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Design of Rigid and Flexible Pavements by Various Methods & Their Cost Analysis of Each Method

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ABSTRACT
Highway and pavement design plays an important role in the DPR projects. The satisfactory performance of the pavement will result in higher savings in terms of vehicle operating costs and travel time, which has a bearing on the overall economic feasibility of the project. This paper discusses about the design methods that are traditionally being followed and examines the "Design of rigid and flexible pavements by various methods & their cost analysis by each method".
Flexible pavement are preferred over cement concrete roads as they have a great advantage that these can be strengthened and improved in stages with the growth of traffic and also their surfaces can be milled and recycled for rehabilitation. The flexible pavements are less expensive also with regard to initial investment and maintenance. Although Rigid pavement is expensive but have less maintenance and having good design period. The economic part are carried out for the design pavement of a section by using the result obtain by design method and their corresponding component layer thickness. It can be done by drawing comparisons with the standard way and practical way. This total work includes collection of data analysis various flexible and rigid pavement designs and their estimation procedure are very much useful to engineer who deals with highways.
Keywords – Design of flexible pavement, Design of rigid pavement, Cost analysis, Estimation.

I. INTRODUCTION

The transportation by road is the only road which could give maximum service to one all. This mode has also the maximum flexibility for travel with reference to route, direction, time and sped of travel. It is possible to provide door to door service only by road transport .Concrete pavement a large number of advantages such as long life span negligible maintenance, user and environment friendly and lower cost. Keeping in this view the whole life cycle cost analysis for the black topping and white topping have been done based on various conditions such as type of lane as single lane, two lane, four lane different traffic categories deterioration of road three categories.

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub- grade. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements. This gives an overview of pavement types, layers and their functions, cost analysis. In India transportation system mainly is governed by Indian road congress (IRC).

Various grades of concrete under similar condition of traffic and design concrete road are found to more suitable than bituminous road. Since the whole life cycle cost comes out to be lower in the range of 30% to 50% but for roads having traffic less than 400cv/day and road is in good condition, the difference between whole life costs of both the road is very less. The initial cost of concrete overlay is 15% to 60% more than the flexible overlay.

To design the road stretch as a flexible pavement by using different flexible methods like group index method, C.B.R. method as per IRC : 37-2001, triaxial method, California resistance value method , and as a rigid pavement as per IRC : for the collected design upon a given black cotton soil sub grade and to estimates the construction cost of designed pavement by each method. To propose a suitable or best methods to a given condition or problem.

The main objective of this study is to develop a strategy to select the most cost efficient pavement design method to carried out for a sections of a highway network and also to identify the cost analysis of different pavement design methods. Prioritization based on Subjective Judgment, Prioritization based on Economic Analysis

To develop a strategy for to select the most appropriate method to be carried out for design of a highway network. Analysis of data for a highway network problem to illustrate the proposed strategy and Interpretation of the results obtained..

II. TRAFFIC DATA (MAX WHEEL LOAD, TRAFFIC VOLUME DAILY&HOURLY)

An accurate estimate of the traffic that is likely to use the project road is very important as it forms the basic input in planning, design, operation and financing. A thorough knowledge of the travel characteristics of the traffic likely to use the project road as well as other major roads in the influence area of the study corridor is, therefore, essential for future traffic estimation. Hence, detailed traffic surveys were carried out to assess the present day traffic and its characteristics..

2.1 Temperature Data:

Generally temperature in this given region varies from 20^0 to 45^0 C.

2.2 Design Speed Data

Pavement is designed for a speed of 100 km/hr as per IRC

2.3 Soil Sub Grade Data

2.3.1For flexible pavement

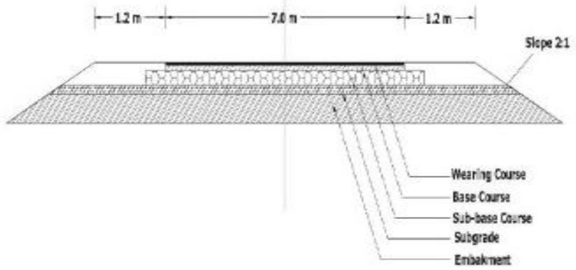
C.B.R of soil sub grade = 5%
Modulus of sub grade Reaction K – value =2.94 Kg/cm^2
Liquid limit = 55%
Plastic limit = 24%
Plasticity index (PI) = 31%
O.M.C = 25%
Standard proctor density (gr./cc) = 1.61 gm/cc

2.3.2 For rigid pavement

A-C.B.R of soil sub grade = 5%
B-Modulus of sub grade Reaction K-DLC of sub-base =14.4Kg/cm^2

