

UNIT - 5

Design pavements

Surface course
base course
Subbase
Subgrade

Functions of the pavement:

- * To distribute the function of the pavement applied vehicle loads through the Subgrade
- * To provide the axis between the two points during all the weather conditions.
- * To provide the smooth, comfortable, economical transportation without any delays.
- * To provide the surface of acceptable riding quality.
- * To provide the aggregate skid resistance
- * To provide the light reflecting characteristics.

Requirements of Ideal pavements (good pavements)

- * To provide the sufficient thickness.
- * To distribute the wheel loads from the surface course to subgrade.
- * To provide the sufficient thickness

- * To provide the structural support to withstand stresses developed on the surface
- * To provide coefficient of friction, to resist the skidding.
- * To provide smooth riding quality for the road users.

* The life span for the pavement high, with low maintenance cost.

Types of pavements

1. flexible pavement
2. Rigid pavement
3. Composite pavement
4. Interlocking cement concrete pavements.

1. Flexible pavements:

* The load is transmitted to the surface coarse by grain to grain contact of the aggregates.

ex: Bituminous pavements.

* The flexural strength is low.

2. Rigid pavements:

The load is transmitted from the surface coarse to the subgrade to the rigid plates.

ex: CC Roads

3. composite pavements:

A thin layer of bituminous coarse laid on the rigid pavements is called as composite pavements.

4. Interlocking cement concrete pavements:

The cement concrete paver blocks is prepared by the specified size, strength. is directly placed on the subgrade.

Differences between the flexible pavements and rigid pavements

Point of difference	F.P	R.P
life span	low (15 years)	High (30 years)
thickness	more (4-5 layers)	less (3 layers)
Joints	Not required	Required (-transfer joints)
Durability.	less	more
Temp effects	No stresses developed	Stresses developed
Opening to traffic	opened after the construction.	It requires curing after the construction.

Functions of pavement components

a. Subgrade

b. Subbase

c. base course

d. Surface course

a. Subgrade:

It is the lowest layer of the pavement system.

The soil subgrade layer may be natural or selected soil from borrow pits for fulfilling the specified requirements of the subgrade.

The thickness of the subgrade is 500 mm for the expressways, national highways and state highways and 300 mm for the other roads which carry the low volume of traffic.

The subgrade layer and other pavement layers should be well graded.

The strength of the subgrade soil is determined.

(i) CBR

(ii) plate load test

(iii) Triaxial compression test

(iv)

b. functions of sub base:

It is the layer ~~the~~ above the Subgrade.
It act as a drynaga layer.

The load transferred from base coarse to subgrade. crushed stone aggregates is used as a subbase.

c. functions of base coarse:

It is the layer above the subbase (or) below the surface coarse.

Sustain the wheel loads & distribute the loads from surface coarse to the sub base.

It increases the load carrying capacity of the pavement.

The purpose of the subbase & base coarse transmitting the loads from the surface coarse to the sub grade, (transmitting medium).

d. functions of the surface coarse:

It is the top layer of the pavement systems. the surface coarse gives the good riding surface for the vehicles.

It sustain the pressures from the wheels.

For the flexible pavements bituminous surface is used as a surface coarse.

cement concrete slab is used as a surface course in the rigid pavement.

Factors to be considered in design of pavements

Design wheel load

subgrade ~~max~~ soil

climatic factors.

Pavement component materials

Environmental factors

Speed factors

1. Design wheel load!

→ Max. wheel load

→ contact pressure

→ dual (or) multiple, Equivalent Single wheel load

→ Repetition of loads

* The thickness of the pavement is depend on the design wheel load

* If the wheel load is high, the thickness of the pavement is more and vice versa.

* If providing the (~~aggregate~~) sufficient thickness of the pavement, the subgrade soil is good.

