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An experimental study of the insulation performance of ballastless track slabs reinforced by new fiber composite bars

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HIGHLIGHTS

- Steel-fiber reinforced polymer composite bar (SFCB) was introduced into ballastless track slabs.
- SFCBs potentially allow increased service life as well as economic and environmental benefits.
- Traditional construction technology is simplified and the cost of labor maybe reduced.
- Insulating test results were compared and suggestions toward a widespread use of SFCB.
- Insulating test results provide experimental data for designing ballastless track slabs.

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ABSTRACT

Due to inductive impedance caused by steel meshes in traditional reinforced ballastless track slabs, the electric properties, primarily rail resistance and inductance, of the track circuit are affected by electromagnetic induction between the slabs and the electric current in the rail. This problem results in poor transmission performance through the track circuit. Insulating heat-shrinkable sleeves between the steel meshes have been used to improve the insulation capability of steel meshes in slabs; however, they reduce the bonding performance between the steel bars and concrete. Because of the highly insulating properties of fiber reinforced polymer (FRP) and steel-fiber reinforced polymer composite bar (SFCB), these composite materials have shown promise to overcome the insulation problem. In the study reported in this paper, single and double layer meshes and ballastless track slabs were manufactured and tested for the first time. In the research reported herein, basalt fiber reinforced polymer (BFRP) and SFCB were used in meshes and slabs, respectively. The electric properties of the rail affected by these meshes and slabs were investigated and compared with steel meshes and ordinary reinforced ballastless track slabs (RC). As the test results demonstrated, the signal frequency and distance between the slabs or meshes and the rail had a significant impact on the electric properties of the rail. Furthermore, the variation in rail resistance induced by the slabs or meshes increased drastically, while the change in rail inductance increment varied slowly. BFRP and SFCB used as transverse reinforcement of slabs or meshes reduced the variation in the electric properties of the rail. BFRP reinforced ballastless track slabs had the highest insulating performance, while those with SFCB demonstrated the second highest performance.

1. Introduction

Compared with a ballasted track slab system, a ballastless track slab system exhibits better performance in terms of stability, durability, and maintenance, and the ballastless system has been widely used in high-speed railways in Japan, Germany, and China. Until recently, ballastless track slabs were extensively used in the ballastless track slab system. Germany's Rheda, Japan's plate-type, and China's CRTS ballastless track slabs are examples of such track slabs [1–3].

In the railway system, a resonant jointless track circuit is commonly used in many countries [4–11]. The closed-loop circuit, which consists of longitudinal and transverse reinforcements in the ballastless track slabs, significantly reduces the transmission performance of the track circuit because a mutual inductance is created between the ballastless track slabs and the electric current

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in the rail; thus, the effect on the electrical properties (the rail resistance and inductance) of the rail poses a significant problem [11–16]. Hence, numerous measures have been undertaken to improve the insulation property of the steel bars, i.e., painting an insulation coating onto steel meshes, applying heat-shrinkable sleeves, or using insulating cards. Unfortunately, the insulation coating is easily broken in the process of constructing the ballastless track slabs, and the insulation capability is reduced as a result. In addition, the bonding performance between the steel bars and concrete tends to deteriorate, and the cost of labor is higher due to the complex construction technology [15,16].

Fiber-reinforced polymer composite bars (FRPs), which are composed of non-metallic materials, provide good insulation performance (except for carbon-fiber-reinforced polymer composite bars (CFRPs)), better anti-corrosion properties, higher tensile strength, and a lighter weight compared to ordinary steel bars [17–22]. FRP composites that have been extensively studied include carbon-fiber-reinforced polymers (CFRPs), glass-fiber-reinforced polymers (GFRPs), aramid-fiber-reinforced polymers (AFRPs) and basalt-fiber-reinforced polymers (BFRPs). Most recently, researchers have begun to study the application of FRP to building insulation in MRI rooms and ballastless track slabs, among other usages. However, FRP composites have distinctly different characteristics. For instance, CFRPs cannot be used as insulating materials because of their high electrical conductivity [23]. GFRPs have excellent insulating properties, but their anti-alkali propriety is not high [20]. Meanwhile, AFRPs cannot be used extensively in civil engineering because of their high cost; on the contrary, due to their strong insulating characteristics and high performance price ratios, BFRPs are a better alternative for this application. However, in addition to the required mechanical properties and insulating performance, any new alternative material should also possess a minimum modulus of elasticity. Unfortunately, with moduli of elasticity of approximately 40 GPa, BFRPs do not satisfy this requirement.

