PVI Chainage 31+588 (Valley Curve)

Design Parameters

Grade in, N_1 = -6.311 %
Grade out, N_2 = 6.250 %
Grade difference, N = -12.561 %

Design speed V = 50 kmph.

PVI Level = 1099.814 m

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

Calculations

Assuming, L > SSD

$$L = \frac{NS^2}{(1.5 + .035 \times S)} = \frac{0.12561 \times (62.87)^2}{(1.50 + 0.035 \times 62.87)}$$ = 134.175 m > SSD………. OK

So, provide the minimum valley curve
Length of curve provided = 130 m

Chainage at the start of curve = PVI. Chainage – L/2
= 31587.7 – 130/2
= 31522.7 m

Chainage at the end of curve = PVI. Chainage + L/2
= 31587.7 + 130/2
= 31652.7 m

Level at start of curve: = Level of PVI - (N_1 X L/2)
= 1099.814 - (-0.06311X 130/2)
= 1103.916 m

Level at end of curve: = Level of PVI + (N_2 x L/2)
= 1099.814 + (0.0625 X 130/2)
= 1103.877 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:

PCC Drain on Hill Side					
Sr. No.	Design Chainage		Design Length (m)	Side	Roadside Drain Length (m)
	From	To			
1	31449	31492.5	43.5	RHS	43.5
2	31560	31650	90	RHS	90
3	31810	31900	90	RHS	90
4	31900	31970	70	RHS	70
5	32070	32180	110	RHS	110
6	32230	32350	120	LHS+RHS	240
7	32350	32390	40	RHS	40
8	32470	32560	90	RHS	90
9	32560	32717.5	157.5	LHS+RHS	315
10	32780	33440	660	RHS	660
11	33440	33700	260	LHS+RHS	520
12	33700	33850	150	RHS	150
13	33850	34100	250	LHS+RHS	500
14	34160	34197.5	37.5	RHS	37.5
15	34272.5	34340	67.5	RHS	67.5
16	34340	34900	560	LHS+RHS	1120
17	35215	35287.5	72.5	RHS	72.5
18	35302.5	35340	37.5	RHS	37.5
19	35340	35460	120	RHS	120
20	35510	35550	40	RHS	40
21	35610	36180	570	RHS	570
22	36240	37092	852	RHS	852

PCC Drain on Hill Side					
Sr. No.	Design Chainage		Design Length (m)	Side	Roadside Drain Length (m)
	From	To			
23	37182	41260	4078	RHS	4078
24	41300	43010	1710.00	RHS	1710
25	43062.5	43704.5	642	RHS	642
26	43729.5	44750	1020.5	RHS	1020.5
27	44880	45130	250	RHS	250
28	45190	46102.5	912.5	RHS	912.5
29	46117.5	47570	1452.5	RHS	1452.5
30	47694	47740	46	RHS	46
31	47800	50950	3150	RHS	3150
32	51150	51180	30	RHS	30
33	51290	51700	410	RHS	410
Total Roadside PCC Drainage Length					**19537**

Catch Water Drainage List					
Sr. No.	Design Chainage		Design Length (m)	Side	Roadside Drain Length (m)
	From	To			
1	31449	31492.5	43.5	RHS	43.5
2	31560	31650	90	RHS	90
3	31810	31900	90	RHS	90
4	31900	31970	70	RHS	70
5	32070	32180	110	RHS	110
6	32230	32350	120	LHS+RHS	240
7	32350	32390	40	RHS	40
8	32470	32560	90	RHS	90
9	32560	32717.5	157.5	LHS+RHS	315
10	32780	33440	660	RHS	660
11	33440	33700	260	LHS+RHS	520
12	33700	33850	150	RHS	150
13	33850	34100	250	LHS+RHS	500
14	34160	34197.5	37.5	RHS	37.5
15	34272.5	34340	67.5	RHS	67.5
16	34340	34900	560	LHS+RHS	1120
17	35215	35287.5	72.5	RHS	72.5
18	35302.5	35340	37.5	RHS	37.5
19	35340	35460	120	RHS	120
20	35510	35550	40	RHS	40
21	35610	36180	570	RHS	570
22	36240	37092	852	RHS	852
23	37182	41260	4078	RHS	4078
24	41300	43010	1710.00	RHS	1710
25	43062.5	43704.5	642	RHS	642
26	43729.5	44750	1020.5	RHS	1020.5
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Catch Water Drainage List					
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30	47694	47740	46	RHS	46
31	47800	50950	3150	RHS	3150
32	51150	51180	30	RHS	30
33	51290	51700	410	RHS	410
Total Length in m					**19537**