III. DESIGN AND COST ANALYSIS OF FLEXIBLE AND RIGID PAVEMENTS

The structural capacity of flexible pavements is attained by combined action of the different layers of the Pavement. The load is directly applied on the wearing course and it gets dispersed with depth in the base, sub-base and sub-grade layers and then ultimately to the ground. Since the stress induced by traffic load is highest at the top, the quality of top and upper laye materials is better. The sub-grade layer is responsible for transferring the load from above layers to the ground. Flexible pavements are designed in such a way that the load transmitted to the sub-grade does not exceed its bearing capacity. Consequently, the thickness of layers Would vary with CBR of soil and it would affect the cost of the pavement.



"Fig." 1 Typical Cross-section of a flexible pavement

The thickness design of a flexible pavement also varies with the amount of traffic. The range of variation in Volume of commercial vehicles at different highways has direct effect on the repetitions of the traffic loads. The damaging effect of different axle loads is also different The Indian Roads Congress method of flexible pavement design uses the concept of ESAL for the purpose of flexible pavement design and the same has been used in this study also.

3.1 Design Strategy And Different Design Methods.

3.1.1Design Of Flexible Pavement By Group Index Method

In order to classify the fine grained soils within one group and for judging their suitability as sub grade material, an indexing system has been introduced in HRB classification which is termed as Group Index. Group Index is function of percentage material passing 200 mesh sieve (0.074mm), liquid limit and plasticity index of soil and is given by equation: (0.074mm) . Liquid limit and plasticity index of soil and is given by equation:
GI=0.2a+0.005ac+0.01bd
Here,
a=that portion of material passing 0.074mm sieve, greater than 35 And not exceeding 75 %
b=that portion of material passing 0.074mm sieve, greater than 15
And not exceeding 35%
c = that value of liquid limit in excess of 40 and less than 60
d = that value of plasticity index exceeding 10 and not more than 30
Or
GI= (F-35) 0.2+0.05(WL -40) +0.01(F-15) (IP-10)
DATA:
F =66%
WL=55%
IP =31%
GI = (F-35)0.2+0.05(WL -40)+0.01(F-15)(IP-10)
=17.35
So Pavement Thickness =700mm
Thickness of Surface Course =35mm
Thickness of DBM =145mm
Thickness of Base Course=200mm
Thickness of Sub Base=320mm

3.1.2 California Resistance Value Method

F.m Hakeem and R.M.Carmany in 1948 provided design method based on stabilometer R-value and cohesiometer Computer- value.Based on performance data it was established by Hveem and Car many that pavements thickness varies directly with R value and logarithm of load repetitions. It varies inversely with fifth root of Computer value. The expression for pavement thickness is given by the empirical equation.

T=K (TI) (90-R)/C1/5
Here T=total thickness of pavement, cm
K=numerical constant=0.166
TI=traffic index
R=stabilometer resistance value
C =Cohesiometer value

The annual value of equivalent wheel load (EWL) here is the accumulated sum of the products of the constant and the number of axle loads .The various constant for the different number of axles in group are given below

Number of axles	EWL Constant(Yearly basis)
2	330
3	1070
4	2460
5	4620
6	3040

DATA
K =0.166, TI =9.66, R = 44, C =61
Pavements thickness is given by the empirical equation:-
T=K(TI)(90-R)/C1/5
Calculation:
TI = 1.35(EWL)0.11
TI=1.35(32729750)0.11
TI=9.66
T=K(TI)(90-RC)/C1/5
T=0.166(9.66)(90-44)611/5
T=730 mm
So Pavement Thickness =730mm
Thickness Of Surface Course =35mm
Thickness Of DBM =145mm
Thickness Of Base Course=210mm
Thickness Of Sub Base=340mm

3.1.3 Design Of Flexible Pavement By California Bearing Ratio Method

The following sub sections describe the various variables and parameters involved in design of flexible pavement of road as per IRC 37 - 2001.

3.1.3.1 Traffic- CV/Day Annual traffic census 24 X 7

For structural design, commercial vehicles are considered. Thus vehicle of gross weight more than 8 tonnes load are considered in design. This is arrived at from classified volume count.

3.1.3.2 Wheel loads

Urban traffic is heterogeneous. There is a wide spectrum of axle loads plying on these roads. For design purpose it is simplified in terms of cumulative number of standard axle (8160 kg) to be carried by the pavement during the design life. This is expressed in terms of million standard axles or msa.

3.1.3.3 Design Traffic

Computation of design Traffic In terms of cumulative number of standard axle to be carried by the pavement during design life.

