Reason Analysis of the Gap between CRTSⅢ Slab and Self-compacting Concrete

Kunteng Zhu
School of Civil Engineering
Central South University
Changsha, China
306353043@qq.com

Bin Wu
School of Civil Engineering
Central South University
Changsha, China
956310155@qq.com

Zhiping Zeng *
School of Civil Engineering
Central South University
Changsha, China
996510155@qq.com
* Corresponding Author

Bin Liu
School of Civil Engineering
Central South University
Changsha, China
269036993@qq.com

Abstract—This paper established mechanical analysis model of track structure including rail, track slab, door type tendon, self-compacting concrete and base according to the CRTSIII track slab structure characteristics, and analyzed the force condition between interface of track slab and self-compacting concrete under different loads. After a series of laboratory testing, obtained the bonding strength between track slab and self-compacting concrete, ranged from 0.736MPa to 1.76MPa, and analyzed the cause of the gap of slab edge, gap of slab center, gap under rail by compared it with the theoretical calculation value. Results show that the negative temperature gradient loads is the main cause leading to the gap of slab edge and the corner of slab is most vulnerable while the train loads and the positive temperature gradient loads are the main causes of the gap of slab center and gap under rail, and the position of 1.0m away from the longitudinal of slab center and the edge of end-slab under the rail are most likely to get gap.

Keywords- CRTSIII Slab Ballastless Track; Interface; Gap; Cause Analysis;

I. INTRODUCTION

As the bond interface of new and old concrete between CRTSIII track slab and self-compacting concrete, layer may have internal potential defects, bond relies on the van der Waals force and mechanical bite force, besides, the void exists in concrete organization and the gap on peripheral aggregate in loading process, which becomes the weakest link in the concrete [1-3]. Poor combination of old and new concrete, unsolidified pouring, temperature stress, shrinkage stress, volumetric shrinkage and creep, the external environment and train loads, etc. could make the gap between the track slab and self-compacting concrete layer[4-6]. According to the relevant literatures of along the lateral length and position of CRTSIII track slab damage situation investigation, three categories conditions of gap can be divided: condition of slab edge gap, condition of slab center gap and condition of gap under rail [7].

II. CALCULATION MODEL AND RELATED PARAMETERS

To study interlaminar mechanical characteristics of track structure, the CRTSIII track slab beam-body model was established by the finite element software ANSYS, the rail use beam element to simulate while track, slab, self-compacting concrete layer and hydraulic support layer use three-dimensional entity unit to simulate, as shown in fig1[8-10]. The bonding destruction of the layer between track slab and self-compacting concrete use contact element to simulate. In reality, bonding failure between the layers are often accompanied by concrete damage so the damage of concrete uses the extinction unit of element birth and death to simulate.
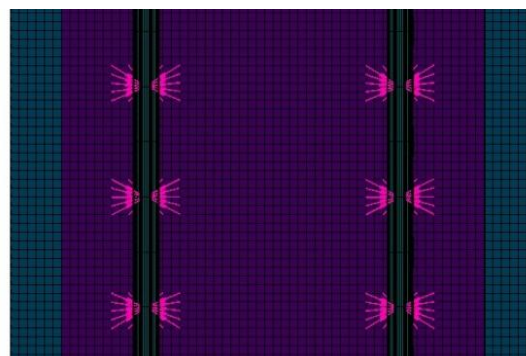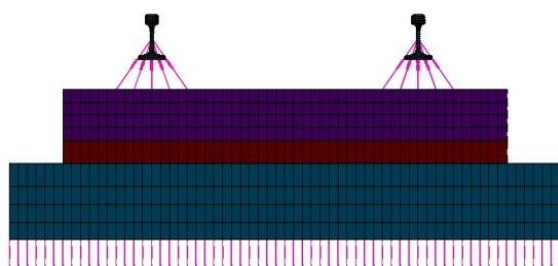

Figure 1. Finite Element Model

In this model, the type of rail is 60 kg/m, the vertical stiffness of fastener is 50 kN/m, the spacing of fasteners is 0.63 m, the track slab is 0.2 m thick, 2.5 m wide and 5.6 m long, the Self-compacting concrete is 0.09 m thick and 2.5 m wide, the basement slab is 0.3 m thick and 3.1 m wide. The wheel load using uniaxial load form and taking the single wheel of 225 kN as vertical load, the most unfavourable load acting on the border between gap area and non-gap area. The largest temperature gradient is 90℃/m and the largest negative temperature gradient is 45℃/m. The commonly used temperature gradient is the half of the maximum temperature gradient. The common temperature gradient is to check the combined train loads [11].

