FEASIBILITY OF RIGID PAVEMENT ON MEHLI SHOGHI ROAD: DESIGN & ANALYSIS

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

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in

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under the Supervision of

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CERTIFICATE

This is to certify that project report entitled **“FEASIBILITY OF RIGID PAVEMENT ON MEHLI-SHOGHI ROAD:DESIGN & ANALYSIS”**, submitted by SIDDHANT MODI (111628) & AMAN GUPTA (111610) in partial fulfillment for the award of degree of Bachelor of Technology in Civil Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

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It has been a wonderful & intellectually stimulating experience working on "**FEASIBILITY OF RIGID PAVEMENT ON MEHLI-SHOGHI ROAD: DESIGN & ANALYSIS** which is in itself a new and innovative idea in the field of highway engineering.

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ABSTRACT

A proper design and analysis of a rigid pavement on a stretch Mehli-Shoghi road using DPR(detailed project report) provided by NHAI(National Highways Authority of India) were done.

Initially, to understand the condition of Mehli-Shoghi road, the site visit was undertaken.We did traffic survey for 24x7 to understand the traffic behavior at Mehli-Shoghi road. We also collected the sample and did light weight compaction proctor test to determine the optimum moisture content present in the soil, so as to do the CBR test at this moisture content. Then we did CBR test to determine the value of modulus of subgrade with the help of table given in IRC 58.By using simple techniques given in IRC 58 (The design of plain jointed rigid pavements for highways), the percentage of axle load, cumulative repetition, expected repetition and the depth of rigid pavement is determined and then this thickness of rigid pavement for combined action of temperature stresses and wheel load is checked. After that the spacing of expansion and contraction joints,design of dowel bar and tie bar is designed. Finally cost estimation of the two pavements was compared and results drawn.

Keywords: Rigid pavement, thickness of slab, expansion joints, contraction joints, cost estimation.

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LIST OF SYMBOLS

C	Thermal expansion of concrete per degree rise in temperature.
T	change in temperature=30°C
δ	maximum expansion in a slab of length Le
Lc	slab length or spacing between contraction joints,m
H	slab thickness,cm
F	coefficient of friction,(max value is 1.5)
W	unit weight of cement concrete, kg/m^3 ($2400 kg/m^3$)
Sc	allowable stress in tension in cement concrete in kg/cm^2($0.8 kg/cm^2$)
P	Load transfer capacity of a single dowel bar,Kg
d	diameter of dowel bar,cm
Ld	total length of embedment of dowel bar,cm
δ	joint width, cm
Fs	permissible shear stress in dowel bar, kg/cm^2
Ff	permissible flexural stress in dowel bar, kg/cm^2
Fb	permissible bearing stress in concrete, kg/cm^2
T	change in temperature=30°C
l	Radius of relative stiffness
Fs	1000 kg/cm^2
Ff	1400 kg/cm^2
Fb	100 kg/cm^2
As	area of steel per metre length of joint,cm^2
b	distance between the joint and nearest free edge ,m
h	thickness of pavement ,cm
f	coefficient of friction(1.5for rough interface)

W	unit weight of cement concrete , kg/m^3($2400 kg/m^3$)
Lt	length of tie bar ,*cm*
Ss	allowable stress in tension ($1400\ kg/cm^2$)
Sb	allowable bond stress in concrete (24.6kg/cm2 for deformed bars and 17.5kg/cm2
as	. cross sectional area of one tie bar, cm^2perimeter of tie bar , *cm*
P	perimeter of tie bar , *cm*

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 sub-zero 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 [1] [3]. All hard road pavements usually fall into two broad categories namely

1. Flexible Pavement

2. Rigid Pavement

The long-term performance of rigid pavement [2] depends not only on proper pavement design and materials selection. It involves many processes including proper preparation of the subgrade and sub-base, 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 [4].

The transportation by road is the only road which could give maximum service to one and 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. [1] 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 [6], 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 suitable and best methods to given conditions and problems.

The main objective of this study is to develop a strategy to select the most cost efficient pavement design method to be carried out for 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.

FIG 1.1(A) Flexible Pavement

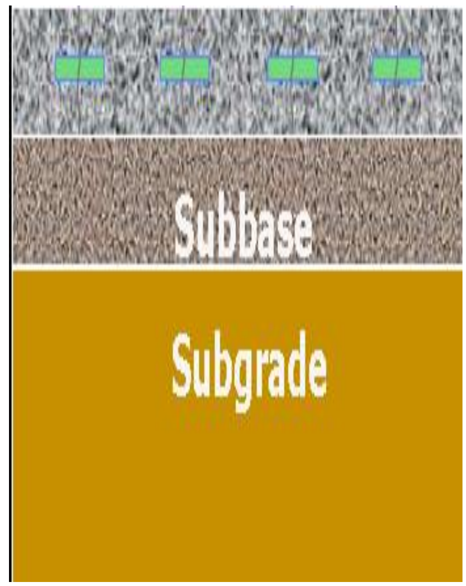

FIG 1.1(B) Rigid Pavement

LITERATURE REVIEW

2.1 OVERVIEW OF RIGID PAVEMENT DESIGN

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 and 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.

2.1.1 MODULUS OF SUBGRADE REACTION

Westergaard considered the rigid pavement slab as a thin elastic plate resting on soil sub-grade, which is assumed as a dense liquid [11]. 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.

2.1.2 RELATIVE STIFFNESS OF SLAB TO SUBGRADE

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 [3]. 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/cm^2, 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 [12].

2.1.3 CRITICAL LOAD POSITION

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 [8]. 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.

2.1.4 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 [12]. Westergaard's gives a relation for equivalent radius of the resisting section in cm in the equation

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

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

2.2 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

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

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

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

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.

2.2.1 TEMPERATURE STRESSES

Temperature stresses are developed in cement concrete pavement due to variation in slab temperature [7]. 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].

2.2.2 WARPING STRESSES

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

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

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

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

2.2.3 FRICTIONAL STRESSES

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

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

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 [11].

2.3 FAILURE OF RIGID PAVEMENT

The defects apparent on rigid pavements may be due to deterioration of the concrete, restrained volume-change stresses, or overload evidenced by pumping and/or structural breaks [9]. Failure in cement concrete pavement are due to two factors:

(a) Deficiency of the pavement materials

- soft aggregates
- poor joint filler
- improper and insufficient curing

(b) Structural in adequacy of pavement system

- inadequate pavement thickness
- incorrect spacing of joint

2.4 OBJECTIVE

- On the basis of literature review we decide to design the thickness of rigid pavement which is safe under the combined action of wheel load and temperature.
- Cost analysis of rigid pavement.

2.5 SCOPE OF STUDY

Along with the design of thickness of rigid pavement one should try to design rigid pavement with camber so that drainage problem can be handled efficiently. We can also try to design the gradient according to the conditions at site to handle the drainage problem.

METHODOLOGY

3.1 ABOUT THE PROJECT

It is about 20kms stretch (Mehli-Shoghi) road which is mostly deteriorated and undulated due to rainy and cold weather. It is a flexible road two lane road with width 7m which is directly linked with National highway-22. Heavy traffic volume of trucks loaded with apple carts are mainly passes from this site. The project is in Shimla urban in Himachal Pradesh.

3.2 MAP OF MEHLI SHOGHI ROAD

Melhi is a Locality in Shimla City in Himachal Pradesh State, India. It is about 1km from from Panthaghati, shiv nagar , shaurala . Pahari is the local language here .We can reach on Mehli-Shoghi road by connected road known as taradevi road and it is about 7km from Shimla airport.

FIG 3.1 Map of Mehli-Shoghi Road

3.3 DATA COLLECTION

For collecting data, first we visited the site to understood the condition and take snapshots. After knowing the weather conditions, observing site conditions we felt that at this site there should be requirement of rigid pavement instead of flexible pavement. So we do traffic survey 24x7 for traffic volume count.

Fig 3.2 Bad condition of mehli shoghi road

From the fig3.2 we see the bad condition of Mehli-Shoghi road which is mostly deteriorated due to rain ,cold weather and not properly organised drainage that why lot of undulations or puddles are formed which causes serious accidents.Road is also deteriorated due to the heavy loads of trucks and the present is that many undulations are formed which causes loss of propetry in form of apples , truck damage, even loss of life also.

3.4 TRAFFIC SURVEY

Traffic survey is the process of intercepting and examining messages in order to deduce information from patterns in communication. A traffic count is a count of traffic along a particular road, either done electronically or by people counting by the side of the road.

