Estimation of Lateral Resistance of Ballasted Track during Seismicity

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1. Introduction

Japan is one of the world's most earthquake-prone countries and enhancing the safety of railway structures against earthquakes is critical. Several safety issues in train operation caused by earthquakes have been reported so far. Among those examples, we have found some cases in which ballasted tracks are notably deformed, although no significant or harmful deformation was recognized in the structures or roadbeds. The ballasted track deformation caused by earthquakes are characterized by remarkably large horizontal displacements in the direction perpendicular to the rail. This is considered to be caused by decline in ballast lateral resistance caused by these seismic ground motions. However, the mechanism of ballasted track deformation during seismicity has not been fully defined. Therefore, we studied the characteristics of ballast lateral resistance during seismicity by performing Large-scale Shaking Table tests using a full-scale mockup. During the test we also estimated the seismic capacity of ballasted track in both straight and curved track sections.

2. Outline

This test assumed a ballasted track of a typical crosssectional shape for Shinkansen on a viaduct. The test configuration consisted of four sets of mockups placed on a shaking table, and each set includes one full-scale sleeper tested at a time (Fig. 1). Two track configurations were simulated: curved track simulated with a superelevation (cant) of 200 mm and straight track simulated with no superelevation. To estimate the ballast lateral resistance during vibration, we used a spring attached to each sleeper and applied tensile loads while measuring sleeper displacements. We also performed a lateral ballast resistance test before and after sinusoidal vibration (input acceleration of 800 gal) and estimated the ballast lateral resistance before and after vibration. (1 gal = 0.01 m/s².)



Fig. 1 Status of Large-scale Shaking Table test (sloped (with cant))

3. Test results

Fig.2 shows the relationship between the lateral resistance before and after sinusoidal 800 gal vibration. The lateral resistance declined after vibration regardless of the ballast shapes, i.e., curved or straight track simulation. Fig.3 shows the



horizontal displacements of the sleeper measured when a tensile load of 4 kN was applied during vibration. The horizontal displacement of the sleeper increased abruptly during sinusoidal 700 gal vibration regardless of the ballast shapes. It has become clear from these tests that even if a tensile load during vibration is smaller than the maximum ballast lateral resistance after vibration, a large residual displacement is induced during vibration. The test results have also indicated that the geometric difference of ballasts has little effect on the lateral resistance before, during and after vibration.



Fig. 2 Lateral resistance before and after 800 gal vibration



Fig. 3 Sleeper displacements during vibration (Straight: Tensile load 4 kN)