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A Comprehensive Study on Life Cycle Cost Examination for a Road (Preamser Hirnikheda Mundla) Project in Madhya Pradesh

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Abstract: ***A Life Cycle Cost Analysis (LCCA) is need to performed at the design period of the projects in order to be proficient to performed more profitable, to help take decision for type of pavement selection either flexible or rigid and also, to decide the comparative expense of different type of pavement. Specially for developing countries like India, due to insufficient funds for the project. However, now-a-days in India many infrastructure development projects like highways are being executed through loan from different external funding agencies like Asian Development Bank (ADB), World Bank, New Development Bank (NDB) etc. in case of a highway construction project, the major expenditure involves in construction of pavements. Therefore, before constructing a new road it is essential to check the life cycle cost analysis of different pavement options to select a most economical pavement option form techno-economic consideration. It is obvious that in our country most of the existing pavements are flexible pavement which has lower design life and higher maintenance requirements due to unpredictable traffic growth with heavy axel load as compared to the rigid pavements. Nowadays rainfall rate also generally found uncertain so at rainy seasons. So lots of case found that the highways are submersed during flood. These is the most common issue found in our developing country. For that bituminous pavements found damaged and cracked mostly. For that Rigid pavements are a good substitute on Flexible pavements, Rigid pavement have long life cycle (30 years as per IRC) with less maintenance cost, But the cost of construction of rigid pavement is higher than that of flexible pavement, but the Life Cycle Cost (LCC) including all maintenance are much less than of flexible pavements and its equally effective at submersible condition even in case of rehabilitation of existing bituminous pavements, concrete overlays or white topping can be good and beneficial alternative when compared to bituminous overlays. In the present study, an attempt is made to evaluate and compare the LCC of flexible and rigid pavements to be used for rehabilitation of an existing bituminous road. It provides results about the best suitable, economical and cost effective pavements. Net present value method of LCC is used for evaluating the pavements, this method takes into consideration initial construction cost and maintenance cost for design life period of both the pavements. With the help of this analysis a comparison of total life cycle cost of concrete pavements and bituminous pavements can be found out and best pavement alternative can be considered. Life cycle cost analysis: It is an important economic analysis used in the selection of alternatives that impact both initial and future cost. It evaluates the cost efficiency of alternatives based on the net present value (NPV) method which provides the total cost required during life cycle of the project.***

Keywords: Life Cycle Cost, Preamsar – Hirnikheda - Mundla Road, Rigid Pavement, Flexible Pavement, Traffic, Cost Estimates, MPRDC, Major District Roads.

I. INTRODUCTION

The Madhya Pradesh Road Development Corporation Ltd. (MPRDC) under Madhya Pradesh road development and local connectivity improvement Project has decided to improve transport connectivity in the backwards district in the state by rehabilitating and upgrading the existing Major District Road (MDR) network to all-weather standards. It is also decided to upgrade the roads with flexible pavement in open country and rigid pavement with drain in built-ups section. The Project rehabilitating and upgrading of newly declared State Highways and MDRs, for two Laning to ensure the safe and efficient movement of traffic and developing of backward district by connectivity and financially also by creating some job opportunity. MPRDC specifically targets roads form key linkage between rural, semi urban and urban areas and complete the major state roads connectivity. All the improvement of roads will be done with financial aid from ADB.

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Most of the existing roads under this project have single lane BT carriageway and the roads shall be converted to two lane carriageway.

As a part of this MPRDC has taken up the up-gradation of Preamser Hirnikeda Mundla Road of Sheopur District. The main objectives are to improve the connectivity and improvement of social and local habitation status.

The project Road Preamsar-Hirnikheda-Mundla starts from a Tee junction on Sheopur-Khatoli road (PWD MDR road MDR no MP-MDR-04-05, 25°40'12.0"N, 76°33'26.9"E) at Premsar village & terminates at Tee junction on Sheopur-Baroda Road (MPRDC MDR road MDR no MP-MDR-04-06, 25°30'34.3"N, 76°39'13.6"E) at Mundla village. Length of the road is 28.890 Km. Key Map of the road is shown below-

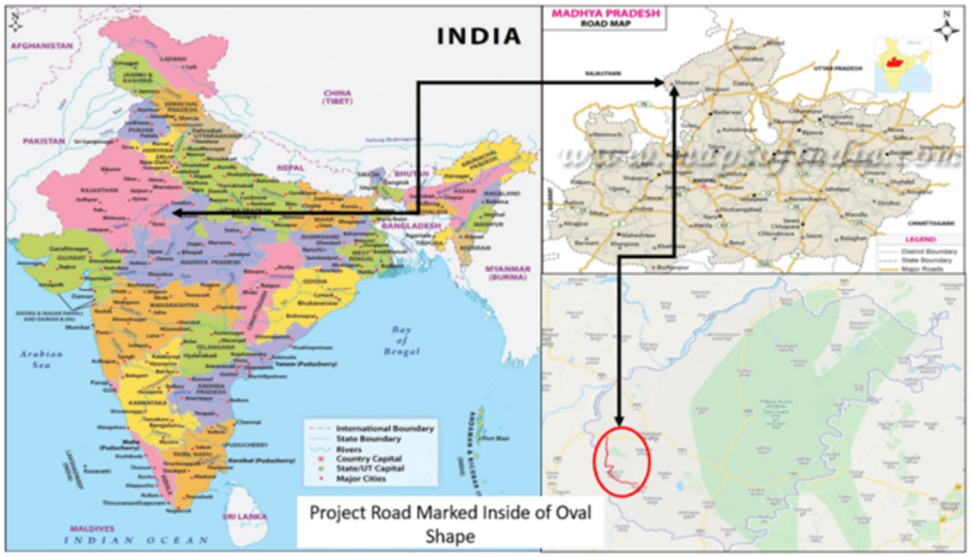

Figure 1: Key Map of the Preamser Hirnikheda Mundla Road

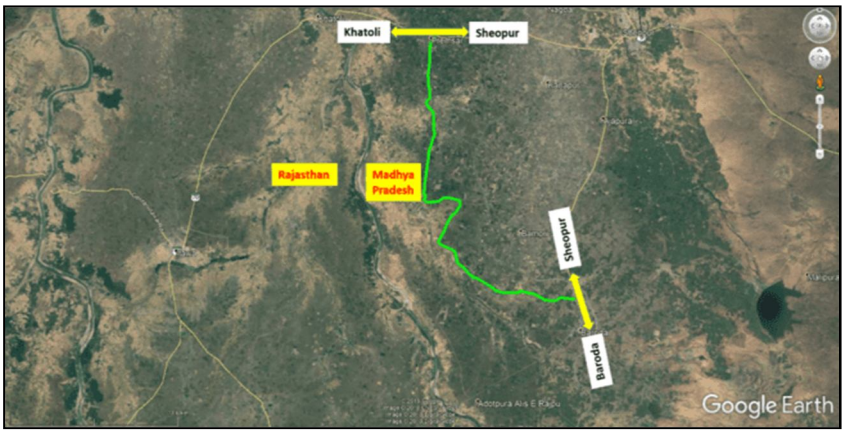

Figure 2: Existing Alignment of the Road on Google Map Image

A. Data Collection, Analysis And Methods

1) Study Area: Preamsar Hirnikeda Mundla Road is selected for study which is a Major District Road (MDR) of Sheopur District of Madhya Pradesh.

