Table of Contents

List of Tables

List of Figures

8 PAVEMENT DESIGN

8.1 GENERAL

8.1.1 General

The design of pavement i.e., calculating the total crust thickness depends on mainly two factors Viz. total cumulative repetitions of standard axle loads for the design life and the strength of sub-grade soils (CBR).

The total cumulative repetitions of standard axles are in turn, a function of the annual average daily traffic (AADT) and applicable growth rate (r) of vehicles for forecasting the traffic after a certain period and Vehicle Damage Factor (VDF) for converting the mixed volume of traffic in terms of standard axle load repetitions. Further, lane distribution factor is applied to account for the vehicle load distribution across the width of pavement depending on the available carriageway width.

8.1.2 Design Guidelines

- Clause 5.3 of "Manual of Specifications and Standards for Four laning of Highways through Public Private Partnership by – IRC: SP:84-2019" states that "new pavements shall be designed in accordance with IRC:37(flexible).
- Clause 5.4.1 of IRC: SP:87-2019, states that "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 20msa. Stage construction shall not be permitted.
- Clause 4.3.1 of IRC:38-2018, states: "A design period of 20 years may be adopted for the structural design of pavements for National Highways, State Highways and Urban Roads "
- Clause 5.4 of IRC: 58-2015, states: Cement concrete pavements may be designed to have a life span of 30 years or more.
- Clause 5.7.4 of IRC: 58-2015, states: A subbase of Dry Lean Concrete (DLC) having a 7-day average compressive strength of 7 MPa determined as per IRC:SP:49 over GSB is recommended for highways. The minimum recommended thickness of DLC for major highways is 150 mm. The DLC shall extend beyond the PQC by 0.5 m on either side.
- Clause 5.7.5 of IRC: 58-2015, states: A de-bonding interlayer of polythene sheet white or transparent having a minimum thickness of 125 micron is recommended as per the current practice in India.

Alternative strategies or combination of initial design, strengthening and maintenance can be developed by the concessionaire to provide the specified level of pavement performance over the operation period subject to satisfying the following minimum design requirements.

8.2 TRAFFIC

The project stretch is divided into 3 homogeneous sections. Below table gives information regarding the HS in project corridor

Table 8-1: Homogeneous Sections

S. No	Homogeneous Section	From (Km.)	To (Km.)	Length (Km.)
1	III	0.020	14.380	14.360

Traffic surveys are conducted in these sections and the Traffic volume in each section is as given in Table 8-2

Table 8-2: Traffic along Homogeneous Sections

Year	PASSENGER TRAFFIC									GOODS TRAFFIC									Non Motorised			TOLL EXEMPTED			Total Traffic volume in numbers	Total tollable traffic volume in numbers	Total Traffic In PCU's	Allowable Traffic in PCU's
	2W	3W	Car / Jeep	Car / Jeep (YB)	Tata Magic	RTC Bus	Private Bus	Mini Bus	School	2 Axle	3 Axle	Multi Axle	Over sized	LGV/ LCV	Mini LCV	Tractor	Tractor with trailer/ Others	3w Goods	Cycle	Cycle Rickshaw	Animal Drawn	car	MINI BUS	TRUCKS				
2023	1945	2764	649	2	1	0	0	0	0	28	68	5	3	29	155	0	2	20	611	37	1	0	2	4	6327	942	5348	1179

8.2.1 Growth rates

Past trends in the growth rates along the proposed project corridor provide valuable information to the likely future traffic. But in most cases, the past traffic data from the statistical department is inconsistent and cannot be taken as a basis for future traffic growth rate. Alternatively, the motor vehicle registration data at the state level during the recent past provides more consistent information regarding the trends in traffic growth and thus presents a better tool for estimating future growth rates of different categories of vehicles. A more rational method is to establish a relationship between the socio - economic variables such as population, Net State Domestic Product and Per-capita income on one hand and the past registration data of different categories of vehicles on the other to determine the Elasticity of Transport Demand with respect to different categories of vehicles. The detailed calculations of growth rates are given in the traffic report. The computed traffic growth rates are given in the below Table 8-3.

