ECONOMIC ANALYSIS AND DESIGN OF RIGID PAVEMENT

Project Report submitted in partial fulfillment of the requirement for the degree of

Bachelor of Technology

in

Civil Engineering

under the Supervision of

Mr. Abhilash Shukla

By

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CERTIFICATE

This is to certify that the work entitled **"ECONOMIC ANALYSIS AND DESIGN OF RIGID PAVEMENT"** submitted by **Prakhar Goyal (111625), Mohit Dadwal (111109),** in partial fulfilment for the award of degree of Bachelor of Technology in Civil Engineering of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

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This project report gives a detailed description of the study work done on the project topic **"Economic analysis and design of rigid pavement"** in the VII semester for the partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering, under the supervision of Mr. Abhilash Shukla.

We are very grateful to our Faculty Coordinator Mr.Abhilash Shukla for his help and able guidance regarding the project. We are also very thankful to the Department of Civil Engineering, Jaypee University of Information Technology (JUIT) for providing me resources and facilities which helped a lot in the completion of the project.

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ABSTRACT

A proper cost analysis and design of a rigid pavement on a section of NH-3 using DPR(detailed project report) provided by NHAI(National Highways Authority of India).

By using method given in IRC 58 (The design of plain jointed rigid pavements for highways), the thickness of rigid pavement is determined. We will have to find out the modulus of subgrade and modulus of rupture to determine thickness. Modulus of subgrade will depend on its CBR value, which will be determined from the report provided by NHAI. Later we will design tie bars and dowel bars to make our pavement of greater strength and as well as economic. The cost estimation of the flexible pavement will be considered from the report itself whereas the cost estimation of rigid pavement will be calculated once it is designed. Taking into account the maintenance cost of both the pavements up till 10 years cost analysis will be done and results will be drawn.

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Pavement structural design is a daunting task. Although the basic geometry of a pavement system is quite simple, everything else is not. Traffic loading is a heterogeneous mix of vehicles, axle types, and axle loads with distributions that vary with time throughout the day, from season to season, and over the pavement design life. Pavement materials respond to these loads in complex ways influenced by stress state and magnitude, temperature, moisture, time, loading rate, and other factors. Exposure to harsh environmental conditions ranging from subzero cold to blistering heat and from parched to saturated moisture states adds further complications.

Pavement is the actual travel surface especially made durable and serviceable to withstand the traffic load commuting upon it . Pavement grants friction for the vehicles thus providing comfort to the driver and transfers the traffic load from the upper surface to the natural soil. Storm water drainage and environmental conditions are a major concern in the designing of a pavement. All hard road pavements usually fall into two broad categories namely

1. Flexible Pavement 2. Rigid Pavement

The long-term performance of rigid pavement depends not only on proper pavement design and materials selection. It involves many processes including proper preparation of the subgrade and subbase, placing reinforcing bars or dowels, choice and handling of aggregates and other materials, development of concrete mix design, production and transport of the concrete, and placing, finishing, curing and joint sawing the concrete.

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).

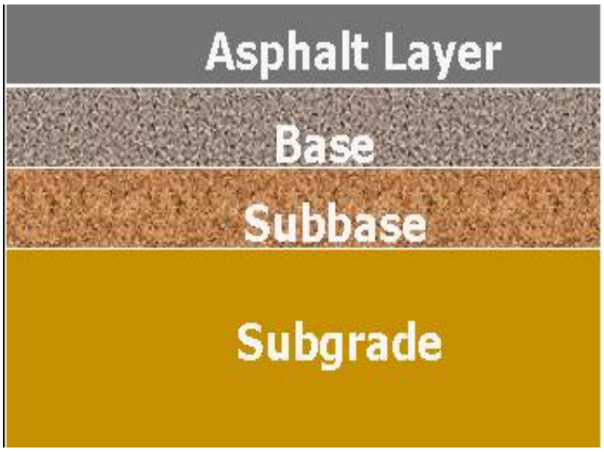
Various grades of concrete under similar condition of traffic and design concrete road are found to more suitable than bituminous road. Since the whole life cycle cost comes out to be lower in the range of 30% to 50% but for roads having traffic less than 400cv/day and road is in good condition, the 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, tri-axial 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.

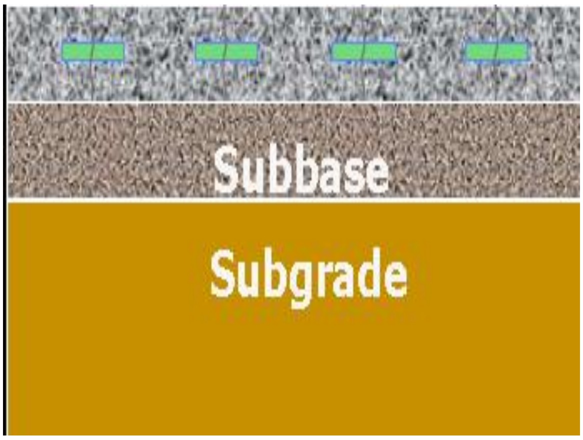
The main objective of this study is to develop a strategy to select the most cost efficient pavement design method to carried out for a sections of a highway network and also to identify the cost analysis of different pavement design methods. Prioritization based on Subjective Judgment, Prioritization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

1.2

Overview of flexible and Rigid pavement



Flexible pavement



Rigid pavement

Fig. 1.1

1.3 SALIENT FEATURE

Agra-Gwalior Section of NH-3 (km 0.0 to km 9.0):

This is a double lane two carriage way. The length of this link is 9km.

- Why this section has been selected?

The pavement condition of the link is generally bad within the city limit. This is highly congested road. Weather condition is also not good.

CHAPTER 2

LITERATURE REVIEW

2.1 MAP OF NH-3

Nagaur
Jaipur
Bharatpur
Mathura
Pokaran
Pushkar
Ajmer
Kishangarh
Jodhpur
Nasirabad
Dausa
Gwalior
Barmer
Pali
Sindari
Sawai Madhopur
Jalor
Bhilwara
Bundi
Shivpuri
Kota
Jhansi
Chittaurgarh
Mount Abu
Udaipur
Guna
Deesa
Radhanpur
Chanderi
Mandsaur
Dungarpur
Gandhinagar
Kandla
Ujjain
Bhopa
Ahmedabad
Dahod
Indore
Rajkot
Vadodara
Mandu
Jetpur
Bhavnagar
Junagadh
Amreli
Khandwa
Betul
Surat
Gir
Melghat
Saputara
Jalgaon
Amravati
Daman
Ajanta
Wardha
Sewagram
Silvassa
Nashik
Ellora
Shirdi
Aurangabad
MUMBAI
Matheran
Ahmadnagar

Fig. 2.1

2.2 SECTION OF NH-3 WHERE THE RIGID PAVEMENT IS DESIGNED

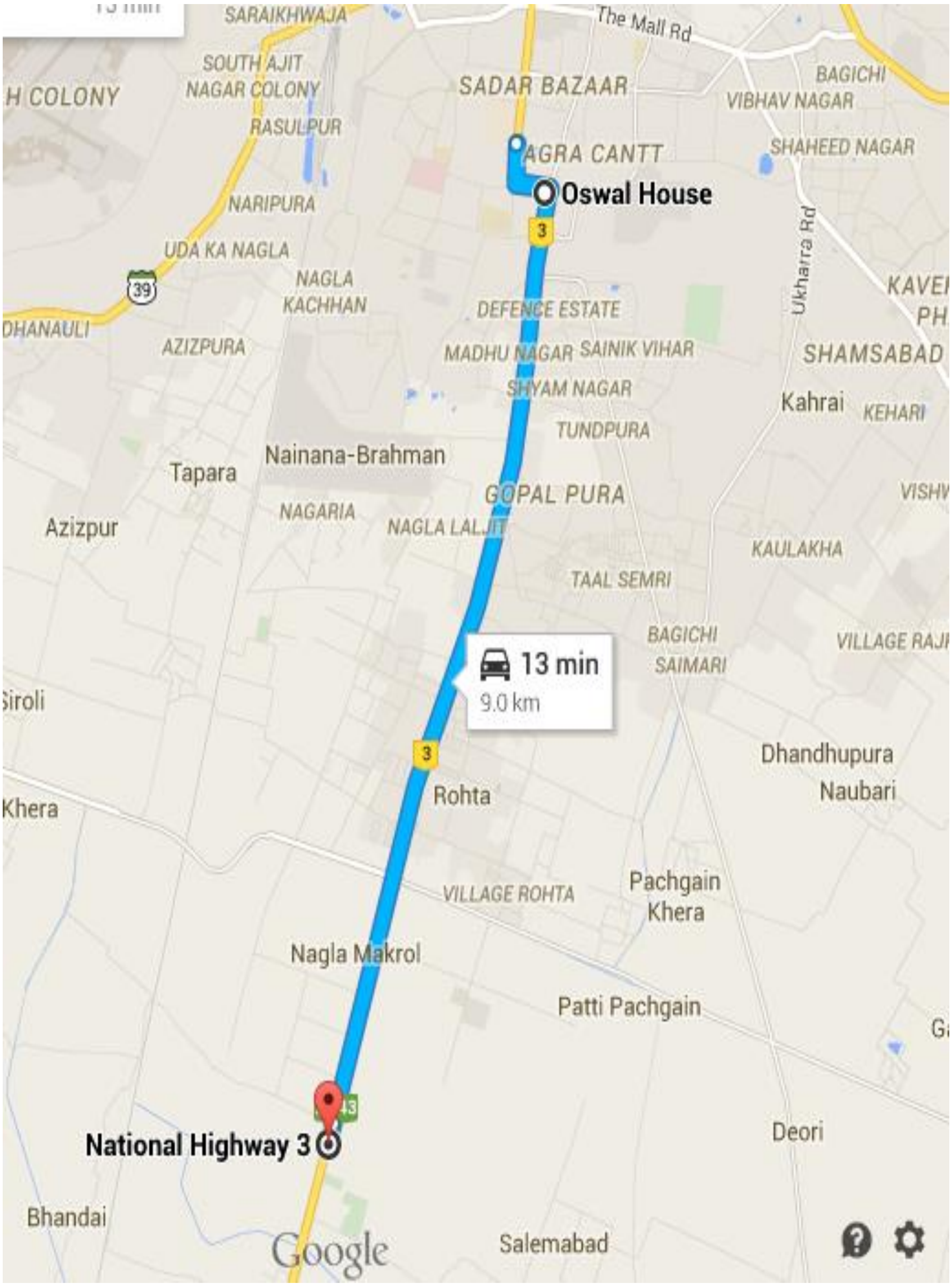


Fig. 2.2

Rigid pavement design

2.3 Overview

As the name implies, rigid pavements are rigid i.e, they do not flex much under loading like flexible pavements. They are constructed using cement concrete. In this case, the load carrying capacity is mainly due to the rigidity ad high modulus of elasticity of the slab (slab action). H. M. Westergaard is considered the pioneer in providing the rational treatment of the rigid pavement analysis.

2.3.1 Modulus of sub-grade reaction

Westergaard considered the rigid pavement slab as a thin elastic plate resting on soil sub-grade, which is assumed as a dense liquid. The upward reaction is assumed to be proportional to the deflection. Base on this assumption, Westergaard defined a modulus of sub-grade reaction K in kg/cm3 given by K =p .Δ

where Δ is the displacement level taken as 0.125 cm and p is the pressure sustained by the rigid plate of 75 cm diameter at a deflection of 0.125 cm.