2) Field Data Collection & Analysis

a) Traffic Surveys & Analysis

Traffic surveys were performed for designing the pavement capacity of the road and thickness of following pavement crust. Conducted traffic surveys study are-

- 7 days X 24 hrs. Classified Traffic Volume Count (CTVC) Survey (from 10-02-2021 to 16-02-2021);
- 1 day X 12 hrs Axle Load Survey (on 14-02-2021).

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- *Survey Locations*

TABLE 1: Location and Schedule of Different Traffic Surveys

Sl No	Type of Survey	Location	Survey Date	Duration of Survey
1	Classified Traffic Volume Count (CTVC)	At Km 4+400 Near Nanawad Village	10/02/2021 to 16/02/2021	7 days 24 hours
2	Axle Load Survey	At Km 4+400 Near Nanawad Village	14/02/2021	24 hours

Figure 3: Photographs of CTVC Survey & Axle Load Survey

- *Average Daily Traffic*

The summary of Average Daily Traffic (ADT) from 10-02-2021 to 16-02-202 in the table below:-

Table 2: Summary of Average Daily Traffic (ADT)

Vehicle Category	ADT (Nos)	ADT (PCU)
Two Wheeler	841	421
Three Wheeler/ Auto	7	7
Car/Jeep/Van/ Taxi	17	17
Mini Bus	0	0
Bus	0	0
LCV	10	15
2-Axle Truck	1	3
3-Axle Truck	8	24
M-Axle Truck	0	0
Tractor With Trailer	32	144
Tractor Without Trailer	12	18
Total First Moving Vehicles(FMV)	928	649
Cycle	13	7
Cycle Rickshaw	0	0
Hand Cart	0	0
Bullock Cart	0	0
Horse Cart	0	0
Total Slow Moving Vehicles(SMV)	13	7
Total	941	656
CVPD	19	—
Tollable Traffic	36	59

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Analysis has been carried out to understand the following parameters on the Project Road:-

- Daily variation of traffic,
- Hourly variation of traffic, and
- Peak Hour Factor (PHF)

Table 3: Daily variation of Traffic

Daily Variation of Traffic	Day-1	Day-2	Day-3	Day-4	Day-5	Day-6	Day-7
Numbers	891	903	979	975	938	987	880
PCU	682	601	664	637	645	639	654

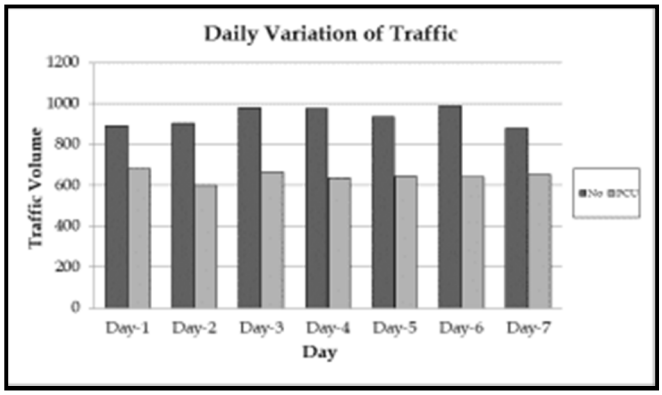

Figure 4: Chart Showing Daily Variation of Traffic Volume

Table 4: Hourly variation of Traffic

Time (Hour)	Traffic (No.)	Traffic (PCU)	Peak Hour Factor (%)
8-9	78	65	10.11
9-10	67	50	7.73
10-11	86	58	8.93
11-12	84	52	8.02
12-13	83	55	8.46
13-14	78	61	9.48
14-15	69	44	6.87
15-16	83	48	7.49
16-17	80	46	7.14
17-18	55	42	6.47
18-19	41	26	3.95
19-20	23	13	2.07
20-21	15	9	1.34
21-22	6	6	0.85
22-23	1	3	0.40
23-00	0	0	0.00
00-1	0	0	0.00
1-2	0	0	0.00
2-3	0	0	0.00
3-4	0	0	0.00
4-5	0	0	0.00
5-6	5	4	0.62
6-7	31	25	3.90
7-8	53	40	6.18
Total	936	646	100

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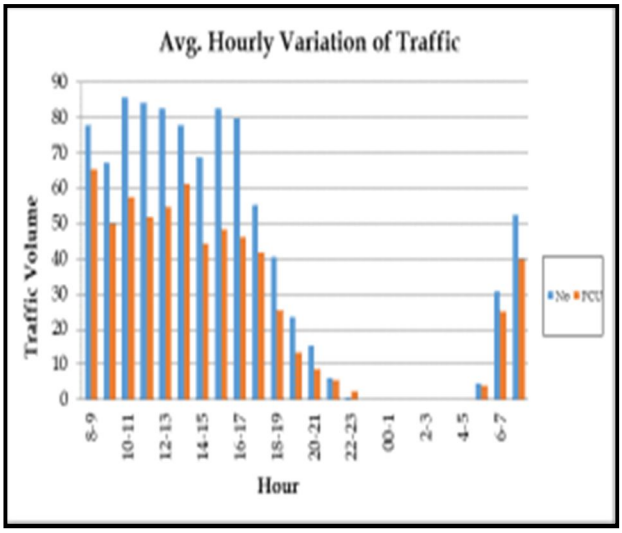

Figure 5: Hourly variation of Traffic at Km 4+400

The passenger traffic moves mostly during the day time, and it is very low particularly between 22:00 hrs in the night to 6:00 am in the morning.

Table 5 Peak Hour Factors observed on Road

Sl. No	Count Location	Peak Hour	PHF (%)
1	Km 4+400	8.00-9.00	10.11

- *Traffic Compositions:* The composition has been shown in the table below:-

Table 6: Traffic Composition Pattern on the Selected Road

Vehicle Category	ADT (No)	ADT % of Total
Two Wheeler	841	89.37
Three Wheeler/ Auto	7	0.74
Car/Jeep/Van/ Taxi	17	1.81
Mini Bus	0	0.00
Bus	0	0.00
LCV	10	1.06
2-Axle Truck	1	0.11
3-Axle Truck	8	0.85
M-Axle Truck	0	0.00
Tractor With Trailer	32	3.40
Tractor Without Trailer	12	1.28
Total First Moving Vehicles(FMV)	928	98.62
Cycle	13	1.38
Cycle Rickshaw	0	0.00
Hand Cart	0	0.00
Bullock Cart	0	0.00
Horse Cart	0	0.00
Total Slow Moving Vehicles(SMV)	13	1.38
Total	941	100.00

