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Life Cycle Cost Analysis of Flexible Pavements and Rigid Pavements in Urban Areas

Shirole Pratik Ashok[1],
Civil Engineering Department,
D.Y. Patil College of Engineering, Akurdi,
Pune, India

Patil Ashwini R.[2],
Civil Engineering Department,
D.Y. Patil College of Engineering, Akurdi,
Pune, India

Abstract **- Majority of pavements in India are bituminous pavements which are showing early sign of distresses and also require periodic maintenance for strengthening. Now a days focus is on pavements which are maintenance free or having low maintenance and economical than flexible pavements. Concrete pavements are a good alternative to bituminous pavements, these pavement perform for a long term and even have a very low maintenance cost, though the initial cost of these pavements is high when life cycle cost is considered the overall cost of these pavement is less than that of overall cost of bituminous pavements. In the present study, an attempt is made to evaluate the life cycle cost of new bituminous and concrete pavements and even the life cycle cost (LCC) of bituminous overlays and concrete white toppings is being evaluated with the help of net present value method of life cycle cost analysis.**

Keywords *- LCC, White Topping, Pavement Rehabilitation, Alternative to bituminous pavements, Overlays.*

I. INTRODUCTION

Infrastructure Development plays an important role in development of a country. In case of developing countries like India, shortage of funds for infrastructure project is a major problem. Therefore before construction of new road and before rehabilitation of bituminous pavements, pavements which perform for long term should be considered.

In India majority of the pavements are bituminous pavements, which are showing early sign of distresses due to increasing traffic, increasing load, high tyre pressure etc. Distresses like rutting, cracking, ageing are the most common in bituminous pavements. Concrete pavements perform for a long period and can be adopted as good alternative for bituminous pavements. 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. This paper highlights the life cycle cost (LCC) analysis of cement concrete road and bituminous road. It provides results about the best suitable, economical and cost effective pavements and also gives the difference between concrete and rigid pavement and overlays. 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.

A. Types of Pavements

1. Flexible pavement: - Flexible pavement can be defined as the pavements which are surfaced with wearing course of bituminous or asphalt layers. These pavements generally consist of four layers which are sub-grade, sub-base, base course and wearing or surface course. Due to increasing traffic, increasing load, high tyre pressure etc. distresses like rutting, cracking, potholes etc. are seen in these pavements. Though the initial cost of these pavements is low their service life is not as good as rigid pavements and their maintenance cost is also high.

2. Rigid Pavements: - Rigid pavements are composed of a cement concrete surface course and concealed base and sub base courses. The surface course is the rigid layer and provides the majority of strength. Rigid pavements have high flexural strength than flexible pavements due to which they can transmit the wheel load stresses over a wider area. Initial cost of these pavements is high as compared to flexible pavements but their maintenance cost is low. These pavements have a service life of 20 years and more.

ISSN No: - 2456 - 2165

II. OBJECTIVES OF STUDY

1.The main objective of this paper is to calculate the total cost of bituminous and concrete pavements by using life cycle lost analysis (LCCA) methodology, which could assist in the pavement selection process and help to improve the pavement system.
2.Compare the overall cost for 1 kilometer of both flexible and rigid pavements.
3.To suggest a better alternative for the maintenance and rehabilitation required in bituminous pavements.

III. METHODOLOGY

In this study the cost required for initial construction and for maintenance of the pavements is calculated by using net present value method of life cycle cost analysis. IRC SP-30 (2009) gives the formula for net present value. Agency costs are calculated from the district schedule of rates of Public Works Department (PWD) Pune region. The procedures of construction and estimates were studied from case studies done on three different roads.

1) Construction of pavements UTWT and TWT, Madhuban area at old Sanghvi ward no 59, PCMC.
2) Construction of PQC pavement road from Chaphekar chowk to bridge on Pavana River towards Thergaon. PCMC
3) Development of 45.00W wide road from Pune Alandi road to Dabhadewasti in PCMC area.

IV. LIFE CYCLE COSTANALYSIS

Analysis period considered is 20 years starting from 2016. Discount rate of 12% is considered as per government policy and inflation rate of 5.5 % has been considered for rise of prices of material in future.

A] Life cycle cost of bituminous pavements:

1) Cost of construction of is shown in Table I

Table I. Construction Cost of Bituminous Pavements

Pavement Layer	Cost/km	Length (m)	Thick (mm)	Width (m)	Rate (Rs)
Bituminous Concrete	3,272,800	1000	40	10	8182.0 /Cum
Dense Bituminous Macadam	7,115,000	1000	100	10	7115.0 /Cum
Wet Mix Macadam	2,875,000	1000	250	10	1150.0 /Cum
Granular Sub-Base	3,175,000	1000	250	10	1270.0 /Cum
Prime Coat	210,000	1000	1 Coats	10	21.00 /Sqm.
Tack Coat	350,000	1000	2 Coats	10	17.50 /Sqm.
Initial Cost	**16,997,800**				

2) Maintenance cost of bituminous pavement.
Overlay shall be provided at every 10th year after construction for strengthening of existing pavement having a 75mm DBM layer and 40mm BC layer. Overlay cost is shown in Table II.