2.3.2 Relative stiffness of slab to sub-grade

A certain degree of resistance to slab deflection is offered by the sub-grade. The sub-grade deformation is same as the slab deflection. Hence the slab deflection is direct measurement of the magnitude of the sub-grade pressure. This pressure deformation characteristics of rigid pavement lead Westergaard to the define the term

$$l = \sqrt[4]{\frac{Eh^3}{12K(1-\mu^2}}$$

where E is the modulus of elasticity of cement concrete in kg/cm2 (3.0_105), is the Poisson's ratio of concrete (0.15), h is the slab thickness in cm and K is the modulus of sub-grade reaction.

2.3.3 Critical load positions

Since the pavement slab has finite length and width, either the character or the intensity of maximum stress induced by the application of a given traffic load is dependent on the location of the load on the pavement surface. There are three typical locations namely the interior, edge and corner, where differing conditions of slab continuity exist. These locations are termed as critical load positions.

2.3.4 Equivalent radius of resisting section

When the interior point is loaded, only a small area of the pavement is resisting the bending moment of the plate. Westergaard's gives a relation for equivalent radius of the resisting section in cm in the equation

$$b = \begin{cases} \sqrt{1.6a^2 + h^2} - 0.675h & if\ a < 1.724h \\ a & otherwise \end{cases}$$

where a is the radius of the wheel load distribution in cm and h is the slab thickness in cm.

2.4 Wheel load stresses - Westergaard's stress equation

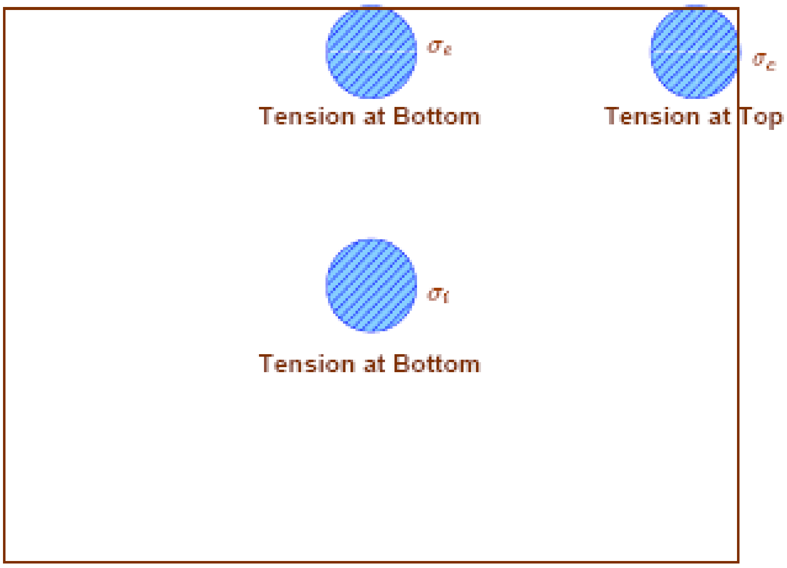
The cement concrete slab is assumed to be homogeneous and to have uniform elastic properties with vertical sub-grade reaction being proportional to the detection. Westergaard developed relationships for the stress at interior, edge and corner regions, and given by the equation

$$\sigma_i = \frac{0.316P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right) + 1.069\right]$$

$$\sigma_e = \frac{0.572P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right) + 0.359\right]$$

$$\sigma_e = \frac{3P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right]$$

where h is the slab thickness in cm, P is the wheel load in kg, a is the radius of the wheel load distribution in cm, l the radius of the relative stiffness in cm and b is the radius of the resisting section in cm



2.4.1 Temperature stresses

Temperature stresses are developed in cement concrete pavement due to variation in slab temperature. This is caused by (i) daily variation resulting in a temperature gradient across the thickness of the slab and (ii) seasonal variation resulting in overall change in the slab temperature. The former results in warping stresses and the later in frictional stresses.

2.4.2 Warping stresses

The warping stress at the interior, edge and corner regions, and given by the equation

$$\sigma_{t_i} = \frac{E \in t}{2}\left(\frac{C_x + \mu C_y}{1-\mu^2}\right)$$

$$\sigma_{t_e} = \mathrm{Max}\left(\frac{C_x E \in t}{2}, \frac{C_y E \in t}{2}\right)$$

$$\sigma_{t_e} = \frac{E \in t}{3(1-\mu)}\sqrt{\frac{a}{l}}$$

2.4.3 Frictional stresses

The frictional stress _f in kg/cm2 is given by the equation

$$\sigma_f = \frac{WLf}{2 * 10^4}$$

where W is the unit weight of concrete in kg/cm2 (2400), f is the coefficient of sub grade friction (1.5) and L is the length of the slab in meters.

CHAPTER 3

Design of thickness

3.1 SUMMARY OF TRAFFIC VOLUME COUNT

MOTORISED VEHICLES	ANNUAL AVERAGE DAILY TRAFFIC	% OF AXLE LOADS	LOAD IN TONNES
CAR	1350	18.87	3
JEEP	1102	15.40	3
AUTO	901		< 3
TWO-WHEELERS	3750		< 3
BUS	401	5.60	12
SINGLE AXLE TRUCK	439	6.136	16
TWO AXLE TRUCK	2957	41.33	20
THREE AXLE TRUCK	263	3.676	24
MULTI AXLE TRUCK	149	2.08	32
TRACTOR	493	6.89	10
TOTAL	7154		

Table 3.1

Present Traffic = 7154 cvpd

Design life = 20 years

Annual rate of growth of traffic(r) = 7.5%

Cumulative repetitions in 20 years = $7154*365(1.075^{20}-1)/1.075$

= 7889136 commercial vehicles

Design traffic = 25% of the total repetitions of commercial vehicles = 1972284

SINGLE AXLE		TANDEM AXLE(More than 1 axle)	
LOAD IN TONNES	EXPECTED REPETITIONS	LOAD IN TONNES	EXPECTED REPETITIONS
16	121019	32	41024
12	110448	24	72501
10	135890	20	815145
8	303732		
8	372170		

Table 3.2

3.2 Modulus of Subgrade

CBR value (Soaked) of NH3= 3.1

K_{value} =2.87 ,

As per IRC 58,Clause 4.6.1

TABLE 2. APPROXIMATE K-VALUE CORRESPONDING TO CBR VALUES FOR HOMOGENEOUS SOIL SUBGRADE

Soaked CBR value %	2	3	4	5	7	10	15	20	50	100
k-value (kg/cm²/cm)	2.1	2.8	3.5	4.2	4.8	5.5	6.2	6.9	14.0	22.2

Table 3.3

As k<6 kg/cm^3,

we will put a layer of dry lean concrete of 100mm thickness,

So **keff = 10.045**

TABLE 4. K-VALUES OVER DRY LEAN CONCRETE SUB-BASE

k-value of Subgrade kg/cm²/cm	2.1	2.8	4.2	4.8	5.5	6.2
Effective k over 100 mm DLC, kg/cm²/cm	5.6	9.7	16.6	20.8	27.8	38.9

Table 3.4

3.3 MODULUS OF RUPTURE

- According to IS 456, the exposure conditions leads to the choice of **M-40** grade concrete.
- So therefore the value of modulus of rupture is 45 kg/cm^3

3.4 Graphs to determine stress in the rigid pavement (IRC 58, Appendix 1)

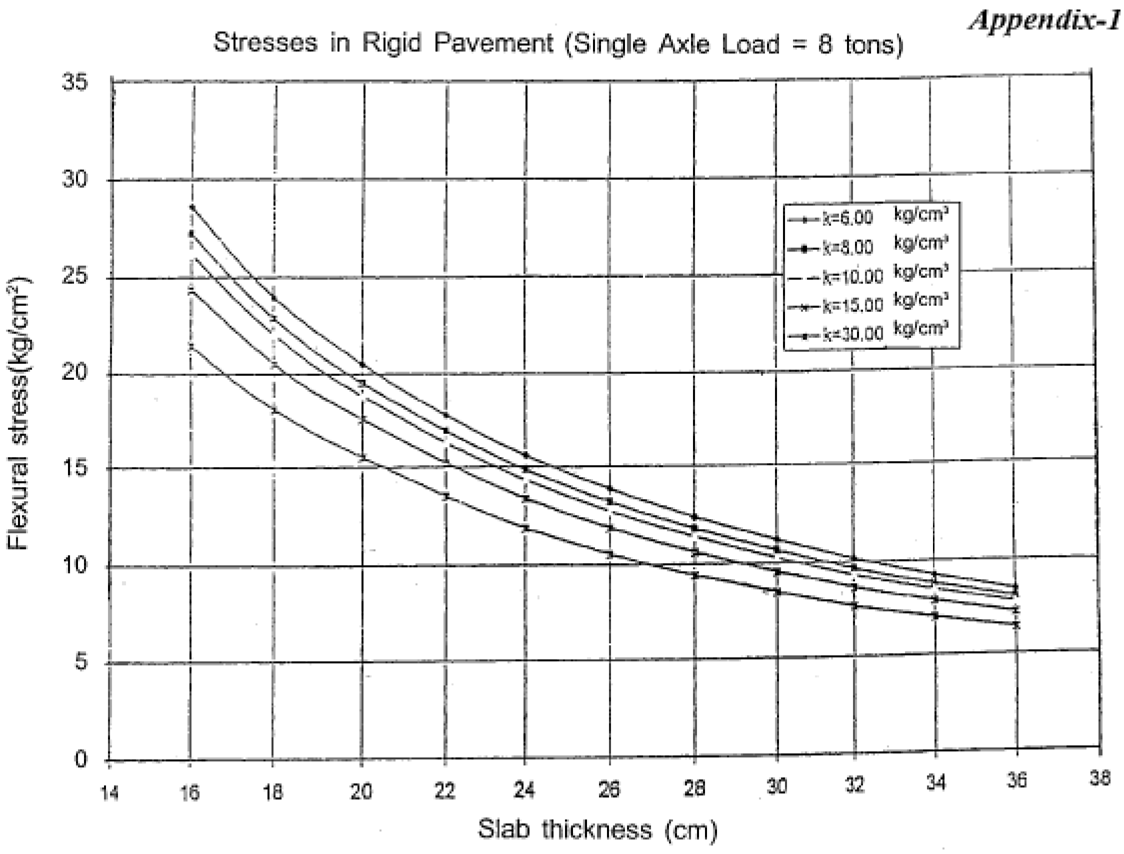
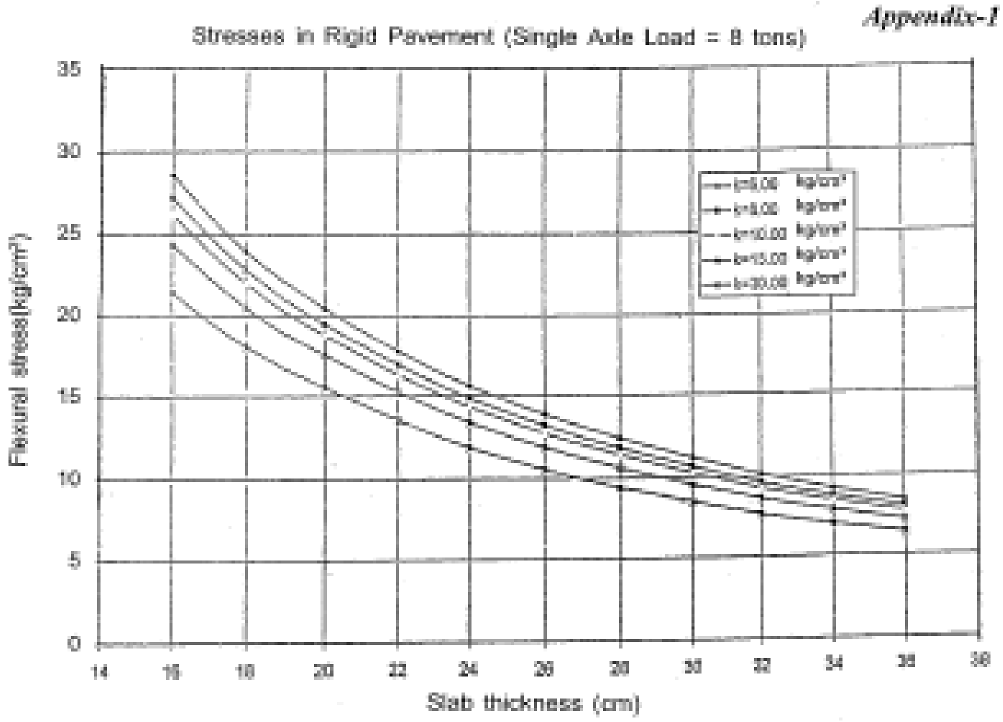


Fig. 3.1

Appendix-1 (Contd.)