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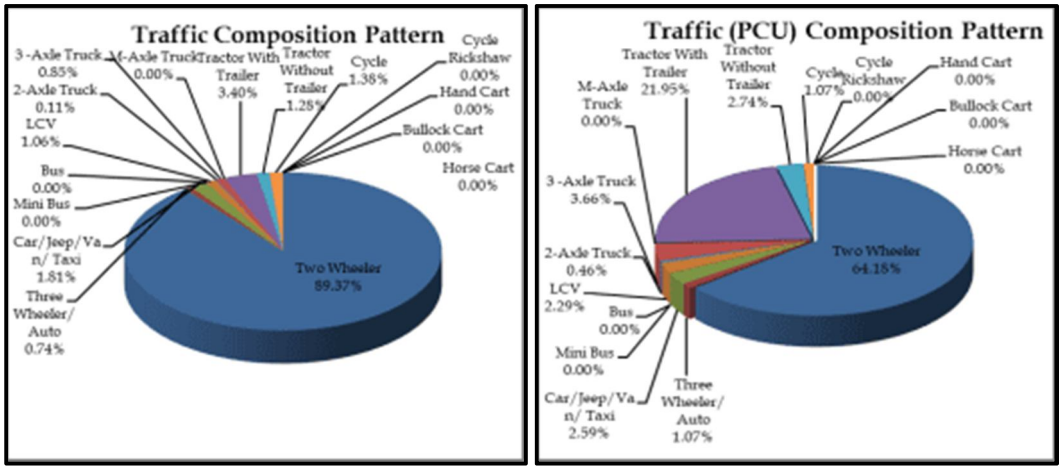

Figure 6 Chart Showing Traffic Composition

- *Vehicle Damage Factor (VDF):* Vehicle Damage Factors (VDF) are calculated from Axle Load Survey data for various vehicle and is presented below :-

Table 7: VDF observed on the Selected Road

TYPE OF VEHICLES	VDF		
	UP	DOWN	MAX
Multi Axle	0.00	0.00	0.00
3-Axle Truck	5.88	0.14	5.88
2-Axle Truck	0.00	0.00	0.00
LCV	0.00	0.00	0.00

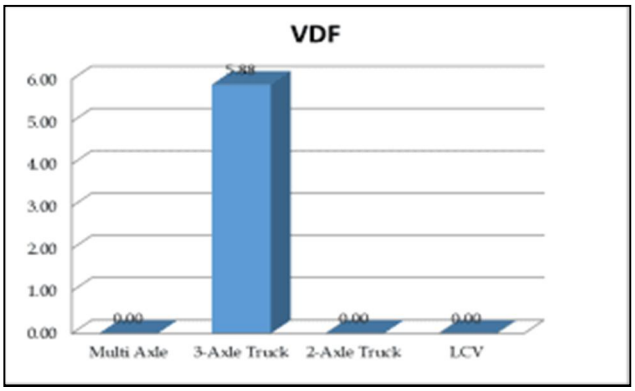

Fig 7: VDF observed along the Selected Road

- *Traffic Growth Rates:* The state economy of Madhya Pradesh has been demonstrating strong economic growth, compares the average economic growth rate in Madhya Pradesh and the Indian average during 2004–2012. Reserve Bank of India has projected the national average economic growth of 7.1% in real terms for the next 10 years (2013-14 to 2022-23) in their latest reports.

Table 8: Average Annual Economic Growth Rates, 2004–2012

Item	Average Annual Economic Growth Rate, 2004–2012 (%)
Madhya Pradesh	15.9
All of India	7.6

Source: Reserve Bank of India – Handbook of Statistics on Indian Economy.

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The growth of registered vehicles on the road gives an indication of the traffic growth below table. Vehicle growth for 2004–2012 was 10.0% for Madhya Pradesh. To have a better view of these annual traffic growth rates across different vehicle types for Madhya Pradesh, the growth of different vehicles during 2007–2009 is shown in Table below for Madhya Pradesh.

Table 9: Growth of Registered Vehicles, 2004–2012

Item	Compound Annual Growth Rate of Registered Vehicles	Elasticity, calculated against GDP growth rate
Madhya Pradesh	10.0%	0.71
All of India	10.3%	0.65

GDP = gross domestic product.

Source: Ministry of Road Transport & Highways – Road Transport Year Book (2011-12).

Table 10: Growth of Registered Vehicles in Madhya Pradesh, 2007–2009

Year	Car	Two-Wheeler	Standard Bus	Mini Bus	Trucks	Tractor	Trailer
2007	208,052	3,895,557	7,134	73,797	135,509	394,356	200,719
2008	237,022	4,292,649	7,119	80,311	149,718	411,424	206,640
2009	272,009	4,691,218	6,960	86,611	162,226	432,618	210,903
Growth (%)	14.3%	9.7%	-1.2%	8.3%	9.4%	4.7%	2.5%

Taking into consideration of the rapid growth of economic activities in the rural areas of Madhya Pradesh, the traffic growth rate throughout the project period has been consider as 6.5%.

- *Traffic demand forecast & lane requirement:*

Traffic Volume have been projected using 6.5% growth rate (in Level of Service B) in the following table-

Table 11 Lane Requirement (In LOS-B)

Year	AADT (PCU)	CVPD	Lane Requirement (LOS B)	Design Year
2021	655	19	Single Lane	
2022	698	20	Single Lane	
2023	743	22	Single Lane	1
2024	791	23	Single Lane	2
2025	843	24	Single Lane	3
2026	897	26	Single Lane	4
2027	956	28	Single Lane	5
2028	1018	30	Single Lane	6
2029	1084	31	Single Lane	7
2030	1154	33	Single Lane	8
2031	1230	36	Single Lane	9
2032	1309	38	Single Lane	10
2033	1395	40	Single Lane	11
2034	1485	43	Single Lane	12
2035	1582	46	Single Lane	13
2036	1685	49	Single Lane	14
2037	1794	52	Single Lane	15
2038	1911	55	Single Lane	16
2039	2035	59	Intermediate Lane	17
2040	2167	63	Intermediate Lane	18
2041	2308	67	Intermediate Lane	19

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Year	AADT (PCU)	CVPD	Lane Requirement (LOS B)	Design Year
2042	2458	71	Intermediate Lane	20
2043	2618	76	Intermediate Lane	21
2044	2788	81	Intermediate Lane	22
2045	2969	86	Intermediate Lane	23
2046	3162	92	Intermediate Lane	24
2047	3368	98	Intermediate Lane	25
2048	3587	104	Intermediate Lane	26
2049	3820	111	Intermediate Lane	27
2050	4068	118	Intermediate Lane	28
2051	4332	126	Intermediate Lane	29
2052	4614	134	Intermediate Lane	30

Present traffic has been projected up to year 2052 (30 year after completion of construction).

b) Soil & Material Survey: At first soil sample collected after that submitted to the laboratory. Test results have the direct influence of the design of pavement and cost of the project. The test results are presented below:-

Table 12 Test Results of existing subgrade & borrow soil.

Summary Soil Test Results										
Sr. No.	Sample ID	Grain Size Analysis			Laboratory Test Results					
		G (%)	S (%)	S&C (%)	LL (%)	PL (%)	PI (%)	OMC (%)	MDD	CBR (%)
1	TP-1	26.60	45.60	27.80	25.49	14.79	10.70	11.30	1.897	7.26
2	TP-2	27.10	45.60	27.30	25.45	14.90	10.55	11.40	1.900	7.44
3	TP-3	27.60	44.70	27.70	25.47	14.66	10.81	10.80	1.901	7.09
4	TP-4	26.60	45.60	27.80	24.92	14.53	10.39	11.70	1.899	7.61
5	TP-5	27.70	46.10	26.20	25.43	14.78	10.65	11.41	1.898	7.26
6	TP-6	26.60	45.60	27.80	25.08	14.52	10.56	11.20	1.900	7.44
7	BP-01	26.10	46.60	27.30	25.43	14.57	10.86	11.70	1.902	7.96
8	BP-02	26.50	46.40	27.10	24.81	14.72	10.09	11.41	1.904	7.61

i.e. 7.0% CBR soil is taken for pavement design purpose.

c) Pavement Design

- ❖ Flexible Pavement
- ❖ Rigid Pavement

- *Design Of Flexible Pavement*

Design period of Flexible pavement is taken as 20 years and the required crust thickness are find out from the charts provided in IRC-37-2018.

