Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

Effects of initial up-warp deformation on the stability of the CRTS II slab track at high temperatures

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Cite this as: Zui Chen, Jie-ling Xiao, Xiao-kai Liu, Xue-yi Liu, Rong-shan Yang, Juan-juan Ren, 2018. Effects of initial up-warp deformation on the stability of the CRTS II slab track at high temperatures. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 19(12):939-950. https://doi.org/10.1631/jzus.A1800162

Introduction

In recent years, the China Railway Track System type II (CRTS II) slab track has been widely applied to other routes in China because of high precision and durability. However, at extremely high temperatures, track slabs would be triggered up-warp displacement, threaten the quality and safety of high-speed vehicle operation, and have aroused widespread concern.

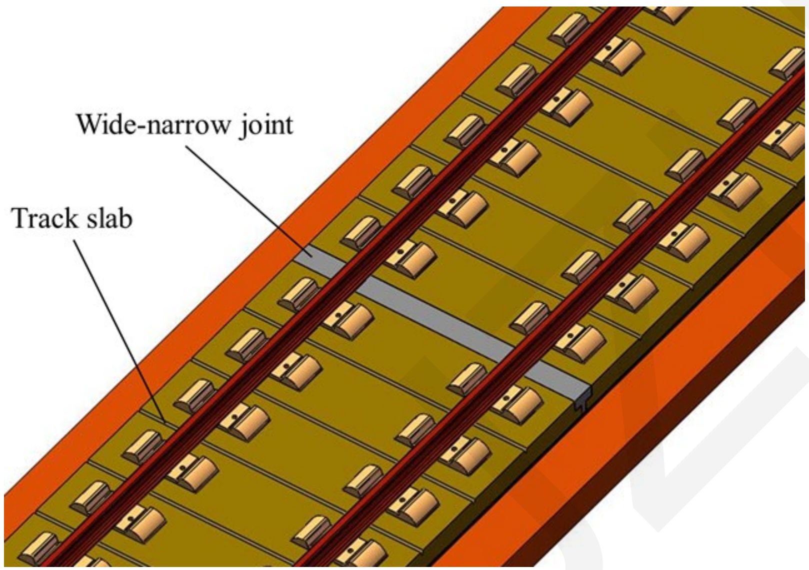

Fig. 1 The structure of CRTS II slab track

Fig. 2 Track slab up-warp on site

Analysis of the up-warp

Based on the principle of energy norm, assume that the total potential energy U of the track slabs consists of compressive deformation energy U_1, bending energy U_2 and gravitational potential energy U_3 during the up-warp process, and the expression of up-warp deformation f , critical load for buckling P_{cr} , relationship between l and l_0 are taken as follows:

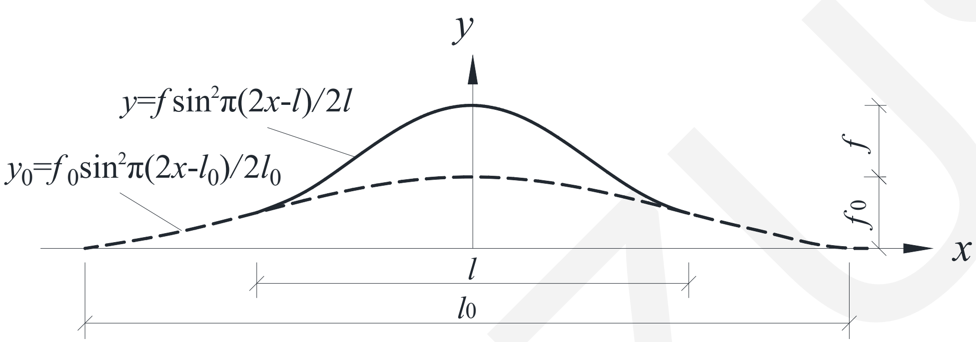

Fig. 3 Assumption of deformed curves

$$f=\frac{\frac{2k\pi\sin k\pi}{1-k^2}f_0l^2P-\rho gAl^4}{4EI\pi^4-\pi^2l^2P}.$$

$$P_{\mathrm{cr}}=\frac{4EI\pi^2}{l_{\mathrm{cr}}^2}.$$

$$\left[\frac{\pi f_0kP}{1-k^2}\left(\frac{3-k^2}{1-k^2}\sin k\pi+k\pi\cos k\pi\right)-2\rho gAl^2\right]\left(4EI\pi^2-Pl^2\right)+Pl^2\left(\frac{2\pi\sin k\pi}{1-k^2}f_0kP-\rho gAl^2\right)=0.$$

The FEM model

On account of the highly nonlinear nature of the model, analytical methods based on energy norm suit only idealized buckling analysis, and cannot accurately solve the problems above. Therefore, FEM was adopted. A geometry model for vertical stability was established.

