

NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION LTD.

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



Consultancy Services for Feasibility Study, Preparation of Detailed Project Report and providing pre-construction services for 2-lane with Paved Shoulder of NH configuration for Baramulla-Gulmarg Road in the state of Jammu & Kashmir.



DRAFT DETAILED PROJECT REPORT VOLUME-IIA: DESIGN REPORT HIGHWAYS

June 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 2-lane with Paved Shoulder of NH configuration for Baramulla-Gulmarg Road in the state of Jammu & Kashmir. NHIDCL has entrusted RODIC CONSULTANTS PVT. LTD., in Joint Venture with 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 2-lane with Paved Shoulder of NH configuration for Baramulla-Gulmarg Road in the UT of Jammu & Kashmir.

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



Salient Features of Project Road

NHIDCL has entrusted RODIC CONSULTANTS PVT. LTD., in Joint Venture with 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 2-lane with Paved Shoulder of NH configuration for Baramulla-Gulmarg Road in the State of Jammu & Kashmir. Project road stretch is the section between Baramulla to Gulmarg. It lies in Baramulla district in the Kashmir valley region of Jammu and Kashmir. The existing road is approximately 42.890 Km long and is situated in Pir Panjal Mountain range in the western Himalayas, at an altitude of 1584 m to 2688 mt. Project road also encounters Gulmarg Wildlife Sanctuary in its stretch which starts nearly from Babreshi and ends at Gulmarg.

As per the Notification published by MoRT&H on 5th July 2018 the Baramulla-Gulmarg Road has been declared as NH-701-A.

The proposed road has a design length of 42.820 Km since it follows the alignment of existing road only. It starts from Design Km 0+000 at Baramulla and ends at Design Km 42+820 at Gulmarg. Existing length of project road is 42.890 Km

This existing road is located between 34.205061°N, 74.347682°E and 34.049160°N, 74.398680°E.

Proposed improvement under the project

The project road requires 2 lane with paved shoulder due to constraint of within 10 km of Gulmarg Wildlife Eco-sensitive zone boundary is affecting the stretch between Km 11+100 to Km 42+820 therefore widening and strengthening to intermediate lane with minor geometric improvements within the existing ROW and Km 0+000 to km 11+100 as of now one time improvement and strengthening is proposed. However, Km 0+000 to km 11+100 will be developed in future with 2 lane with paved shoulder as a new green field alignment i.e. Baramulla Bypass as an Option-2. The geometric designs would be as per recommendations of IRC: SP:73-2018 & IRC: 48 Hill road Manual.

1.3 Reporting Requirement and Structure of the Report

1.3.1 Reporting Requirements

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

Stage 1 - Inception Report

Stage 2 - Feasibility Study Report

Stage 3- Detailed Project Report (DPR)

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

1.3.2 Structure of the Report

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

Part – 1 : Roads & Highways

Part – 2 : Bridges and CD Structures

Part –1 comprises the following chapters:

Chapter – 1 : Introduction

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

Chapter – 2 : Design Criteria and Standards

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

Chapter – 3 : Geometric Design

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

Chapter – 4 : Drainage Design

Deals with drainage of the road and road side.

Chapter – 5 : 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

Project road stretch is the section between Baramulla to Gulmarg. It lies in Baramulla district in the Kashmir valley region of Jammu and Kashmir. The existing road is approximately 42.82 Km long and is situated in Pir Panjal Mountain range in the western Himalayas, at an altitude of 1584 m to 2688 mt. Project road also encounters Gulmarg Wildlife Sanctuary in its stretch which starts nearly from Babareshi and ends at Gulmarg. Project road can be reached from Baramulla via Srinagar – Baramulla Highway part of NH-1.

The proposed road has a design length of 42.820 Km since it follows the alignment of existing road only. It starts from Design Km 0+000 at Baramulla and ends at Design Km 42+820 (Same as Ex. Km 42+820) at Gulmarg.

The cross-section elements have been adjusted to far extent to accommodate within the existing ROW 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 Codal Design Values

(i)	Design Speed (Km/hr.)		
	Mountainous Terrain	:	60 (Ruling), 40(Minimum)
(ii)	Level of Service	:	B
(iii)	Roadway Widths (m)	:	

	Mountainous Terrain	11 m for 2-lanes with paved shoulders/ Earthen Shoulder
(iv)	Roadway Elements Mountainous Terrain	
	With Retaining wall and parapet	: Carriageway 2-lane- 2x3.5 m Paved Shoulder 2x1.5 m Earthen Shoulder 1.0 m (Valley Side)
(v)	Camber	Carriageway Flexible- 2.50% Rigid - 2.00 % Paved Shoulder Flexible- 2.50% Rigid - 2.00 % Unpaved Shoulder Flexible- 3.50% Rigid - 3.00 %
(vi)	Right of Way	As per Plan and Profile
	Embankment/ Cutting Slope	
(vii)	Fill height, up to 3.0 m	In filling- 1V: 2 H
	Fill height from 3.0 m to 6.0 m	In filling- 1V: 1.5 H
	Fill height exceeding 6.0 m	To be designed based on soil parameters, (IRC:75-1979) In cutting- 1V:1H
	Stopping Sight Distance	20 m for design speed of 20 km/hr. 25 m for design speed of 25 km/hr. 30 m for design speed of 30 km/hr. 40 m for design speed of 35 Km /hr. 45m for design speed of 40km/hr. 60 m for design speed of 50km/hr.
(viii)	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.
	Super-elevation	
(ix)	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%
	Radii for Horizontal Curves	
(x)	Mountainous Terrain	Ruling Minimum 150 m

		Absolute minimum 75 m
(xi)	Gradient (As per IRC: SP:73-2018) Clause 2.9.7.2	
	Mountainous Terrain	
	Ruling	5.00%
	Limiting	6.00%
	Steep Terrain	
	Ruling	6.00%
	Limiting	7.00%
(xii)	Minimum k factor	
	Summit Curve	
	Mountainous Terrain	Desirable: 8
		Minimum: 5
	Valley Curve	
	Mountainous Terrain	Desirable: 10
		Minimum: 7
(xiii)	Bridge Clearance	
	Vehicular underpass	5.5 m
	Cattle and Pedestrian	3.0m
(xiv)	Design Flood Frequency	
	Bridges	More than 50 years
	Sewers and Ditches	60 years

Note:- The above design standards are as per IRC:SP:73-2018 but the proposed section is widening and strengthening to intermediate lane within existing ROW due to alignment is passing through within 10 km of Gulmarg Wildlife Eco-sensitive zone boundary between km 11.100 to km 42.820. In future, km 0.00 to km 11.100 will be developed as 2 lane with paved shoulder standard as a new green field alignment of Baramulla Bypass.