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.

$$Q = A\left(\frac{1}{n} R^{2/3} S^{1/2}\right)$$

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).

Traffic Control

CHAPTER – 5

DESIGN OF TRAFFIC CONTROL AND OTHER FACILITIES

5.1 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

5.2 Junctions

5.2.1 Major & Minor Junctions

There are total of 2 major junctions and 25 minor junctions 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.

5.3 Traffic Signs and Road Markings

5.3.1 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.

5.3.2 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.

5.4 Bypasses & Realignments

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

5.5 Service Roads/Slip Roads

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

5.6 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.

5.7 Other Appurtenances

5.7.1 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.

5.7.2 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.

5.7.3 Roadside Safety Barriers

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

Type of Crash Barrier	Location Provided
a) Flexible type	Not Provided
b) Metal Beam Type	Provided where TCS – 1, 1A, 2 and 3 are followed.
c) Rigid type (like concrete crash barrier)	Not Provided
d) Pedestrian Steel Railing	Not Provided

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

5.7.4 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.

5.8 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 – 6

PAVEMENT DESIGN

6 PAVEMENT DESIGN REPORT

6.1 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.

6.2 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.

6.3 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.

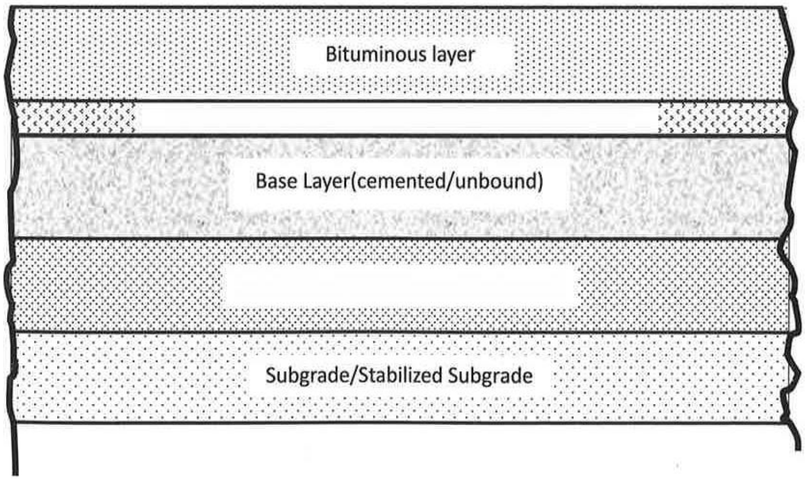
C. The whole pavement design concept has been divided into two parts:

- 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.

6.4 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.

6.4.1 Bituminous Pavement with Unbound Base and Sub Base Layer

6.4.1.1 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 enough strength and thickness to serve the construction traffic.

6.4.1.2 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.

6.4.1.3 Bituminous Layers

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

6.5 Recommended Pavement Option

6.5.1 Flexible Pavement:

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

6.5.2 Rigid Pavement:

No rigid pavement is proposed.

6.6 Parameters for Design

6.6.1 Design Life

The design life adopted in the analysis is 20 years for flexible pavement.

6.6.2 Traffic Homogenous Sections

The following stretch has been adopted for traffic homogenous sections:

- Khellani (Ch. 44+500) – Gandoh Junction (Ch. 82+710).
- Gandoh Jn. (Ch. 82+710) – Kishtwar (Ch. 110+560).
- Kishtwar (Ch. 110+560) – Chattroo (Ch. 140+870).

