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# High temperature deformation and damage mechanism of CRTSIIBallastless track on high speed railway

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**Abstract**: To study the temperature deformation characteristic and damage mechanism under system temperature rise and temperature gradient, finite element method was used to establish the theoretical analysis model of the ballastless track which covered 12 slabs with length of nearly 80 meters. The view of jaw effect of track joint force was put forward to explain the way how joint concrete crush. The track deformation characteristics were calculated under homogeneous joint damage and inhomogeneous joint damage, as while as their combination. Through theoretical calculation, the mechanism of track local instability has been partly rigorously studied.

**Keywords**: High speed railway, slab ballastless track, temperature deformation, damage mechanism, local instability

## 1 Introduction

CRTSII slab type ballastless track is one type of China’s own ballastless track and has been widely used in China high speed railways. Being laid continuously in longitudinal direction, this kind of track usually has visible temperature effect. As the operation years increase, track damages gradually accumulate. With the occurrence of damages including slab warpage, joint concrete crushing and others, continuous mechanical characteristics of track system change in some extend. On the temperature effect of the track system, some scholars have studied the problem from the point of view of heat transfer[1]. Meanwhile, some focus on the slab temperature field distribution characteristics[2-4]. More pay attention to the track temperature effect itself under different conditions[5-13]. To meet the safe and efficient operation of high speed railways, it’s critical to study the evolution trend of track continuous mechanical characteristics, and its deformation under combination of different track damages.

## 2 Temperature Effect Analysis Model of Ballastless track

Based on finite element solution, temperature analysis model of one track segment has been established, covering 12 track slabs in total length of 80 meters, as shown in Figure 1. Materials of track slab, rail and joint concrete are selected according to design. Rail is simulated by Timoshenko beam, track slab and joint by solid element. Both ends of the segment have fixed constraints, as shown in Figure 2. Rail fasteners are simulated by 3-D springs, as shown in Figure 3. The constraint condition of the contact surface between track bottom and Concrete-Asphalt(CA) mortar cushion is simplified to vertical bearing spring, as shown in Figure 4. 20°rise of system temperature and 100°C/m temperature gradient are considered in analysis model.

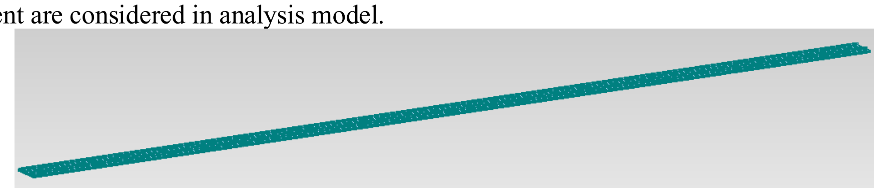

**Figure 1.** 3-D View of Track Segment

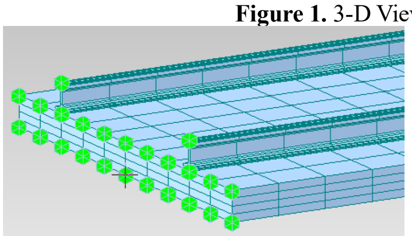

**Figure 2** Fixed Constraints at Segment Ends

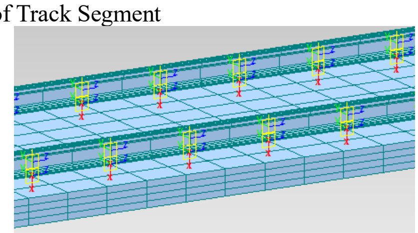

**Figure 3** Rail fasteners constraints

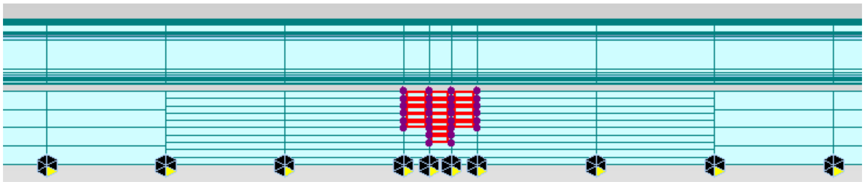

**Figure 4** Mortar Cushion Bearing Constraints

Temperature effect of track system is calculated under combinations of different track slab concrete damages to find out the development law of track temperature diseases.

