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Seismic Proving Test of a Reinforced Concrete Containment Vessel (RCCV)

Part 1. Outline of the Test, Result from Small Acceleration Excitations and Analysis Method for Observed Data

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I. Introduction

The RCCV seismic proving test study was started in 1992 and excitation tests from small accelerations to S2 accelerations were performed in 1998. Large acceleration tests up to collapse will be performed in 1999 to determine the seismic safety margin. RCCVs are used in advanced BWR, important as final barriers and have advantages of seismic safety, design flexibility and compactness. However, the margin has not been confirmed by dynamic loading. Therefore, a shaking table test up to collapse was planned with a large scale 1/8 model. Part 1 outlines the tests, results of small acceleration tests such as transition of peak frequency and damping ratio, an accurate method of estimating dynamic characteristics of the model under table pitching, and a reasonable, multilateral estimation of transfer functions using their real and imaginary parts and the inverse Nyquist diagram. Part 2 presents S1 and S2 results.

II. Outline of The Test

1. Modeling

The RCCV portion of an ABWR (advanced boiling water reactor) type nuclear power plant prototype building is separated from the building to make the test. This modeling is necessary to enable the final collapsing stage tests within the shaking table's capacity. A part of the floor slab is also modeled to simulate the restraining effect of the outer building on the response to the earthquake load and the inner pressure. Masses are set at the top part of the model to make the acceleration and the stress the same as that of the prototype. Fig.1 and Table 1 show the outline of the model.

2. Peak Frequency and Damping Ratio Transition

The transition of the 1st peak frequencies and damping ratios are shown in Fig.2 and Fig.3. Results in Fig.2 and Fig.3 are obtained using two optimization methods. The damping ratios show some differences depending on the methods used. At first they are about 1% and then they increase to 5~6% with small variation.

III. Dynamic Characteristics Estimation Method and its Application

1. Transfer Function Estimation for Pitching Elimination

The applicability of the proposed method is examined using a simulation model with the RCCV model, the shaking table and the rocking spring for the pitching compliance. The rocking spring incorporates servo system characteristics. For analysis conditions, the model damping ratio is 1% and 5%, the table is with the rocking spring and fixed, and the transfer function is calculated relative to $\ddot{u}_0$ and $(\ddot{u}_0 + {}_s h_{eq} \ddot{\theta}_0)$. The $\ddot{u}_0$ and $\ddot{\theta}_0$ are table horizontal and pitching motions. The ${}_s h_{eq}$ is equivalent height of the model. Results are shown in Table 2. Transfer functions similar to the fixed table cases (i. e., perfect horizontal excitation) are obtained if $(\ddot{u}_0 + {}_s h_{eq} \ddot{\theta}_0)$ is used as input motion. However, if $\ddot{u}_0$ is used for cases with pitching motion, the transfer functions have comparatively large errors.

2. Transfer Function Optimizations Using Real and Imaginary Parts and the Inverse Nyquist Diagram

Fig.4(a) shows an example of optimization using real and imaginary parts of a transfer function and Fig.4(b) shows one for the inverse Nyquist diagram. The former method uses theoretical curves of single - degree - of - freedom systems for fitting and the latter uses straight lines. Bode's diagram and Nyquist's diagram for the same data are also shown for reference. The following can be stated.

a. There is little difference between the peak frequencies of the two methods. Therefore, they can be regarded as giving accurate results.

b. There is some difference between the damping ratios in many cases, where the data show strong nonlinearity. In such cases, the damping ratio estimation ranging from 5 ~ 6% for instance, is very natural. Therefore, it is desirable to apply plural methods for multilateral and reasonable estimation.

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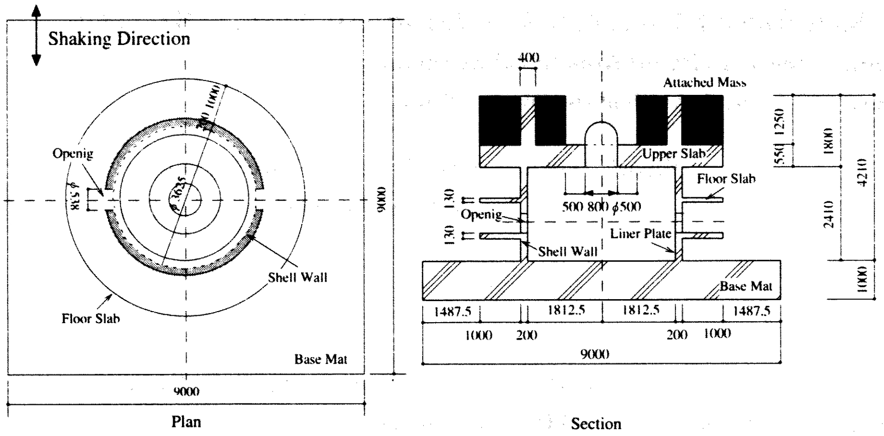


Fig. 1 Test Model Configuration

Table 1 Outline of the Specimen

(a) Test Model Scale

Whole Test Model Scale	1/8 (ID. 3260mm)
Concrete Wall Thickness	1/10 (200mm)
Liner Plate Thickness	1/4 (1.6mm)