SCHEDULE	TRUCK(6 tyre)		BUS		JEEP	TWO WHEELER (Nos.)
DATE-03/09/2014	EMPTY (Nos.)	LOADED (Nos.)	EMPTY (Nos.)	LOADED (Nos.)	LOADED (Nos.)	
12:00-1:00pm	20	22	9	20	74	48
1:00-2:00pm	35	27	10	16	102	34
2:00-3:00pm	31	89	23	28	99	29
3:00-4:00pm	75	34	18	25	88	49
4:00-5:00pm	84	54	12	35	70	34
5:00-6:00pm	52	16	22	24	51	75
6:00-7:00pm	32	17	31	23	59	23
7:00-8:00pm	40	16	20	13	108	13
8:00-9:00pm	28	13	34	18	78	27
9:00-10:00pm	25	22	16	22	103	33
10:00-11:00pm	63	24	13	32	66	35
11:00-12:00pm	55	19	26	20	88	10
TOTAL	**540**	**353**	**234**	**276**	**986**	**410**
DATE-04/09/2014						
12:00-1:00am	3	16	15	10	148	23
1:00-2:00am	11	38	18	20	55	34
2:00-3:00am	4	47	23	25	58	56
3:00-4:00am	8	25	32	12	163	76
4:00-5:00am	5	20	28	18	40	53
5:00-6:00am	10	46	16	11	84	40
6:00-7:00am	20	50	24	34	76	35
7:00-8:00am	43	36	34	13	106	23
8:00-9:00am	23	26	30	23	174	11
9:00-10:00am	32	20	20	15	72	14
10:00-11:00am	27	22	25	16	108	19
11:00-12:00am	23	34	13	15	102	35
TOTAL	**209**	**380**	**278**	**212**	**1186**	**419**

Table 3.1 Traffic Census

3.5 DATA INFERENCE FROM TRAFFIC CENSUS

From traffic volume count for 24x7 we find that total number of heavy loaded vehicles per day (weight of around 12-16 tonnes) are 300 units which is mostly loaded with apple carts and passenger vehicles like buses and jeep are 250 and 1050 respectively. All these vehicles have more than 3tonne load so come under the design consideration of thickness of rigid pavement. The summary that we get from traffic volume count

TYPE OF VEHICLE	AVERAGE NUMBER OF VEHICLES PER DAY	LOAD (TONNES)
TRUCK	300	15
BUS	250	12
JEEP	1050	3
TWO WHEELER	410	< 3

Table 3.2(a) Volume Count

We calculate the percentage of axle load by dividing average number of vehicles per day for each category with the summation of total number of vehicles per day for all the caterories.

TYPE OF VEHICLE	AVERAGE NUMBER OF VEHICLE PER DAY	AXLE LOAD CLASS (TONNES)	%AGE OF AXLE LOAD
Truck	300	17 – 19	18.75
Bus	250	11-13	15.25
Jeep	1050	Less than 9	65.625
Total	1600		

Table3.3 (b) Percentage Axle Load

Now we calculate cumulative repetitions for the 20 years design life of rigid pavement with cumulative vehicles per day which is 1600 units and the annual rate of growth (r) is 7.5% (according to IRC:58-2002).

Assume that the construction period for rigid pavement is 1 year so at the end of construction number of cumulative vehicles per day = $A*(1+r)^{n}$

$= 1600*(1+0.075)^{1}$

= 1720 vehicles

Cumulative repetitions in 20yrs = $\frac{365*A*\{(1+r)^{n}-1\}}{r}$

$= \frac{365*1720*\{(1+.075)20-1\}}{.075}$

=27186678commercial vehicle

According to IRC:58-2002, design traffic is 25% of the total repetition of vehicle in 20 yrs

Design traffic = 25% of the total repetition

= 0.25* 27186678

= 6796669commercial vehicle

As per the formula given in IRC:58-20002 we calculate the expected repetitions for each types of vehicle.

Formula Used:

Expected repetition = $\frac{DESIGN\ TRAFFIC\ *\%AGE\ OF\ AXIAL\ LOAD}{100}$

AXLE LOAD (TONNES)	EXPECTED REPEITION
15	12,74,375
12	10,36,492
3	44,60,314
<3	Not considered

Table3.3(c) Expected Repetition

3.6 TESTING OF SOIL SAMPLE

To find out modulus of subgrade (k value) for that we had to done CBR test. As we know that CBR test has been done on optimum moisture content (OMC) so to find out OMC we did proctor test first. We get the material (soil sample) from our site and did a proctor test instantly to check whether the moisture content is more or less than optimum moisture content (OMC).

3.7 MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT USING LIGHT COMPACTION

3.7.1 APPARATUS

1. Cylindrical metal mould – It shall be either of 100 mm diameter and 1000 cm^3.
2. Oven
3. Container
4. Hammer of 2.6kg
5. Mixing tools

3.7.2 PROCEDURE

- A 5 kg sample of air dried soil passing the 19 mm IS test sieve shall be taken .The sample shall be mixed thoroughly with a suitable amount of water depending on the soil type.
- The mould of 1000 cm^3 capacity with base plate attached shall be weighed to the nearest 1gm (m1). The mould shall be placed on a solid base, such as a concrete floor or plinth and the moist soil shall be compacted into the mould, with the extension attached, in three layers of approximately equal mass, each layer being given 25 blows from the 2.6 Kg rammer dropped from a height of 310 mm above the soil

- The blows shall be distributed uniformly over the surface of each layer. The operator shall ensure that the tube of the rammer is kept clear of soil so that the rammer always falls freely.
- The amount of soil used shall be sufficient to fill the mould, leaving not more than about 6 mm to be struck off when the extension is removed.
- The extension shall be removed and the compacted soil shall be leveled off carefully to the top of the mould by means of the straightedge. The mould and soil shall then be weighed to 1gm (m^2)
- The compacted soil specimen shall be removed from the mould and placed on the mixing tray. The water content of a representative sample of the specimen shall be determined
- The remainder of the soil specimen shall be broken up, rubbed through the 19 mm IS test sieve, and then mixed with the remainder of the original sample. Suitable increments of water shall be added.

Fig 3.3 Procter test apparatus

3.7.3 DETRMINATION

Graph is plotted between water content on abscissa and dry density on ordinate. The maximum value of dry density gives maximum dry density and the corresponding water content gives optimum moisture content.

Now we draw the graph.

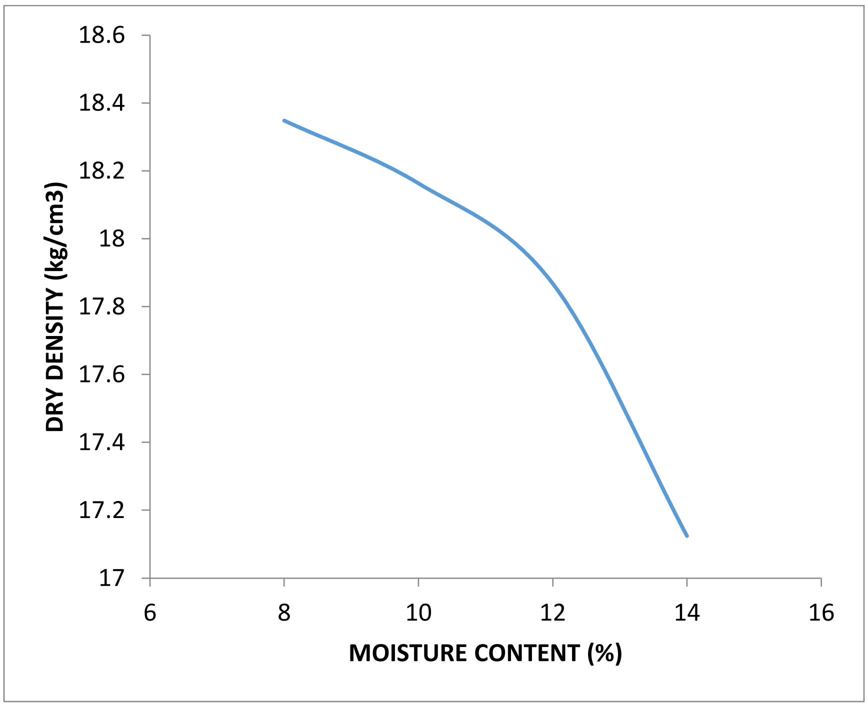

Fig 3.4 Graph between dry density and moisture content

From this graph we know that our moisture content is more than optimum moisture content.so for finding OMC we first oven dried the soil and then did proctor test again.

