CHAPTER – 5
DESIGN STANDARD AND IMPROVEMENT PROPOSALS

5.1 General

This chapter describes the various improvement proposals and their necessities to upgrade the existing carriageway facility of project road into two lanes with or without paved shoulder in accordance to the Indian standard configuration and design standards proposed for the project road. These improvement proposals are based on the findings of various engineering survey, investigations and analysis carried out on the project roads such as Traffic Survey and Analysis (Chapter-3), Inventory Data and Pavement Investigations (Chapter-4)'Manual of Standards & Specifications for Two Laning (IRC:SP:73-2007)'.

The improvement proposals for proposed widening include the provisions for the following major items:

a) Curvature Improvement
b) Realignment
c) Widening Proposal
d) Proposed Pavement Design & Overlay Design
e) Cross Drainage Structures
f) Traffic Control and Safety Measures
g) Miscellaneous

5.2 Design Standards

5.2.1 Summary

Following is a summary of the recommended design standards proposed to be adopted for the project road:

The design standards proposed to be followed for the Highway geometric design are as follows:

Table 5.1: Design Standards

Sl. No.	Item / Element	Standard
i.	Design speed	Ruling/Desirable 100/80 KMPH Minimum 80/65 KMPH Inhabited area 50 KMPH
ii.	Level of Service	'B'
iii.	Road way width (2-lane)	12.0 m.
iv.	Cross-sectional elements	
	❖ Carriageway	7.0 m
	❖ Earthen / Hard shoulder	2 X 2.50 m
	Four lane (urban section)	
	❖ Carriageway	2 X 7.5 m
v.	Right of way	15m – 30m
vi.	Camber	Main carriageway/paved shoulder 2.5% Earthen Shoulder 3.0%
vii.	Slope of embankment	IV:2H
viii.	Slope in cutting	IV:1H
ix.	Radii for Horizontal curves	• 360 m for design speed of 100 km/hr • 230 m for design speed of 80 km/hr • 155 m in urban stretches for a speed of 65 kmph

Sl. No.	Item / Element	Standard
x.	Ruling Gradient	3.3% for plain & rolling terrain
xi.	Minimum length of vertical curves	60m for design speed of 100 km/hr 50m for design speed of 80 km/hr
i.	Super elevation	5%
ii.	Friction factor	0.15 - 0.2%
iii.	Sight distance(SD)	Speed (KPH) ISD (m) 100 360 80 260 65 180

Geometric Design

5.2.2 General

Geometric design of a highway is the process whereby the layout of the road in specific terrain is designed to meet the needs of the road users keeping in view the road function, type and volume of traffic, potential traffic hazards and safety as well as convenience of the road users. The principal areas of control for fulfilment of this objective are- the horizontal alignment, vertical alignment and the road cross-section.

The Consultants have referred to the design standards and general features as per Manual of Specifications and Standards for two laning of highways through Public Private Partnership Published by IRC(IRC:SP-73-2007).

5.2.3 Design Speed

The project road highway passes through Plain/ rolling terrain. Rural highways, except expressways, are normally designed for speed of 100 km/hr, however depending on terrain and whether the design is for new alignment or reconstruction of an existing facility, the design speed is determined as per the site requirement.

5.2.4 Cross Sectional Elements

5.2.4.1 Roadway Width for Two lane Highways

Adequate roadway width will be provided for the requisite number of traffic lanes besides the shoulders. As specified in the above mentioned manual in general, for highways the shoulder width shall be 2.5 m, and lane width 3.5 m per lane.

5.2.4.2 Shoulders

Shoulders are a critical element of the roadway cross section. These provide recovery area for errant vehicles; a refuge for stopped or disabled vehicles; and access for emergency and maintenance vehicles. Shoulders can also provide an opportunity to improve sight distance through cut sections.

As per manual normal shoulders width shall be 2.50 m in open and isolated built up area.

The Consultants propose to adopt an outer shoulder width of minimum 2.5 m shoulder for the project highway. However, the configuration of shoulder depends upon the traffic capacity on the section of road. Accordingly, 2.5 m wide unpaved shoulders will be provided.

5.2.4.3 Pavement Camber (Cross-fall)

As per the provisions of the Manual a cross fall of 2.50% on bituminous roads and 2% on cement concrete road with low annual rainfall is being adopted.

5.2.4.4 Right of Way (ROW)

A ROW of 18 m is being proposed throughout on existing road and 30 m along the re-alignment

5.2.4.5 Typical Cross sections

Typical cross sections are prepared to guide the widening scheme of the proposed highway in different conditions. The broad conditions considered are :

- Type of terrain

- Existing pavement condition and width
- Realignment / Bypass
- Land use along the highway (Built up area / open area)
- Lane configuration
- Treatment over existing road

Based on the above considerations, following typical cross sections have been developed.

Table 5.2: Typical Cross Sections

S. No.	Type	Feature	Applicable to
1	1	Widening from Single Lane to 2-lane alongwith shoulders covered with 150 mm thick layer of granular material	Where the existing carriageway (3.0 m to 3.75 m wide) is to be widened to 7.0 m wide carriageway.
2	2	Widening and strengthening of Single Lane to 2-lanewith paved shoulders in built up area	Where the existing carriageway 3.0 m to 3.75m wide is to be widened to 7.0 m wide carriageway in Urban stretch
5	5	Bypass / Realignment	Re-alignment / bypasses

* The stretch having Intermediate Lane falls in the common position with H-III.

