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LIFE CYCLE COST ANALYSIS (LCCA) OF RIGID & FLEXIBLE PAVEMENT OF RURAL ROAD IN RAJASTHAN

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Abstract: Life cycle cost analysis (LCCA) for the Bitumen and Concrete Road is the process for determining the total cost of road pavements including initial construction cost, operational and maintenance cost. To reduce the life cycle cost of road pavements it is necessary to deal with the initial cost and need to learn preventive maintenance of pavements. The proper implementation of preventive maintenance techniques for road pavements can extend the life of a pavements structure in a cost-effective manner. Different researchers in the field of road construction have found that Economic and Sensitivity Analysis can be used as methods to analyze LCCA results found by NPV and IRR with different affecting input parameters.

Keywords: component; LCCA: bitumen; concrete; life cycle cost

I. INTRODUCTION

The purpose of this project is to develop a model (either Bitumen or concrete road), based on Life Cycle Cost Analysis (LCCA) methodology, which could assist in the pavement selection process and hopefully help to improve the road and street system.

The dramatic increase in traffic in built-up areas, such as the Capital Area, results in more and more construction of new roads and modernization of old ones. Therefore, this requires further studies on how road pavements are selected.

Agencies could make more informed and better investment decisions, because pavement type has a significant impact on future cost and service quality. Traffic growth, especially in heavy axle traffic, can cause damage to pavements much quicker than expected, in turn causing more maintenance and thereby increasing agencies and users' costs. Pavement type decision is usually based on traffic level, soil conditions, atmospheric factors and costs. In many cases, the initial construction cost is the main consideration; the future maintenance and rehabilitation costs may sometimes be forgotten.

II. PAVEMENTS

A multi layer system that distributes the vehicular loads over a larger area, Highway pavement is a structure consisting of superimposed layers of selected and processed materials whose primary function is to distribute the applied vehicle load to the sub grade.

It can also be defined as "Structure which separates the tires of vehicles from the under lying foundation." Pavement is the upper part of roadway, airport or parking area structure; it includes all layers resting on the original ground.

A. Flexible Pavements

Flexible Pavements are constructed from bituminous or unbound material and the stress is transmitted to the sub-grade through the lateral distribution of the applied load with depth.

Everyone is aware about the benefits and advantages of a good constructed road. Roads play very crucial role in

modern society providing services and goods for modern people. Today a vast majority of road are constructed using Asphalt. The bituminous material is more often asphalt whose viscous nature allows significant plastic deformation. Now question arises in your mind is "What is Asphalt"? Asphalt is the sticky dark brown viscous liquid present in some natural deposits like crude petroleum. It is the name given to technically or natural mixture used in road construction for road surfacing and compaction.

Features of the Flexible Pavement:

- It has no flexural strength,
- It reflects the deformation of lower layers,
- It will transmit the vertical stress to bottom layers by grain-to-grain transfer,
- The lower layer has to take up only lesser magnitudes of stress and there is no direct wearing action due to traffic loads, therefore inferior materials with low cost can be used in the lower layers.

Flexible pavements consist of the following components:

1. Soil sub grade
2. Sub base course
3. Base course
4. Surface course

Bituminous concrete, granular materials with or without bituminous binders, WBM, soil aggregate mixes etc.., are common examples of flexible pavements.

Flexible pavements are commonly designed using empirical charts or equations. There are also semi-empirical and theoretical methods for the design of flexible pavements.

A valuable advantage of flexible pavement is that it can be opened for traffic within 24 hrs after completion. Also, the repair and maintenance of flexible pavement is easy and cost effective.

B. Rigid Pavements

Rigid pavements are constructed of portland cement concrete slabs resting on a prepared sub-base of granular material or directly on a granular subgrade. Load is transmitted through the slabs to the underlying sub-grade by flexure of the slabs.

A rigid pavement is constructed from cement concrete or reinforced concrete slabs. Grouted concrete roads are in the category of semi-rigid pavements. The design of rigid pavement is based on providing a structural cement concrete slab of sufficient strength to resists the loads from traffic. The rigid pavement has rigidity and high modulus of elasticity to distribute the load over a relatively wide area of soil.

