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Design Of Flexible And Rigid Pavements By Various Methods And Their Cost Analysis

Dodda.Vamsi Krishnamohan[1], Dr. B. Manoj[2]

[1]M-Tech Scholar, [2]Professor
Department of Civil Engineering
QIS COLLEGE OF ENGINEERING AND TECHNOLOGY (AUTONOMOUS)
Approved by AICTE | Permanent Affiliation: JNTU-Kakinada | UGC-Recognized
Accredited by NBA | Accredited by NAAC | ISO 9001:2015 Certified
Vengamukkapalem (V), Ongole, Prakasam dist., Andhra Pradesh-523272

Abstract
Pavements are required for the smooth, safe and systematic passage of traffic. Pavements are generally classified as flexible and rigid pavements. Flexible pavements are those which have low flexural strength and are flexible in their structural action under loads. Rigid pavements are those which possess note worthy flexural strength and flexural rigidity.
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.
In our project we are calculating thickness of flexible pavement by comparing various design methods such as, Group Index method (GI), California Bearing Ratio method (CBR), California Resistance Value Method, Tri axial method is done and rigid pavement was done by Indian Road Congress method (IRC). From this design method maximum thickness is adopted for the construction of flexible pavement.
Keywords – Design of flexible pavement, GI, CBR.

1. Introduction

For economic and efficient construction of highways, correct design of the thickness of pavements for different conditions of traffic and sub-grades is essential. The science of pavement design is relatively new.

In India, previously road crust was designed on some rational data but more on the experience of the road engineer. Some arbitrary thicknesses of the pavements were used which lead to costly failures and wastage as in some cases, the thickness of pavements was insufficient and in the other cases expensive. As there are no proper design criteria, the construction of roads was more or less uneconomical in almost all cases.

Hence judicious method of designing and calculating the crust thickness on the basis of estimation of traffic loads and bearing capacity of sub-grade etc.., will lead to economical construction of roads.

The surface of a pavement should be stable and non-yielding, to allow the heavy wheel loads of the road traffic to move with least possible rolling resistance. The road should be even along the longitudinal profile to enable the fast vehicles to move safely and comfortably at the design speed. A pavement layer is considered more effective or superior, if it is able to distribute the wheel load stress through a larger area per unit depth of the layer. The elastic deformation of the pavement should be within the permissible limits, so that the pavement can sustain a large number of repeated load applications during the design life. It is always desirable to construct the pavement well above the maximum level of the ground water to keep the sub-grade relatively dry even during monsoons. At high moisture contents, the soil becomes weaker and soft and starts yielding under heavy wheel loads, thus increasing the tractive resistance.

Types of pavements

Based on the structural behavior, pavements are generally classified into the following three categories:

1. Flexible pavement
2. Rigid pavement
3. Semi-rigid pavement.

Different methods of design of pavements

1. Group index method
2. California resistance value method
3. California bearing ratio method
4. Tri axial method

Cost analysis of Pavement

Cost estimates are made at various times during the development of solutions to identified transportation needs and deficiencies. These estimates support funding and program decisions. The estimating approach that is used at these various times must conform to the information available when the estimate is prepared. For example, when only concept information is available, then conceptual estimating methods are used to determine planning–level cost projections. Cost estimating management is practiced as projects are identified and developed. Cost estimating management methods will also vary depending on the level of project scope definition and cost details provided in the estimates.

Methodology and materials used

Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge.

A methodology does not set out to provide solutions - it is therefore, not the same as a method. Instead, a methodology offers the theoretical underpinning for understanding which method, set of methods, or best practices can be applied to a specific case, for example, to calculate a specific result..

Red soil

Red soil is an important soil resource, which bears substantial implication for sustainable development of agriculture and healthy growth of economy. We also summarized how the iron redox cycling may be affected by other biogeochemical processes or active constituents, such as the nitrogen cycling, the sulfur cycling and humic substances. Finally, future research needs pertaining to iron redox cycling coupled to the fate of heavy metals are suggested. The results summarized in this review may provide insights for solving the heavy metal pollution of paddy soils in the red soil regions.

Design of payments

Design of flexible pavements

1. 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.

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. 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.

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.

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.

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. DESIGN 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
   (As per Clause 3.3.4.4 Table 1 of IRC -37 -2001)
8. Vehicle Damage Factor =3.5Standard Axle per CV
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.

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.

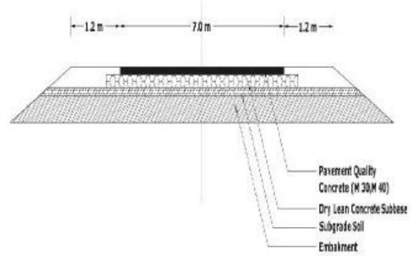
$$\sqrt{(\frac{3P}{2\Delta\pi E})2 - a2}$$

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= √(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

Design of Rigid Pavement



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

Cost comparison of pavements

Flexible pavement

S. No	Method Used	Cost for construction of 3Km road in Rs
1	Group Index	1394451.45
2	California Resistance Value method	1442136.15
3	California Bearing Ratio method	1412085.15
4	Tri axial method	1449648.9

Rigid pavement

S. No	Method Used	Cost for construction of 3Km road in Rs
1	Group Index	1444406.04

Conclusions

1. In this project work, an attempt is made to incorporate latest techniques of geometric design, pavement design for a road for an existing colony which 2 km away from Car Shed Junction, P.M.Palem. The IRC specifications are based on rational thinking, the proposed road is safe in both geometrics as well as pavement design.

2. It is also proposed to design a flexible pavement by Group Index method and CBR method. Some more methods are available in the design of flexible pavement, which are much advanced like California resisting value method, Mc leod method, Triaxial method and Burnister method. Because of the limitations of time and scope, only GI method and CBR method are adopted.
3. To have a practical concept of estimation analysis, an attempt is made to estimate the quantities of earth work of flexible pavement
4. The cost of tri axial method is more as compared with group index, California Resistance Value method, and California Bearing Ratio method.
5. The cost for costruction of Rigid pavement is 1444406.04.

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