## 3 Track slab temperature deformation and joint damage mechanism

### 3.1 Damage mechanism of track slab joint concrete

Before track damages accumulation, the structure temperature stress is in the self-balanced state, while structure deformation is very small. However, joint concrete has stress concentration at its bottom, as shown in Figure 5.

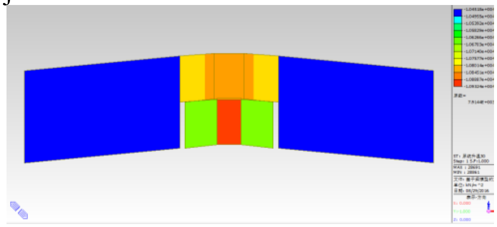

**Figure 5.** Stress Concentration at Bottom of Joint Concrete

Considering the low level of concrete strength, difficulty of pouring work and other minus points, narrow joint is supposed to crush earlier than wide joint. After the occurrence of narrow joint partial crushing, the whole joint concrete comes into eccentric compression state, which accelerates the crushing of narrow joint. As shown in Figure 6.

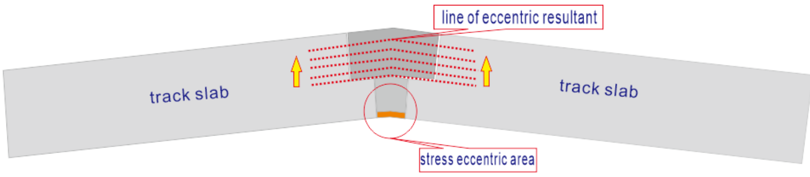


**Figure 6** Eccentric Resultant in the Joint

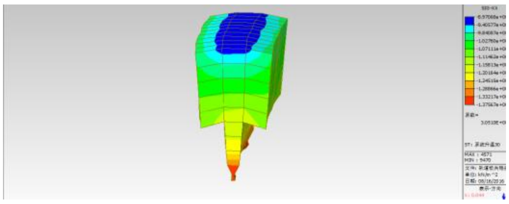

**Figure 7.** Stress Redistribution in Joint Concrete

With the increase of narrow joint damage, it's predictable that the wide joint would follow hard on the heels. Along with the rise of the temperature in the track slabs, stress in the joint arises. When stress comes to the material strength level, joint concrete begins to crush.

### 3.2 Track structure temperature deformation characteristics

Field investigation results shows that the actual damage level of each joint in the operation line is different, and there is a combination effect to the track structure temperature deformation. To simulate this combination effect, track structure temperature deformation under different even and uneven joint damage is calculated.

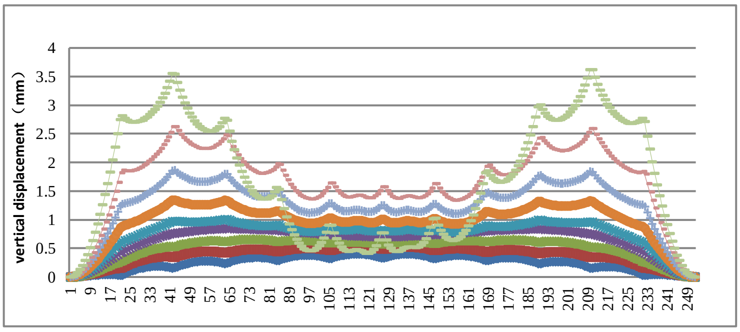


**Figure 8.** Track Slab Displacement under Joint's Different Even Damage

As shown in Figure 8, track structure's temperature deformation increases when narrow joint's even damage gets worse. Besides, calculation results show that the maximum deformation could reach 3.5mm when narrow joint's even damage come up to 90%. Considering rail's compression on track slabs, this deformation result could reflect most of rail's top displacement.