According to MoRTH guidelines a layer of 25mm BC is to be provided once in 5 years. Cost of overlays is shown in Table III.

Table II. Cost of Overlay to be provided at every 10th year

Overlay Layer	Cost/km	Length (m)	Thick(mm)	Width (m)	Rate (Rs)
Bituminous Concrete	3,272,800	1000	40	10	8182.0 /Cum
Dense Bituminous Macadam	5,336,250	1000	75	10	7115.0 /Cum
Tack Coat	350,000	1000	2 Coats	10	17.50 /Sqm.
Initial Cost	**8,959,050**				

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Overlay Year	Initial Cost (Rs)	Inflated Cost @5.50% p.a.
10 th Year	8,959,050	16,145,035.95
Total	**8,959,050**	16,145,036

Table III. Periodic Resurfacing in every Five Years (BC 25mm)

Pavement Layer	Cost/km	Length (m)	Thick(mm)	Width (m)	Rate (Rs)
Bituminous Concrete	**2,045,500**	1000	25	10	8182.0 /Cum

Year	Cost per Km.	Inflated Cost @5.50% p.a.
5th Year	2,045,500	2,820,422.96
	2,045,500	4,566,530.66
18th Year	2,045,500	5,657,130.76
Total	**6,136,500**	**13,044,084**

B) Life Cycle Cost of Concrete Pavement

1) Construction Cost is shown in Table IV

Table IV. Construction Cost of Concrete Pavements

Pavement Layer	Cost/km	Length (m)	Thick (mm)	Width (m)	Rate (Rs)
PQC	1,72,23,000	1000	300	10	5741.0 /Cum
DLC Layer	25,96,000	1000	100	10	2596.0/Cum
GSB Layer	31,75,000	1000	250	10	1270.0/Sqm.
Initial Cost	**2,29,94,000**				

2) Maintenance cost of Concrete Pavements

Joint Sealing: 50 % of the joint sealants are to be replaced in every 5 year.

Joint Length: Contraction Joint length per km. for 10m wide carriageway 10000m.

Longitudinal Joint length for 1 km and two joints in 10m width 10000m Length to be replaced every 5 years is 30% of total length

Contraction joint = 3333.333 m

Longitudinal joint = 3333.333 m

Cost of joint seals in shown in Table V

Table V Cost of Joint Seals (Preformed Seals) per Km

Item	Unit	Quantity	Rate (Rs.)	Cost /Km.
Contraction Joint	m	3333.333 m	150	500000
Longitudinal Joint	m	3333.333 m	100	333333.333
			Total	**833333.333**

ISSN No: - 2456 - 2165

Concrete spalling :-

0.5% of Joint length for a width of 500mm in every 10 years

10th year spalling concrete = 50 SqmRepairs of concrete spalling = 50*6889.2 = 344460 Rs

Table VI Total Cost and Inflated Cost of Concrete Spalling

CONCRETE SPALLING		
Maintenance Year	**Maintenance Cost (Rs.)**	**Inflated Cost @5.50% p.a.**
10 th Year	344,460	620,748.75
Total	**344,460**	**620,749**

C) Life Cycle Cost of Overlays

1) Bituminous overlays

Bituminous Overlays		
Overlay	**Initial Cost**	**Inflated cost**
Strengthening overlay	8,959,050	16,145,036
Periodic overlays	6,136,500	13,044,084
Total	**15,095,550**	**29,189,120**

2) Concrete overlays

Table VIII Thin White Topping overlay

Pavement Layer	**Cost/km**	**Length (m)**	**Thick (mm)**	**Width (m)**	**Rate (Rs)**
Thin White Topping (TWT)	8,6,11,500	1000	150	10	5741.0 /Cum
Milling	26,775	1000	50	10	53.6 /Cum
Initial Cost	**8,638,275**				

Table IX Ultra Thin White Topping Overlay

Pavement Layer	**Cost/km**	**Length (m)**	**Thick (mm)**	**Width (m)**	**Rate (Rs)**
Ultra-Thin White Topping (UTWT)	5,741,000	1000	100	10	5741.0 /Cum
Milling	26,775	1000	50	10	53.6 /Cum
Initial Cost	**5,767,775**				

Maintenance cost for concrete overlays will be same as that of new concrete roads.

ISSN No: - 2456 - 2165

Table X Maintenance cost of Concrete Pavements

Stages	Initial cost	Inflated cost
Joint sealing	2,500,000	46,13,498
Concrete spalling	344,460	620,749
Re-Texturing	20,00,000	4,011,548
Total	**46,53,400**	**9,245,795**

V. RESULTS AND DISCUSSION

1) Life cycle cost comparison of new bituminous and concrete pavements is shown in Table no XI

2) Life cycle cost comparison of bituminous and concrete Overlays is shown in Table no XII.

Table No XI Life Cycle Cost Comparison of New Bituminous and Concrete Pavements.

