Unit-II

Rigid Pavements Design

Westegard's theory :→

- Westegard considered the rigid pavement slab as a thin elastic plate resting on soil subgrade, which is assumed as a dense liquid.
- Here it is assumed that the upward reaction is proportional to the deflection i.e. $P = k\Delta_2$ where the constant k is defined as modulus of subgrade reaction. The unit of k is kg/cm^2 per cm deflection i.e. kg/cm^3

$k \propto$ displacement $(\Delta = 0.125)$

$$k = \frac{P}{\Delta} = \frac{P}{0.125} \; kg/cm^3$$

A/ this theory, Relative Stiffness Radius is

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

Here, l = Relative Stiffness Radius

E = Modulus of elasticity of cement concrete, kg/cm^2

μ = Poisson Ratio for concrete = 0.15

h = Slab thickness, cm

k = Subgrade modulus, kg/cm^3

The stresses acting on a rigid Pavement are:
- (i) Wheel load stresses
- (ii) temperature stresses.

(i) Wheel load Stresses :-

A.T. Goldbeck formula for stress due to corner load is given by:

$$S_c = \frac{3P}{h^2}$$

Here, 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

Westergaard's Stress equation:

The cement concrete slab is assumed to be a homogeneous thin elastic plate with subgrade reaction being vertical and proportional to the deflection.

Interior Loading,

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

Edge Loading,

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

are: corner Loading,

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

Here,

S_i, S_e, S_c = Max. stress at interior, edge and corner loading resp., kg/cm²

h = Slab thickness, cm

P = Wheel load, kg

a = Radius of wheel load distribution, cm

l = Radius of relative stiffness, cm

b = Radius of resisting section, cm

ted

(ii) Temperature Stresses:→

- Temp. stresses are developed in cement concrete pavement due to variation in slab temp.
- The variation in temp. across the depth of the slab is caused by daily variation whereas an overall increase or decrease in slab temp. is caused by seasonal variation in temp.
- During the day, the top of the pavement slab gets heated under the sun light when the bottom of the slab still remains relatively colder.
- The max. diff. in temp. b/w the top & bottom of slab cause ~~lap~~ warp or bend.
- Warping stresses are developed late in the evening.
- During summer season, as the temp. of the slab

increases, the concrete pavement expands towards the expansion joints.

- Due to frictional resistance at the interface, compressive stress is developed at the bottom of the slab, as it tends to expand.
- Frictional stresses are developed due to seasonal variation in temp.

⊠ Critical load Position :->

There are three typical locations, where differing conditions of slab continuity exist.

<u>Interior Loading:</u> When load is applied ~~on an edge~~ in the interior of the slab at any place remote from ~~a corner~~ all edges.

<u>Corner Loading:</u> When the centre of load app. is located on the bisector of the corner angle formed by two intersecting edges of the slab, and the loaded area is at the corner touching the two corner edges.

<u>Edge Loading:</u> When load is applied on an edge of the slab at any place remote from a corner.

Critical Combination of Stresses:→

Following conditions are considered to provide the critical combinations:

(i) <u>During Summer:</u>–

The critical combinations at interior and edge regions during mid day occur when the slab tends to warp downward. During this, max tensile stress is developed at the bottom fibre.

(ii) <u>During Winter:</u>

The critical combination of stresses at the above regions occurs at the bottom fibre when the slab contracts and the slab warps downward during the mid day. The frictional stress is tensile during contraction.

(iii) At corner region the critical combination occurs at the top fibre of the slab, when the slab warps upwards during the mid nights. There is no frictional stress at the corner region.