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

Where
N = The cumulative number of standard axles to be catered for in design in terms of million standard axles - msa.
A = Initial traffic in the year of completion of construction duly modified as shown below.
D = Lane distribution factor
F = Vehicle damage factor, VDF
n = Design life in years
r = Annual growth rate of commercial vehicles {this can be taken as 7.5% if no data is available}

OBSERVATION DURING PENETRATION AND DETERMINATION OF CBR

S.No	Penetration Y (mm)	Standard load Value (p)(kgf)	Proving Ring Dial Gauge Reading (R)	Plunger Load on (Pt)=R x f =R x 1.282 (kgf)
1	0		0	0
2	0.5		10	12.82
3	1.0		18	23.07
4	2.0		33	42.30
5	2.5	1370	54	69.22
6	3.5		63	80.76
7	4.0		71	91.02
8	5.0	2055	78	99.99
9	7.5		85	108.97
10	10.0		91	116.66
11	12.5		102	130.76

3.1.3.4DESIGN OF FLEXIBLE PAVEMENT BY CBR

DATA
1. Length of Road= 3.45/00 km
2. Traffic intensity as worked out =1001 CV/D Average
3. Growth rate of traffic (assumed) = 7.5%
4. Total Period of Construction =4 months
5. Design C.B.R. of Sub grade Soil=5.00%
6. Design Period of the Road= 10 Years

7. Initial Traffic in the Year of Completion of Construction
A = P x (1 +r) x
Where:
A = Traffic in the year of completion of construction CV/ Day
P = Traffic at last Count April 2013
r = Annual growth rate of traffic
x = Number of years between the last census and the year of completion of construction
A =1001 x (1 + 0.075) x1
1076 CV / Day
8. Vehicle Damage Factor =3.5Standard Axle per CV (As per Clause 3.3.4.4 Table 1 of IRC -37 -2001)
9. Design Calculation
Initial traffic in design lane = Initial traffic x Distribution factor
= 1076 x 0.75 = 807.05 CVPD
N = [365 x {(1+r) x - 1} x A x F] / r
=365 x [{(807(1 +0.075)^10-1}x3.5]/0.075 = 14.58 msa
Say 15.00 msa
10. Total Pavement Thickness for design C.B.R. = 660 mm
(As per Plate - 2 of IRC-37-2001)
The thickness of individual component layers of flexible pavement by CBR method is given below:
So pavement thickness =660mm
Thickness of surface course =40mm
Thickness of DBM =70mm
Thickness of base course=250mm
Thickness of sub base=300mm

3.1.4 Triaxial Method

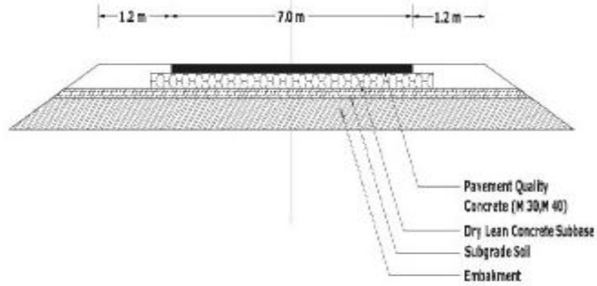
L.A.Palmer and E.S.Barber in 1910 proposed the design method based on Boussinesq's displacement for homogeneous elastic single layer: The thickness of pavement.

$$T = \sqrt{(3P/2\Delta\Pi Es)^2 - a^2}$$

Here T=Pavement thickness, cm
Es=modulus of elasticity of sub grade from triaxial test result, Kg/cm2
A=radius of contact area, cm
Δ=design deflection (0.25 cm)
DATA :
Wheel load=4100Kg
Radius of contact area=15cm
Traffic coefficient=1.5
Rainfall coefficient=1.0
Design deflection=.25cm
E-value of sub grade soil Es=100 Kg/cm2
E-value of base course material Eb =400kg/cm2

CALCULATIONS:
$T = \sqrt{(3P/2\Delta\Pi Es)^2 - a^2}$
T= √(3*4100/2*100)2-152
T=740 mm
So Pavement thickness=740mm
Thickness of surface course =35mm
Thickness of DBM =145mm
Thickness of base course=210mm
Thickness of sub base=350mm