(b) Test Model Weight (ton)

Base Mat	213
ShellWall and Slabs	76
Attached Mass	276
Measuring Frame and Protection Equipment	30
Total	595

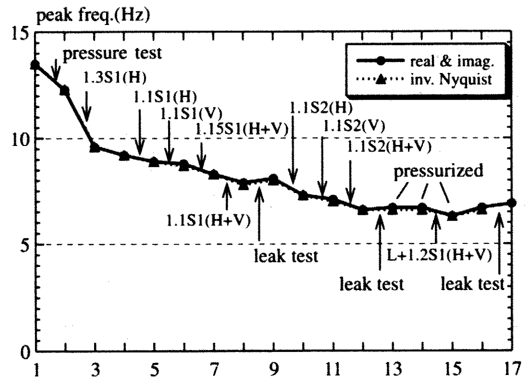


Fig.2 Transition of the 1st Peak Frequency

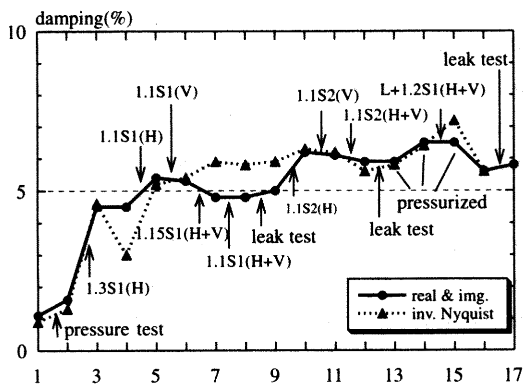
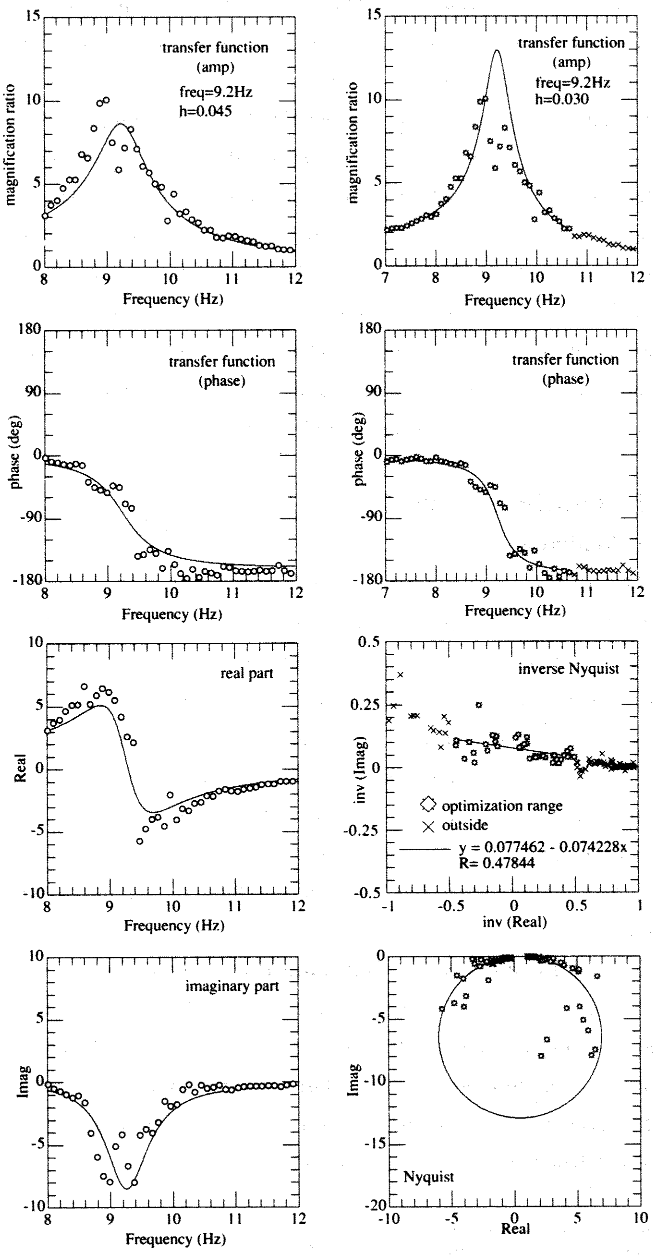


Fig.3 Transition of the 1st Peak Damping Ratios

Table 2 Pitching Effect Simulation Result

upper : 1st peak frequency
lower : 1st peak damping ratio

model damping	with pitching $\frac{\ddot{u}}{\ddot{u}_0}$	with pitching $\frac{\ddot{u}}{\ddot{u}_0 + {}_s h_{eq}\ddot{\theta}_0}$	without pitching
1%	12.4Hz 3.2%	13.3Hz 1.5%	13.4Hz 1.0%
5%	12.3Hz 6.8%	13.2Hz 5.5%	13.4Hz 5.0%



(a) real and imaginary　　(b) inverse Nyquist

Fig.4 Optimization Example (98063003)