Table 8-3: Actual growth rates in percentages

Projected Growth Rates of Assam							
S. No	Period	2W	Car	Truck	Bus	Tractor	Tractor with trailer
1	2023 - 2027	13.5%	14.5%	8.50%	6.5%	12.0%	10.5%
2	2028 – 2032	13.5%	14.5%	7.50%	6.0%	11.0%	9.5%
3	2033 – 2037	13.0%	14.0%	7.0%	5.5%	10.5%	9.0%
4	2038 - 2042	12.5%	13.0%	6.5%	5.0%	10.0%	8.5%
5	Beyond 2043	12.0%	12.0%	6.0%	5.0%	9.0%	8.0%

8.2.2 Axle Load Surveys

The Vehicle Damage Factor (VDF) is an index characterizing the traffic loading for a highway and is defined as a multiplier for converting the number of commercial vehicles of different axle loads to Standard Axle Loads (SAL). Equivalency factor (EF) is normally worked out by using the Fourth Power Rule derived by AASHTO. However, TRRL has suggested a factor of 4.5 for developing countries. In the present study, the Fourth Power Rule given by CRRI has been adopted. With the help of equivalency factors and frequency distribution of axle loads, Equivalent Axle Loads (EAL) are computed. The standard axle loads, and the legal axle loads considered while calculating the equivalency factors for various axles are furnished below.

Table 8-4: Standard and legal Axle loads

S.No	Type of Axle	Standard Axle Load (Tonnes)	Legal Axle Load (Tonnes)	Reference
1	Single Axle (1le wheel)	6.60	6.60	IRC-3
2	Single Axle (2al wheel)	8.16	10.20	IRC-37/IRC-3
3	Tandem Axle	15.09	19.00	IRC-37/IRC-3

VDF depends on the composition of commercial traffic, the load carried and the actual sample collected. Axle load survey was not conducted in section-III of project corridor because there is no truck moment observed in that section due to construction of bridge at Assam-Bangladesh boarder. So, VDF at Bakarshal is adopted for pavement design for this section. The following table gives the VDF's adopted in design.

Table 8-5: Vehicle Damage Factor (VDF)

S. No	Mode	At Bakarshal	
		Towards Badarpur	Towards Karimganj
1	2 Axle	0.47	1.54
2	3 Axle	1.46	5.00
3	M axle	3.10	10.20
4	LCV	0.11	0.12

Anticipating heavy commercial traffic movement on the proposed highway due to the future developments, average VDFs are adopted and the values are given in the Table 8-6.

Table 8-6: Vehicle Damage Factor (VDF) adopted

S. No	Mode	At Bakarshal
1	2 Axle	1.54

S. No	Mode	At Bakarshal
2	3 Axle	5.00
3	M axle	10.20
4	LCV	0.12

8.2.3 Million Standard Axles (MSA)

Design traffic in terms of Million Standard Axles (MSA) is determined at location, where both volume count and axle load surveys were conducted.

The traffic loading in terms of the cumulative number of standard axles for the design period is computed using the following relationship.

$N = 365 * [(1+r)^n – 1] * A * D * L * F / r$

Where,

N: The cumulative number of standard axles 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

L: Lane Distribution Factor

D: Directional Distribution Factor

n: Design Life in years

r: Annual Growth rate of commercial vehicles (5 %).

F: Vehicle Damage Factor

8.3 PRELIMINARY INVESTIGATIONS

8.3.1 General

The flexible pavement is modeled as an elastic multi-layer structure. Stresses and strains at critical locations are computed using a 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.

Horizontal Tensile Strain at bottom of bituminous layer, which can cause fatigue failure of bituminous layer.

Vertical Compressive Strain at the top of subgrade, which can cause rutting failure of pavement layers.

Horizontal Tensile Strain at bottom of Cement treated base, which can cause fatigue failure of cement treated layer.

The flexible pavement has low flexural strength and hence layers reflect the deformation of the lower layers/sub-grade on to the surface layer after the withdrawal of wheel load. To control the deflections in the sub-grade so that no permanent deflections result the pavement thickness is so designed that the stresses on the subgrade 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 subgrade. To structural design, only the number of commercial vehicles of laden weight of 3 tonnes or more and their axle loading will be considered.