3.7.4 DRAW GRAPH AGAIN AFTER OVEN DRY THE SOIL MATERIAL

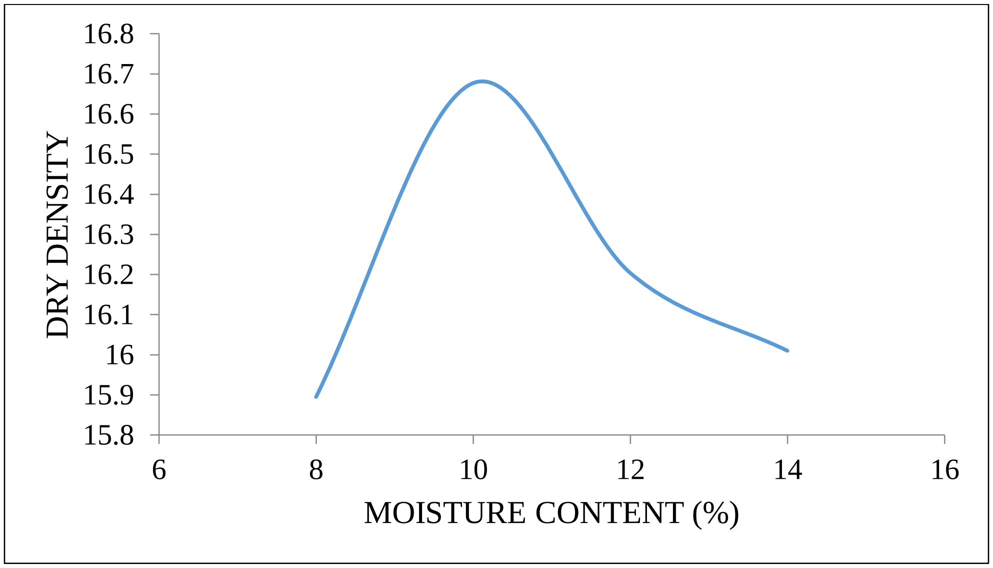

Fig 3.5 Graph between dry density and moisture content

From this graph we found our OMC which comes out to be around 11%.so by taking 11% we did CBR test.

3.8 CALIFORNIA BEARING RATIO (CBR) TEST

The California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of road subgrades and base courses. It was developed by the California Department of Transportation before World War II.

The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area. The measured pressure is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material. The CBR test is described in ASTM Standards D1883-05 (for laboratory-prepared samples) and D4429 (for soils in place in field), and AASHTO T193. The CBR test is fully described in BS 1377 : Soils for civil engineering purposes : Part 4, Compaction related tests.

The CBR rating was developed for measuring the load-bearing capacity of soils used for building roads. The CBR can also be used for measuring the load-bearing capacity of unimproved airstrips or for soils under paved airstrips. The harder the surface, the higher the CBR rating. A CBR of 3 equates to tilled farmland, a CBR of 4.75 equates to turf or moist clay, while moist sand may have a CBR of 10. High quality crushed rock has a CBR over 80. The standard material for this test is crushed California limestone which has a value of 100.

$$\text{CBR}=\frac{p}{p_s}$$

p = measured pressure for site soils [N/mm²]

p_s = pressure to achieve equal penetration on standard soil [N/mm²]

The ratio expressed in percentage of force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2.5 and 5.0 mm. Where the ratio at 5 mm is consistently higher than that at 2.5 mm, the ratio at 5 mm is used.

3.8.1 APPARATUS USED

1. Moulds with base plate stay rod and wing nut
2. Collar
3. Spacer disc
4. Metal Rammer
5. Expansion Measuring Apparatus
6. Weights
7. Loading Machine
8. Penetration plunger
9. Dial gauges –two dial gauges reading to 0.01 mm
10. Sieves- 4.75 mm IS Sieve and 19 mm IS Sieve.

3.8.2 PROCEDURE

The mould containing the specimen with the base plate in position but the top face exposed shall be placed on the lower plate of the testing machine. Surcharge weights, sufficient to produce an intensity of loading equal to the weight of the base material and pavement shall be placed on the specimen. If the specimen has been soaked previously, the surcharge shall be equal to that used during the soaking period. To prevent upheaval of soil into the hole of the surcharge weights, 2.5 kg annular weight shall be placed on the soil surface prior to seating the penetration plunger after which the remainder of the surcharge weight shall be placed. The plunger shall be seated under a load of 4 kg so that full contact is established between the surcharge of the specimen and the plunger. The load and deformation gauges shall then be set to zero (In other words, the initial load applied to the plunger shall be considered as zero when determining the load penetration relation). Load shall be applied to the plunger into the soil at the rate of 1.25 mm/min. Reading of the load shall be taken at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10.0 and 12.5 mm(The maximum load and penetration shall be recorded if it occurs for a penetration of less than 12.5 mm). The plunger shall be raised and the mould detached from the loading equipment. About 20 to 50 g of soil shall be collected from the top 30 mm layer of the specimen and the water content determined according to IS: 2720 (Part 2) – 1973. If the average water content of the whole specimen is desired, water content sample shall be taken from the entire depth of the specimen. The undisturbed specimen for the test should be carefully examined after the test is completed for the presence of any oversize soil particles which are likely to affect the results if they happen to be located directly below the penetration plunger.

Fig 3.6(a) CBR Machine

Fig 3.6(b) CBR Machine

3.8.3 CBR CORRECTION

The load-penetration curve may show initial concavity due to the following reasons:

- The top layer of the sample might have become too soft due to soaking in water.
- The surface of the plunger or the surface of the sample might not be horizontal.

How we apply correction

- Draw a tangent to the load-penetration curve where it changes concavity to convexity.
- The point of intersection of this tangent line with the x-axis is taken as the new origin.
- Shift the origin to this point (new origin) and correct all the penetration values.

3.8.4 CBR TEST READING

PENETRATION(mm)	LOAD(kg)
0.5	8.75
1	27.5
1.5	45
2	77.5
2.5	130
3	182.5
4	225
5	262.5
7.5	315
10	335

Table 3.4

3.8.5 GRAPH

Graph is plotted between penetration on abscissa and load on ordinate.

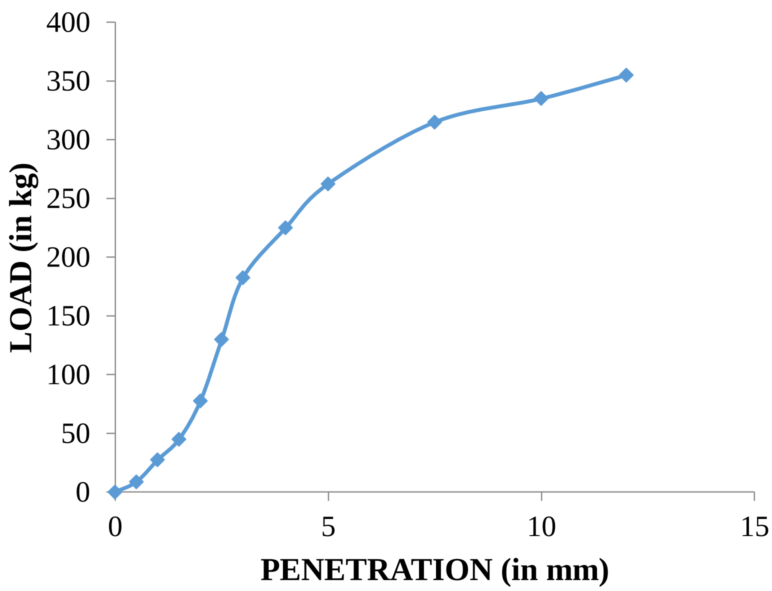

Fig 3.7 CBR graph

3.8.6 CBR VALUE AFTER APPLYING CORRECTION

- CBR at 2.5mm $= \frac{165*100}{1370}$

  $=12.043\%$

- CBR at 5mm $= \frac{280*100}{2055}$

  $=13.6\%$

We will take minimum CBR value so by using CBR value at 2.5mm we find the value of modulus of subgrade (k) corresponding to the value of CBR given in the table 2 of IRC 58-2002.