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 Design 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 but at present the proposed alignment is widening and strengthening to intermediate lane only.

2.4.2 Paved Shoulders

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

2.4.3 Earthen Shoulders

It is proposed to have 1 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 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.

2.4.5 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

Sr. No.	Detail	TCS	Length	
			M.	Kms.
1	ONE SIDE FILL & ONE SIDE CUT	TCS-1	21905	21.905
2	ONE SIDE FILL & ONE SIDE CUT WITH PROTECTION WORK ON BOTH SIDE	TCS-2	60	0.060
3	ONE SIDE FILL & ONE SIDE CUT WITH PROTECTION WORK	TCS-3	860	0.860
4	ONE SIDE FILL WITH PROTECTION WORK & ONE SIDE CUT	TCS-4	160	0.160
5	OVERLAY WITHOUT WIDENING	TCS-5	13806	13.806
6	BUILTUP -LOCATION	TCS-6	5975	5.975
7	MINOR BRIDGE		54.1	0.054
TOTAL DESIGN LENGTH			42820	42.820

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 Km/h	IRC SP 23:1993	
	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 proposed road has a design length of 42.820 Km since it follows the alignment of existing road only. It starts from Design Km 0+000 at Baramulla and ends at Design Km 42+820 at Gulmarg.

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

Further it has been ensured that the alignment would enable consistent, safe and

smooth movement of vehicles operating at the design speed.

Super elevation and side Friction details

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

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

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

e = pavement superelevation (m/m)

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

R = curve radius (m)

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

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

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

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

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

Transition curves

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

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

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

Set Back Distance

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

Recommended Elements of Horizontal Alignment:

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

Horizontal Radii Criteria

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

Adopted Horizontal Radii

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

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

lower speeds.

2.7 Vertical Alignment

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

- Generally vertical curve is designed based upon SSD

2.7.1 Gradient

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

Vertical Gradient

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

2.7.2 Summit or Crest Curves

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

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

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

2.7.3 Valley or Sag Curves

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

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

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

2.8 Cross-fall

In case of intermediate road, TCS-1, 2, 3, 4, 5 and 6 each lane will have unidirectional cross fall. For effective drainage consideration the cross-fall for the pavement and paved shoulders will be 2.5%. For earthen shoulders, the corresponding value will be 3.0%.

2.9 Geometric Design Control

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

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

2.10 Roadway Width at Cross-Drainage Structures

2.10.1 Culverts

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

2.10.2 Bridges

The bridges will be built/widened as per guidelines of IRC: SP:73-2018 but at present in Option-1, width of the bridges shall be 8.50 m.

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:

- | | |
|----------------------------------|---|
| <i>Earthen Trapezoidal drain</i> | : This will generally apply for stretches with low to medium discharge |
| <i>RCC Covered Drain</i> | : This will be applied in urban areas. Covers will be provided at all the built-up areas use as footpath. |
| <i>Catch Drain</i> | : This will be applied on Hill Side to protect the carriageway as per TCS-1 and TCS-3. |

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 intermediate lane within existing ROW due to alignment is passing through within 10 km of Gulmarg Wildlife Eco-sensitive zone boundary between km 11.100 to km 42.820. In future, km 0.00 to km 11.100 will be developed as 2 lane with paved shoulder standard as a new green field alignment of Baramulla Bypass.
- ❖ 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 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-17, Chainage 1+055	Centre line of road
2	Vertical Curve	PVI Chainage 4+424	Summit Curve
		PVI Chainage 4+780	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-17, Chainage 1+055****Design Parameters**

$$\begin{aligned} R &= 50 \text{ m} \\ \Delta &= 23^\circ 49' 43.32'' \\ V &= 20 \text{ Km/h.} \end{aligned}$$

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)

$$C = \frac{80}{75+V} = \frac{80}{75+20} = 0.8421$$

Since $c > 0.8$, we take $c = 0.8$

$$\begin{aligned} L_s &= \frac{0.0215 V^3}{CR} \\ &= \frac{0.0215 (20)^3}{0.8 \times 50} \\ &= 4.3 \text{ m} \text{-----(i)} \end{aligned}$$

According to the rate of change of super elevation:

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

$$\begin{aligned} e &= \frac{V^2}{225 R} \\ &= 0.036 \end{aligned}$$

Adopted value $e = 0.025$

$$\begin{aligned} \text{Therefore, } L_s &= 1.0 \times V^2 / R \\ &= 8 \text{ m} \text{-----(ii)} \end{aligned}$$

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

$$e + f = \frac{V^2}{127 R} = \frac{(20)^2}{127 (50)} = \frac{400}{127 \times 50} = 0.063$$

$$0.07 + f = 0.063$$

$f = 0.027 < 0.15$ (coefficient of friction should be less than or equal to 0.15) ...Hence safe

c) Features of the Curve

$$s = \frac{L_s^2}{24 R} = \frac{(20)^2}{24 \times 50} = 0.333 \text{ m}$$

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

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

$$L_c = R \times \Delta_c$$

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

$$\Delta = 0.416 \text{ Rad}$$

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

$$= \frac{L_s}{2 R} = \frac{20}{2 \times 50} = 0.2 \text{ Rad}$$

$$\Delta_c = (\Delta - 2\Delta_s) \\ = 0.016 \text{ Rad}$$

Therefore, $T_s = (50 + 0.333) \tan \frac{(23^\circ 49' 43.32'')}{2} + \frac{20}{2}$

$$= 20.620$$

$$L_c = 50 \times 0.016$$

$$= 0.794 \text{ m}$$

$$E_s = (50 + 0.333) \sec \frac{(23^\circ 49' 43.32'')}{2} - 50$$

$$= 1.44 \text{ m}$$

$$L_{Total} = 0.794 + 2 \times 20$$

$$= 40.794 \text{ m}$$

C. Design Calculation for Vertical Curve**i) PVI Chainage 4+424 (Summit Curve)****Design Parameters**

$$\begin{aligned} \text{Grade in, } N_1 &= 13.840 \% \\ \text{Grade out, } N_2 &= 2.317 \% \\ \text{Grade difference, } N &= 11.523 \% \end{aligned}$$

$$\text{Design speed } V = 10 \text{ Kmph.}$$

$$\text{PVI Level} = 1784.467 \text{ m}$$

$$\text{Stopping Sight Distance (I.S.D.), } S = 36.8 \text{ m}$$

Type of curve: Summit curve.