8.3.2 Fatigue Model

Due to repetition of loads, tensile strain develops cracks at the bottom of bituminous layers which is a problem for long term serviceability. 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 life of the pavement. Two fatigue equations are considered, one in which the computed strains correspond to 80% reliability level and the other corresponding to 90% reliability level.

The 80% reliability equation is used for the pavement where VG30 grade bitumen is used and 90% reliability equation is used for the pavement where VG40 grade bitumen is used. The two equations for the conventional bituminous mixes designed by Marshall method are given below.

$$N_f = 2.21 \times 10^{-4} \times (1/E_t)^{3.89} \times (1/M_R)^{0.854} \text{ ---------1 (80\% Reliability)}$$

$$N_f = 0.711 \times 10^{-4} \times (1/E_t)^{3.89} \times (1/M_R)^{0.854} \text{ --------2 (90\% Reliability)}$$

N_f = Fatigue life in number of standard axles

E_t = Maximum tensile strain at the bottom of Bituminous layer.

M_R = Resilient Modulus of the Bituminous layer

The ***equation 2*** is modified by considering 90% reliability with air voids around 3% and the volume of bitumen about 13%.

8.3.3 Rutting Model

Rutting is the permanent deformation in pavement usually occurring longitudinally along the wheel path. The rutting may partly be caused by deformation in the subgrade and other non-bituminous layers which would reflect to the overlying layers to take a deformed shape. The 80% reliability equation is used for the pavement where VG30 grade bitumen is used and 90% reliability equation is used for the pavement where VG40 grade bitumen is used. The rutting model considers the vertical strain in subgrade and the two equations are given below by considering 80% & 90% reliability.

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

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

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

E_v = Maximum Vertical subgrade strain (micro strain)

8.3.4 Pavement Layers

In accordance with IRC:37-2018 the following base and sub-base options are available.

Granular base and sub-base.

Cementitious bases and sub-bases with a crack relief layer of aggregate inter-layer below bituminous surfacing.

Cementitious bases and sub-bases with SAMI in between bituminous surfacing and the contentious base layer for retarding the reflection cracks into the bituminous layer.

Cemented base and granular subbase with crack relief inter-layer of aggregate above Cemented base.

Bituminous surfacing over treated RAP and cemented subbase.

Stage construction is not permitted when we are using cemented base and sub-bases according to the guidelines of the code as it may lead to cracking of the stabilized layer leading to failure of the pavement. Hence, the consultants adopt Granular Base & Granular Sub-base for main carriageway pavement with stage construction.

8.3.4.1 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. Material passing through 0.425 mm (425 micron), LL & PI shall not more than 25 and 6 %. Material shall have a minimum 10% fines 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 subbase is used as a drainage layer, Los Angeles 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 subgrade soil into the pavement and upper layer forms the drainage layer to drain away any water that may enter through surface cracks.

Strength Parameter: Resilient Modulus (M_{Rgsb})

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

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

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

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

8.3.4.2 Base layer

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

Strength Parameter: Resilient Modulus ($M_{R\ granular}$)

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

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

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

8.3.4.3 Bituminous layers (Binder and Surface)

The binder layer consists of DBM and BM are to be adopted for construction. It acts like a load distribution and supporting layer.

Strength Parameter: Resilient Modulus ($M_{RBC/DBM}$)

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 for different mix types and temperatures are given below.

Table 8-7: Resilient Modulus of Bituminous Mixes, Mpa

Mix Type	Temperature °C				
	20	25	30	35	40
BC and DBM for VG10 bitumen	2300	2000	1450	1000	800
BC and DBM for VG30 bitumen	3500	3000	2500	2000	1250
BC and DBM for VG40 bitumen	6000	5000	4000	3000	2000
BC with Modified bitumen (IRC:SP:13)	5700	3800	2400	1650	1300
BM with VG10 bitumen	-	-	-	500	-
BM with VG30 bitumen	-	-	-	700	-
RAP treated with 4% bitumen	-	-	-	800	-

8.3.5 Flexible pavement design for Greenfield corridor

Design of flexible pavement is carried out in accordance with IRC:37-2018 for Granular base and sub-base. The standard designs given in plate-6, 14 and 22 of clause 12.1, 12.2 & 12.2 of IRC:37-2018 specify the minimum thickness and specifications of various component layers for different options for the given traffic in terms of cumulative standard axles and the 10% subgrade CBR. Cumulative standard axles calculated for the 20 year design life for leg wise is given in Table-7.

