NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION LTD.

(MINISTRY OF ROAD TRANSPORT & HIGHWAYS, GOVT. OF INDIA)

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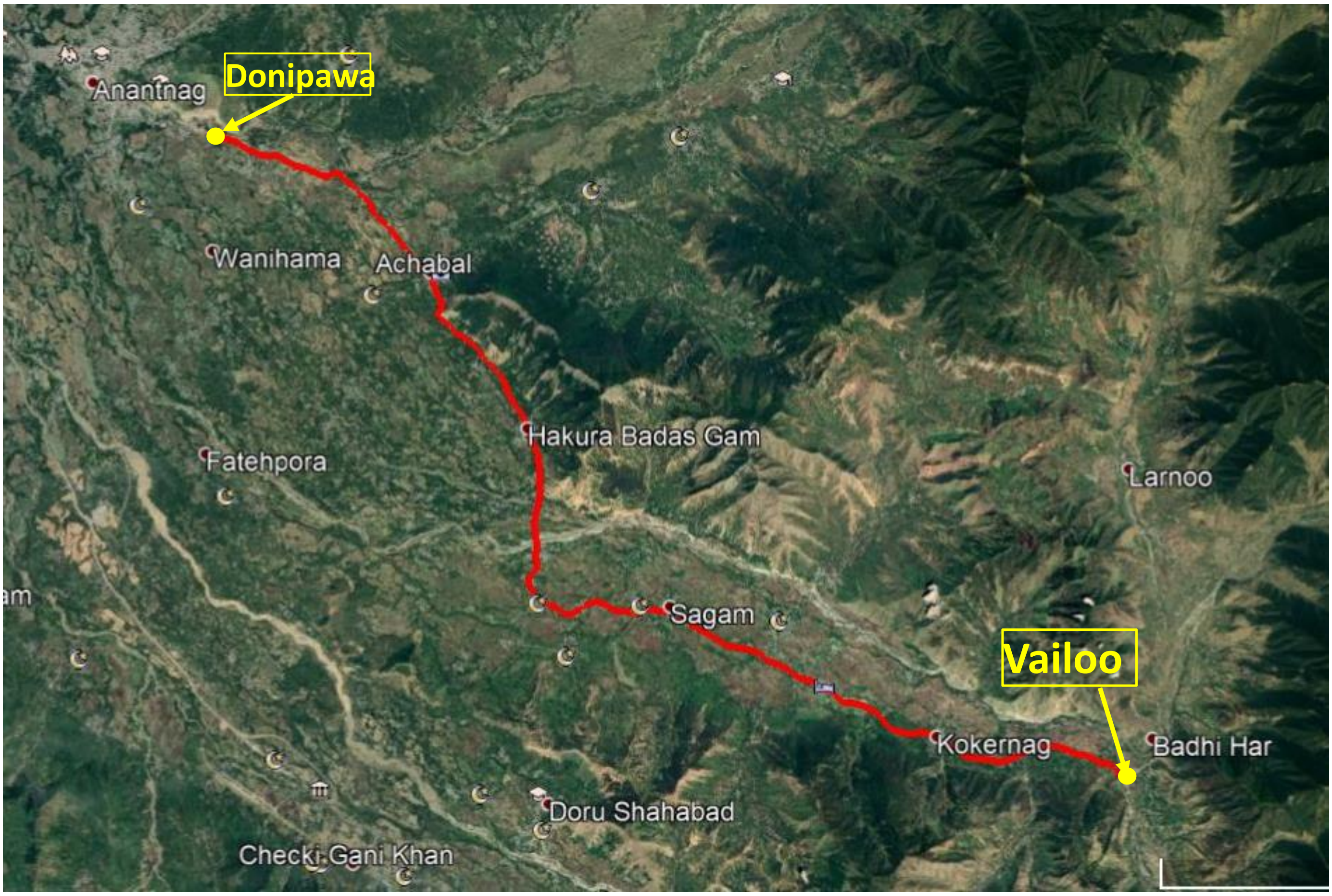
Consultancy Services for Feasibility Study, Preparation of Detailed Project Report and providing pre-construction services for upgradation to 2 lane with paved shoulder from (i) Km 44.500 to Km 142.000 of Chattroo Village & (ii) Km 235.00 (Vailoo Village) to Km 269.00 (Khanabal) of Khellani- Kishtwar-Chattroo- Khanabal Section of NH 244 in the state of Jammu & Kashmir



FINAL DETAILED PROJECT REPORT
VAILOO TO DONIPAWA SECTION
VOLUME-II A: DESIGN REPORT HIGHWAYS

NOVEMBER 2020

RODIC CONSULTANTS PVT. LTD.

IN JV WITH

MONARCH SURVEYORS AND ENGINEERING CONSULTANTS PVT. LTD.