5.2.5 Horizontal Alignment

5.2.5.1 General

Though it is necessary to improve the sub-standard horizontal curves for the safety of the traffic. Therefore, the existing sub-standard curves have to be improved to have minimum radii of 230 m in rural area or to the extent possible within ROW. In the stretches passing through urban areas sub-standard curves are to be improved to have a radius of 155 m in general.

5.2.5.2 Sight Distances

Sight distance is a direct function of the design speed.

Safe stopping sight distances, intermediate and overtaking sight distances corresponding to various design speeds are given below:

Table 5.3: Stopping Sight Distance Criteria

Speed	Safe Stopping Sight Distance	Immediate Sight Distance	Overtaking Sight Distance
100	180	360	640
80	120	240	470
65	90	180	340
60	80	160	300

Mostly Intermediate sight distance has been adopted.

5.2.5.3 Transition (Spiral) Curves

The purpose of a transition (spiral) curve is to provide a smooth and aesthetically pleasing transition from a tangent and a circular curve. In addition, the transition curves provide the necessary length for attainment of super-elevation runoff.

The minimum transition length required as per the 'Manual of Standards & Specifications for Two Laning (IRC: SP: 73-2007)' for various speed and radius of curved is tabulated below.

Table 5.4: Minimum Transition Length

Speed (km/h)	Design Radius (m)	Length of Transition Curve (m)
100	360	130
80	230	90
65	155	80

It is proposed to adopt transition curve as per the above table in general site conditions...

5.2.5.4 Super-elevation

The limiting value of the super-elevation on the project highway in plain terrain is proposed to be **5% as per IRC: SP 73 -2007.**

5.2.6 Vertical Alignment

5.2.6.1 General

The vertical alignment should produce a smooth longitudinal profile consistent with standard of the road and terrain. Where it maybe possible horizontal and vertical curvature should be so combined that the safety and operational efficiency of the road is enhanced.

5.2.6.2 Gradients

The IRC: 73-1980 geometric design standards provide ruling vertical grades of 3.3% to 5.0% for plain terrains. However, for the project highway, maximum grade adopted is 1.5%.

5.2.6.3 Vertical Curves

When a motorised traffic travelling along upgrade is to move on to low grade or vice version, a change of direction of motion in the vertical plane is involved. If the change is not effected gradually the vehicle will be subjected to shock and occupants of the vehicle will experience discomfort. Hence a vertical curve is introduced to ease off the change in gradient. The vertical curves are designed for intermediate sight distance.

Minimum Length of Vertical Curve: The minimum length of vertical curve and the maximum grade change not requiring a vertical curve are summarized below:

Table5.5: Minimum Length of Vertical Curve

Design Speed (Km/hr)	Maximum grade change not requiring a vertical curve (in %)	Minimum length of vertical curve (m)
100	0.5	40
80	0.6	50

1. Summit or Crest Curves

A curve with convexity upwards is called a Summit curve. The design of Summit curve is mostly governed by considerations of sight distance. In general a simple parabolic curve is used for design of summit curve.

There are two case of calculation of length of summit curve for various sight distances:

Case-I: When the length of curve is greater than the required sight distance.

Case-II: When the length of curve is less than the required sight distance.

The minimum K values for Summit or Crest curves, in accordance with IRC –SP23 (1993) design guidelines for the case-I length of curve is greater than sight distance are tabulated below:

Table 5.6: K value

Design Speed km/h	Minimum K value		
	Stopping Sight Distance	Intermediate Sight Distance	Over Taking Sight Distance
100	73.6	135	426.7
80	32.6	60	230.1
65	18.4	33.8	93.7

The curve length which is calculated based on the above K values is subjected to the minimum length of the vertical curve described above.

However, the above values of ‘K’ are the minimum and consultant has adopted more than the above values.

2. Valley or Sag Curves

There are number of criteria available for establishing the length of Valley Curve. Out of that the most common one is

i) Headlight sight distance
ii) Rider comfort

To calculate the length following criteria is applied:

i) Height of headlight above road surface is 0.75
ii) The useful beam of headlight is up to one degree upwards from the grade of the roads.
iii) The height of the object is nil

The minimum K values for valley or sag curves, in accordance with IRC –SP23 (1993) design guidelines are 41.5, 25.3 and 17.4 for design speeds of100 km/hr, 80 km/hr and65 km/hr respectively. The curve length which is calculated based on the above K values is subjected to the minimum length of the vertical curve described above.

However, the above values of ‘K’ are minimum and consultant has adopted more than the above values.

Widening Scheme:

In order to meet future traffic requirement the existing carriageway is proposed to be upgraded to achieve high speed of travel with comfort and safety. Widening scheme is studied as follows.

Widening the existing lane to 2-lane paved shoulder in built up area only with formation width of 12m including realignments / Bypasses to achieve the design speed of 100kmph ruling and 80kmph minimum.

