Project Research — **Establishment of Optimal Risk Management**

Seismic Margin Evaluation of Civil Engineering Structures in Nuclear Power Plants

Background and Objective

After the nuclear accident at the Fukushima Daiichi Nuclear Power Plant following the 2011 Great East Japan Earthquake, electric power companies have been required to make a re-evaluation of the seismic safety of existing power plants (back check) and a preliminary assessment of the comprehensive assessment of safety (stress tests).

In this project, we aim to investigate the limit of strong-ground motion and the functional limit strength of structures, as well as to provide a comprehensible explanation of seismic margin.

Main results

1 Evaluation of the Simultaneous Rupture of Active Faults

It is important to evaluate the magnitude of an earthquake caused by multiple active faults, taking into account simultaneous effects. Some factors for the simultaneous rupture assessment of faults were found through geophysical, tectonic geomorphologic, and paleoseismological investigations, along with numerical and experimental studies from the 1891 Nobi earthquake. For example, the results suggest that a stress field will control the direction of fault rupture and that the length ratio of the cross-structure to a fault segment is associated with the possibility of the propagation of fault rupture beyond the cross-structure (N11047) (N11046) (N11049).

2 Attenuation Measurements of Hard Rock Ground and its Systematization for Earthquake Ground Motion Estimation

It is necessary to validate the damping factor (attenuation) of hard rock ground in the formulation of “Design Basis Earthquake Ground Motion Ss” of a nuclear power plant. The main issues of the validity of attenuation are as follows: the reason why the damping factor of near-surface rock ground is larger than generally thought; and the validation of the damping factor estimated at a site that has no vertical-array seismic observation records. The study found that the standard deviation of the heterogeneity of the near-surface rock ground obtained from borehole velocity logging relate the damping factors with each other, which are independently estimated from vertical-array seismic observations, borehole PS-logging, and laboratory measurements using ultrasonic waves. The results showed that heterogeneity of the near-surface rock affects the attenuation and that the damping factor at a point where there are no seismic observation records can be evaluated from borehole PS-logging and laboratory tests of core samples (N11063) (N17).

3 Development of a Seismic Margin Risk Diagram

A seismic margin risk diagram can represent the relationship between structural capacity based on the intensity of earthquake ground motions (i.e., peak ground acceleration) and seismic risk. This type of diagram is characterized by the fact that it can link the seismic margin of structures evaluated in a deterministic way to probabilistic seismic risk (or the annual probability of failure) (N10007). The proposed diagram can be applied to the seismic risk assessment of critical structures and components in the system analyses of nuclear power plants.