Max wheel load:

The total load influences the thickness of the pavement

The vertical stress at a depth of z from the surface.

$$\sigma_z = P \left[1 - \frac{z^3}{(a^2 + z^2)^{3/2}} \right]$$

where $\sigma_z \rightarrow$ vertical stress at a depth of z

$P \rightarrow$ pressure developed in the surface

$z \rightarrow$ depth (for finding the σ_z)

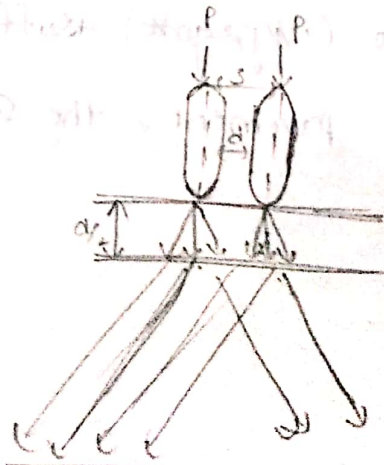
$a \rightarrow$ radius of the contact

contact pressure:

It is defined as the load on the wheel by contact area.

(Dual or multiple) Equivalent single wheel load:

To maintain the max. load with the specified load limit and carry the heavy wheel loads of the rear axle.



Where $s \Rightarrow$ spacing b/w the center to center.

$d =$ clear gap b/w the wheel.

Repetition of loads:

When the load is applied continuously.

Subgrade Soil:

The thickness of pavement is depends upon the strength of Subgrade.

The strength of Subgrade is low. The thickness of pavement is high. The properties of the Subgrade depends on the stability, Incompressibility, strength, ease of compaction, Drainage conditions.

climatic factors:

Rain-force

Temperature

The groundwater water table at least 1m below the pavement due to the temperature variations the stresses are induced in

The materials used in the pavement should possess sufficient strength and durability under all weather conditions.

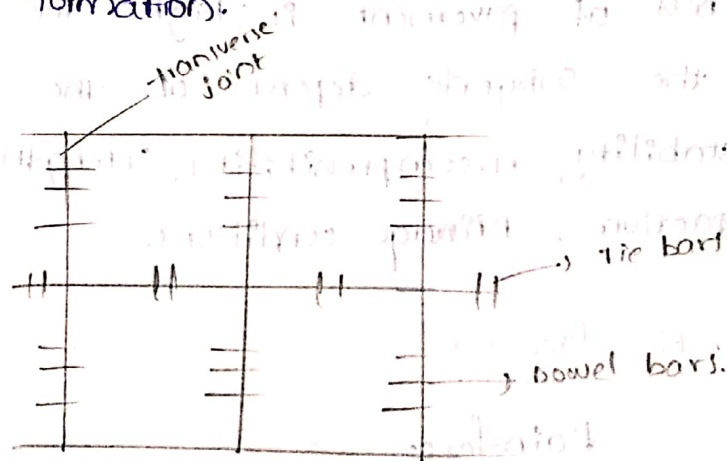
Environmental factors:

1. depth of cutting
2. Height of the embankment
3. details of the foundation.
4. Ground water table.

Ground water table

Special factor:

The materials used in the composite pavements possess sufficient strength and observed the development of the cracks and also formation.



Stresses in the rigid pavements!

1. wheel load stresses
2. warping stresses.
3. frictional stresses

* The wheel load stresses are produced heavy vehicle loads move on the pavement surface.

* The warping stresses and frictional stresses are developed due to the temperature variations.

Analysis of stresses by Westergaard's theory:

Assumptions:

→ The rigid pavement slab assumed as a thin elastic plate

→ The upward pressure which directly proportional to the deflection.

$$P \propto \Delta$$

$$P = K \Delta$$

Where $K \rightarrow$ modulus of subgrade reaction.

Formulas

1. K :

$$K = \frac{P}{\Delta}$$

$$= \frac{P}{0.125}$$

$$\left[\begin{array}{l} A = 0.125 \text{ cm} \\ 75 \text{ cm dia plate} \end{array} \right]$$

↓
standard plate.

2. Radius of Relative stiffness: (l)

$$l = \left[\frac{E h^3}{12 K (1 - \mu^2)} \right]^{1/4}$$

Where $l \rightarrow$ radius of relative stiffness in cm.

$h \rightarrow$ slab thickness in (cm.)

