EARTHQUAKE RESPONSE ANALYSIS OF REACTOR STRUCTURES

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The general nature of the principles upon which earthquake resistant design is based is described with particular reference to components and elements of nuclear reactor facilities. Special attention is paid to the response and design criteria of items of equipment or of components that are mounted on or attached to responding elements, and basic procedures are developed to bound the dynamic response of such items.

Consideration is given to vertical as well as horizontal excitation, and the combination of the effects of the various excitations. Suitable approximations are developed for inelastic response estimates.

One section of the paper is devoted to relative motions of points some distance apart, and to bounds for such relative motions.

Recommendations are made for the general criteria governing the design of nuclear facilities, including the basic parameters governing response characteristics and energy absorption.

* Published in *Nuclear Engineering and Design* 20 (1972).

DISCUSSION

R. SCHNEIDER, Germany

Q

Your research is mainly based on acceleration record by El-Centro-Earthquake (magnitude $M \approx 7.0$). In Central Europe the maximum magnitude is about $M = 6-6.5$. What about the similarity between ground and design spectra between a $M \approx 6.0$ -earthquake and the 7.0 magnitude earthquake ? Can one use the design spectra cited in your lecture also for Central Europe maximum earthquakes just by multiplying the spectra by diminishing factors ?

N. M. NEWMARK, U. S. A.

A

First, my research is not based mainly on the El-Centro 1940 record, but on the records of many other earthquakes and of motions due to blasting and impact as well. The general conclusions are applicable, regardless of earthquake magnitude. I would recommend that a ground velocity of 15 cm/sec or 6 in. /sec be used as a minimum design value, and this corresponds to about 0.1 g acceleration. The use of anything less would in my opinion be distinctly unsafe. I believe strongly that the frequency range for design for earthquakes of any intensity, on moderately firm ground, should be similar to the design spectrum range shown in my paper. This needs modification by a slight shift to higher velocities for a given acceleration for very soft soils, and a slight shift to higher accelerations but unchanges velocities for hard rock.

Q

Ch. CHEN, U. S. A.

1. How should the response from vertical response spectrum and horizontal response spectrum be combined ? It seems that the absolute addition is too conservative.
2. Since there is no normal modes in plastic region for multidegree of freedom system, is there any way to apply the inelastic single degree of freedom spectrum to multidegree of freedom system in inelastic region ?

A

N. M. NEWMARK, U. S. A.

1. The addition of the absolute values of response to vertical and horizontal excitation is much too conservative. I have recommended in earlier papers that the individual responses in the two horizontal directions and the vertical direction be combined by taking the square root of the sums of the squares of the component responses.
2. Since there are no modes in the responses in the non-linear range, for the plastic region the modified response spectra I have described can be used only as an approximation for multi-degree of freedom systems. With some judgment in the selection of the modes of the elastic system that have the major inelastic response, a reasonably good approximation can be developed for use in design, however.

H. SATO, Japan

Q

We have not been successful to know acceleration and displacement simultaneously by instrumentation. Displacement motion might be larger than that we know at the moment when it contains longer period beyond the capability of the accelerometer. Would you please make any comment on the accuracy of the proposed maximum value of displacement ?

N. M. NEWMARK, U. S. A.

A

In general large displacements are not controlling factors in the design of nuclear power plant facilities and components except possibly for very long period elements, with periods longer than 5 seconds. However, even for these, one can use the maximum ground velocity as a measure to obtain a conservative estimate of the response. In the case of fault motions at the surface near the epicenter, values have been recorded as much as 20 ft for very large earthquakes, but the ground velocity associated with them is very much less than the maximum ground velocity. Hence it is not a serious matter that we do not have good records of maximum transient ground displacement if we have records of maximum ground velocity one can cipher these values from measurements of maximum ground acceleration.

H. SHIBATA, Japan

Q

Dominant periods of liquid surface in torus of BWR type reactors might be more than 15 seconds. So the estimation of displacement of such long period ground motion seems to be also important for actual design.

N. M. NEWMARK, U. S. A.

A

The importance of the response of the liquid in the torus is great, but the response is affected also by ground velocity as well as displacement. The comments made in my reply to Dr. Sato are also applicable in this case.