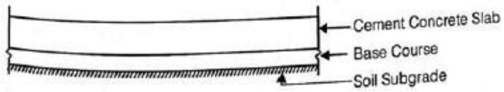
Rigid Pavement

Rigid pavements are those which possess noteworthy flexural strength or flexural rigidity. The stresses are not transferred from grain to grain to the lower layers with the ease of flexible pavement layers. The rigid pavements are made of Portland cement concrete-either plain, reinforced, or prestressed concrete. The plain cement concrete slabs are expected to take up about 40 kg/cm^2 flexural stress.



Parameters of the Design of Rigid Pavement

Rigid pavement is generally designed with reinforced concrete materials based on the different properties of the subgrade materials. These parameters of the design are explained below.

- Modulus of subgrade reaction (k) ⇒ $K=P/\Delta$

where

  - k = Modulus of subgrade reaction (kg/cm^2/cm)
  - P = Pressure required for 'Δ' deflection (kg/cm^2)
  - Δ = Deflection(cm) ⇒ For 75 cm dia plate, Δ = 1.25 mm

- The radius of Relative Stiffness (l)

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

where

  - l = Radius of relative stiffness, cm
  - E = Modulus of elasticity of cement concrete (kg/cm^2)
  - μ = Poisson's ratio for concrete = 0.15
  - h = Slab thickness (cm)
  - k = Subgrade modulus or modulus of subgrade reaction (kg/cm^3)

- Equivalent Radius of Resisting Section (b)

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

when a < 1.724 h and,

b = a when a > 1.724 h

where

- a = Radius of contact area (cm)
- h = Slab thickness (cm)

Stresses in Rigid Pavement

In rigid pavement, stress will occur due to various loads acting over it. The stresses are mainly calculated at the corner location and mid-location of the concrete pavement. It can be calculated by different methods.

Goldbeck's Formula for Stress due to Corner Load

$$S_c = 3P/h^2$$

where,

- S_C = Stress due to corner load (kg/cm^2)
- P = Corner load assumed as a concentrated point load, (kg)
- h = Thickness of slab (cm).

Westergards Stress Equation

(i) Stress at Interior Loading (S_i)

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

(ii) Stress at Edge Loading (S_e)

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

(iii) Stress at Corner Loading (S_c)

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

where,

- h = Slab thickness (cm)
- P = Wheel load (kg)

- a = Radius of contact area (cm)
- l = Radius of relative stiffness (cm)
- b = Radius at resisting section (cm).

Warping Stresses

(i) Stress in the Interior Region (S_{ti})

$$S_{t_i} = \frac{E\alpha T}{2}\left[\frac{C_X + \mu C_y}{1-\mu^2}\right]$$

where,

- (S_{ti}) is warping stress at the interior region (kg/cm^2)
- E = Modulus of elasticity of concrete, elastic constant (kg/cm^2)
- α = Coefficient of thermal expansion (/°c)
- C_X = Coefficient based on (L_x/l) in the desired direction.
- C_y = Coefficient based on (L_y/l) in the right angle to the above direction.
- μ = Poissons' ratio ~ 0.15

(L_x/l) or (L_y/l)	**C_X or C_y**
4	0.6
8	1.1
12	1.02

L_X and L_y are the dimensions of the slab considering X and Y directions along the length and width of the slab.

(ii) Stress at Edge Region (S_{te})

$$S_{t_e} = \text{maximum}\begin{cases} \frac{E\alpha T}{2}.c_X \\ \frac{E\alpha T}{2}.c_y \end{cases}$$

(iii) Stress Corner Region (S_{te})

$$S_{t_c} = \frac{E\alpha T}{3(1-\mu)}\sqrt{\frac{a}{l}}$$

Where,

- a = Radius of contact area
- l = Radius of relative stiffness

Frictional Stress (S_f)

$S_f = WLf/(2\times10^4)$

where,

- S_f = Frictional stress (kg/cm^2)
- W = Unit weight of concrete, (kg/cm^3)
- f = Friction constant or the coefficient of subgrade reaction
- L = Slab length (m)
- B = Slab width (m)

Critical Combination of Stresses in Rigid Pavement

In rigid pavement, different stresses occur at almost every point. But at certain locations within the pavement, it will be maximum. These occur due to different kinds of loading over the pavement surface. Sresses at these locations are known as the critical combination of stresses. The critical combination of stresses can be explained below.

1. Critical Combination During Summer

(a) Stress for edge/interior regions at Bottom = (+ load stress) + (warping stress of day time) – Frictional stress

(b) Stress for corner region at top = (+ load stress + warping stress at night)

2. Critical Combination During Winter

(a) Stress for edge/interior at bottom = (+ load stress + warping stress at day time + Frictional stress)

(b) Stress for corner at top = (load stress + warping stress at night)

Design of Joints in Cement Concrete Pavements

Concrete pavements are joints with different joints; these joints connect the various part of the pavement through each other. These joints can be the type of expansion, contraction, transverse, etc. The spacing of different joints can be calculated below.

Spacing of Expansion Joints (L_e)

$L_e = \delta'/[100\alpha(T_2 - T_1)]$

Where,

- δ' = Maximum expansion in the slab (cm)
- L_e = Spacing of expansion joint (m)
- α = Coefficient of thermal expansion of concrete (/°c)

Spacing of the contraction joint (L_c)

(a) When reinforcement is not provided

$L_c = (2\times10^4)S_c/wf$

where,

- L_c = Spacing of contraction joint (m)
- S_C = Allowable stress in tension in cement concrete.
- f = Coefficient friction ~ 1.5
- w = Unit weight of cement concrete (kg/m^3).

(b) When reinforcement is provided

$L_c = 200S_sA_s/bgwf$

where,

- S_S = Allowable tensile stress in steel (kg/cm^2) $\simeq$ 1400kg/cm^2
- A_S = Total area of steel in cm^2.

Longitudinal Joints

A_s = bfhw/100 S_s

where,

- A_S = Area of steel required per meter length of joint (cm^2)
- b = Distance between the joint & nearest free edge (m)
- h = Thickness of the pavement (cm)
- f = coefficient of friction $\simeq$ 1.5
- w = Unit wt. of concrete (kg/cm^3)
- S_s = Allowable working stress in tension for steel (kg/cm^2)

$L_t = dS_s/2S_b$

where,

- L_t = Length of tie bar

- S_S = Allowable stress in tension (kg/cm^2) $\simeq$ 1400
- S_b = Allowable bond stress in concrete (kg/cm^2)
  S_b = 24.6 kg/cm^2 for deformed bars
  S_b = 17.5 kg/cm^2 for plain tie bars

- d = diameter of tie bar (cm).

IRC recommendations for the design of cement concrete pavements: $A_d = P'[1+r]^{(n+20)}$

where,

- A_d = Number of commercial vehicles per day (laden weight > 3 tonnes)
- P' = Number of commercial vehicles per day at last count.
- r = Annual rate of increase in traffic intensity.
- n = Number of years between the last traffic count & the commissioning of new cement concrete pavement.