Introduction

CHAPTER - 1

INTRODUCTION

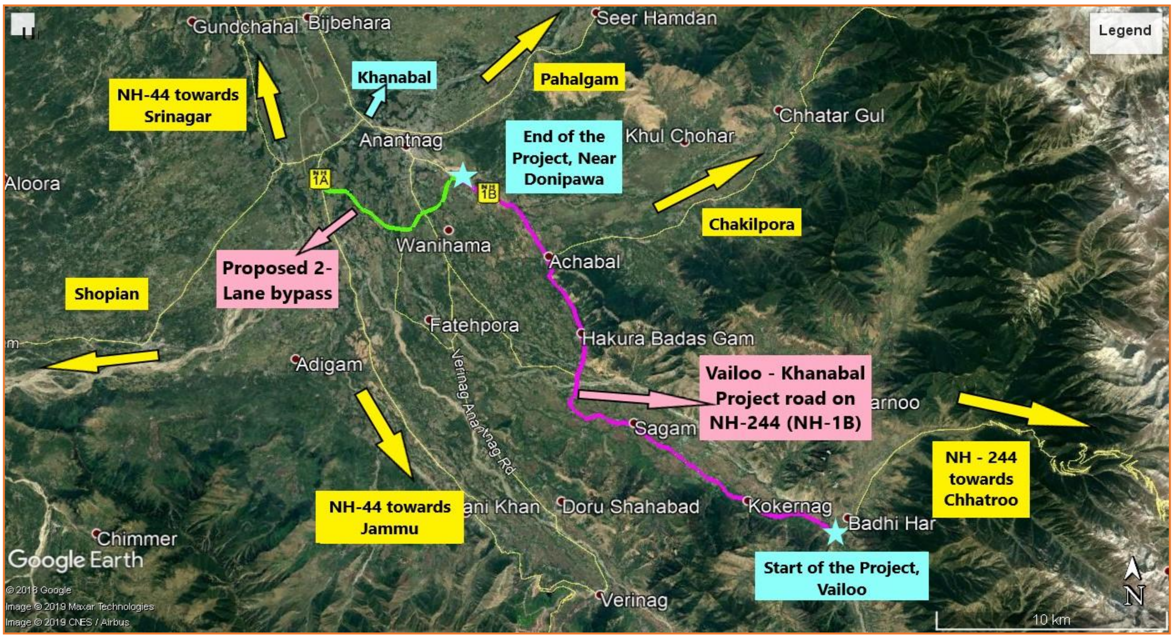
1.1 The Project Road

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 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.

NHIDCL has entrusted Rodic Consultants Pvt. Ltd., in Joint Venture with M/S Monarch Surveyors and Engineering Consultants Pvt. Ltd., to carry out 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.

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 brief details of salient feature of road is given below:

Attributes	Details
NH No.	244
Origin – Destination	Vailoo (Km 235+070) - Donipawa (Km 263+107) 33.5640° N, 75.3602° E 33.7184° N, 75.1677° E
Via Town	Vailoo, Achabal, Kokernag, Donipawa
Existing Carriageway	2lane (7m) over 90% of the road stretch with 14 m in 10% of the stretch in some urban area.
Service lanes and slip road	Nil
Shoulder	1 to 2m
Condition of Existing Pavement	Good to fair
Right of Way	Varying from 20 to 30 m as per visual
Land Use along project road	Built up & Agricultural
Traffic on the stretch	AADT-8059PCUs
Structures along the stretches	Major Bridge – 01 No. , Minor Bridge -14 nos. and Culverts- 109nos. (107 Re-constructed and 02 new construction); Side Drain-01 with length of 50m and span of 1x4x3m.
Junctions	2 Major and 29 Minor
Terrain	Km 148+589 to Km 165+589 Mountainous/Hilly Terrain Km 165+589 to Km 176+532 is Plain/Rolling Terrain.
Key utilities in the proposed ROW	Electric poles & water pipeline etc. NP-4 Pipe of Dia 600 mm at spacing of 500m in Builtup areas and 2000 m spacing in Open area.
Protection Works	Toe Walls, Guard Railings and Jersey barriers.
Rail Crossing along RoW	Nil
Other clearance related aspects	Utilities and Tree cutting

Proposed improvement under the project

The existing road shall be widened and reconstructed from 2-lane to 2x7m carriageway with 0.6 wide median in built-up area and 2-lane with paved shoulder in rural area.

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 : *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 project road lies on NH-244 (previously NH-1B) and connects Batote with Khanbal, passing through the Union territory of Jammu & Kashmir. The proposed project alignment passes through Vailoo town, Achabal, Kokernag, Donipawa for a total length of 27.943 km.

As per contract the stretch of project road is from Ex. Km. 235.000 to Km. 269+000 with total length of 34 Km. The project road starts from Vailoo and heads north west via Achabal through NH-244 and terminates at the junction of NH-44 at Khanabal. However, actual Start point is at Vailoo (Existing Km 235.070) and end at Donipawa (Existing km 263.107) i.e. Start of the Donipawa-Ashajipora Bypass as per direction of NHIDCL official.

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

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

Design Standards			
	Design Speed (Km/hr.) as per IRC SP:73-2018		
(i)	Plain/Rolling Terrain	:	100 (Ruling), 80(Minimum)
(ii)	Level of Service	:	B

Design Standards			
(iii)	Roadway Widths (m) as per IRC SP:73-2018 (modified as per Circular RW/NH-33044/22/2020-S&R(P&B) dtd.-17th July 2020)	:	7 m for 2-lanes carriageway , Paved shoulder and earthen shoulders of 1.5 m and 1.5 m respectively on either side.
	Plain/Rolling Terrain		
	Mountainous Terrain		11 m for 2-lane carriageway, with paved shoulders of 1.5m on either sides and earthen shoulder of 1.0m on valley side.
(iv)	Roadway Elements as per IRC SP: 73-2018, Plain/rolling Terrain with Paved and earthen shoulders either sides.	:	Carriageway 2-lane - 2X3.5m Paved Shoulder: 2x1.5 m Earthen Shoulder: 2x1.0 m
(v)	In built-up area roadway width as per IRC: SP-84:2019 (for 4-lane divide carriageway)		2x7m carriageway with 0.6m wide median and railing
(vi)	Camber as per IRC SP:73-2018	:	Carriageway Flexible- 2.50% Rigid - 2.00 % Paved Shoulder Flexible- 2.50% Rigid - 2.00 % Unpaved Shoulder Flexible- 3.50% Rigid - 3.00 %
(vii)	Right of Way	:	As per Plan and Profile
(viii)	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:75-2015)
	Fill height exceeding 6.0 m		In cutting- 1V:1H
(ix)	Minimum Sight Distance	:	90 m for design speed of 40 km/hr 180 m for design speed of 60 Km /hr 240 m for design speed of 80 km/hr 360 m for design speed of 100 km/hr
	Overtaking sight distance	:	165 m for design speed of 40 km/hr 340 m for design speed of 60 Km /hr 470 m for design speed of 80 km/hr 640 m for design speed of 100 km/hr
(x)	Super-elevation (As per IRC: SP:73-2018) Clause No-2.9.3	:	7%, if radius of curve is less than 400 m (Desirable Minimum) 5%, if radius of curve is more than 400 m (Absolute Minimum)
(xi)	Radii for Horizontal Curves as per IRC SP:73-2018 Plain/Rolling Terrain	:	Ruling (Desirable) Minimum Radius 400m, Absolute Minimum Radius 250 m
(xii)	**Gradient** (As per IRC: SP:73-2018) Clause 2.9.7.2		
	Plain/Rolling Terrain		
	Ruling	:	2.5%
	Limiting	:	3.3%
	Mountainous Terrain		

