Priority Subjects with Limited Terms — **Establishment of Optimal Risk Management**

Assessment of Fragility of Nuclear Facilities due to External Natural Events

Background and Objective

The Fukushima Daiichi nuclear disaster wrought severe damage on the reliability of nuclear safety and societal trust. Most nuclear power plants are currently shut down for these reasons. Since nuclear power would play an important role for realizing a low carbon society, we should avoid long term shutdown. In this project the safety assessment methodologies for nuclear power plants subjected to natural disaster are studied.

Main results

1 Development of nonlinear time history response analysis method for the seismic stability evaluation of ground

A constitutive model for two-dimensional nonlinear time history response analysis was developed in order to evaluate the stability of rock slopes and the foundation of nuclear power plant during major earthquakes. The stress-strain relationship of this model was derived on the basis of a multi-spring model in plane strain state, and the influence of shear and tensile failure was considered. A numerical simulation of the dynamic centrifugal model test of slope was conducted for verification of the model. As a result, the timing of failure and residual displacements in the simulation were almost consistent with the model test (Fig. 1).

2 Stability evaluation methods of rubble mound breakwaters against tsunamis

In order to assess the strength of rubble mound breakwaters in nuclear power plants against tsunamis, a stability evaluation method of armor units in the breakwaters has been investigated [1]. Model-scale experiments, in which masses of armor units and overflow velocities were varied, were carried out and damages of the armor units were observed. The experimental results showed that the stability conditions of armor units against tsunamis were judged by the relationship between the mass of armor units and the overflow velocity (Fig. 2). Furthermore, a numerical method for evaluation of the overflow velocity was developed, and validated by experimental data.

3 Development of evaluation methods of tsunami hydrodynamic force and debris impact force

In order to develop the fragility evaluation methods of structures and components against tsunamis, large scale experiments on tsunami-induced loads were carried out using the Large-scale Tsunami Physical Simulator. The experiments on tsunami wave pressures on a seawall and a square column showed large, yet short-duration, pressures on the structures immediately after tsunami tips impacted the structures, and we proposed an estimation method for the impact pressures (Fig. 3) [2]. In order to obtain a dataset for verification and validation of the evaluation method of the tsunami-debris impact force, we carried out tsunami-debris impact experiments in which wood-logs and a real car were drifted in the tsunami inundation flow and impacted on a wall (Fig. 4) [3].

[1] T. Sakakiyama, J. JSCE, Ser. B2 (Coast. Eng.), 67, 791-795, 2011.
[2] N. Kihara et al., Coastal Engineering, 99, 46-63, 2015.
[3] D. Takabatake et al., J. JSCE, Ser. B2 (Coast. Eng.), 70, I_1491-I_1495, 2014.

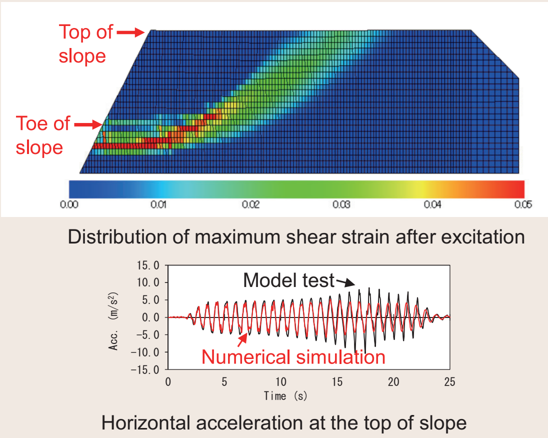

Fig. 1: Numerical simulation of dynamic centrifugal model test of slope (upper part: distribution of strain, lower part: comparison with the experiment of response acceleration)

A numerical simulation of the dynamic centrifugal model test of slope was conducted for verification of the nonlinear time history response analysis method. As a result, it was confirmed that the simulation results were relatively consistent with the model tests.