Anticipating heavy commercial traffic movement on the proposed highway due to the future developments flexible pavement is adopted for **50 MSA**. Along with the flexible pavement composition with conventional layers option, layer composition with alternate materials have been considered and given in the following tables:

Table 8-8: Conventional Pavement Composition (Option-1)

Package	Eff. CBR (%)	MSA for 20 yrs design life	Bitumen Grade	Crust Composition (mm)				
				BC	DBM	WMM	GSB	Total
VII	8	50	VG-40	40	115	250	200	**605**

Table 8-9: Composition details Bituminous pavement with Cemented base and subbase with Crack Relief Interlayer of aggregate (Option-2)

Section	Eff. CBR (%)	MSA for 20 yrs design life	Bitumen Grade	Crust Composition (mm)					
				BC	DBM	AIL	CTB	CTSB	Total
Section-III	8	50	VG-40	40	60	100	100	200	**500**

Table 8-10: Composition details Bituminous pavement with Cemented base and Granular Subbase with AIL (Option-3)

Section	Eff. CBR (%)	MSA for 20 yrs design life	Bitumen Grade	Crust Composition (mm)					
				BC	DBM	AIL	CTB	GSB	Total
Section-III	8	50	VG-40	40	60	100	165	200	**565**

Table 8-11: Composition details Bituminous pavement with Cemented base and Cemented Sub base with SAMI Layer (Option-4)

Section	Eff. CBR (%)	MSA for 20 yrs design life	Bitumen Grade	Crust Composition (mm)					
				BC	DBM	SAMI	CTB	CTSB	Total
Section-III	8	50	VG-40	40	60	SAMI	140	200	440

8.4 Final Flexible Pavement design Option for Main carriageway

As per the equations mentioned in 2.3.2 and 2.3.3 of IRC 37-2018: Following are the results observed from the IIT-PAVE Software for crust composition mentioned in the below table.

Calculation of Allowable Strains at Critical Locations:

Allowable Horizontal Tensile Strian (Et): At Bottom of the Bituminous layer

Nf = 2.021 X 10-4 X (1/Et)3.89 X (1/MR)0.854 ---------> 1 (90% Reliability)

Tensile Strian(Et) = 149.10 Micro Strain (Allowable Tensile Strain)

Allowable Horizontal Tensile Strian(Et): At Bottom of Cement Treated Base layer

Tensile Strian (Et) = 66.99 Micro Strain (Allowable Tensile Strain)

$$N = RF\left[\frac{\left(\frac{113000}{E^{0.804}}+191\right)}{\varepsilon_t}\right]^{12} \longrightarrow \mathbf{2}$$

Where,

RF = reliability factor for cementitious materials for failure against fatigue

= 1 for Expressways, National Highways, Sate Highways and Urban Roads and for other categories of roads if the design traffic is more than 10 msa

= 2 for all other cases

N = No of standard axle load repetitions which the CTB can sustain

Allowable Vertical Compressible Strian(Ev): At top of the sub-grade layer
N = 1.41 X 10-8 X (1/Ez)4.5337 --------> 3 (90% Reliability)
Compressive Strian(Ev) = 319 Micro Strain.

Calculation of Maximum Strains at Critical Locations by IIT-PAVE:

