Project Subjects

Seismic Margin Evaluation of Civil-engineered Structures at Nuclear Power Plants

Background and Objective

Since Nuclear Safety Commission revised the Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities in 2006, electric power companies have been required to make reevaluation of seismic safety of the existing nuclear power plants (back-checks), seismic margin evaluation, and residual risk evaluation, etc. The purposes of the project are to investigate the functional limit strength of structures in order to establish seismic margin evaluation method for civil-engineering structures in nuclear power plants.

Main results

1. Evaluation of damping factor of near surface rock for the Design Basis Earthquake Ground Motion

We identified a damping factor of near surface rock from borehole earthquake records using the bi-linear-type frequency dependent damping factor model which has a frequency dependent lower limit. The identified lower limit of about 3% was in good agreement with the other estimations at the same borehole using PS-logging and spectral decay of up-going wave. We also showed the relationship between the identified lower limit of damping factor and the standard deviation of random S-wave velocity fluctuation of the rock observed in the PS-logging [N10004] (Fig.1).

2. Evaluation of simultaneous rupture of active faults

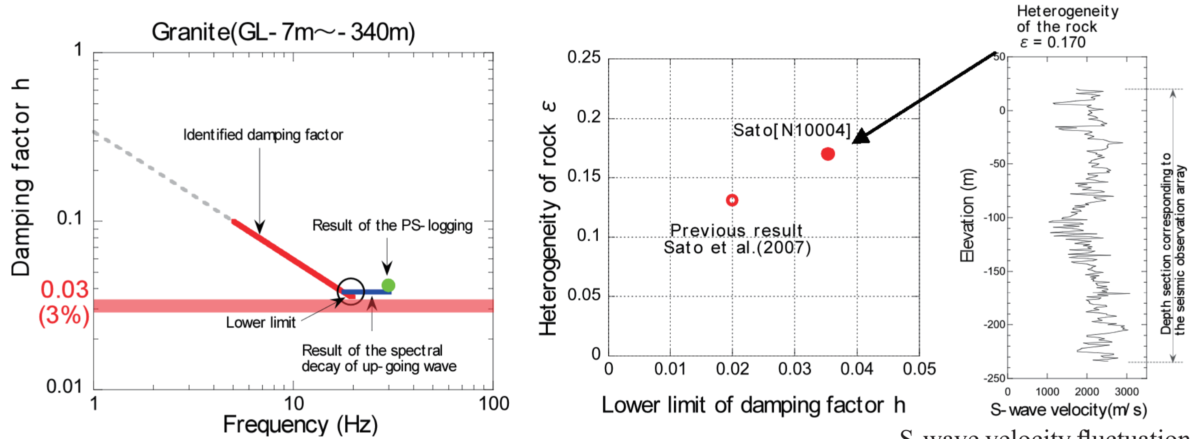
Seismic tomography using a temporal dense network was carried out in the northern part of the 1891 Nobi earthquake source region. It is remarkable that an E-W trend velocity perturbation like a zebra zone runs across the source regions of two large earthquakes (Fig.2). This pattern indicates a subsurface extension of a geological structure 'Hida Gaien belt' which has the same trend on the surface. Such geological structure in the seismogenic layer may act as a barrier to earthquake rupture propagation. It is inferred that an abrupt change of seismic velocity structure is an important factor to estimate simultaneous rupture.

3. Evaluation of tensile strength and dynamic characteristics of rock mass

When a major earthquake occurs, the foundation ground under a reactor building and the surrounding slopes are subjected to tensile stress. The tensile stress has been estimated as zero for various reasons, for instance, it has not been possible to measure the reliable tensile strength of rock mass in the field . We conducted several types of tensile tests in the laboratory to evaluate the tensile strength of Tuff stone and compared the results to find a rational test method (Fig. 3).

4. Model experiment for reproduction of earthquake-induced rock slope failure

We conducted a centrifuge model test on earthquake-induced rock slope failure for the verification and improvement of the numerical methods that can evaluate the behavior of rock slopes around the facilities in nuclear power plants during major earthquakes. In the experiments, we found that the characteristics of the artificial discontinuities in the model considerably affected the collapse behavior of the slope (Fig.4).



S-wave velocity fluctuation observed in PS-logging (ε shows the heterogeneity of the medium).