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Appendix-1 (Contd.)

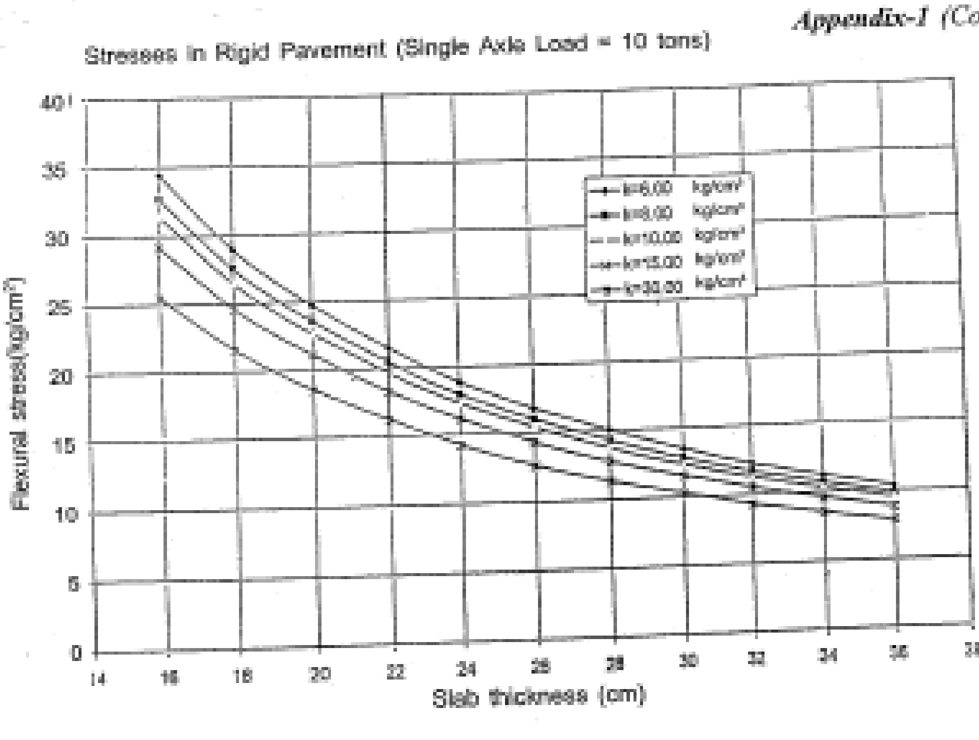

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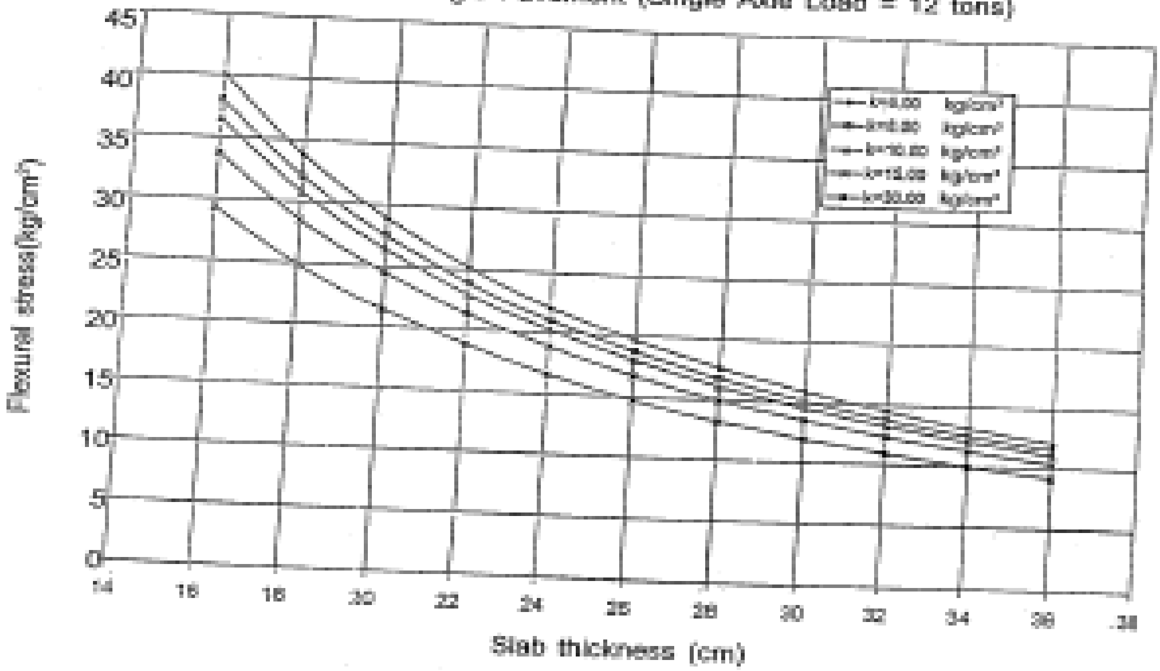
Fig. 3.2

Appendix-1 (Contd.)

Stresses in Rigid Pavement (Single Axle Load = 12 tons)



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Appendix-1 (Contd.)

Stresses in Rigid Pavement (Single Axle Load = 14 tons)

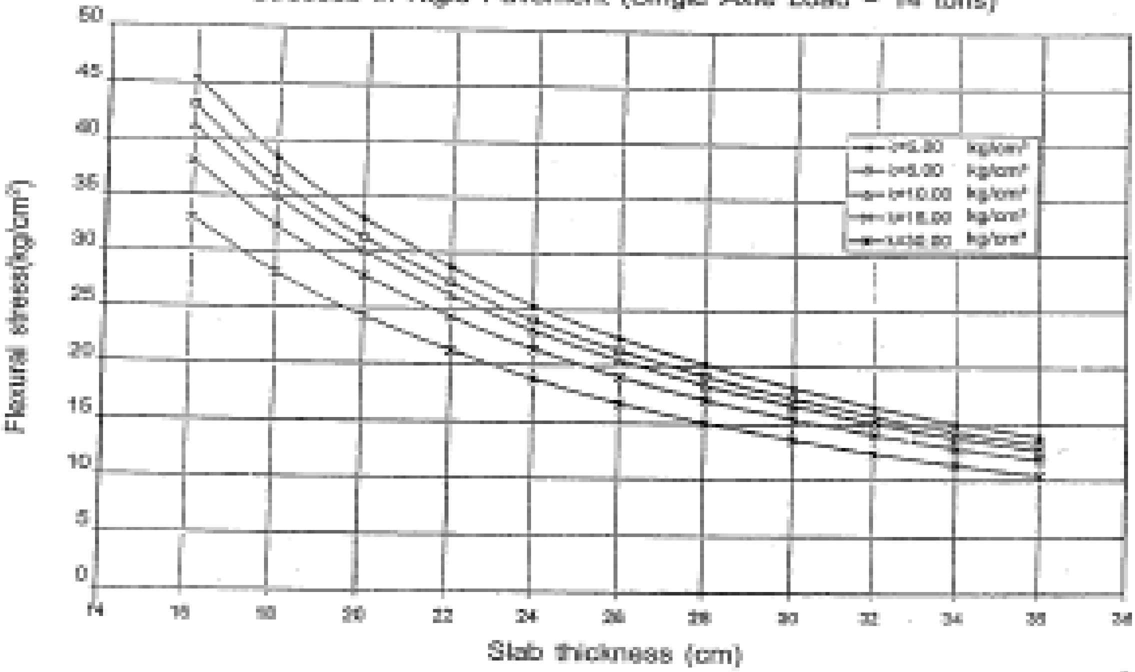

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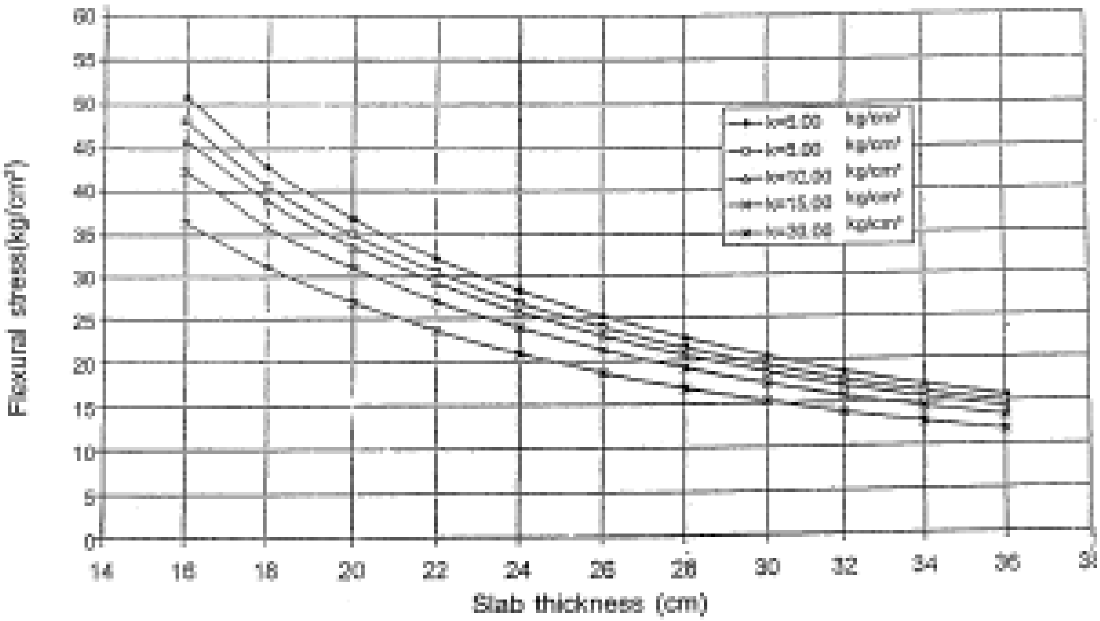
Fig. 3.3

Stresses in Rigid Pavement (Single Axle Load = 16 tons)



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Appendix-1 (Contd.)