$k \rightarrow$ modulus of subgrade reaction in kg/cm^2

$\mu \rightarrow$ poissions ratio for concrete. $[0.15]$

$E \rightarrow$ elastic modulus of the concrete.
 kg/cm^2

3. Equivalent radius of resisting section: (b)

$$b = \sqrt{1.6a^2 + h^2} - 0.675h \quad [a < 1.724h]$$

$$b = a \quad [a > 1.724h]$$

Where $b \rightarrow$ Equivalent radius of resisting section in cm

$a \rightarrow$ radius of wheel load distribution in cm

$h \rightarrow$ slab thickness in cm

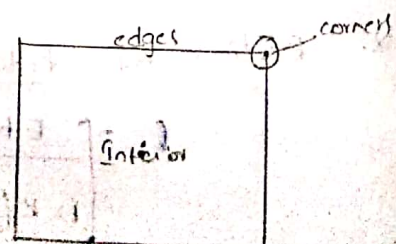
4. critical positions of loading:

The maximum stress induced by the application of heavy loads on the location of pavement surface.

(i) Interior of the slab

(ii) Edges

(iii) corner



Wheel loads stress eq's by using Westergaard's analysis:

Formulas

1. Stresses at interior:

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

2. Stresses at edges:

$$S_e = \frac{0.507 P}{h^2} \left[4 \log_{10} (l/b) + 0.359 \right]$$

3. Stresses at corner:

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

Where S_i, S_e, S_c are the wheel load stresses at the interior, edge, corner respectively.

$P \rightarrow$ wheel load in kg.

$l \rightarrow$ radius of relative stiffness in cm

$h \rightarrow$ slab thickness in cm

$b \rightarrow$ equivalent radius of resisting section in cm.

$a \rightarrow$ radius of wheel load distribution in cm.

Modified stress equations for the wheel loads:

1. Edge load stress equation by the Telles & Sutherland.

$$S_e = 0.509 \frac{P}{h^2} [1 + 0.54u] \left[4 \log_{10} (l/b) + \log_{10} b - 0.4046 \right]$$

2. corner load stress equation by the Kelley

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

where S_c, S_e are the wheel load stresses at corner and edge respectively produced by the wheel load in kg/cm.

Temperature stresses:

Due to the variation of the temperature in the rigid pavement the following stresses are developed.

1. warping stresses
2. frictional stresses.

1. Warping stresses:

Due to the daily variation of the temperatures there is a difference b/w the top and bottom surface of pavement.

Warping stress at the interior

$$S_{t(i)} = \frac{Eet}{2} \left[\frac{C_x + \mu C_y}{1 - \mu} \right]$$

Warping stress at the edge

$$S_{t(e)} = \frac{Eet C_x}{2} \quad \text{or} \quad \frac{Eet C_y}{2} \quad [\text{whichever is higher}]$$

Warping stress at the corner

$$S_{t(c)} = \frac{Eet}{3(1-\mu)} \sqrt{\frac{a}{l}}$$

Where $S_{t(i)}$, $S_{t(e)}$, $S_{t(c)}$ are the warping stresses induced at the interior, edge, corner in kg/cm^2 .

$E \rightarrow$ Elastic modulus of the concrete in kg/cm^2 .

$e \rightarrow$ coefficient of thermal expansion of concrete for $^{\circ}\text{C}$.

$t \rightarrow$ temp. difference b/w bottom & top surfaces.

$\mu \rightarrow$ poisson's ratio for the concrete (0.15)

$C_x \rightarrow$ coefficient in x-direction, it depends on $\frac{L_x}{l}$

$C_y \rightarrow$ coefficient in y-direction, it depends on $\frac{L_y}{l}$

L_x, L_y are the length and width of the slab.

a. frictional stresses:

Due to the seasonal variations of the temperature there is a expansion and contraction of the slab.

The slab is in contact with the supporting layer below the slab and the movements of the slab is restricted by the frictional force developed b/w the bottom of the pavement and the supporting layer.

frictional stress

$$S_f = \frac{W L_c f}{2 \times 10^4}$$

Where $S_f \rightarrow$ frictional stress

$W \rightarrow$ unit weight of concrete.

$f \rightarrow$ coefficient of friction [1.5]

$L_c \rightarrow$ slab length

Critical combination of stresses:

* compressive -ve
* tensile +ve

(i) During Summer Season

= wheel load stress + warping stress - frictional stress

(ii) During winter season

= wheel load stress + warping stress + frictional stress.

