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Effect of Dynamic Load on Rigid Pavement

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Abstract - **There is growing interest in the construction of concrete pavements in India due to their high strength, durability, better serviceability and overall economy in long run. The structural adequacy of a rigid or concrete pavement can normally be predicted based on its structural response to the applied loads. While considerable knowledge of pavement behaviour under static loads is available word-wide, only very limited number of studies have been carried out in the past to determine the effect of dynamic loads on rigid pavement deteriorations. Some software studies show that the effect of the moving load on the concrete pavement much important. Hence, opinions differ as to which type of load (static or dynamic) results in greater values of base deflection or flexural stress.**

The need for modern transportation system together with the high demand for sustainable pavements under applied loads has led to a great deal of research on concrete pavement worldwide. Progressive knowledge of concrete pavement behavior under applied loads, concrete pavement still suffer from deterioration due to crack initiation and propagation, indicating the need for further research. Cracks can be related to fatigue of the concrete or erosion of material in sub-layer. Although longitudinal, mid edge and corner cracks are the most common damage mode in concrete pavement.Present review study includes the behavior study and compared it with dynamic analysis results.

Keywords; Dynamic Analysis,Deterioration, Flexural strength,Elastic foundation, Damping ratio.

1. INTRODUCTION

Pavements are an essential feature of the urban communication system and provide an efficient means of transportation of goods and services. The concrete pavements are now a day becoming more popular in India because of steep rise in the cost of bituminous construction. Rigid pavement is the technical term for any road surface made of concrete. Concrete roads are called rigid. The largest advantages to using concrete pavement are in its durability and ability to hold a shape. There are three basic types of rigid pavement commonly used worldwide. The concrete pavement may be jointed plain concrete pavement

(JPCP), jointed reinforced concrete pavement (JRCP), continuous reinforced concrete pavement (CRCP), or pre-stressed concrete pavement (PCP).The serviceability and durability of rigid pavement constructions depend on the rate of pavementdeterioration which is a function of factors such as material properties, climatic effects andVehicular load characteristics. As the main reason behind deterioration and failure processes, cracks can be considered as a tensile failure in concrete or rigid pavements. Cracks can occur at any location within the pavement where tensile stresses exceed the concrete flexural strength. Tensile stresses are induced in a rigid pavement due to bending action of concrete base under vehicular as well as climatic forces.

The design of concrete pavements is traditionally based on the analytical solution of an infinitely long beam or plate on an elastic foundation under an equivalent static load. Westergaard's assume thesubgrade support is continuous, the foundation is dense liquid and slab is infinite dimension. In the IRC (Indian Road Congress) they considered the single and the tandem axle load along the edge for computation of stresses. In above two methods only the fatigue damage is considered. But the PCA (Portland Cement Association) method considered the fatigue as well as the erosion analysis while design of the pavement. Pavement distresses such as pumping, erosion of foundation, and joint faulting are related more to pavement deflection than flexural stresses.

Numerical modeling is often performed to complement experimental research. Concrete pavements were modeled as a thick or thin plate as solid elements, or as beam element resting on Visco elastic foundation (a combination of damper and spring) in finite element analysis. However, structural dynamic responses of concrete pavements may be affected by configuration, magnitude, frequency and location of applied loads.

The conventional methods of rigid pavement are based on static analysis. The dynamic effects of moving vehicles are should be considered while designing the pavement. The pavement should be design for static as well as dynamic loading because effect of the both loading condition is much important.

2. LITERATURE REVIEW

Mostafa Yousefi Darestani studied the most common fatigue related distress in concrete pavement. For the study he used the finite element model and analysis to determine the structural behavior of concrete pavement under vehicular load and environmental effects. The results of study indicate that the induced tensile stresses within the concrete pavement are significantly affected by vehicle speed, differential temperature gradient and loss of moisture content. Also a new fatigue test setup is developed to take into consideration effect of pavement curvature on fatigue life of the concrete Syed Oliur Rahaman and Iftekhar Anamstudied that importance of dynamic analysis in the design of rigid pavement. For that finite element formulation of thick plate on elastic foundation, parametric studies are performed and depends on that they investigate the some significant aspect of dynamic behavior of rigid pavement. In the parametric study indicate the difference between static and dynamic response and investigate the effect of structural damping. Also they found in this study the less effect of vehicular speed on the stresses formation.