III. THE CALCULATION RESULTS AND ANALYSIS

This section mainly analysis on the causes of gap from the numerical calculation.

A. Causes of Slab Edge Gap

Under the effection of negative temperature gradient, the slab corner, slab end and slab edge are in the vertical tensile stress as 0.43MPa, the bonding strength of track slab and self-compacting concrete ranged from 0.736MPa to 1.76MPa, as the bond interface of new and old concrete between CRTSIII track slab and self-compacting concrete layer may have internal potential defects, the poor combination of old and new concrete, unsolidified pouring, temperature stress, shrinkage stress, volumetric shrinkage and creep, the external environment and train loads, etc. could make the gap between the track slab and self-compacting concrete layer. Once the bonding destruction between CRTSIII track slab layers happened, the tensile stress of slab corner would increase significantly and the length of gap would increase further, the specific calculation results as shown in figure 2. Condition of 1-0 represents the intact interface while condition 1-a to condition 1-f represents the gap on slab edge with the transverse length × longitudinal length's size of 0.1m×0.1m, 0.2m×0.1m, 0.2m×0.2m, 0.3m×0.2m, 0.3m×0.3m, 0.4m×0.3m. Select the maximum compressive and tensile stress of track slab and self-compacting concrete interface from the Figure 2, as shown in Table 1. According to Table 1, when the transverse and longitudinal length of gap is less than 0.4 m, the gap area would develop along the shorter direction, when the gap has the equally length in transverse and longitudinal, the gap area would develop along the vertical direction. When the transverse length of gap is equal to 0.4 m, because of the limitation of door tendons, the gap would develop along the longitudinal direction.
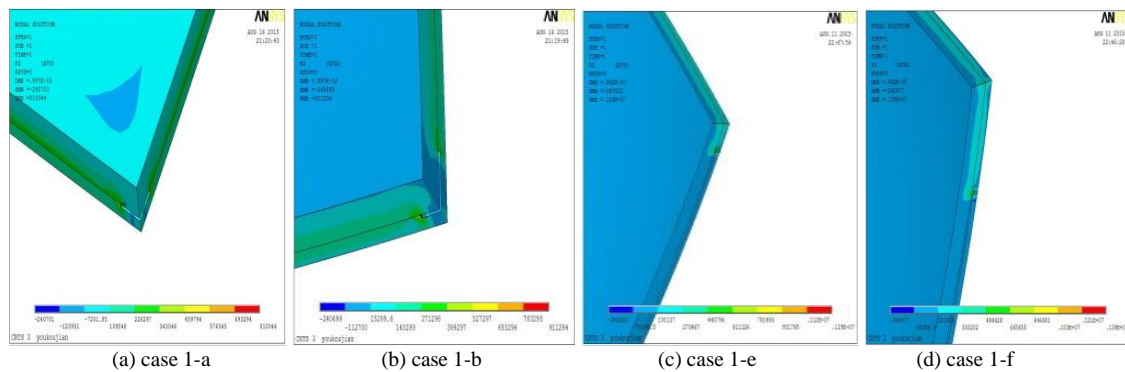

(a) case 1-a   (b) case 1-b   (c) case 1-e   (d) case 1-f

Figure 2. The Interface of Vertical Stress Cloud

TABLE I. The Position and Size of the Vertical Stress(MPa)of the Interface

CASE		Maximum stress position	Interface between slab and self compacting concrete
			Vertical stress
Case 1-0		Tensile stress	Slab angle	0.43
Case 1-a		Tensile stress	The ends of slab	0.81
Case 1-b		Tensile stress	Slab edges	0.86
Case 1-c		Tensile stress	The ends of slab	0.91
Case 1-d		Tensile stress	Slab edges	1.02
Case 1-e		Tensile stress	The ends of slab	1.1
Case 1-f		Tensile stress	Slab edges	1.11

B. Causes of Slab Center Gap

Under the coupling effect of the train load and positive temperature gradient, the interface between track slab and the self-compacting concrete is in the vertical tension, while the train loads is acting on a quarter of track slab, the interface between track slab and the self-compacting concrete which under the second set of fastener has the largest vertical tensile stress as 1.27MPa. the bonding strength of track slab and self-compacting concrete ranged from 0.736MPa to 1.76MPa and average being 1.1MPa, slab center is easy to get gap.