(iii) At the corner region there is no development of frictional force.

= W.L.S + W.P

[At corner frictional force is zero]

* using the data calculate the wheel load stresses at (i) Interior (ii) Edge (iii) corner

By using the Westergaard's stress equations, and modified equation of Telles and Sutherland at the edge load condition. and modified eq'n of Kelley at the corner region.

Wheel load $P = 5100 \text{ kg}$

Modulus of elasticity of concrete $= E = 3 \times 10^5 \text{ kg/cm}^2$

pavement thickness $h = 18 \text{ cm}$

Poisson's ratio for the concrete $\mu = 0.15$

Modulus of Subgrade reaction $K = 6 \text{ kg/cm}^2$

Radius of contact area $a = 15 \text{ cm}$.

* Radius of relative stiffness

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

$$l = \left[\frac{3 \times 10^5 \times 18^3}{12(6)(1-0.15^2)} \right]^{1/4}$$

$$l = 70.61 \text{ cm}$$

*

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

$$a < 1.724h ; \quad a > 1.724h$$

1.724h is greater than a (31.03)

(or)

$$a/h = \frac{15}{18} = 0.83$$

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

$$b = 14.17 \text{ cm}$$

Westergaard's stress eqs.

$$\begin{aligned}
 S_i &= \frac{0.316 P}{h^2} \left[4 \log_{10} (l/b) + 1.069 \right] \\
 &= \frac{0.316 (5100)}{18^2} \left[4 \log_{10} \left(\frac{70.61}{14.17} \right) + 1.069 \right] \\
 &= 4.97 \text{ (21.00) } 3.85 \\
 &= 104.037 \cdot 19.17 \text{ kg/cm}^2
 \end{aligned}$$

$$\begin{aligned}
 S_c &= \frac{0.527 P}{h^2} \left[4 \log_{10} (l/b) + 0.359 \right] \\
 &= \frac{0.527 (5100)}{18^2} \left[4 \log_{10} \left(\frac{70.61}{14.17} \right) + 0.359 \right] \\
 &= 8.29 \text{ (3.14)} \\
 &= 26.04 \text{ kg/cm}^2
 \end{aligned}$$

$$\begin{aligned}
 S_c &= \frac{3P}{h^2} \left[1 - \left(\frac{a\sqrt{2}}{l} \right)^{0.6} \right] \\
 &= \frac{3 \times 5100}{18^2} \left[1 - \left(\frac{15\sqrt{2}}{70.61} \right)^{0.6} \right] \\
 &= 24.27 \text{ kg/cm}^2
 \end{aligned}$$

location where the crack is to develop due to corner loading.

$$x = 2.58 \sqrt{al}$$

$$x = 2.58 \sqrt{15 \times 70.61} = 83.96 \text{ cm}$$

Modified stress eqns (teller & Sutherland) at edge

$$S_e = 0.529 \frac{P}{h^2} [1 + 0.54 u] \left[4 \log_{10} \left(\frac{1}{b} \right) + \log_{10} b - 0.4048 \right]$$

$$= 0.529 \left[\frac{5100}{18^2} \right] [1 + 0.54 (0.15)] \left[4 \log_{10} \left(\frac{70.61}{14.17} \right) + \log_{10} (14.17) \right.$$

$$\left. - 0.4048 \right]$$

$$= 31.83 \text{ kg/cm}^2$$

~~31.83~~

Modified stress eqn (Kelly) at corner

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

$$= \frac{3(5100)}{18^2} \left[1 - \left(\frac{15\sqrt{2}}{70.61} \right)^{1.2} \right]$$

$$= 36.06 \text{ kg/cm}^2$$

Calculate the stresses at the corner, interior and edge regions of the cement concrete slab using the westergaard's eq'n with the following data.

Radius of relative stiffness $l = 80 \text{ cm}$.

