Rigid pavement design

Overview

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 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 in kg/cm given by where is the displacement level taken as 0.125 cm and is the pressure sustained by the rigid plate of 75 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 in cm is given by the equation 1.

(1)

where E is the modulus of elasticity of cement concrete in kg/cm (3.0 10 ), is the Poisson's ratio of concrete (0.15), is the slab thickness in cm and 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 1.

(1)

where is the radius of the wheel load distribution in cm and 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 in kg/cm respectively and given by the equation 1-3.

(1)

(2)

(3)

where is the slab thickness in cm, is the wheel load in kg, is the radius of the wheel load distribution in cm, the radius of the relative stiffness in cm and is the radius of the resisting section in cm

Figure 1: 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 variation resulting in overall change in the slab temperature. The former results in warping stresses and the later in frictional stresses.

Warping stress

The warping stress at the interior, edge and corner regions, denoted as in kg/cm respectively and given by the equation 2-3.

(1)

(2)

(3)

where is the modulus of elasticity of concrete in kg/cm (3 10 ), is the thermal coefficient of concrete per C (1 10 ) is the temperature difference between the top and bottom of the slab, and are the coefficient based on in the desired direction and right angle to the desired direction, is the Poisson's ration (0.15), is the radius of the contact area and is the radius of the relative stiffness.

Example

A cement concrete pavement of thickness 18 cm, has two lanes of 7.2 m with a joint. Design the tie bars.

(Solution:)

Given h=18 cm, b=7.2/2=3.6m, .

Step 1: diameter and spacing: Get from

Assume . Therefore spacing is , say

Step 2: Length of the bar: Get from

[Ans] Use tie bars of length of

Problems

Design size and spacing of dowel bars at an expansion joint of concrete pavement of thickness 20 cm. Given the radius of relative stiffness of 90 cm. design wheel load 4000 kg. Load capacity of the dowel system is 40 percent of design wheel load. Joint width is 3.0 cm and the permissible stress in shear, bending and bearing stress in dowel bars are 1000,1500 and 100 respectively.

Design the length and spacing of tie bars given that the pavement thickness is 20cm and width of the road is 7m with one longitudinal joint. The unit weight of concrete is 2400 , the coefficient of friction is 1.5, allowable working tensile stress in steel is 1750 , and bond stress of deformed bars is 24.6