

## THE EARTHQUAKE RESPONSE ANALYSIS FOR A BWR NUCLEAR POWER PLANT USING RECORDED DATA

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The aim of this paper is to analyze the results of observed vibrations caused by a vibrator and an actual earthquake in various parts of a BWR nuclear power plant, and then to draw conclusions as to that plant's earthquake vibration character.

To conduct an earthquake response analysis, the most important thing is to evaluate such input data as masses, rigidities, damping factors, etc. for each part of the vibration model. The reasons why nuclear power plants are considered to have among the most complicated of vibration systems are 1) that they consist of both a reinforced concrete building and a shielding wall where can be found ~~steel~~ containment, equipment, piping and instruments; and 2) that they are supported by a foundation with a large damping.

From this point of view, it therefore becomes necessary to consider different damping factors for each structural part of the plant. During the past several years, we have been engaged in the development of computer programs which in conjunction with observed earthquake and vibration test data have then been used for analysis of the vibration model. Fortunately, in November of 1969, we were able to perform a forced vibration test on the Tokyo Electric Power Company's nuclear power plant located in Northern Japan's Fukushima prefecture. As a result, we were able to arrive at that plant's vibration character and then to evaluate the rigidities and damping factors in foundation, building, roof, etc..

After that, sets of seismographs were installed in various parts of this plant. On May 26, 1970, the acceleration waves from an earthquake with Fukushima offshore epicenter were thereby recorded on each floor, in the foundation, roof, containment, circular wall, etc.. We then applied the resulting data to the above-mentioned computer programs and were able to determine to what extent our method of analysis had been correct.

DISCUSSION

J. P. LAFAILLE, Belgium

Q

When studying the response of a building with a 2-dimensional model it is impossible to detect any response of the building in a direction different from the excitation. This coupling effect would occur if the excitation did not occur in a principal direction of inertia. Were there checks made to verify that there were not such effects ?

K. MUTO, Japan

A

The earthquake in May 1970 had ground motion in both NS and EW directions, and coupled effects would have occurred in the building. Our measurement was made in NS direction only because of economy. Analysis was then limited in this direction. But the fairly accurate coincidence of theory and measurement was taken. In future, for a three-dimensional approach, a lot of instruments and measurements would be desirable as well as relevant analysis.

C. B. SMITH, U. S. A.

Q

Could you tell us about the experimental methods used in your work ?

K. MUTO, Japan

A

A large vibration machine was installed on the 5th floor of the reactor building. The displacement was measured at many points of the building at every small step of frequency, then the response curve was taken due to the sinusoidal excitations.

Ch. CHEN, U. S. A.

Q

The elegant complex eigenvalue problem was used to consider different damping ratios in the same model. The engineers always have the tendency to use a simplified method so long as the difference is within engineering tolerance. I wonder if the authors compared these results with other simplified results based on weighted damping ratio. It seems that there is some basic agreement between these two approaches as shown on the slides, namely modes 1 and 7 have higher damping coefficients.

K. MUTO, Japan

A

In the 1st, 4th and 7th modes, the movements of soil are very pronounced. On the basis of the analysis, we consider a large damping coefficient of 0.044 sec. for the soil part of the vibration model. So it may be natural that the mode in which the soil movement is pronounced has a large damping factor.

A. H. HADJIAN, U. S. A.

Q

Viscous damping is a equivalence and generally determined by tests of actual structures. How are then the damping coefficients  $V_i$  determined and why was the damping matrix made proportional to the stiffness matrix ?

K. MUTO, Japan

A

The damping coefficient  $V$  of the vibration element is computed from both the natural period ( $T$ ) and the damping factor ( $h$ ) which are usually measured by the vibration test. In case of one mass system, the  $V$  may be expressed as follows:

$$V = Th / \pi$$

As for the definition of  $V$ , refer the equation (1):

$$\{f\}_i = [B]_i \{v\}_i + [v B]_i \{v\}_i$$

in which

$\{f\}$  = external force vector

$[B]$  = stiffness matrix of the element

$\{v\}$  = displacement vector.