Calculations

Assuming, $L > \text{ISD}$

$$L = \frac{NS^2}{9.6} = \frac{0.11523 \times (36.8)^2}{9.6} = 16.254 \text{ m} < \text{ISD} \dots\dots\dots \text{Not OK}$$

So now assuming $L < \text{ISD}$

$$\begin{aligned} L &= 2S - \frac{9.6}{N} \\ &= 2 \times 36.8 - \frac{9.6}{0.11523} \\ &= 9.714 < \text{ISD} \dots\dots\dots \text{O.K.} \end{aligned}$$

Length of curve provided = 30 m

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

$$\begin{aligned} &= 4424.138 - 30/2 \\ &= 4409.138 \end{aligned}$$

Chainage at the end of curve = PVI. Chainage + $L/2$

$$\begin{aligned} &= 4424.138 + 30/2 \\ &= 4439.138 \end{aligned}$$

$$\begin{aligned} \text{Level at start of curve:} &= \text{Level of PVI} - (N_1 \times L/2) \\ &= 1784.467 - (0.1384 \times 30/2) \\ &= 1782.391 \text{ m} \end{aligned}$$

$$\begin{aligned}
 \text{Level at end of curve:} &= \text{Level of PVI} + (N_2 \times L/2) \\
 &= 1784.467 + (0.02317 \times 30/2) \\
 &= 1784.815 \text{ m}
 \end{aligned}$$

ii) PVI Chainage 4+780 (Valley Curve)

Design Parameters

$$\begin{aligned}
 \text{Grade in, } N_1 &= -3.562 \% \\
 \text{Grade out, } N_2 &= 11.525 \% \\
 \text{Grade difference, } N &= -15.087 \%
 \end{aligned}$$

$$\text{Design speed } V = 20 \text{ kmph.}$$

$$\text{PVI Level} = 1795.853$$

$$\text{Stopping Sight Distance (S.S.D.) } S = 18.4 \text{ m}$$

Type of curve: Valley curve.

Calculations

Assuming, $L > \text{SSD}$

$$L = \frac{NS^2}{(1.5 + 0.035 \times S)} = \frac{0.15087 \times (18.4)^2}{(1.50 + 0.035 \times 18.4)} = 23.823 \text{ m} > \text{SSD} \dots\dots\dots \text{OK}$$

So, provide the minimum valley curve

Length of curve provided = 40 m

$$\begin{aligned}
 \text{Chainage at the start of curve} &= \text{PVI. Chainage} - L/2 \\
 &= 4780 - 40/2 \\
 &= 4760 \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 \text{Chainage at the end of curve} &= \text{PVI. Chainage} + L/2 \\
 &= 4780 + 40/2 \\
 &= 4800 \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 \text{Level at start of curve:} &= \text{Level of PVI} - (N_1 \times L/2) \\
 &= 1795.853 - (-0.03562 \times 40/2) \\
 &= 1796.565 \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 \text{Level at end of curve:} &= \text{Level of PVI} + (N_2 \times L/2) \\
 &= 1795.853 + (0.11525 \times 40/2) \\
 &= 1798.158 \text{ m}
 \end{aligned}$$

Drainage Design

CHAPTER - 4

DRAINAGE DESIGN

4.1 General

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

4.2 Principle

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

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

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

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

4.3 Selection of Drains Sections

The choice of cross-section of open drains is generally limited to 3 types; triangular, trapezoidal and rectangular. Each of the cross-section type has its be met suitable from

traffic consideration, but this form of cross section has the disadvantage of lesser flow capacity. Rectangular section is well suited for roadside drains when large discharge is required but unless they are covered or kept sufficiently away from traffic, they may prove to be greater traffic hazard. Trapezoidal section is a compromise between triangular and rectangular section. However large top width of trapezoidal drain may also prove to be a traffic hazard.

4.4 Type Adopted

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

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

Drainage Detail						
Sr. No.	Design Chainage (Km)		Length (Km)	TCS Type	Drain Type	Side
	From	To				
1	00+000	01+700	1700	TCS-6	Footpath cum Drain	Both Side
2	01+700	01+810	110	TCS-1	PCC	One Side
3	01+810	01+840	30	TCS-3	PCC	One Side
4	01+840	01+900	60	TCS-1	PCC	One Side
5	01+900	01+920	20	TCS-3	PCC	One Side
6	01+920	02+090	170	TCS-1	PCC	One Side
7	02+090	02+170	80	TCS-3	PCC	One Side
8	02+170	02+210	40	TCS-4	PCC	One Side
9	02+210	02+300	90	TCS-1	PCC	One Side
10	02+300	02+330	30	TCS-4	PCC	One Side
11	02+330	02+390	60	TCS-2	PCC	One Side
12	02+390	02+420	30	TCS-4	PCC	One Side
13	02+420	02+450	30	TCS-3	PCC	One Side
14	02+450	02+540	90	TCS-1	PCC	One Side
15	02+540	02+580	40	TCS-3	PCC	One Side
16	02+580	02+660	80	TCS-1	PCC	One Side
17	02+660	02+680	20	TCS-3	PCC	One Side
18	02+680	02+900	220	TCS-1	PCC	One Side
19	02+900	02+980	80	TCS-3	PCC	One Side
20	02+980	03+160	180	TCS-1	PCC	One Side
21	03+160	03+190	30	TCS-3	PCC	One Side
22	03+190	04+430	1240	TCS-1	PCC	One Side