6.6.3 No. of Lanes for Proposed Carriageway

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

6.7 Functional and Structural Overlay

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

6.7.1 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.

6.7.2 Structural Overlay

If the pavement is not strengthened before the expiry of its design life (20 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.

6.8 Preliminary Investigation

6.8.1 TRAFFIC

6.8.1.1 Commercial Vehicles:

The base year traffic has been assessed by carrying out traffic surveys at 3 Locations. For pavement design purpose, commercial vehicles of laden weight more than 8 tonnes have been considered.

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

Traffic Data 2019	Location	Direction (Up & Down)	BUS	LMV/ LCV	2-Axle Trucks	3-Axle Trucks	Total
7-days	Pull Doda	Average	53	114	170	14	351
7-days	Kishtwar	Average	41	125	197	24	387

Traffic Data 2019	Location	Direction (Up & Down)	BUS	LMV/ LCV	2-Axle Trucks	3-Axle Trucks	Total
7-days	Poochal	Average	8	37	40	0	85

The details of Traffic Volume Count, AADT and commercial Vehicle Calculations of the Project Stretch is attached in Annexure 3.2 (Volume-IA: Annex. To Main Report).

6.8.1.2 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 3.3 (Volume-IA: Annex. To Main Report).

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

Location	Summary	LCV	Bus	2-Axle	3-Axle
Pull Doda	Average VDF	1.546	1.385	2.929	8.247
Kishtwar	Average VDF	0.143	0.811	2.548	3.710
Poochal	Average VDF	1.550	0.592	3.616	-

6.8.1.3 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 20 years design period time, distribution factor is taken as 0.40. The Calculation of the MSA is as follows:

Location	MSA				
	5 Years	10 Years	15 Years	20 years	Adopted design MSA for 20 years
Pull Doda	1.058	2.408	4.131	6.330	20 MSA
Kishtwar	0.787	1.791	3.073	4.709	
Poochal	0.253	0.577	0.990	1.516	

The Calculation Sheet of MSA is attached in Annexure 1 (at the end of this chapter).

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.

6.9 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 9.35% - 12.5 % 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.

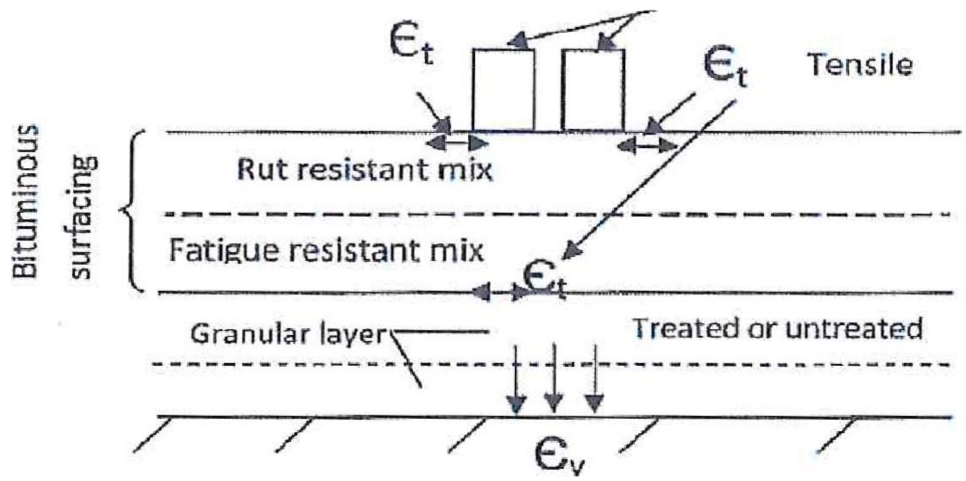
6.10 Design of Flexible Pavement by IRC Method

6.10.1 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.



6.10.2 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.

6.11 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.

