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Original Research Article

# Full-scale field experimental investigation on the interfacial shear capacity of continuous slab track structure

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ABSTRACT

This paper presents the experimental observations and results of six full-scale field ballastless track structure specimens, and tested under longitudinal and transverse shear load. The tests aimed to examine the interfacial shear capacity of the continuous slab track structure and investigate the interfacial bond–slip behaviour. The results show that bond strength of the two interfaces which were on the top and bottom of mortar layer, respectively, have a large difference. Until the top interface of the mortar layer fractured, no slip displacement was observed in the bottom interface. In addition to the experimental study, a finite element model using nonlinear interface elements was employed to simulate the tests. The numerical calculated capacity agreed well with the experimental results, showing that the proposed bond–slip law is reliable. Finally, the track slab's evenness with the bond–slip effect under the dynamic load was studied.

## 1. Introduction

Continuous slab track (CST) structure as a new slab ballastless track has been widely used in the high-speed rail (HSR) in China, such as the Beijing–Shanghai HSR, Shanghai–Kunming HSR, Beijing–Wuhan HSR and Hangzhou–Ningbo HSR [1–3]. Approximately 8830 km HSR line with CST structure has been constructed by the end of 2014. The prefabricated standard reinforced concrete slabs are positioned and paved through the accurate adjustment devices, then they are connected with the continuous base plate firmly by the cement emulsified asphalt mortar (CA mortar) layer (Fig. 1). The standard track slabs with the dimensions of 6.45 m × 2.55 m × 0.2 m are connected to each other by six reinforcing bars with 20 mm in diameter. While the rail is fastened on the track slab every 0.65 m.

The bond interfaces between the mortar layer and the prefabricated track slab as well as the base plate play an important role in transferring the longitudinal, transverse, and vertical load. The external forces such as the live load, braking force of train, and the thermal load are transferred from track slab to the base plate then to the bridge or the subgrade structure through them. A perfect interfacial bond has been assumed in the initial design of the CST structure [4]. This assumption can give a realistic simplification of the real

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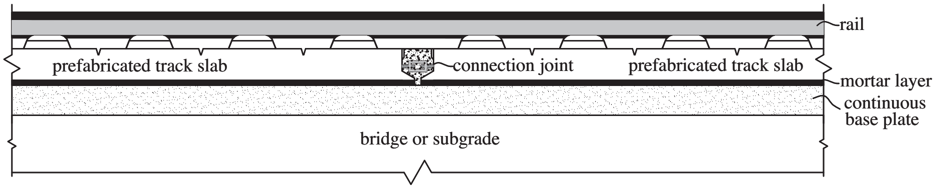

**Fig. 1 – Continuous slab track structure in HSR of China.**

bonding only if the bond strength is large enough compared with the interfacial stresses caused by the external load and no interfacial relative displacement occurs in the CST structure. However, when the bond strength is not large enough in practice, especially affected by the extreme weather or climatic loads additionally, interfacial bond–slip usually takes place. Since the interfacial bond–slip has a bad effect on the track evenness [5], it should not be ignored.

Similar problems are existing commonly in the bonded connections such as the laminated plate of composite [6,7], the FRP-concrete structure [8,9], and the bonded joints [10]. A lot of relevant theoretical and experimental analyses have been carried out. But until now, very few studies on the bond–slip behaviour of the interface between the track slab and mortar layer are reported. The perfect bond has been assumed in most of the CST structure's static and dynamic analyses instead [11,12]. The connection test of the Borg slab ballastless track [13] is one of the few studies that investigate the interfacial bond–slip behaviour, and the longitudinal shear capability of 410 kN was obtained in that experiment. But the mortar material is different from that is used in CST structure of HSR in China.

In this paper, the results of an extensive experimental campaign consist of six full-scale prefabricated standard track slabs are presented. Among them, three specimens are used to test the longitudinal shear capacity and others are used for the transverse shear capacity. In the first section, the experimental programme is elaborated. The specimen properties and the experimental setup are reported. In the second part of this paper, the experimental results are presented, the failure mode and the interfacial bond–slip law of the CST structure are discussed. In addition, the finite element models (FEMs) with the nonlinear interface elements are used to simulate the test and analyse the track evenness of CST structure with interfacial bond–slip effect. Based on the study, the real ultimate shear resistance of the interface between track slab and CA mortar layer for CST structure can be determined.

## 2. Experimental research

### 2.1. Specimen design and construction

This paper presents the shear test results of six specimens. As the track slabs are unit type and prefabricated in the factory then connected together for the CST structure, the full-scale single track slab attached with the CA mortar layer are chosen as a specimen. A large reinforced concrete experiment platform was designed and constructed, which was used as the specimen's base plate and the reaction force wall of the test. The platform was built in the outdoor open field due to the large size of full-scale specimens.

The manufacture procedure of the specimens was completely the same as the construction of the real CST structure in order to ensure the experiment can reflect the real bond condition of the CST structure exactly. In addition, the specimens were made by the experienced and talented technique workers of the China Railway 16th Bureau Group CO., Ltd. (one of the contractors for Shanghai–Kunming HSR). The platform (or called base plate) was constructed first then six track slabs were laid on the platform. A cavity with the height of 30 mm was set between each track slab and the platform.

As one of the most important and complex processes for CST structure construction, the main procedures of the CA mortar injection are presented as follows [14,15]: (1) To prevent the track slab floating as a result of the mortar fluid pressure, the position limiting devices are erected all around them in advance. (2) Then the cavity is cleaned and wetted by the high-pressure water jet many times. The cavity must be keep moist but without the open water so that the CA mortar can has a good bond with the track slab as well as the platform. (3) After confirming the cavity in the condition of saturated surface dry, the edges of the cavity are sealed by the fibre belts and angle steels immediately. (4) In less than 0.5–1 h after that, the freshly mixed CA mortar is injected into the cavity from the grouting holes with the diameter of 160 mm on the top of track slab at last.

The injection speed is controlled strictly in the range of 4–6 min for every specimen, and all specimens are manufactured using the same batch of freshly mixed mortar. The position limiting devices, the sealing belts, and angle steels are removed 24 h later after the injection. Then the specimens are covered with the water absorption sponge at least 7 days to maintain the freshly CA mortar.

### 2.2. Materials

The type of concrete grades is C50 (characteristic cube compressive strength equal to 50 MPa) for the platform, C55 (characteristic cube compressive strength equal to 55 MPa) for the prefabricated track slab. The materials that constituted the CA mortar mainly included asphalt emulsion and dry mixture. The dry mixture is fully mixed by the cement, expansion agent, foaming agent, fine aggregate, and other obligatory additives in the factory [16]. According to the relevant specification [14], the mechanical properties of hardened mortar including the fluidity, gas content, expansion ratio, density, flexural strength, compressive strength, and elasticity were tested. The results are summarized in Table 1.