CBR VALUES (%)	2	3	4	5	7	10	15	20	50
K-VALUE $(N/mm^2/mm)*10^{-3}$	21	28	35	42	48	55	62	69	140

Table 3.5: k value on the basis of CBR value

By Using this Table modulus of subgrade (k) value we get is **5.908** $\frac{kg}{cm^2}$**.** This value is further used to design the thickness of rigid pavement.

3.9 DESIGN OF THICKNESS

The pavement structure is best characterized by slab depth (D). The number of ESALs a rigid pavement can carry over its lifetime is very sensitive to slab depth. At the time of design of thickness we have to kept number of parameters in mind like axle load ,safety factor, stress ratio, expected repetition, fatigue life consume and many other factor also.

- Design period = 20 yrs
- Load safety factor = 1.2
- STRESS RATIO = $\frac{Flexural\ Stress}{Flexural\ strength\ of\ cement\ concrete}$

3.10 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 45kg/cm^3

3.11 THICKNESS OF SLAB

- Trial thickness = 30 cm
- Modulus of subgrade = 5.908 $\frac{kg}{cm^2}$

AXLE LOAD (tonnes)	AXLE LOAD * 1.2	STRESS (Kg/cm^2)	STRESS RATIO	EXPECTED REPETITION	FATIGUE LIFE (N)	FATIGUE LIFE CONSUMED
15	18	21.15	0.47	1274375	5.2*10^6	0.190
12	14.4	22.3	0.495	1036492	1.287*10^6	0.805
9	10.8	13.5	0.3	4460314	∞	0.000
					TOTAL	0.995

Table 3.6: Slab thickness

Using the graph of Stresses in Rigid Pavement (Flexural Stress vs. Slab thickness) in IRC 58, the stress in the above table is calculated. From this stress, stress ratio is obtained by dividing it by modulus of rupture.

Calculation of Fatigue Life (N):

- IF N = unlimited for SR < 0.45
- $N = [\frac{4.2577}{SR-0.4325}]^{3.26}$ When 0.45< SR <0.55
- $N= \frac{.9718-SR}{.0828}$ When SR > 0.55

Our cumulative fatigue life is .995 which is less than one means our design thickness of rigid pavement are safe for fatigue consideration able to resist expected repetition of different axle loads that we are calculated on the basis of traffic survey.

3.12 CHECK FOR TEMPERATURE STRESSES

Temperature stresses are developed in cement concrete pavement due to variation in slab temperature. The variation across the depth of the slab is caused by daily variation whereas an overall increase or decrease in slab temperature is caused by seasonal variation in temperature.

3.12.1 DESIGN PARAMETERS

- L= slab length or spacing between consecutive contraction joints, cm
- B=slab width or spacing between longitudinal joints, cm
- l= radius of relative stiffness, cm

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

$$= \sqrt[4]{\frac{3*105*303}{12*5.908(1-.152)}}$$

$$=103.97cm$$

- C= Bradbury's coefficient which can be ascertained directly from Bradbury's chart against values of L/l and B/l.

Chart for Determination of Coefficient C:

L/l or B/l	C	L/l or B/l	C
1	0.000	7	1.030
2	0.040	8	1.077
3	0.175	9	1.080
4	0.440	10	1.075
5	0.720	11	1.050
6	0.920	12	1.000

Table 3.7: Finding c value

By interpolation and using value of L_x , L_y and l value of C are 0.5156 and 0.2704.

3.12.2 STRESSES IN EDGE REGION

- Warping stress $St_e = \frac{\boldsymbol{Cx*E*\alpha*t}}{\boldsymbol{2}}$

  $= \frac{0.5156*3*105*10-6}{30}$

  $=23.202\ kg/cm^2$

- Edge load stress $S_e = \frac{0.572P}{h2}\left[4\log\left(\frac{l}{b}\right)+.359\right]$

  $=17.59 kg/cm^2$

Total stress combination = 23.202 + 17.59 = 40.799 kg/cm^2 < 45kg/cm^2 the flexural strength. So the pavement thickness of 30cm is safe under the combined action of wheel load and temperature.

3.12.3 STRESSES IN CORNER REGION

- Load stress $S_C = \frac{3p}{h2}\ [1-(\frac{a\sqrt{2}}{l})0.6]$

  $=15.35\ kg/cm^2$

- Maximum Warping stress $St_e = \frac{E*e*t}{3(1-\mu)}\sqrt{\frac{a}{l}}$

  $=13.41\ kg/cm2$

Total stress combination=15.35+13.41 = 28.76 kg/cm^2 < 45 kg/cm^2 the flexural strength. So the pavement thickness of 30 cm is safe under the combined action of wheel load and temperature.

3.13 DESIGN OF JOINTS

There are four types of joints in cement concrete pavement.

- Contraction joint
- Longitudinal joints
- Expansion joints
- Construction joints

Contraction joints: These are purposely made weakened planes which relieve the tensile stresses in the concrete caused due to changes in the moisture content or temperature and prevent the formation of irregular cracks due to restraint in free contraction of concrete.

Longitudinal joints: lanes are jointed together by joint known as longitudinal joint. Longitudinal joints are provided in multilane pavements.

Expansion joints: There are full-depth joints provided transversely into which pavement can expand, thus relieving compressive stresses due to expansion of concrete slabs, and preventing any tendency towards distortion, buckling, blow-up and spalling.

These joints are very difficult to maintain and they get filled up with dirt etc. causing locking of joints. They are therefore not in use. The current practice is to provide these joints only when concrete slab abuts with bridge or culvert.

Construction joints: The need for such joint arises when construction work is required to be stopped at a place other than the location of contraction or an expansion joint, due to some breakdown of the machinery or any other reason. Such joints are of butt type and extend to the full depth of the pavement.

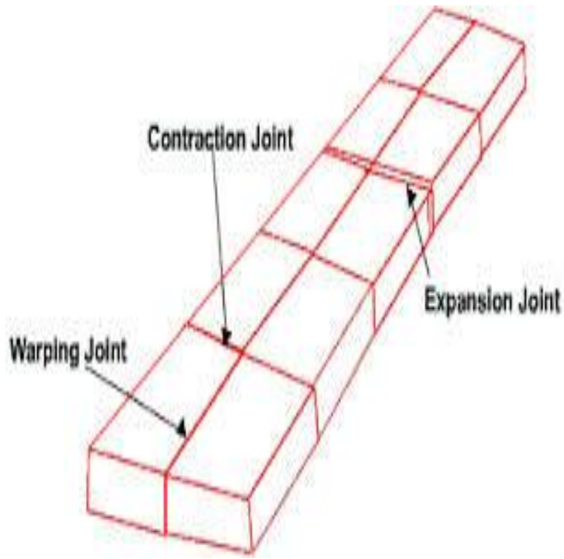

Fig 3.8: Showing different types of joints

3.13.1 DESIGN OF SPACING OF EXPANSION JOINTS

The width or the gap in expansion joint depends upon the length of slab. It is recommended not to have a gap more than 2.5cm in any case. The IRC has recommended that the maximum spacing between expansion joints should not exceed 140m.

Width of expansion joint gap=2.5cm

$$\boldsymbol{Le} = \frac{\boldsymbol{\delta}}{\mathbf{100}*\boldsymbol{c}*(\boldsymbol{T2}-\boldsymbol{T1})}$$

$$\boldsymbol{Le} = \frac{2.5}{100*10*10-6*(30)}$$

$$\boldsymbol{Le} = 41.66m < 140(correct)$$

3.13.2 DESIGN OF SPACING OF CONTRACTION JOINTS

Maximum spacing suggested by the IRC is 4.5m for plain CC pavements.

When reinforcement is not provided in spacing of contraction joints:

$$\mathbf{L_c}=\frac{\mathbf{2Sc*104}}{\mathbf{W*f}}$$

$$\mathbf{L_c}=\frac{\mathbf{2*0.8*104}}{\mathbf{2400*1.5}}$$

$$\mathbf{L_c}=4.44\text{m}$$

Therefore provide spacing of expansion joints=9*4.44=39.96m (As 10*4.44=44.4m which is higher than 41.66m, expansion joints are provided after eight contraction joints or after ninth slab).

