International Journal of Engineering, Management, Humanities and Social Sciences Paradigms (IJEMHS)
Volume 30, Issue 03, Quarter 03 (July-August-September 2018)
An Indexed and Referred Journal with Impact Factor: 2.75
ISSN (Online): 2347-601X
www.ijemhs.com

Study, Analysis and Design of Jointed Plain Rigid Pavement

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Publishing Date: July 07, 2018

Abstract

The purpose of a rigid pavement design is to determine the thickness of the layers and the quality of the materials used in the pavement. The stresses occurring in a pavement should not exceed the modulus of rupture of the concrete. In this study, we chose the site at Kasna, Greater Noida and the answer to the most reliable and cost effective solution for a pavement design for a single axle and different temperature gradient was investigated. Concrete pavement has been used for highways, airport, streets, local roads, parking lots, industrial facilities and other types of infrastructure. When properly designed and built out of durable material, concrete pavement can provide many decades of service with little or no maintenance. “Concrete generally has a higher initial cost than asphalt but last longer and has lower maintenance cost. In some cases however design or construction error or poorly selected. Materials have considerably reduced pavement life. It is therefore important for pavement engineer to understand material selection, mixture proportioning, design and detailing, drainage, construction techniques and pavement performance. It is also important to understand the theoretical framework underlying commonly used design procedures and to know the limits of applicability of the procedures.

Keywords: *Jointed Plain Rigid Pavement, Portland Cement Concrete, Rigid Pavement.*

Introduction

Rigid pavements are those which possess noteworthy flexural strength or flexural rigidity. The rigid pavements are generally made of Portland Cement Concrete (CC) and are therefore called ‘CC pavement’. The rigid pavements usually are made of cement concrete and may or may not have a base course between the surface and sub grade. The design of this class of pavement is based on, the principle of providing sufficient strength in the structural cement concrete slab to resist the destructive of action of the traffic. Due to their rigidity and high modulus of elasticity they distribute the load over a relatively wider area of soil. The rigid pavement can resist appreciable tensile stresses; therefore the minor variations in the strength of sub grade have no influence on the structural capacity of the pavement. Thus they are capable of bridging small weak patches and depression. These classes of pavements are capable of developing flexural strength of about 50 kg/cm^2. Rigid pavements are so named because the pavement structure deflects very little under loading.

Figure 1: Rigid Pavement

The cement concrete pavement slab made of Pavement Quality Concrete (PQC) can very well serve as a good wearing surface as well an effective base course. The cement concrete pavement slab is not laid directly over the soil subgrade, considering the desirable long life of CC pavement. A good base or sub-base course laid under the CC pavement slab along with a good drainage layer underneath increase the life of the pavement considerably and therefore work out more economical in the long run. The CC pavement are usually designed and constructed for a design life of 30 year or even higher period. Generally a well designed and constructed CC pavement structure will not require major maintenance work except maintenance of the drainage system and the joint of the CC pavement.

Pavement design may be defined as the determination of structural, material and drainage characteristics and dimensions of the pavement subgrade structure(including all components of the pavement) through direct analytical consideration of the traffic and climatic loads that the pavement/sub grade structure is expected to be subjected to over a selected design period.

In general, a jointed plain concrete pavement system can be divided into a number of components, namely, concrete slab, transverse and longitudinal joints, load transfer devices (dowel bars) and tie bars, sub-base and subgrade soil supporting the slab. This pavement system may be subjected to the following loading conditions: vehicle wheel loads, self-weight of the slab, and environmental loadings (temperature and moisture). Under the above loading conditions the pavement system may experience cracking of the concrete slab, loss of support of slab due to temperature induced curling, closing and opening of joints along transverse and longitudinal directions, and failure of load transfer devices such as dowel bars.

Design of Rigid Pavement

General

In cement concrete road, load carrying capacity is mainly due to rigidity and high modulus of elasticity of slab (slab action).

H.M. Westergaard considered the rigid pavement slab as a thin elastic plate resting on soil, 1subgrade which is assume as dense liquid.

$$P \propto \text{Deflection}$$

$$\text{Upward reaction} \propto \text{reflection}$$

$$P = k\Delta$$

Where, k = modulus of subgrade reaction = kg/cm^3

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 = P/0.125 (rigid plate 75cm diameter)

Relative stiffness of slab to sub-grade

A certain degree of resistance to slab deflection is offered by the sub-grade. This is dependent upon stiffness of subgrade. This is dependent upon stiffness of sub-grade soil,

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

Where

μ = Poisson's ratio of concrete = 0.15
h = thickness of slab (in cm)
E = modulus of elasticity of cement concrete
$E = 3\times10^5$ kg/cm^2
k = modulus of subgrade reaction (in kg/cm$^{3)}$
ℓ = radius of relative stiffness (in cm)

The stresses acting on a rigid pavement are:

1) Wheel load stresses
2) Temperature

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

a) Interior loading
b) Edge loading
c) Corner loading

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:

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

Here,

b = equivalent radius of resisting section, in cm
a = radius of wheel load distribution, in cm
h = slab thickness, in cm

Evaluation of Stresses for Design

Wheel Load Stresses

The cement concrete slab is assumed to be homogeneous and to haveuniform 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 S_i, S_c, S_i in kg/cm2 respectively and given by the equation:

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

Where,

P = point corner load

h = thickness of the slab (in cm)
S_c = stress due to corner loading

This equation is also known as GOLD BECK formula.

i. Westergaard's edge load stress formula, modified by Teller and Sutherland for critical edge region.
$S_e = 0.529P/h^2(1+0.54\mu) \times (4\log_{10}l/b + \log_{10}b - 0.4048)$
ii. Westergaard's corner load stress analysis by Kelley.
$S_c = 3P/h^2\ [1-(a\sqrt{2}/l)^{1.2}]$