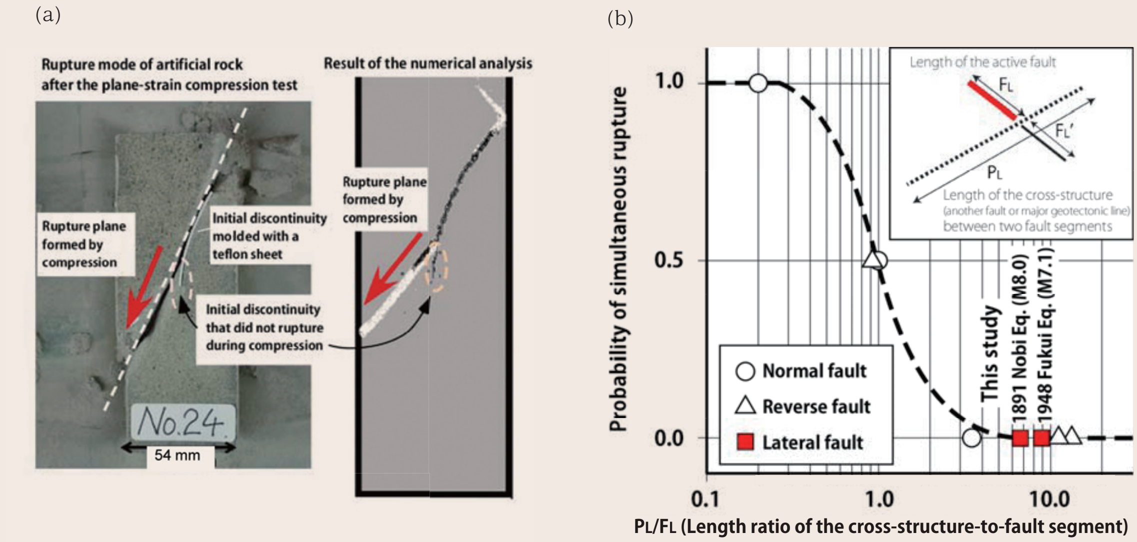

Fig. 1: Indices of the simultaneous rupture of active faults

(a) The results of the experimental and numerical studies showed that the rupture plane expected from the stress field overrode the initial discontinuity, which suggests that the stress field will control the direction of fault rupture. (b) The results from this study and other research showed that the length ratio of the cross-structure, which is another fault or a geotectonic line between fault segments, to the fault segment, is associated with the possibility of the simultaneous rupture of the fault segments.

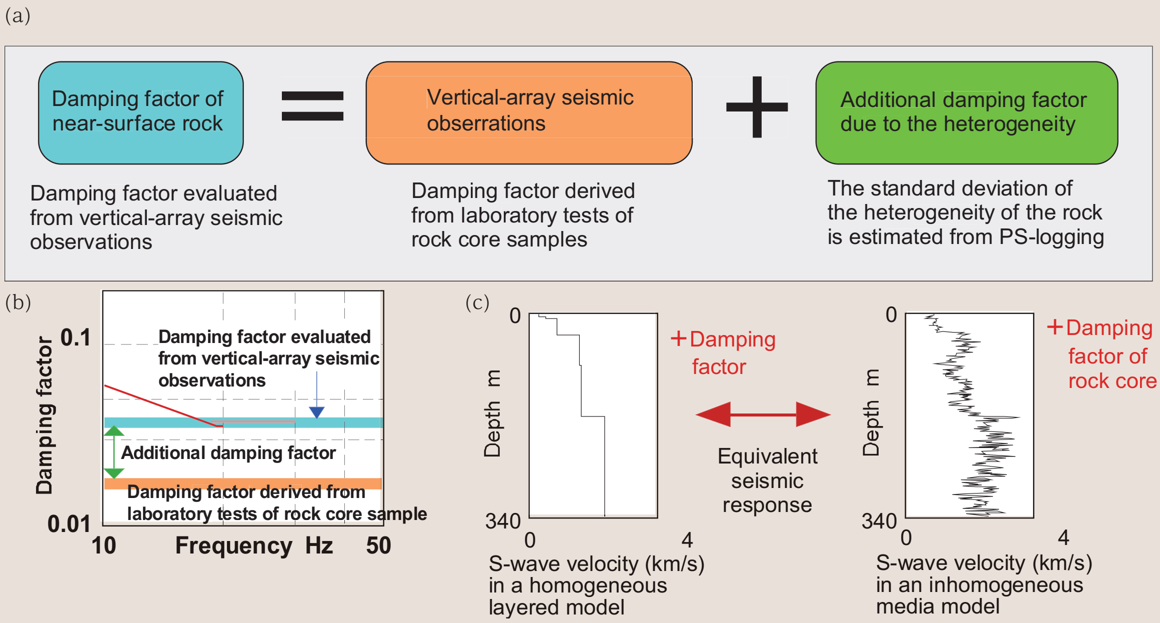

Fig. 2: Attenuation characteristics of hard rock ground

(a) and (b) Conceptual diagrams on the relationships of damping factors estimated from seismic observations, borehole PS-logging, and laboratory tests of rock cores; (c) the seismic ground response evaluated by using the damping factor from seismic observations with a homogeneous layered model is equivalent to that evaluated by using the damping factor for the rock core with an inhomogeneous media model derived from PS-logging.