Stresses in Rigid Pavement (Single Axle Load = 18 tons)

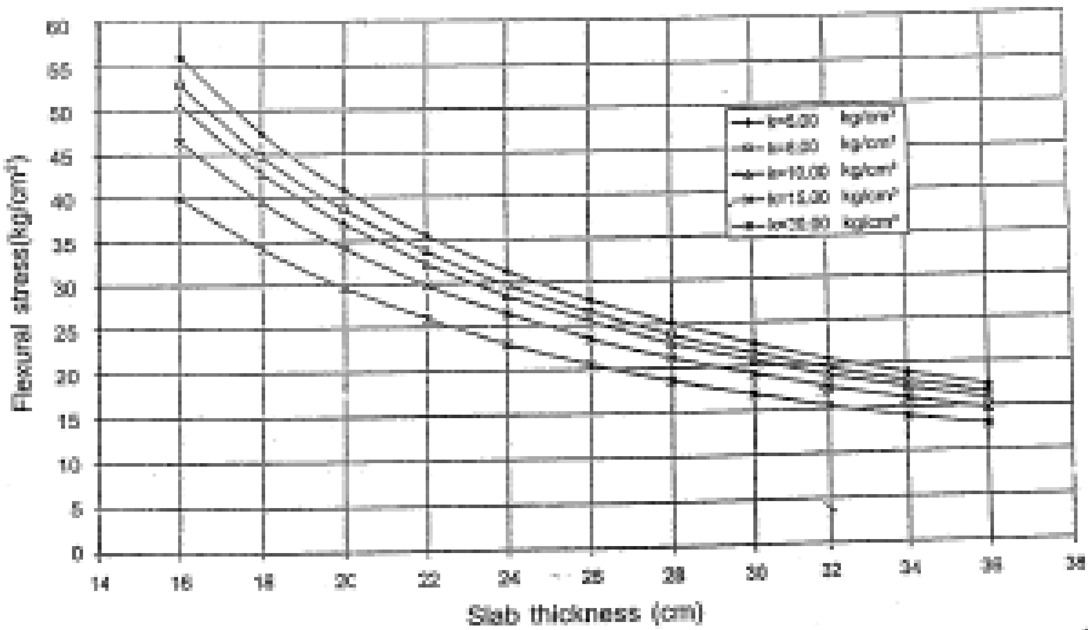

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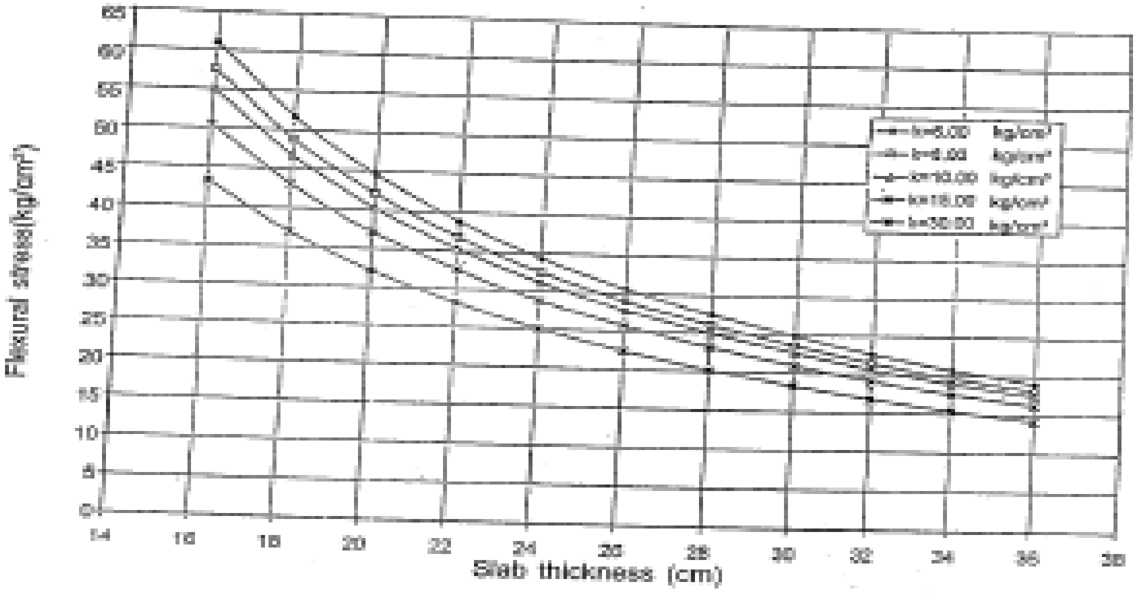
Fig. 3.4

***Appendix-I** (Contd.)*

Stresses in Rigid Pavement (Single Axle Load = 20 tons)



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***Appendix-I** (Contd*

Stresses in Rigid Pavement (Single Axle Load = 22 tons)

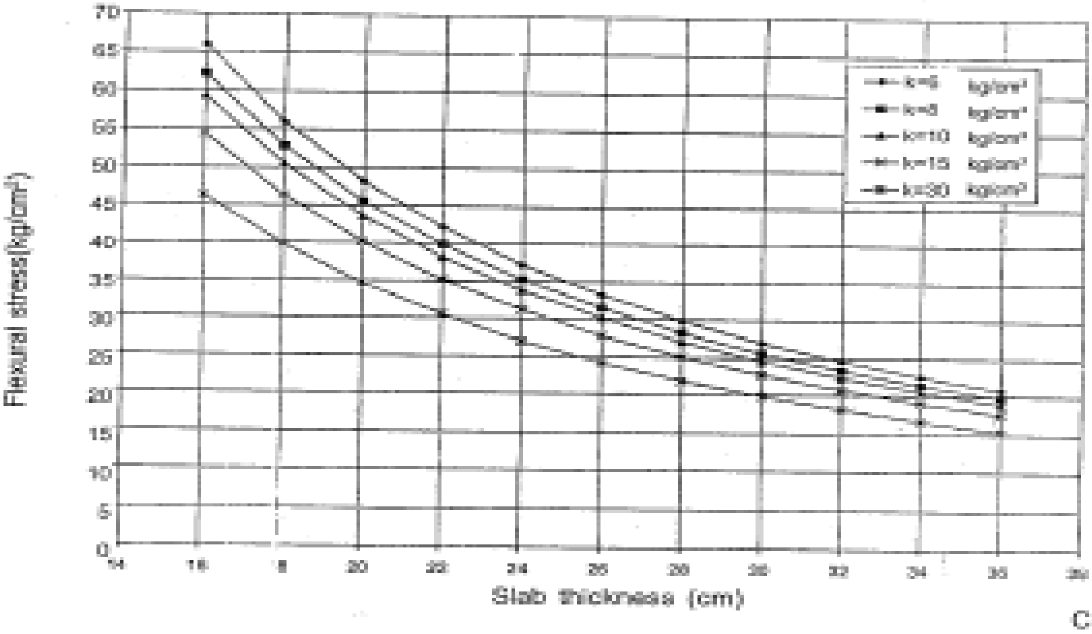

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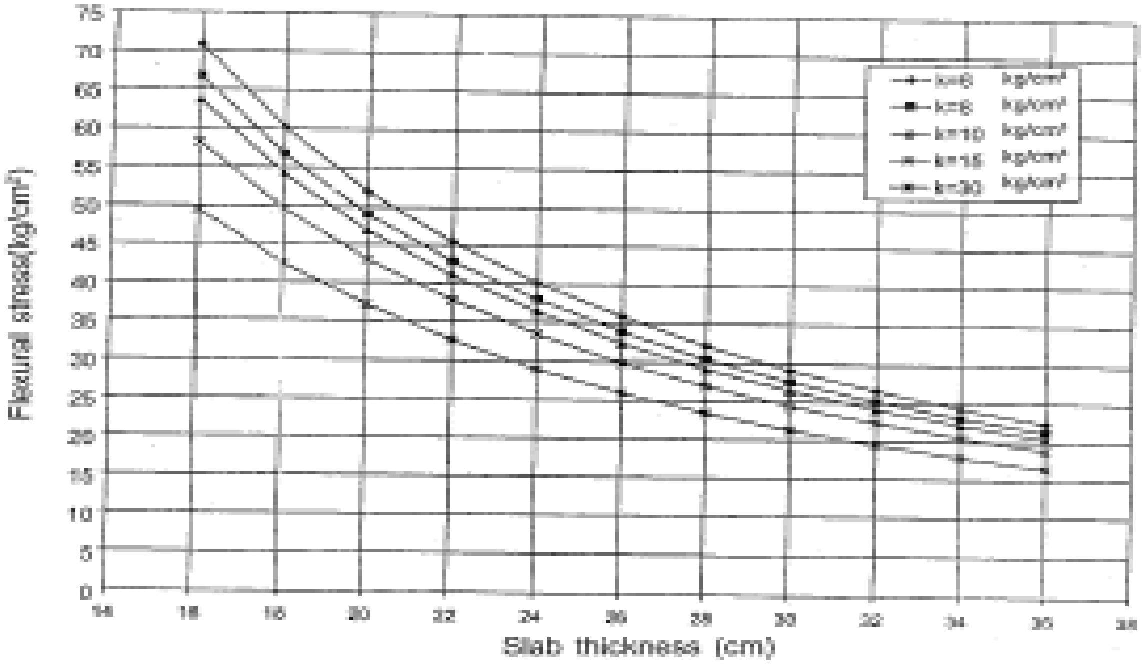
Fig. 3.5

Appendix-1 (Contd.)

Stresses in Rigid Pavement (Single Axle Load = 24 tons)



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Appendix-1 (Contd.)