- ➢ MSA (Million Standard Axles)
- ➢ Subgrade CBR.

MSA Calculating formula: - $N = [365 \times \{(1+r)^n-1\}/r] \times A \times D \times F$

Where r = Growth rate of commercial vehicles in decimal (6.5%), r = 0.065
n = Year of design
A = Commercial vehicles per day in the year of completion of construction. =22 (design year 2023)
D = Lane Distribution Factor = 0.5 for 2-lane road (as per IRC-37-2018 para 4.5)
F = VDF provided in Table-7.

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A = No of Commercial Vehicles = 22 (year 2023 traffic opening year)
MSA calculation for the project road in the following Table.

Table 13 MSA Calculation

Year VDF	Total yearly CVs (nos.)	Cummulative yearly CVs (nos.)	Yearly Design ESA	Cummulative Design ESA	MSA
2021	Traffic Survey & Report Prepared				
2022	Constuction Period				
2023					
2024	8377	8377	14007	14007	0.01
2025	8922	17299	14918	28925	0.03
2026	9502	26800	15888	44813	0.04
2027	10119	36919	16920	61733	0.06
2028	10777	47696	18020	79753	0.08
2029	11477	59174	19191	98945	0.10
2030	12223	71397	20439	119384	0.12
2031	13018	84415	21767	141151	0.14
2032	13864	98279	23182	164333	0.16
2033	14765	113045	24689	189022	0.19
2034	15725	128770	26294	215316	0.22
2035	16747	145517	28003	243319	0.24
2036	17836	163352	29823	273142	0.27
2037	18995	182347	31762	304904	0.30
2038	20230	202577	33826	338730	0.34
2039	21545	224122	36025	374755	0.37
2040	22945	247067	38367	413122	0.41
2041	24436	271503	40860	453982	0.45
2042	26025	297528	43516	497498	0.50
2043	27716	325245	46345	543843	0.54
2044	29518	354763	49357	593201	0.59
2045	31437	386199	52565	645766	0.65
2046	33480	419680	55982	701748	0.70
2047	35656	455336	59621	761369	0.76
2048	37974	493310	63496	824866	0.82
2049	40442	533752	67624	892490	0.89
2050	43071	576823	72019	964509	0.96
2051	45871	622694	76701	1041209	1.04
2052	48852	671546	81686	1122895	1.12
2053	52028	723574	86996	1209891	1.21

From the above table found that the MSA value for the project road is very low (MSA = 1.21 for at 30th design year). The crust composition has been taken for minimum 10 MSA to be adopted during design of pavement on MDR as per department.
As per Catalogue of IRC 37: 2018 (Plate-3, Page No 38), crust thickness of flexible pavement is as follows.

Table 14 Proposed Pavement Composition for Flexible pavement

Design MSA	CBR (%)	Pavement Crust Compositions			
		BC (mm)	DBM (mm)	WMM (mm)	GSB (mm)
10	7	30	70	250	200

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- *Design Of Rigid Pavement*

Design period of Rigid pavement is taken as 30 years and the required crust thickness are designed from in IRC-58-2015.

- Effective CBR (%) of Subgrade = 7%
- Modulus of subgrade reaction (k) = 48 MPa/m (from Table-2 of IRC 58-2015)
- Provide Granular Sub-base (GSB) of 150 mm thick
- Provide DLC sub-base of 100 mm thick.
- Effective k of combined foundation of subgrade + GSB and DLC sub-base as per Table-4 of IRC 58-2015 = 208.00 MPa/m.

Selection of design traffic for fatigue analysis:-

- Design Life (n) =30 years
- Annual rate of growth of commercial traffic (r) =6.5 %
- 2-way commercial traffic volume per day after completion of construction (A) =22 CVPD
- Total 2-way commercial vehicles during design life of the pavement (C) = 693590 CVPD
- Avg. number of axles (steering/single/tandem/tridem) per commercial vehicle =2.0 Nos
- Total two-way axle load repetitions during the design period = 1387180.317 Axles
- Number of axles in predominant direction = 1387180 Axles (100% of two way repetitions)
- Design traffic after adjustment for lateral placement of axles = 346795 (25% of total 2-way repetitions)
- Day time (6 a.m to 6 p.m) commercial traffic (% of total Commercial traffic) =90%
- Day time (12 hrs) design axle repetitions = 312116 Axles
- Day time 6 hrs axle repetitions = 156058 Axles
- Hence, design number axle repetitions for bottom-up cracking (BUC) analysis = 156058 Axles
- Night time (12 hrs) design axle repetitions = 34680 Axles % of commercial vehicles having the spacing between the front (steering) & the 1st axle of the rear axle unit < 4.50m =82%
- Night time (6 hrs) design axle repetitions = 17340
- Hence, 6 hr night time design axle load repetitions for top-down cracking (TDC) analysis (wheel base < 4.5m) = 14219 Axles

IRC:58-2015 Guidelines for Design of Plain Jointed Rigid Pavements for Highways

Example of Design of Slab Thickness for Pavement

(with and without doweled transverse joints. Beta value will be 0.66 for doweled joint and 0.90 for without dowels case)