The Critical Stress Combination = (load stress + warping stress + frictional stress) at edge & corn region

= (load stress + warping stress) at corner region

Spacing of expansion joints :→

- The width or the gap in expansion joint depends upon the length of slab.
- Greater the distance b/w the expansion joints, the greater is the width reqd. of the gap for expansion.
- The dowels would develop high bending and bearing stresses with wider openings.
- It is recommended not to have a gap more than 2.5 cm in any case.
- The IRC has recommended that the max. spacing b/w expansion joints should not exceed 140 m for rough interface layer.

$$\delta' = L_e C [T_2 - T_1]$$

where,

δ' = Max. expansion in a slab

L_e = Length of slab

T_2, T_1 = Temp.

C = Thermal expansion of concrete

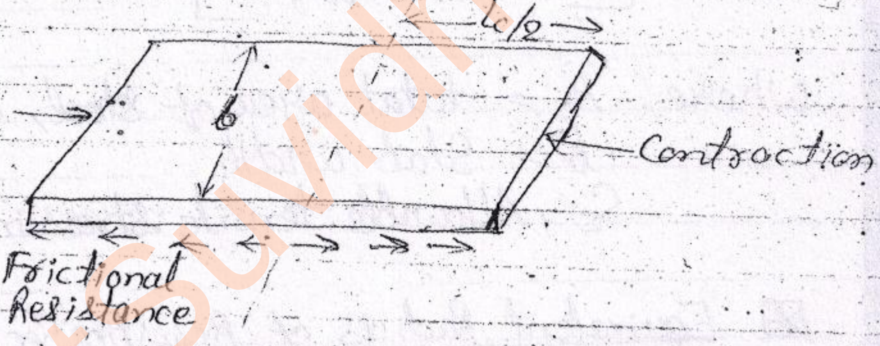
The joint filler may be assumed to be compressed upto 50% of its thickness and therefore, the expansion joint gap should be twice the allowable expansion in concrete i.e. $2\delta'$.

The spacing of expansion joint is given by

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

Spacing of Contraction joints:→

- The slab contracts due to the fall in slab temp below the construction temp.
- This movement is resisted by the subgrade drag or friction b/w the bottom fibre or the slab and the subgrade.



Total frictional resistance upto $L_c/2$

$$= W \times b \times (L_c/2) \times (h \times 100) \times f$$

Allowable tension in cement concrete

$$= S_c \times h \times b \times 100$$

Equating both the eqns, we get

Length of slab to resist the frictional drag i.e. spacing of contraction joints

$$L_c = \frac{2S_c}{Wf} \times 10^4$$

where, L_c = Slab length or spacing b/w contraction joints, m
h = Slab thickness, cm
f = coefficient of friction = 1.5
W = Unit wt. of cement concrete = 2400 kg/m^3
S_c = allowable stress in tension = 0.8 kg/cm^2

When Reinforcement Provided,

$$W \times b \times \frac{L_c}{2} \times \frac{h}{100} \times f = S_s A_s$$

or,

$$\boxed{L_c = \frac{200\, S_s A_s}{b h W f}}$$

where, A_s = total area of steel, cm^2
b = Slab width
S_s = Allowable tensile stress in steel = 1400 kg/cm^2

☒ Equivalent Radius of Resisting Section:→

- In the case of interior loading, the max. bending moment occurs at the loaded area and acts radially in all directions.
- According to Westergaard, the equivalent radius of resisting section is approximated, in terms of radius of load distribution and slab thickness,

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

Here, b = equivalent radius of resisting section (cm): when 'a' is less than $1.724h$

a = Radius of wheel load distribution, cm

h = Slab thickness, cm

when 'a' is greater than $1.724h$, the value of $b = a$

⊠ Joints :→

1) Transverse Joints:

(a) Expansion joints (b) Contraction joints

(c) Warping joints (d) Construction joint

2) Longitudinal joints

Following are the requirement of a good joint:-

(a) Joint must move freely

(b) Joint must not allow infiltration of rain water and ingress of stone grits

(c) Joint must not produce out the general level of the slab

Arrangement of joints :—

(a) Staggered arrangement

(b) Uniform arrangement

(c) Skew arrangement