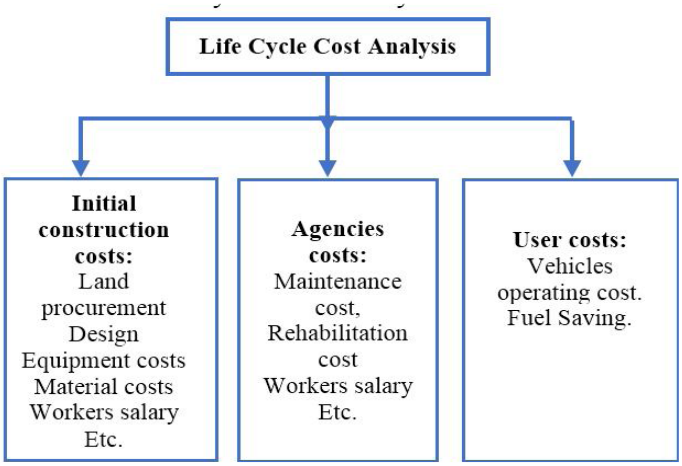
Minor variations in sub grade strength have little influence on the structural capacity of a rigid pavement. In the design of a rigid pavement, the flexural strength of concrete is the major factor and not the strength of sub grade. Due to this property of pavement, when the sub grade deflects beneath the rigid pavement, the concrete slab is able to bridge over the localized failures and areas of inadequate support from sub grade because of slab action.

Rigid Pavements consists of the following components:

1. Cement Concrete slab
2. Base course
3. Soil sub grade

Rigid pavements are made of Portland cement concrete either plain, reinforced or pre-stressed. The plain cement is expected to take up about 40 kg/cm^2 flexural stress. These are designed using elastic theory, assuming the pavement as an elastic plate resting over an elastic or viscous foundation.

III. METHODOLOGY



The steps involved in LCCA Methodology are as follows:

1. Estimate the initial construction cost
2. Estimate maintenance cost
3. Estimate road user costs

A. Design criteria for road pavements

a) Flexible Pavement Design

- The design of flexible pavements depends upon the CBR value of sub grade and number of commercial vehicles per day that will use the road during its design life, which is 10 years for rural roads.
- It greatly influenced by sub grade strength and its stability depends upon the aggregate interlock, particle friction and cohesion.

GSB = 175 mm
WBM = 150 mm
Premixed Carpet = 20 mm

b) Rigid Pavement Design

A typical pavement composition consists for non-expansive soil area, this consist of following configuration.
Sand: 100 mm
(M30): 100 mm
(M15): 100 mm

IV. LIFE CYCLE COST ANALYSIS OF PAVMENT

A. *Construction cost of flexible pavement*

Table I- Cost of materials

S. No.	Items	Quantity	Rates/cum or sq.	Cost
1.	Granular Sub-base	612.5 cum	536.00	328,300
2.	Water Bound Macadam	525 cum	1308.00	686,700
3.	Premixed Carpet with other layers such as Prime coat, Tack coat, Seal coat	3500 sq.	147.00	514,500
	Total Initial Cost			1,529,500

The cost of the above 3.5 m wide pavement will thus be about Rs. 15.295 laths per km.

B. *Maintenance Cost of Flexible Pavement*

- It has been assumed that one layer of WBM (75 mm) will be laid every 10th Year after construction.
- Surface renewals (20 mm Premix Carpet) are to be provided once in every 5 years. The cost of ordinary repairs for rural roads with bituminous pavement has been taken as Rs. 20, 000 per year (average) for analysis.

C. *Construction cost of rigid pavement*

Table II- Cost of materials

S. No.	Items	No.	Quantity	Rates/cum	Cost
1.	PCC M30 Grade	1	350	5516	1,930,600
2.	PCC M10 Grade	1	350	3800	1,330,000
3	Sand	1	350	840	294,000
4	Cut off (both side)	2	67.5	3800	513,000
	Total Initial Cost				4,067,600

As per PRI department estimate, the cost of above pavement composition will be about Rs. 40.676 lakh per km

D. *Maintenance Cost of Rigid Pavement*

1. The average yearly maintenance cost of rigid pavement will be about Rs. 10,000/- per km for a single lane rural road to cover filling of sealing compound in the joints
2. For a 3.5 m wide road this cost will be Rs. 3.60 lakhs per km using the rate of concrete adopted for life cycle cost analysis.

E. *Life Cycle Cost Analysis*

Period of analysis has been considered as 20 years, being the design life of concrete pavement in rural area. The discount rate of 10% has been taken. Inflation rate of 5% has been considered for future rise in prices of materials.

