Key Technology of the Prefabricated Pipe Gallery Underpassing the Railway

Yue Li[a], Yong Zeng[b], Xinyu Yan*

CCCC Second Harbor Engineering Co. Ltd, Wuhan 430040, China

[a]360590996@qq.com, [b]xinyuwithyou@126.com, *347832087@qq.com

Abstract. When the integrated pipe gallery passes through the railway line at a close distance, when the railway line is overhead, the temporary reinforcement system of the line will bear the main load of the continuous operation train, so the stability of the line reinforcement system determines the safety of the railway operation. Based on the project of a prefabricated pipe gallery of the Shenzhen Meiguan expressway corridor through Pingnan railway, this paper uses the finite element numerical analysis method to analyze the stress deformation characteristics of each structure of the reinforcement system under different traffic conditions, to provide a reference for the structural design and construction scheme adjustment of similar projects in the future.

Keywords: prefabricated pipe gallery, expressway, numerical simulation, reinforcement

1 Introduction

With the continuous development of urban traffic, the intersection of urban municipal roads and the existing operating railway lines is inevitable. When the integrated prefabricated pipe gallery crosses the existing railway, it is an important problem to ensure the safe, smooth, and reliable progress of the underpass project under the premise without interruption of the railway. In the underpass construction, the most important thing is to minimize the construction impact on the railway operation. It is an urgent problem to solve the reinforcement system in the underpass construction and put forward the corresponding control measures [1-6]. In the background of the comprehensive pipe corridor of the Meiguan expressway project in Shenzhen City, Guangdong Province, using theoretical research, field monitoring, and numerical simulation, the temporary reinforcement system and safety evaluation method of the railway line are studied.

2 Engineering situation

Shenzhen Meiguan Expressway project includes two municipal comprehensive pipe

D. Li et al. (eds.), *Proceedings of the 2023 9th International Conference on Architectural, Civil and Hydraulic Engineering (ICACHE 2023)*, Advances in Engineering Research 228,
https://doi.org/10.2991/978-94-6463-336-8_9

corridors under the existing Pingnan railway, the underpass process is a pushing method, and the rest is open-dig cast-in-place construction. D24 type steel girder is used to use overhead protection for the Pingnan railway line, the design length of the comprehensive pipe gallery is 20 meters, and the total top distance is 25.94 meters. The 8.8 m×4.1 m concrete frame is used, and the pipe gallery frame is prefabricated in the working foundation pit. The oblique angle at the intersection between the gallery structure and Pingnan railway is about 67 degrees. The buried depth of the pipe gallery is 4.91 meters, and 1.3 meters away from the top of Pingnan railway. Meiguan Expressway is shown in Figure 1, and the structure of the pipe gallery running through the railway is shown in Figure 2.

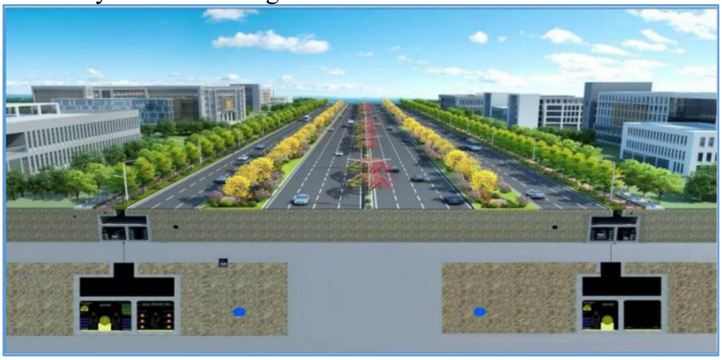


Fig. 1. Schematic diagram of the prefabricated pipe gallery structure of the Meiguan Expressway project.

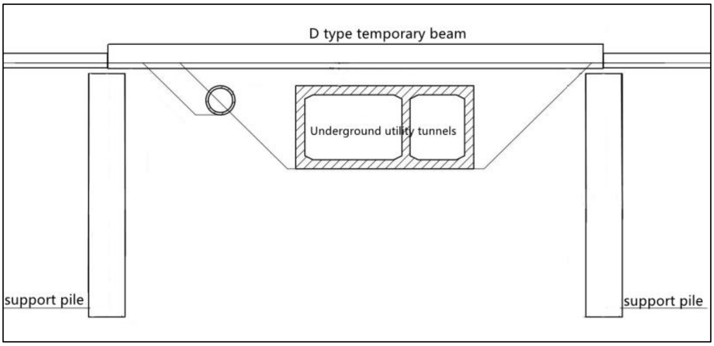


Fig. 2. Schematic diagram of the pipe gallery running through the railway.