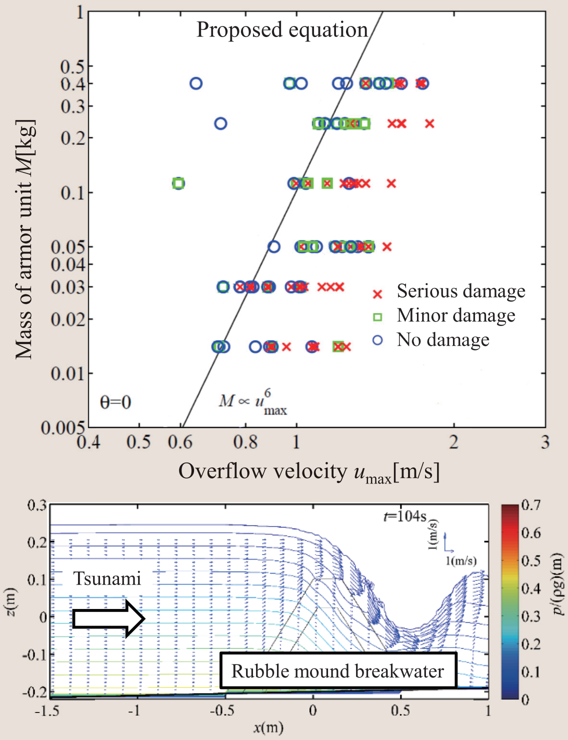

Fig. 2: Stability assessment of rubble mound breakwater

When the tsunami overflows a breakwater, a hydrodynamic load was applied to armor units of the breakwater. In the case that the hydrodynamic load is larger than the drag force of armor units, the armor units are drifted by the tsunami flow. The hydrodynamic load depends on the overflow velocity and the drag force depends on the mass of the armor unit. By carrying out model-scale experiments, we clarified the relationship between the mass of armor units and the overflow velocity in the stability condition (upper figure). The tsunami overflow was able to be numerically simulated well (lower figure).

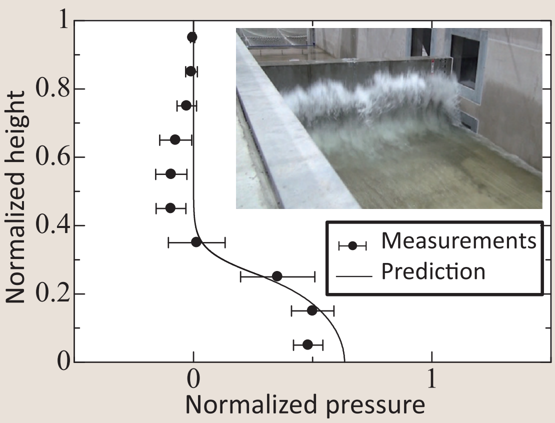

Fig. 3: Evaluation of tsunami impact pressure

An evaluation method of vertical profiles of tsunami impact pressure, which occur just after a tsunami tip impacts a structure, was proposed.

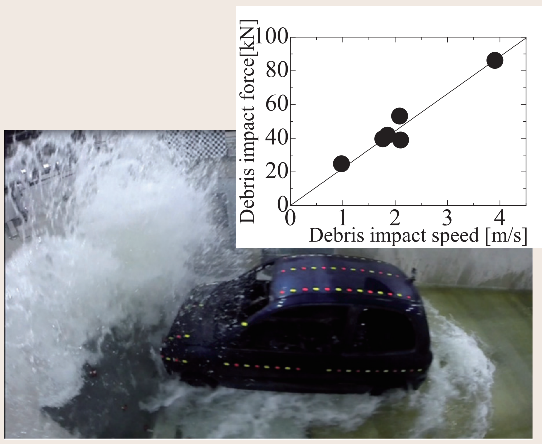

Fig. 4: Evaluation of tsunami-debris impact force

The graph shows the relationship between the debris (a real car) impact speed and force. The car was drifted in the tsunami bore. The graph shows that, in the velocity regime of tsunami inundation flow, the debris impact force linearly increases with the impact speed.