Design Standards			
	Ruling	:	5.0%
	Limiting		6.0%
(xiii)	**Minimum k factor**		
	Summit Curve		
	Plain/Rolling Terrain	:	Desirable: 135
			Minimum: 60
	Valley Curve		
	Plain/Rolling Terrain	:	Desirable: 41.5
			Minimum: 25.3
(xiv)	**Bridge Clearance**		
	Vehicular underpass	:	5.5 m
	Light and Smaller Vehicular Underpass	:	4.0m
(xv)	Design Flood Frequency		
	Bridges	:	100 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 2.0 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

Sl. No.	TCS No.	Description	Length in m	Length in km
1	TCS-1	2-Lane Left side Cut	201.00	0.201
2	TCS-2	2-Lane Rural	8142.00	8.142
3	TCS-3	4-Lane Urban	17510.00	17.510
4	TCS-4	4-Lane Urban(15m)	1750.00	1.750
5		Major Bridge	105.00	0.105
6		Minor Bridge	235	0.235
Total Length			**27943**	**27.943**

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

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

$$e + f = V^2/(127*R)$$

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 centre line 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

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

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.

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 148+674	Centre line of road
2	Vertical Curve	PVI Chainage; 148.934	Summit Curve
		PVI Chainage; 148+822	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 148+674

Design Parameters

R = 150 m
Δ = 17° 55' 48"
V = 80 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)

$$C = \frac{80}{75+V} = \frac{80}{75+50} = 0.6400$$

Since c<0.8, we take c = 0.6400

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

$$= \frac{0.0215\ (50)^3}{0.5161 \times 290}$$

=27.99 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.

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

= 0.074

Adopted value e = 0.070

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

= 16.67 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 60 m

b) **Check for the friction**

$$e + f = \frac{V^2}{127\ R} \quad = \frac{(50)^2}{127\ (290)} \quad = \frac{2500}{127 \times 290} \quad = 0.131$$

$$0.07 + f \quad = 0.131$$

$f =$ $0.061 < 0.15$.......Hence safe

c) **Features of the Curve**

$$s = \frac{{L_s}^2}{24\ R} \quad = \frac{(60)^2}{24 \times 150} \quad = 1.000\ m$$

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

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

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

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

$$\Delta = 0.313\ Rad$$

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

$$= \frac{L_S}{2\ R} \quad = \frac{60}{2\ \times 150} \quad = 0.200\ Rad$$

$$\Delta_c = (\Delta - 2\Delta_s)$$
$$= -0.087\ Rad$$

Therefore,

$$T_s = (150 + 1.0) Tan\ \frac{(17°\ 55'\ 48")}{2} + \frac{60}{2}$$
$$= 53.819$$
$$L_c = 150\ \times (-0.087)$$
$$= -13.065$$
$$E_s = (150 + 1.0)\ Sec\ \frac{(17°\ 55'\ 48")}{2} - 150$$
$$= 2.87$$
$$L_{Total} = (-13.065) + 2\ \times 60$$
$$= 106.935\ m$$

C. Design Calculation for Vertical Curve

i) PVI Chainage 148+394 (Summit Curve)

Design Parameters

Grade in, N_1 = 3.3 %
Grade out, N_2 = -1.2 %
Grade difference, N = 4.500 %

Design speed V = 70 Kmph.

PVI Level = 2022.00 m

Intermediate Sight Distance (I.S.D.), S = 363.97 m
Type of curve: Summit curve.

Calculations

Assuming, L > ISD

$$L = \frac{NS^2}{9.6} \quad = \frac{04.500 \times (363.97)^2}{9.6} \quad = 620.979 \text{ m} > \text{ISD} \ldots\ldots\ldots\ldots\ldots\ldots \text{OK}$$

So now assuming L < ISD

$$L = 2S - \frac{9.6}{N}$$
$$= 2 \times 363.97 - \frac{9.6}{4.500}$$

=514.610 >ISD .... NOT O.K.

Length of curve provided = 70 m

Chainage at the start of curve = PVI. Chainage – L/2

= 345.000– 70/2
= 310

Chainage at the end of curve = PVI. Chainage + L/2
= 345.000+ 70/2
= 370

Level at start of curve: = Level of PVI - (N_1 X L/2)
= 2022.00– (3.3 X 70/2)
= 2021.580 m

Level at end of curve: = Level of PVI +(N_2 x L/2)
= 2022.00+ (-1.2 X 70/2)
= 2021.606 m

ii) PVI Chainage 148+822 (Valley Curve)

Design Parameters

Grade in, N_1 = -2.800 %
Grade out, N_2 = 3.300 %
Grade difference, N = -6.100 %

Design speed V = 65 kmph.

PVI Level = 2018.300

Stopping Sight Distance (S.S.D.) S = 181.99 m
Type of curve: Valley curve.

Calculations

Assuming, L > SSD

$$L = \frac{NS^2}{(1.5 + .035 \times S)} = \frac{(6.100/100) \times (181.99)^2}{(1.50 + 0.035 \times 181.99)} = 256.719 \text{ m} > \text{SSD} \ldots\ldots\ldots\ \text{OK}$$

So now assuming L < SSD

$$L = 2S - \frac{1.50 + 0.035\ \mathrm{S}}{N}$$

$$= 2 \times 181.99 - \frac{1.50 + 0.035 \times 181.99}{(6.1/100)}$$

= 234.96 m < SSD………………. NOT O.K.