3 Finite element analysis of temporary reinforcement system under train load

When the railway line is overhead, the temporary reinforcement system of the line will bear the main load of the continuous operation trains, so the stability of the line reinforcement system determines the safety of the railway [7-11]. Based on the project of a comprehensive pipe corridor crossing Pingnan railway, the finite element numerical analysis method is used to analyze the force deformation characteristics of each structure of the line reinforcement system under different traffic conditions, to provide a reference for the structural design and construction of similar projects in the future.

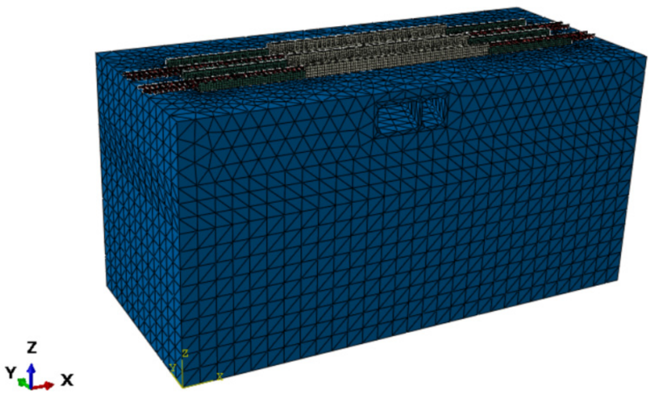
3.1 Model foundation

According to the construction scheme, the deformation characteristics of the temporary reinforcement system under the train load are analyzed, and the finite element software of ABAQUS is selected to establish the 3-D numerical model. The calculation model is mainly composed of three parts: upper rail reinforcement system, lower support pile, and railway subgrade. To reflect the change law of the line reinforcement system under the action of train load, the establishment of the model includes the existing railway subgrade, track, and reinforcement system (D24 longitudinal beam, steel beam, supporting pile). The specific parameters are shown in Table 1.

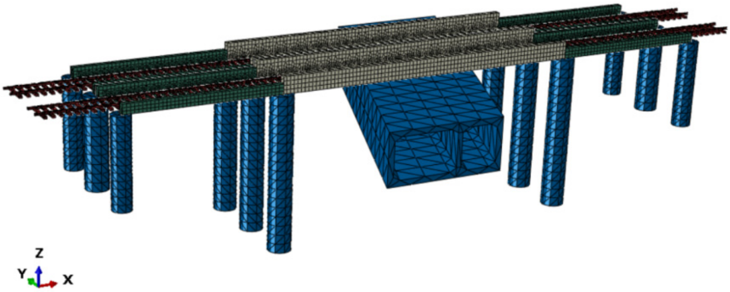
Table 1. Reinforcement system parameters.

Material	Elastic modulus (MPa)	Poisson ratio	Density (kg/m³)
D-type steel beam	2.1×10^5	0.28	78.5×10^3
Crossbeam	2.1×10^5	0.28	78×10^3
Steel inclined rod	2.0×10^5	0.3	78×10^3
Pile	3.15×10^4	0.2	24×10^3

As shown in Figure 3, the height of the pipe gallery is 4.4 meters, and the width of the single hole is 8.8 meters. Considering the overall structural width of 20 meters, to effectively simulate the force situation of the line reinforcement system, according to the principle of Saint Venan, taking 3 times the structural width of the soil on both sides of the pipe gallery along the road direction, the size of the road direction (Y direction) along the soil under the track is 100 m, the width along the excavation direction (X direction) is 50 m, and the model height (Z direction) is 30 m.



(a)



(b)

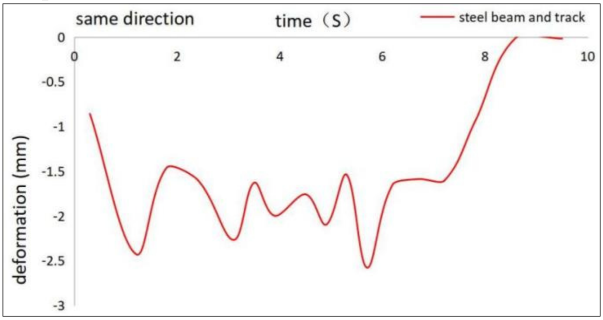
Fig. 3. Computational model

3.2 Analysis of computational results

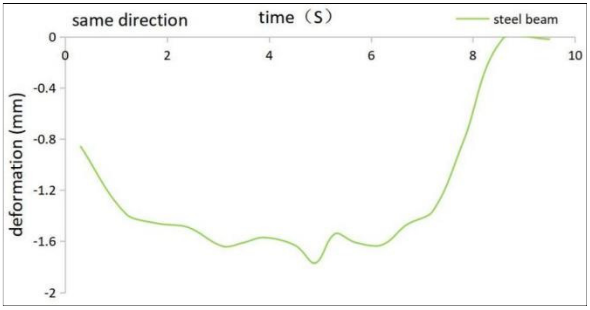
Two trains with 5 carriages, and 8 wheels, each train running at a speed of 12 m/s, considering the deformation characteristics of D-type beam under the condition of dynamic load.