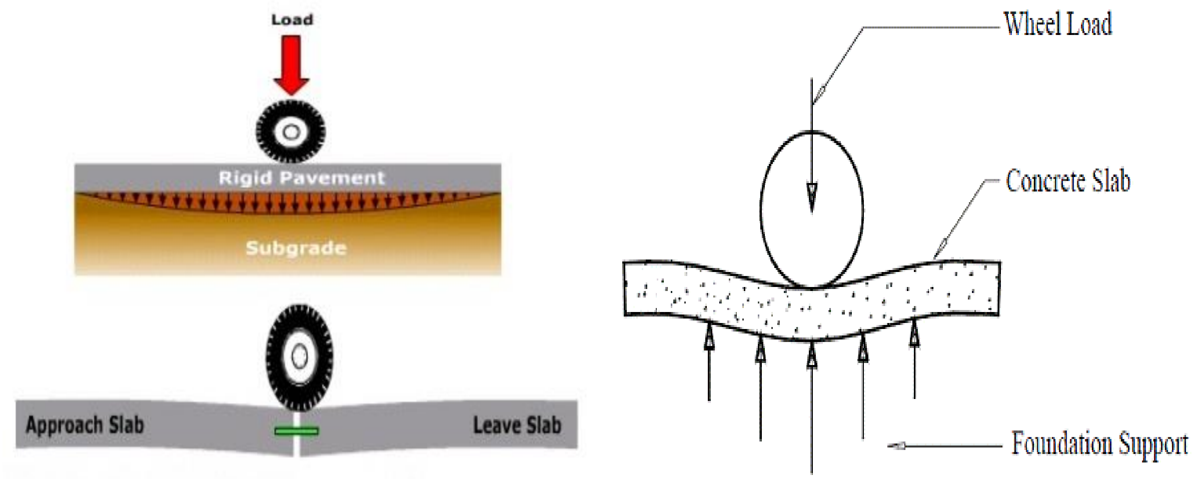

Figure 2: Wheel load distribution

Laboratory Testing for Aggregates

Los Angeles Abrasion Test

Los Angeles abrasion test on aggregates is the measure of aggregate toughness and abrasion resistance such as crushing, degradation and disintegration. The aggregate used in surface course of the highway pavements are subjected to wearing due to movement of traffic. When vehicles move on the road, the soil particles present between the pneumatic tyres and road surface cause abrasion of road aggregates. The steel rimmed wheels of animal driven vehicles also cause considerable abrasion of the road surface. Therefore, the road aggregates should be hard enough to resist abrasion. Resistance to abrasion of aggregate is determined in laboratory by Los Angeles test machine.

Figure 3: Los Angeles Test Machine

The principle of Los Angeles abrasion test is to produce abrasive action by use of standard steel balls which when mixed with aggregates and rotated in a drum for specific number of revolutions also causes impact on aggregates. The percentage wear of the aggregates due to rubbing with steel balls is determined and is known as Los Angeles Abrasion Value.

Objective

1. To determine the LOS Angeles abrasion value
2. To find the suitability of aggregates for use in road construction.

Apparatus for Los Angeles Test

The apparatus as per IS: 2386 (PART IV)-1963 consist of:

1. Los Angeles Machine
2. Abrasive charge: Cast iron or steel balls, approximately 48mm in diameter and each weighing between 390 to 445 g; six to twelve balls are required.
3. Sieve: 1.70, 2.36, 4.75, 6.3, 10, 12.5, 20, 25, 40, 50, 63, 80 mm IS Sieves.
4. Balance of capacity 5 kg or 10 kg
5. Drying oven
6. Miscellaneous like tray

Procedure for Los Angeles Test

The test sample consists of clean aggregates dried in oven at 105° – 110°C. The sample should conform to any of the grading:

1. Select the grading to be used in the test such that it conforms to the grading to be used in construction, to the maximum extent possible.
2. Take 5 kg of sample for gradings A, B, C & D and 10 kg for gradings E, F & G.
3. Choose the abrasive charge as per Table 2 depending on grading of aggregates.
4. Place the aggregates and abrasive charge on the cylinder and fix the cover.
5. Rotate the machine at a speed of 30 to 33 revolutions per minute. The number of revolutions is 500 for gradings A, B, C & D and 1000 for gradings E, F & G. The machine should be balanced and driven such that there is uniform peripheral speed.
6. The machine is stopped after the desired number of revolutions and material is discharged to a tray.
7. The entire stone dust is sieved on 1.70 mm IS sieve.
8. The material coarser than 1.7mm size is weighed correct to one gram

Material Used

- Aggregate weight = 5.0 kg
- Total steel balls = 12
- Total revolutions =500
- Weight of ball = 420 gm.

Result

- Power obtained = 1225 gm.
- Abrasion value = (1225/5000)x100 = 24.5 %

Scope for Future Work

With a brief background on PCC pavement history and a look at what we don't know behind us, we now want to look toward the future. Rigid pavement is generally preferred for locations experiencing heavy rainfall, waterlogged areas and areas having sub-grade soil with low CBR (California Bearing Ratio) values.

Although many innovations have been proposed over the years - such as self-stressing concrete pavements, prefabricated component pavements, pre-stressed pavements, and others - few of the ideas have been marketing successes.

- Self-Compacting Concrete,
- Self-Curing Concrete,
- Durable Concrete without Entrained Air,
- High-Strength Concrete,
- One-Pass Paving,
- Ultra-High-Strength Concrete for Continuous Pavements.

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