Drainage Detail						
Sr. No.	Design Chainage (Km)		Length (Km)	TCS Type	Drain Type	Side
	From	To				
23	04+430	04+450	20	TCS-3	PCC	One Side
24	04+450	04+980	530	TCS-1	PCC	One Side
25	04+980	05+000	20	TCS-3	PCC	One Side
26	05+000	05+070	70	TCS-1	PCC	One Side
27	05+070	05+100	30	TCS-3	PCC	One Side
28	05+100	05+120	20	TCS-1	PCC	One Side
29	05+120	05+140	20	TCS-3	PCC	One Side
30	05+140	05+190	50	TCS-1	PCC	One Side
31	05+190	05+210	20	TCS-3	PCC	One Side
32	05+210	06+200	990	TCS-1	PCC	One Side
33	06+200	06+220	20	TCS-4	PCC	One Side
34	06+220	06+410	190	TCS-1	PCC	One Side
35	06+410	06+430	20	TCS-3	PCC	One Side
36	06+430	07+310	880	TCS-1	PCC	One Side
37	07+310	07+350	40	TCS-4	PCC	One Side
38	07+350	07+390	40	TCS-1	PCC	One Side
39	07+390	07+420	30	TCS-3	PCC	One Side
40	07+420	07+470	50	TCS-1	PCC	One Side
41	07+470	07+540	70	TCS-3	PCC	One Side
42	07+540	08+900	1360	TCS-1	PCC	One Side
43	08+900	09+200	300	TCS-6	Footpath cum Drain	Both Side
44	09+200	09+280	80	TCS-1	PCC	One Side
45	09+280	09+300	20	TCS-3	PCC	One Side
46	09+300	09+930	630	TCS-1	PCC	One Side
47	09+930	09+950	20	TCS-3	PCC	One Side
48	09+950	12+500	2550	TCS-1	PCC	One Side
49	12+500	14+900	2400	TCS-6	Footpath cum Drain	Both Side
50	14+900	16+948	2047.5	TCS-1	PCC	One Side
51	16+963	17+300	337.5	TCS-1	PCC	One Side
52	17+300	17+850	550	TCS-6	Footpath cum Drain	Both Side
53	17+850	18+000	150	TCS-6	Footpath cum Drain	Both Side
54	18+000	18+191	190.5	TCS-6	Footpath cum Drain	Both Side
55	18+216	18+500	284.5	TCS-6	Footpath cum Drain	Both Side
56	18+500	23+000	4500	TCS-1	PCC	One Side
57	23+000	23+400	400	TCS-6	Footpath cum Drain	Both Side
58	23+400	25+280	1880	TCS-1	PCC	One Side
59	25+280	25+300	20	TCS-3	PCC	One Side
60	25+300	25+420	120	TCS-1	PCC	One Side
61	25+420	25+500	80	TCS-3	PCC	One Side
62	25+500	25+890	390	TCS-1	PCC	One Side

Drainage Detail						
Sr. No.	Design Chainage (Km)		Length (Km)	TCS Type	Drain Type	Side
	From	To				
63	25+890	26+010	120	TCS-3	PCC	One Side
64	26+010	26+050	40	TCS-1	PCC	One Side
65	26+050	26+090	40	TCS-3	PCC	One Side
66	26+090	29+000	2910	TCS-1	PCC	One Side
67	29+000	32+349	3348.95	TCS-5	PCC	One Side
68	32+355	37+337	4981.95	TCS-5	PCC	One Side
69	37+345	42+820	5475	TCS-5	PCC	One Side

4.5 Hydrological Design

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

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

The formula is: $Q = 0.028 PAI_c$

Where:

Q = discharge (peak runoff) in cumec

P = coefficient of run-off for the catchment characteristics

A = area of catchment in hectares

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

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

The primary component in designing drains is the design storm viz. rainfall value of specified duration and specific return period. As the extent of drainage system for

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

Once the time of concentration has been fixed, the next step consists in reading the intensity of rainfall from the appropriate rainfall map for storm duration equal to time of concentration 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 m²

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 & Realignment

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

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

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

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.

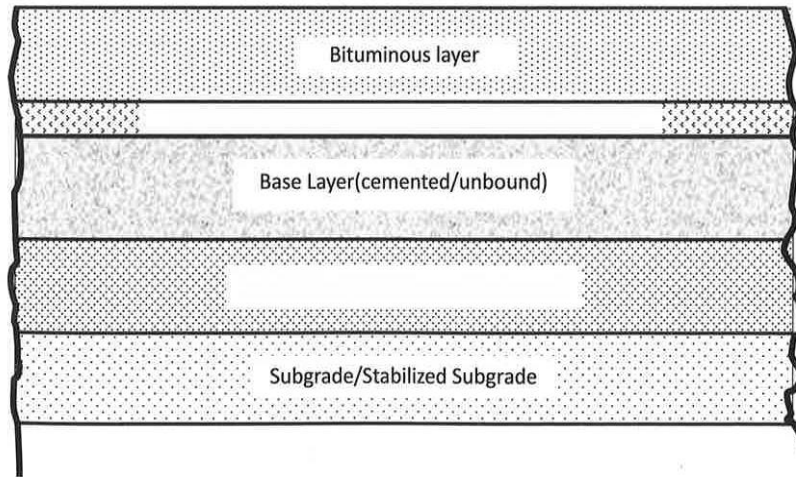
6.3 General Design Guidelines

- 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 15 years for flexible pavement.

6.6.2 Traffic Homogenous Sections

The following stretch has been adopted for traffic homogenous sections:

- Baramulla (km 0+000) – Gulmarg (km 42+820).

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 (15 years) for the future traffic loading, then the underlying layers of the pavement will be overstressed. The over stressing of pavement layers including sub grade will damage the physical condition of the pavement in the form of occurrence of cracks, faulting, ravelling, rutting or other conditions, which would affect the load carrying capabilities of the pavement structures.

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

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

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 Location – Khellani. 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	Total
7-days	Babareshi	Average	200	2913	45	3158

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

Project Stretch is attached in Annexure 1.

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 2.

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

Babareshi	Summary	LCV	Bus	2-Axle
	Average V.D. F	1.345	2.584	4.544

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

Location	MSA				Adopted design MSA for 15 years
	5 Years	10 Years	15 Years	20 years	
Babareshi	0.941	2.171	3.77	5.833	20 MSA

The Calculation Sheet of MSA is attached in Annexure 3.

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

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.