Type of pavement considered		**Pavement Structural Details**	
Carriageway	2-lane	Modulus of subgrade reaction of subgrade, MPa/m	48
		Thickness of Granular Subbase, mm	150
Shoulders :- Tied concrete shoulders ? (yes/no)	no	Thickness of Dry Lean Concrete, mm	100
Transverse joint spacing (m)	4.5	Effective modulus of subgrade reaction of foundation, MPa/m	208
Lane width (m)	3.5	Unit weight of Concrete, kN/m^3	24
Transverse Joints have dowel bars? (yes/no)	No	28-day Flexural strength of cement concrete, MPa	4.5
Design Traffic Estimation		Max. day-time Temperature Differential in slab, ^{0}C (for bottom-up cracking)	14.3
Design Period (years)	30	Night-time Temperature Differential in slab, ^{0}C (for top-down cracking) = day-time diff/2 + 5	12.15
Total Two-way Commercial Traffic (cvpd) in the year of completion of construction	22	Trial Thickness of Concrete Slab, m	0.25
Av. Annual rate of growth of commercial traffic (expressed as decimal)	0.065	Load Transfer Efficiency Factor for TDC analysis, Beta = 0.66 for dowel Joints, 0.90 for joints without dowels	0.90
Cumulative No of Commercial vehicles during design period (two-way), **A**	693590	Elastic Modulus of Concrete, Ec (MPa)	30000
Average No of axles per commercial vehicle, **B**	2.00	Poisson's Ratio of Concrete, Mu	0.15
Cumulative No of Commercial Axles during design period (two-way), **C = A*B**	1387180	Radius of relative stiffness, m	0.66206
Proportion of traffic in predominant direction (For 2-lane 2-way highways use a value of 1.0), **D**	1.00	**Design Axle Load Repetitions for Fatigue Analysis**	
Lateral Placement factor (0.25 for 2-lane 2-way. For multilane highways the value is 0.25 X **C**), **E**	0.250	**For Bottom-up Cracking Analysis**	
Factor for selection of traffic for BUC analysis (for six-hour period during day), **F**	0.45	Front single (steering) Axles = H * K1	78029
Factor for selection of traffic for TDC analysis (for six-hour period during day), **G**	0.05	Rear single Axles = H * K2	78029
Design axle repetitions for BUC analysis (for 6 hour day time traffic), **H = B*E*F**	156058	Tandem Axles = H * K3	0
Proportion of vehicles with spacing between front and the first rear axle less than the spacing of transverse joints, **I**	0.82	Tridem Axles = H * K4	0
Design axle repetitions for TDC analysis (for 6-hour night time traffic), **J = B*E*G*I**	14219	**For Top-Down Cracking Analysis**	
Proportion of Front single (steering) Axles, **K1**	0.5000	Front single (steering) Axles = J * K1	7109
Proportion of Rear single Axles,**K2**	0.5000	Rear single Axles = J * K2	7109
Proportion of tandem Axles, **K3**	0.0000	Tandem Axles = J * K3	0
Proportion of Tridem Axles, **K4 = (1-K1-K2-K3)**	0.0000	Tridem Axles = J * K4	0

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Axle Load Spectrum Data

Rear Single Axle			Rear Tandem Axle			Rear Tridem Axle		
Load Group (kN)	Mid-Point of Load Group (kN)	Frequency (%)	Load Group (kN)	Mid-Point of Load Group (kN)	Frequency (%)	Load Group (kN)	Mid-Point of Load Group (kN)	Frequency (%)
185-195	190	0.00	380 - 400	390	0.00	530-560	545	0.00
175-185	180	0.00	360 - 380	370	0.00	500-530	515	0.00
165-175	170	0.00	340 - 360	350	0.00	470-500	485	0.00
155-165	160	0.00	320 - 340	330	0.00	440-470	455	0.00
145-155	150	9.09	300 - 320	310	0.00	410-440	425	0.00
135-145	140	18.18	280 - 300	290	0.00	380-410	395	0.00
125-135	130	27.27	260 - 280	270	0.00	350-380	365	0.00
115-125	120	9.09	240 - 260	250	0.00	320-350	335	0.00
105-115	110	0.00	220 - 240	230	0.00	290-320	305	0.00
95-105	100	0.00	200 - 220	210	0.00	260-290	275	0.00
85-95	90	18.18	180 - 200	190	0.00	230-260	245	0.00
< 85	80	18.19	< 180	170	0.00	< 230	215	0.00
		100			0			0

Front Single Axles and Rear Tridem axles not considered for bottom-up analysis

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Fatigue Damage Analysis

Bottom-up Cracking Fatigue Analysis for Day-time (6 hour) traffic and Positive Temperature Differential

Rear Single Axles

Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
0	3.579	0.723	1012	0.000
0	3.428	0.693	2361	0.000
0	3.277	0.662	5508	0.000
0	3.126	0.632	12848	0.000
7093	2.976	0.601	29971	0.237
14186	2.825	0.571	69912	0.203
21278	2.674	0.540	165461	0.129
7093	2.523	0.510	490246	0.014
0	2.373	0.479	2522962	0.000
0	2.222	0.449	infinite	0.000
14186	2.071	0.418	infinite	0.000
14193	1.920	0.388	infinite	0.000
78029	Fat Dam from Sing. Axles =			0.583

Rear Tandem Axles

Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
0	2.993	0.605	27103.751	0.000
0	2.873	0.580	53409.653	0.000
0	2.752	0.556	105247.09	0.000
0	2.631	0.532	217480.61	0.000
0	2.511	0.507	547737.44	0.000
0	2.39	0.483	1994573.1	0.000
0	2.269	0.458	17453464	0.000
0	2.148	0.434	infinite	0.000
0	2.028	0.410	infinite	0.000
0	1.907	0.385	infinite	0.000
0	1.786	0.361	infinite	0.000
0	1.665	0.336	infinite	0.000
0	Fat Dam from Tand Axles =			0.000

Total Bottom-up Fatigue Damage due to single and tandem axle loads = 0.583 + 0.000 = 0.583

Sum of CFD for BUC & TDC= 0.591

Top-Down Cracking Fatigue Analysis for Night-time (6 hour) traffic and Negative Temperature Differential

Rear Single Axles

Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
0	3.023	0.611	22927	0.000
0	2.928	0.592	39081	0.000
0	2.833	0.572	66616	0.000
0	2.738	0.553	113551	0.000
646	2.644	0.534	200574	0.003
1292	2.549	0.515	397484	0.003
1939	2.454	0.496	945039	0.002
646	2.359	0.477	3080951	0.000
0	2.264	0.457	19981377	0.000
0	2.169	0.438	infinite	0.000
1292	2.074	0.419	infinite	0.000
1293	1.979	0.400	infinite	0.000
7109	Fat Dam from Sing. Axles =			0.009

Rear Tandem Axles (Stess computed for 50% of axle load)

Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
0	3.071	0.620	17561	0.000
0	2.976	0.601	29934	0.000
0	2.881	0.582	51024	0.000
0	2.786	0.563	86973	0.000
0	2.691	0.544	149355	0.000
0	2.596	0.524	277358	0.000
0	2.501	0.505	595608	0.000
0	2.406	0.486	1618054	0.000
0	2.311	0.467	6876508	0.000
0	2.216	0.448	infinite	0.000
0	2.121	0.429	infinite	0.000
0	2.027	0.409	infinite	0.000
0	Fat Dam from Tand Axles =			0.000

Rear Tridem Axles (Stress computed for 33% of axle load)

Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
0	2.944	0.595	35757	0.000
0	2.849	0.576	60950	0.000
0	2.754	0.556	103893	0.000
0	2.659	0.537	181257	0.000
0	2.564	0.518	350987	0.000
0	2.47	0.499	804314	0.000
0	2.375	0.480	2450208	0.000
0	2.28	0.461	13453983	0.000
0	2.185	0.441	infinite	0.000
0	2.09	0.422	infinite	0.000
0	1.995	0.403	infinite	0.000
0	1.9	0.384	infinite	0.000
0	Fat Dam from Tridem Axles =			0.000

Total Top-Down Fatigue Damage = 0.009 + 0.000 + 0.000 = 0.009

DESIGN IS SAFE SINCE SUM OF CFD FOR BUC AND TDC< OR EQ.1

Fig 8: IRC-58-2015 Design & Calculation Sheet.

Diameter, length & spacing of dowel bars and tie bars are adopted from Table-5 & Table-6 of IRC-58-2015.