6.11.1 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

6.12 Base Layer:

6.12.1 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.

6.13 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				

6.14 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	
	20 years
Design MSA	
	20
Design CBR	
CBR for entire Stretch	10 %

6.15 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.

6.15.1 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.

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

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

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.

6.15.2 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 ^oC and -5 ^oC in the project area respectively. An average pavement temperature of 20 ^oC 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 5.

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	2300	40	70	250	200	560	250.4	364.9	347.5	577.7

The detailed output of IIT-Pave is attached in Annexure – 2 (at the end of this chapter).

IIT PAVE Analysis		
1	Design Life	20 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	240.16
	$(M_{R\ granular} = 0.2 * h^{0.45} * M_{R\ Subgrade})$	
8	Poisson's ratio for Subgrade	0.35
9	Poisson's ratio for granular & bituminous layers	0.35
10	Bitumen Grade	VG 10
11	Pavement Temperature	20^0C
12	Resilient Modulus of Bituminous layers	2300
13	Fatigue & Rutting Strain	
	As per IRC 37, since Design Traffic < 30 MSA - 80% Reliability	
(i)	Allowable Strains-	
(a)	Fatigue, N_f - $1.6064 * C * 10^{-04} x [1/€t]^{3.89} * [1/M_{Rm}]^{0.854}$	
	Allowable Fatigue Strain (€t)	364.9
(b)	Rutting, N - $4.1656 x 10^{-08} [1/€_v]^{4.5337}$	
	Allowable Rutting Strain (€v)	577.7
(ii)	Actual Strains generated by IIT PAVE	
(a)	Fatigue Strain (€t)	250.4
(b)	Rutting Strain (€v)	347.5
As the allowable Strain is more than actual generated strains by IIT PAVE software, the pavement is safe		

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

6.16 Conclusions

Recommendations for Pavement Design:

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

Annexure – 1

MSA

Location – Pull Doda								
Year	Bus	LCV	2 Axle	3 Axle	Yearly Design ESA	Cumulative Design ESA	MSA	Design Period
VDF	1.39	1.546	2.929	8.25				
2019	53	114	170	14	157506		Base Year	
2020	56	120	179	15	165381			
2021	58	126	187	15	173650			
2022	61	132	197	16	182333			
2023	64	139	207	17	191449	191449	**0.191**	**1-year**
2024	68	145	217	18	201022	392471		
2025	71	153	228	19	211073	603544		
2026	75	160	239	20	221626	825170		
2027	78	168	251	21	232708	1057878	**1.058**	**5-years**
2028	82	177	264	22	244343	1302221		
2029	86	186	277	23	256560	1558781		
2030	91	195	291	24	269388	1828170		
2031	95	205	305	25	282858	2111028		
2032	100	215	321	26	297001	2408028	**2.408**	**10-years**
2033	105	226	337	28	311851	2719879		
2034	110	237	353	29	327443	3047322		
2035	116	249	371	31	343815	3391137		
2036	121	261	390	32	361006	3752144		
2037	128	274	409	34	379056	4131200	**4.131**	**15-years**
2038	134	288	430	35	398009	4529209		
2039	141	302	451	37	417910	4947119		
2040	148	318	474	39	438805	5385924		
2041	155	333	497	41	460745	5846670		
2042	163	350	522	43	483783	6330452	**6.33**	**20-years**

Location – Kishtwar								
Year	Bus	LCV	2 Axle	3 Axle	Yearly Design ESA	Cumulative	MSA	Design Period
VDF	0.81	0.143	2.548	3.71		Design ESA		
2019	**41**	**125**	**197**	**24**	117175		Base Year	
2020	43	131	207	25	123034			
2021	45	138	217	26	129185			
2022	47	145	228	28	135644			
2023	50	152	239	29	142427	142427	**0.142**	**1-year**
2024	52	160	251	31	149548	291975		
2025	55	168	264	32	157025	449000		
2026	58	176	277	34	164877	613877		
2027	61	185	291	35	173121	786998	**0.787**	**5-years**
2028	64	194	306	37	181777	968774		
2029	67	204	321	39	190865	1159640		
2030	70	214	337	41	200409	1360048		