Wheel load, $P = 5100 \text{ kg}$

Elasticity modulus of concrete $E = 3 \times 10^5 \text{ kg/cm}^2$.

pavement thickness $h = 18 \text{ cm}$.

modulus of subgrade reaction $k = 6 \text{ kg/cm}^2$.

radius of contact area $a = 15 \text{ cm}$

$$* \quad 15 < 31.03$$

$$a < 1.724h$$

$$a > 1.724h$$

$$b = \sqrt{1.6a^2 + h^2} - 0.625h$$

$$b = 26.15 - (0.625 \times 18) = 14 \text{ cm}$$

Westergaard's Stress eqⁿs

$$\begin{aligned}
 S_p &= \frac{0.316P}{h^2} \left[4 \log_{10}(l/b) + 1.069 \right] \\
 &= \frac{0.316(5100)}{18^2} \left[4 \log_{10}\left(\frac{20}{14}\right) + 1.069 \right] \\
 &= 8.39 \text{ kg/cm}^2
 \end{aligned}$$

$$\begin{aligned}
 S_e &= \frac{0.527P}{h^2} \left[4 \log_{10}(l/b) + 0.359 \right] \\
 &= \frac{0.527(5100)}{18^2} \left[4 \log_{10}\left(\frac{20}{14}\right) + 0.359 \right] \\
 &= 8.12 \text{ kg/cm}^2
 \end{aligned}$$

$$\begin{aligned}
 S_c &= \frac{3P}{h^2} \left[1 - \left(\frac{a\sqrt{2}}{l} \right)^{0.6} \right] \\
 &= \frac{3(5100)}{18^2} \left[1 - \left(\frac{15\sqrt{2}}{20} \right)^{0.6} \right] \\
 &= -1.69 \text{ kg/cm}^2
 \end{aligned}$$

For a 25 cm thick cement concrete pavement analysis of stresses gives the following values

Wheel load stress due to the corner loading

$$= 30 \text{ kg/cm}^2$$

Wheel load stress due to edge loading.

$$= 30 \text{ kg/cm}^2$$

Warping stress at the corner region during the summer 9 kg/cm^2

Warping stress at the corner region during the winter 7 kg/cm^2

Warping stress at the edge region during the summer 8 kg/cm^2

Warping stress at the edge region during the winter 6 kg/cm^2

Frictional stress during the summer 5 kg/cm^2

Frictional stress during the winter 4 kg/cm^2

What is the most critical stress value for this pavement.

edge

During the summer

= wheel load stress + warping stress - frictional stress

$$= 32 + 8 - 5 = 35 \text{ kg/cm}^2$$

During the winter

= wheel load stress + warping stress + frictional stress

$$= 32 + 6 + 4 = 42 \text{ kg/cm}^2$$

Corners

Summer = wheel load + warping

$$= 30 + 9 = 39 \text{ kg/cm}^2$$

winter

winter = wheel load + warping

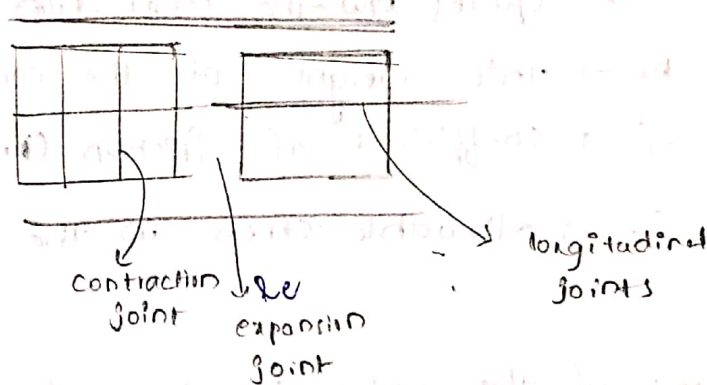
$$= 30 + 7 = 37 \text{ kg/cm}^2$$

Most critical condition

Design of Joints

In the cement concrete pavements expansion joints, contraction joints.

spacing of the expansion joint :



$$L_e = \frac{\delta'}{100C(T_2 - T_1)}$$

$$L_e = \frac{\delta'}{100C(T_2 - T_1)}$$

~~Spacing of the contraction joint :~~

where L_e = spacing of the expansion joint

δ' = maximum expansion in the slab due to the temperature variation from T_1 to T_2

C = coefficient of thermal expansion of the concrete. ($10^{-5}/^{\circ}\text{C}$)

* The width of the expansion joint should not be more than 2.5 cm L_e

* The spacing b/w the expansion joint should not be more than ^{$L_e >$} 140 m L_e -

* The expansion joint gap should be twice the allowable expansion in the concrete.