Stresses in Rigid Pavement (Tandem Axle Load 12 tons)

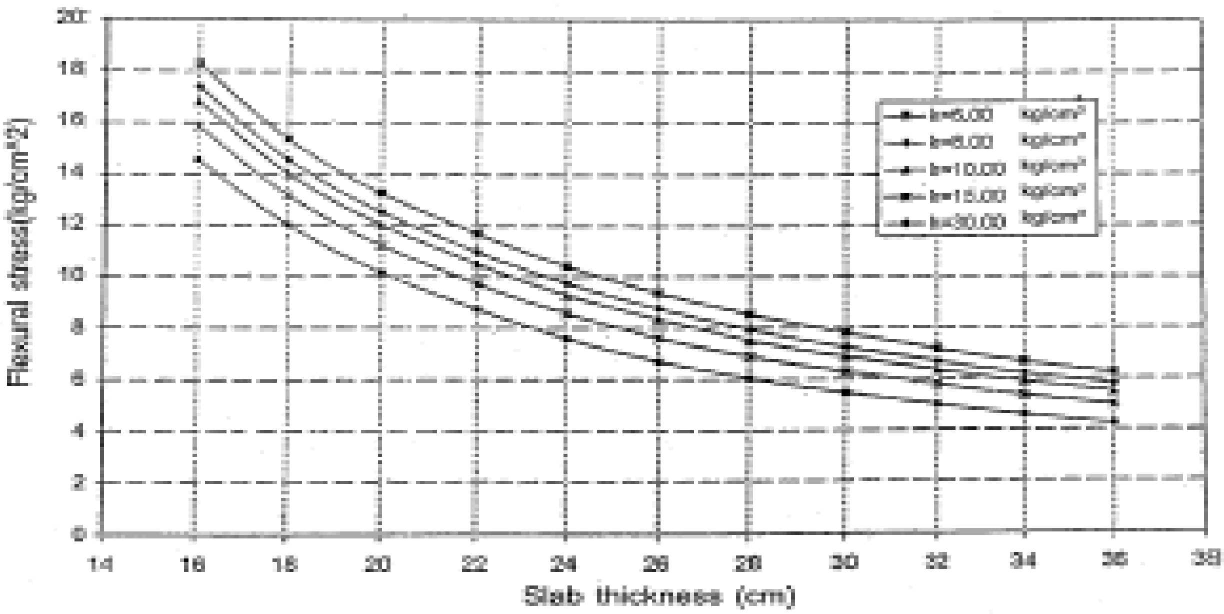

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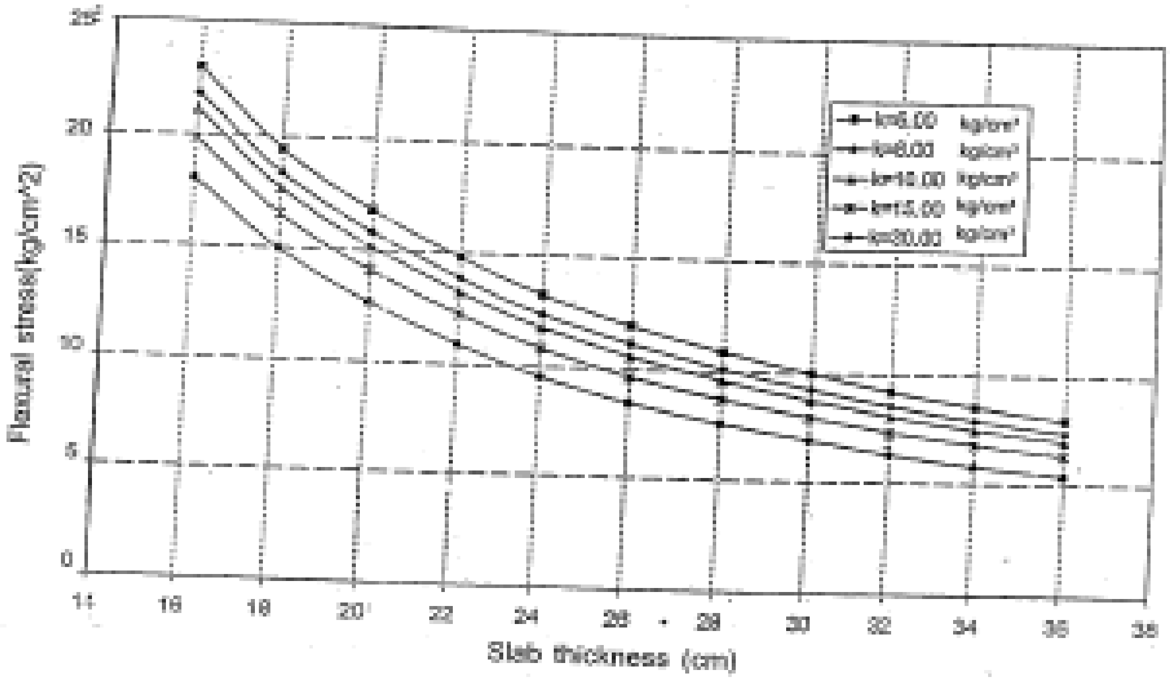
Fig. 3.6

Appendix-1 (C

Stresses in Rigid Pavement (Tandem Axle Load 16 tons)



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Appendix-1 (Contd.)

Stresses in Rigid Pavement (Tandem Axle Load 20 tons)

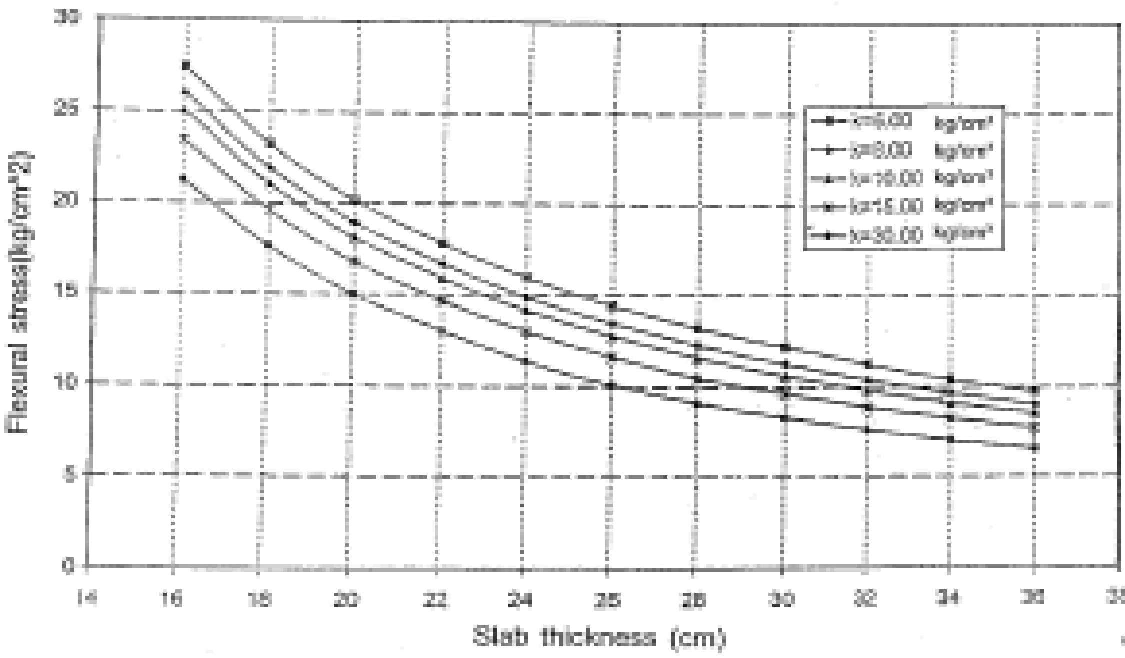

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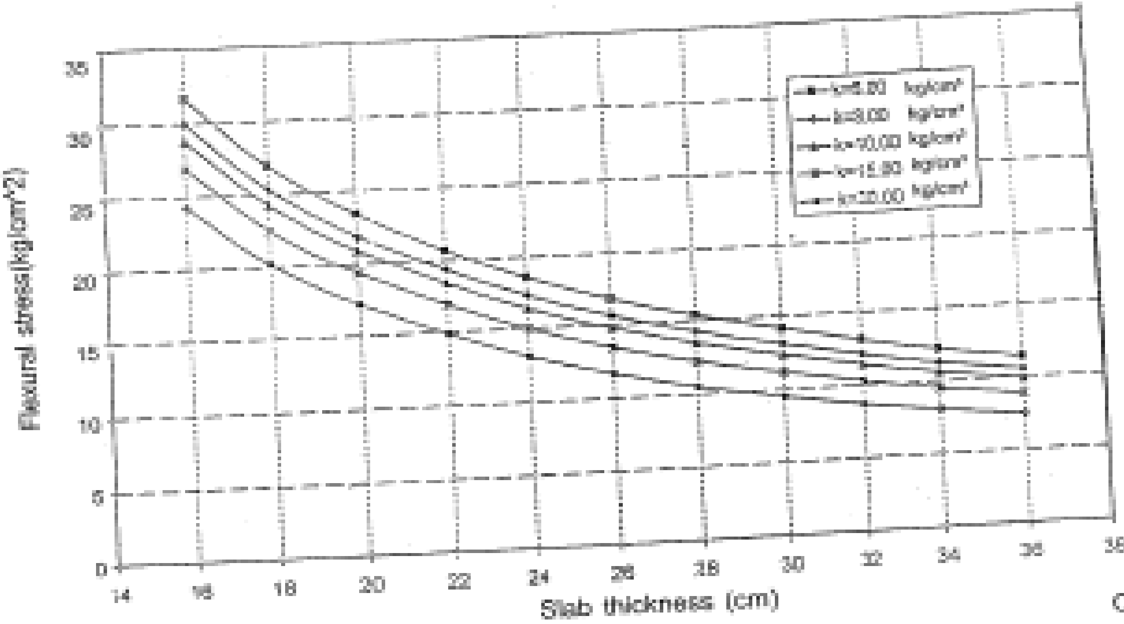
Fig. 3.7

Stresses in Rigid Pavement (Tandem Axle Load 24 tons)



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Appendix-I (Contd.)

Stresses in Rigid Pavement (Tandem Axle Load 28 tons)