3.13.3 DESIGN OF DOWEL BAR

- Assume the diameter of dowel bar ,d=2.5cm
- For equal capacity of dowel bar in bending and bearing.

$$L_d= 5d\sqrt{\frac{Ff*(\text{Ld}+1.5\delta)}{Fb*(\text{Ld}+8.8\delta)}}$$

$$L_d=5*2.5\sqrt{\frac{1400*(\text{Ld}+1.5*2.5)}{100*(\text{Ld}+8.8*2.5)}}$$

$$L_d=42.2cm$$

- Length of dowel bar=Ld+δ=42.2+2.5=44.7cm
- Therefore provide 45cm long dowel bars of diameter 2.5cm.
- Actual value of Ld =45-2.5 =42.5cm.

<u>Load transfer capacity of single dowel bar (P):</u>

- P (shear)=0.785$d^2 Fs$ =4906kg
- P (bending)=$\frac{2d^3\text{Ff}}{\text{Ld}+8.8\delta}$

  =678kg

- P (bearing)=$\frac{F_b * Ld^2 * d}{12.5(Ld+1.5\delta)}$

$=\frac{100*42.52*2.5}{12.5(42.5+1.5*2.5)}$

$=781kg$

Taking the lowest of the three values for design, load capacity of a dowel bar, P=678kg

Required load capacity factor:

Load capacity of dowel group $=\frac{40}{100}*7500$

$=3000kg$

Required capacity factor for dowel group $=\frac{3000}{678}$

$=4.42$

Spacing of dowel bars:

Effective distance upto which there is load transfer=1.8l

=103.97*1.8=187.146cm

Assuming a trial spacing of 30cm between the dowel bars

Capacity factor available for the group = $1 + \frac{l-s}{l} + \frac{l-2s}{l} + \frac{l-3s}{l}$+…….

$=1+ \frac{187.146-30}{187.146} + \frac{187.146-(2*30)}{187.146} + \frac{187.146-(3*30)}{187.146} + \ldots$

$= 3.622$

This value of capacity factor available is less than capacity factor required i.e. ;4.42

∴ Assuming a closer spacing of 25cm

Capacity factor available for the group = $1 + \frac{l-s}{l} + \frac{l-2s}{l} + \frac{l-3s}{l}$+…….

$=1 + 0.866 + .732 + .599 + .465 + .332 + .198 + .064$

$= 4.25 < 4.42$

∴ Assuming a closer spacing of 20cm

Capacity factor available for the group = $1 + \frac{l-s}{l} + \frac{l-2s}{l} + \frac{l-3s}{l}$+…….

$= 1 + .893 + 0.7862 + 0.679 + 0.572 + 0.465 + .3587 + 0.251 + .145 + .03$

$= 5.187 < 4.42$

Dowel bars of total length 45cm at 20cm spacing.

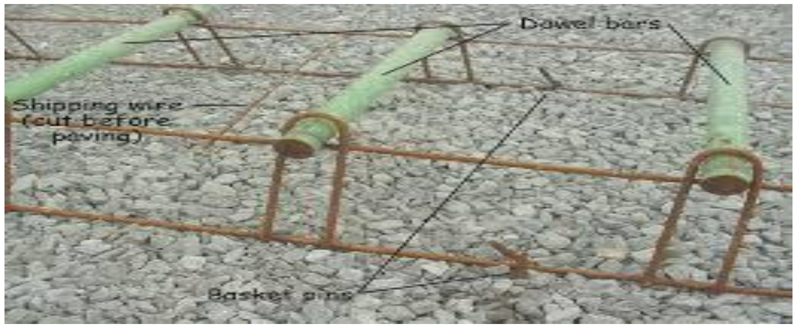

Fig. 3.9: Dowel bar arrangement

3.14 DESIGN OF TIE BAR

In contrast to dowel bars, tie bars are not load transfer devices, but serve as a means to tie two slabs. Hence tie bars must be deformed or hooked and must be firmly anchored into the concrete to function properly. They are smaller than dowel bars and placed at large intervals. They are provided across longitudinal joints.

3.14.1 DIAMETER AND SPACING

The diameter and the spacing is first found out by equating the total sub-grade friction to the total tensile stress for a unit length (one meter). Hence the area of steel per one meter in cm^2.

$$A_s = \frac{bfhW}{100 * Ss}$$

$$= 2.7\ cm^2/m \text{ length}$$

Using 1cm dia. bars having area of cross section as=0.785cm^2

Perimeter of tie bar = 3.14cm

No. of tie bars required /meter length of joint

$$= \frac{As}{as} = \frac{2.7}{0.785} = 3.44$$

- Spacing of tie bar=100/3.44=29.06cm

Provide a spacing of tie bar, say 25cm.

3.14.2 LENGTH OF TIE BAR

Length of the tie bar is twice the length needed to develop bond stress equal to the working tensile stress.

$$= \frac{d * Ss}{2Sb}$$

= 28.5 cm

The length of the tie bar may be increased by 5cm for tolerance in placement. Provide 1cm dia deformed tie bars, 34 cm in total length at a spacing of 25cm

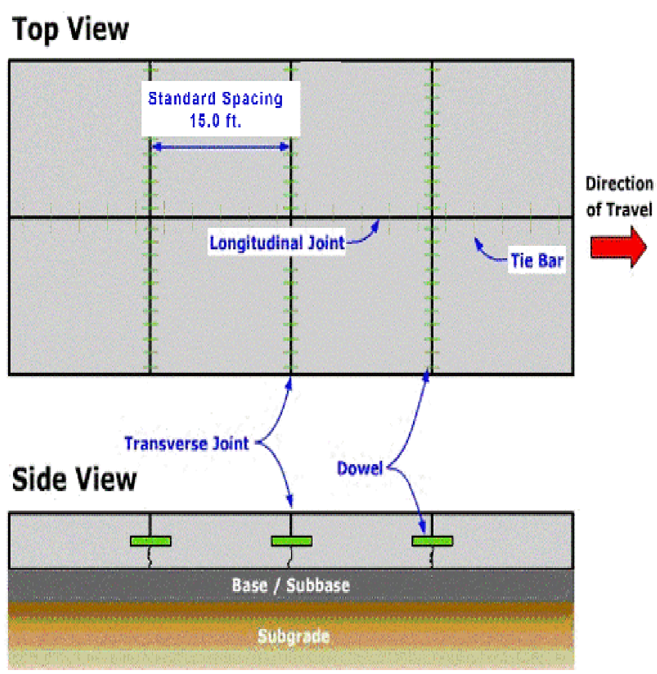

Fig 3.10: Different views of tie bar and dowel bar

3.15 COST ESTIMATION

Every Estimate should be accompanied by the analysis of rates of the items provided in it. Analysis of rates comprises of cost of material, cost of labour , tool& plants, sundries, carriage, contractor’s profit.

Tools and Plants (T & P) = 2.5 to 3 % of the labour cost

Transportation cost more than 8 km is considered.

Water charges = 1.5 to 2 % 0f total cost.

Contractor‘s profit = 10 %.

In this we are calculating the cost of 1km (1000mtr) stretch .on the basis of this we can calculate cost of overall stretch under consideration from mehli to shoghi.

- Height of slab = 30 cm
- Breadth of each slab is 3.5 m with 2.5cm spacing between two slab in longitudinal direction.
- Length of each slab is 4.44 m with 2.5 cm spacing between two slabs in transverse direction.
- It is two lane road. So total breadth is 7.025m including spacing.

Calculation of cost estimation

Calculating Quality of Materials Used in rigid pavement	***Calculation of Cost***
a)Total volume of material used in 1km stretch	1000*3*7.025=2107.5 m^3
b)Total number of concrete slab in 1km stretch	1000/4.44+0.25=223.96m^3
c)Volume of spacing between concrete slab in transverse direction	0.025*30*7*223=11.7075m^3
d)Volume of spacing between concrete slab in longitudinal direction	1000*.025*30=7.5m^3
Finding volume of dowel bar steel embedded in slab	
a)Diameter of bar use for dowel bar	2.5cm
b)Embedded length of dowel bar	42.5cm
c)Spacing between dowel bars	20cm
d)Number of dowel bars in 223 transverse spacing	700/20*223=7805
e)Volume of dowel bar steel embedded in concrete slab	π/4*.0252*.425*7805=1.6823m^3
Finding volume of tie bar embedded in slab	