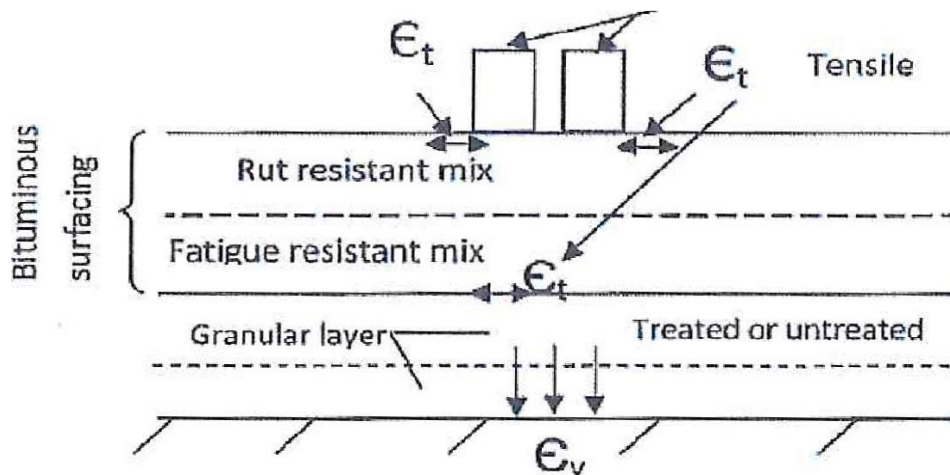
Based on the material investigations carried out on the project road, it is found that the existing ground is within the range of 9.7% - 11.8 % CBR at majority of locations. Hence, keeping in view the availability of material within the permissible leads, However for the safety measures and on conservative basis of design, the CBR value of 9% 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 (ϵ_t) at bottom of bituminous layer, which can cause cracking in the bituminous layer.
- ii. And Vertical Compressive Strain (ϵ_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-

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

$$N_f = 0.5161 * C * 10^{-04} \times [1/\epsilon_t]^{3.89} * [1/M_{Rm}]^{0.854} \dots\dots\dots (90 \text{ percent reliability})$$

Where,

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

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;

ϵ_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 ($M_{R_{gsb}}$)

$M_{R_{gsb}} = 0.2 \times h^{(0.45)} \times M_{R_{subgrade}}$, 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.

$M_{R_{subgrade}} = 10 \times \text{CBR}$ if Subgrade CBR is ≤ 5

$M_{R_{subgrade}} = 17.6 \times (\text{CBR})^{0.64}$ 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:

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

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

Poisson's ratio 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 °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° C				
BM with VG 30 bitumen	700 MPa at 35° C				
WMM/RAP treated with 3 percent bitumen emulsion/foamed bitumen	600 MPa at 35° 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	
	15 years
Design MSA	
	20
Design CBR	
CBR for entire Stretch	9 %

6.15 Methodology for Pavement Sections with Design CBR of 9 %

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 than 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 outlined in the Appendix I of IRC: 37-2018. The equation is as follows.

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

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

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.

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

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

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 °C and -5 °C in the project area respectively. An average pavement temperature of 20 °C has been considered for pavement design and selection of modulus of bitumen.

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

The pavement layer thickness is derived for the traffic volume of 20 msa corresponding to 9 % CBR, the pavement crust thickness is tabulated below according to IRC: 37 - 2018 plate 5.

Table- 2: Pavement structural Analysis with 9 % 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	9	20	71.82	224.5	2300	40	75	250	200	565	251.9	364.9	359.1	577.7

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

IIT PAVE Analysis		
1	Design Life	15 Years
2	Design MSA	20
3	Design CBR	9 %
4	CBR for entire Stretch	9 %
5	Pavement Thickness as per Plate 6 (with Unbound base & Sub base)	
	BC	40
	DBM	75
	WMM	250
	GSB	200
6	Resilient Modulus of Subgrade	71.82
	$M_R \text{ Subgrade} = 17.6 * (\text{CBR})^{0.64} \text{ for CBR} > 5$	
7	Elastic Modulus of granular layers	224.5
	$(M_R \text{ granular} = 0.2 * h^{0.45} * M_R \text{ Subgrade})$	
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°C
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)	$\text{Fatigue, } N_f - 1.6064 * C * 10^{-04} * [1/\epsilon_t]^{3.89} * [1/M_{Rm}]^{0.854}$	
	Allowable Fatigue Strain (ϵ_t)	364.9
(b)	$\text{Rutting, } N - 4.1656 * 10^{-08} * [1/\epsilon_v]^{4.5337}$	
	Allowable Rutting Strain (ϵ_v)	577.7
(ii)	Actual Strains generated by IIT PAVE	
(a)	Fatigue Strain (ϵ_t)	251.9
(b)	Rutting Strain (ϵ_v)	359.1
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 9 % 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:	Baramulla - Gulmarg							
Flexible Pavement Composition	CBR	MSA	VG	Pavement Crust Composition (mm)				
				BC	DBM	WMM	GSB	Total
	9 %	20	VG - 10	40	75	250	200	565

6.16 Conclusions

Recommendations for Pavement Design:

- The flexible pavement has been designed for design life of 15 years and projected traffic.
- The sub-base and base courses are designed for 15 years and 20 MSA projected traffic and design CBR of 9 %.

Annexure 1

Annual Average Daily Traffic (AADT)

Road : **Gulmarg-Baramulla Road**

Starting Date : **14-Jul-19**

Location : **Babreshi**

Ending Date : **21-Jul-19**

Type of Vehicle		ADT (Up+Dn)		Annual Average Daily Traffic (AADT)		
		No.	PCU	No.	PCU	
Fast / Motorised Vehicles	Two Wheeler	581	291	523	262	
	Three Wheeler / Auto Rickshaw	72	72	66	66	
	Motorized Van	0	0	0	0	
	Car/ Jeep/ Van/ Taxi	3084	3084	2837	2837	
	Bus	Mini	74	222	66	198
		Full	151	453	134	403
		LCV (Mini Truck)	85	128	76	114
	Truck	2-Axle Rigid Truck	51	153	45	136
		3-Axle Rigid Truck	0	0	0	0
		Multi-Axle Rigid Truck	0	0	0	0
		Truck Trailer (Artic/ Semi-artic)	0	0	0	0
		Tractor With Trailer	0	0	0	0
	Tractor Without Trailer	0	0	0	0	
Slow / Non-motorised Vehicles	Cycle	377	189	377	189	
	Cycle Rickshaw	0	0	0	0	
	Bullock Cart	0	0	0	0	
	Horse Drawn Vehicle	0	0	0	0	