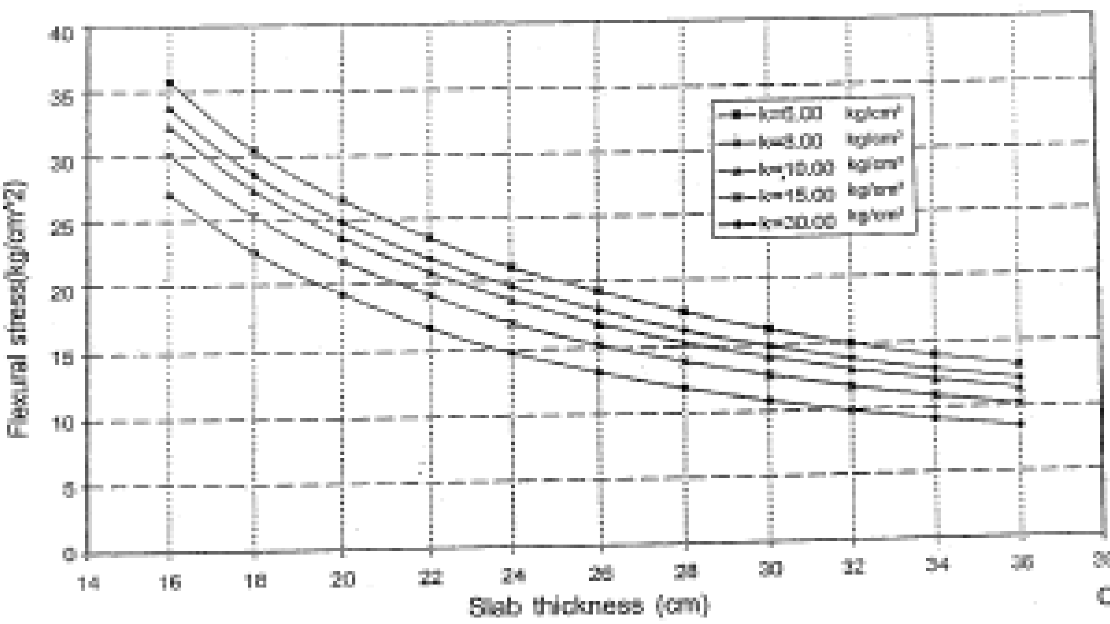

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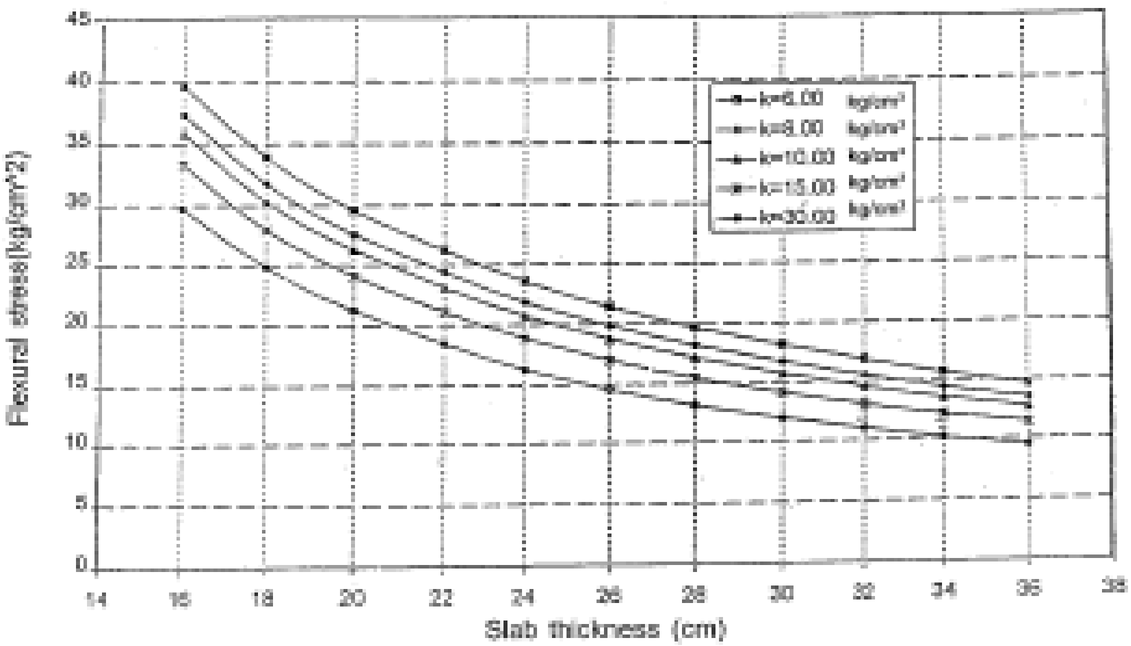
Fig. 3.8

Appendix-I (Contd.)

Stresses in Rigid Pavement (Tandem Axle Load 32 tons)



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Appendix-I (Contd.)

Stresses in Rigid Pavement (Tandem Axle Load 36 tons)

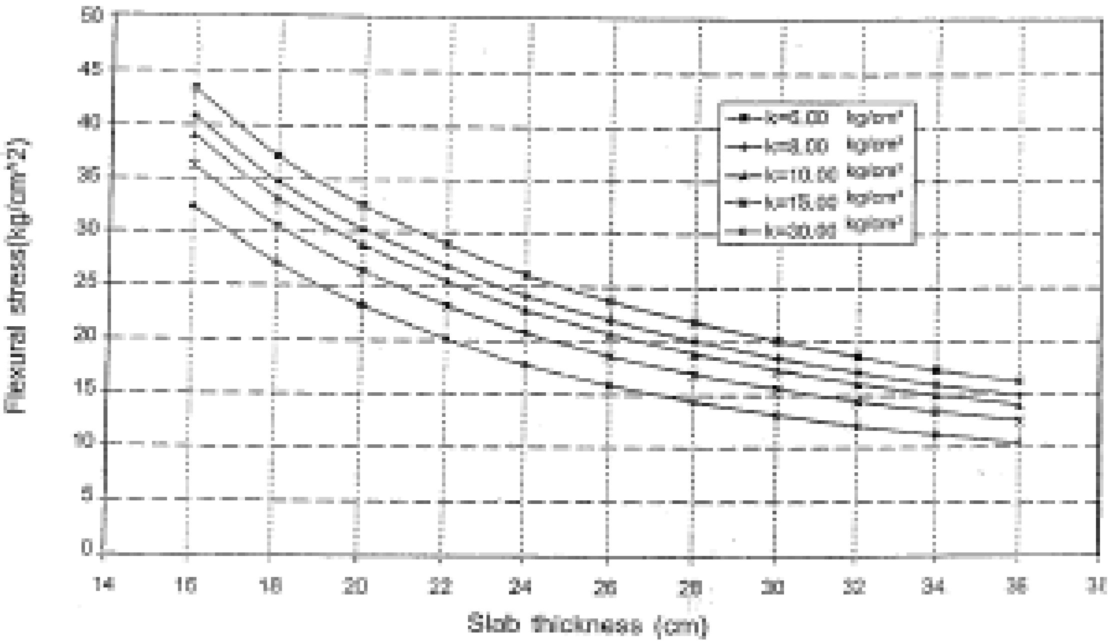

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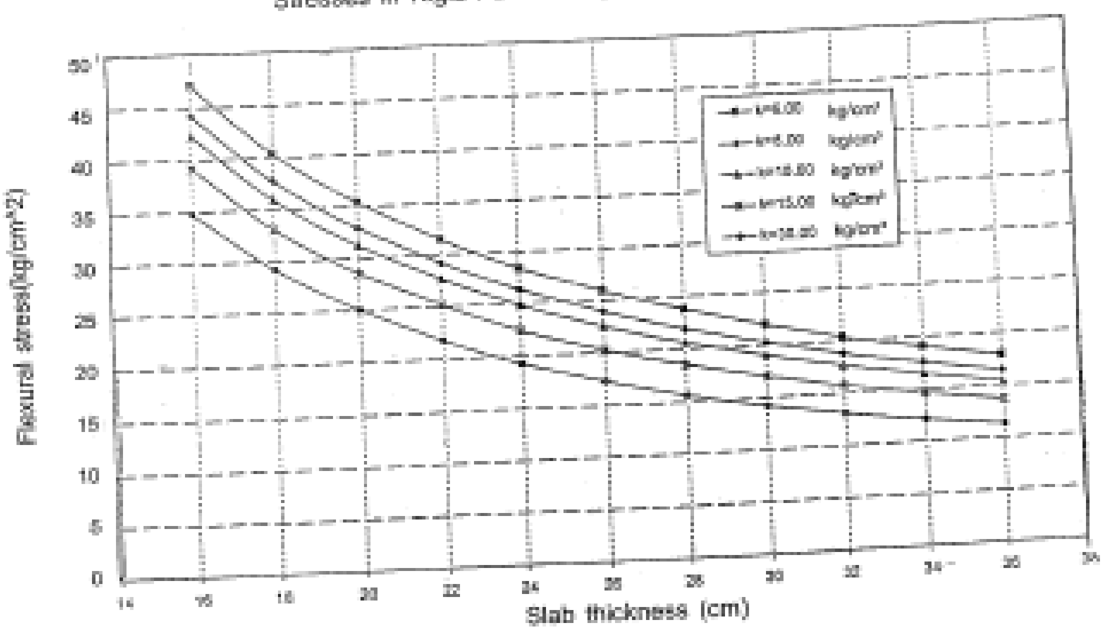
Fig. 3.9

Appendix-1 (Contd.)

Stresses in Rigid Pavement (Tandem Axle Load 40 tons)



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Appendix-1 (Contd.)

Stresses in Rigid Pavement (Tandem Axle Load 42 tons)

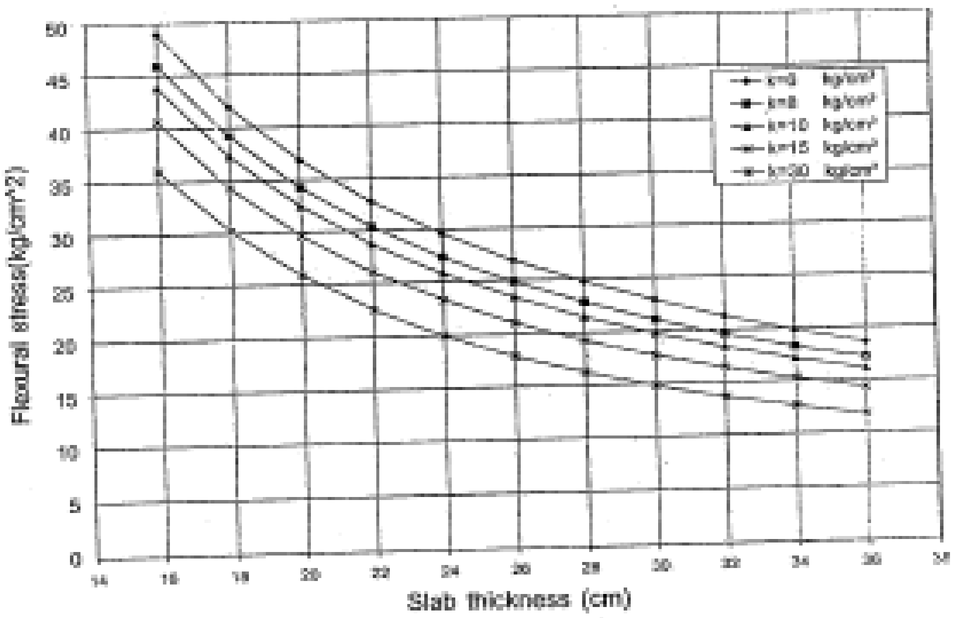

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Fig. 3.10

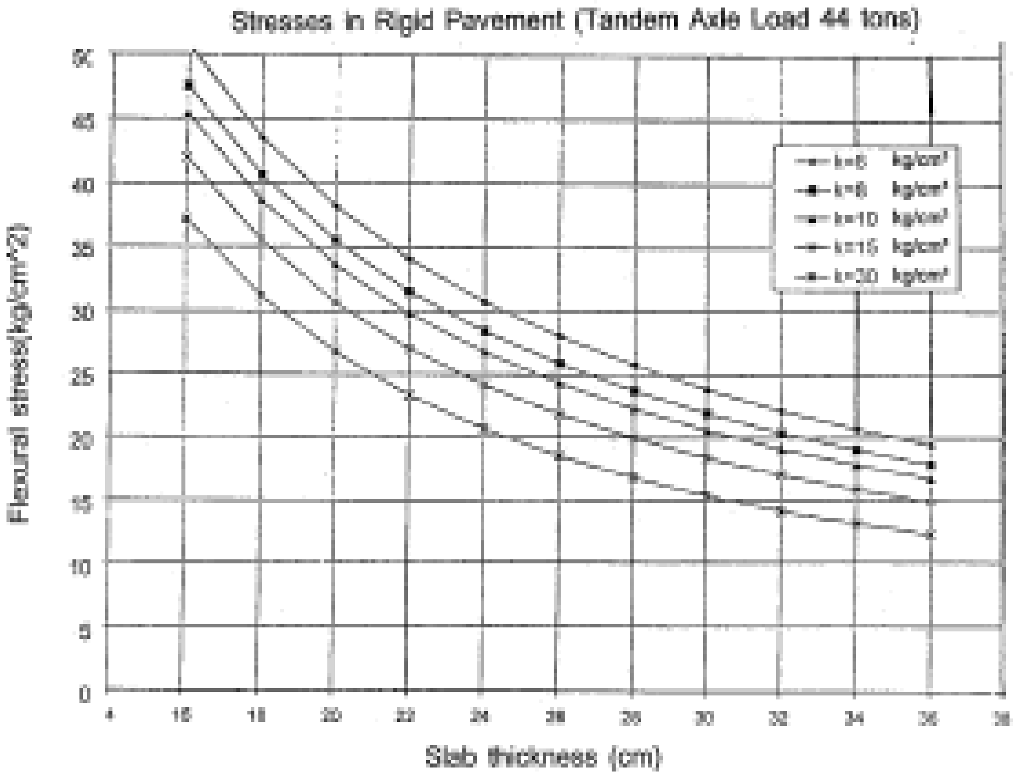

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Fig. 3.11

Trial Thickness = 20 cm, subgrade modulus = 10.045 kg/cm3, design period = 20 years, Modulus of rupture = 45kg/cm2, Load Safety Factor = 1.2

