Development of an Earthquake Disaster Simulator for Railways

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1 Purpose and background

After the Southern Hyogo Prefecture Earthquake in 1995, Japan has frequently been hit by large-scale earthquakes across the country. It is said, therefore, that Japan is now in a high seismic activity age. Railways are strongly associated with public interests and it is very important for them to continue to function even after earthquakes. The railway system features long routes and diversified component elements and it is difficult to imagine what sorts of disaster risks exist at any particular location. However, it is important to be prepared for earthquakes by doing the following.

(1) Determine potential earthquake disaster scenarios and earthquake risks to appropriately implement measures against earthquakes in order to protect the railway system.

(2) Establish common recognition against earthquake disaster risks among railway promoters, users and the Railway Technical Research Institute (RTRI) and construct a mechanism for these parties to evaluate and quantify earthquake disaster risks.

RTRI has been developing a “railway simulator” under its five-year plan since 2010. As a part of this overall program, RTRI is developing an “earthquake disaster simulator” to evaluate the safety of the total routes during earthquakes and, to use as an effective tool to appropriately visualize and mitigate earthquake disaster risks.

2 Features of the simulator

Figure 1 shows the primary features of the earthquake disaster simulator for railways and Fig. 2 a visual depiction of the simulator’s capabilities.

This system can broadly be divided into four components: (1) a “database”, (2) a “simulator of earthquake motion”, (3) a “software to construct a model of a group of railway structures (hereinafter referred to simply as structures)” and (4) a “simulator of the behavior of railway structures.”

The “database” stores the data on the ground and structures. It consists of data possessed primarily by RTRI at the moment and will be updated in the future. The “simulator of earthquake motion” calculates the propagating process of the earthquake motion generated at faults. The seismic motions in hundreds-kilometer square are calculated. The simulation is conducted not by the conventionally-used finite difference method (FDM) but by the voxel finite element method (FEM) that enables sophisticated calculations for mountain and ground-surface profiles. This method is considered appropriate to accommodate the required speed and data volume of the calculation. See Fig. 3 for the results of a simulation conducted to reproduce the behavior of the Southern Hyogo Prefecture Earthquake in 1995.

The “software to construct railway structures” is one that automatically compiles a numeric calculation model of structures including information on the ground in a several hundred-meter-long section. The data is based on the information in the database. In normal cases, models for structural calculation are manually created by human beings by referring to design drawings, a process which cannot cope with a great number of structures. Therefore, RTRI has developed a new block assembling method to disassemble a structure into blocks first and then assemble into a new structure model in the same way as children stack blocks to construct a structure (see Fig. 4). This method enables construction of a large-size model.

The “simulator of the behavior of railway structures” is a simulator to calculate the earthquake response of the model of structures constructed by the “software to construct railway structures” against the earthquake motion predicted by the “simulator of earthquake motion.”

3 Conclusions

RTRI will complete the basic portion of the earthquake disaster simulator in fiscal 2014.

In the future, RTRI will use this simulator to evaluate various scenarios caused by huge earthquakes that might occur in years ahead and predict risks existing in the railway system. In this way, the simulator will be utilized to better guarantee the safety of railways.

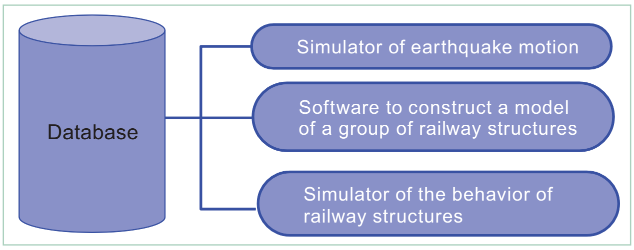

Fig. 1 Construction of the earthquake disaster simulator

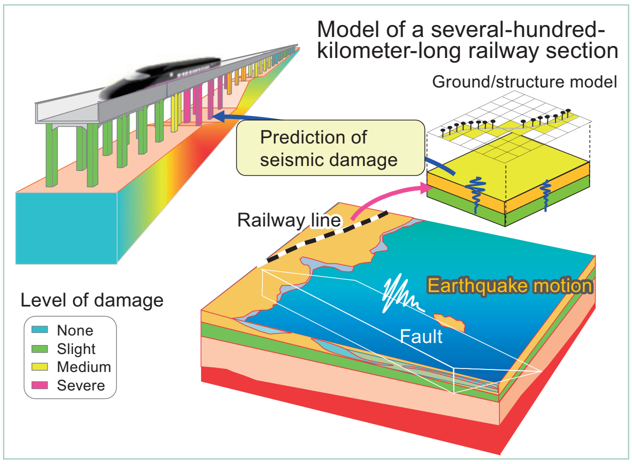

Fig. 2 An image of the earthquake disaster simulator for railways

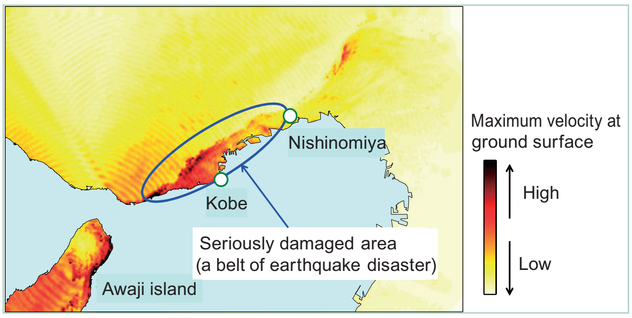

Fig. 3 Simulation to reproduce the behavior of the Southern Hyogo Prefecture Earthquake in 1995

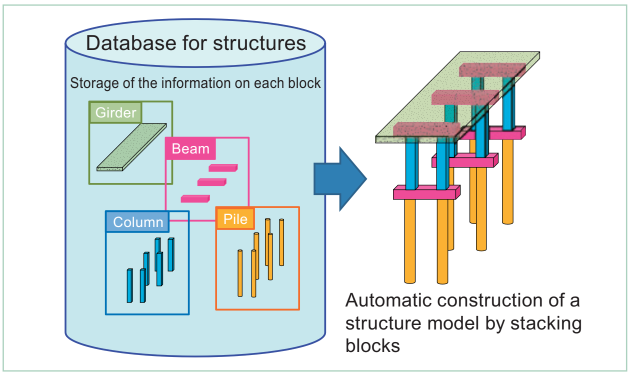

Fig. 4 Automatic modeling of structures by the block assembling method