Total Motorised Vehicles	4098	4403	3747	4016
Total Non-motorised Vehicles	377	189	377	189
Total Vehicles	4475		4124	
Total PCU	4592		4205	
Commercial Vehicles per Day (CVPD)	361		321	

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-wheeler]
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	In Tonne	1st	2nd	SW-FSA	DW-SA	SW-RSA		
1	LCV	Empty	1011	2100	3.11	19.84	41.20	0.009		0.161	61.038	0.170
2	LCV	Food Items	2013	3587	5.60	39.50	70.38	0.136		1.374	109.872	1.511
3	LCV	Fruits	2123	3571	5.69	41.65	70.06	0.169		1.350	111.716	1.519
4	LCV	Cereals	2890	3587	6.48	56.70	70.38	0.579		1.374	127.079	1.953
5	LCV	Vegetables	2017	3578	5.60	39.57	70.20	0.137		1.361	109.774	1.498
6	LCV	Groceries	1941	2158	4.10	38.08	42.34	0.118		0.180	80.422	0.298
7	LCV	Cereals	2580	3789	6.37	50.62	74.34	0.368	0.746		124.960	1.113

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	In Tonne	1st	2nd	SW-FSA	DW-SA	SW-RSA		
8	LCV	Groceries	2014	2267	4.28	39.51	44.48	0.137	0.096		83.993	0.232
9	LCV	Vegetables	2018	3391	5.41	39.59	66.53	0.138		1.098	106.125	1.235
10	LCV	Bricks	3017	4127	7.14	59.19	80.97	0.688		2.408	140.165	3.096
11	LCV	Empty	1024	1598	2.62	20.09	31.35	0.009		0.054	51.444	0.063
12	LCV	Groceries	1922	3361	5.28	37.71	65.94	0.113		1.059	103.652	1.173
13	LCV	Animals	1978	3510	5.49	38.81	68.87	0.127	0.549		107.675	0.676
14	LCV	Bricks	3127	4228	7.36	61.35	82.95	0.794		2.653	144.305	3.446
15	LCV	Electronic Material	2011	3497	5.51	39.46	68.61	0.136		1.241	108.067	1.377
16	LCV	Vegetables	1880	3329	5.21	36.89	65.31	0.104		1.020	102.201	1.123

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	In Tonne	1st	2nd	SW-FSA	DW-SA	SW-RSA		
17	LCV	Sand	3369	4370	7.74	66.10	85.74	1.069	1.319		151.839	2.389
											VDF	1.345

BUS

Sl. 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	Passenger	3175	4328	62.29	84.92	0.844	1.269	147.21	2.11
2	Bus	Passenger	3580	4821	70.24	94.59	1.364	1.954	164.83	3.32
3	Bus	Passenger	3690	4897	72.40	96.08	1.539	2.080	168.48	3.62
4	Bus	Empty	2214	3412	43.44	66.94	0.199	0.490	110.38	0.69
5	Bus	Passenger	3312	4470	64.98	87.70	0.999	1.444	152.68	2.44
6	Bus	Passenger	3690	4789	72.40	93.96	1.539	1.903	166.36	3.44
7	Bus	Passenger	3600	4788	70.63	93.94	1.394	1.901	164.57	3.30
8	Bus	Passenger	3570	4601	70.04	90.27	1.35	1.62	160.32	2.97

Sl. 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		
9	Bus	Empty	2012	3223	39.48	63.24	0.14	0.39	102.71	0.53
10	Bus	Passenger	3570	4800	70.04	94.18	1.35	1.92	164.22	3.27
11	Bus	Passenger	3697	4878	72.54	95.71	1.55	2.05	168.24	3.60
12	Bus	Passenger	3028	4012	59.41	78.72	0.70	0.94	138.12	1.64
13	Bus	Passenger	3710	4800	72.79	94.18	1.57	1.92	166.97	3.49
14	Bus	Empty	2013	3212	39.50	63.02	0.14	0.39	102.51	0.52
15	Bus	Passenger	3328	4590	65.30	90.06	1.02	1.61	155.35	2.62
16	Bus	Passenger	3652	4670	71.65	91.63	1.48	1.72	163.28	3.20
17	Bus	Passenger	3570	4837	70.04	94.90	1.35	1.98	164.95	3.33
18	Bus	Passenger	3514	4710	68.94	92.41	1.27	1.78	161.35	3.05
19	Bus	Passenger	3201	4102	62.80	80.48	0.87	1.02	143.28	1.90
20	Bus	Passenger	2978	4218	58.43	82.76	0.65	1.15	141.19	1.80
21	Bus	Passenger	3347	4217	65.67	82.74	1.04	1.14	148.41	2.19
22	Bus	Passenger	3523	4511	69.12	88.51	1.28	1.50	157.63	2.78
23	Bus	Passenger	3288	4387	64.51	86.07	0.97	1.34	150.58	2.31
24	Bus	Empty	2134	3378	41.87	66.28	0.17	0.47	108.15	0.64
25	Bus	Passenger	3471	4681	68.10	91.84	1.20	1.74	159.94	2.94

Sl. 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		
26	Bus	Passenger	3500	4780	68.67	93.78	1.25	1.89	162.45	3.13
27	Bus	Passenger	3536	4697	69.38	92.16	1.30	1.76	161.53	3.06
28	Bus	Passenger	3967	4870	77.83	95.55	2.06	2.03	173.38	4.09
29	Bus	Passenger	3670	4870	72.01	95.55	1.51	2.03	167.55	3.54
30	Bus	Passenger	3049	4017	59.82	78.81	0.72	0.94	138.63	1.66
31	Bus	Passenger	3601	4478	70.65	87.86	1.40	1.45	158.51	2.85
32	Bus	Passenger	3462	4597	67.92	90.19	1.19	1.62	158.12	2.81
33	Bus	Passenger	2978	4074	58.43	79.93	0.65	1.00	138.36	1.65
34	Bus	Passenger	3287	4387	64.49	86.07	0.97	1.34	150.56	2.31
35	Bus	Passenger	3369	4612	66.10	90.49	1.07	1.64	156.59	2.71
36	Bus	Passenger	3600	4789	70.63	93.96	1.39	1.90	164.59	3.30
37	Bus	Passenger	3870	4870	75.93	95.55	1.86	2.03	171.48	3.90
38	Bus	Passenger	3845	4823	75.44	94.63	1.81	1.96	170.07	3.77
39	Bus	Passenger	3028	4172	59.41	81.85	0.70	1.10	141.26	1.79
40	Bus	Passenger	2971	3912	58.29	76.75	0.65	0.85	135.04	1.49
41	Bus	Passenger	3690	4879	72.40	95.73	1.54	2.05	168.12	3.59
42	Bus	Passenger	3173	4289	62.25	84.15	0.84	1.22	146.40	2.07