Cumulative fatigue life consumed = 296.0506

Axle Load (AL), tonnes	AL* 1.2	Stress, Kg/cm2 From charts	Stress ratio	Expected Repetition, N	Fatigue Life, N	Fatigue life consumed
(1)	(2)	(3)	(4)	(5)	(6)	Ratio(5)/(6)
Single axle						
16	19.2	26.8	0.6	121019	30927.02	3.91
12	14.4	22.9	0.51	110448	485183.61	.22
10	12	33.69	0.75	135890	467	290.98
3	3.6	-	-	303732	-	-
3	3.6	-	-	372170	-	-
Tandem axle						
32	38.4	26.4	0.587	41024	43651.5	.93
24	28.8	21	0.467	72501	6832053.92	.0106
20	24	18	0.4	815145	Infinity	

Table 3.5

- Calculation of Fatigue life :- (As per IRC 58 under clause 4.7.4)

N = unlimited for SR < 0.45

$N = [\frac{4.2577}{(SR-0.4325)}]^{3.268}$ when 0.45 <= SR <= 0.55

$\log_{10} N = \frac{(0.9718-SR)}{0.0828}$ for SR > 0.55

Trial Thickness = 24 cm, subgrade modulus = 10.045 kg/cm3, design period = 20years, Modulus of rupture = 45kg/cm2,Load Safety Factor = 1.2

Cumulative fatigue life consumed = 1.700286

Axle Load (AL), tonnes	AL* 1.2	Stress, Kg/cm2 From charts	Stress ratio	Expected Repetition, N	Fatigue Life,N	Fatigue life consumed
(1)	(2)	(3)	(4)	(5)	(6)	Ratio(5)/(6)
Single axle						
16	19.2	25.8	0.57	121019	7.12*10^4	1.7
12	14.4	20	0.44	110448	infinity	0
10	12	17.5	0.39	135890	infinity	0
3	3.6	-	-	303732	-	-
3	3.6	-	-	372170	-	-
Tandem axle						
32	38.4	20.65	0.46	41024	1.4335*10^7	0.00286
24	28.8	16.6	0.37	72501	Infinity	0
20	24	14	0.31	815145	Infinity	0

Table 3.6

Trial Thickness = 32 cm, subgrade modulus = 10.045 kg/cm3, design period = 20years, Modulus of rupture = 45kg/cm2,Load Safety Factor = 1.2

Cumulative fatigue life consumed = 0

Axle Load (AL), tonnes	AL* 1.2	Stress, Kg/cm2 From charts	Stress ratio	Expected Repetition, N	Fatigue Life,N	Fatigue life consumed
(1)	(2)	(3)	(4)	(5)	(6)	Ratio(5)/(6)
Single axle						
16	19.2	17.5	0.39	121019	infinity	0
12	14.4	13	0.29	110448	Infinity	0
10	12	11.3	0.2511	135890	Infinity	0
3	3.6	-	-	303732	-	-
3	3.6	-	-	372170	-	-
Tandem axle						
32	38.4	13.93	0.31	41024	Infinity	0
24	28.8	11.8	0.2622	72501	Infinity	0
20	24	9.8	0.2178	815145	infinity	0

Table 3.7

Trial Thickness = 26 cm, subgrade modulus = 10.045 kg/cm3, design period = 20years, Modulus of rupture = 45kg/cm2,Load Safety Factor = 1.2

Cumulative fatigue life consumed = 0.249

Axle Load (AL), tonnes	AL* 1.2	Stress, Kg/cm2 From charts	Stress ratio	Expected Repetition, N	Fatigue Life,N	Fatigue life consumed
(1)	(2)	(3)	(4)	(5)	(6)	Ratio(5)/(6)
Single axle						
16	19.2	23	0.51	121019	4.85*10^5	0.249
12	14.4	17.9	0.4	110448	infinity	0
10	12	15.9	0.35	135890	infinity	0
3	3.6	-	-	303732	-	-
3	3.6	-	-	372170	-	-
Tandem axle						
32	38.4	18.8	0.42	41024	infinity	0
24	28.8	14.8	0.33	72501	infinity	0
20	24	12.5	0.28	815145	infinity	0

Table 3.8

- The cumulative fatigue life consumed being **less than 1**,the design is **safe** from fatigue considerations.

CHAPTER 4

Design of Dowel Bar

4.1 CHECK FOR TEMPERATURE STRESS

- Edge warping stress = (C×E×α×t)÷2
- E = Elastic modulus of concrete

  E = 3×10^5 Kg/cm^2
- t = Temperature differential

  t = 18◦c
- C = Bradbury's coefficient from chart (IRC 58 clause 5.2.2)
- α = coefficient of thermal expansion

  α = 10×10^{-6}/◦c
- l = Radius of relative stiffness
- h = pavement thickness

  h = 26 cm
- K = modulus of subgrade

  K=10.045
- μ = poisons ratio

  μ = 0.15
- l = $\sqrt[4]{\frac{Eh^3}{12K(1-\mu^2}}$

  l = 81.8 cm
- L = 450 cm
- B = 350 cm
- L/l = 450/81.8=5.5
- C = 0.82 (calculated from fig 2 as per IRC 58)

- Edge warping stress = (C×E×α×t)÷2
- $S = (.82\times3\times10^{5}\times10\times10^{-6}\times18)\div2 = 22.14$ Kg/cm^2

  = 22.14+20<45

  Hence safe.

4.2 CHECK FOR CORNER STRESS

- 98 % axle load is 20 tonnes .The wheel load is 10 tonnes .
- P = 10,000 kg
- S = c/c spacing between two tyres

  S = 31 cm
- K = 10.045 kg/cm^3
- a = radius of area of contact of wheel
- Tyre pressure (q) = 8 kg/cm^2
- $a = \left(0.8521\left(\frac{p}{q\pi}\right) + \frac{S}{\pi}\left(\frac{P}{0.5227q}\right)^{0.5}\right)^{0.5}$

  = 28.67
- Corner stress = $\frac{3P}{h^2}\left[1-\left(\frac{a\sqrt{2}}{l}\right)^{1.2}\right]$

  = 19.11 kg/cm^2 < 45 kg/cm^2

  Hence safe.

4.3 Design of joints

4.3.1 Spacing and layout

Great care is needed in the design and construction of joints in cement concrete pavements, as these are critical locations having significant effect on the pavement performance. The joints also needs to be effectively sealed, and maintained well. The recommendations of IRC 15, para 8 and supplementary notes para N.2 "Arrangements of joints" may be followed with regard to joint layout and contraction joint spacings (Table 7).

Cement concrete pavements have transverse and longitudinal joints. Different types of transverse joints are :

1 Expansion joints

2 Contraction joints

3 Construction joints

Longitudinal joints are required in pavements of width greater than 4.5 m to allow for transverse contraction and warping.

Slab thickness, cm	**Maximum contraction joint spacing, m**
Unreinforced slabs	
15	4.5
20	4.5
25	4.5
30	5.0
35	5.0

Expansion joints may be omitted when dowels are provided at contraction joints except when the cement concrete pavements abut against permanent structures, like bridges and culverts.

4.3.2 Load Transfer at Transverse Joints

Load transfer to relieve part of the load stresses in edge and corner regions of pavement slabs at transverse joints is provided by means of mild steel round dowel bars. Coated dowel bars are often used to provide resistance to corrosion. The coating may be zinc or lead based paint or epoxy coating. Dowel bars enable good riding quality to be maintained by preventing faulting at the joints. For heavy traffic, dowel bar should be provided at contraction joints.

From the experience all over the world, it is found that it is only the bearing stress in the concrete that is responsible for the performance of the joints for the dowel bars. High concrete bearing stress can fracture the concrete surrounding the dowel bar, leading to the looseness of the dowel bar and the deterioration of the load transfer system with the eventual faulting of the slab.

Maximum bearing stress between the concrete and dowel bar is obtained from the equation as:

$$\sigma_{max} = \frac{(P_t * K) * (2 + \beta z)}{4\beta^3 EI}$$

- E = Elastic modulus of concrete (Kg/cm^2)
- K = modulus of subgrade (Kg/cm^2 /cm)
- P_t = load transfer by dowel bar
- Z = Joint width(cm)
- β = relative stiffness of dowel bar embedded in concrete
  $\beta = (kb/4EI)^{1\div4}$
- b=diameter of dowel bar (cm)
- I=Moment of inertia(cm^4)
- Each dowel bar should transfer load that is less than the design load for the maximum bearing pressure. Following equation based on the expression given by the American concrete institution ,committee - 225 may be used for the calculation of the allowable bearing stress on concrete :

$$F_b = \frac{(10.16 - b) * f_{ck}}{9.525}$$

- f_{ck} = Characteristic Compressive strength of concrete cube after 28 days curing concrete = 400 Kg/cm^2
- b = diameter of dowel bar (cm)
- F_b = allowable bearing stress(Kg/cm^2)

The dowel bar are installed at suitable spacing across the joint and the dowel bar system is assumed to transfer 40 percent of the wheel load. For heavy traffic, dowel are to be provided at the contraction joints since aggregate inter lock cannot be relied upon to affect the load transfer across the joint to prevent faulting due to repeated loading of heavy axles. Joint width of 20 mm be taken for stress computation in dowel bar at the expansion and contraction in view of the fact that under the dowel there is likely to be grinding of concrete take place and consequent loss of support. Recommended diameter and length of dowel bars are given in Table 8.

RECOMMENDED DIMENSIONS OF DOWEL BAR FOR RIGID PAVEMENT

SLAB THICKNESS (cm)	DOWEL BAR DETAILS		
	DIAMETER (mm)	LENGTH (mm)	SPACING (mm)
20	25	500	250
25	25	500	300
30	32	500	300
35	32	500	300

Table 4.1

Dowel bars are not satisfactory for slabs of small thickness and shall not be provided for slab of less than 15 cm thickness.

Dowel Group Action :

when loads are applied at a joint, a portion of a load transferred to the other side of the slab through the dowel bars. The dowel bar immediately below a wheel load carries maximum amount of load and other dowel bars transfer progressively lower amount of loads. Repeatedly loading causes looseness between the dowel bars and concrete slab and recent study indicate that the dowel bars within a distance of one radius of relative stiffness (1.01l) from the point of load application participate in load transfer. Assuming a linear variation of the load carried by different dowel bars within (1.0l), maximum load carried by a dowel bar can be computed as illustrated in Appendix 3.

