

Test and Evaluation on Seismic Reliability of Nuclear Facilities (1)

Structural Reliability Evaluation Group of the Organization is making efforts on research works to improve seismic regulations through seismic tests or investigation. Those studies vary on extensive areas from methodologies to determine the design base earthquake ground motion to evaluation methodologies of the integrity and functionality of the components and structures.

The aim of seismic tests is recently changing to focus on examination of structural or functional limit (fragility test) to improve the accuracy of the evaluation of margin or to help the probabilistic seismic safety assessment (seismic PSA). Therefore, projects of the Group are almost following such a tendency.

1. Proving Tests on the Seismic Reliability for Nuclear Power Plant

Components important for the safety of nuclear power plant undergo the vibration test, using test models of actual or near actual size. Based on the test results, seismic reliability, safety margin for function and adequacy of seismic design methods are confirmed. And also, the technology to evaluate seismic reliability of components is being prepared, making a lot of efforts in establishing simulation analysis methods which can simulate the behavior of test models.

Ultimate Strength of Piping System (1998 to 2003)

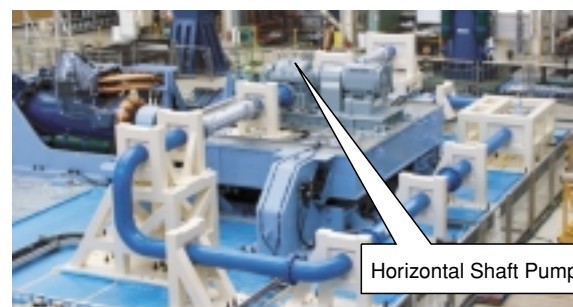
The safety margin of the seismic design method for piping system was clarified by implementing various tests and simulation analysis. And, the safety margin of the seismic allowable stress was also evaluated taking consideration of the elasto-plastic behavior.



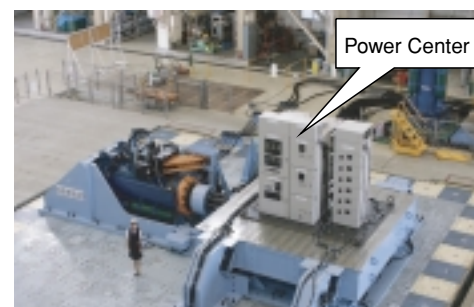
Test of Actual Scale Piping System

Equipment Fragility, Step 1 (2002 to 2004)

The function limits of the horizontal shaft pump and several types of electrical equipment were obtained by conducting the vibration test with high accelerations (maximum acceleration: 6G) using an amplified shaking table. Various element tests were performed in advance. The data of fragility are under evaluation.



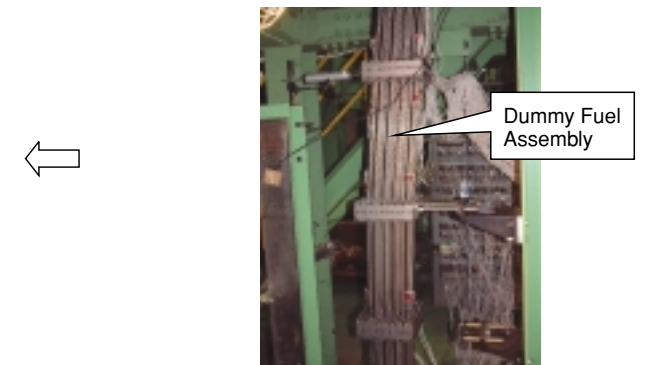
Vibration Test of Horizontal Shaft Pump



Vibration Test of Power Center

Equipment Fragility, Step 2 (2002 to 2005)

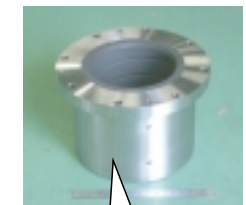
To investigate the limits of function and to evaluate the fragility of components related to the scrammability of control rods (for both BWR and PWR), the vibration test with high accelerations (maximum acceleration: 3G) is performed using a large shaking table. Various element tests were implemented for preparation.



Vibration Test of PWR Dummy Fuel Assembly (Single Unit)

Equipment Fragility, Step 3 (2003 to 2005)

Various element tests were implemented in advance to investigate the functional limit of the vertical shaft pump and to evaluate the fragility data by conducting the vibration test with high accelerations (maximum acceleration: 3G) using a large shaking table. The vibration test of actual size is scheduled in early 2005.