So, provide the minimum valley curve
Length of curve provided = 65 m

Chainage at the start of curve = PVI. Chainage – L/2

= 233.00– 65/2
= 200+500

Chainage at the end of curve = PVI. Chainage + L/2
= 233.000+ 65/2
= 265.500

Level at start of curve:	=	Level of PVI - (N_1 X L/2)
	=	2018.33– ((-2.800/100) X (65/2))
	=	2019.210 m
Level at end of curve:	=	Level of PVI + (N_2 x L/2)
	=	2018.33+ ((3.300/100) X (65/2))
	=	2019.273 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:

Table 4.1: Drains Details

Roadside PCC Drainage List				
Design Chainage in Km		**Design Length (m)**	**Side**	**Roadside Drain Length (m)**
From	**To**			
148+589	148+790	201.5	LHS	201.5

Roadside Earthen Drainage List				
Design Chainage in Km		**Design Length (m)**	**Side**	**Roadside Drain Length (m)**
From	**To**			
148+589	148+790	201.5	RHS	201.5
150+940	151+082	142	LHS+RHS	284
151+112	151+240	128	LHS+RHS	256
151+690	152+290	600	LHS+RHS	1200
153+490	154+090	600	LHS+RHS	1200
157+740	158+050	310	LHS+RHS	620
158+060	158+910	850	LHS+RHS	1700
160+440	161+140	700	LHS+RHS	1400
163+740	163+790	50	LHS+RHS	100
163+800	163+933	132.5	LHS+RHS	265
164+038	164+115	77.5	LHS+RHS	155
164+125	164+385	259.8	LHS+RHS	519.6
164+409	164+710	300.45	LHS+RHS	600.9

Roadside Earthen Drainage List				
Design Chainage in Km		Design Length (m)	Side	Roadside Drain Length (m)
From	To			
164+750	164+829	78.65	LHS+RHS	157.3
164+839	164+890	51	LHS+RHS	102
166+990	167+590	600	LHS+RHS	1200
168+690	169+790	1100	LHS+RHS	2200
171+590	172+410	820	LHS+RHS	1640
173+890	175+090	1200	LHS+RHS	2400
176+390	176+532	142	LHS+RHS	284
Total Roadside Earthen Drainage Length				**16485**

Roadside RCC Drainage List				
Design Chainage in Km		Design Length (m)	Side	Roadside Drain Length (m)
From	To			
148+790	150+290	1500	LHS+RHS	3000
150+290	150+490	200	LHS+RHS	400
150+490	150+940	450	LHS+RHS	900
151+240	151+690	450	LHS+RHS	900
152+290	152+786	496	LHS+RHS	992
152+796	152+890	94	LHS+RHS	188
152+890	153+090	200	LHS+RHS	400
153+090	153+490	400	LHS+RHS	800
154+090	156+290	2200	LHS+RHS	4400
156+290	156+490	200	LHS+RHS	400
156+490	157+740	1250	LHS+RHS	2500
158+910	159+079	169	LHS+RHS	338
159+089	159+293	204	LHS+RHS	408
159+303	160+440	1137	LHS+RHS	2274
161+140	163+285	2145	LHS+RHS	4290
163+295	163+740	445	LHS+RHS	890
164+890	164+938	47.5	LHS+RHS	95
164+963	164+999	36	LHS+RHS	72
165+024	166+990	1966.5	LHS+RHS	3933
167+590	168+690	1100	LHS+RHS	2200
169+790	170+260	470	LHS+RHS	940
170+260	170+450	190	LHS+RHS	380
170+460	170+780	320	LHS+RHS	640
170+780	171+590	810	LHS+RHS	1620
172+410	173+090	680	LHS+RHS	1360
173+090	173+590	500	LHS+RHS	1000
173+590	173+890	300	LHS+RHS	600
175+090	175+160	70	LHS+RHS	140
175+160	175+300	140	LHS+RHS	280
175+300	176+390	1090	LHS+RHS	2180

Roadside RCC Drainage List				
Design Chainage in Km		Design Length (m)	Side	Roadside Drain Length (m)
From	To			
Total Roadside RCC Drainage Length				38520

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 50 Sq. Km.

The formula is: $Q = 0.028\ PAI_c$

Where:

Q = discharge (peak runoff) in cum/sec

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 countryside 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 are 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 Stops

(iv) Street Lighting

(v) Other Appurtenant

5.2 Junctions

5.2.1 Major & Minor Junctions

There are 2 major and 29 minor junctions on the project road. These 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 signpost 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 signpost 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 centreline 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	Not Provided
c) Rigid type (like concrete crash barrier)	Provided (jersey Barrier at Median)/Toe Wall

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

Locations of Jersey barrier:

New Jersey Barrier List				
SL No	Chainage		TCS Type	Length of Jersey Barrier
	From	To		
1	148+790	150+290	TCS-3	01+500
2	150+290	150+490	TCS-4	00+200
3	150+490	150+940	TCS-3	00+450
4	151+240	151+690	TCS-3	00+450
5	152+290	152+786	TCS-3	00+496

New Jersey Barrier List				
SL No	Chainage		TCS Type	Length of Jersey Barrier
	From	To		
6	152+796	152+890	TCS-3	00+094
7	152+890	153+090	TCS-4	00+200
8	153+090	153+490	TCS-3	00+400
9	154+090	156+290	TCS-3	02+200
10	156+290	156+490	TCS-4	00+200
11	156+490	157+740	TCS-3	01+250
12	158+910	159+079	TCS-3	00+169
13	159+089	159+293	TCS-3	00+204
14	159+303	160+440	TCS-3	01+137
15	161+140	163+285	TCS-3	02+145
16	163+295	163+740	TCS-3	00+445
17	164+890	164+938	TCS-3	00+048
18	164+963	164+999	TCS-3	00+036
19	165+024	166+990	TCS-3	01+967
20	167+590	168+690	TCS-3	01+100
21	169+790	170+260	TCS-3	00+470
22	170+260	170+450	TCS-4	00+190
23	170+460	170+780	TCS-4	00+320
24	170+780	171+590	TCS-3	00+810
25	172+410	173+090	TCS-3	00+680
26	173+090	173+590	TCS-4	00+500
27	173+590	173+890	TCS-3	00+300
28	175+090	175+160	TCS-3	00+070
29	175+160	175+300	TCS-4	00+140
30	175+300	176+390	TCS-3	01+090
Total length of Jersey Barrier				**19+260**

Toe Wall

It is a small retaining wall structure at the foot of an earth slope. The list of Toe walls provided on the project road are given below:

Toe Wall					
Design Chainage Km		Length in m	Height Adopted in m	Side	Length in m
From	To				
151+015	151+080	65	2	Both	130
151+115	151+190	75	2	Both	150
Total Length					280

And Pedestrian Railing is provided, and details can be found given below:

