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Smart Connection Development for Modular Roadway Slab

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ABSTRACT

Transportation agencies have recently been struggling to provide rapid roadway construction and repair work with minimal disruption to traffic. They are also pursuing satisfactory roadway systems with minimal maintenance over their service life. For example, precast members were provides controlled roadway quality and rapid construction. However, using the precast member has probability to damage filler between slabs due to penetrating of water and debris. Also, Anchor bolts might be suffered unexpected displacement if the force acting on the anchor bolts is quite large. This study conducted a finite element analysis to develop a modular road slab. Two preliminary analysis models were proposed as varying boundary conditions. Then combination of various loads selected appropriate boundary conditions. Based on analysis results, the Case 2 model selected comparing displacement and stress intensity. The Case 2 model had high horizontal force due to boundary conditions fixed at the end of slab. So, Horizontal force would decrease if the boundary conditions at the end of slab allow small displacements. Based on preliminary results, a detailed analysis model proposed. The Detailed model had mortar between slabs and a cross-beam. Also Anchor bolts installed to connect slabs and a cross-beam. Review the results of detailed analysis model, displacements allowance of horizontal filler is needed about 5 mm and anchor bolts needed horizontal shear forces about 80 kN.

1. INTRODUCTION

Transportation agencies have recently been struggling to provide rapid roadway construction and repair work with minimal disruption to traffic. They are also pursuing satisfactory roadway systems with minimal maintenance over their service life. Using precast members, it is provides high quality and rapid construction is one of the solution that can fulfill ideal for maintenance. However, using the precast member has

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probability to damage filler between slabs due to penetrating of water and debris. Also, Anchor bolts might be suffered unexpected displacement if the force acting on the anchor bolts is quite large. The present study was established appropriate roadway boundary conditions to accommodate less displacement as well as internal force. Generally, a modular roadway system is composed of precast roadway slab, crossbeams, and supporting piles, as presented in figure 1. Thus, the present study was conducted to establish internal forces and displacements of the slab under the various loads. First, proper boundary conditions were selected in preliminary analysis with two models. Then combination of various loads selected appropriate boundary conditions. Based on the results, this study developed detailed model.

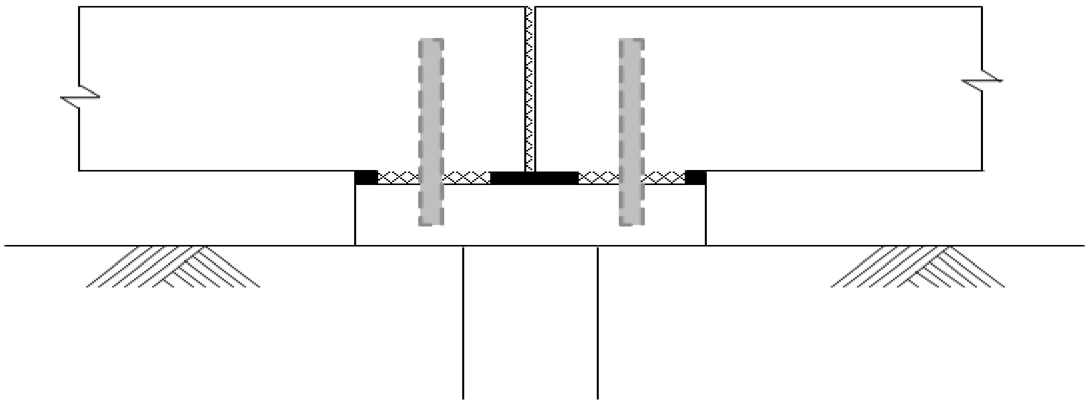


Fig. 1 Modular roadway system

2. PRELIMINARY ANALYSIS

For the preliminary models, two different boundary conditions were reviewed to determine the appropriate connection for modular slab. Also support offsets (*d*) were spaced at 0.0 to 0.3 m away from the slab end.

2.1 Case 1

For the Case 1, the suggested boundary conditions are presented in Figure 2(a). The modular slab has a hinge support at the middle support and roller supports at both ends. Roller support allows free displacement and zero horizontal reactions at both end supports.

2.2 Case 2

For the Case 2, the suggested boundary conditions are presented in Figure 2(b). The modular slab has a hinge supports at all three supports. The horizontal displacement is not restricted in the Case 1 boundary condition and the horizontal reaction force at both ends is zero.

(a) Case 1 (b) Case 2

Fig. 1 Preliminary models

2.3 Loads and material properties

Dead load, live load and temperature load were considered in the analysis. Live loads were suggested based on an influence line analysis to determine the truck locations that produce the maximum displacements and internal forces. For Temperature load, both uniform temperature and a temperature gradient were considered based on actual roadway temperature measurements of KRPSDG[1]. The live load location and temperature load of the season was categorized into two cases : (1) Convex shape and (2) Concave shape of the right span of the slab. Table 1 shows material properties of the considered preliminary models.

Table 1. Material properties

Modulus of elasticity (GPa)	Poisson's ratio	Unit mass (kg/m^3)
37.3	0.18	2500

2.4 Analysis the results

Table 2 shows the value of displacements and horizontal forces of each case. Both Case 1 and Case 2 analysis results exhibited that both displacements and horizontal forces increased with increasing support offset (*d*). The minimum displacement occurred at Case 2 with *d* = 0.0 m. However Case 2 has a high horizontal force. Thus detailed analysis model will to allow for the horizontal displacement of the end.

