3.4 RIGID PAVEMENT DESIGN BY IRC METHOD

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.

- **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/cm^3 given by $K = \frac{p}{\Delta}$

where Δ is the displacement level taken as 0.125 cm and p is the pressure sustained by the rigid plate of75 cm diameter at a deflection of 0.125 cm.

- **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 radius of relative stiffness l in cm is given by the equation .

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

where E is the modulus of elasticity of cement concrete in kg/cm^2 (3.0×10^5), μ 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.

- **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.

- **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 .

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

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

- **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 deflection. Westergaard developed relationships for the stress at interior, edge and corner regions, denoted as $\sigma_i, \sigma_e, \sigma_c$ in kg/cm ^{2} respectively and given by the equation - .

$$\sigma_i = \frac{0.316\ P}{h^2}\left[4\ \log_{10}\left(\frac{l}{b}\right) + 1.069\right] \quad (3)$$

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

$$\sigma_c = \frac{3\ P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right] \quad (5)$$

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

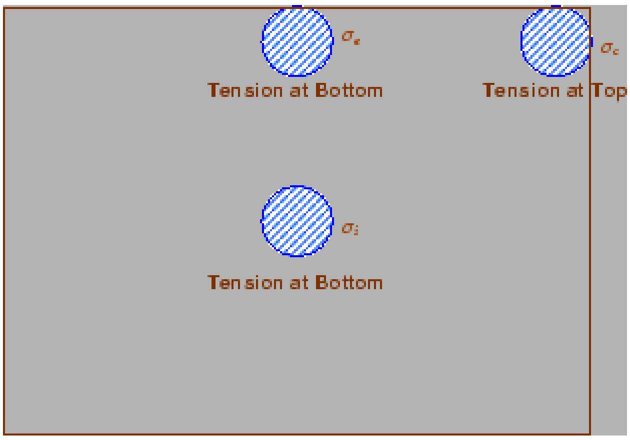

Figure: Critical stress locations

- **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 variationresulting in overall change in the slab temperature. The former results in warping stresses and the later in frictionalstresses.

- **Warping stress**

The warping stress at the interior, edge and corner regions, denoted as $\sigma_{t_i}, \sigma_{t_e}, \sigma_{t_c}$ in kg/cm^2 respectively and given by the equation - .

$$\sigma_{t_i} = \frac{E\epsilon t}{2}\left(\frac{C_x + \mu C_y}{1-\mu^2}\right) \quad (6)$$

$$\sigma_{t_e} = \mathrm{Max}\left(\frac{C_x E\epsilon t}{2}, \frac{C_y E\epsilon t}{2}\right) \quad (7)$$

$$\sigma_{t_c} = \frac{E\epsilon t}{3(1-\mu)}\sqrt{\frac{a}{l}} \quad (8)$$

where E is the modulus of elasticity of concrete in kg/cm^2 (3×10^5), ϵ is the thermal coefficient of concrete per ^{o}C (1×10^{-7}) t is the temperature difference between the top and bottom of the slab, C_x and C_y are the coefficient based on L_x/l in the desired direction and L_y/l right angle to the desired direction, μ is the Poisson's ration (0.15), a is the radius of the contact area and l is the radius of the relative stiffness.

- **Frictional stresses**

The frictional stress σ_f in kg/cm^2 is given by the equation

$$\sigma_f = \frac{WLf}{2 \times 10^4} \quad (9)$$

where W is the unit weight of concrete in kg/cm^2 (2400), f is the coefficient of sub grade friction (1.5) and L is the length of the slab in meters.

Combination of stresses

The cumulative effect of the different stress give rise to the following thee critical cases

$$\sigma_{critical} = \sigma_e + \sigma_{t_e} - \sigma_f$$

- Summer, mid-day: The critical stress is for edge region given by
- Winter, mid-day: The critical combination of stress is for the edge region given by $\sigma_{critical} = \sigma_e + \sigma_{t_e} + \sigma_f$
- Mid-nights: The critical combination of stress is for the corner region given by $\sigma_{critical} = \sigma_c + \sigma_{t_c}$