3.2 Design Of Rigid Pavement



"Fig." 2 Typical Cross-section of a Rigid Pavement

Data:
Width of expansion joint gap=2.5cm
Maximum variation in temperature between summer and winter=13.10c
Thermal coefficient of concrete=10*100C
Allowable tensile stress in CC during curing=0.8Kg/cm2
Coefficient of friction=1.5
Unit weight of CC=2400kg/cm3
Design wheel load=5100Kg
Radius of contact area=15Cm
Modulus of reaction of sub base course=14.5Kg/cm3
Flexural strength of concrete =45Kg/cm2+
E value of concrete=3*105Kg/cm2
Δ Value =0.15
Design load transfer through dowel system=40%
Permissible flexural stress in dowel bar=1400Kg/cm2
Permissible shear stress in dowel bar=1000Kg/cm2
Permissible bearing stress in concrete =100Kg/cm2
Permissible tensile stress in steel=1400Kg/cm2
Permissible bond stress in deformed tie bars=24.6Kg/cm2
Present traffic intensity=4100 commercial vehicles/day (Data collected by traffic survey)
(Note: The data assumed based on IRC-58:2002)
SLAB THICKNESS
Assume trial thickness of slab=20cm
Radius of relative stiffness,
$I=[Eh^3/12K(1-\mu^2)]^{1/4}$
=[3*105*203/12*14.5(1-0.152)]1/4
L=61.28
Lx/I=445/95.41 =4.66
Ly/I = 350/95.41 =3.66(according to I.R.C.Chart)
Adjustment for traffic intensity
Ad =P' (1+r)(n+30)
Assuming growth rate =75 %
Number of year after the last count before new pavement is opened to traffic n =3
Ad =4100 (1+ (7.5/100))(3+30)
=44592.6 CV/day
So traffic intensity being in the range >4500,
Fall in group and the adjustment factor =+2cm So revised design thickness of the slab =20+2 =22 cm

3.3 Cost Analysis

The estimated costs of flexible pavement in different methods are given below:

S.No.	METHODS	ESTIMATED COST (Rs)
1.	Group Index Method	15822515.00
2.	CBR Method	14909074.00
3.	California Resistance Value Method	16134971.00
4.	Tri axial Method	16186485.00

The estimated cost of rigid pavement is given below:

S.No.	METHODS	ESTIMATED COST (Rs)
1.	Rigid Pavement Method as per IRC	25854264.00

IV. DISCUSSION

By observing the above result of pavement by using different flexible and rigid methods, the difference in total thickness and individual component layers are not much. However by close observation the results of CBR method are slightly more because of poor CBR value of sub grade .But in the other method the CBR value of sub grade is not considered ,only soil properties like liquid limit ,plastic limit, shrinkage limit, grain size distribution of sub grade soil are considered GI method, modulus of sub grade from triaxial test are considered in triaxial method, the resistance value of sub grade, expansion pressure, exudation pressure at different moisture content of sub grade soil are considered in California resistance value method. Similarly modulus of sub grade reaction is considered in rigid pavement design.

The Indian road congress IRC: 37-2001 has received the guidelines for the design of flexible pavements, based on the concept of cumulative STD axle loads rather than the total number of all commercial vehicles as done earlier. The total pavement thickness required is determined using the design charts with the different value of msa (million std. axles).The IRC has also suggested the minimum thickness of the pavement component layers of sub base, base course and surfacing and the combination of various range of cumulative std. axles. So this method is more conviently and widely used in fields due to its relevant simplicity and the appropriate value of different component layers. Now days this method is more popular for design of flexible pavements. But the flexible pavements are design for period of 15 years so the periodical maintenance is much more when compared with rigid pavements. Another advantage of rigid pavements is it design for a period of 30 years which is doubled the life of flexible ,comparatively less maintenance and better quality of riding surface and other advantages.

While looking into the economics, the flexible pavement methods there is not big difference in cost but in the CBR the cost is little bit low because of its low total thickness comparatively with other methods .Similarly in rigid pavement the cost is very high than the flexible pavement. But the rigid pavement is having long life, better riding surface visibility, less maintenance etc advantage...So rigid pavements are widely used in the present road works. Also in flexible pavement always preference is given to CBR Method**.**

V. CONCLUSION

The pavement is designed as a flexible pavement upon a black cotton soil sub grade, the CBR method as per IRC 37-2001 is most appropriate method than available methods.

The pavement is designed as a flexible method from which each method is designed on the basis of their design thickness from which each method has different cost analysis of a section, from which CBR as per IRC is most appropriate in terms of cost analysis.

The pavement is designed as a rigid pavement, the method suggested by IRC is most suitable.

It is observed that flexible pavements are more economical for lesser volume of traffic.The life of flexible pavement is near about 15 years whose initial cost is low needs a periodic maintenance after a certain period and maintenance costs very high. The life of rigid pavement is much more than the flexible pavement of about 40 years approx 2.5 times life of flexible pavement whose initial cost is much more then the flexible pavement but maintenance cost is very less.

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