Table: 5.7

S. No.	Homogeneous Section	Lane Configuration
1	Km 0 -31 (Bhawi – Sathin, including common portion with H-III)	2-Lane With 2.5 m wide shoulder covered with 150 mm thick granular material.
2	Km 31 – 71 (Sathin - Palri)	2-Lane with 2.50 m wide shoulder covered with 150 mm thick granular material.
3	Km 75 - 97 (Lawari Piou – Khimsar, including common portion with H-II)	2-Lane with 2.50 m wide shoulder covered with 150 mm thick granular material.

Above stretches also include the stretches passing through the towns details given below where the lane configuration will be two lane with 1.5 m wide paved shoulder on either side alongwith 1 m wide earthen shoulder over layed with 150 mm thick granular material.

S. No.	Name of Township	Location Ch (km – km)	Length (m)	Pavement type	Remarks
1	Ghana Mangra	5.400 – 6.170	0.77	CC/BT	Partly CC
2	Tilwasni	7.000 – 8.200	1.20	CC/BT	Partly CC
3	Selari	10.480 – 11.500	1.02	CC/BT	Partly CC
4	Pipar	18.500 – 20.850	2.35	CC/BT	Partly CC
5	Ratkuria	41.150 – 42.000	0.85	CC/BT	Partly CC
6	Bhopalgarh	53.900 – 56.900	3.00	CC/BT	Partly CC
7	Surpura	62.100 – 63.100	1.00	CC/BT	Partly CC
8	Gajsinghpur	79.500- 81.100	1.60	CC/BT	Partly CC
9	Mangeria	86.300 – 87.400	1.10	CC/BT	Partly CC
10	Dharnawas	92.150 – 93.000	0.85	CC/BT	Partly CC
11	Lalawas	95.600 – 96.000	0.40	CC/BT	Partly CC

Existing Alignment

The project highway taking off from Chainage Km. 59.700 of NH-112 ends at Ch. 217.200 of NH-65 after running along MDR-90 and passes through the villages Bhawi, Silari, Pipar city, Sathin, Ratkuriya, Bhopalgarh, Palri Ranawat, Lawari Piou, Gajsinghpura Mangeria, Tadawas, Lalawas.The project road is located between 26^{o} 13' 43" and 26^{o} 56' 38" latitude and 73^{o} 36' 28" and 73^{o} 24' 07" longitude.

The horizontal alignment is passing through plain rolling terrain. The existing alignment in some locations especially in built up areas has sharp curve and deficient geometrics the vertical alignment is generally within lain down standards.

The land along the project road is mostly used for agriculture purposes with some built up areas. The major built up area along the project road are Pipar, Rathkuria, Bhopalgarh, Gajsinghpura.

The width of existing carriageway is generally single lane (3.50 m to 3.66 m).

From the preliminary survey it has been found that The Existing ROW varies within 15 to 30 m in most of the open areas. However, after the collection of revenue maps, it is noted that the existing ROW varies from 8 to 20 m.

Widening Scheme

The existing project highway has multi-dimensional facets with respect to land use and road geometry and considering all these aspects, the section wise widening scheme based on the investigations as adopted is given in **Table 5.8:**

Table 5.8: Widening Scheme

Nature of widening	Existing Chainage (Km.)		Designing Chainage (Km.)		Length (Km)
	From	To	From	To	
Concentric	0+000.000	0+039.720	0+000.000	0+039.200	39.200
Realignment	0+039.720	0+041.275	0+039.200	0+041.200	2.000
Concentric	0+041.200	0+097.150	0+041.200	0+096.978	55.778

Chainage Reference:

The existing km stone available on ground wherever available have been used as referencing pillar only. The development proposal has been finalised based on Design chainage system.

Summary of Widening Scheme:

The widening scheme can be summarised as given in **Table 5.8**

Design Standards, Improvement Proposal and Design

Table: 5.9 : Improvement Proposals

1	Widening and Strengthening from Single Lane to 2-lane with shoulders covered with 150 mm thick layer of granular material	
2	Widening and strengthening of Single Lane to 2-lanewith paved shoulders in built up area	
3	Bypass / Realignment	
4	Existing road (overlay) without paved shoulder where width is 3.50 m or more (Rural Section)	
5	Existing road (overlay) with paved shoulder where width is 3.50 m or more (Built up Section)	

Typical Cross Sections

Proposed typical cross – sections are at **Annexure T 1 to T 3** and also are tabulated below:

Table 5.10: Typical Cross sections

S. No.	Type	Description
1	1	Widening from Single Lane to 2-lane alongwith shoulders covered with 150 mm thick layer of granular material

2	2	Widening and strengthening of Single Lane to 2-lanewith paved shoulders in built up area
3	3	Bypass / Realignment

Cross Section Schedule

Table: 5.11

S. No.	Proposed Chainage		Length
	From	To	(Km.)
TCS - 1			
1	2.50	5.40	2.90
2	6.17	7.00	0.83
3	8.20	10.71	2.51
4	11.50	18.60	7.10
5	20.76	39.20	18.44
6	41.20	40.77	-0.43
7	42.00	53.40	11.40
8	56.94	79.50	22.56
9	81.10	92.15	11.05
10	93.00	95.60	2.60

TCS - 2			
1	5.4	6.17	0.77
2	7	7.41	0.41
3	7.41	8.2	0.79
4	10.71	11.5	0.79
5	18.6	19.48	0.88
6	19.48	20.76	1.28
7	41.15	42	0.85
8	40.77	41.23	0.46
9	53.4	53.93	0.53
10	53.93	56.9	2. 97
11	54.9	55.3	0.4
12	55.3	56.94	1.64
13	79.5	81.1	1.6
14	92.15	93	0.85
15	95.6	96.8	1.2

TCS - 3			
1	0.00	2.50	2.50
2	39.20	41.20	2.00

5.3 Bypass / Realignment

5.3.1 Requirement of re-alignment and bypasses

Based on site visit and considering, existing ROW available, geometrics of the existing road and associated problems of acquisition of structures, it is proposed to provide a short realignment in Rathkuriya village.