Table 15 Proposed Pavement Composition for Rigid pavement

Design Period (Years)	CVPD	CBR (%)	Pavement Crust Compositions		
			PQC (mm)	DLC (mm)	GSB (mm)
30	22	7	250	100	150

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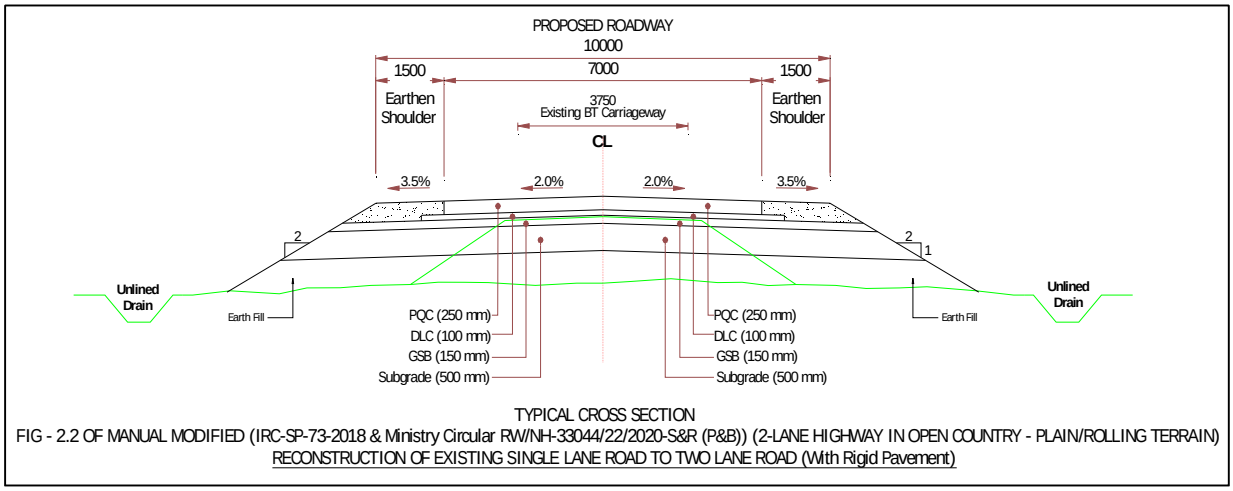
d) Typical Cross Section (TCS)

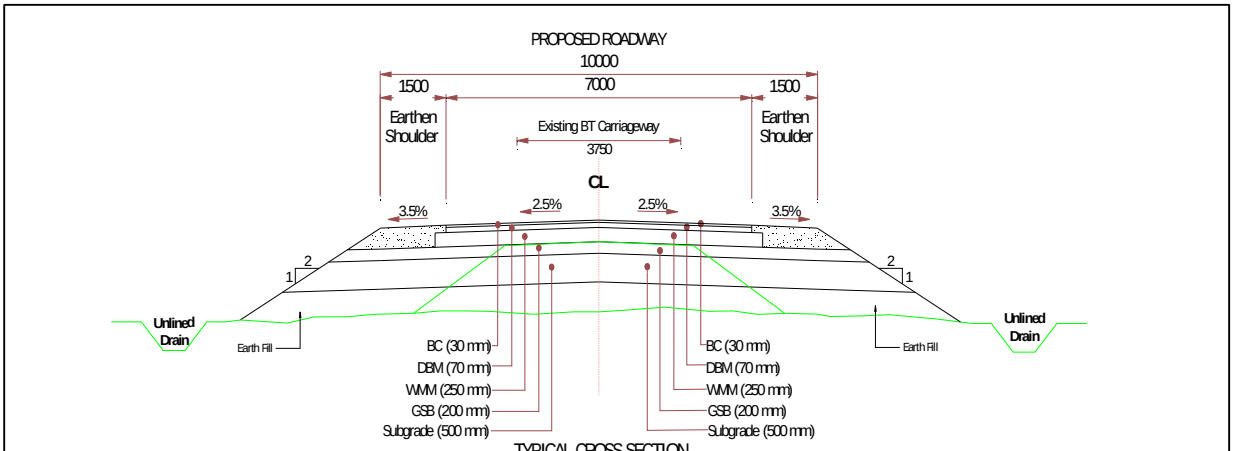
Figure 9 Photographs showing the Condition of the carriageway along the Project Road

Figure 10 Typical cross section with Rigid pavement



TYPICAL CROSS SECTION
FIG - 2.2 OF MANUAL MODIFIED (IRC-SP-73-2018 & Ministry Circular RW/NH-33044/22/2020-S&R (P&B)) (2-LANE HIGHWAY IN OPEN COUNTRY - PLAIN/ROLLING TERRAIN)
RECONSTRUCTION OF EXISTING SINGLE LANE ROAD TO TWO LANE ROAD (With Rigid Pavement)

Figure 11 Typical cross section with Flexible pavement



TYPICAL CROSS SECTION
FIG - 2.2 OF MANUAL MODIFIED (IRC-SP-73-2018 & Ministry Circular RW/NH-33044/22/2020-S&R (P&B)) (2-LANE HIGHWAY IN OPEN COUNTRY - PLAIN/ROLLING TERRAIN)
RECONSTRUCTION OF EXISTING SINGLE LANE ROAD TO TWO LANE ROAD (With Flexiable Pavement)

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e) Cross Drainage Details.

Existing Structure: 47 Nos.

Photographs showing existing Slab culverts on the Project Road

Photographs Showing Pipe Culverts on the Project Road

Photographs Showing VCW & FCW on the Project Road

Figure 12 Existing Structure Photograph.

Table 16 Summary of the cross drainage works

Structure	HPC	Slab Culvert	Box Culvert	RCC Barrel	Major Bridge	Minor Bridge
Widening	15	-	5	-	-	-
Reconstruction	13	4	-	9	-	1
Retained	-	-	-	-	1	-
New proposed	7	-	-	-	-	-
Total	35	4	5	9	1	1

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f) Proposed Protection work & Road Appurtenances

Bus Shelters: 16 nos. (2 x 8 location)
Metal Beam Crash Barriers: 1.340 Km.
Guard Stone: 434 Nos.
Toe Wall: 2.950 Km.

g) Cost Estimate.

Civil cost of the project road has been calculated with both pavement options (rigid & flexible).
Civil cost of the project road has been calculated by following steps

- Site Clearance.
- Earthwork.
- Sub-base & Base Course.
- Pavement.
- Traffic Signs, Marking and Road Appurtenances.
- Drainage & Protection Works.
- Cross Drainage Works.