Made of Carbon

Example of a Element Test Piece for Large Vertical Shaft Pump (Underwater Bearing)

Future Development: Equipment Fragility, Step 4 (2005 to 2007)

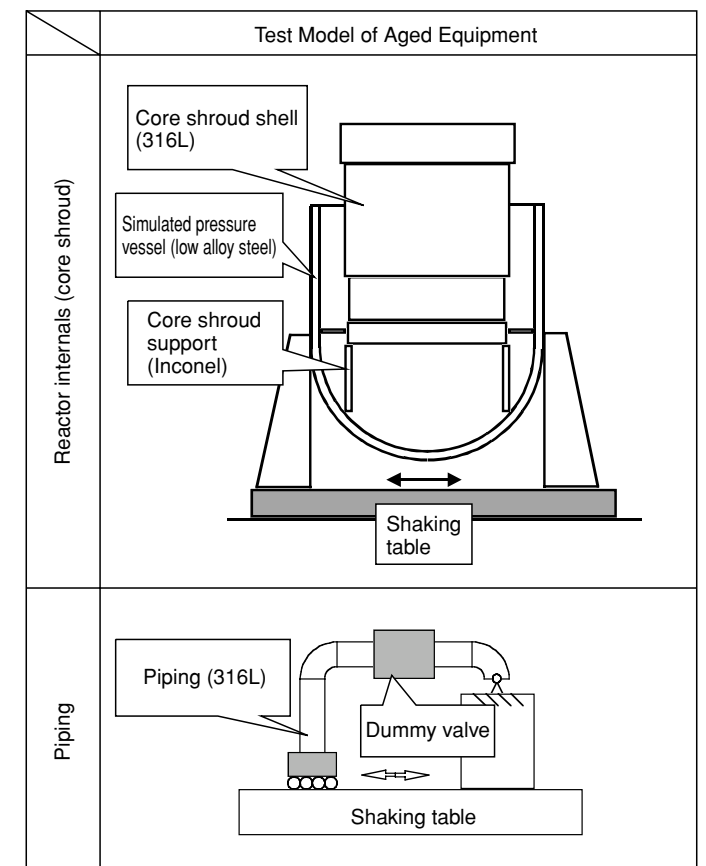
Test Equipment: Valves, Tanks and Support Structures

Future Development: Seismic Integrity of Aged Equipment (2004 to 2006)

In order to respond for aged degradation occurring in the equipment, the vibration tests of the reactor internals (core shroud) and PLR piping will be performed, assuming the defect due to stress corrosion cracking (refer to the note).

The seismic safety margin of the aged equipment will be confirmed, and the methodology to evaluate the structural integrity of the equipment with defects under large seismic input will be established.

Note: Assuming the maximum allowable defect in the fitness-for-service rules (JSME S NA1-2002)



Test and Evaluation on Seismic Reliability of Nuclear Facilities (2)

2. Test to Improve Seismic Structural Response Analysis: Model Tests of Multi-axes Loading on RC Shear Walls

The findings on the recent earthquake experiences and the results of the earthquake observation indicate that it is necessary to study the effect of three directional earthquake ground motion on the seismic capacity of buildings. Taking into account the indication, "Multi-Directional Loading Test of Reactor Building" had been carried out from 1994 through 2003 to study various properties of seismic shear walls of reinforced concrete structures and to accumulate their test data. In 2003, the final year of the project, the dynamic loading test of a cylindrical wall specimen was performed using a three dimensional shaking table and their results were processed and analyzed. In addition, the test was summarized in overall and the restoring force characteristics (seismic capacity and deformation) of seismic shear walls under the simultaneous multi-directional loading conditions were evaluated.



Setting View of Test Model



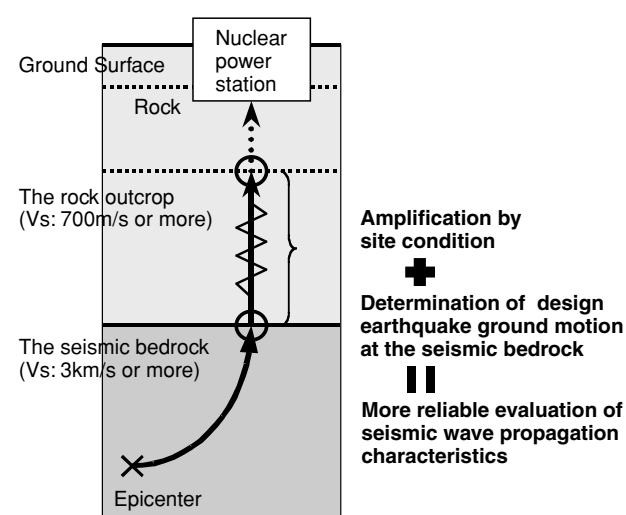
View of Destruction after the Test

Blue: added load, Green: Protection Device, Yellow: Instrument Flame

3. Siting Reliability Studies of Nuclear Power Plants: Study of Evaluation Methods for Seismic Wave Propagation Characteristics