SL No	Chainage		Design Length in Km	TCS Type	Length of Pedestrian railing in Km
	From	To			
1	148+790	150+290	01+500	TCS-3	03+000

SL No	Chainage		Design Length in Km	TCS Type	Length of Pedestrian railing in Km
	From	To			
2	150+290	150+490	00+200	TCS-4	00+400
3	150+490	150+940	00+450	TCS-3	00+900
4	151+240	151+690	00+450	TCS-3	00+900
5	152+290	152+786	00+496	TCS-3	00+992
6	152+796	152+890	00+094	TCS-3	00+188
7	152+890	153+090	00+200	TCS-4	00+400
8	153+090	153+490	00+400	TCS-3	00+800
9	154+090	156+290	02+200	TCS-3	04+400
10	156+290	156+490	00+200	TCS-4	00+400
11	156+490	157+740	01+250	TCS-3	02+500
12	158+910	159+079	00+169	TCS-3	00+338
13	159+089	159+293	00+204	TCS-3	00+408
14	159+303	160+440	01+137	TCS-3	02+274
15	161+140	163+285	02+145	TCS-3	04+290
16	163+295	163+740	00+445	TCS-3	00+890
17	164+890	164+938	00+048	TCS-3	00+095
18	164+963	164+999	00+036	TCS-3	00+072
19	165+024	166+990	01+967	TCS-3	03+933
20	167+590	168+690	01+100	TCS-3	02+200
21	169+790	170+260	00+470	TCS-3	00+940
22	170+260	170+450	00+190	TCS-4	00+380
23	170+460	170+780	00+320	TCS-4	00+640
24	170+780	171+590	00+810	TCS-3	01+620
25	172+410	173+090	00+680	TCS-3	01+360
26	173+090	173+590	00+500	TCS-4	01+000
27	173+590	173+890	00+300	TCS-3	00+600
28	175+090	175+160	00+070	TCS-3	00+140
29	175+160	175+300	00+140	TCS-4	00+280
30	175+300	176+390	01+090	TCS-3	02+180
Total length of Jersey Barrier					**38+520**

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 stops 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 20 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.

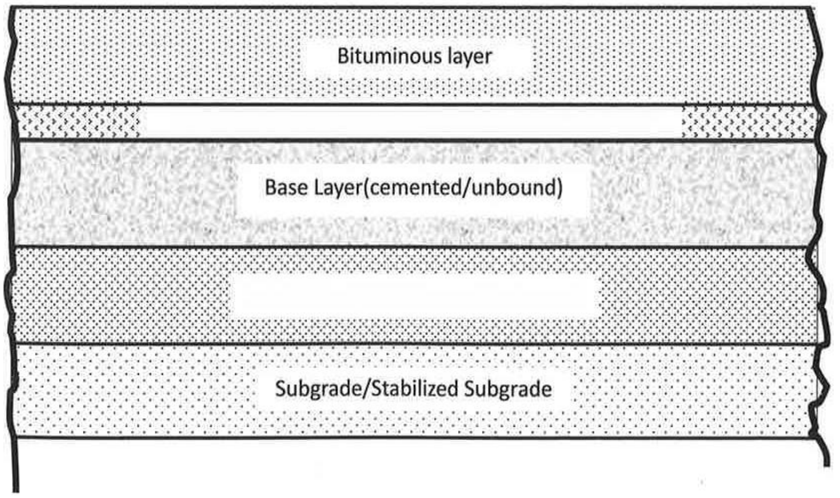
C. The whole pavement design concept has been divided into two parts:

- 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.

6.5 BITUMINOUS PAVEMENT WITH UNBOUND BASE AND SUBBASE LAYER

6.5.1 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.

6.5.2 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.

6.5.3 Bituminous Layers

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

6.6 RECOMMENDED PAVEMENT OPTION

6.6.1 Flexible Pavement:

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

6.6.2 Rigid Pavement:

No rigid pavement is proposed.

6.7 PARAMETERS FOR DESIGN

6.7.1 Design Life

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

6.7.2 Traffic Homogenous Sections

The following stretch has been adopted for traffic homogenous sections:

- Vailoo to Donipawa

6.7.3 No. of Lanes for Proposed Carriageway

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

6.8 Functional and Structural Overlay

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

6.8.1 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.

6.8.2 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.

6.9 PRELIMINARY INVESTIGATION

6.9.1 TRAFFIC

6.9.1.1 Commercial Vehicles:

The base year traffic has been assessed by carrying out traffic surveys at Location – Brakpora. 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 2019-2020	Location	Direction (Up & Down)	BUS	LMV/ LCV	2-Axle Trucks	3-Axle Trucks	Multi Axle	Total CVPD
7-days	Brakpora	Average	414	492	975	45	20	846

The details of Traffic Volume Count, AADT and commercial Vehicle Calculations of the Project Stretch is attached in **Annexure 1.**

6.9.1.2 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:

Brakpora	**Summary**	**LCV**	**Bus**	**2-Axle**	**3-Axle**	**Multi Axle**
	Average V.D.F	1.104	1.048	2.942	1.820	4.389

6.9.1.3 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 and 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**
Brakpora	3.358	6.017	9.377	13.665	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 20 years subject to the condition that design traffic shall not be less than 20 msa.

6.9.1.4 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 7.8 % - 8.4 % 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.

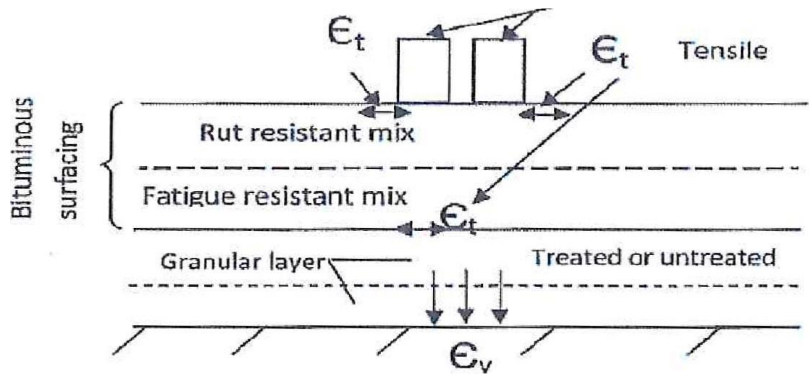
6.10 DESIGN OF FLEXIBLE PAVEMENT BY IRC METHOD

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-

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

$N_f = 0.5161 * C * 10^{-04} x [1/€_t]^{3.89} * [1/M_{Rm}]^{0.854}$ .... (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;

Nf = fatigue life in number of standard axis;

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

MR = 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 75 mm 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.