Abstract of cost estimate is provided in the Tables below-

Table 17 Abstract of cost estimates with rigid pavement

Sr. No.	Description	Total Amount (Rs.)	Total Amount (Rs. in Crore)	% of each Item as a whole
1	Site Clearance	3,02,338.94	0.03	0.06%
2	Earthwork	5,61,56,533.42	5.62	10.44%
3	Sub-base, Base Courses	5,44,25,847.89	5.44	10.11%
4	Pavement (Flexible)	32,26,33,235.24	32.26	59.94%
5	Traffic Signs, Marking and Road Appurtenances	96,21,530.71	0.96	1.78%
6	Drainage & Protection Works	3,99,86,102.82	4.00	7.43%
7	Cross Drainage Works	5,50,70,032.01	5.51	10.24%
	Total Civil Construction Cost	53,81,95,621.03	53.82	100.00%
	Total Civil Construction Cost per Km	1,86,29,131.92	1.86	

Table 18 Abstract of cost estimates with flexible pavement

Sr. No.	Description	Total Amount (Rs.)	Total Amount (Rs. in Crore)	% of each Item as a whole
1	Site Clearance	3,02,338.94	0.03	0.10%
2	Earthwork	5,65,80,869.74	5.66	12.30%
3	Sub-base, Base Courses	14,03,46,733.08	14.03	30.50%
4	Pavement (Flexible)	15,76,46,567.38	15.76	34.30%
5	Traffic Signs, Marking and Road Appurtenances	96,21,530.71	0.96	2.10%
6	Drainage & Protection Works	3,99,86,102.82	4.00	8.70%
7	Cross Drainage Works	5,50,70,032.01	5.51	12.00%
	Total Civil Construction Cost	45,95,54,174.68	45.95	100.00%
	Total Civil Construction Cost per Km	1,59,07,032.70	1.59	

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3) Life Cycle Cost Analysis

Life Cycle Cost Analysis has been calculated based on the detailed cost estimates with rigid pavement as well as flexible pavement.

a) Flexible pavement during Operation & Maintenance Period.

- Say, Start of Construction of road: 1-Apr-2021.
- Construction period = 1.5 years =18 months = 540 days.
- Thus, Completion of Construction/ Commercial operation date (COD): 23-Sep-2022.
- End of design Period/ Concession: 23-Sep-2052 (Operation period 30 years).
- Frequency for Periodical Renewal: 05 Years (1st Periodical Renewal): 23-Sep-2027
- 10 Years (2nd Periodical Renewal): 23-Sep-2032
- 15 Years (3rd Periodical Renewal): 23-Sep-2037
- 20 Years (4th Periodical Renewal): 23-Sep-2042
- 25 Years (5th Periodical Renewal): 23-Sep-2047
- 30 Years (6th Periodical Renewal): 23-Sep-2052

b) Area of Pavement

- Width of 2-lane Carriageway: 7.0m
- Length of Stretch: 28.890 Km
- Area of Carriageway: 2,12,341.50 Sqm. (5% extra taken for Junction improvement)
- Area of Shoulder: 86,670.00 Sqm.

Table: 19 Cost for Periodical Renewal (at Present Rates for 1st, 2nd, 4th & 5th periodical slab):

Description	Unit	Qty	Rate	Amount (Rs.)
Tack Coat @ 0.30 kg per sqm (dry & hungry bituminous surfaces) below BC	M^2	2,12,341.50	16.00	33,97,464
Tack Coat @ 0.30 kg per sqm (dry & hungry bituminous surfaces) below DBM	M^2	-	16.00	-
Quantity of BC	M^3	8,493.66	7669.00	6,51,37,879
Quantity of DBM (for 2nd Periodic renewal)	M^3	-	6640.00	-
Quantity of Hard Shoulders	M^3	13,000.50	181.00	23,53,091
Thermoplastic Paint (Lane/edge marking & Arrrow painting)	M^2	9,630.00	516.00	49,69,080
Total Cost for 1st, 2nd, 4th & 5th periodic renewal with BC:				7,58,57,513

Table: 20 Cost for Periodical Renewal (at Present Rates for 3rd & 6th periodical slab):

Description	Unit	Qty	Rate	Amount (Rs.)
Tack Coat @ 0.30 kg per sqm (dry & hungry bituminous surfaces) below BC	M^2	2,12,341.50	16.00	33,97,464
Tack Coat @ 0.30 kg per sqm (dry & hungry bituminous surfaces) below DBM	M^2	2,12,341.50	16.00	33,97,464
Quantity of BC	M^3	6,370.25	7669.00	4,88,53,409
Quantity of DBM (for 2nd Periodic renewal)	M^3	10,617.08	6640.00	7,04,97,378
Quantity of Hard Shoulders	M^3	13,000.50	181.00	23,53,091
Thermoplastic Paint (Lane/edge marking & Arrrow painting)	M^2	9,630.00	516.00	49,69,080
Total Cost for 3rd & 6th periodic renewal with BC and DBM :				3,34,67,885

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Table 21 Schedule of Periodic Maintenance & Cost involved

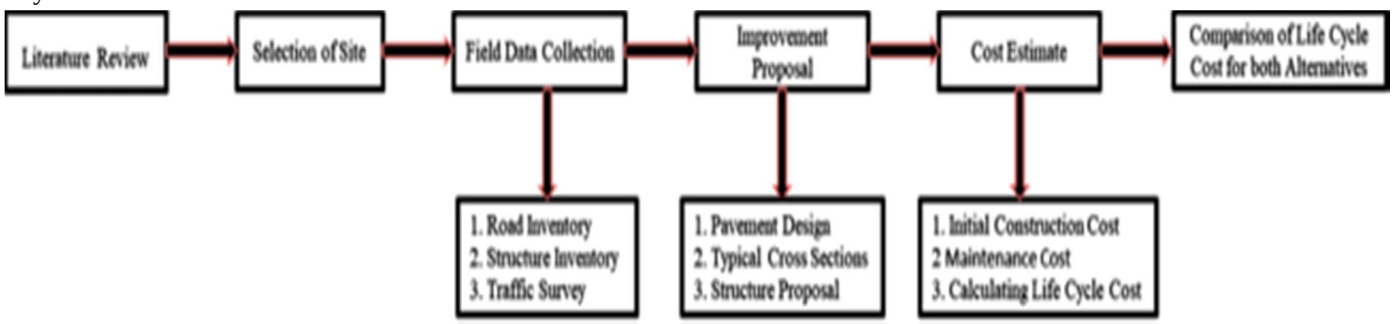
Description	2027(5 Yr.)	2032 (10 Yr.)	2037 (15 Yr.)	2042 (20 Yr.)	2047 (25 Yr.)	2052 (30 Yr.)
Cost of Periodical Renewal with BC	7,58,57,513	7,58,57,513	0	7,58,57,513	7,58,57,513	0
Cost of Strengthening with BC and DBM	0	0	13,34,67,885	0	0	13,34,67,885
Total Cost (at present rate)	7,58,57,513	7,58,57,513	13,34,67,885	7,58,57,513	7,58,57,513	13,34,67,885
	7.59	7.59	13.35	7.59	7.59	13.35

c) Boundaries for calculation of Life Cycle Cost as follow. Year wise life cycle cost of rigid & flexible pavement have been calculated using the following bounds-

- Cost of civil works excluding centages of rigid pavement: 53.82 Crore and flexible pavement: 45.95 Crore
- Cost Phasing 1st yr : 2nd Yr = 60 : 40
- Annual routine maintenance of rigid pavement for joint repair @ 0.1% of civil cost = 0.054 Crore
- Annual routine maintenance of flexible pavement for shoulder rain cut repair, potholes etc. @ 0.25% of civil cost = 0.11 Crore
- Routine routine maintenance of flexible pavement: as provided in Table 21
- Rate of Inflation: 5%
- Discount Rate: 12%

4) Methods

Life cycle cost analysis process is presented in the following flow chat. Below flow Chart showing procedure of Life cycle cost analysis.



