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콘크리트 포장구조에서 조인트 강성의 영향

(The effects of Joint Stiffness On Concrete Pavements)

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Abstract

Although concrete pavements were successfully widespread throughout the nation due to the desirable surface characteristics, durability, and economy, it still causes several transverse cracking and joint failure problems in sone areas.

In this paper, the major enphasis was given to provide a rational analytical approach on joint failure mechanisms, considering several sets of joint stiffnesses on different subgrade moduli.

Besides, load transfer mechanisms on concrete pavement joints were highlighted with finite element method and computer modeling.

1. Introduction

A concrete pavement which has shown severe premature cracking has been viewed with great concern by highway officials and engineers. As traffic loads are applied, a pavement system experiences deformation, stress, strain, and load transfer at the joints between two adjoining concrete slabs in the presence of thermal gradients and moisture variation.

These applied traffic loads are transferred to neighboring slabs across joints through shear and moment resistance by two means, interlocking of aggregate and dowel bars. The degree of load transfer is dependent on the joint stiffness which is governed by shear and moment resistance. In return, the joint stiffness affects the load response of the pavement.

The stiffness factors can be found for a particular pavement under particular conditions by correlating measured linear pavement response, from Falling Weight Deflectometer test data.

2. Concrete Pavement Modeling

The concrete pavement is modeled by using a three slab system with two intermediate joints as shown in Figure 1.

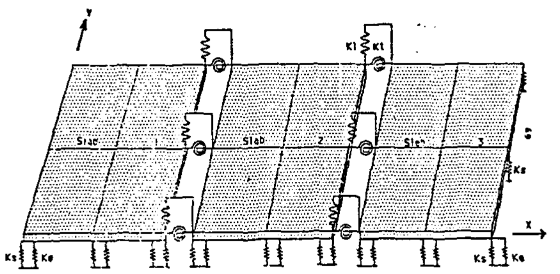

Fig.1:FINITE ELEMENT MODELING OF A THREE SLAB PAVEMENT SYSTEM

2.1 Joints

Load transfer mechanisms across the joints between two adjoining slabs are modeled by shear (or linear) and rotational springs connecting the slabs at the nodes along the joint as shown in Figure 2.

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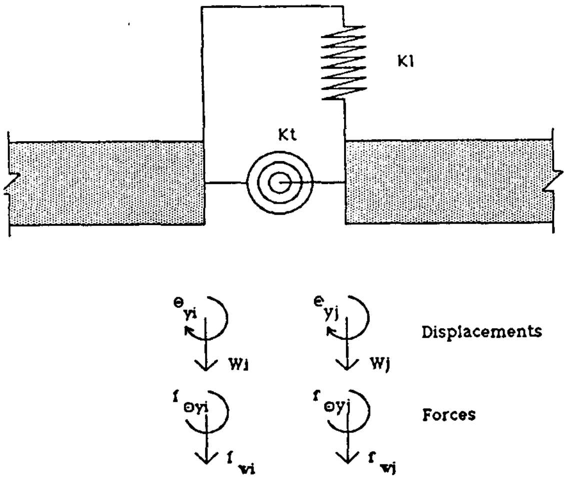

$$\begin{bmatrix} f_{vi} \\ f_{\theta yi} \\ f_{vj} \\ f_{\theta yj} \end{bmatrix} = \begin{bmatrix} K_l & 0 & -K_l & 0 \\ 0 & K_t & 0 & -K_t \\ -K_l & 0 & K_l & 0 \\ 0 & -K_t & 0 & K_t \end{bmatrix} \times \begin{bmatrix} v_i \\ \theta_{yi} \\ v_j \\ \theta_{yj} \end{bmatrix}$$

Force -- Displacement Relationship

FIGURE .2 LINEAR AND ROTATIONAL SPRING ELEMENTS MODELING JOINT BEHAVIOR

2.2 Dowel Bars

Looseness of the dowel bars is modeled by a specified slip distance, such that shear and moment stiffness become fully effective only when the slip distance is overcome. The effective dowel stiffness is modeled as varying linearly with the difference in deflection at the joint, when the difference in deflection is less than the slip distance.

