Ladder Track Structure and Performance

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1. Introduction

Sleepers, slabs and other rail supporting members play a vital role as the interface to connect rails with the track bed and structures. They are closely related to the issues of safety, economy, maintenance, and track-system environment. We have developed a "ladder sleeper," an innovative new interface that has remarkable advantages for the above issues. Using this new sleeper, we are proposing a ballasted ladder track and a floating ladder track.

2. Structure of the ladder sleeper

The ladder sleeper, as shown in Fig. 1, is a mixed ladder-shaped structure composed of twin prestressed concrete longitudinal beams and transverse steel pipe connectors. The transverse steel pipe connector, which is made from a thick-walled pipe, is rigidly joined to the longitudinal beam by inserting it between indented prestressing strands, which are arranged close to the top and bottom surface of the longitudinal beam. Sufficient reinforcement is provided around the steel pipe and then high-strength concrete is cast to be monolithic.

3. Ladder track system

Using the ladder sleeper, we have developed a ballasted ladder track and a floating ladder track. The fundamental structural concept of the ladder track is a "combined rail" composed of the steel rail and concrete longitudinal sleeper (see Fig. 2). It features high rigidity and remarkable stability against track buckling.

4. Performance of ballasted ladder track

The ballasted ladder track significantly reduces maintenance work compared with the crosstie track, owing to the reduction of dynamic load transferred to the ballast. In order to evaluate structural durability and the effect of reducing maintenance of the ballasted ladder track, we conducted an accelerated endurance test using a heavy-haul freight train, having a static wheel load of 175 kN, at the Transportation Technology Center, Inc. (TTCI) in Pueblo, Colorado, U.S.A. (see Fig. 3). By the end of the test, the passing tonnage reached 150 million. The longitudinal prestressed concrete beams bore without a single crack or any other damage, and all the steel pipe connectors remained sound. Then, we could confirm the appropriateness of the design of the ladder sleeper. In addition, we also confirmed the remarkable effectiveness of the ladder sleeper at reducing maintenance, because the ballasted ladder track required no maintenance throughout the endurance test, while the crosstie track has required thorough tamping five times (see Fig.4).

5. Performance of floating ladder track

The floating ladder track is a lightweight, vibration-proof track system that is floated from the concrete track-bed by supporting the ladder sleepers with low-stiffness springs at a constant interval. Owing to the vibration-isolation effect of low-stiffness springs, the floating ladder track can significantly reduce the structure-borne noise. In order to evaluate the effectiveness of the reduction, we measured the vertical vibration of the concrete track-bed under a floating ladder track and a non-ballasted crosstie track on a rigid-frame viaduct (see Fig. 5). Fig. 6 illustrates the frequency analysis of the vertical vibration level of velocity, which has a close relation to structure-borne noise, and it shows that the floating ladder track can reduce the vibration level of velocity by approximately 13.4 dB (all-pass filtered) over the non-ballasted crosstie track. As a matter of fact, no structure-borne noise was audible under the viaduct at the site.

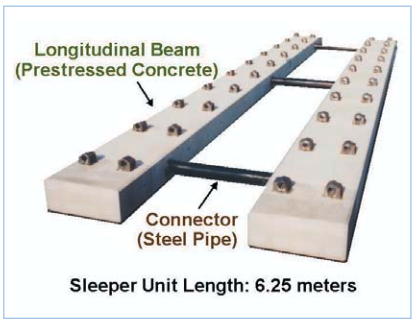

Figure 1. Ladder sleeper.

Figure 3. Ballasted ladder track in TTCI.

Figure 5. An example of floating ladder track laid out for testing.

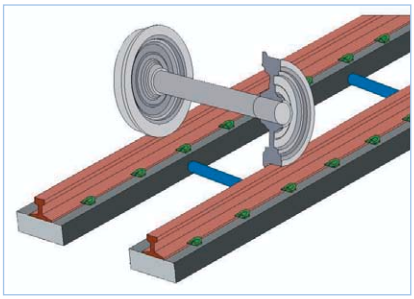

Figure 2. "Combined rail" — structural concept of ladder track.

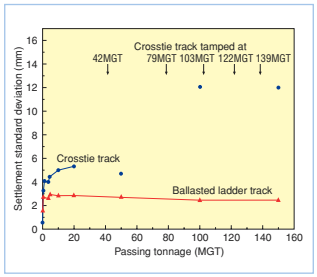

Figure 4. Settlement standard deviation.

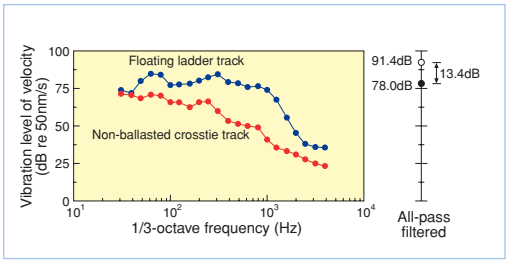

Figure 6. Comparison of track-bed vibration level of velocity.