4.4 Design of Dowel Bar :

- Design wheel load = 10000 kg
- % of load transfer = 40
- Thickness (h) = 26 cm
- Joint width, Z = 2 cm
- Radius of relative thickness (l) = 81.8 cm
- Permissible bearing stress in concrete is calculated as under :
- $F_b = ((10.16\text{-}b)\times f_{ck}) \div 9.525$
- f_{ck} = Characteristic Compressive strength of concrete cube after 28 days curing concrete = 400 Kg/cm^2
- b = diameter of dowel bar = 2.6 cm (assumed)
- F_b = 317.48 Kg/cm^2

Spacing = 30 cm (assumed)

Length = 50 cm (assumed)

No of dowel bars = 1 + l/spacing = 4 dowels

Load transfer = (1 + (81.8-30)/81.8 + (81.8-60)/81.8 + (81.8-90)/81.8)P_t

= 1.79 P_t

Load carried by the outer dowel bar, Pt = 10000 * 0.4/ 1.79

= 2234.64 kg

4.4.1 Check for bearing stress :-

- Moment of inertia of dowel = $\pi \times b^4 /64$

  $= 2.24\ cm^4$
- β = relative stiffness of dowel bar embedded in concrete
- $\beta = (kb/4EI)^{1 \div 4}$

  $= 0.278$

  therefore, $E = 2*10^6$
- Bearing stress in dowel bar = $(P_t \times K) \times (2 + \beta z)/4\beta^3 EI$

  $= 615.66\ Kg/cm^2$

CHAPTER 5

Design of Tie Bars

5.1 Tie Bars for Longitudinal Joints

In case opening of longitudinal joints is anticipated in service, for example, in case of heavy traffic, expansive subgrades, etc., tie bar may be designed in accordance with the recommendations of IRC:15-2002,Supplementary note, para N.5 Tie bars. For the sake of convenience of the designers the design procedure recommended in IRC:15-2002 is given here.

5.2 Design of Tie Bars

The area of steel required per meter length of joint may be computed using the following formula:

- $A_s = (b \times f \times W) \div S$
- f = Coefficient of friction between pavement and sub base /base=1.5
- b = lane width in meters
- W = weight of slab in kg/m^2
- S = allowable working stress of steel in kg/cm^2

The length of any tie bar should be at least twice that required to develop a bond strength equal to the working stress of the steel. Expressed as a formula, this becomes:

$$L=(2 \times S \times A) \div (B \times P)$$

in which

L=Length of tie bar (cm)

S = Allowable working stress of steel in kg/cm^2

P = Perimeter of tie bar (cm)

A = Cross section area of one tie bar cm^2

B* = Permissible bond stress of concrete (i) for deformed tie bars - 24.6 Kg/ cm2 (ii) for plain tie bars - 17.5 kg / cm2

To permit warping at the joint, the maximum diameter of tie bars may be limited to 20 mm, and to avoid concentration of tensile stresses they should not be spaced more than 75 cm apart. The calculated length L, may be increased by 5-8 cm to account for any inaccuracy in placement during construction.

Typical tie bar details for use at central longitudinal joint in double - lane rigid pavements with a width of 3.5 m are given in table given below.

SLAB THICKNESS (cm)	**TIE BAR DETAILS**				
	DIAMETER (d) (mm)	**Max spacing (cm)**		**Min Length (cm)**	
		Plain Bars	**Deformed bars**	**Plains bars**	**Deformed Bars**
15	8	33	53	44	48
	10	52	83	51	56
20	10	39	62	51	56
	12	56	90	58	64
25	12	45	72	58	64
	16	80	128	72	80
30	12	37	60	58	64
	16	66	106	72	80
35	12	32	51	58	64
	16	57	91	72	80

Table 5.1

Design parameters :

- Slab thickness = 26 cm
- Lane width (b) = 350 cm
- Coefficient of friction between pavement and sub base /base (f) = 1.5
- Density of concrete = 2400 kg/m^3
- Allowable tensile stress in plain bars (S) = 1250 kg/cm^2
- Allowable tensile stress in deformed bars (S) = 2000 kg/cm^2
- Allowable bond stress for plain tie bars (B) = 17.5 kg/cm^2
- Allowable bond stress for deformed tie bars (B) = 24.6 kg/cm^2

5.2.1 SPACING AND LENGTH OF PLAIN BARS

- Assuming a diameter of tie bar =12 mm
- Area of steel bar per meter width of joint to resist the frictional force at slam at bottom
- A_s = (b×f×W)÷S

  = (3.5×1.5×2400×.26)÷1250

  = 2.6208 cm^2 /m
- Area of cross section of one bar

  A= (π×1.2^2)÷4 = 1.13 cm^2
- Perimeter (P) = π×d

  = π×1.2 =3.77 cm
- Spacing of bars = A/A_s

  = (100×1.13)÷2.6208 = 43.11 cm
- Provide at a spacing of 44 cm
- Length of tie bar, L = (2×S×A)÷(B×P)

  = (2×1250×1.13) ÷ (17.5×3.77)

  = 42.82 cm
- Increase length by 10 cm for loss of bond due to painting and another 5 cm for tolerance in placement .
- Total length = 42.82+10+5 = 57.82 cm
- Total length taken = 58 cm

5.2.2 SPACING AND LENGTH OF DEFORMED BARS

- Assuming a diameter of tie bar = 12 mm
- Area of steel bar per meter width of joint to resist the frictional force at slam at bottom
- A_s = (b×f×W)÷S
  = (3.5×1.5×2400×.26)÷2000
  = 1.638 cm^2 /m
- Area of cross section of one bar
  A= (π×1.2^2)÷4 =1.13 cm^2
- Perimeter (P)= π×d
  = π×1.2 =3.77 cm
- Spacing of bars = A/A_s
  = (100×1.13)÷1.638 = 68.98 cm
- Provide at a spacing of 69 cm
- Length of tie bar, L=(2×S×A)÷(B×P)
  = (2×2000×1.13)÷(24.6×3.77)
  = 48.74 cm
- Increase length by 10 cm for loss of bond due to painting and another 5 cm for tolerance in placement .
- Total length = 48.74+10+5 = 63.74 cm
- Total length taken = 64 cm

CHAPTER 6

Cost estimation of Rigid and Flexible Pavement

6.1 Initial cost

This is the cost of construction of the pavement which mainly depends upon the pavement thickness, governed by the strength of subgrade soil and traffic loading, cost of materials and cost of execution of the work. The above have a wide range of variability across the country and is difficult to generalise.

6.2 Maintenance cost

The maintenance cost includes the maintenance of pavement during the design life of pavement to keep the pavement at the specified service level.

In case of rural roads, maintenance of these roads is to be done by the respective State Government from its available financial resources. Most of the states have poor past performance record to maintain such low volume roads built through other schemes, mainly because of having inadequate funds for maintenance of road infrastructure in the state.

6.3 Life Cycle Cost Analysis

The choice of the appropriate economically advantageous pavement type, flexible or rigid, is made by carrying out life Cycle Cost analysis which takes into account the initial investment cost and also the maintenance/rehabilitation cost over the design life of the pavement structure. Life cycle cost analysis can be defined as a procedure by which a pavement design alternative will be selected, which will provide a satisfactory level of service at the lowest cost over design life. The economic analysis method used most commonly for this purpose include present worth, annualized cost, and rate of return. The analysis is most sensitive to the factors of inflation, discount rate, and analysis period.

In the subsequent paragraphs, an attempt has been made to study the long-term economic viability of pavement types using Present-worth method of analysis. Thus, as a case study, comparative cost of one kilometer each of flexible pavement and rigid pavement representing a uniform section has been worked out at current market rate, with respective maintenance strategy for a road under NHAI.

6.4 Calculation of quantity of material used

- Considering 1km stretch of rigid pavement.
- Length of in 1 km stretch=1000m
- Breadth of block =7 m
- Depth of block=.26 m
- Volume of pavement =1000 *7.02*.26

  =1825.2 m^3
- Volume of spacing between the concrete blocks in transverse direction(dowel bar) = 7*.26*.02*221 = 8.044 m^3
- Volume of spacing between the concrete blocks in longitudinal direction(tie bar) = 1000*.02*.26 = 5.2 m^3
- Volume of steel (dowel bar) embedded in concrete block = (.785*.026^2*.48*24*221) = 0.13509 m^3
- Volume of steel (tie bar) embedded in concrete block = .785*.012^2*.56*(1000-221*.02)/44 = 0.0015 m^3
- Net effective volume of M40 grade concrete per km = 1825.2-8.044-5.2-.13509 .0015 = 1811.82 m^3
- Net volume of steel = .785*.026^2*.50*24*22+ .785*.012^2*.58*23

  = 1.4085 m^3

  = 2650.07 Kg + 13.263 Kg = 2663.33 Kg
- Mix design of M40 grade concrete=

  cement : water : F.A : C.A= 1 : 0.4 : 1.65 : 2.92
- Net quantity of cement = 303.5 m^3
- Net quantity of water = 121.4 m^3
- Net quantity of F.A = 500.78 m^3
- Net quantity of C.A = 886.23 m^3

6.5 Cost of rigid pavement

- Cost = Price * Quantity
- Cost of cement = 30*350*303.5 = 3186750 Rs
- Cost of F.A = 300*500.78 = 150234 Rs
- Cost of C.A = 581*886.23 = 514899.63 Rs
- Cost of steel = 38.5*2663.33 = 102538.32 Rs

  TOTAL = 3954421.95 Rs
- Net cost of rigid pavement per km = T + 10% of T

  = Rs 4349864.14

6.6 Cost of flexible pavement

- Sub – base & base course = 13.6 Cr
- Bituminous course = 22.3 Cr
- Cost per km stretch = (13.6+22.3)/32.8

  = 1.09 Cr
- Net cost of flexible pavement per km = 1.09 + 15% of 1.09

  = 1.26 Cr

CHAPTER 7

Comparison of cost

7.1 Comparison of cost

- Cost of flexible pavement per km = 1.26 Cr
- Cost of rigid pavement per km = 0.44 Cr

From above it can be observed that the net cost of a concrete pavement is cheaper than a flexible pavement. This is despite other factors such interruption of traffic, costs of advertisement for works due to the recurrent reconstruction of flexible pavement and continued reduced level of service due to fast deterioration. Further to that, the cost of importation of fuel and fuel products makes the flexible pavement more expensive as compared to the locally available materials for making cement and the production processes.

- Difference in cost = 0.82 Cr

It can be concluded that from the analysis, the net cost of a flexible pavement is 65.08% more expensive than the cost of a concrete pavement.

CONCLUSION

In-service cement concrete pavements are subjected to stresses due to a variety of factors acting simultaneously. The severest combination of different factors that induce the maximum stress in the pavement gives the critical stress condition. The factors commonly considered for design of pavement thickness are flexural stress due to traffic loads and temp. Differentials between top and bottom fibres of the concrete slab, as the two are assumed to be additive under critical condition. The effect of moisture changes are opposite of those of temp. changes and are not normally considered critical to thickness design.

Taking into account all the conditions we come up to the conclusion that the thickness of the rigid pavement should be 26cm. Taking into account the material and maintenance cost of both the pavement we can conclude that rigid pavement is cost effective then the flexible pavement. So if NHAI provides the same stretch with rigid pavement than it would be cost effective for them in the long run.

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