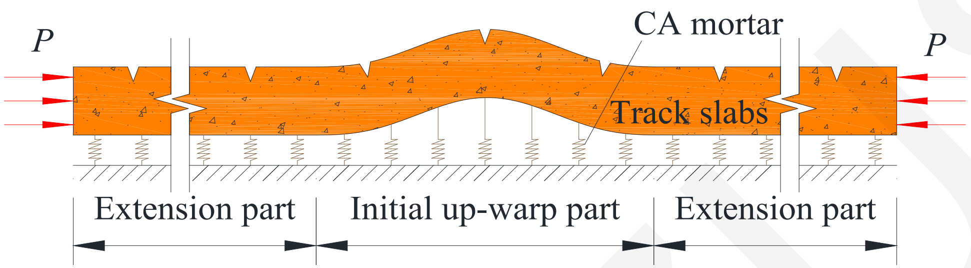

Fig. 4 Diagram of the geometry model

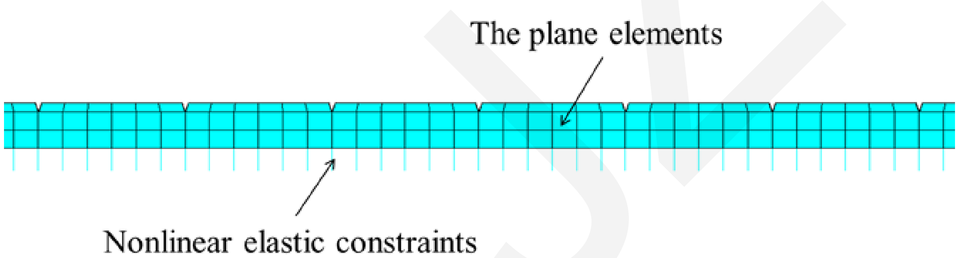

Fig. 5 Diagram of the local model for FEM

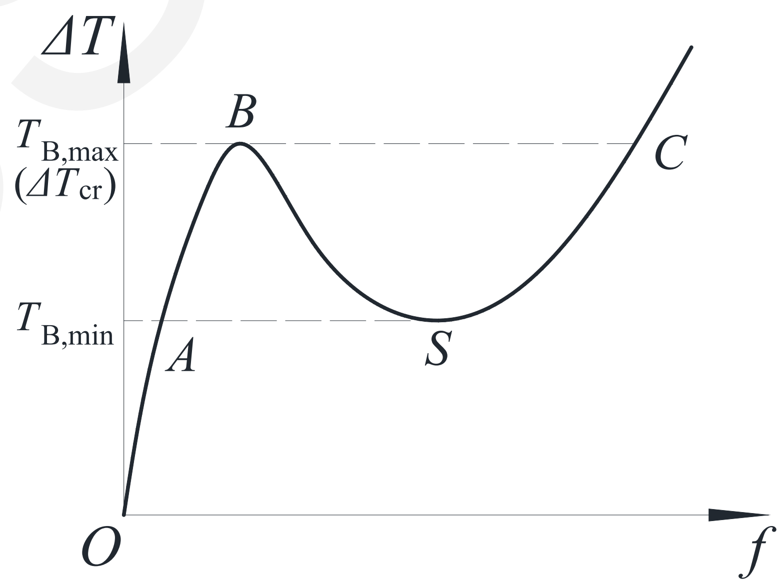

Fig. 6 The Δ*T*-*f* curve of the track slabs

Model verification

The reasonableness and usability of the model were verified by the scale model test on site. A continuous track slab model with a size of 2200 mm × 120 mm × 10 mm was established with a scale ratio of 1:20. It was verified that the FEM above can be used for further analysis of the stability of track slabs.