Rathkuriya Re-alignment

The existing road between Km. 41.500 to 42.000 is having sub-standard geometrics. It is therefore, necessary to re-align the stretch between Km. 40-42 to avoid bad geometrics. Accordingly, the realignment proposal was prepared and submitted to the Authority which was approved by them subsequently. However, topographic survey could not be taken up due to public agitation. Project Director was kept informed in this regard.

Table 5.12: Summary of details of Re-alignment

S.No.	Name of Re-alignment	Existing Chainage (Km.)		Proposed Chainage (Km.)		Proposed length (Km)
		From	TO	From	TO	
1	Rathkuriya	40.375	42.000	39.150	41.200	2.050
2	Pipar bypass	18.600	21.450	0.000	2.500	2.500

Geometric Improvement Design

As per IRCl73-2007, the project highway should be designed with 100 kmpH ruling speed and 80 KMPH minimum speed for plain terrain and 80 KMPH/65 KMPH for rolling terrain. However, keeping in view the diverse mix of traffic on the project highway, minimum design speed of 65 kmph (Radius 155m) has been adopted. In built up areas, the speed has been restricted to 50 / 40 kmph where there is no scope at all to improve the geometric further within ROW.

Proposal for New Bridge

There is no proposal to construct the new bridge on the Project Highway.

Proposal for replacement of Existing LC with ROB

The project road crosses railway track at one location (Km 272-60) at Merta Road junction. As per railway records, the TVU (Train Vehicle Units) at the LC is 67440 as on April 2014. According to IRC 62- 1976 "Grade Separator should be provided across existing railway crossing if the product of ADT (Fast vehicle only) and the number of trains passing per day exceed 50,000. However, the cost of construction of this ROB is not included in the overall cost of the project.

Cross Drainage Structures

Introduction

Upgrading of the road section from Single Lane /Intermediate Lane to 2-Lane carriageway involves widening of the existing CD structures. Wherever the new alignment is away from the existing road, new culverts opposite to the existing ones would be required in the new alignment. New culverts are also required where the capacities of the existing ones are inadequate or where the vents/diameters are too small from maintenance point of view. Repair or replacement of culverts is called for when these are in distressed condition. Accordingly detailed inventory of all the culverts was made and their conditions survey was carried out to determine their present conditions.

The pipe culverts, which are having diameter less than 1000 mm have been replaced by pipe of NP4 1200 mm keeping in view the constraints and inadvertence of maintenance. Similarly the CD structures other than pipes having widths and heights up to one metre have been proposed to be replaced by 1200 mm diameter pipes or Slab culvert as appropriate to maintain the vertical profile. All causeways have been proposed to be replaced by new pipe culverts (2x1.2m dia. / 3x1.2m dia.) as per the hydrology of the area. All other existing cross drainage structures have simply been recommended for widening / repair / reconstruction.

The schemes for widening or replacement of CD Structure have been prepared based on available data, visual assessment of the CD structures, the surrounding tell-tale marks of HFL, local enquiry and the concept mentioned above. Functional cross-section of the culvert for 2-laning configuration is presented in Typical GADs for Pipe & Slab Culverts is enclosed in **Drawing volume.**

Summary of different types of Culverts/CD structures:

Culverts:

Table: 5.13 Details of Cross - Drainage Structure

Pipe Culvert								
S.No.	Existing Chainage (km)	Proposed Chainage (km)	Type of structure	Span Arrangement (m)	Vertical Clearance (m)	Road Level (m)	Bed Level (m)	Structure proposed
1	0+000	0+013	Pipe	2X0.90	1.1	267.327	266.382	2 H.P. 1.2m Dia

Slab Culvert									
S.No.	Existing Chainage (km)	Proposed Chainage (km)	Type of structure	Span Arrangement (m)	Invert Level LHS (m)	Invert Level RHS (m)	Soffit Level (m)	Road Level (m)	Structure proposed
1	53+622	51+998	Slab	2X1.10	297.36	297.5	298.9	299.646	To be widened
2	56+338	55+750	Slab	1X4.0	297.03	297.62	301.97	302.356	To be widened