To overcome this major shortcoming, Wu et al. [24] proposed and manufactured a novel steel-fiber reinforced polymer composite bar (SFCB), which is the subject of the study presented in this paper. SFCB have steel bars as the inner core and are coated by a longitudinal FRP (with more stable secondary stiffness); thus, this novel composite bar has the high performance and advantages of FRP, as discussed above, while the presence of the steel core alleviates the shortcomings of FRP. The specific and unique features of SFCB are as follows [15,24–27]: (1) they incorporate most of the insulating capabilities and corrosion resistance of FRP to avoid the loop caused by steel meshes, while they protect the steel bars

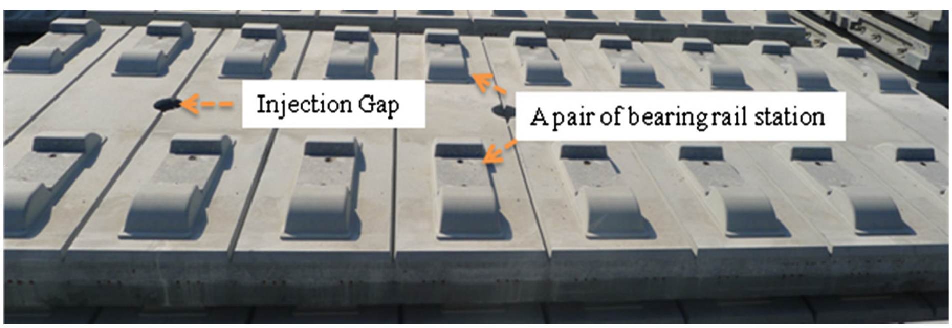

Fig. 1. Configuration of ballastless slab.

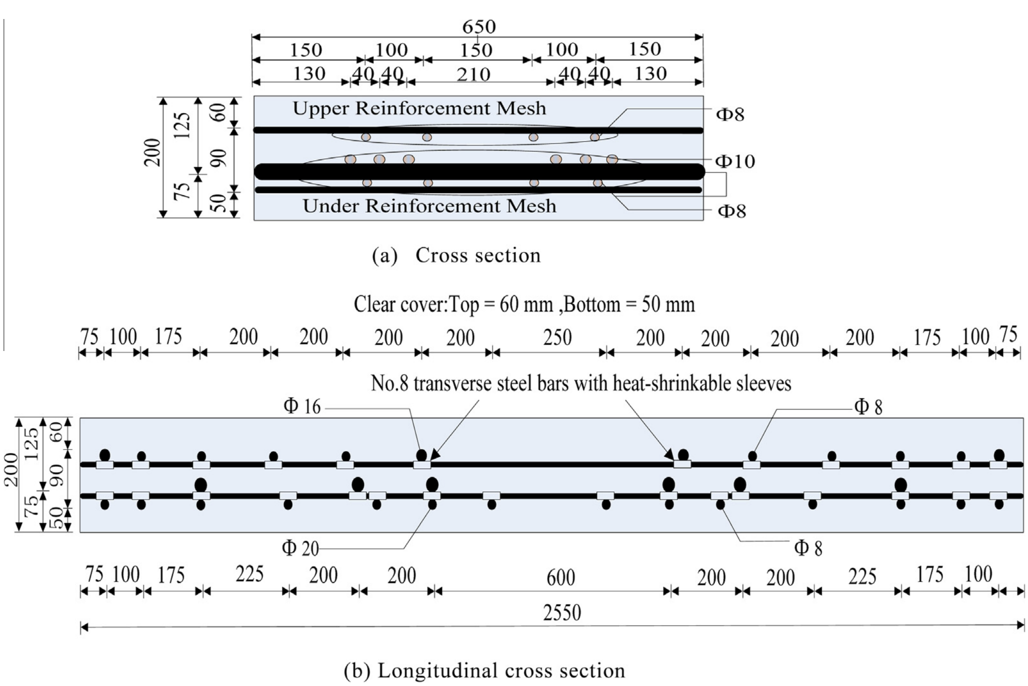

Fig. 2. Section of specimen: (a) cross section; (b) longitudinal cross section.