M.Y.Darestani, David p. Thambiratnam and A.Nataatmadja completed the experimental study on structural response of rigid pavement under moving truck load. The structural adequacy of rigid pavement is based on the structural response to the applied loads. They carried out rigid pavement test section consisting of two jointed reinforced concrete pavement and two jointed plain concrete pavements was constructed and tested under both quasi-static and dynamic truck load.
Investigation of the recorded time history response of the test section indicate the importance of dynamic analysis in pavement design. Results also indicate that dowel position can strongly influenced the pavement responses. Concluded that the variation in subgrade property, differential temperature gradient and loss of moisture content within the concrete base may influence the dynamic response of the concrete pavement.

Vishwas Sawant studied dynamic response of pavement due to moving load such as vehicles and aircraft has received significant attention in recent years because of its relevance to the design of pavement and airport runway. Graphical results are presented to demonstrate the significance of the dynamic interaction between the pavement and the vehicle on pavement response. Results indicated that slab thickness, soil modulus and velocity of aircraft had a significant effect on the response of the pavement.

M.H. Haung and D.P.Thambiratnam studied that a procedure incorporating the finite strip method and a spring system has been developed and applied to treat the dynamic response of plate structure resting on an elastic foundation to moving loads. They first investigate the response of single moving concentrated load and then the effect of velocity, elastic foundation stiffness, moving path and distance between multiple moving loads are studied. Results indicate that the foundation stiffness and the velocity and frequency of the moving load have significant effect on the dynamic response of the plate.

3. STATEMENT OF PROBLEM

The various methods developed worldwide for analysis and design of pavement are based on static analysis. Since vehicle loads acting over pavements are dynamic in nature the dynamic effect has to be considered in analysis and design for zeromaintenance pavements. Present study includes the review of dynamic analysis of pavement without considering the environmental factors and then compared it with static analysis.

4. OBJECTIVE

To study the present method of analysis of pavement.
To study behavior of pavement under traffic load
To study behavior of pavement under moving dynamic load through literature review.
To compare the dynamic behavior with static behavior.

5. PROBLEM DESCRIPTION

a) Dynamic analysis of rigid pavement:
For dynamic analysis of rigid pavement the following section of rigid pavement is selected. The results obtained in the following table is taken from the researcher Syed Oliur Rahman and Iftekhar Anam [ii].
Material properties:Modulus of elasticity of concrete: $2.0\text{x}10^5 kg/cm^2$Modulus of subgrade reaction (k): $5.kg/cm^3$Poisson's ratio for concrete(μ): 0.25Slab thickness (h): 23cmMesh size: 4.8mx4.8mWheel load (p): 2000kgVehicle speed (v): 100kphDamping ratio: 5%

Result from the numerical analysis for the dynamic loading for the edge, center and corner are summarized in the following table.

Table 1: Maximum deflection and stresses for single wheel (dynamic analysis)

Model	Wheel along edge		Wheel along center		Wheel along corner	
Winkler	δ_E	σ_E	δ_I	σI	δ_C	σ_C
soil dynamic analysis	0.060	6.14	0.0192	2.30	0.1592	9.89

(All deflections are in cm and stresses are in kg/cm^2)

b) Static analysis of rigid pavement by using Westergaard's theory (1926):

The calculation of stresses and deflection for static wheel load we used the westergard's theory. The same input parameter is taken for calculation purposes as stated above. Stresses and deflection is calculate at three location like edge,center and corner by using following westergard's formulaes.
a.Stresses due to edge loading

$$\sigma_e = \frac{0.572P}{h^2} \times [4\log(\frac{l}{b}) + o.359] \quad (1)$$

b. Stresses due to interior or centerline loading

$$\sigma_i = \frac{0.316P}{h^2} \times [4\log(\frac{l}{b}) + 1.069] \quad (2)$$

c. Stresses due to corner loading

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

d. Deflection due to edge loading

$$\delta_e = \frac{0.431P}{kl^2}[1 - 0.349(\frac{a}{l})] \quad (4)$$

e. Deflection due to interior or centerline loading

$$\delta_i = \frac{P}{8kl^2} \times \{1 + \frac{1}{2\pi}\left[in(\frac{a}{2l}) - 0.673\right]\left(\frac{a}{l}\right)^2\} \quad (5)$$

f. Deflection due to corner loading

$$\delta_c = \frac{P}{kl^2}[1.1 - 0.88(\frac{a\sqrt{2}}{l})] \quad (6)$$

where,

$\sigma_{e}, \sigma_{i}, \sigma_{c}$= stresses at edge, interior and corner in kg/cm^2.