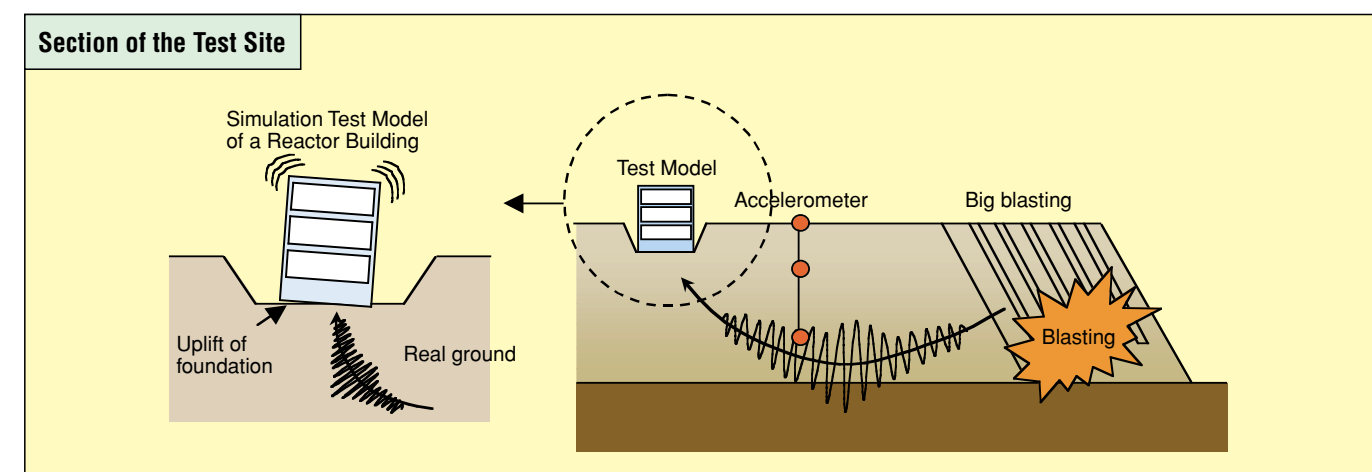
The design basis earthquake ground motion, which is the current base for aseismic design of nuclear facilities, is defined as the motion at the rock outcrop (the rock with the shear wave velocity more than 700m/s). However, the propagation characteristics from the epicenter could not be evaluated accurately, because the earthquake ground motion at the rock outcrop includes the site-specific effect. Therefore, the characteristics of earthquake ground motion is being studied so that the future design basis earthquake ground motion can be defined at the seismic bedrock (the rock with the shear wave velocity more than 3000m/s).

Two deep downhole seismographic arrays at Kobe and Narita were assembled between the ground surface and the seismic bedrock for continuous earthquakes observation. Using the observed records, the analytical method and model which can accurately simulate wave propagation is being developed. Then seismic waves at the seismic bedrocks, where only seismic records at the ground surfaces are gotten, can be estimated with this method. Collecting many of these waves, the average image of earthquake ground motion at the seismic bedrock will be clarified and the recommended evaluation method of the reference earthquake ground motion for design will be established by the end of 2004 fiscal year.



4. The Non-linear Soil-Structures Interaction Test of Nuclear Facilities and Implementation of its Standard

The objectives of the project are to obtain the data of the interaction between the ground and structures when the structures are subjected to an earthquake ground motion that exceeds the design level, to study on a limit of the applicability of the existing evaluation method of the interaction, and to improve the method to be applicable to the big earthquake ground motions. Therefore, it is planned to subject a model of nuclear reactor building installed on the real field to some big artificial earthquake ground motions with paying attention to the non-linear behaviors of the model such as foundation uplift etc. This project starts in the 2003 fiscal year, and the test method will be studied at the first stage.



It is planned to use artificial ground motion of coal-mining blast, where vast amount of explosive will be ignited with time delay and the ground vibration similar to the real earthquake will be produced.

In 2004 and 2005, test method will be investigated in detail as phase-I study such as what kind input wave and what level of response we can have, and how to measure uplift of the mat etc.

Thereafter, "Phase-II, Test and Evaluation" is planned for four years of 2006 to 2009.