Sl. 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		
43	Bus	Empty	2258	3365	44.30	66.02	0.22	0.46	110.32	0.68
44	Bus	Passenger	3568	4781	70.00	93.80	1.35	1.89	163.81	3.24
45	Bus	Passenger	3478	4697	68.24	92.16	1.21	1.76	160.39	2.98
									VDF	2.584

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	In ton n	1st	2nd	SW-FSA	DW-SA		
1	2 Axle Truck	Fruits	3021	4071	7.09	59.27	79.87	0.69	0.99	139.15	1.69
2	2 Axle Truck	Electronic Items	3124	3998	7.12	61.29	78.44	0.79	0.92	139.73	1.71
3	2 Axle Truck	Construction Material	3897	5367	9.26	76.46	105.30	1.91	3.00	181.76	4.92
4	2 Axle Truck	Vegetables	3470	4430	7.90	68.08	86.92	1.20	1.39	155.00	2.60
5	2 Axle Truck	Food Items	3211	4068	7.28	63.00	79.81	0.88	0.99	142.81	1.87
6	2 Axle Truck	Bricks	4217	6026	10.24	82.74	118.23	2.63	4.77	200.97	7.40
7	2 Axle Truck	Cereals	3587	5120	8.71	70.38	100.45	1.37	2.49	170.83	3.86

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	In ton n	1st	2nd	SW-FSA	DW-SA		
8	2 Axle Truck	Construction Material	3898	5284	9.18	76.48	103.67	1.92	2.82	180.15	4.74
9	2 Axle Truck	Construction Material	3901	5174	9.08	76.54	101.51	1.92	2.59	178.05	4.52
10	2 Axle Truck	Bricks	4021	6133	10.15	78.89	120.33	2.17	5.12	199.22	7.29
11	2 Axle Truck	Sand	4217	6580	10.80	82.74	129.10	2.63	6.78	211.84	9.41
										VDF	4.544