NPV Bituminous Pavements					NPV Concrete Pavements				
Sr No	Year	Construction & Maintenance cost	(1/1.12)^n	NPV	Sr No	Year	Construction & Maintenance cost	(1/1.12)^n	NPV
1	2016	16997800	1.00	16997800	1	2016	22994000	1.00	22994000
2	2017		0.89	0	2	2017		0.89	0
3	2018		0.80	0	3	2018		0.80	0
4	2019		0.71	0	4	2019		0.71	0
5	2020		0.64	0	5	2020		0.64	0
6	2021	2,820,422.96	0.57	1,600,383.73	6	2021	1,149,035.67	0.57	651,993.70
7	2022		0.51	0	7	2022		0.51	0
8	2023		0.45	0	8	2023		0.45	0
9	2024		0.40	0	9	2024		0.40	0
10	2025		0.36	0	10	2025		0.36	0
11	2026	16,145,035.95	0.32	5,198,269.48	11	2026	1,846,203.67	0.32	594,428.17
12	2027		0.29	0	12	2027		0.29	0
13	2028		0.26	0	13	2028		0.26	0
14	2029		0.23	0	14	2029		0.23	0
15	2030	4,566,530.66	0.20	934,402.65	15	2030		0.20	0
16	2031		0.18	0	16	2031	1,962,718.92	0.18	358,581.41
17	2032		0.16	0	17	2032		0.16	0
18	2033		0.15		18	2033		0.15	0
19	2034	5,657,130.76	0.13	735,650.96	19	2034		0.13	0
20	2035		0.12	0	20	2035		0.12	
21	2036		0.10	0	21	2036	2,565,195.13	0.10	265,925.48
			Total	**25466506.83**				**Total**	**24864928.76**

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Table No XII Life Cycle Cost Comparison of Bituminous and Concrete Overlays.

NPV Bituminous Overlays					NPV Concrete Overlays (Ultra Thin White Topping Thickness - 100mm)					NPV Concrete Overlays (Thin White Topping Thickness - 150mm)				
Sr No	Year	Construction & Maintenance cost	(1/1.12) ^n	NPV	Sr No	Year	Construction & Maintenance cost	(1/1.12) ^n	NPV	Sr No	Year	Construction & Maintenance cost	(1/1.12)^n	NPV
1	2016	8959050	1.00	8959050	1	2016	5942775	1.00	5942775	1	2016	8813275	1.00	8813275
2	2017		0.89	0	2	2017		0.89	0	2	2017		0.89	0
3	2018		0.80	0	3	2018		0.80	0	3	2018		0.80	0
4	2019		0.71	0	4	2019		0.71	0	4	2019		0.71	0
5	2020		0.64	0	5	2020		0.64	0	5	2020		0.64	0
6	2021	2,820,422	0.57	1,600,383	6	2021	1,149,035	0.57	651,993	6	2021	1,149,035	0.57	651,993
7	2022		0.51	0	7	2022		0.51	0	7	2022		0.51	0
8	2023		0.45	0	8	2023		0.45	0	8	2023		0.45	0
9	2024		0.40	0	9	2024		0.40	0	9	2024		0.40	0
10	2025		0.36	0	10	2025		0.36	0	10	2025		0.36	0
11	2026	16,145,035	0.32	5,198,269	11	2026	1,846,203	0.32	594,428	11	2026	1,846,203	0.32	594,428
12	2027		0.29	0	12	2027		0.29	0	12	2027		0.29	0
13	2028		0.26	0	13	2028		0.26	0	13	2028		0.26	0
14	2029		0.23	0	14	2029		0.23	0	14	2029		0.23	0
15	2030		0.20	0	15	2030		0.20	0	15	2030		0.20	0
16	2031	4,566,530	0.18	834,288	16	2031	1,962,718	0.18	358,581	16	2031	1,962,718	0.18	358,581
17	2032		0.16	0	17	2032		0.16	0	17	2032		0.16	0
18	2033		0.15	0	18	2033		0.15	0	18	2033		0.15	0
19	2034		0.13	0	19	2034		0.13	0	19	2034		0.13	0
20	2035		0.12	0	20	2035		0.12		20	2035		0.12	
21	2036	5,657,130	0.10	586,456	21	2036	2,565,195	0.10	265,925	21	2036	2,565,195	0.10	265,925
			Total	**17178447**				**Total**	**7813703**				**Total**	**10684203**

VI. CONCLUSION

1) Life cycle cost analysis shows that net present value of concrete pavements is less than bituminous pavements.
2) When life cycle cost of bituminous overlays and concrete white toppings is considered the total cost of bituminous overlays is Rs 1,71,78,447 and that of concrete white toppings is Rs 1,06,84,203 for thin white topping and Rs 78,13,703 for ultra thin white topping, which is 38% and 55% lesser than bituminous overlays.
3) LCCA concludes that concrete pavements are more beneficial than bituminous pavements and concrete overlays can be considered as beneficial option for rehabilitation of existing bituminous pavements.

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