3. Input Parameters

Six sets of joint stiffness as listed in Table 1, are selected in calculating pavement response.

Table 1. Joint stiffness: Kr, Kl

Rotational stiff. Kr(k-in/in)	Linear stiff. Kl(ksi)
1000 (low)	10
	200
	750
10,000 (High)	200
	750
	1500

The general dimensions of the I-75 concrete pavement are given as follows:

1) Slab lengths : 22 ft. (6.7 m)
2) Slab width: 12 ft (3.7 m)
3) Slab thickness: 9 inch(23 cm)
4) Skew angle: 9.4623 o in degrees
5) Concrete-econocrete interface: Unbonded
6) Number of lanes: 6 lanes
7) Shoulder: Econocrete-tied
8) Pavement opened to traffic: 1980 ~ 1982

4. Effects of Joint Stiffness

4.1 Initial Deflection and Stress

First, initial deflection profiles with different joint stiffnesses are compared. Computer results show that higher joint stiffnesses are compared. Computer results show that higher joint stiffness cause less deflections in a slab compared to those of lower joint stiffness, especially at the joint center regions, which makes an initial dome shape of deflection profiles transform to the "barrel arch" type of profiles, which curl less-downward at the center of joint with -10 oF and +25 oF temperature differentials.

This might be due to the fact that higher joint stiffness induces more restraining action at the joint and approaches a certain "barrel arch" as joint stiffens.

4.2 Final Deflections and Stresses

Table 2 shows the maximum longitudinal and transverse stresses to see how those stresses varies with the various combinations of joint stiffnesses. It is seen that higher joint stiffness results in increase of flexural stresses (σx, σy) with a positive temperature differential and decrease of flexural stresses (σx, σy) with a negative temperature differential. On the other hand, with no temperature differential, it shows increase of σx and decrease of σy. From Table, it can be noted that σx is more sensitive to higher joint stiffness rather than σy.

Table 2. EFFECTS OF JOINT STIFFNESS ON MAXIMUM STRESS DUE TO EJE 40 KIPS AXLE LOADING

Sub	Joint Stiffness		Temperature differentials dT (°F)					
			-10		0		+25	
Ks	Kr	Kl	σx	σy	σx	σy	σx	σy
0.1 (S)	Low 1000	10	-307 N	361 L	-209 L	475 L		
		200	-260 N	207 L	177 L	324 L		
		750	-260 N	172 L	181 L	288 L	451 F	574 L
	High 10000	200	-251 N	209 L	321 L	327 L		
		750	-247 N	174 L	324 L	293 L		
		1500			325 L	286 L	669 L	594 L
0.3 (M)	Low 1000	10	-296 N	250 L	-196 L	393 L		
		200	-248 N	-208 C	159 L	255 L		
		750	-243 N	-209 C	164 L	219 L	447 F	563 L
	High 10000	200	-243 N	-211 C	281 L	266 L		
		750	-240 N	-211 C	284 L	231 L		
		1500			285 L	224 L	657 L	605 L
1.2 (H)	Low 1000	10	-281 N	-264 C	-176 L	321 L		
		200	-235 N	-275 C	135 L	213 L		
		750	-234 N	-283 C	141 L	178 L	414 F	583 L
	High 10000	200	-235 N	-283 C	227 L	222 L		
		750	-234 N	-283 C	231 L	189 L		
		1500			231 L	182 L	615 L	644 L

5. Conclusions

It is obvious that with joint edge loadings deflections were far more sensitive to variation in Kl values. Increasing Kl values with a low fixed Kr values results in the decrease of maximum principal stress on the loaded slab, while increasing Kl values with a high fixed Kr values does not affect maximum principal stress significantly. On the other hand, mid-slab loadings has shown no effects on both flexural and shear stress with variations of joint stiffness.

It seems that joint stiffness affect the structural performance of joint loading case only, and does not seriously affect mid-slab loading case. Besides, joint stiffness is never important when maximum principal stress occurs away from the joint. This is interesting as one would expect the uplifted corner of a slab to be the maximum stress region and be very sensitive to joint stiffness.