Location – Kishtwar								
Year	**Bus**	**LCV**	**2 Axle**	**3 Axle**	**Yearly Design ESA**	**Cumulative**	**MSA**	**Design Period**
VDF	**0.81**	**0.143**	**2.548**	**3.71**		**Design ESA**		
2031	74	224	354	43	210429	1570477		
2032	77	236	371	45	220951	1791428	**1.791**	**10-years**
2033	81	247	390	48	231998	2023426		
2034	85	260	410	50	243598	2267024		
2035	89	273	430	52	255778	2522802		
2036	94	287	452	55	268567	2791369		
2037	99	301	474	58	281995	3073364	**3.073**	**15-years**
2038	104	316	498	61	296095	3369459		
2039	109	332	523	64	310900	3680358		
2040	114	348	549	67	326445	4006803		
2041	120	366	576	70	342767	4349570		
2042	126	384	605	74	359905	4709475	**4.709**	**20-years**

Location – Poochal							
Year	**Mini Bus**	**LCV**	**2 Axle**	**Yearly Design ESA**	**Cumulative Design ESA**	**MSA**	**Design Period**
VDF	**0.592**	**1.55**	**3.616**				
2019	**8**	**37**	**40**	37727		**Base Year**	
2020	8	39	42	39614			
2021	9	41	44	41595			
2022	9	43	46	43674			
2023	10	45	49	45858	45858	**0.046**	**1-year**
2024	10	47	51	48151	94009		
2025	11	50	54	50558	144567		
2026	11	52	56	53086	197654		
2027	12	55	59	55741	253394	**0.253**	**5-years**
2028	12	57	62	58528	311922		
2029	13	60	65	61454	373376		
2030	14	63	68	64527	437903		
2031	14	66	72	67753	505656		
2032	15	70	75	71141	576797	**0.577**	**10-years**
2033	16	73	79	74698	651495		
2034	17	77	83	78433	729928		
2035	17	81	87	82354	812282		
2036	18	85	92	86472	898754		
2037	19	89	96	90796	989550	**0.99**	**15-years**
2038	20	93	101	95336	1084885		
2039	21	98	106	100102	1184988		
2040	22	103	111	105107	1290095		
2041	23	108	117	110363	1400458		
2042	25	114	123	115881	1516339	**1.516**	**20-years**

