An "T" Type Reinforcement Scheme of Portal Steel to Restrain the Gap between CRTSIII Slab and Self-compacting Concrete

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Abstract—The gap between slab and self-compacting concrete is one of the typical disease for CRTSIII slab ballastless track structure under service condition. This paper established finite element mechanical analysis model of track structure including rail, fastener, track slab, portal steel, self-compacting concrete, isolation layer and base according to the CRTSIII track slab structure characteristics, an "t" type reinforcement scheme of portal steel was proposed, and analyses the vertical stress characteristics of the interface between slab and self-compacting concrete under train and temperature gradient load before and after reinforce portal steel. The results show that when the interface appears gap and is non-gap, the vertical maximum tensile stress of interface is respectively reduced 80% and 87% after reinforce portal steel. It can also reduce the probability of the occurrence of gap between the slab and self compacting concrete, slow down the expansion rate of the isolated region, and improve the durability of rail structure in the course of service.

Keywords-CRTSIII Type Slab Ballastless Track Structures; Temperature Gradient; Gap between Slab and Self-Compacting Concrete; Reinforce Pportal Steel; Interfacial Stress;

I.   INTRODUCTION

CRTS III Type Slab Ballastless Track as a new type of slab structure in our country, the application of the time is short, and its structure design has been widely concerned by scholars [1-4]. For the moment, China has not yet systematic in-depth study of how to prevent the gap between slab and self-compacting concrete [5]. In this paper, according to CRTS III Type Slab Ballastless Track characteristics, a finite element analysis mode is established which include rail, fastener, track plate, door type steel bar connection, self compacting concrete, isolation layer and the base. Based on the analysis of the causes of the gap, an "t" type reinforcement scheme of portal steel was proposed.

II.   CALCULATION MODEL AND PARAMETERS

A finite element models were established using the commercial finite package ANSYS [6-9]. Rail is simulated by beam element and slab, self compacting concrete layer and the base are simulated by 3D solid element, as shown in Figure 1. Because of considering inter layer interactions, a door shaped rib is simplified for two pins and simulated by 3D linear finite strain beam. In the actual situation, the failure of the middle layer is often accompanied with the destruction of concrete, and the failure of the concrete is simulated by the death element of the unit and the life and death.
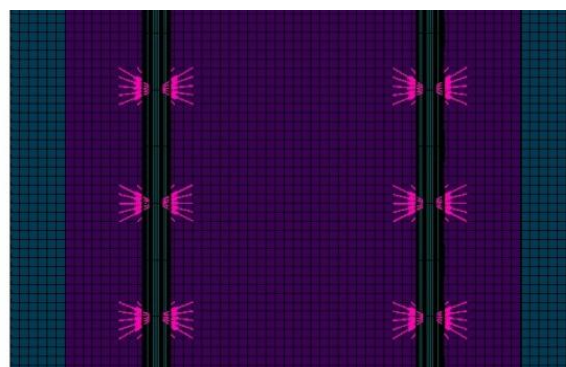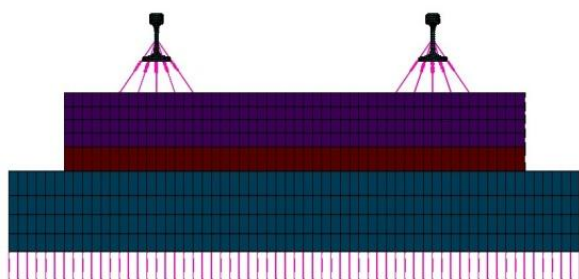

Figure 1. Finite Element Model

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 [9].