As shown in Figure 4 (a) (b), it is the vertical deformation of the D-type beam and the track under the dynamic load of two trains in the same direction. When the train is located at the starting point of the line reinforcement system, the maximum vertical deformation of the D beam + track is 0.86 mm and 0.86 mm respectively, when the rear of the train is located in the line reinforcement system, the maximum vertical deformation of D beam and tracks tend to be zero, as shown in vertical deformation cloud Figure 5 (a) (b), D beam and track maximum vertical deformation occurred near the D24 beam span, the maximum is about 2.58 mm,1.77 mm.

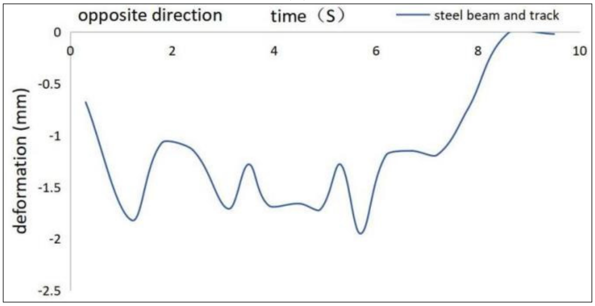
As shown in Figure 4 (c) (d), it is the vertical deformation of the D-type beam and the rail of the reinforcement system under the dynamic load of the two directional trains respectively. When the train is located at the starting point of the line reinforcement system, the maximum vertical deformation of D beam + track is 0.68 mm and 0.68 mm, when the rear of the train is located at the end of the line reinforcement system, the maximum vertical deformation of D beam and track tends to be zero, as shown in Figure 5 (c) (d), the maximum vertical deformation of D beam and track occurred near the span of D24 beam, the maximum is about 1.95 mm, 1.60 mm.



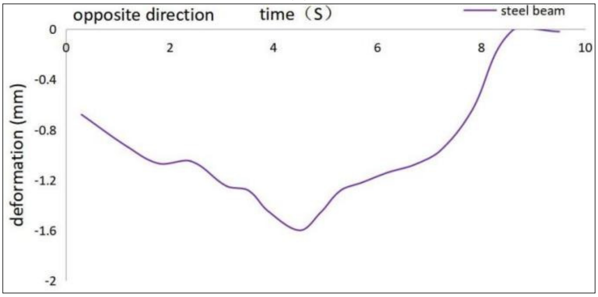
(a)



(b)

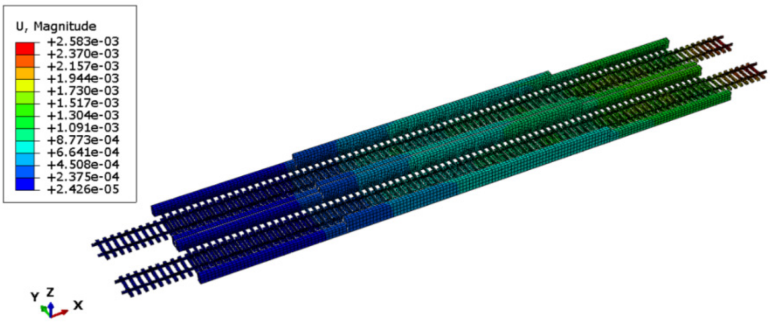


(c)

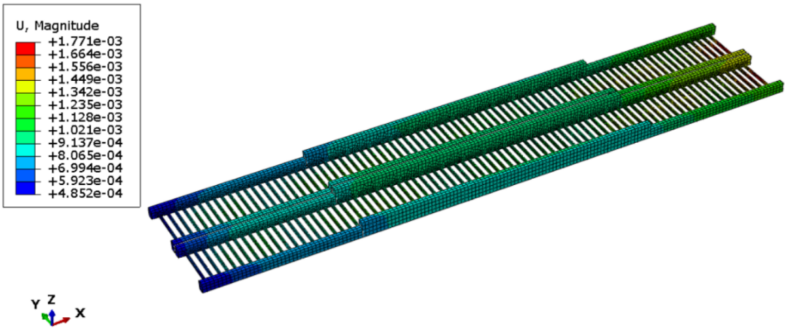


(d)