Table 2. Analysis results

	d (m)	Displacement (mm)		Horizontal forces (kN)
		Convex	Concave	
Case 1	0.0	0.93	0.69	-
	0.1	0.94	0.69	-
	0.2	0.96	0.70	-
	0.3	1.03	0.71	-
Case 2	0.0	0.83	0.63	4628
	0.1	0.89	0.66	4702
	0.2	1.02	0.74	4707
	0.3	1.18	0.85	4710

3. DETAILED ANALYSIS

The detailed model is two-span continuous beam and reinforced with cross beams under the slab. Between the slab and cross beam a steel anchor was proposed as in figure 3 with debonding treatment around the anchor in the slab.

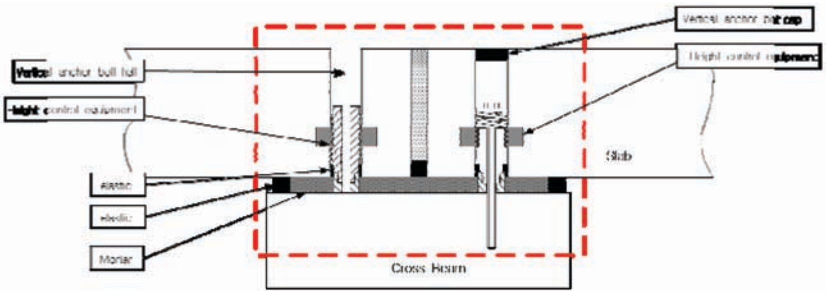


Fig. 3 Detailed model

2.1 Loads and material properties

The same loads and material properties used preliminary model. In addition, the long-term behavior of concrete creep and shrinkage were considered. Also preliminary analysis models showed results that temperature loads induced the greatest displacements and horizontal forces compared to other loads. Thus, only temperature loads were considered in the parametric study. Table 3 shows material properties of the considered detailed models.

Table 3. Material properties

	Modulus of elasticity (GPa)	Poisson's ratio	Unit mass (kg/m^3)
Slab	36.6	0.18	2500
Mortar	18.5	0.18	2150
Cross beam	36.6	0.18	2500
Anchor bolt	200	0.3	7850

2.2 Parameters

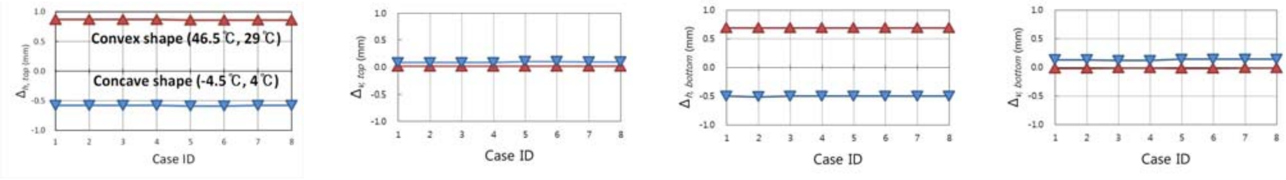
In detailed model (i) the distance to the anchor bolts in the slab (*a*), (ii) the distance to the anchor bolts, the cross beam (*b*), (iii) the height of the mortar (*h*) were considered as a parameters. Table 3 was determined as possible ranges.

Table 4. Using the parameters scope and Case ID

Case ID	Case Name	*a* (mm)	*b* (mm)	*h* (mm)
1	a150b100h30	150	100	30
2	a150b100h50			50
3	a150b200h30		200	30
4	a150b200h50			50
5	a200b100h30	200	100	30
6	a200b100h50			50
7	a200b200h30		200	30
8	a200b200h50			50

2.3 Parametric study results

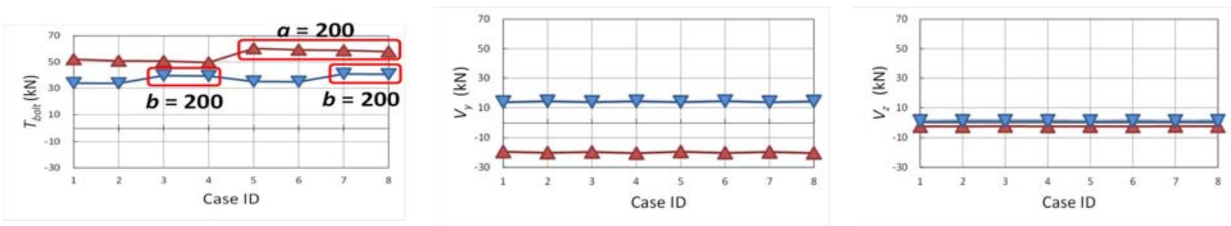
Figure 3 show that the horizontal displacements greater than vertical displacements. Also result value is constant in accordance with parameters.



(c) Horizontal displacement of A | (d) Vertical displacement of A | (c) Horizontal displacement of B | (d) Vertical displacement of B

Fig. 3 Slab displacement

Figure 4 show that the tensile forces greater than shear forces. Similarly, result value is constant in accordance with parameters.



(a)Axial force | (b) Shearing force (Longitudinal) | (c) Shearing force (Transverse)

Fig. 4 Anchor bolts internal force

2.4 Load combination results

Then Case which has parameter *a150b100h30* is a smallest displacements and internal forces. Thus, it was selected as the appropriate parameters. Total load was loading. Table 5 shows displacement results of slab and internal forces of Anchor bolt when applied total load.

Table 5. Total load analysis results

Load		Slab ends displacement				Anchor bolt internal forces		
		Δ_{ht}	Δ_{vt}	Δ_{hb}	Δ_{vb}	T_{Bolt}	$V_{Long.}$	$V_{Tran.}$
Sum.	Concave	-2.53	0.12	-2.42	0.36	72.9	62.7	34.7
	Convex	-1.03	-0.01	-1.28	0.14	81.7	30.3	31.6

4. CONCLUSION

Allowable displacement of filler is needed about 5 mm at ultimate load case and anchor bolt needed horizontal load bearing capacity more than 80 kN.

Acknowledgement

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