Design of Flexible and Rigid Pavement: A Review

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Abstract— Flexible pavements are widely used despite some doubts regarding their economics under different conditions. Two most important parameters that govern the pavement design are soil sub-grade and traffic loading. The Indian guidelines for the design of flexible pavements use soil sub-grade strength in terms of California Bearing Ratio (CBR) and traffic loading in terms of million standard axles (msa). For the design of rigid pavements, IRC: 58-2002 uses the same parameters in terms of modulus of sub-grade reaction, k, and axle load distribution (ALD). To compare the cost of two types of pavements, it is necessary to ensure that they are designed for the same traffic loading. Therefore, a study was done to convert the traffic load given in msa into ALD and vice-versa. Mathematical models are developed to estimate the ALD from individual vehicle counts. Mathematical expressions are developed to relate the cost of pavements with soil CBR and traffic in msa. The critical line of equal costs on the plane of CBR versus msa is also identified. This is a swing line which delineates the economic feasibility of two types of pavements

Key words: Flexible pavements, soil sub-grade strength, California Bearing Ratio (CBR), rigid pavement axle load distribution (ALD)

I. INTRODUCTION

The spectacular growth of automobile as one of convenient modes of travel has brought various problems one of which is roads of inadequate structural strength or faulty design which ultimately leads to the unsafe, inefficient and uncomfortable movement of traffic. To deal with these problems such as inadequate strength or faulty design a new subject of design namely "PAVEMENT DESIGN" was introduced to ensure the longer life of the pavement along with proper structural strength and appropriate design Pavement Design deals with the design of various types of pavements mainly Flexible pavements and Rigid pavements. The types of pavements to be used in a particular area depend upon the traffic density.

In India, the pavements are designed on the standards and specifications given by Indian Road Congress. The IRC is the oldest and most representative technical body dealing with pavements and its designs.

The origin of the IRC can be traced back to the Indian Road Development committee (the Jayakar Committee) appointed by the Government of India in November, 1927. The IRC provides a National forum for sharing of knowledge and pooling of experience on the entire range of subjects dealing with the construction and maintenance of roads and bridges, including technology, equipment, research, planning, finance, taxation, organization and all connected policy issues. It can be claimed that the development of roads in the country has been significantly influenced by the wise counsels given by the IRC and has progressed according to the policies enunciated by it. Indian roads congress has specified the design procedures for flexible pavements based on CBR values.These guidelines will apply to design of flexible pavements for Expressway, National Highways, State Highways, Major District Roads, and other categories of roads. Flexible pavements are considered to include the pavements which have bituminous surfacing and granular base and sub-base courses conforming to IRC standard.

Flexible Pavements: Flexible Pavements are those, which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads. The flexible pavement layers reflect the deformation of the lower layers on to the surface of the layer. Thus if the lower layer of the pavement surface also get undulated. It consists of four components i.e. soil sub grade, Sub Base Course, Base Course, Surface Course.

The Flexible Pavements layers transmit the vertical or compressive stresses to the lower layers by grain to grain transfer through the points of contact in the granular structure. A well compacted granular surface consisting of strong graded aggregate (Interlocked aggregate structure with or without binder materials) can transfer the compressive stresses through a wider area and thus forms a good flexible pavement layer. The road spreading ability of this layer therefore depends on the types of the materials and the mix design factors. Other materials which fall under the group are all granular materials with or without bituminous binder granular base and sub-base course, materials like the water bond macadam, crushed aggregate, gravel soil, aggregate mixer etc.

Rigid pavements: Rigid Pavements are those which pass not worthy flexure strength or flexural rigidity. In general, according to the manner, there pavement is made up hard materials. Thus uses of such hard material into culturance in the year 1910 in India. And that hard material in nothing but the "Cement Concrete". The concept was evolved by testing's done on concrete. Thus it was seen, the plain cement concrete slabs are expected to take up@40 kg/cm2 flexural stress & the slab action is capable to transmit the wheel load stresses through a wider area below. The rigid pavements are made of Portland cement concrete either plane, reinforced or pre-stressed concrete. The cement concrete pavement slab can very well serve as a wearing surface as well as effective base course. Therefore usually a rigid pavement structure consists of a cement concrete slab, below which a granular base or sub-base course may be provided. Though the cement concrete slab can also be laid directly over the soil-subgrade, consists of fine graded soil. Providing a good base or sub base course layer under the cement concrete slab increases the pavement life considerably & therefore workout more economical in long run. The rigid pavements are usually designed & the stresses are analysis using the elastic theory, according the pavements as an elastic plate resisting plate resting over elastic foundation.

II. Analysis and Comparison

A. Design Method Of Flexible Pavement :

1) Group Index Method
2) Modified CBR Method
3) CBR (California Bearing Ratio Method
4) Mc-Leod Method.

1) Group Index Method:

G.I= 0.2A+0.005AC+0.01BD

A = That portion of the percentage of material passing the no. 200 sieve ,greater than 35 & exceed 75 expressed as positive whole number from 0 to 40.

Whwre, B = That portion of the percentage of material passing through the no. 200 sieve , greater than 15 & not exceeding 55, expressed as positive whole number from 0 to 40.

C = That portion of the numerical liquid limit greater than 10 and not exceeding 60 , expressed as a positive whole number between 0 to 20.

D = That portion of the numerical elasticity index greater than 10 and not exceeding 30 expressed as a positive whole number between 0 to 20.

The group index of a soil is expressed to the nearest whole number.

Higher the group index weaker is the material and hence higher the thickness of pavement requires.

