Development of a Large Two-Dimensional Shaking Test Facility to Determine How Railway Equipments and Structures are Damaged or Destroyed during an Earthquake

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The Railway Technical Research Institute (RTRI) has introduced an embankment shaking test facility as part of a research programme to improve the resistance of embankments to earthquakes. This research applies specifically to embankments on soft ground that were seriously damaged by the Tokachi Offshore Earthquake in May 1968. The series of research works have led to a number of achievements in the development of quakproof embankments and similar structures thanks to shaking tests conducted on full-scale model embankments.

Railway structures were badly damaged by the earthquake that occurred in the southern part of Hyogo Prefecture in January 1995. On another occasion a Shinkansen train running in commercial service was derailed when an earthquake struck the Chuetsu District, Niigata Prefecture, in October 2004. This was the first accident of its kind to occur in the history of Shinkansen passenger services. As a result, railway engineers and researchers are now urgently required to find out the behaviour of track, rolling stock and infrastructure when an earthquake occurs and to put in place countermeasures to prevent derailments.

In order to find out the behaviour of the railway structures, track and rolling stock that are damaged or destroyed by strong seismic movements during an earthquake, RTRI decided to build and install a large two-dimensional shaking test facility on its own premises. This enables simulation of actual earthquake motions with a seismic intensity of 7; the facility also permits the bogies of rolling stock to be shaken.

As analysis, measurement and control technologies have progressed dramatically in recent years, real-time hybrid tests that combine "dynamic analysis" and "shaking tests" are now being used.

In particular, finding out the dynamic interaction of structures with track and rolling stock is an extremely important subject for railways. In order to satisfy this requirement, we considered it necessary to have our sights set on establishing and developing a system capable of performing tests to verify the ability of structures to withstand earthquakes at extremely low cost. The system also had to be able to evaluate the relationship between the response of the entire system and local damage by linking dynamic tests using full-size or small scale-ratio models with multi-freedom dynamic analysis performed using computers, on a real-time basis. Consequently, the shaking test facility that has been introduced has main characteristics that respond to these requirements, as shown below.

(1) The largest displacement amplitude of the shaking table is ±1,000 mm. "*Excitation with large displacement amplitude*"
(2) Controlling excitation makes use of a real-time reaction force compensation control system. "*Excitation with high precision*"
(3) The foundation of the shaking test facility makes use of a floating structure. "*This is because of the need to avoid disturbing the environment in the surrounding area*"

Table 1 shows the basic specifications of the shaking test facility, and Figs. 1 and 2 show its structure and appearance.

Having started designing and constructing the shaking test facility in September 2006, RTRI finished the construction work after two years, and the test facility was completed at the end of October 2008. RTRI began full-scale operations with the facility in fiscal 2009. In order to determine how railway equipments and structures are damaged or destroyed during an earthquake, RTRI is going to perform shaking tests using seismic motions. This shaking test facility was designed and manufactured with financial support from the Ministry of Land, Infrastructure, Transport and Tourism.

Table 1 Basic specifications of the shaking test facility

Excitation method	Hydraulic servo type
Dimensions of shaking table	7m (X-axis) ×5m (Y-axis)
Maximum surcharge load	50 tons
Direction of excitation	Lateral 2 axes (X- and Y-axes)
Maximum displacement (acceleration at the maximum displacement)	X-axis：±1.0m (0.25G) Y-axis：±0.25m (0.23G)
Maximum speed	X-axis：±1.5m/sec Y-axis：±0.75 m/sec
Maximum acceleration	X-axis：±1.0G Y-axis：±2.0G
Excitation frequency	0.1～20Hz
Excitation pattern	Seismic wave excitation, sine wave excitation
Excitation control method	Acceleration control, displacement control Reaction force compensation control

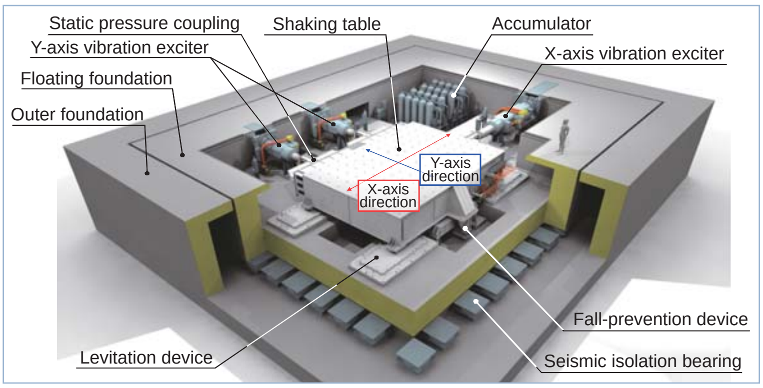

Fig. 1 Structure of the shaking test facility

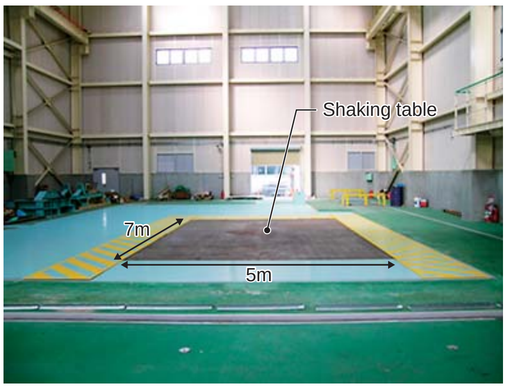

Fig. 2 An appearance of the shaking test facility