Causeway					
S. No.	**Existing Chainage (km)**	**Proposed Chainage (km)**	**Type of structure**	**Span Arrangement (m)**	**Structure proposed**
1	5+305	5+315	Cause Way	7.8X98.7	3 H.P. 1.2m Dia
2	12+430	11+973	Cause Way	5.00X40.750	2 H.P. 1.2m Dia
3	42+302	41+500	Cause Way	7.0x85.0	3 H.P. 1.2m Dia
4	47+788	46+396	Cause Way	6.3X77.2	3 H.P. 1.2m Dia
5	48+525	47+139	Cause Way	13.0X91.2	3 H.P. 1.2m Dia
6	49+685	48+248	Cause Way	7.0X61.7	3 H.P. 1.2m Dia
7	58+470	57+884	Cause Way	7.3X20.3	2 H.P. 1.2m Dia
8	59+880	59+332	Cause Way	30X8	2 H.P. 1.2m Dia
9	60+044	59+525	Cause Way	30X8	2 H.P. 1.2m Dia
10	60+225	59+710	Cause Way	30X8	2 H.P. 1.2m Dia
11	61+757	61+363	Cause Way	30X8	2 H.P. 1.2m Dia
12		85+927	Cause Way	7.1x32.9	Chocked
13	On Pipar bypass	0+600	Hume Pipe	2X1.2	2 H.P. 1.2m Dia
14	On Pipar bypass	1+300	Hume Pipe	2X1.2	2 H.P. 1.2m Dia
15	On Pipar bypass	2+000	Hume Pipe	2X1.2	2 H.P. 1.2m Dia

Road Markings, Signs and other safety Devices

5.4 Road Markings

Pavement markings are proposed as per IRC: 35, “Code of Practice for Road Marking” with edge line, continuity line, stop line, give way lines, diagonal/chevron markings and zebra crossings etc. The pavement marking shall be of hot applied thermoplastic paint with glass beads as per the MORT&H specification for Road and Bridge Works, 2013.

5.5 Road Signs

Adequate road signs are proposed for the project road in order to provide advance information to regulate/control traffic flow and ensure safety of operations. All normal warning and regulatory road signs will be provided in accordance with IRC-67-2012. Typical drawings of road signs with its erection details are given in the drawing volume.

The signs will be of retro reflective sheeting of high intensity grade with encapsulated lens and fixing details as per clause 801 of MOSRTH Specifications for Road and Bridge Works, 2013 (5th Revision).

5.6 Kilometre Stone:

Standard Kilometre, 5th kilometre and hectometre stones have been proposed as per provisions of IRC: 8 and IRC 26. In addition, boundary stones at an interval of 100 m staggered on each side have been proposed as per IRC: 25.

5.7 Delineators

Delineator provides visual assistance to drivers about the road alignment. Delineators have been proposed as per guidelines vide IRC 79 "Recommended Practice for Road Delineators."

5.8 Miscellaneous Requirements:

Proposal for Bus Shelter

There are no existing Bus Shelter son the project road. However, from the survey of bus travelling and its stoppages the following locations have been identified for provision of bus shelter on either side. The general layout of bus shelter shall be as per Cl.13.5.3. of IRC: SP 73-2007.

Table 5.14: Bus Shelter Locations

S. No.		(Existing Chainage Km.)		Proposed Chainage (km)	
		LHS	RHS	LHS	RHS
1	Ghano-Mangia	6.150	6.250	6.150	6.250
2	Talwasni	7.600	7.350	7.600	7.350
3	Silari	10.750	10.650	10.750	10.650
4	Rathkuria	40.200	40.350	39.800	39+950
5	Bhopalgarh	53.800	53.900	53.734	53.834
6	Surpura Khurd	62.250	61.900	62.178	61.828
7	Palri Ranawat	70+649	70+864	70+574	70+789
8	Gajsinghpur	80+905	80+645	80+743	80+483
9	Mangeria	86+880	86+920	86+720	86+760
10	Dharmawas	92+820	92+880	92+625	92+685
11	Lalawas	95+690	95+780	95+491	95+580

The above locations are, however, tentative and can be adjusted during construction in consultation with IE/AE.

5.9 Cattle Crossings:

Though no separate cattle crossings have been proposed, the culverts, however, having minimum 2m height during dry season may serve as cattle crossings.

5.10 Toll Plazas Stations

Toll plaza location has been strategically identified to collect maximum toll revenue. In addition, the availability of flat open ground and straight reach to provide clear visibility, safe distance from intersections and availability of basic facilities for the personnel employed in toll collection has been considered.

Three Toll Plazas having two lane (plus one lane on each side for oversized vehicles) are proposed for the entire length of the project road after considering land availability, stream of traffic, geometric considerations and terrain condition etc. Proposed locations of toll plazas are given in table below.

A minimum semi-automatic system for toll collection may be adopted. The general layout of toll plaza shall be as per IRC: SP: 73-2007

Table 5.15: Toll Plaza Location

S. No.	Existing Chainage	Proposed Chainage of Project Highway
1	Km. 3.000 (Bhawi- Sathin Section)	Km. 3.00
2	Km. 49.400 (Sathin- Palri Section)	Km. 48.000
3	Km. 85.700 (Lawari Piou-Khimsar Section)	Km. 85.535

5.11 Pavement Design

5.11.1 General

Pavement design basically aims at determining the total thickness of the pavement structure as well as the thickness of the individual structural components. Different accepted methods for design are available, such as those of IRC37-2012, AASHTO, etc. and according to the scope of services the overlay design has been worked out following the IRC 81-2002.