OPEN FIILE IN EDITOR
VIEW HERE
BACK TO EDIT
HOME

```
No. of layers               5
E values (MPa)         3000.00  450.00 5000.00  600.00   76.83
Mu values                 0.350.350.250.250.35
thicknesses (mm)        100.00  100.00  100.00  200.00
single wheel load (N) 20012.00
tyre pressure (MPa)       0.80
Dual  Wheel
  Z         R      SigmaZ      SigmaT      SigmaR      TaoRZ      DispZ       epZ        epT        epR
100.00     0.00-0.2933E+00 0.5545E+00 0.4670E+00-0.1871E-01 0.2958E+00-0.2169E-03 0.1646E-03 0.1252E-03
100.00L    0.00-0.2933E+00-0.5106E-01-0.6418E-01-0.1871E-01 0.2958E+00-0.5621E-03 0.1646E-03 0.1252E-03
100.00   155.00-0.1681E+00 0.2025E+00-0.2768E+00-0.8998E-01 0.2869E+00-0.4737E-04 0.1194E-03-0.9629E-04
100.00L  155.00-0.1681E+00-0.4658E-01-0.1185E+00-0.8998E-01 0.2869E+00-0.2452E-03 0.1194E-03-0.9629E-04
300.00     0.00-0.5880E-01 0.3215E+00 0.2449E+00-0.1869E-01 0.2543E+00-0.4008E-04 0.5500E-04 0.3584E-04
300.00L    0.00-0.5880E-01 0.2133E-01 0.1214E-01-0.1869E-01 0.2543E+00-0.1119E-03 0.5499E-04 0.3584E-04
300.00   155.00-0.6336E-01 0.3451E+00 0.2578E+00-0.3940E-01 0.2615E+00-0.4281E-04 0.5929E-04 0.3747E-04
300.00L  155.00-0.6336E-01 0.2282E-01 0.1235E-01-0.3940E-01 0.2615E+00-0.1203E-03 0.5929E-04 0.3747E-04
500.00     0.00-0.1777E-01 0.6691E-01 0.5615E-01-0.2852E-02 0.2373E+00-0.8089E-04 0.9553E-04 0.7310E-04
500.00L    0.00-0.1771E-01 0.1063E-02-0.2213E-03-0.2852E-02 0.2373E+00-0.2344E-03 0.9553E-04 0.7297E-04
500.00   155.00-0.1902E-01 0.7178E-01 0.6372E-01-0.4228E-02 0.2430E+00-0.8815E-04 0.1010E-03 0.8421E-04
500.00L  155.00-0.1902E-01 0.1185E-02 0.2294E-03-0.4228E-02 0.2430E+00-0.2539E-03 0.1010E-03 0.8421E-04
```

Figure 8-1: IITPAVE Output for Section-III

Table 8-12: Comparison of Strains With IIT-PAVE

S. No	Allowable Strains			IIT-PAVE Results		
	Tensile Strain below BT layer (E_t)	Tensile Strain below CTB lyer (E_t)	Vertical Compressive (E_v)	Tensile Strain below BT layer (E_t)	Tensile Strain below CTB (E_t)	Vertical Compressive Strain (E_v)
1	178.1	70.982	371.7	164.6	59.29	253.9

Note: Bituminous mixes are carried out based on MS-2 and MoRT&H Clause 505.3.2 provisions, it was assumed 3% air voids and 13% binder content by volume of the mix for DBM, and the crust thickness were worked out using eq 3.4 as given in IRC:37-2018.

However, contractor/concessionaire shall carry out the actual mix design of DBM with proposed aggregates and binder to get the best properties. Properties such as air voids and optimum binder content thus arrived shall be used for determining the actual pavement Composition. Hence, the crust composition given above is for indicative purposes only.

8.5 Recommended Pavement Option

Considering the use of the alternate materials in the composition of flexible pavement, due to the lack in the significant practical experience while adopting the mix design and performance after laying, flexible pavement option with the cemented base, cemented sub base and AIL is adopted for flexible pavement.

Table 8-13: Recommended Pavement Composition (BT, Crack Relief Interlayer of Aggregate, CTB & CTSB)

Package	Eff. CBR (%)	MSA for 20 yrs design life	Bitumen Grade	Crust Composition (mm)					
				BC	DBM	AIL	CTB	CTSB	Total
VII	8	50	VG-40	40	60	100	100	200	**500**

8.6 Preliminary Design of Rigid Pavement

Rigid pavement has been designed in accordance with IRC:58-2015. The area of toll plaza including the flared portion shall be provided with concrete pavement. Rigid pavement for entire project corridor including toll plaza is considered as second alternative in accordance with IRC:58-2015.

(a) Design Life and Traffic parameters

30 years design period has been considered. The cumulative number of commercial vehicles over 30 years design life is estimated and considered as design traffic. The design Tyre pressure has been taken as 0.80 Mpa cemented base and 0.56 MPa for granular layers.

(b) Wheel Base Characteristics

Axles with spacing of less than 4.5m (transverse joint spacing) are considered for estimation of top-down cracking damage analysis. The percentage of axles with less than 4.5m wheelbase is estimated from the axle load survey.