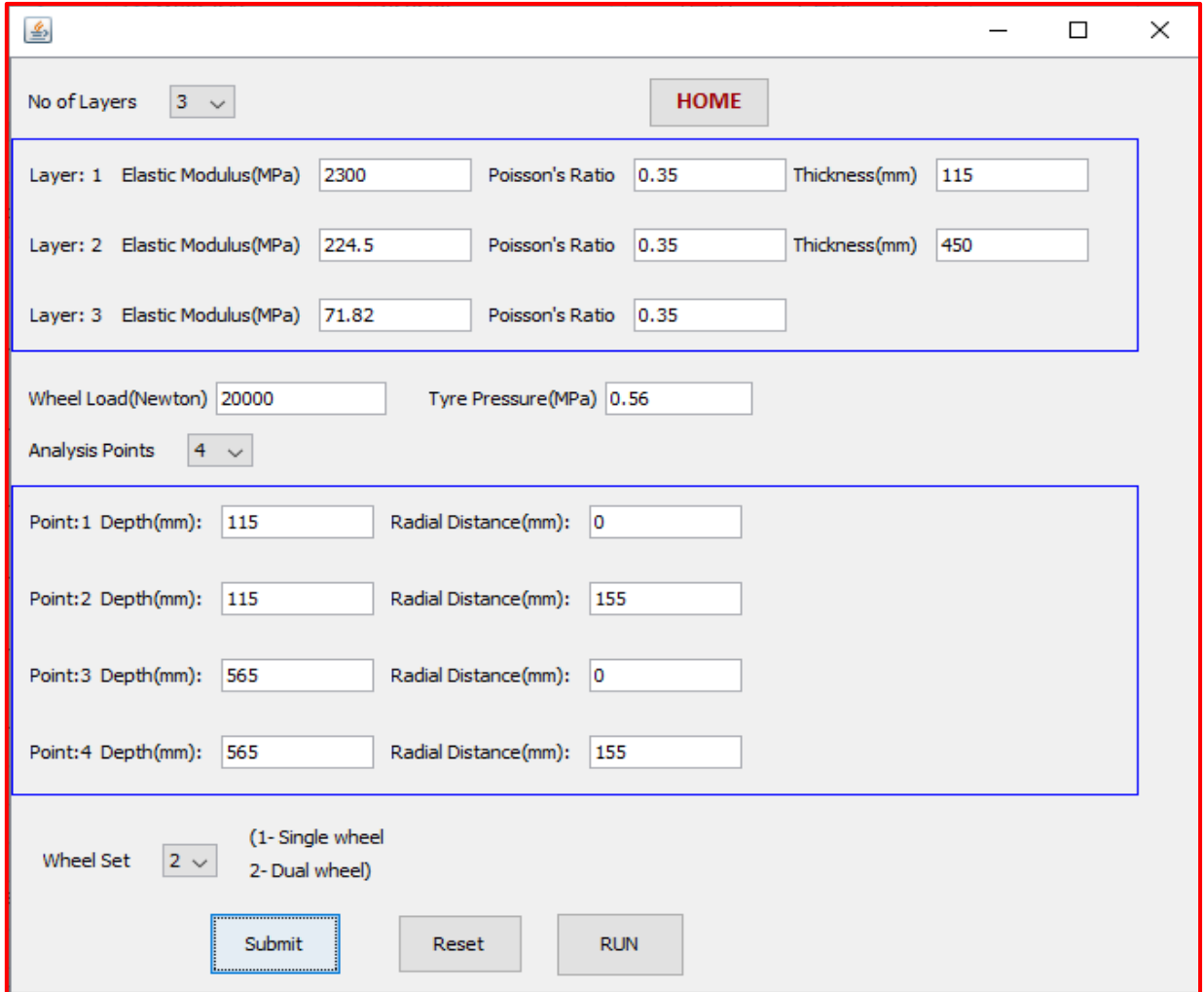
Annexure 3

MSA

Equivalent Single Axle Load Calculation for Station (At Babareshi)							
Year	Bus	LCV	2 Axle	Yearly Design ESA	Cumulative Design ESA	MSA	Design Period
VDF	2.58	1.345	4.544				
2020	225	85	51	135426		Base Year	
2021	236	94	54	143033			
2022	248	103	56	151103			
2023	260	112	59	159466			
2024	273	122	62	168320	168320	0.168	1-year
2025	287	133	65	177696	346016		
2026	302	145	68	187627	533644		
2027	317	158	72	198150	731793		
2028	332	171	75	208990	940783	0.941	5-years
2029	349	185	79	220446	1161229		
2030	367	199	83	232556	1393786		
2031	385	215	87	245359	1639144		
2032	404	233	92	258896	1898040		
2033	424	249	96	272754	2170794	2.171	10-years
2034	445	266	101	287369	2458163		
2035	468	285	106	302783	2760946		
2036	491	305	111	319042	3079988		
2037	516	326	117	336191	3416179		
2038	541	346	123	353641	3769820	3.770	15-years
2039	569	366	129	372002	4141823		
2040	597	388	135	391322	4533145		
2041	627	412	142	411651	4944796		
2042	658	436	149	433043	5377839		
2043	691	463	157	455552	5833391	5.833	20-years

Annexure 4

IITPAVE Analysis



The screenshot shows the IITPAVE software input interface. It includes a 'HOME' button, a 'No of Layers' dropdown set to 3, and three layer input sections. Each layer section contains fields for Elastic Modulus (MPa), Poisson's Ratio, and Thickness (mm). Below these are fields for Wheel Load (Newton) and Tyre Pressure (MPa), and an 'Analysis Points' dropdown set to 4. The analysis points section contains four rows, each with 'Depth (mm)' and 'Radial Distance (mm)' fields. At the bottom, there is a 'Wheel Set' dropdown set to 2, with a note '(1- Single wheel, 2- Dual wheel)', and three buttons: 'Submit', 'Reset', and 'RUN'.

Layer	Elastic Modulus (MPa)	Poisson's Ratio	Thickness (mm)
Layer: 1	2300	0.35	115
Layer: 2	224.5	0.35	450
Layer: 3	71.82	0.35	

Point	Depth (mm)	Radial Distance (mm)
Point: 1	115	0
Point: 2	115	155
Point: 3	565	0
Point: 4	565	155

Figure- 01: Input to IITPAVE Software

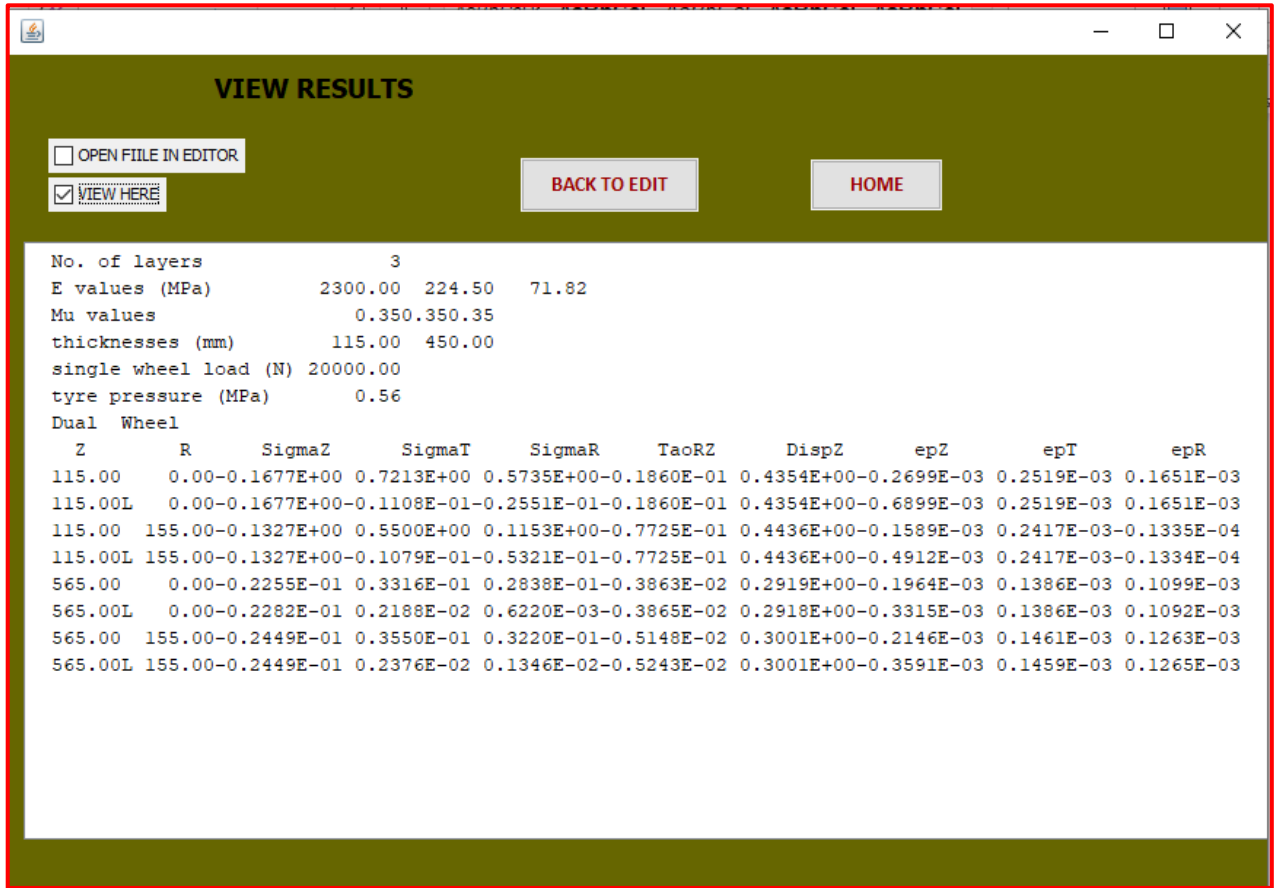


Figure- 02: Output from IITPAVE Software