a)Diameter of tie bar use	1cm
b)Spacing between tie bars	25cm
c)Embedded length of tie bar	31.5cm
d)Number of tie bars	1000-.025*223/25=40
Calculating Quality of Materials Used in rigid pavement	***Calculation of Cost***
e)Volume of tie bar steel embedded in slab	π/4*.012*.315*40=9.896*10^{-4}m^3
Net total volume of steel used	
volume of dowel bar steel + volume of tie bar steel	π/4*.0252*45*7805*7700+π/4*.012*34*40*770
	13824.2kg
Net total volume of concrete used	2107.5-11.707-7.5-(9.896*10-4)-1.628
	2086.66m^3
Dry materials required for 2086.66cu m cconcrete 1:1.65:2.92	
a)Sum of ratio	1+1.65+2.92=5.57
b)Total dry mortar for 1 cu m cement concrete	1.54cu m
(i)calculating quality of materials used in rigid pavement	3213.45cu m
d)Net quantity of cement	3213.45*28.8/5.57=16615.35bags
e)Net quantity of F.A	3213.45*1.65/5.57=95191m^3
f)Net quantity of C.A	1684.6m^3
Calculating Cost	
Materials at site for 2086.66 cu m	**Payment**
a) Cement 16615.35 bags @310 bag	5150758.5Rs.
b)Fine aggregate 951.91 cu m @ 300per cu m	285573Rs.
c)Coarse aggregate 1684.6 cu m @581 per cu m	978753Rs
d)Steel 13284 kg @ 43 per kg	571222Rs.
TOTAL	6105428Rs.
e)Water charges =1.5 to 2% of total cost	
(f)Contractors profit =10%	
TOTAL COST	1.12*6105428=68,38,079.36Rs
(g)Net cost of rigid pavement per	75,21,887Rs.

km = Total+ 10% of Total cost	
<u>Cost Estimation of Flexible Pavement</u>	
a)Base & Bituminous course	Rs.13.36 Crores
Cost per km stretch	13,36,19,780/20 = 6680989Rs.
Net cost of flexible pavement per km	6680989+ 15% of 6680989= 7683137Rs.
<u>Comparison of Cost</u>	
a)Cost of flexible pavement per km	**76.83lacs**
b)Cost of rigid pavement per km	**75.21lacs**

Table: 3.8 Abstract of cost

The rigid pavement was found to be more feasible in comparison to flexible pavement design in terms of maintenance.

RESULTS AND DISCUSSIONS

4.1 RESULTS

- The traffic volume count per day for Shoghi-Mehli road stands as follows:-
  - Trucks (Heavy Load Vehicles)= 300 units
  - Buses (Passenger vehicles)=250 units
  - Jeeps ((Light Load vehicles)= 1050units
  - Two-wheelers (< 3Tonnnes)=410 units

  Traffic volume count was used to calculate design traffic = 6796669 units.
- The optimum moisture content according to Light Weight Proctor Test =11%
- CBR value done at optimum moisture content at 2.5mm = 12.043%
- CBR value done at optimum moisture content at 5.0mm = 13.6%.
- The k-value on the basis of CBR value= 5.908 Kg/cm^2
- Thickness of proposed slab= 30cm
- Spacing of Expansion Joints =41.667m
- Spacing of Contraction Joints =4.44m
- Length of Dowel bars (provided)=45cm, 2.5cm-dia.,20cm spacing
- Length of Tie bars (provided)=34cm, 1.0cm-dia.,25cm spacing
- Cost of rigid Pavement per Km=Rs.75,21,887
- Cost of flexible Pavement per Km=Rs.76,83,137

4.2 DISCUSSIONS

On comparing our traffic survey results with the results done by the state H.P.P.W.D.'s traffic survey which was done when they constructed the road five years back we found a cumulative increase in number of vehicles per day from 1740 to 2010 .

Also our optimum water content is nearly equal to that of the tests done by the state P.W.D. which was the base of our calculations for CBR test. Here, the CBR test performed by us with utmost care but the final value cannot be exact because during the experiment we experienced the failure of CBR test machine and thus we can say it is near to the exact value.

Further, we followed IRC: 58-2002 as the base for our design calculations. 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 temperature differentials between top and bottom fibers 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 temperature changes and are not normally considered critical to thickness design. All the calculations for the thickness of slab for rigid pavement, expansion joints, contraction joints, dowel bar, tie bar were made on the assumptions and formulas proposed by the code. Here, our cumulative fatigue life is 0.995 which is < 1, which means our design thickness of rigid pavement is safe for fatigue consideration. Thus, taking into account all the conditions we come up with the value of 30cm as the thickness of the rigid pavement.

All the other parameters like spacing of joints, length of dowel bars, tie bars are within the permissible ranges according to IRC:58-2002.So we can say that our design fully safe and can serve safely with proper maintenance for the next 20 years.

Also the rigid pavement along with giving good serviceability is economical than the flexible pavement as for every 1Km of rigid pavement there is a decrease by 2% of the cost for 1km of flexible pavement. Hence, we can say our design is economical too.

CONCLUSION

- In the current work, we design and analyze the feasibility of rigid pavement on a stretch of Mehli-Shoghi road using DPR (detailed project report) provided by NHAI (National Highways Authority of India) and IRC: 58-2001 code for design of plain jointed rigid pavements for highways.
- After the site visit and traffic survey of the road under consideration, the percentage of axle load for different vehicles, cumulative repetition, and expected repetition was determined. Also the OMC was obtained by doing light weight compaction proctor test on soil sample collected from site and was determined to be around 11%.
- At moisture content of 11% CBR test was done and obtained a value of 12.04% at 2.5mm and 13.6% at 5mm. With the help of table 2 of IRC 58 – 2002, the value of modulus of subgrade (k) was calculated to be 5.908 kg/cm^2.
- By using simple techniques given in IRC 58, depth of rigid pavement is determined which was found to be 30cm and this pavement thickness of 30cm was found safe under the combined action of wheel load and temperature stresses.
- For finding the quantity of steel to be used in rigid pavement we design the length and spacing of dowel and tie bars and the quantity of cement, sand and coarse aggregate were calculated from the ratio of M40 grade concrete. The quantities of steel, cement, sand and coarse aggregate was found to be 13284 kg, 16615 bags, 951.91m^3 and 1684.6 m^3 respectively.
- On the basis of these quantities, the cost of rigid pavement was calculated and compared to the cost of flexible pavement. On comparing cost for both pavements we can conclude that the cost of rigid pavement is less than cost of flexible pavement in long term. So, the work proposed is to make rigid pavement at the given stretch instead of flexible pavement. It was also inferred that rigid pavement may require less maintenance and better serviceability in comparison to flexible pavement.
- FUTURE SCOPE OF WORK
    - Along with the design of rigid pavement one should try to design rigid pavement with camber so that drainage problem can be handled efficiently.

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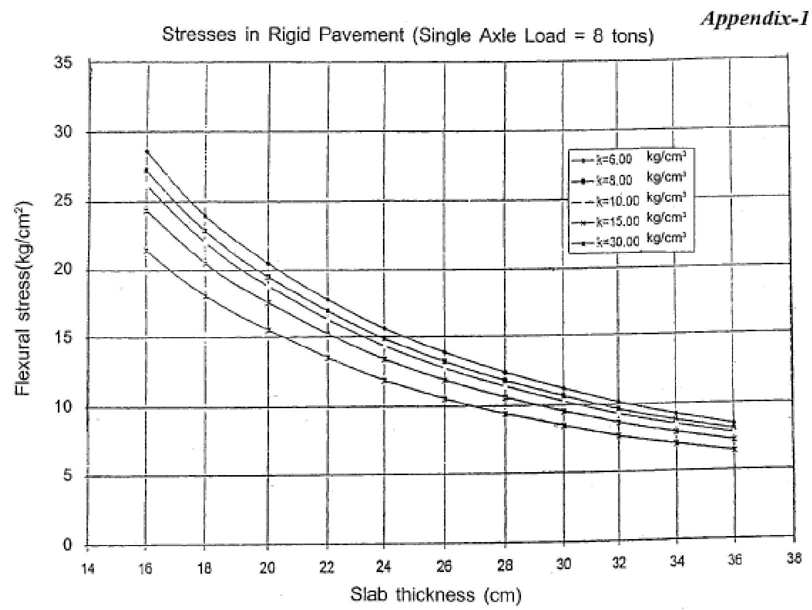
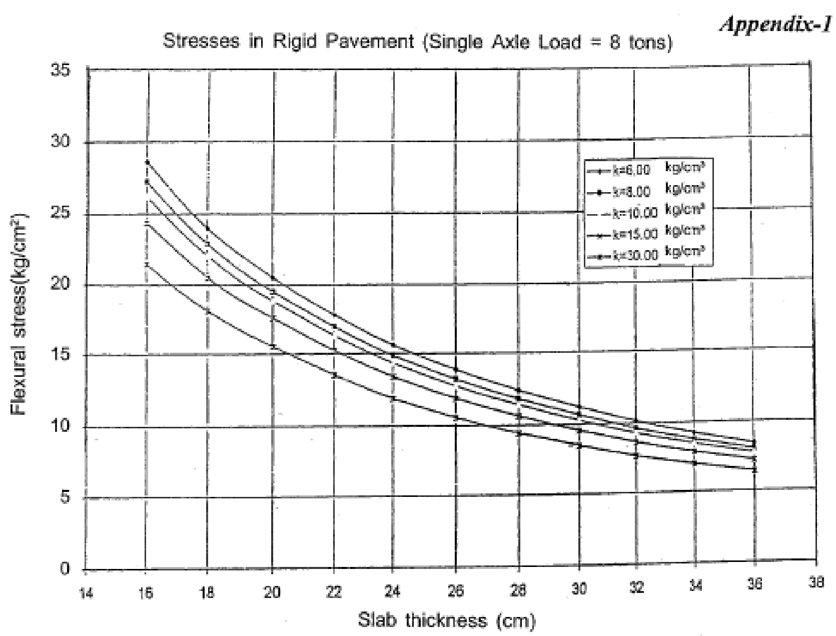
APPENDIX-A