III. THE REINFORCEMENT SCHEME OF PORTAL STEEL

The negative temperature gradient loads is the main cause leading to the gap of slab edge and the corner of slab is the most vulnerable [5]. 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. 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. With the slab center gaps, with the different positions of train load, the length of gap would increase further. By encrypting portal steel to reduce the vertical tensile stress of the interface, specific encryption scheme as shown in figure 2. In the figure 2, hollow circles represent intrinsic portal steel of CRTS III Type Slab Ballastless Track, solid circle represents reinforce portal steel.
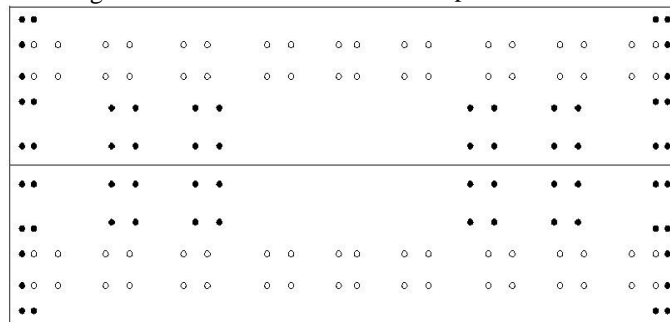

Figure 2. Schematic Diagram of Portal Reinforcement Encryption Scheme

IV. A COMPARATIVE ANALYSIS OF THE VERTICAL STRESS OF THE INTERFACE AROUND THE PORTAL REINFORCEMENT ENCRYPTION.
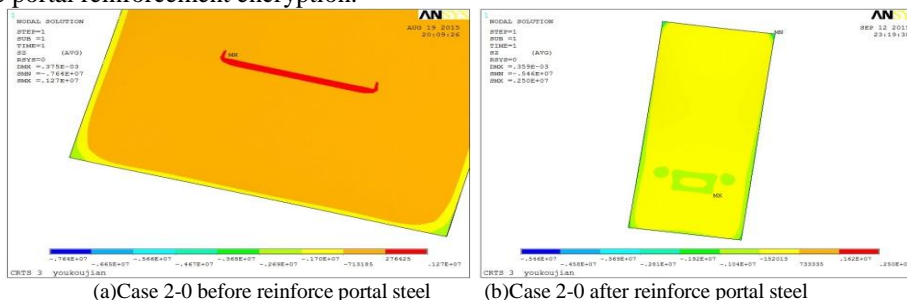
This section mainly introduces the comparison of the vertical stress around the portal reinforcement encryption of the gap and non-gap.

A. Comparison of the Vertical Stress of the Interface Around the Portal Reinforcement Encryption under the Condition of the Non-gap.

Negative temperature gradient load is the main cause of the gap at the edge of the slab, and the coupling load of the train and the positive temperature gradient is the main reason leading to the gap of the rail and the slab. Therefore, compare the negative temperature gradient load with the coupling load. The vertical stress cloud of the interface is shown in Figure 3, the position and size of maximum value of the vertical tension stress is shown in Table 1 around the portal reinforcement encryption.

From the Figure 3 and Table 1, we can see that under the influence of the negative temperature gradient load, the position of maximum tensile stress of the track slab and the self compacting concrete is constant around the portal reinforcement encryption, but tensile stress decreases about 26%, from 0.43Mpa to 0.32Mpa. However under the influence of the train and temperature gradient coupling load, the position is still constant, But tensile stress decreases about 80%, from 1.27Mpa to 0.25Mpa.

In summary, under the influence of the negative temperature gradient load, the tensile stress between the track slab and the self compacting concrete decreases after the portal reinforcement encryption, reduce the probability of the gap at the edge of the slab. However, under the influence of the train and temperature gradient coupling load, the tensile stress still decreases, but greatly reduce the probability of the emergence of the plate.

(a)Case 2-0 before reinforce portal steel   (b)Case 2-0 after reinforce portal steel

Figure 3. The Vertical Stress Cloud before and after Reinforce Portal Steel under Non-Gap Case

TABLE I. The maximum Vertical Tensile Stress of Interface after and before Reinforce Portal Steel under Non-Gap Case

CASE	The maximum vertical tensile stress before reinforce portal steel		The maximum vertical tensile stress after reinforce portal steel	
	Position	Size(MPa)	Position	Size(MPa)
case 1-0	Slab angle	0.43	Slab angle	0.32
case 2-0	the 1.0 m of longitudinal	1.27	the 1.0 m of longitudinal	0.25

B. Comparison of the Vertical Stress of the Interface Around the Portal Reinforcement Encryption under the Condition of the Gap.

1) A Comparative Analysis of the Vertical Stress of the Interface under the Condition of the Gap at the Edge of Slab.