5.11.2 Project Proposals

The existing project highway has most of single lane (3.0-3.66m wide) There exists about 1 - 2m wide earthen shoulder on either side of the carriageway. The surface of the carriageway is generally bituminous except in built up areas where it is partly cement concrete. The project proposal is to widen the existing carriageway to standard 2-lane / 2-lane with paved shoulder on both flanked with 2.5m wide earthen shoulder with top 150mm thick with granular material. In built up area, 1.5m wide paved shoulder have been proposed and 1.0 m wide earthen shoulder on both sides to be covered with 0.15 m thick granular material.

5.11.3 Pavement Works

The pavement works for implementing the above proposals will mainly consist of:

- Strengthening of the existing pavement
- Construction of additional width to make the carriageway standard two lanes with or without paved shoulder.
- New construction in Bypasses and Realignments

Pavement design has been done as per the guidelines given in IRC and AASHTO Codes as under:-

Table5.16 : IRC Codes

Flexible Pavement	IRC : 37 – 2012	Guidelines for Design of Flexible Pavement
Strengthening of Flexible Pavement	IRC : 81 – 1997	Guidelines for strengthening of Flexible Road Pavements using Benkelman Beam Deflection Techniques
Rigid Pavement	IRC : 58 – 2011	Guidelines for the Design of Plain jointed Rigid Pavement for Highways

5.11.4 Factors affecting pavement design

The principal factors that will govern the design of pavements including overlays/reconstruction of the existing carriageway are:

- Traffic
- Design Life
- Growth Rates
- Lane Distribution Factor
- Vehicle Damage Factor (VDF)
- Cumulative Million Standard Axels (CMSA)
- CBR of Subgrade

5.11.5 Traffic

The detailed traffic surveys for the project road were conducted by the consultants in (Nov. / Dec. 2014)). The survey data and its analysis for the project road stretch under report are given in Chapter 3 of this Report.

Average Daily Traffic

Based on the traffic survey data and the project road stretch under report is divided into 4 homogeneous traffic sections as shown in **Table 2.2.**

Table 5.17: Homogeneous Traffic Sections and Commercial Vehicles in base Year 2014-15

Section	Chainage (km)	Length (km)	Vehicle No. In Base Year 2014-15					
			Standard Bus	LCV	2-Axle	Tractor with trailer	3-Axle	Multi-Axle
1	Km. 0 – 21 (Bhawi to Sathin)	21*	90	26	219	142	234	164
2	Km. 31-55 (Sathin to Bhopalgarh)	24	33	55	223	67	68	23
3	Km. 55-71 (Bhopalgarh to Palri)	16	13	1	12	28	4	0
4	Km. 75-97 (Lawari Piou to Khimsar)	22	11	1	11	23	3	0

Note: * This excludes common portion (Km. 21-30.50) with H-III.

Pavement Option

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. Its cost represents largest proportion of the total construction cost (i.e. for new roads and for rehabilitation projects).

The purpose of the pavement study is to make analysis of different pavement alternatives to provide a basis for selection of the most advantage solution, considering all costs occurring during the life of the pavement, viz., construction costs, maintenance costs and costs for the road user.

In pavement option study, the following is studied in detail:

- New flexible pavement on the widening part and for full reconstruction stretches
- Flexible overlay over the existing pavement
- Flexible pavement for partial reconstruction stretches of existing pavement.

The different pavement design methods for above pavement options are studied and applied, which are given in Table 2.3.

Table 5.18: Pavement Design Methods

Pavement Option	Option Type	Design Method
1	New Flexible Pavement	IRC: 37-2012
2	Flexible Overlay	IRC: 81-1997

Design Life:

For the design of pavement, design life is defined in terms of cumulative number of standard axle that can be carried before the pavement is required to be strengthened. The thickness of sub-base and base is designed for 15 years and the initial bitumen surfacing for a period of 10 years.

Growth Rates:

The projected growth rates for different periods are given in below:

Table 5.19: Adopted Growth rate In Slab of each 5years

Vehicles	Year					
	2014-2018	2018-2020	2020-2025	2025-2030	2030-2035	2035-2040
Two Wheelers	5 %	5 %	5 %	5 %	5 %	5 %
Cars/Jeeps	5 %	5 %	5 %	5 %	5 %	5 %
Buses	5 %	5 %	5 %	5 %	5 %	5 %
Trucks	5 %	5 %	5 %	5 %	5 %	5 %
Multi Axle Vehicles	5 %	5 %	5 %	5 %	5 %	5 %
Tractor	5 %	5 %	5 %	5 %	5 %	5 %

Lane Distribution Factor (LDF)

As per IRC 37 : 2012 Clause 4.5.1, for 2 lane single carriageway the lane distribution factor shall be 50% of the total number of commercial vehicles in both directions.

However, if the vehicle damage factor (VDF) in one direction is higher the traffic in the direction of higher VDF will be adopted.