Condition of 2-0 represents the intact interface while the specific meaning of condition 2-a to condition 2-g has shown in Figure 3, and the calculation results are shown in Figure 4. According to Figure 4, once the bonding destruction under the rail of CRTSIII track slab happened, the vertical stress gap developed to the underneath of first set of fasten, then the gap would develop along the slab center, when the gap developed to the underneath of third set of fastener, while the train loads is acting on a quarter of track slab, interface tension stress is lesser than the train loads acting on slab center as 1.53MPa, and the gap would develop to slab center further, when the gap developed to the underneath of forth set of fastener, the maximum tensile stress appears in the 4.6 m of longitudinal and gap would develop to slab center, when the gap developed to the underneath of seventh set of fastener, the gap would develop to slab edge, when the gap developed to the underneath of ninth set of fastener, the gap would develop to slab center and in condition of longitudinal transfixion.
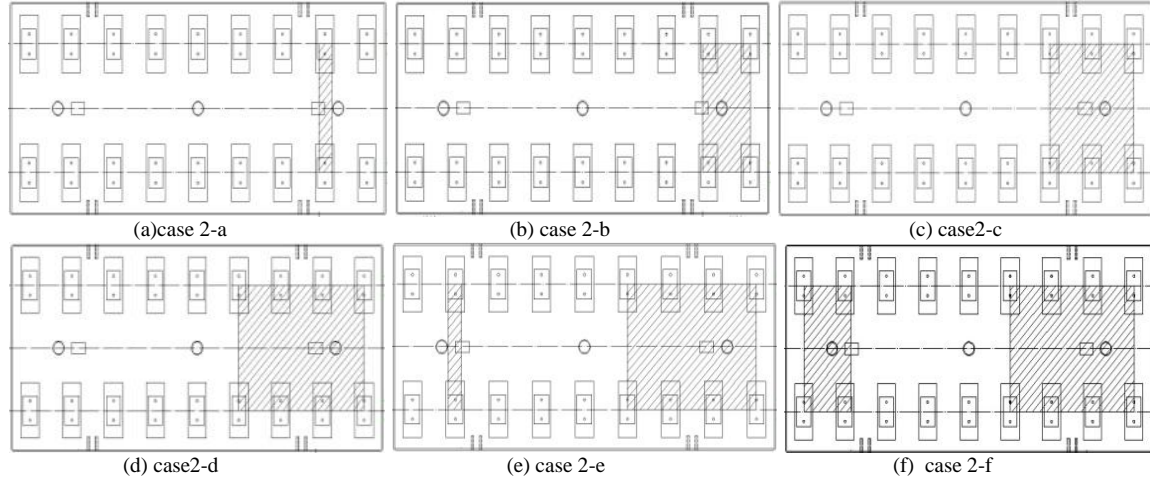

(a)case 2-a   (b) case 2-b   (c) case2-c

(d) case2-d   (e) case 2-e   (f) case 2-f

Figure 3. The Gap Chart of Case 2-a to 2-f

(a)case 2-a   (b)case 2-b   (c)case2-c   (d) case 2-d

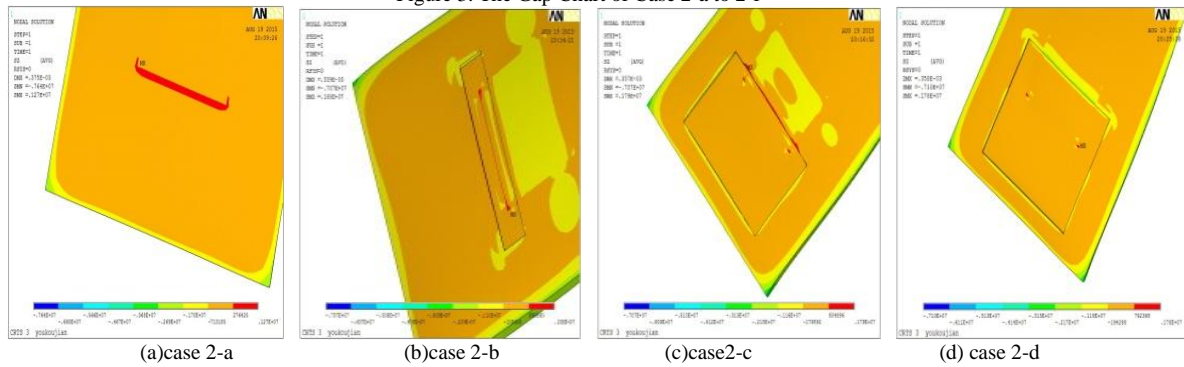Figure 4. The Interface of Vertical Stress Cloud

C. Causes of Gap Under Rail

Once the bonding destruction under the rail of CRTSIII track slab happened, the stress of interface between gap slab and the self-compacting concrete would increase significantly, Under the coupling effect of the train load (acting on slab center) and positive temperature gradient and the length of gap would increase further.