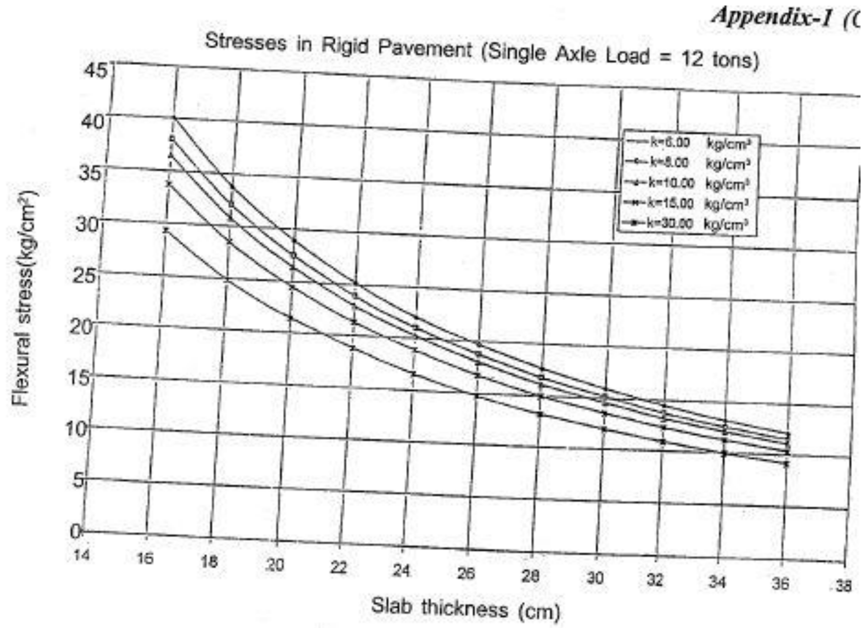
GRAPHS DETERMINING STRESS IN RIGID PAVEMENT (IRC- 58)



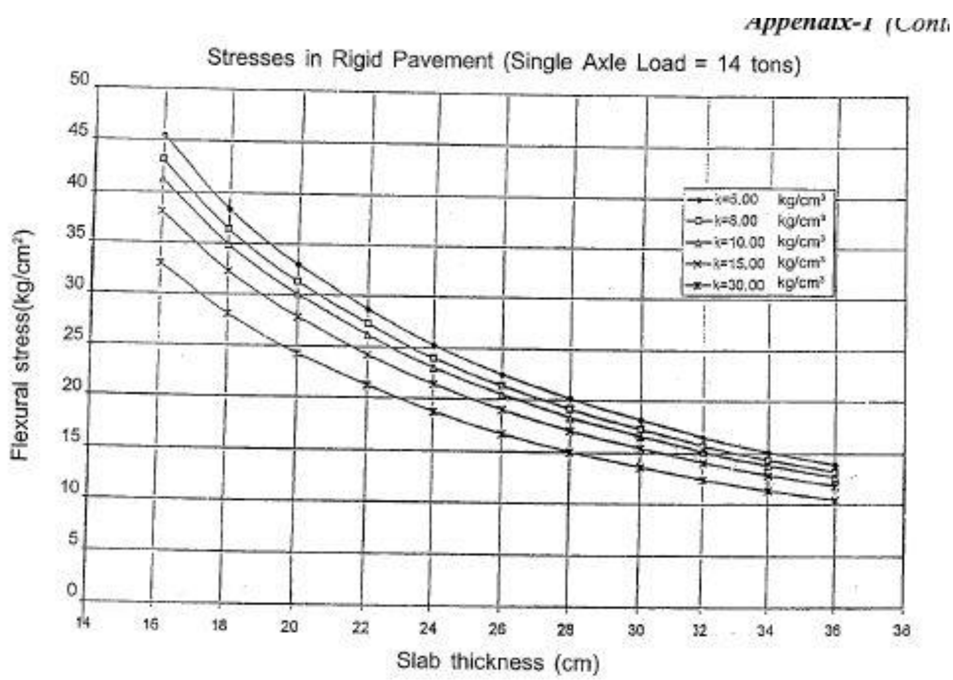
Stress in rigid pavement for 8 ton single axle load



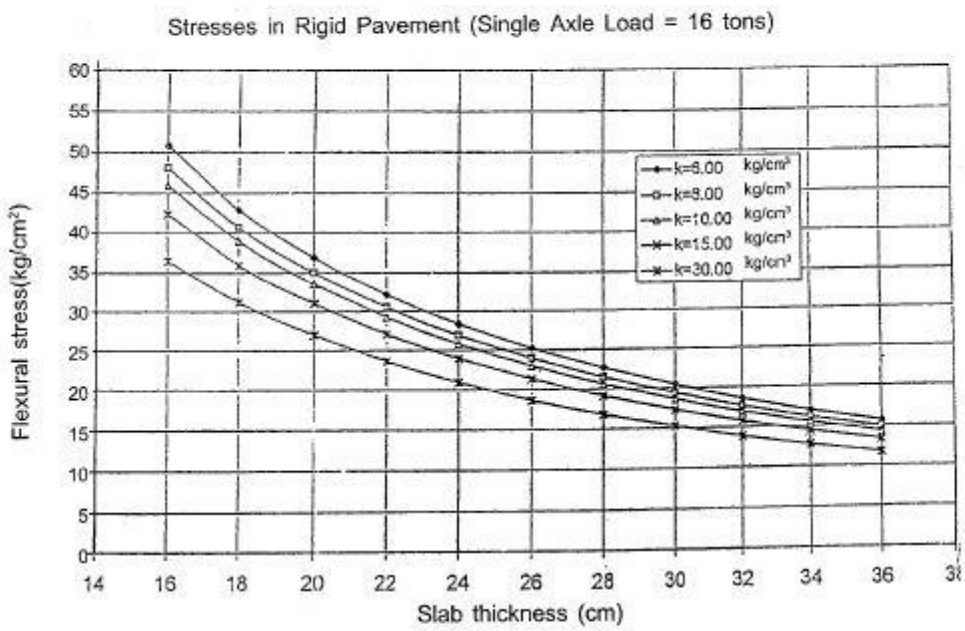
Stress in rigid pavement for 10 ton single axle load