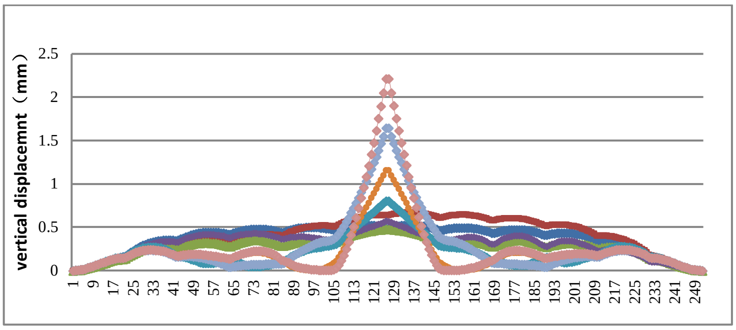


**Figure 9** Track Slab Displacement under Joint's Single Uneven Damage

When track system have a single uneven damage in one narrow joint combined with 20% even damages in others, track temperature deformation at the feature point grow with the increasing of uneven damage. When damage comes up to 90%, deformation peak could be 2.2mm. As shown in Figure 9.

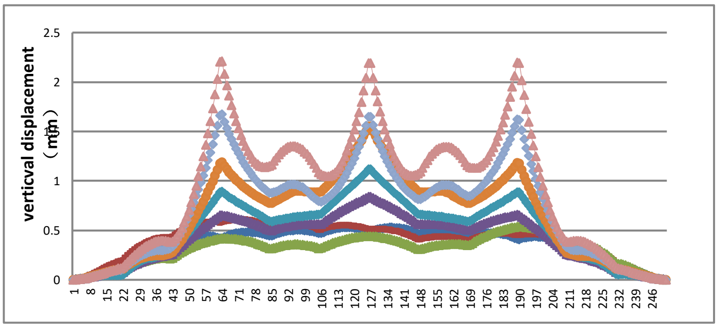


**Figure 10** Track Slab Displacement under Joint's Three Uneven Damage

Considering multipoint uneven damages, track temperature deformation trend is similar to single uneven situation, as while as its peak value. As shown in Figure 10.

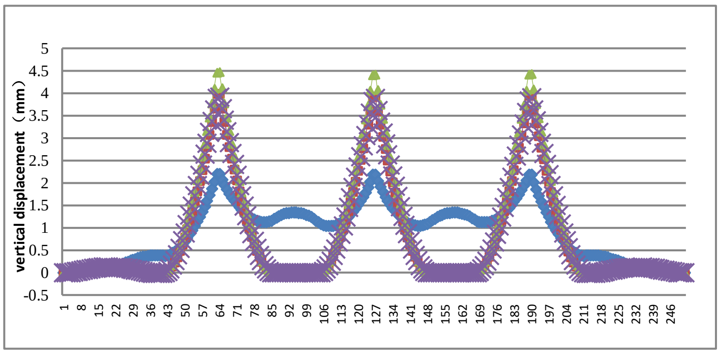


**Figure 11** Track Slab Displacement under Three Narrow Joints' Failure

According to joint damage mechanism above, eccentric resultant line moves upward along with the crushing of joint bottom concrete. Consequently, wide joint concrete would begin to crush from the bottom which could enlarge the deformation of track slabs. Calculation results show that the deformation peak value could reach 4.5mm when the three feature wide joints approach their failure state. As shown in the Figure 11.

