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Criteria for repairing damages of CA mortar for prefabricated framework-type slab track

Ren Juanjuan *, Li Xiao, Yang Rongshan, Wang Ping, Xie Peng

MOE Key Laboratory of High-speed Railway Engineering, Southwest Jiaotong University, Chengdu 610031, PR China
School of Civil Engineering, Southwest Jiaotong University, Chengdu 610031, PR China

HIGHLIGHTS

- Influence of CA mortar damages on the structure's carrying capacity was studied.
- A 3-D FEM of framework-type slab track reflecting CA mortar damages is established.
- A dynamic test of the slab track with damage to CA mortar has been conducted on site.
- Recommendation of the classification and criteria of mortar damages was put forward.

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ABSTRACT

Damage of bagged cement–emulsified asphalt (CA) mortar tends to create voids underneath the track slab and will reduce the carrying capacity of the track structure, which is contrary to its design purpose of providing a long-term, safe and reliable service. In this paper, a study on the criteria for repairing damages of the CA mortar was conducted by establishing a 3-D FEM of the prefabricated framework-type slab track on elastic foundation. In order to verify the calculation results, a field test was carried out by comparison of the slab with or without the repair of damaged CA mortar. Based on the limited results in this study, the recommended values for criteria of repairing damages to CA mortar are preliminarily put forward. The results show that the mortar damages have the most adverse impacts on the carrying capacity of the track slab and CA mortar, but less impact on the concrete base. The numerical simulation indicates the critical length of 0.20 m and critical width of 0.40 m for the transverse damage type, and the critical length of 0.60 m and critical width of 0.20 m for the longitudinal damage type. For the damage type of the interfacial loss of bond, a critical gap size of about 2 mm was also deduced. If the actual dimensions of the damage to CA mortar are greater than the critical values, the tensile stress of track slab or the compressive stress of CA mortar will increase significantly and may exceed their characteristic value; and the dynamic deformation and vibration performance of track structure becomes apparent; the fatigue damage of CA mortar under the area adjacent to the damage would also be accelerated.

1. Introduction

Slab track is characterized by its high stability, availability, reliability, and low maintenance associated costs, which reveals that it is a developing trend for high speed railways. By the end of 2015, China is expected to complete the construction of 18,000 km high-speed railways, among which the slab track technology accounts for about 78%. The Japanese prefabricated concrete slab track (J-slab track for short) has been widely used on high-speed railway or passenger dedicated lines in China with the total length about 2203 km (double track) for its convenient construction, easy maintenance and low structure height [1,2]. Although high-speed railway places strict requirements on the regularity and reliability of railway track, the frequent train loading and its operation in harsh natural conditions subject the parts of track structure to a long-term degradation [3], which will inevitably give rise to a variety of damages.

Framework-type prefabricated slab track is one main kind of J-slab track applied to China's high-speed railways. This slab track structure is mainly composed of the steel rail, the WJ-7 fastening system, the framework-type track slab, the bagged cement–emulsified asphalt (CA) mortar, the cylindrical stopper/bollard and the concrete base. It has the following advantages: reducing the warping of track slab caused by temperature change, which can cut

* Corresponding author at: MOE Key Laboratory of High-speed Railway Engineering, Southwest Jiaotong University, Chengdu 610031, PR China.
E-mail address: renjuanjuan1983@hotmail.com (J. Ren).

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down the repair work of CA mortar; reducing the volume and dead weight of the track slab and the dosage of CA mortar, which can accordingly reduce the production cost and freight and get better engineering and economic benefits; and improving the workability, which makes the distribution of the CA mortar filled underneath the slab more uniform. Fig. 1(a) and (b) are the schematic diagram and the after-laying site picture of framework-type slab track structure.

With high fluidity, the 40–100 mm thick cement–emulsified asphalt mortar (CA mortar) layer can be poured into the gap between the prefabricated track slab and the concrete base purely by means of its own gravity, playing the roles of leveling, supporting and damping [4]. It is a key component of the prefabricated slab track and its mechanical properties (such as strength, stiffness, and damping) play an important role for a smooth and safe ride. CA mortar is a metastable suspension consisting of cement, emulsified asphalt, sand, water and admixtures (such as aluminum powder and superplasticizer), which has unique properties that differ from concrete and asphalt alone as this hybrid material combines strength of cement mortar and flexibility of asphalt binder [4,5].