(c) Temperature Differential

According to Table-1 of IRC:58-2015, the temperature differential is a function of geographical location of the project road and the temperature differential to be adopted for the project area (Assam) is given below:

Table 8-14: Temperature Differential

Concrete Thickness	150 mm	200 mm	250 mm	300 mm – 400 mm
Temperature Differential (^{0}C)	15.6	16.4	16.6	16.8

(d) Modulus of Subgrade reaction

Dry Lean Concrete (DLC) subbase is generally recommended for modern concrete pavements, particularly those with high intensity of traffic.

- CBR of the subgrade soil is considered 10 % and k-value becomes 55 Mpa/m.

150 mm DLC layer is provided as sub-base.

Effective k-value, after providing DLC layer is 300 MPa/m

(e) Concrete Strength

The 90 days flexural strength for the pavement quality concrete (PQC) has been taken as 4.95 Mpa for the purpose of design.

(f) Modulus of Elasticity, Poisson's Ratio & Coefficient of Thermal Expansion

The modulus of elasticity (E) and Poisson's Ratio (μ) of the cement concrete vary with concrete materials and strength. The elastic modulus increases with increase in strength, and Poisson's ratio decreases with increase in the modulus of elasticity. The coefficient of thermal expansion of concrete is dependent to a great extent on the type of aggregates used in concrete.

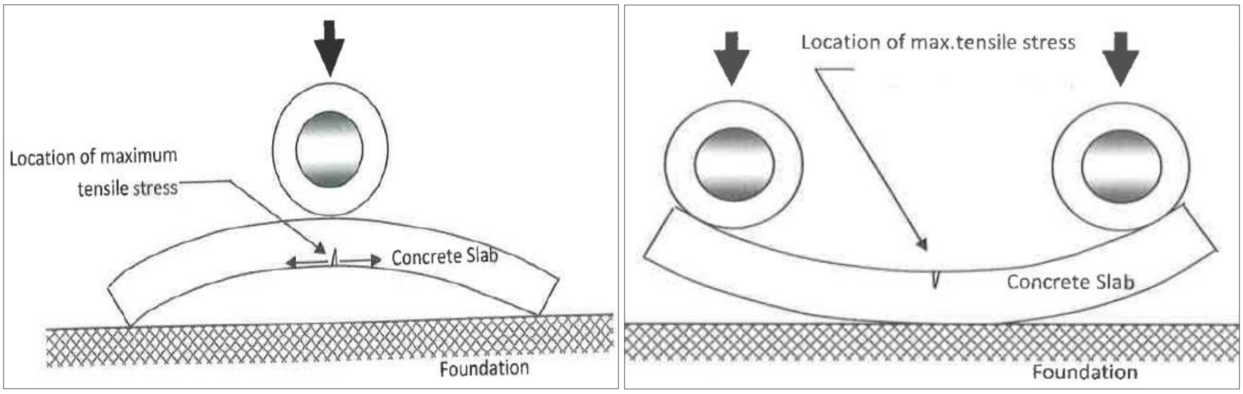
The values of the various parameters adopted are:

Modulus of Elasticity (E) = 30,000 MPa
Poisson's Ratio (μ) = 0.15
Coefficient of thermal expansion (a) = $10 \times 10^{-6}/\ ^{o}C$

(g) Design of slab thickness

The flexural stress due to the combined action of traffic loads and temperature differential between the top and bottom fibers of the concrete slab is considered for design of pavement thickness. Positive temperature during day time will create bottom-up cracking and negative temperature during night will create top-down cracking in concrete slab. Hence analysis has been done for these two cases. For bottom-up cracking case, the combination of load and positive non-linear temperature differential has been considered where as for top-down cracking analysis, the combination of load and negative linear temperature differential has been taken.

For a trial slab thickness and other design parameters, the pavement will be checked for cumulative bottom-up and top-down fatigue damage. Cumulative fatigue damage (CFD) for bottom-up cracking is significant only during 10 AM to 4 PM because of higher stresses, hence the day traffic during the six hour (10 AM to 4 PM) is considered for bottom-up cracking analysis. Where as CFD for top-down cracking is significant only during 12 AM to 6 AM, hence the six hour night time traffic (12 AM to 6 AM) is considered for top-down cracking analysis.