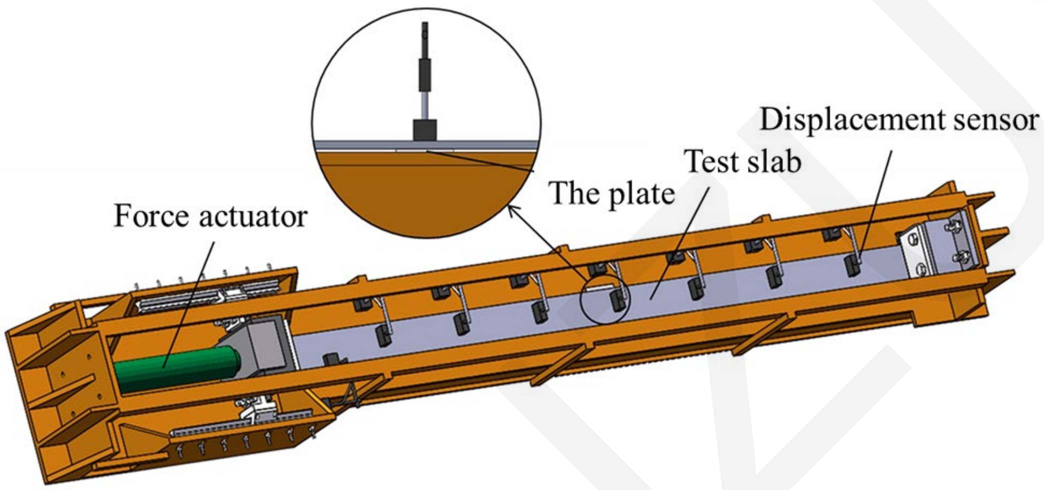

Fig. 7 Diagram of experiment tools

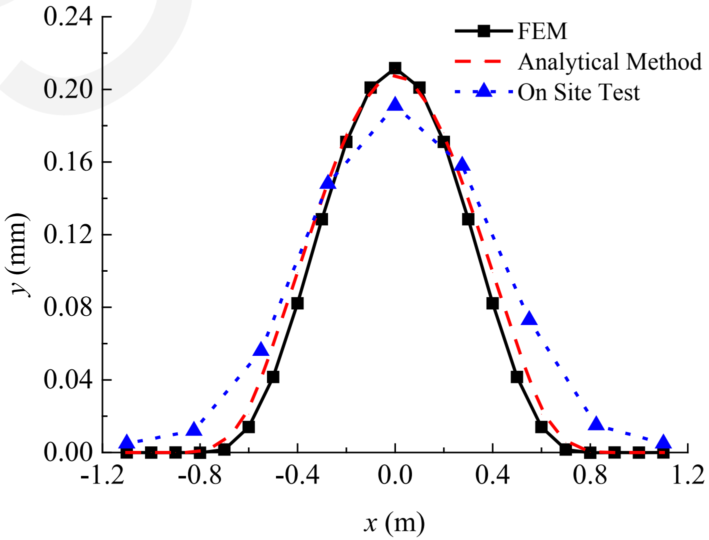

Fig. 8 Vertical displacement distribution of the test slab

Effects of initial up-warp analysis

On the base of the FEM model above, the effects of initial up-warp displacement f_0, initial up-warp length l_0 and line types of initial up-warp on the stability of track slabs on the stability of track slabs are analyzed. For examples, the effects of f_0 are shown as follows.

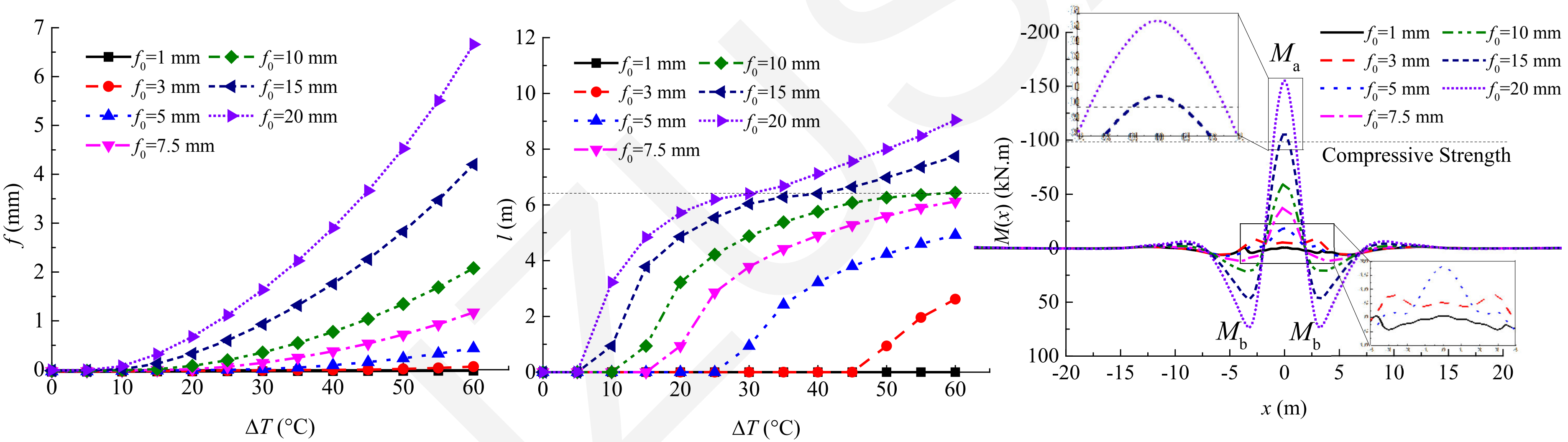

Fig. 9 Variation in *f* with different values of f_0

Fig. 10 Variation in *l* with different values of f_0

Fig. 11 Distribution of *M*(*x*) with different values of f_0 (ΔT=60 ° C)

Conclusions

(1) The trend in f was almost the same when estimated by FEM, analytical method or on site testing, but there was a better agreement between the FEM and the analytical method. The error of f from the test result was maintained within the range of 0.1 mm in the stage of elastic deformation, and the error of P_{cr} was almost within the range of 10%.

(2) Early processes of construction and operation will not induce instability in the track system. If l_0 remains unchanged, the ratio f/l becomes larger with a greater value of f_0.

(3) If track slabs remain with l_0=6.5 m, when f_0 exceeds 15 mm, concrete at the bottom of the apex is most susceptible to compressional destruction. In high temperature environments, the ratio f/l is at its maximum when l_0 =6.5 m.

(4) Slabs which have line types of initial up-warp that have angles at the apex or have smooth boundaries more easily maintain their original form under high temperatures. However, concrete at the bottom of the apex is more prone to pressure failure if track slabs have smooth boundaries.