Vehicle Damage Factors (VDF):

The VDF is a multiple to convert the number of commercial vehicle of different axle loads and axle configuration to the number of standard axle load repetitions. It is defined as equivalent number of standard axle per commercial vehicle. The VDF varies with the vehicle axle configuration axle loadings, terrain, type of road and region to region. The average Vehicle Damage Factors (VDF) for project road sections as obtained from the 24 hrs. Axle load surveys conducted on 05.12.14 at selected locations of project road, are given below:

Table 5.20: Adopted Vehicle Damage Factors

Location	Vehicle Type						
	Bus	Mini Bus	Mini LCV	LCV	2-Axle truck	3-Axle Truck	4-6 Axle vehicle
SH-86C KM-1+500	1.27	0.28	0.045	1.61	8.87	6.64	4.83
SH-86C KM-55+500	1.11	-	0.055	1.86	11.62	9.72	6.50

Cumulative Million Standard Axels (CMSA) :

Cumulative Million Standard Axles are computed for the design period of 10/20 years based on the above commercial vehicles.

Million Standard Axles is worked out from the following equation:

$$N = \frac{365 * [(1+r)^n -1] * A * D * F}{r}$$

Where,

N : The Cumulative Million Standard Axles (CMSA) to be catered for in the design in terms of msa.

A : Initial Traffic in the year of completion of construction in terms of the number of commercial vehicles per day.

D : Lane Distribution Factor

n : Design Life in Years (10 years for bituminous layers and 20 years for GSB and WMM

r : Annual Growth Rate of Vehicles.

F : Vehicle Damage Factor

Based on the above said parameters the CMSA's have been computed upto the year 2042 and the details are given in **Annexure 2.1,** respectively. Based on MSA computations, the design traffic (MSA) adopted for 10/15 years of pavement life for the sections of the project road stretch under report is tabulated below:

Table 5.21: Design Traffic for 10 / 15 Years

Homogenous Section Km. 0.00 –Km. 31.000	Length (Km.)	10 years (Design traffic) into MSA	15 years Design traffic in MSA
(Km. 0 – 20)	21	0.344	0.906
Km. 31 – 55	24	10.604	17.605
Km. 55 – 71	16	8.900	14.830
Km. 75 – 89 Km. 95 - 97	18	0.488	0.813

Note: The Stretch from Km. 89-94 is Katcha Road

5.11.6 Condition of the Existing Pavement

Detailed pavement investigations including condition surveys by (a) visual inspection, (b) examination of pavement composition by excavating test pits at regular intervals and testing the properties of the existing subgrade soil. Its structural strength as indicated by Benkleman Beam Deflection (BBD) was carried out to determine the extent and nature of pavement distress of the existing carriageway. The results of the investigations have been presented in the **Chapter 4.**

5.11.7 Benkelman Beam Deflection

Benkelman Beam test for the project road was conducted at selected locations to evaluate the structural strength of the pavement. The test was carried out in accordance with the guidelines given in IRC: 81- 1997. The Benkelman Beam Deflection (BBD) data was analysed to determine the Characteristic Deflection of the pavement of the project road. The detailed BBD data and it analysis for the project road stretch under report are given in the **Annexure 4.4, chapter 4** the characteristic deflection values are found to vary from 0.3 to 1.246.

5.11.8 Homogeneous Sections

The characteristics deflection and roughness of the project road is not varying in significant continuous length, however, the traffic volume of the road is having the significant change in their value in four sections. Hence, the Project road is divided into 4 Homogeneous sections based on Traffic, Roughness and BBD as following for the Pavement Design.

Table 5.22: Homogeneous Sections

Sr. No.	Homogeneous section	From (km)	To (km)	Length (m)	Traffic (msa)
1	HS-1	0.000	21.000	21	5
2	HS-2	31.000	55.000	24	10
3	HS-3	55.000	71.000	16	10
4	HS-4	75.000	89.000	22	5
		95.000	97.000		

5.11.9 Characteristics of the Subgrade Soil

While the design of strengthening measures will depend upon the strength and other engineering characteristics of the subgrade soil under the existing pavement, the new pavements will be built on and designed for the selected subgrade material obtained from borrow areas found suitable for the purpose.

The detailed investigations of the existing subgrade soil and the borrow area material were carried out to determine their strength (soaked CBR) and other engineering properties. The results of these investigations for the project roads are summarized in **Table 5.23**below:

Table 5.23: Engineering Characteristics of the Subgrade Soil

From	To	Soil Type	PI (%)	MDD (gm/cc)	CBR (%) (Soaked at 97% MDD)
0	21	SM / SM-SC	NP	Varies from 1.94 to 2.01 Average is 1.95	Average is 23
21	55	SM	NP	Average is 1.95	Average is 24
55	71	SM / SM-WG / GM-SM	NP	Average is 2.01	Average is 22
75	89	SM / GM-SM	NP	Average is 1.96	Average is 25
95	97				

SM – Silty Sand
SM – WG – Silty Sand with gravel
GM-SM - Gravel with Silty Sand
SM-SC - Clayey with Silty Sand

Table 5.24: Summary of Test Results of Borrow area Soil

Type of Test	Value
Liquid Limit %	NP
Plastic Limit %	NP
Plasticity Index%	NP
MDD gm/cc	1.94
OMC %	11.50
Soaked CBR %	24.05

5.11.10New Construction

Flexible pavements have been designed for the new construction in the widened and bypass / realignment section.