(h) Design Thickness

Following Rigid Pavement design elements are proposed for the project road and details are provided in ***Appendix-2***.

Table 8-15: Rigid Pavement Composition

S.No	Item	Rigid Pavement Crust Composition Details
1	PQC of M40 grade (mm)	300
2	DLC of M10 grade (mm)	150

S.No	Item	Rigid Pavement Crust Composition Details
3	GSB (mm)	150
4	Dia. of Dowel bar (mm)	38
5	Length of Dowel bar (mm)	500
6	Spacing of Dowel bar (mm)	300
7	Dia. of Plain tie bar (mm)	12
8	Length of Plain tie bar (mm)	580
9	Spacing of Plain bar (mm)	370
10	Dia. of Deformed bar (mm)	12
11	Length of Deformed bar (mm)	640
12	Spacing of Deformed bar (mm)	595

8.7 Design of Shoulders

Earthen Shoulder: Earthen shoulders shall be covered with 150 mm thick layer of granular material confirming to the requirements given in Clause 401.2.1 of MoRT&H specifications.

8.8 Flexible Pavement Composition for Service Road

Service road pavement composition is designed for a minimum of 20 MSA traffic loading. Design MSA for service road shall be considered as 20 MSA The crust composition and thickness of component layers as worked out and given below in **Table 8-17**.

Table 8-16: Pavement Composition for Service Roads

S.No	Pavement composition	Design thickness for 10 MSA (mm)
1	Bituminous Concrete (BC)	40
2	Dense Bituminous Macadam (DBM)	80
3	Wet Mix Macadam (WMM)	250
4	Granular Sub-Base (GSB)	200
Total (mm)		**570**

8.9 LIFE CYCLE COST ANALYSIS

Life Cycle Cost Analysis has been conducted during the project development stage. The levels of detail in the analysis are consistent with the level of investment. Basically, the process involves following steps:

- Develop rehabilitation and maintenance strategies for the analysis period.

Establish the agency costs for construction, rehabilitation and maintenance strategies.

Estimating the agency costs for construction, rehabilitation, and maintenance

Estimate user and non-user costs

Develop expenditure streams

Compute the Net present value (NPV)

The primary purpose of LCCA is to quantify the long-term economic implications of initial pavement decisions. Various rehabilitation and maintenance strategies can be employed over the analysis period. The next step is to obtain estimates of expected lives for the various rehabilitation and maintenance strategies. Agency costs include all costs incurred directly by the agency over the life of the project. The costs typically include expenditures for preliminary engineering, contract administration, construction, including construction supervision, and all future maintenance (routine and periodic), resurfacing and rehabilitation. These are generally developed for each pavement design strategy to visualize the extent and timing of expenditures. LCCA is a form of economic analysis used to evaluate the cost efficiency of various investment options. Once all costs and their timings have been established, the future costs must be discounted to the base year and added to the initial cost to determine net present value (NPV). NPV is calculated as follows.

Inputs for the Life Cycle Cost Analysis:

$$NPV_O = (B_O - C_O) + [(B_1 - C_1)/(1+i)^1] + [(B_2 - C_2)/(1+i)^2] + \text{............} + [(B_t - C_t)/(1+i)^n]$$

Where,

NPV_O = Net Present Value in the year 0.

B_t = Value of benefits which occur in the year 1.

C_t = Value of costs which occur in the year 1.

I = Discount rate per annum in decimals.

n = Number of years taken for analysis.

8.9.1 Methodology

Life Cycle Cost (LCC) has been carried out with the following options, for the sections as mentioned below.

Flexible Pavement Option (Alternate-1)

Rigid Pavement Option (Alternate-2)

In the Life Cycle Cost Analysis, the present values of all the costs for each of the alternative have been computed. The alternative giving the lowest present value of the costs is to be considered as the most advantageous option from economic perspective.

Net Present value has been computed for Flexible as well as Rigid Pavement option.The Net Present values of both options are given in Table-15.