M_R value of subbase is dependent on M_R 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:

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

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 VG 30 bitumen	3500	3000	2500	2000	1250
BC and DBM for VG 40 bitumen	6000	5000	4000	3000	2000
BC and DBM for Modified bitumen	5700	3800	2400	1600	1300
BM with VG 10 bitumen	500 MPa at 35 ^{0}C				
BM with VG 30 bitumen	700 MPa at 35 ^{0}C				
RAP treated with 4 percent bitumen emulsion/foamed bitumen with 2-2.5 percent residual bitumen and 1.0 percent cementitious material	800 MPa at 35 ^{0}C				

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 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 rutting. 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 mentioned in 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 mentioned in 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 32 ^{o}C and -15 ^{o}C in the project area respectively. An average pavement temperature of 20 ^{o}C has been taken as per IRC:37-2018 (snowbound areas) for pavement design and selection of modulus of bitumen.

The type 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	2300	40	70	250	200	560	250.4	364.9	347.5	577.7

The detailed output of IIT-Pave is attached in **Annexure-4.**

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	**20⁰C**
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, Nf - $(1.6064*C*(10)^{-04} * [1/€_t]^{3.89} * [1/M_R]^{0.854}$	
	Allowable Fatigue Strain (€t)	364.9
(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)	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		

The screenshots of IIT PAVE software input and output are shown below

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:	**Vailoo Donipawa**							
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

Annual Average Daily Traffic (AADT)

Road : Brakpora Road Starting Date : 10-Jul-19

Location : Brakpora Ending Date : 17-Jul-19

Type of Vehicle			ADT (Up+Dn)		Annual Average Daily Traffic (AADT)	
			No.	PCU	No.	PCU
Fast / Motorised Vehicles		Two Wheeler	2329	1165	2096	1049
		Three Wheeler / Auto Rickshaw	467	467	430	430
		Motorized Van	9	9	8	8
		Car/ Jeep/ Van/ Taxi	4750	4750	4370	4370
	Bus	Mini	15	45	13	40
		Full	140	420	125	374
		LCV (Mini Truck)	368	553	328	492
	Truck	2-Axle Rigid Truck	365	1095	325	975
		3-Axle Rigid Truck	11	50	10	45
		Multi-Axle Rigid Truck	5	23	4	20
		Truck Trailer (Artic/ Semi-artic)	0	0	0	0
		Tractor With Trailer	46	208	41	185
		Tractor Without Trailer	0	0	0	0
Slow / Non-motorisedVehicles		Cycle	81	41	81	41
		Cycle Rickshaw	11	22	11	22
		Bullock Cart	0	0	0	0
		Horse Drawn Vehicle	2	8	2	8

Total Motorised Vehicles	8505	8785	7750	7988
Total Non-motorised Vehicles	94	71	94	71
Total Vehicles	8599		7844	
Total PCU	8856		8059	
Commercial Vehicles per Day (CVPD)	950		846	

Average Seasonal Correction Factor

For vehicles operated on Diesel	= 0.89	[For Bus, LCV, Truck & Tractor]
For vehicles operated on Petrol	= 0.92	[For 3-wheeler, Motorised Van & 4-whee
For vehicle operated on both Petrol & Diesel	= 0.90	[For 2-wheeler]

Annexure 2

VDF

LCV

Sr.No.	Vehicle Type	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	Mini LCV	Vegetables	645	1890	12.65	37.08	0.001		0.106	49.74	0.11
2	Mini LCV	Animals	600	860	11.77	16.87	0.001		0.005	28.65	0.01
3	Mini LCV	Cold Drinks	660	1550	12.95	30.41	0.002		0.048	43.36	0.05
4	Mini LCV	Vegetables	1160	1200	22.76	23.54	0.015		0.017	46.30	0.03
5	Mini LCV	Cold Drinks	900	1530	17.66	30.02	0.005		0.045	47.68	0.05
6	Mini LCV	Pillar	560	960	10.99	18.84	0.001		0.007	29.82	0.01
7	Mini LCV	Foods	630	1125	12.36	22.07	0.001		0.013	34.43	0.01
8	Mini LCV	Grains	710	1330	13.93	26.09	0.002		0.026	40.02	0.03
9	Mini LCV	Chicken	525	960	10.30	18.84	0.001		0.007	29.14	0.01
10	Mini LCV	Animals	650	590	12.75	11.58	0.001		0.001	24.33	0.00
11	LCV	Cold Drinks	1120	1900	21.97	37.28	0.013	0.047		59.25	0.06
12	Mini LCV	Animals	555	470	10.89	9.22	0.001		0.000	20.11	0.00
13	Mini LCV	Wood	610	1890	11.97	37.08	0.001		0.106	49.05	0.11
14	Mini LCV	Wood	580	1400	11.38	27.47	0.001		0.032	38.85	0.03
15	Mini LCV	Marble	1145	570	22.46	11.18	0.014		0.001	33.65	0.02
16	LCV	Grocery	4870	6770	95.55	132.83	4.669	7.600		228.38	12.27
										50.172	0.799

BUS

Sr.No.	Vehicle Type	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	Bus	People	2000	3010	39.24	59.06	0.133	0.297	98.30	0.43
2	Bus	People	2100	3230	41.20	63.37	0.161	0.394	104.57	0.56
3	Bus	People	2680	3610	52.58	70.83	0.428	0.614	123.41	1.04
4	Bus	Passenger	2200	3330	43.16	65.33	0.194	0.445	108.50	0.64
5	Bus	Passenger	1870	2920	36.69	57.29	0.102	0.263	93.98	0.36