The main cause of the marginal gap is the negative temperature gradient load. Therefore, the negative temperature gradient load is applied, and the vertical stress cloud is shown in Figure 4, the position and size of maximum value of the vertical tension stress is shown in Table 2 around the portal reinforcement encryption.

From the Figure 4 and Table 2, we can see that under the influence of the negative temperature gradient load, the position of maximum tensile stress of the track slab and the self compacting concrete is constant around the portal reinforcement encryption. But tensile stress decreases. When the gap area is 1-a, tensile stress decreases about 30%,from0.81Mpa to 0.57Mpa,when is 1-c, tensile stress decreases about 47%,from 0.86Mpa to 0.46Mpa, when is 1-e, tensile stress decreases about 55%,from 1.1Mpa to 0.49Mpa, when is 1-g, tensile stress decreases about 63%,from 1.12Mpa to 0.41Mpa.Before the portal reinforcement encryption, With the increase of the gap area, the maximum tensile stress of the interface increases, but after it, the maximum tensile stress of the interface remains constant or slightly decreases.

In summary, when gap appears in a small area of corner-slab, the vertical tensile stress of the interface is also significantly lower than before, and this greatly controls the development of the interlayer to the horizontal and vertical direction.

(a)Case 1-a after reinforce portal steel   (b)Case 1-a after reinforce portal steel
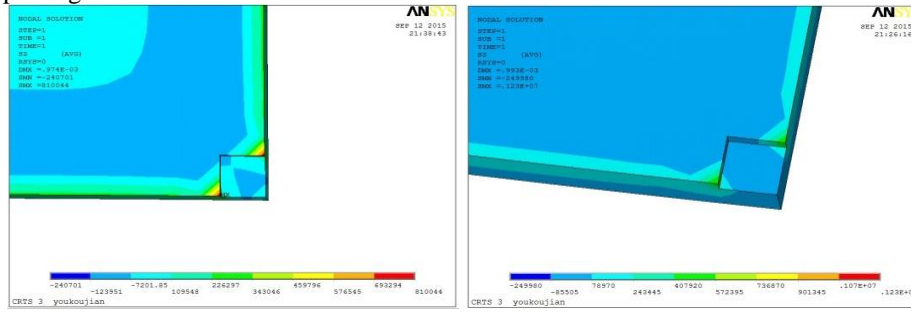
Figure 4. The Vertical Stress Cloud before and after Reinforce Portal Steel under Gap Case

TABLE II. The Maximum Vertical Tensile Stress of Interface after and before Reinforce Portal Steel under Gap Case

CASE	The maximum vertical tensile stress before reinforce portal steel		The maximum vertical tensile stress after reinforce portal steel	
	Position	Size(MPa)	Position	Size(MPa)
case 1-a	The ends of slab	1.27	The ends of slab	0.57
case 1-c	The ends of slab	0.86	The ends of slab	0.46
case 1-e	The ends of slab	1.10	The ends of slab	0.49
case 1-g	The ends of slab	1.12	The ends of slab	0.41

2) A Comparative Analysis of the Vertical Stress of the Interface under the Condition of the Gap at the Central of Slab.

The main cause of the gap in the slab is the coupling of the train load and the positive temperature gradient. therefore, comparing the coupling positive temperature gradient load with the train load, and the vertical stress cloud is shown in Figure 5, the position and size of maximum value of the vertical tension stress is shown in Table 3 around the portal reinforcement encryption.

From the Figure 5 and Table 3, we can see that under the influence of the coupling positive temperature gradient load and the train load, the position of maximum tensile stress of the track slab and the self compacting concrete is constant around the portal reinforcement encryption, But tensile stress decreases. When the gap area is 2-a, tensile stress decreases about 58%, from 1.88Mpa to 0.78Mpa, when is 2-b, tensile stress decreases about 60%, from 1.79Mpa to 0.49Mpa.Before the portal reinforcement encryption, With the increase of the gap area, the maximum tensile stress of the interface increases, but after it, the maximum tensile stress of the interface increase, yet the value is small.

In summary, when gap appears in a small area of middle-slab, the vertical tensile stress of the interface is also significantly lower than before, and this greatly controls the development of the gap to the horizontal and vertical direction.