5.11.11Design Method

IRC: 37–2012

Design Input

Design Traffic

The values of design traffic are ranging from 0.344 to 10.64 msa for 10 yrs. and 0.80 – 17.60 for 15 yrs. The adopted values are given below:

Section		**MSA 10 Years**	**MSA 15 Years**
HS 1	-	5	5
HS 2	-	11	20
HS 3	-	10	15
HS 4	-	5	5

Subgrade CBR

Based on the investigations of the borrow area soils identified for the construction of new pavements, Subgrade CBR of 10 % has been adopted for the design of flexible pavement.

5.11.12 Pavement Composition

The flexible pavements for the different project roads have been designed for service life of twenty years for sub-base / Base course and 10 years for bituminous layers. The pavement composition details as per IRC: 37-2012 with these design parameters are tabulated below:

Table 5.25: Composition of New Flexible Pavement

S.No.	Section	Traffic (msa)	Layer Thickness (mm)				
			BC	DBM	WMM	GSB	Total
1	0-21	5	25	50	250	150	475
2	30-55	11	40	55	250	200	545
3	55-71	10	40	50	250	200	540
4	75-89	5	25	50	250	150	475

GSB in the widened portion will be extended up to full formation width

5.11.13 Pavement Material

The general specification sections and characterization of material is presented in **Table 5.26.**

Table 5.26 : Pavement Layers and Materials

S. No.	Pavement Layers and Materials	Sections Details MoRTH Specification	Remarks
1	Embankment Construction	Section 305	Minimum Soaked CBR 8%

2	Subgrade	Section 305	Minimum Soaked CBR 8%
3	Granular Sub-base upper layer lower layer	Section 401	Minimum compacted thickness 150mm Grading I of Table 400-1 Grading I of Table 400-2
4	Base Course – WMM	Section 406	Thickness of single layer shall be 75mm – 200mm
5	Prime Coat	Section 502	
6	Tack Coat	Section 503	
7	Dense Bituminous Macadam	Section 505	Thickness of single layer shall be 50mm – 100mm
8	Bituminous Concrete	Section 507	Thickness of single layer shall be 30mm – 50mm
9	Dry Lean Concrete	Section 601	Thickness of single layer shall be 100mm and 150mm
10	Pavement Quality Concrete	Section 602	Minimum compacted thickness of 140mm

5.11.14 Proposed New Pavement

Pavement thickness has been recommended for all homogeneous sections are summarised below:

Table 5.27 : Proposed Layer of the New Pavement

S. No.	Sections (km)		MSA	Layer Thickness (mm)				
				BC	DBM	WMM	GSB	Total
1	HS – 1	21	5	25	50	250	150	475
2	HS – 2	24	11	40	55	250	200	545
3	HS – 3	16	10	40	50	250	200	540
4	HS - 4	22	5	25	50	250	150	475

5.11.15Strengthening of the Existing Pavement

Design Method

IRC: 81–1997

Design Input

Design Traffic
The design traffic for Homogeneous sections has been taken min **10 msa**.
Characteristic Deflection by BBD

The characteristic deflections for all the homogeneous section are taken in annexure 4.4, Chapter -4.

5.11.16Strengthening of the existing pavement

Based on the BBD test results for the existing pavement and compliance to IRC codes / guidelines, a strengthening bituminous overlay of minimum of 50mm DBM+50mm BC with appropriate profile corrective course (10-15cm) with DBM has been proposed except for the stretch from Km. 89 – Km. 94 where altogether a new pavement has been proposed.

5.11.17IRC: 58-2011 method of Rigid Pavement Design – for toll plaza locations

Rigid pavement for new carriageway has been designed as per IRC:58-2011.

Wheel Load

A tyre pressure of 8 Kg. /CM^2 may be adopted for the design.

For important roads and other roads where there will be uninterrupted traffic flow and high volume of truck traffic, the suggested value of Load Safety Factor (LSF) is 1.2. For roads of lesser importance having lower proportion of truck traffic, LSF may be taken as 1.1. For residential and other streets that carry small number of commercial traffic, the LSF may be taken as 1.0.

It is recommended that the basic design of the slab be done with a 98th percentile axle load, and the design there after checked by for fatigue consumption for higher axle loads.

Design Period

Normally, cement concrete pavements have a life span of 30 years and should be designed for this period.

Design Traffic

Design traffic of 25 per cent of the total two – lane two-way commercial vehicles may be considered as very conservative estimate for design against fatigue failure.

Temperature Differential

Temperature differential between the top and bottom of pavements causes the concrete slab to warp, giving rise to stresses. For this purpose, guidance may be had from table 2.13:

Table 5.28 : Recommended Temperature Differentials for Concrete

Zone	States	Temperatures Differentials, ^{0}C in Slabs of Thickness			
		15cm	20cm	25cm	30cm
1	Punjab, U.P., Uttarakhand, Gujarat, Rajasthan, Haryana and North M.P., excluding hilly regions.	12.5	13.1	14.3	15.8

Considering all the stipulation of IRC 58-2011 the proposed rigid pavement thickness at Toll Plaza locations is presented in Table.2.14:

Table 5.29 : Proposed Rigid Pavement Thickness at All Toll Plaza Locations

Material Type	Thickness (mm)
Pavement Quality Concrete (M-40)	300
Dry Lean Concrete (M-15)	150
Granular Sub-base	150
Subgrade	500