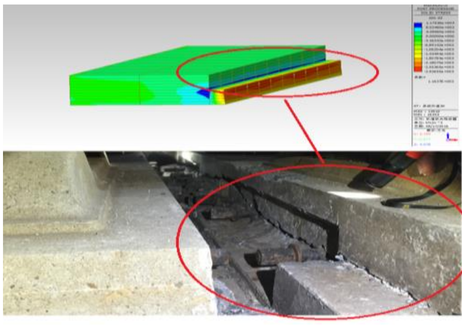

**Figure 12** Instability Characteristics of Track Slab Joint

When wide joint concrete begins to crush, track structure actually has come into critical state of instability. If the track system temperature continuously gets high, wide joint concrete would collapse very fast. Meanwhile, the end of track slab would crack along the half height section surface.

## 3 Conclusion

1) Narrow joints are supposed to damage earlier than wide joints because of pouring difficulty and low concrete strength. Stress concentration at the bottom of joint would accelerate this procedure.

2) Track structure's temperature deformation increases along with the rising of joint's even and uneven damages. The deformation maximum could be 3~4mm.

3) Track structure step into critical state of instability when wide joint begins to collapse, while the end of track slab cracks along the section's half height surface.

## References


[1] SHI Xianfeng, LI Jianbin. Research on Temperature Effect on the Structure of Slab Ballastless Track. JOURNAL OF RAILWAY ENGINEERING SOCIATY, 2008,(5):30-33.

[2] LIU Yu, CHEN Pan, ZHAO Guotang. Study on the Characteristics of Early Temperature Field of CRTSII Slab Ballastless Track Structure. China Railway Science,2014,35(1):1-6.

[3] WU Bin, LIU Can, ZENG Zhiping, et al. Research on the Temperature Filed Characteristics of CRTSII Slab Ballastless Track. JOURNAL OF RAILWAY ENGINEERING SOCIATY, 2016,(3):29-33.

[4] LI Dongsheng, DONG Liang, JIANG Ziqing, et al. Experimental study on temperature load features of CRTSII slab-type ballastless track structure on bridge. Railway Engineering, 2015,(9):106-120.

[5] LIU Yu, ZHAO Guotang. Analysis of Early Gap between Layers of CRTSII Slab Ballastless Track Structure. China Railway Science, 2013,34(4):1-7.

[6] TANG Jinfeng, YIN Huatuo, ZENG Zhiping, et al. Mechanical Characteristic of Slab Track on Switch Area under Temperature Gradient. Journal of Railway Science and Engineering, 2011,8(1):24-28.

[7] ZHAO Lei, GAO Liang, XIN Tao, et al. Analysis on Calculation of Ballastless Track Composite Slab Temperature Stress in Consideration of Inter-layer Adhesive Effect. Journal of the China Railway Sociaty,2014,36(10):81-87.

[8] Li Wei. [J].Study on Temperature Effect of CRTSII Slab Ballastless Track on High Speed Railway Bridge. Railway Engineering, 2014,(6):122-125.

[9] OU Zumin, SUN Lu. Simplified Calculation Method on Nonlinear Temperature Effects of High-speed Railway Ballastless Track Slab.Journal of the China Railway Sociaty, 2015,37(6):79-87.

[10] HU Jia. STUDY ON DAMAGE BEHAVIOR OF WIDE JUNCTION IN CRTSIISLAB TRACK. Chengdu: Southwest Jiaotong University,2015.

[11] DONG Liang, JIANG Ziqing, WANG Jijun, et al. The Stress-Deformation Characteristics of the End Spine Structure of Bridge Abutment Anchorage System on CRTSII Type Slab Ballastless Track on Bridge. China Railway Science, 2012,33(3):1-7.

[12] BAN Xia.Analysis of the performance of slab ballastless track structure under temperature. Changsha: CENTRAL SOUTH UNIVERSITY,2012.

[13] WEI Jun, BAN Xia, DONG Rongzhen. Analysis of Effect and Damage of Ballastless Track Structure System Induced by Temperature. JOURNAL OF WUHAN UNIVERSITY OF TECHNOLOGY, 2012,34(10):80-85.