2 AXLE

Sr.No.	Vehicle Type	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	2 Axle Truck	Oil	2625	5860	51.50	114.97	0.394	4.266	166.48	4.66
2	2 Axle Truck	Chips	2260	3560	44.34	69.85	0.217	0.581	114.19	0.80
3	2 Axle Truck	Empty	1720	1510	33.75	29.63	0.073	0.019	63.37	0.09
4	2 Axle Truck	Drum	3210	5000	62.98	98.10	0.881	2.261	161.08	3.14
5	2 Axle Truck	Goods	3260	5490	63.96	107.71	0.938	3.286	171.68	4.22
6	2 Axle Truck	Bitumen	2990	5385	58.66	105.65	0.663	3.042	164.32	3.71
7	2 Axle Truck	Empty	1750	1550	34.34	30.41	0.078	0.021	64.75	0.10
8	2 Axle Truck	Foods	3390	4945	66.51	97.02	1.096	2.163	163.53	3.26
9	2 Axle Truck	Goods	2690	6010	52.78	117.92	0.435	4.720	170.69	5.15
10	2 Axle Truck	Empty	1760	1490	34.53	29.23	0.080	0.018	63.77	0.10
11	2 Axle Truck	Empty	1690	1560	33.16	30.61	0.068	0.021	63.77	0.09
12	2 Axle Truck	Aggregates	2500	5930	49.05	116.35	0.324	4.474	165.40	4.80
13	2 Axle Truck	Aggregates	2430	6390	47.68	125.37	0.289	6.032	173.05	6.32
14	2 Axle Truck	Empty	1710	1590	33.55	31.20	0.071	0.023	64.75	0.09
15	2 Axle Truck	Oil	3360	5190	65.92	101.83	1.058	2.625	167.75	3.68

Sr.No.	Vehicle Type	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		
16	2 Axle Truck	Oil	3010	4850	59.06	95.16	0.681	2.002	154.21	2.68
									130.80	2.68

3 AXLE

Sr.No.	Vehicle Type	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	3 Axle Truck	Empty	1760	1610	1505	34.53	31.59	29.53	0.080	0.03	95.65	0.11
2	3 Axle Truck	Empty	1910	2010	1720	37.47	39.44	33.75	0.110	0.06	110.66	0.17
3	3 Axle Truck	Vegetables	3640	5500	4800	71.42	107.91	94.18	1.457	3.48	273.50	4.93
										Average	159.936	1.737

MULTI AXLE

Sr. No.	Vehicle Type	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	DW-TA3		
1	Multi Axle Truck	Grocery	2410	3140	5430	5350	47.28	61.61	106.54	104.97	0.280	0.807	4.17	_	320.39	5.26
2	Multi Axle Truck	Empty	1813	2010	1956	1895	35.57	39.44	38.38	37.18	0.090	0.135	_	0.069	150.56	0.23
														Average	**235.48**	**2.74**

Annexure 3

MSA

Year	Standard Bus	LCV	2 Axle	3 Axle	MAV	Yearly Design ESA	Cumulative Design ESA	MSA	Design Period
VDF	0.61	0.80	2.68	1.74	2.74				
2019	155	368	365	11	5	383078	383078	Base Year	
2020	163	405	383	12	5	406256	789334		
2021	171	445	402	12	6	430996	1220329		
2022	179	490	423	13	6	457415	1677745		
2023	188	539	444	13	6	485643	2163387		
2024	198	593	466	14	6	515817	2679205		
2025	208	652	489	15	7	548090	3227294		
2026	218	717	514	15	7	582624	3809918		
2027	229	789	539	16	7	619598	4429516	**4.4295**	**5-year**
2028	240	868	566	17	8	659205	5088721		
2029	252	954	595	18	8	701655	5790376		
2030	265	1050	624	19	9	747176	6537552		
2031	278	1155	655	20	9	796018	7333570		
2032	292	1270	688	21	9	848449	8182019	**8.182**	**10-year**
2033	307	1397	723	22	10	904766	9086784		
2034	322	1537	759	23	10	965287	10052071		
2035	338	1691	797	24	11	1030363	11082434		
2036	355	1860	837	25	11	1100374	12182808		
2037	373	2046	878	26	12	1175735	13358543	**13.359**	**15-year**
2038	392	2251	922	28	13	1256898	14615441		
2039	411	2476	968	29	13	1344356	15959797		
2040	432	2723	1017	31	14	1438649	17398447		
2041	453	2996	1068	32	15	1540365	18938811		
2042	476	3295	1121	34	15	1650144	20588956	**20.589**	**20-year**

Year	Standard Bus	LCV	2 Axle	3 Axle	MAV	Yearly Design ESA	Cumulative Design ESA	MSA	Design Period
VDF	**0.61**	**0.80**	**2.68**	**1.74**	**2.74**				
2043	500	3625	1177	35	16	1768688	22357644		
2044	525	3987	1236	37	17	1896764	24254408		
2045	551	4386	1298	39	18	2035207	26289614		
2046	579	4824	1363	41	19	2184933	28474547		
2047	608	5307	1431	43	20	2346941	30821488	**30.821**	**25-year**
2048	638	5838	1502	45	21	2522326	33343815		
2049	670	6421	1578	48	22	2712285	36056100		
2050	703	6845	1656	50	23	2870371	38926471		