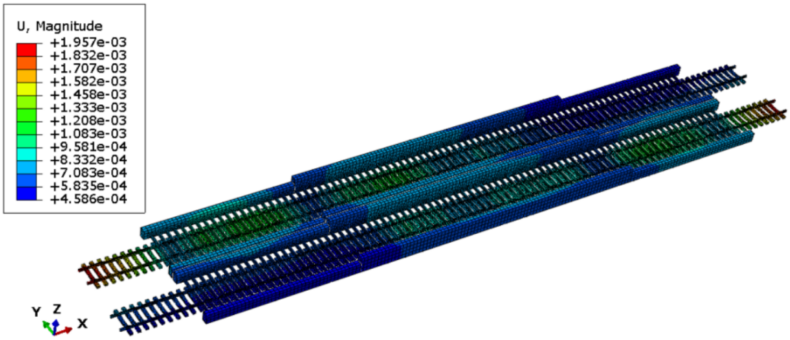
Fig. 4. Vertical displacement time course curves of D-type beam and track



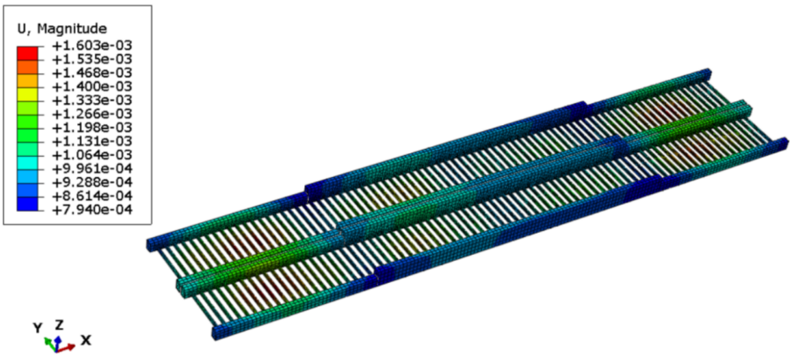
(a)



(b)



(c)



(d)

Fig. 5. Vertical displacement cloud map of D-type beam and track

4 Conclusion

This paper analyzes the generating mechanism of train dynamic load, analyzes the deformation characteristics of the railway temporary reinforcement system by ABAQUS, compares the numerical calculation results with the field monitoring data, and obtains the following conclusions:

(1) When the train passes through the temporary reinforcement area of the line at a speed of less than 45 km / h, the vertical deformation of the line reinforcement structure is within the range of monitoring and control value, indicating that the reinforcement method of the line reinforcement method is feasible. When the train locomotive reaches the starting point of the line reinforcement area, the maximum vertical displacement of the D-shaped steel is greater than the displacement when the rear of the train reaches the end of the line reinforcement area, indicating that the reinforcement system of the train line has a greater impact on the vertical deformation of the reinforcement structure than the train out of the line reinforcement system.

(2) When the two-track is running in the same direction, the maximum vertical deformation value of the D-shaped steel beam is 1.32 times that of the opposite direction, indicating that the vibration effect caused by the train in the opposite direction has a superposition effect, but it is not a multiplier relationship.

References

1. Ertugrul O L. Numerical modeling of the seismic racking behavior of box culverts in dry cohesionless soils[J]. KSCE Journal of Civil Engineering, 2016, 20(05): 1737- 1746.
2. Fairweather V. Pipe Jacking Advances[J]. Civil Engineering, 1988, 58(12): 60-63.
3. W. M. Zhai&X. Sun. A detailed model for investigating vertical interaction between railway vehicles and track. Vehicle System Dynamics (Supplement). [J]. 1 994. (23).
4. Mohammadi, Mohsen, Karabalis, Dimitris L. Dynamic 3-1) soil-railway track interaction by BEM-FEM. Earthquake Engineering&Structural Dynamics. 1 995(5).
5. Wang H, Qin WM, Jiao YY. Stability assessment for highway with large-span box culvert jacking underneath: a case study[J]. Canadian Geotechnical Journal, 2013, 50(6):585-594. (In Chinese)
6. Wang ZC, Hu Z, Lai JX, et al. Settlement Characteristics of Jacked Box Tunneling underneath a Highway Embankment[J]. Journal of Performance of Constructed Facilities, 2019, 33(2): 1-12. (In Chinese)
7. Hall L. Simulations and analyses of train-induced ground vibrations in finite element models[J]. Soil Dynamics and Earthquake Engineering, 2003, 23(5): 403-413.
8. He X. Study of vibration effects of underground trains upon surrounding environments[J]. Advances in Structural Engineering, 1995, 3: 116-122. (In Chinese)
9. Soil movements induced by tunneling and their effects on pipelines and structures, by P.B. Atte well, A. Yeates, and A.R. Selby, 1st ed, book review[J]. Civil Engineer in South Africa,1988,30(8).
10. Zhang D, QingJiu Z, XuYang Z. Analysis of the influence of a large shield tunnel passing under a railway frame bridge[J]. Modern Tunnelling Technology, 2013, 50(06):131-138. (In Chinese)
11. Jia Yaofei. Discussion on key technology of D-shaped steel temporary girder erection of large railway frame culvert [J]. Technology Innovation and Application, 2018(26):149-151. (In Chinese)