Annexure – 2

IITPAVE Analysis

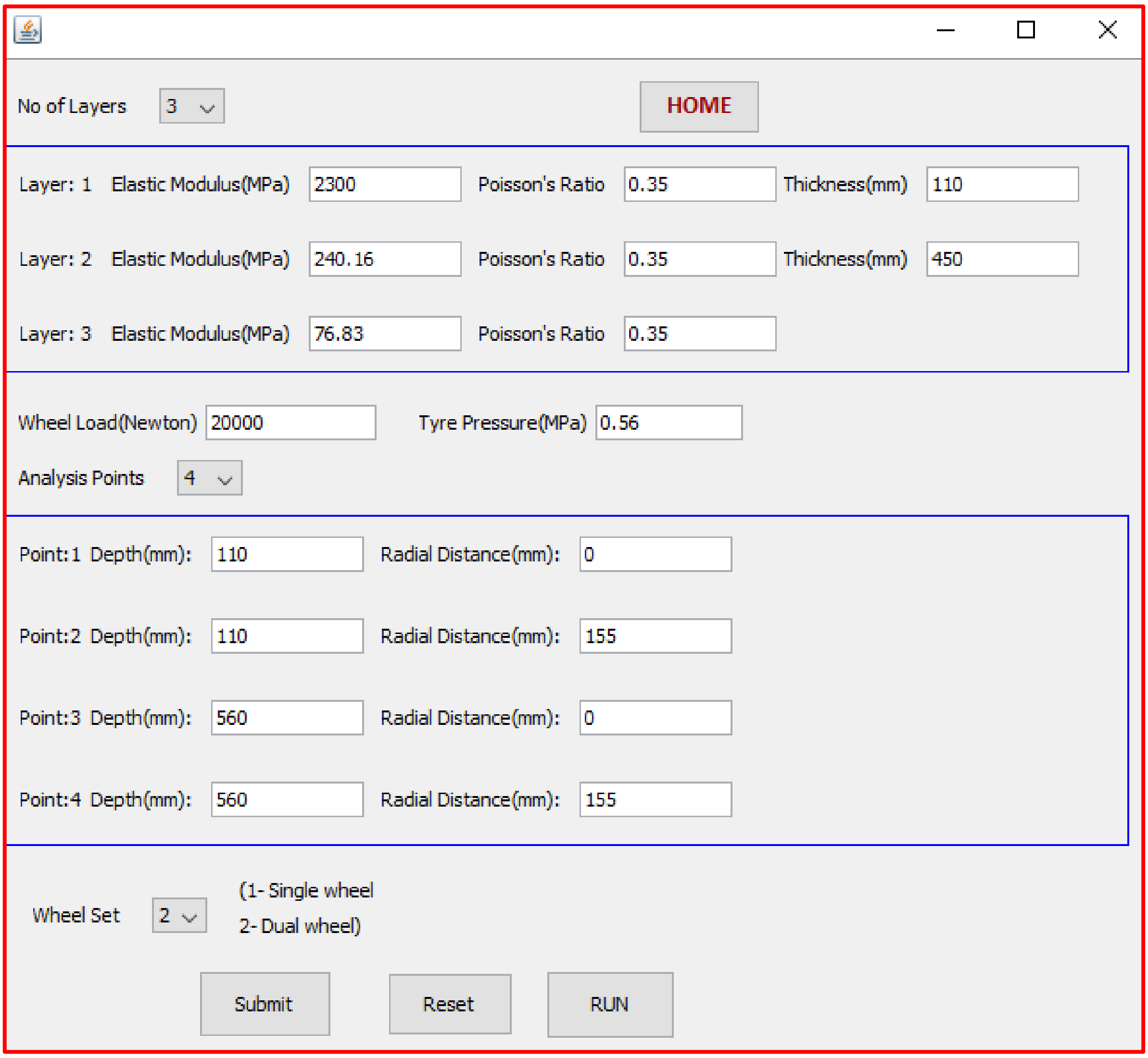
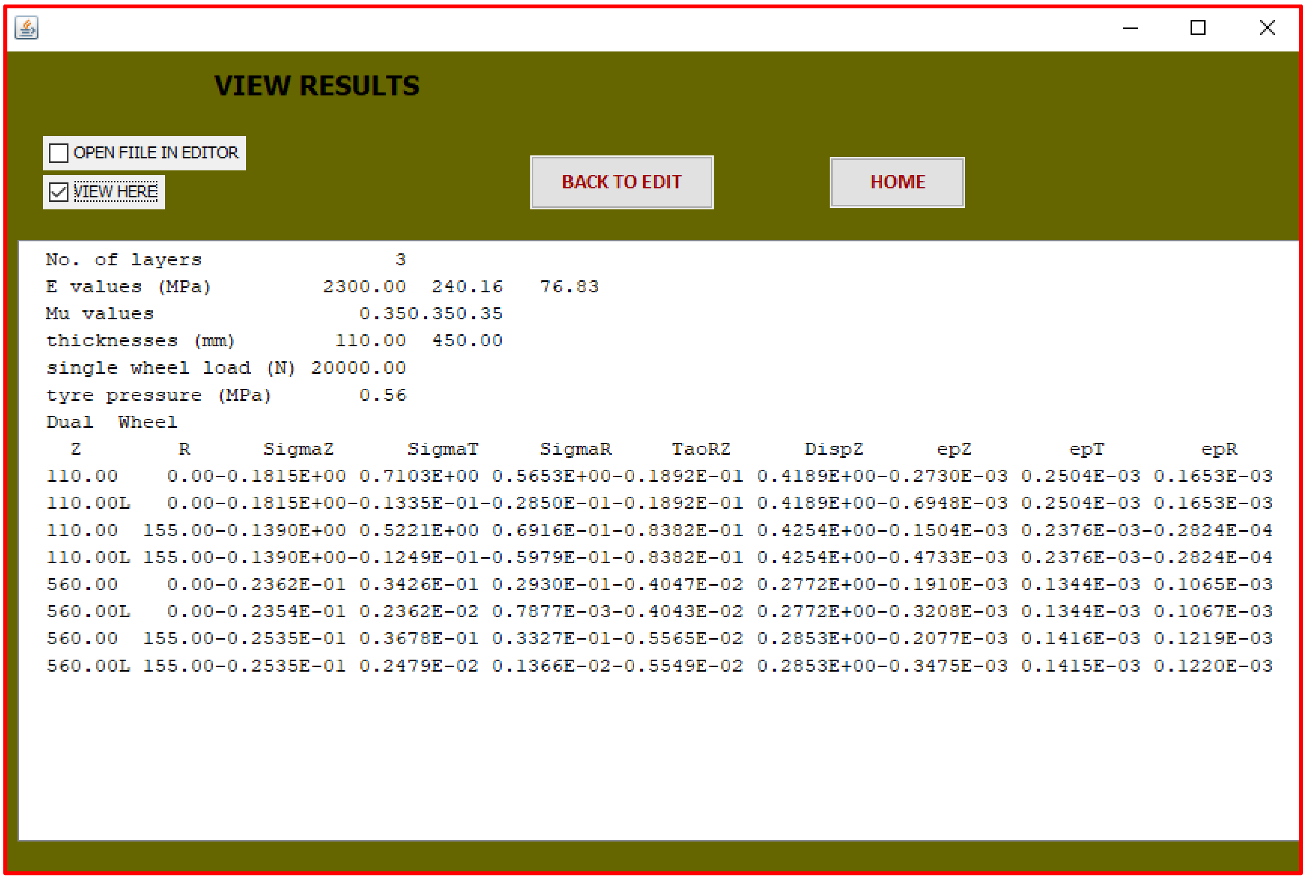