F. *Cost Estimate:*

1. Initial Cost of Flexible Pavement = Rs. 15.295 lakh per km
2. Initial Cost of Rigid Pavement = Rs. 40.67 lakh per km
3. Annual Maintenance of flexible pavement= Rs. 0.20 lakh per km.
4. Renewal of wearing course of flexible pavement is considered in every 5 years.

   renewal cost = 147 x 3.50 x 1000= Rs. 5.145 lakhs
5. Strengthening with WBM and pre-mix carpet every 10th year:

   WBM 75 mm = 0.075 x 3.50 x 1000 x 1308 = Rs. 3.4335 lakhs
   PC 20mm = 147 x 3.50 x 1000= Rs. 5.145 lakhs
   Total Cost= Rs. 8.5785 lakhs
6. Average maintenance cost of CC road pavement is Rs.0.10 lakh per year
7. Rehabilitation/ strengthening of the concrete pavement after 10 years with 75 mm of cement concrete = Rs. 10.80 lakhs per km.
   DATA ASSUMPTION:
   Analysis Period: 40 Years
   Discount Rate: 10%
   Inflation Rate: 5% per Year

G. *Cost (Rs. In Lakhs) Per Km.*

	Bituminous Pavement	*CC Road Pavement*
Construction Cost	15.295	40.676
Routine Maintenance/Year	0.20 (avg.)	0.1 (avg.)
Renewal (5 Years)	6.00	-
Strengthening (10 Years)	11.625	10.80

Table III: life cycle cost analysis of bituminous and concrete pavement

Year	Bituminous Road Pavement			CC Road Pavement		
	Const. Cost	Maint. Cost	NPV	Const. Cost	Maint. Cost	NPV
0	15.295	-	15.295	40.676	-	40.676
1		0.2	0.18		0.11	0.09
2		0.22	0.18		0.11	0.09
3		0.23	0.17		0.12	0.09
4		0.24	0.17		0.12	0.08
5		7.66	4.75		0.13	0.08
6		0.27	0.15		0.13	0.08
7		0.28	0.14		0.14	0.07
8		0.30	0.14		0.15	0.07
9		0.31	0.13		0.16	0.07
10		18.94	7.30		17.59	6.78
11		0.34	0.12		0.17	0.06
12		0.36	0.11		0.18	0.06
13		0.38	0.11		0.19	0.05
14		0.40	0.10		0.20	0.05
15		12.47	2.99		0.21	0.05
16		0.44	0.10		0.22	0.05
17		0.46	0.09		0.23	0.05
18		0.48	0.09		0.24	0.04
19		0.51	0.08		0.25	0.04
20		31.55	4.69		29.30	4.36
21		0.57	0.07		0.29	0.04
22		0.60	0.07		0.30	0.03
23		0.63	0.07		0.32	0.03
24		0.66	0.06		0.33	0.03
25		20.89	1.93		0.35	0.03
26		0.73	0.06		0.37	0.03
27		0.77	0.06		0.38	0.02
28		0.81	0.05		0.40	0.02
29		0.85	0.05		0.43	0.02
30		51.94	2.98		48.25	2.76
31		0.94	0.05		0.47	0.02
32		0.99	0.04		0.49	0.02
33		1.04	0.04		0.52	0.02
34		1.09	0.04		0.55	0.02
35		34.40	1.22		0.57	0.02
36		1.21	0.04		0.60	0.01
37		1.27	0.03		0.63	0.01
38		1.33	0.03		0.67	0.01
39		1.40	0.03		0.70	0.01
40		1.47	0.03		0.74	0.01
	Total NPV Cost		44.035			56.146

H. Economic Analysis

The details of economic analysis based on net present worth method, i.e., net present value of total construction cost and maintenance cost over the analysis period of 40 years are provided in Table for flexible and rigid pavement. The summary of Initial and Life Cycle Costs are given below:

Table IV- Summary of Initial and life Cycle Cost

S No.	Pavement Type	Initial Cost (Rs. In Lakhs)	Life Cycle Cost (for 20 yrs period) (Rs. In Lakhs)
1	Flexible/bituminous	15.295	44.035
2	Rigid/concrete	40.676	56.146

The Life cycle cost of a concrete pavement (as per present practice) for construction/maintenance costs is approximately same to bituminous pavements considering an analysis period of 40 years. From the above, it can be concluded that although the initial cost of concrete pavement is higher, the life cycle cost is at par with bituminous pavement considering 40 years of period of service life

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