Spacing of the contraction joints:

$$L_c = \frac{\alpha s_c \times 10^4}{W \times f}$$

Where L_c spacing b/w the contraction joints

$W \rightarrow$ unit weight of the concrete (2400 kg/m^3)

$f \rightarrow$ coefficient of friction (1.5)

$s_c \rightarrow$ allowable stress in the tension (0.8 kg/cm^2)

* Spacing of the contraction joint when the reinforcement is provided.

$$L_c = \frac{200 S_s A_s}{b h w f}$$

Where S_s allowable stress in the steel (tensile stress) 1400 kg/cm^2

A_s total area of steel in cm^2 .

b equivalent radius of resisting section in cm

h slab thickness in cm

W unit wt. of concrete (2400 kg/m^3)

f coefficient of friction (1.5) max

The Design thickness of a cc pavement is 25 cm and the spacing b/w the longitudinal joint is 3.5 cm. The allowable tensile stress in the concrete is 0.8 kg/cm². Determine the spacing b/w the contraction joints. The coefficient of friction is 1.2.

allowable tensile stress in steel = 1400 kg/cm²

$$A_s = \frac{\text{Spacing}}{3.5} \times \frac{\pi d^2}{4}$$

3.5

I.R.C Method for the Rigid pavement design:

Design parameters

calculation of stresses

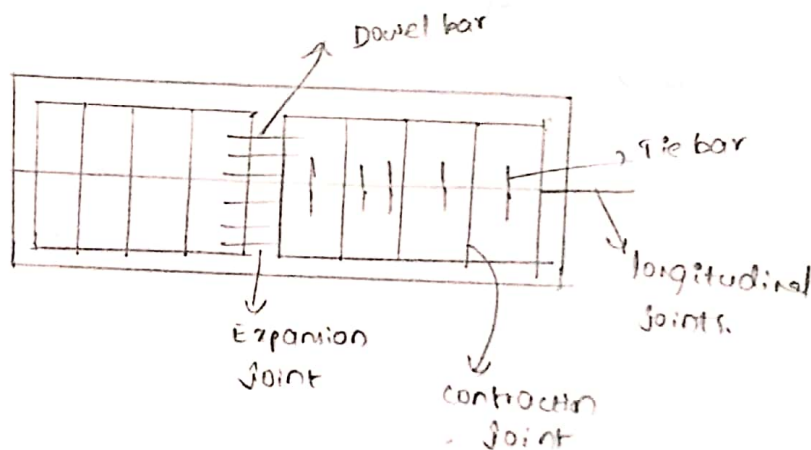
Design of slab thickness

Spacing of joints

Design of dowel bars

Design of tie bars

Design of reinforcement.



Design parameters:

The design wheel load. 5100 kg, radius of wheel load distribution $a = 15 \text{ cm}$ and tyre pressure varies strength 0.62 to 0.7 kg/cm^2

The design traffic volume is calculated by using the formula

$$A_d = P(1+r)^{n+20}$$

Where P = design wheel load

r = rate of growth of annually (7.5%)

n = no. of years b/w the last traffic count and the new construction pavement.

The modulus of subgrade reaction K is determined by using the standard plate of (75cm) diameter at 0.125 cm deflection.

The poissons ratio for the concrete is $\mu (0.15)$. And the elastic modulus of the concrete $E = 3 \times 10^5 \text{ kg/cm}^2$.

The coefficient of thermal expansion of the concrete $\alpha = 10^{-5} / ^\circ\text{C}$.

Calculation of the stresses:

The wheel load stresses at the edge region is calculated by using the teller & Sutherland.

The wheel load stresses at the corner region is calculated by the Kelley.

The temperature stresses is calculated by using the westergaard's analysis.

Design of slab thickness

The width of the slab is depends on the spacing between the longitudinal joints. (3.5m to 4.5m)

Assume the trail thickness of the slab and find out the wheel load stresses and warping stresses at the edge regions.