Figure- 01: Input to IITPAVE Software




```
No. of layers                 3
E values (MPa)         2300.00  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    0.00-0.1815E+00 0.7103E+00 0.5653E+00-0.1892E-01 0.4189E+00-0.2730E-03 0.2504E-03 0.1653E-03
110.00L   0.00-0.1815E+00-0.1335E-01-0.2850E-01-0.1892E-01 0.4189E+00-0.6948E-03 0.2504E-03 0.1653E-03
110.00  155.00-0.1390E+00 0.5221E+00 0.6916E-01-0.8382E-01 0.4254E+00-0.1504E-03 0.2376E-03-0.2824E-04
110.00L 155.00-0.1390E+00-0.1249E-01-0.5979E-01-0.8382E-01 0.4254E+00-0.4733E-03 0.2376E-03-0.2824E-04
560.00    0.00-0.2362E-01 0.3426E-01 0.2930E-01-0.4047E-02 0.2772E+00-0.1910E-03 0.1344E-03 0.1065E-03
560.00L   0.00-0.2354E-01 0.2362E-02 0.7877E-03-0.4043E-02 0.2772E+00-0.3208E-03 0.1344E-03 0.1067E-03
560.00  155.00-0.2535E-01 0.3678E-01 0.3327E-01-0.5565E-02 0.2853E+00-0.2077E-03 0.1416E-03 0.1219E-03
560.00L 155.00-0.2535E-01 0.2479E-02 0.1366E-02-0.5549E-02 0.2853E+00-0.3475E-03 0.1415E-03 0.1220E-03
```

Figure- 02: Output from IITPAVE Software