5) Data Source & Collection

For the project, data were collected from the following sources:

a) Road maintenance & rehabilitation data from Madhya Pradesh Road Development Corporation, Chambal Division.
b) Field inspection of Preamser Hirnikheda Mundla road for project design and specifications.
c) Traffic surveys, & soil investigation survey, Road & structure inventory & condition surveys etc. also done at Preamser Hirnikheda Mundla road.
d) Informal Interviews to road project consultants & Chambal Division Manager.
e) Primary and secondary data were also collected from literatures, feasibility report, internets and websites and senior of collage.

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II. RESULTS AND DISCUSSION

Comparison of life cycle cost is presented in the following table:

Table 22 Comparison of Life Cycle Cost

Year	(Initial cost + Maintenance cost) Rigid	(Initial cost + Maintenance cost) Flexible	Remarks
2021	32.29	27.57	Initial Construction cost is high for Rigid Pavement by 17.13%
2022	52.47	44.80	
2023	52.52	44.90	
2024	52.57	45.00	
2025	52.61	45.09	
2026	52.65	45.17	
2027	52.68	50.32	
2028	52.72	50.39	
2029	52.75	50.46	
2030	52.78	50.52	
2031	52.81	50.59	
2032	52.83	54.31	Break even point
2033	52.86	54.37	
2034	52.88	54.42	
2035	52.90	54.46	
2036	52.92	54.51	
2037	52.94	59.26	
2038	52.96	59.30	
2039	52.98	59.33	
2040	52.99	59.37	
2041	53.01	59.40	
2042	53.02	61.36	Life cycle cost for rigid pavement is cheaper by 13.58%
2043	53.04	61.38	
2044	53.05	61.41	
2045	53.06	61.43	
2046	53.07	61.46	
2047	53.08	62.87	
2048	53.09	62.89	
2049	53.10	62.91	
2050	53.11	62.93	
2051	53.11	62.95	
2052	53.12	64.75	Life cycle cost for rigid pavement is cheaper by 17.96%

Thus the analysis shows that the initial construction cost of rigid pavement is 17.13% higher than that of flexible pavement, however the Life cycle cost for rigid pavement is 17.96% cheaper than flexible pavement.

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III. CONCLUSIONS

Say, average per km cost of construction of rigid pavement is 1.86 Crore and for flexible pavement is 1.59 Crore. Project roads are two lane roads. Thus total project cost for construction of 1,200 (total ADB VI-VII Pkg) Km roads with flexible pavement. = 1200 X 1.59 Cr. = Rs. 1908 Cr. and total project cost for construction of 1,200 (total ADB VI-VII Pkg) Km roads with rigid pavement. = 1200 X 1.86 Cr = Rs. 2232 Cr.

But the above analysis shows that the life cycle cost of rigid pavement is 17.96% cheaper than that of flexible pavement. Which is at the end of life cycle analysis per Km wise rigid pavement cost will reach 1.83 Cr. and for flexible 2.24 cr. So 2.24 X 1200 Km = 2688 Cr. and for rigid 1.83 X 1200 Km = 2,196 Cr. Which indicates that 492 Cr. will be more invested at the end of life cycle for Flexible pavement. Which can be invested for 265 Km. other roads if we consider for rigid.

Thus, the decision of up-grading the newly declared SH and MDR with flexible pavement is not going to be profitable for the State govt. and Department also.

IV. ACKNOWLEDGMENT

Construction of flexible pavement for up-gradation of the existing MDR & newly declared SH network of the State is not recommended. However in our country the major roads are constructed with flexible pavement due to rigid pavement are need to maintain the quality of construction, non-availability of modern instruments to the local contractors, lack of skill full labour etc.

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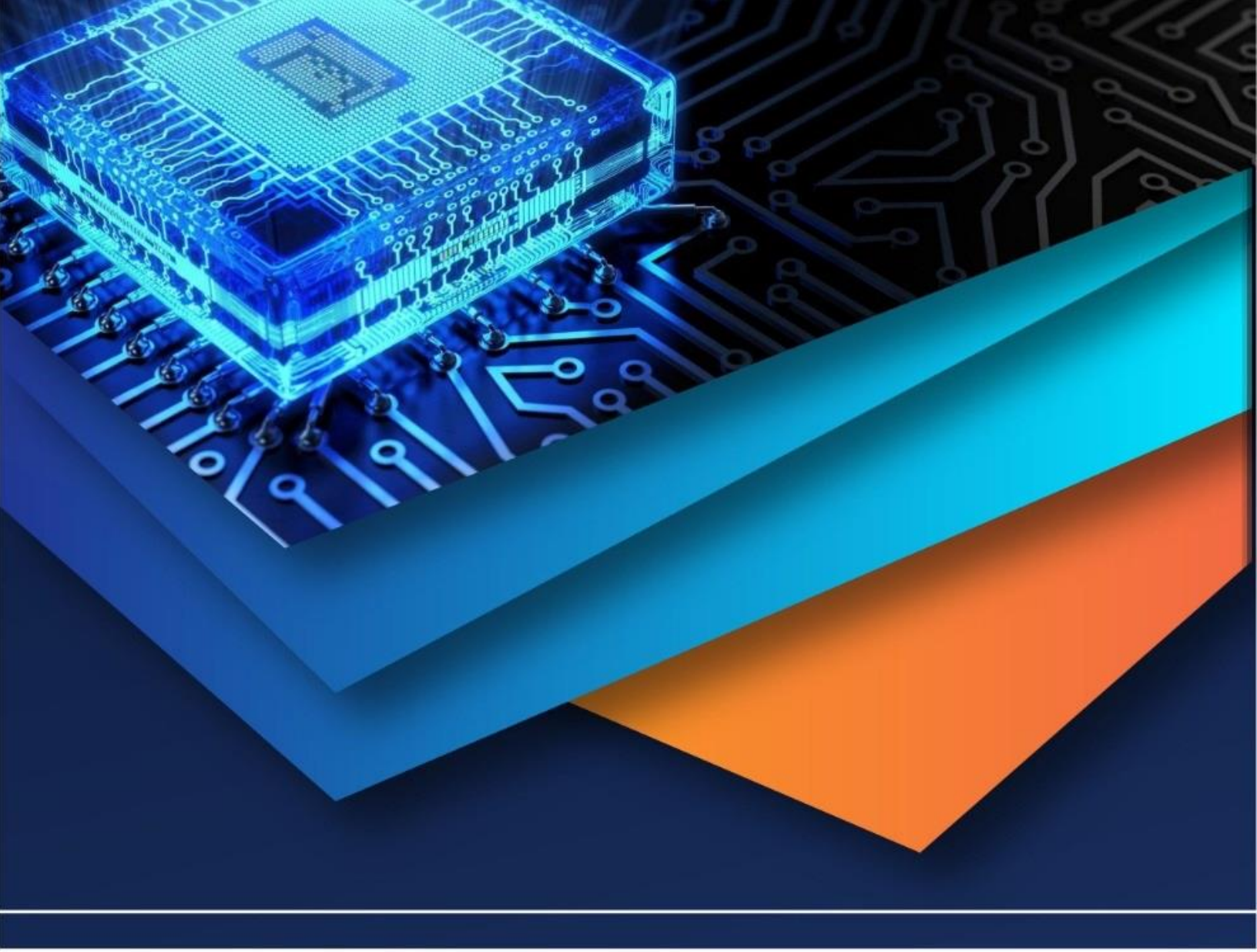

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