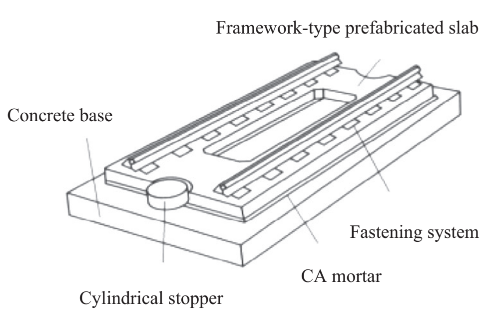
This slab track type adopts an assembled structure and its CA mortar with low elastic modulus (E = 100–300 MPa) has relatively weak constraints on the track slab. Therefore the unstable vertical layered structure tends to cause damages to the weakest CA mortar and then possibly to the track slab. The previous investigations mainly focused on the material performance and engineering applications of CA mortar. By conducting dynamic compression tests of CA mortar within its strain rate range of 10^{-5}–10^{-2} s^{-1}, Wang Ping et al. [6] investigated the constitutive relation of CA mortar, and the impact of strain rate on the CA mortar's compressive strength, elastic modulus and peak strain, and presented relevant recommended values for the CA mortar's stress–strain curve equation under different strain rates. Xie Youjun et al. [7] investigated the dynamic mechanical properties of CA mortar through the Split Hopkinson Pressure Bar (SHPB) test. The results provided the theoretical basis for the structural design of slab track. Jin Shouhua et al. [8] proposed the mortar formulation design and established the quality inspection system according to its application performance. They worked out a reasonable formulation of new materials based on the inversion of the aggregate properties of CA mortar and on the analysis of the aggregate properties.

At present, the investigations on the influence of CA mortar damage on the track system have been carried out mainly on the flat-type prefabricated slab tracks, involving less framework-type prefabricated slab track. In addition, the main factor to be considered during the analysis process is the contingency of the influence of CA mortar damage on the track system, not taking into account of the cumulative effect of CA mortar damage and its influence on the structural durability of the track system. Zeng Zhen [9] studied the carrying capacity of the track structure with different contact areas between the CA mortar and the track slab using the ''Element Birth and Death" and the embeddable random function methods. Based on the dynamics of the wheel-track system, Li Peigang et al. [10] established a 2-D vertical vibration model of the train-track-bridge by which the influence of CA mortar void on the dynamic characteristics of the slab track element on bridge is investigated. Zhu Shengyang [11] analyzed the influence of the damage to the interface between the flat-type prefabricated slab track and high elastic modulus CA mortar on the vibration of slab track system under the effect of temperature loads and train loads. Xiang Jun et al. [12] studied the influence of suspended track slab on track vibration response which was caused by the degradation of CA mortar based on the dynamics analysis of the train-slab track coupling system.

It should be also drawn attention that the similar problem on conventional railway track – the effect of unsupported sleepers has been investigated. The main difference between models for FEM calculations (regardless of the variety of parameters related to the vehicle itself and track system) consists in different modeling of track construction beneath the fastening system. The ballast at some sections of railway tracks subsides seriously and unevenly, which is also mainly caused by the contact vibration of the wheel and the rail due to the existence of various irregularities of the track and the wheelset. Nielsen and Igeland [13] investigated the vertical dynamic behavior for a railway bogie moving on a rail which is discretely supported, via rail pads, by sleepers resting on an elastic foundation, and analyzed the influences of three types of practically important imperfections in the compound vehicle-track system. Shuguang Zhang et al. [14] built a coupling dynamic model of vehicle-track which can consider the effect of the discrete support by sleepers on the coupling dynamic behavior of the vehicle and track. A nonlinear spring and a nonlinear damper are used to simulate a gap between the unsupported sleeper and the ballast mass. Zhu et al. [15] studied the dynamic wheel-rail interaction force due to one or multiple unsupported sleepers, and put forward that the vehicle speed, the gap size and the number of unsupported sleepers primarily dictate the magnitude of impact load which can be significant. Shi et al. [16] also investigated the behavior of a section of existing track on the ballasted heavy haul railway line, and showed that the maximum displacement of the rails and sleepers increases significantly with the number of consecutive unsupported sleepers.

2. Criteria for repairing CA mortar damages

The structure of slab track is composed of multiple structures or components which have different materials and characteristics. Any change of any component in the performance, strength and structure will impose an influence on the working conditions of



(a) schematic diagram of framework-type slab track

(b) site picture of framework-type slab track

Fig. 1. Framework-type prefabricated slab track.