Condition of 3-1 to 3-9 represents the transverse of gap area is 0.7 m and the longitudinal of gap area is increasing stepwise with units of fastener spacing. The results as shown in figure 5, according to the figure 5, the stress of gap in longitudinal edge interface and the position of maximum stress position, as shown in table 2.
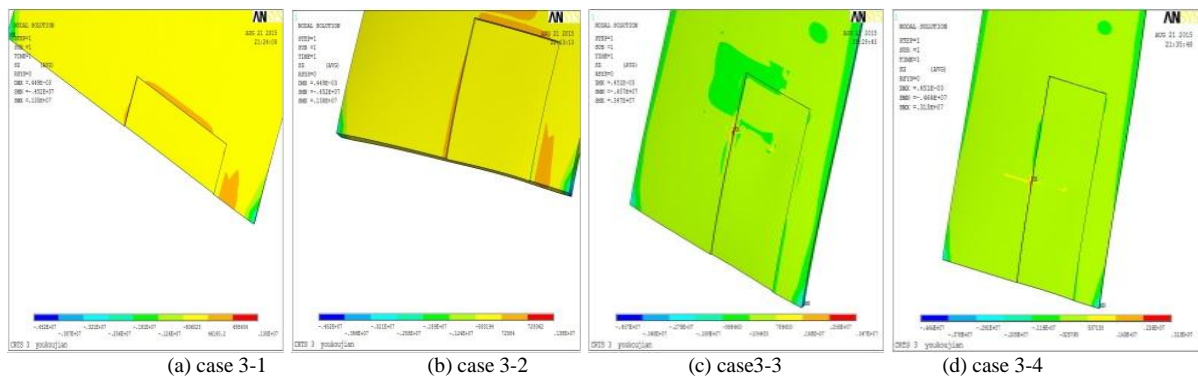

(a) case 3-1   (b) case 3-2   (c) case3-3   (d) case 3-4

Figure 5. The Interface of Vertical Stress Cloud

TABLE II. The Position and Size of the Vertical Stress(MPa)of the Interface

CASE		Longitudinal edge of the gap	Maximum stress position	Interface between slab and self compacting concrete
				Vertical stress
Case 3-1	Tensile stress	0.69	Longitudinal edge of the gap	0.69
Case 3-2	Tensile stress	0.73	Second sets of fasteners	1.88
Case 3-3	Tensile stress	1.68	Second sets of fasteners	2.58
Case 3-4	Tensile stress	1.40	Second sets of fasteners	2.26
Case 3-5	Tensile stress	0.33	Second sets of fasteners	2.26
Case 3-6	Tensile stress	0.33	Second sets of fasteners	2.26
Case 3-7	Tensile stress	0.33	Second sets of fasteners	2.26
Case 3-8	Tensile stress	1.39	Second sets of fasteners	2.26
Case 3-9	Tensile stress	0.31	Second sets of fasteners	2.32

IV. CONCLUSION

(1) The negative temperature gradient loads are the main cause leading to the gap of slab edge and the corner of slab is the most vulnerable. When the horizontal and vertical length of gap is less than 0.4 m, the gap area would develop along the shorter direction, when the gap has the equally length in horizontal and vertical, the gap area would develop along the vertical direction. when the horizontal length of gap is equal to 0.4 m, because of the limitation of door tendons, the gap would develop along the vertical direction.

(2) The train loads and the positive temperature gradient loads are the main causes leading to the gap of slab center, and the position of 1.0m away from the longitudinal of slab center is most likely to get gap. When the slab center gaps, with the different positions of train load, the length of gap would increase further.

(3) The train loads and the positive temperature gradient loads is the main cause of the gap under rail, and the edge of end-slab is most likely to get gap. When the edge of end-slab gaps, the interface stress would increase and gap develop to longitudinal.

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