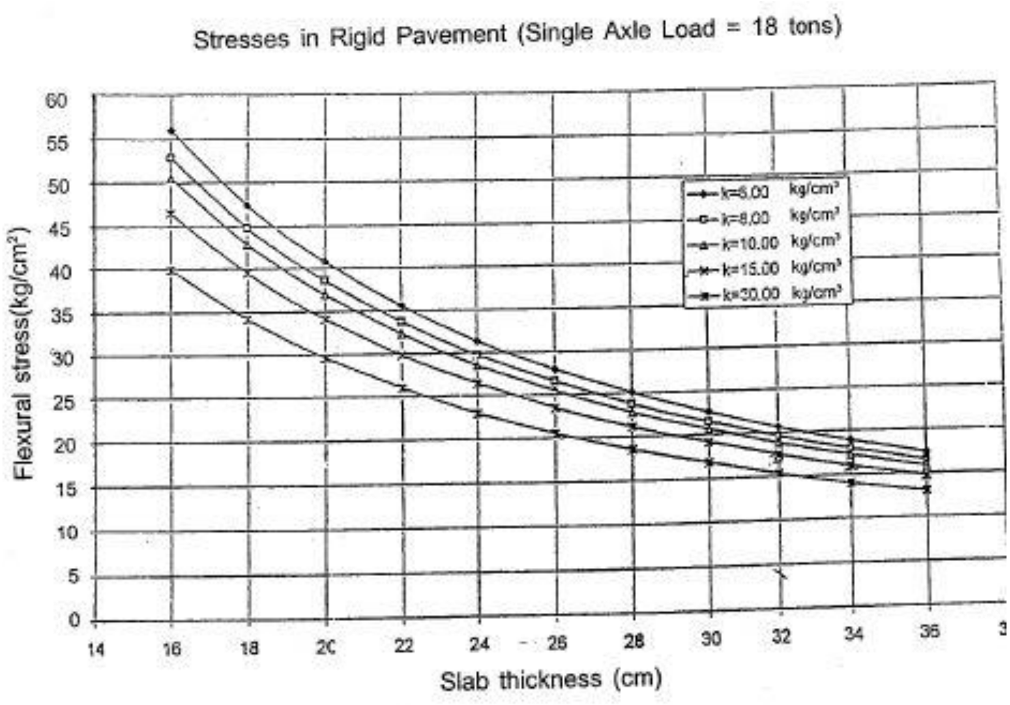
Stress in rigid pavement for 12 ton single axle load



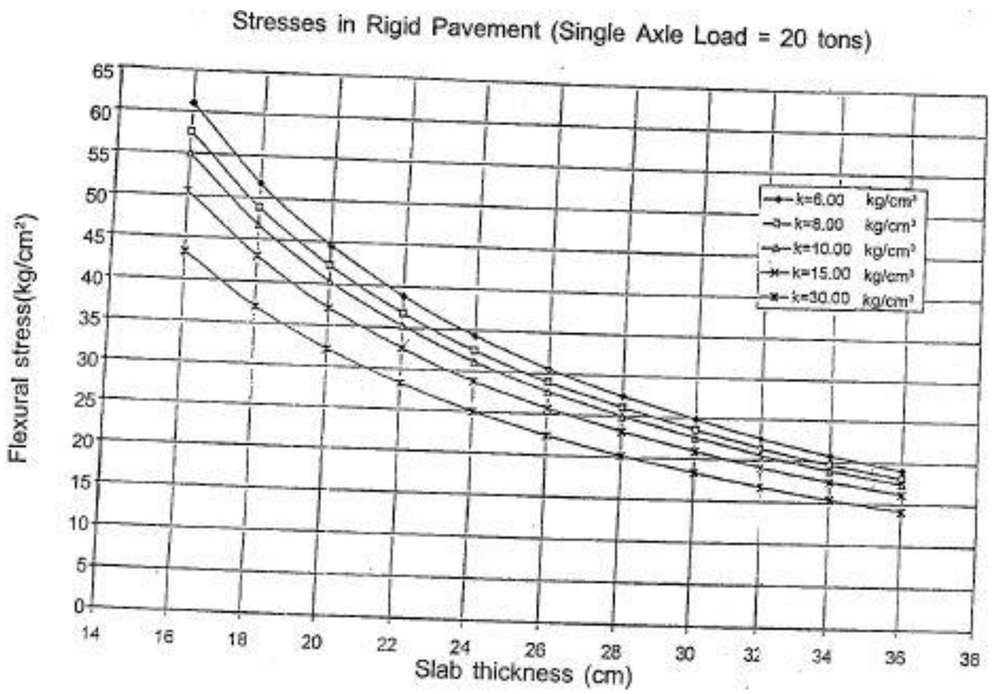
Stress in rigid pavement for 14 ton single axle load



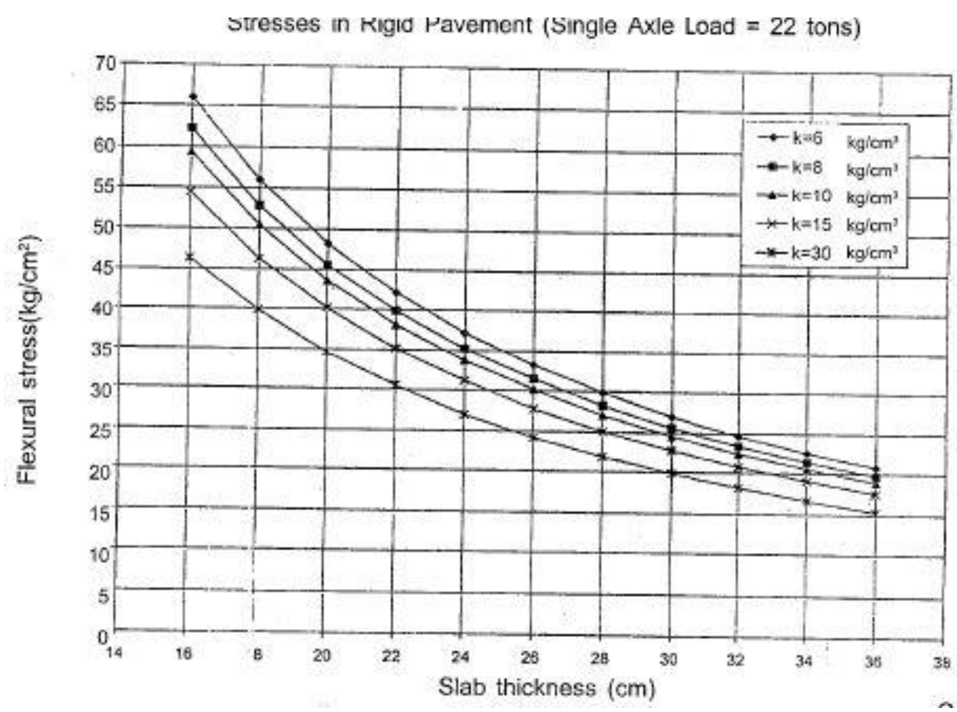
Stress in rigid pavement for 16 ton single axle load



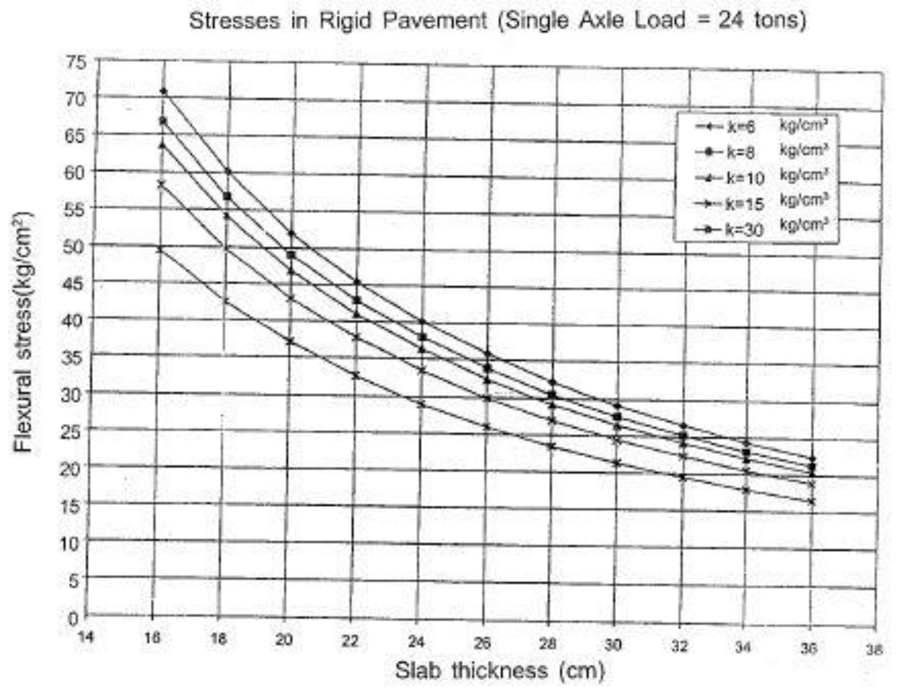
Stress in rigid pavement for 18 ton single axle load



Stress in rigid pavement for 20 ton single axle load



Stress in rigid pavement for 22 ton single axle load



Stress in rigid pavement for 24 ton single axle load