The residual strength is calculated =
edge stress - flexural strength.
(f_{cr})

The edge load stress is calculated by using the chart with the help of the slab thickness.

The factor of safety is determined (edge load stress by using the chart by residual strength).

The factor of safety greater than (or) less than one another trail thickness value is assumed till the factor of safety value is one.

Finally the design slab thickness 'h' is calculated.

Spacing of Joints :

spacing of expansion joints

→ If the foundation is rough the spacing of expansion joints is taken as 140 m for all the slab thicknesses.

→ If the foundation is smooth the

summer

* The spacing of the expansion joints is taken as 90 m for the slab thickness value upto 20 cm.

Winter
The spacing of ^{contraction} joints is 120 m for the slab thickness value $h = 25 \text{ cm}$.

Jointer

* The spacing of the E.J is generally taken as 50m, 60m for all the slab thickness values.

* Spacing of the E.J contraction joints and
↓
2 types

unreinforced slab

→ Spacing of contraction joints is 4.5m

Reinforced slab

→ Spacing of C.J is 13m when slab thickness is 15cm (h)

→ Spacing of C.J is 14m when slab thickness is 20cm (h)

Design of Dowel bars

The dowel bars are provided in the expansion joints for transfer of the load safely.

Design of tie bars

The tie bars are placed or provided in the longitudinal joints.

Design of reinforcement

The purpose of providing the reinforcement in the rigid pavements to control the cracks. And increase the life span of the pavement.

Continuously reinforce cement concrete pavements

flexible pavement design methods:

- * The reinforcement is provided along the length of the rigid pavement
- * In this type of pavements joints are not provided.
- * The life span of the pavement is 45-50 years.
- * The cost of construction is very high.

Flexible pavement design methods

1. Burmister method
2. MC-load method
3. IRC method
4. Mechanistic method
5. CBR method.

1. Burmister method (layered system method)

- Assumptions :

→ The materials used in the pavement layers are homogeneous, isotropic, elastic

→ The elastic modulus of the subgrade, subbase, base course and surface course is assumed as E_1, E_2, E_3 & E_4 .

S.C	E_1
b.c	E_2
S.b	E_3
S.G	E_4

→ It is considered as

$$E_1 > E_2 > E_3 > E_4.$$

→ The applied load is uniform through out circular area.

Displacement eq's: (In two layer system)

Flexible plate

$$\Delta = 1.5 \frac{Pa}{E_2} F_2$$

Rigid plate

$$\Delta = 1.18 \frac{Pa}{E_1} F_2$$

$$\left[\begin{array}{l} \text{Where } E_1 \rightarrow \text{top layer} \\ E_2 \rightarrow \text{Bottom layer.} \end{array} \right]$$

Where

$P \rightarrow$ Applied load on the circular area.

$a \rightarrow$ radius of wheel load distribution

$E_1 \rightarrow$ Elastic modulus of top layer

$E_2 \rightarrow$ Elastic modulus of bottom layer (subgrade)

$F_2 \rightarrow$ Deflection factor which is

introduced in the two layer system

which depends on the $\frac{E_1}{E_2}$ & $\frac{h}{a}$ values

$h \rightarrow$ Thickness of the pavement.

2. M.C load Method

It is a plate bearing test. which is conducted on the highway pavements and air fields. from the plate bearing test the empirical eqn is developed.

$$T = k \log_{10}(P/s)$$

Where $T \rightarrow$ Thickness of the base course

$k \rightarrow$ Base course constant.

$P \rightarrow$ wheel load (kg)

$s \rightarrow$ Subgrade Support.

3. I.R.C Method

* The pavement design is applicable upto a design traffic 150 million standard axes (msa)

* The axle load is 80kN is called as 'standard axle load'.

(i) Design criteria

(ii). Design procedure

(iii) Failure criteria.

(i) Design criteria.

A mechanistic method

(design criteria 4 points)

$\rightarrow$ Due to the repeated application of axle loads the stresses and strains are developed.

$\rightarrow$ The vertical compressive strain is developed at the top of the subgrade which leads

to the permanent deformation of the subgrade.
→ The horizontal tensile strain is developed at the bottom of the bituminous surface, which leads to the fracture of the bituminous layer.