The options for Life cycle cost analysis are,

Option A : Flexible pavement with Cement Treated base and cement treated sub base

Option B : Rigid pavement

Routine maintenance for Flexible and Rigid pavements have been considered from the MORT&H guidelines 1997 prices, cost for the year 2021 has been computed with an escalation of 5.0% (whole sale index price). It is calculated based on the Guidelines given in 'Report of the Committee on Norms for Maintenance of Roads in India, MORT&H, published by IRC, 2001.The ordinary repair costs and periodic renewal costs for the configurations with flexible and rigid pavement options are given in Tables below The calculations whole stretch are shown below as a sample. Samples for total cost per year are given in Table 8-18.

Table 8-17: Costs for Ordinary Repairs

S.No	Item	1997 Prices (in Rs)		2023 Prices (in Rs)	
		Flexible Pavement	Rigid Pavement	Flexible Pavement	Rigid Pavement
1	Ordinary Repairs	187020	231168	664983	821957

Table 8-18: Periodic renewal costs-Flexible Pavement (at every 5th year)

Flexible Pavement Overlay (Functional) - at every 5th year							
Layer	Thickness (mm)	m	Width (m)	Total Length (m)	Quntity (cum)	Rates (INR)	Cost(INR)
BC	**40**	0.04	18	14250	10260	14376.187	147499678.62
Total (INR)							**147499678.62**

Table 8-19: Periodic renewal costs-Flexible Pavement (at every 10th year)

Flexible Pavement Overlay (Structural) - at every 10th year							
Layer	Thickness (mm)	m	Width(m)	Total Length (m)	Quntity (cum)	Rates (INR)	Cost(INR)
BC	**40**	0.04	18	14250	10260	14376.187	147499678.62
DBM	**65**	0.065	18.08	14250	16746.6	13036.4	218315376.24
Total(INR)							**9867953135**

Table 8-20: Periodic renewal costs-Rigid Pavement (at every 10th year)

Replacement of Cracked Slabs 20% of total Length of the project- at every 10th year							
Layer	**Thickness (mm)**	**m**	**Width(m)**	**Total Length(m)**	**Quntity (cum)**	**Rates (INR)**	**Cost(INR)**
PQC	**300**	0.3	18	2850	15390	10180	156670815.6
Total(INR)							**156670815.6**

Table 8-21: Total Cost per year

S.No	Item	2024 Prices (in Rs)		2036 Prices (in Rs)		2031 Prices (in Rs)	
		Flexible Pavement	Rigid Pavement	Flexible Pavement	Rigid Pavement	Flexible Pavement	Rigid Pavement
1	Initial cost	1026238493	1166998832			-	-
2	Ordinary Repairs	-	-	-	-	-	17305262
3	Periodical Renewal	-	-	689798844	295426189	-	-

In the Life Cycle Cost Analysis, the present values of all the costs for each of the alternatives have been computed.

Net Present value per Km has been computed for Flexible as well as Rigid Pavement option. Net Present Values for Flexible and Rigid Pavement are given in Table 8-23.

Table 8-22: Net Present Values

Package	Flexible pavement (BC+DBM+AIL+CTB+CTSB) (in. Cr)	Rigid Pavement (in. Cr)
VII	9.75	8.96

MoRTH circular no. RW/NH-33044/31/2014-S&R(R) Pt. dated 04th August, 2014 states that "The price of cement vis-à-vis bitumen varies widely in different parts of the country depending upon the lead from the production centers/refineries etc. This variation would be required to be mapped out and unless there is price comparison within an acceptable limit up to 20%, the use of flexible pavements may perhaps required to be continued."

It means that rigid pavement could be considered when the cost comparison between Cement (PQC layer) used at the time of construction doesn't exceed that of Bitumen (BC & DBM layers) by more than 20%. (In this case, the cost of construction of PQC layer is 46.69% more than the cost of construction of BC+DBM layers. So Flexible pavement can be considered)

Also, as per MoRTH circular no. RW/NH-35079/01/2018-S&R(P & B) dated 21st June 2018,due to the constraints of limited/non-availability of sand in certain areas/states,and certain restrictions imposed by the Hon'ble Courts or for other reasons came to be highlighted by contractors,it has been decided to provide flexible pavement in place of rigid pavement.

Recommended option: Flexible Pavement with Cement Treated Base (CTB) and Cement Treated subbase (CTSB).