$\delta_{e}, \delta_{i}, \delta_{c}$= deflection at edge, interior and corner in cm.

p, h, k, μ = as stated above.

l= radius of relative stiffness in cm= $[\frac{Eh^3}{12k(1-\mu^2)}]^{1/4}$

a= radius of load contact area assumed circular.

b= radius of equivalent distribution of pressure.

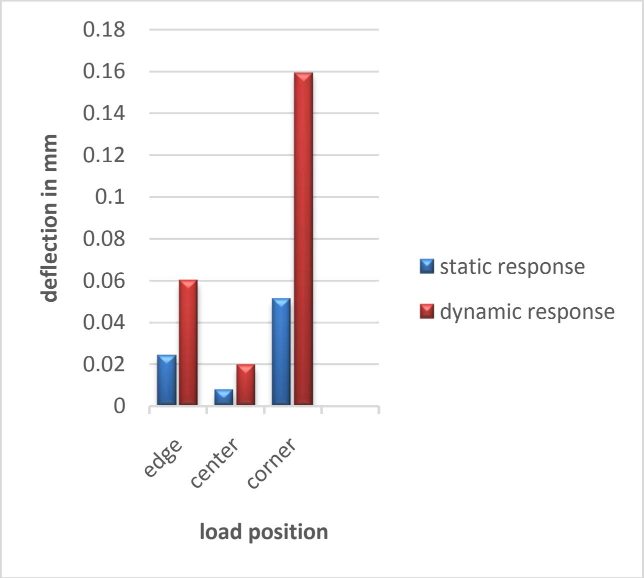
Table 2: Maximum deflection and stresses for single wheel (static analysis)

Model	Wheel along edge		Wheel along center		Wheel along corner	
Winkler soil static analysis	δ_E	σ_E	δ_I	σI	δ_C	σ_C
	0.0241	6.91	0.0076	4.66	0.051	5.9

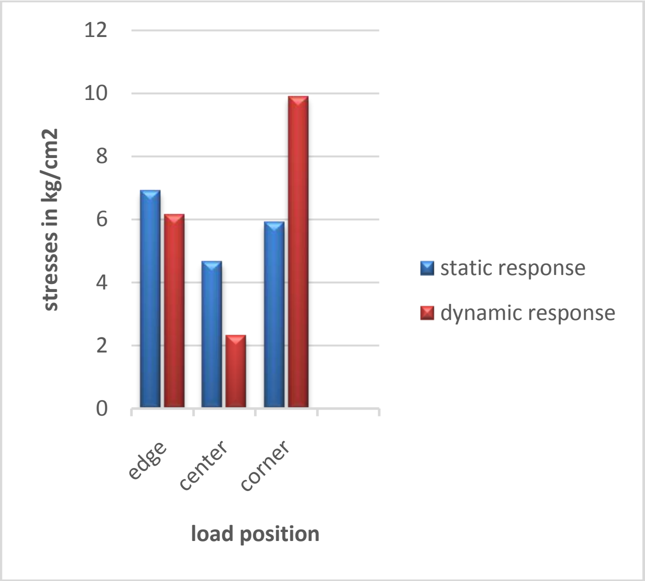
(All deflections are in cm and stresses are in kg/cm^2)

6. RESULTS AND DISCUSSION

The following graph shows the comparison between the static analysis and dynamic analysis study.



Graph 1: Deflection comparison due to static and dynamic load



Graph 2: Stresses comparison due to static and dynamic load

Comparison between static and dynamic analysis shows that the effect of dynamic wheel loads on rigid pavements is considerable. The deflection is more in case of dynamic analysis for edge, center, and corner load cases and in computation of stresses it is observed that the stress is more in case of corner loading.

7. CONCLUSION

Following conclusion can be drawn

- For the single wheel load passing on the corner the deflection at corner occurred is more in the dynamic wheel load. The corner section is found to be more critical.
- The deflection occurs at three loading position is greater in the dynamic wheel load as compare to the static wheel load.
- The stresses occurs in the corner area is higher for the dynamic wheel load, but in case of the edge and center loading it is less as compared to static load.
- For the design of corner section the separate precaution should be required to satisfy the zero maintenance pavement.
- The effect of dynamic wheel load is more in all loading cases which show the importance of dynamic analysis in the design of pavement.

8. REFERENCES

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