→ permanent deformation of the pavement due to application of axle loads

(ii) Design procedure:

The input parameters for the design of flexible pavements are

a. Design traffic

Initial traffic — commercial vehicles / day

Traffic growth rate — 7.5% / annum (assumed)

Design life —

vehicle damage factor

lane distribution factor.

b. CBR value of Subgrade.

(std. axle load)
↓
80 kN

(a) → The life span of the pavement for the ^{Express} ~~flexible~~ ~~pavements~~ ways 20 years, remaining is 50 years

→ vehicle damage factor is used for converting the axle load into standard axle load based on the no. of axles in a vehicle.

→ 150 to 1500 vehicles / day (when passed)

Plaine & rolling VDF = 3.5

hilly VDF = 1.5

* > 1500 vehicles/hr

plain & rolling

VDF = 4.5

hilly

VDF = 2.5

→ * The transverse direction of the pavement across the width of the vehicle is considered as.

— * Based on the single lane carriage way the lane distribution factor $D=1$

* Based on the two lane carriage way the lane distribution factor $D=2$.

⑥ → * CBR value of Subgrade

Based on the CBR value of subgrade we have to design the thickness of the pavement.

5. C.B.R Method

→ The thickness of pavement design is depends on the

(i) CBR value of Subgrade on which the pavement to be laid.

(ii) Magnitude of wheel loads

→ A weaker subgrade has low CBR value requires thickness of the pavement is more.

→ Due to the increase of heavy wheel loads
thickness of the pavement is more.

Advantages of C.B.R method:

* The conducting of CBR test in the laboratory and the method of pavement thickness design is very simple.

* Skilled labour is not required for conducting the CBR method.

* The testing of the soil gives the material stability.

* The CBR method of flexible pavement thickness design is depends on the design charts.

Disadvantages of C.B.R method:

* The CBR test doesn't give the properties of the soil. (friction, cohesion).

* The design charts is developed based on the design factors (traffic load or traffic intensity, climatic conditions and the CBR values of the soil).

* These type of charts is not applicable to different sets of design factors.

* The CBR method of flexible pavement thickness is mainly depends on the CBR value of the subgrade w.r. of materials used in the pavement layers.

* The CBR method is conducted only in the laboratory and it is very slow and expensive compared to the other design method.

Pavement thickness determination in CBR method:

If the CBR value is less than 12%.

$$t = p \left[\frac{1.75}{\text{CBR}} - \frac{1}{p \pi} \right]^{\frac{1}{2}}$$

Where $p \rightarrow$ design wheel load

$t \rightarrow$ thickness of the pavement.

$p \rightarrow$ Tyre pressure in kg/cm^2 .

CBR $\rightarrow$ California bearing ratio.

$\rightarrow$ The CBR value is determined and the corresponding wheel loads of the pavement is taken.

$\rightarrow$ By using the CBR design charts with the help of CBR value of the soil and design wheel loads to determine the thickness of the flexible pavement.

IRC recommendations for the CBR method of flexible pavement thickness.

$\rightarrow$ The CBR test is recommended only for the laboratory test.

- In the case of new construction of the roads before testing of the soil, the soil is immersed in water for 4 days.
- The soil is compacted by using the rammers (static or dynamic compaction) at the same moisture content take the 3 soil samples note down the CBR values.
- If there is large variations in the CBR value again take the 6 samples take the avg value.

I.R.C method

(iii) - failure criteria:

→ - fatigue criteria

The relationship b/w the fatigue life of the pavement and the horizontal tensile strain developed in the bottom of the bituminous layer.

$$N_f = 2.21 \times 10^{-4} \times \left[\frac{1}{\epsilon_t} \right]^{3.89} \times \left[\frac{1}{E} \right]^{0.854}$$

where N_f → allowable number of low limitations to control the fatigue cracking

E → elastic modulus of the Subgrade

ϵ_t → horizontal tensile strain developed at the bituminous layer.

→ Rutting criteria.

$$N_R = 4.1656 \times 10^8 \left[\frac{1}{\epsilon_z} \right]^{4.5337}$$

Where ϵ_z → vertical compression strain developed at the top of the subgrade.

N_R → No. of cumulative standard axles.