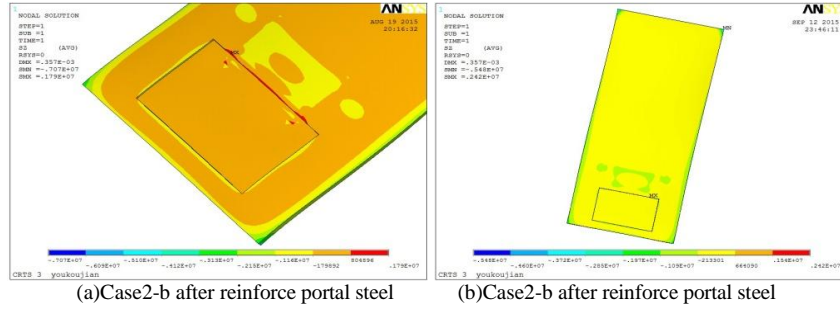(a)Case2-b after reinforce portal steel   (b)Case2-b after reinforce portal steel

Figure 5. The Vertical Stress Cloud before and after Reinforce Portal Steel under Gap Case

TABLE III. The Maximum Vertical Tensile Stress of Interface after and before Reinforce Portal Steel under Gap Case

CASE	The maximum vertical tensile stress before reinforce portal steel		The maximum vertical tensile stress after reinforce portal steel	
	Position	Size(MPa)	Position	Size(MPa)
case 2-a	The 1.0 m of longitudinal	1.88	The 1.0 m of longitudinal	0.78
case 2-b	The 1.0 m of longitudinal	1.79	The 1.0 m of longitudinal	0.71

V. CONCLUSION

(1) In this paper, according to CRTS III type slab ballastless track structure stress characteristics, through the establishment of finite element mechanical analysis model, putting forward an "t" type reinforcement scheme of portal steel.

(2) Under the influence of the train and negative temperature gradient load, whether before or after the gap appears, the safety factor of the interface of slab and self compacting concrete was severely shattered was significantly increased after reinforce portal steel. It can also reduce the probability of the occurrence of gap between the slab and self compacting concrete, slow down the expansion rate of the isolated region, and improve the durability of rail structure in the course of service.

(3) The influence of reinforce portal steel for the adhesion property of interface and construct self compacting concrete will need to be further research.

REFERENCES

[1] GAO Liang, ZHAO Lei, QU Cun, CAI Xiaopei. Analysis on Design Scheme of CRTS III Type Slab Ballastless Track [J]. Journal of Tongji University (Natural Science), 2013, 41(6): 848-855.

[2] WEI Hedao. Research on the Structure Design of New Unit Slab Ballastelss Track on the Zhengzhou-Xuzhou Railway Passenger Dedicated Line [D]. Changsha: Central South University, 2013.

[3] LI Yangcun. CRTS III Type Slab Track Technology Applied in Wuhan to Xianniing Intercity Railway [J]. Journal of Railway Engineering Society, 2013, 15 (4):51-55.

[4] WANG Pu, GAO Liang, ZHAO Lei, QUN Cun. Study on Setting Method of Position-limitation Recess of CRTS III Type Slab Ballastless Track[J]. Engineering Mechanics, 2014, 31(2):110-115.

[5] YANG Zheng. Mechanics and Maintenance Standards of Connection Damage for CRTS III Slab Track [D]. Chengdu: Southwest Jiaotong University, 2011.

[6] WANG Yuhang, WANG Jijun. Multi-scale Finite Element Model for CRTS III Type Slab Ballastless Track Structures [J]. Journal of Railway Science and Engineering, 2015, 12(3): 468-474.

[7] WANG Xinmin. Numerical Analysis of Ansys Engineering structure[M]. Beijing: China Communications Press, 2007.

[8] ZHU Bofang. Application of the finite element method[M]. Beijing: China Water Power Press, 2004.

[9] China Academy of Railway Sciences. General Reference Map of High Speed Railway CRTS III Type Slab Ballastless Track Structures[S]. Beijing: China Academy of Railway Sciences, 2015.

[10] China Academy of Railway Sciences. General Reference Map of High Speed Railway CRTS III Type Slab Ballastless Track Structures[S].Beijing: China Academy of Railway Sciences, 2015.