Fig. 1 Damping factor of near surface rock

Lower limit of the damping factor of the near surface rock identified from the seismic records is consistent with the damping factors derived from PS-logging and spectral analysis of up-going waves (left). The right figure shows the relationship between the lower limit of damping factor of rock and the S-wave velocity fluctuation.

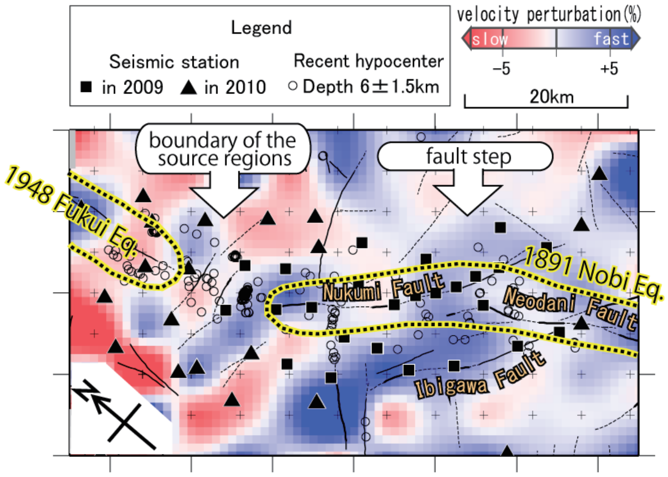


Fig.2 P-wave velocity perturbation in northern part of the Nobi earthquake (Depth=6km)

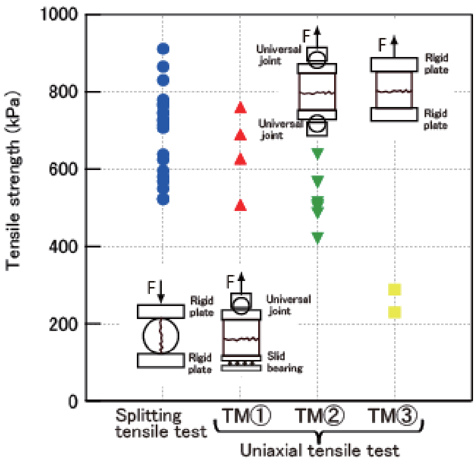


Fig.3 Tensile strength evaluated by a splitting tensile test and uniaxial tensile tests

The tensile strengths obtained by the conventional splitting tensile test and the uniaxial tensile test (TM①) installed a universal joint and a slide bearing at both ends are in reasonable agreement.

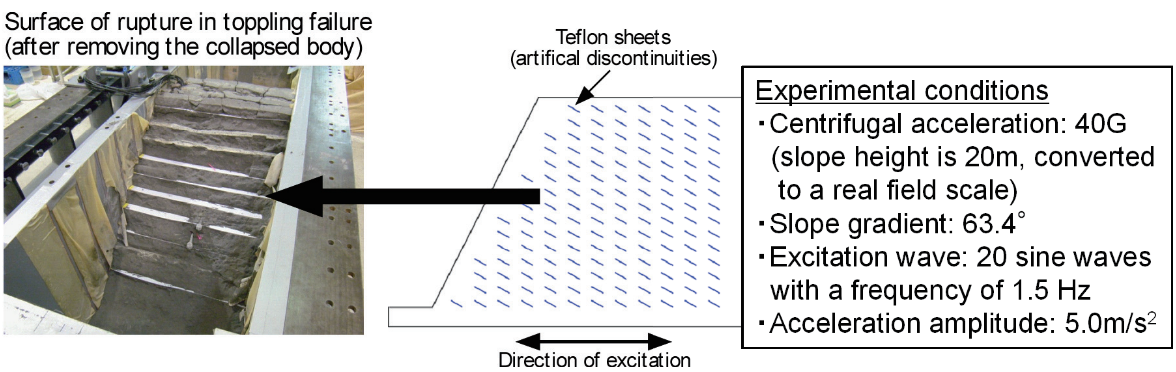


Fig.4 Earthquake-induced rock slope failure by centrifuge model test

We obtained experimental data on characteristic failure behavior of rock slope (ex. toppling failure, plane failure) by the centrifuge model test using the slope model with discontinuities imitated by Teflon sheets.