Annexure 4

IIT - PAVE

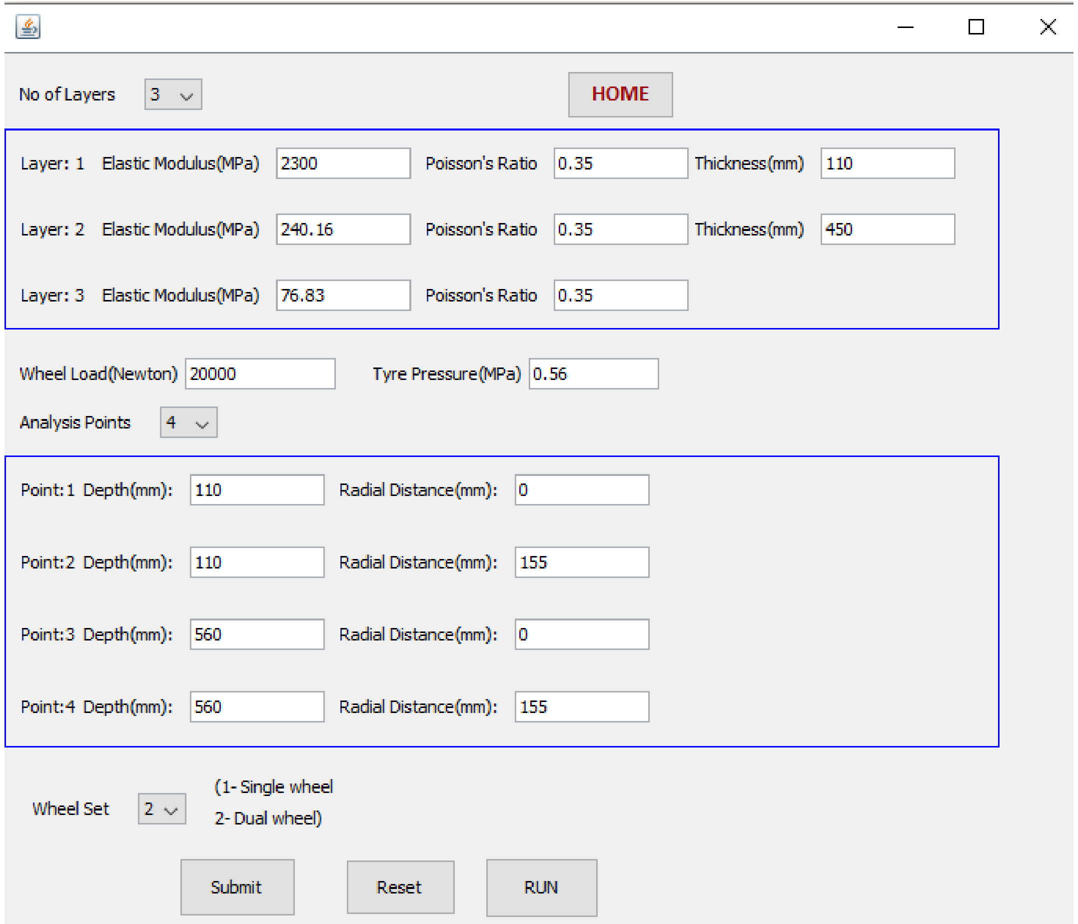
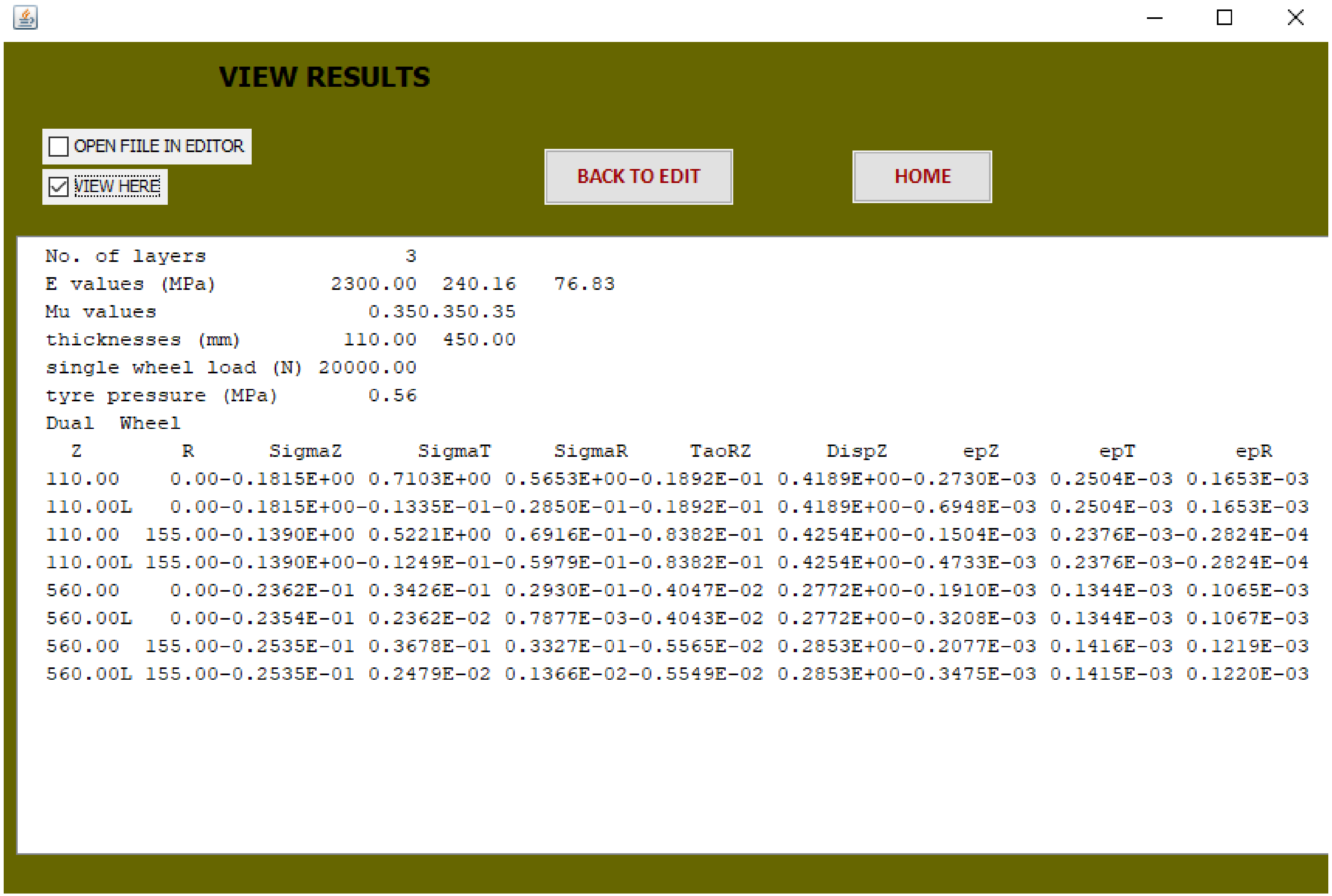


Figure- 01: Input to IITPAVE Software




```
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