Mr. D. J Steel in the year 1945 developed a design chart for the finding the total thickness of pavement and also of sub base and base course depending upon G.I. of and design traffic volume .The volume is classified as:

Light = < 50 CVD
Medium = 50 to 300 CVD
Heavy = > 300 CVD

2) Modified CBR Method:

$$Ns = \frac{365[(1+r)^{n-1}]}{r} \text{ x VDF x Vp}$$

Where,
Vp= No of commercial vehicles per day
Ns = Million standard axel
r = Annual growth rate of commercial vehicles.
n = Design life of pavement taken as 10 to 15 years
VDF = Vehicle damage factor,equivalent to numbers of standard Axel per commercial vehicle on the road street.

3) CBR (California Bearing Ratio) Method:

$$T = [(1.75P/ CBR) – (a/\pi)]$$

Note : The above equation is only applicable when the CBR values of sub grade soil is less than 12 %.

Otherwise use , design charts by IRC based on categorization of traffic volume count.

Where,
T = pavement thickness, cm.
P = wheel load in kg.
CBR= California Bearing ratio in % (test conducted on sub grade sample
A = Area of contact sq. cm

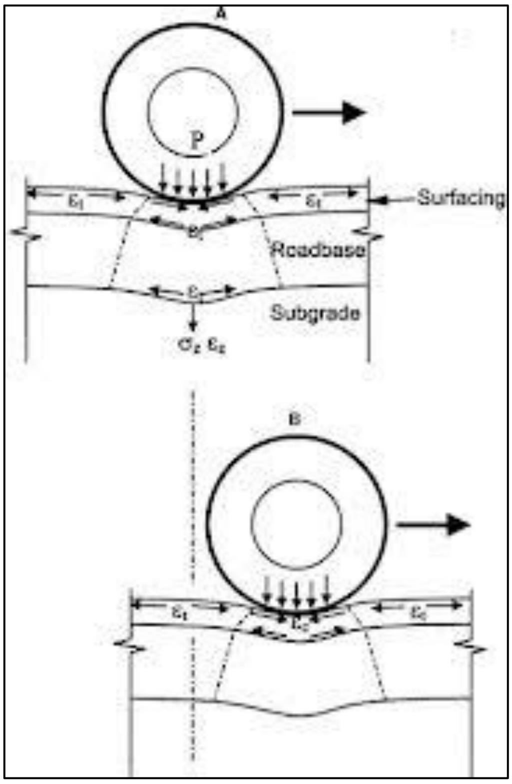

Fig. 1: Critical Locations in Pavement

4) Mc-Leod Method:

Formula: $T = \log_{10}(P / K)$
Where,
T = Required thickness of gravel base cm.
P = gross wheel load , kg.
K = base course const.

B. Design Method of Rigid Pavement:

Wheel Load Stresses:

1) Corner- By Kelly's Formula:

$$P_{6C} = \frac{3P}{h^2}\left[1 - \frac{(a\sqrt{2})^{1.2}}{l}\right]$$

$$l = \left[\frac{\sqrt[4]{Ec\,hc^3}}{12Ks(1-1^2)}\right]$$

2) Edge- By Teller's Formula:

$$P_{6E} = \frac{0.529P}{h^2}[1+0.54\mu c][4\log_{10}\left(\frac{l}{b}\right) + \log_{10}(b-0.405)$$

$$b = \sqrt{1.6a^2+h^2} - 0.675h$$

3) Interior- (Westergard):

$$P_{6I} = \frac{0.275P}{h^2}(1+\mu c)\ [4\log_{10}\left(\frac{l}{b}\right) + 1.069]$$

4) Temperature Stresses:

$$T_{6C} = \frac{(E\alpha T)}{(3(1-\mu^2))}\sqrt{\left(\frac{a}{L}\right)}$$

$$T_{6E} = \frac{(E\alpha T)}{2}\ Cx$$

OR

$$T_{6E} = \frac{(E\alpha T)}{2}\ Cy$$

Whichever is higher.

$$T_{6I} = \frac{E\alpha T}{2}\left(\frac{Cx+Cy\mu}{1-\mu c^2}\right)$$

5) Sub-Grade Resistance Stress:

$$F_6 = \frac{¥.Lx\ F}{2*10^4}$$

6) Check for Stresses:

$P_{6E} + T_{6E} – F_6 \leq R$

Therefore; R= $\left(\frac{1}{6}\right)$ *OR* $\left(\frac{1}{7}\right)$ given grade of concrete.

Where
P = Wheel Load in "Kg"
H = Thickness of rigid pavement "cm"
A = Contact Area "cm^2"
L = Radius of Relative Stiffness "cm"
B = Radius of Relative Section
E_c= Modulus of Elasticity of Concrete
L_c= Poisson Ratio of Concrete
α = Co-efficient of Thermal Expansion
Ks= Reaction Modules of Pavement Foundation
T = Temperature Difference between the Top & Bottom of Slab in "^{o}C"
C_x= Co-efficient based on L_x/l in Desired Direction
C_y= Co-efficient based on L_y/l in Right Angle to Above Direction
= Unit Weight of Concrete
F = Co-efficient of Sub-grade resistant
L = Slab length in "metres"

III. Result and Conclusion

As per our aim, set towards finding out the best suited method of pavement design for Flexible pavement, is seen to be achieved by means of this project The output of completion of this project may be, expressed as study of several design methods for Flexible pavement & to be decide whether the one out of them best suitable for the given conditions Thus, out of various design methods discussed above the best suited method for flexible pavements design is "Indian Road Congress" method of Pavement design. This method is based on practical findings from laboratory and on site also.

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