

# ROCKING EFFECTS IN A NUCLEAR POWER PLANT SUBJECTED TO A SEISMIC DISTURBANCE

by

C.A. Miller<sup>I</sup> and C.J. Costantino<sup>I</sup>

## SYNOPSIS

Floor response spectra are used as seismic design criteria for equipment housed in nuclear power plants. These response spectra are generated from a time-history analysis of the primary structure subjected to the free-field seismic disturbance. Two methods are considered in this paper which reduce the effort involved in generating the floor response spectra and the methods are shown to give reasonable results for a typical Reactor Containment Building.

## INTRODUCTION

The seismic design of internal components of a nuclear power plant is usually based upon floor response spectra. Ideally the floor response spectra are calculated as a result of a dynamic analysis of the primary structure with the motion of the equipment support points used to determine floor response spectra. This requires a rather lengthy numerical calculation at the outset of a project when only meager data describing the facility is available, and the calculation of spectra at many floor support points. Approximate methods for circumventing these difficulties are discussed in this paper.

## RESPONSE ANALYSIS

The approximate methods are presented and compared with the more rigorous time-history analysis of the Reactor Containment Building (RCB) of the Fast Flux Test Facility (FFTF). A sketch of the RCB is shown in Fig. 1. The soil is layered with a density of 110 pcf and shear moduli as shown. The total weight of the structure is 130,000 kips and its moment of inertia about the center of gravity is  $1.1 \times 10^8$  kip-feet<sup>2</sup>.

The horizontal response of this structure to the TAFT (1952) earthquake is calculated using the SIM Code<sup>(1)</sup>. For this solution the structure is assumed to be rigid and interaction forces are applied at the wall and foundation. The interaction forces are assumed to be linearly proportional

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<sup>I</sup> Associate Professor, Department of Civil Engineering, The City College of New York, New York, New York.

to the relative displacement and velocity of the free field and the structure<sup>(1)</sup>. The resulting rigid body translation mode of the structure is at 6 cps with a damping of 50% of critical while the rocking mode is at 31 cps with damping at 23% of critical.

Shock spectra of the horizontal motion at point "x" in the facility is calculated and shown on Fig. 2. All shock spectra are computed for 2% equipment damping. The free field horizontal spectra is shown on Fig. 3 so that the amount of amplification may be noted. The point "x" spectra would be an example of a floor response spectra to be used for equipment design.

#### FLOOR SPECTRA FROM C.G. SPECTRA

An approximate method of computing the point "x" spectra from the C.G. spectra is next considered. Shock spectra for the horizontal and notational motion of the structure's center of gravity (as computed in SIM Code) are determined. The shock spectral acceleration ( $a_f$ ) at any frequency for point "x" is then taken as the sum of the translation and rocking components. Two methods of summing the components are considered,

$$\text{RMS: } a_f = \sqrt{(H_f)^2 + (vR_f)^2}$$

$$\text{Abs. Value: } a_f = |H_f| + |vR_f|$$

where  $H_f$  = horizontal acceleration of cg at frequency (f)

$R_f$  = notational acceleration of cg at frequency (f)

$v$  = vertical separation of point "x" and cg.

Shock spectra based upon each of these equations are plotted on Fig. 2 together with the SIM Code Spectra for point "x". As may be seen good agreement is found between the results and the second of the above equations would represent a workable method for generating preliminary floor spectra at various points in the facility.

#### FLOOR SPECTRA FROM FREE FIELD SPECTRA

Biggs<sup>(2)</sup> has suggested a method whereby floor response spectra may be calculated based upon a free field spectra and the eigenvalues of the structure. This method is applied to the RCB and the floor response spectra calculated for point "x". This spectra together with the spectra resulting from the time history analysis are plotted on Fig. 4. Good correlation is again found between this simplified

approach and the spectra generated from the time history analysis.

#### SUMMARY

Two approximate methods are considered to generate floor response spectra. In the first a time history analysis of the structure is performed and the shock spectra at any point in the facility is related to the shock spectra of the structure's center of gravity translation and rotational mode components. The second method is due to Briggs and relates the shock spectra of the motion at any point in the facility to the free field spectra through the eigenvalues of the structure. Both methods result in shock spectra which are in good agreement with those derived from a time history analysis.

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1. C.A. Miller, and C.J. Costantino, "Structure-Foundation Interaction of a Nuclear Power Plant with a Seismic Disturbance", Nuclear Engineering and Design 14 (1970), 332-342.
  2. J.M. Briggs and J.M. Roesset, "Seismic Analysis of Equipment Mounted on a Massive Structure", Seismic Design for Nuclear Power Plants, MIT Press, 1970.

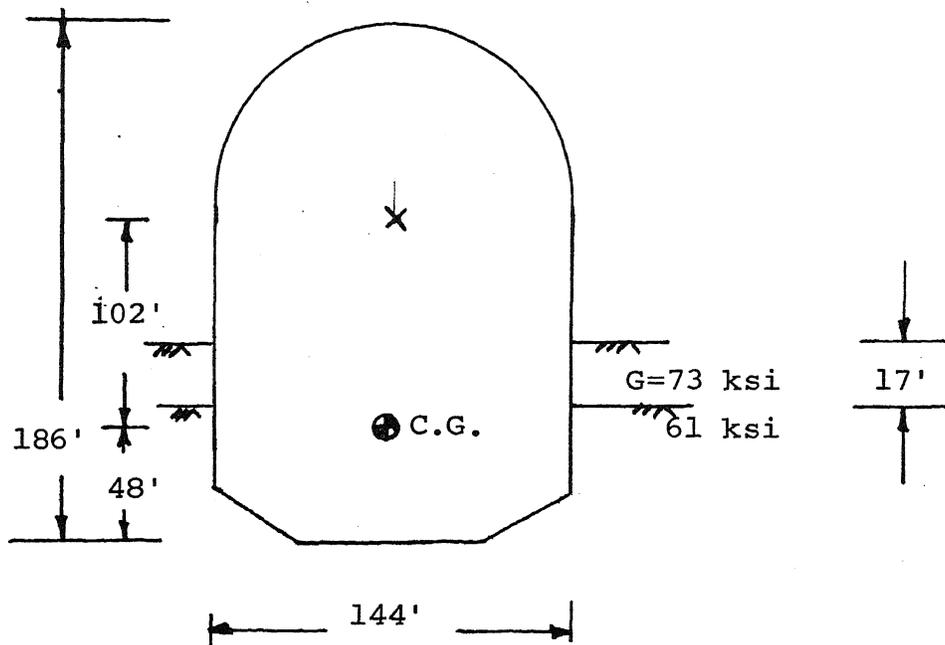


Fig.1 Reactor Containment Building

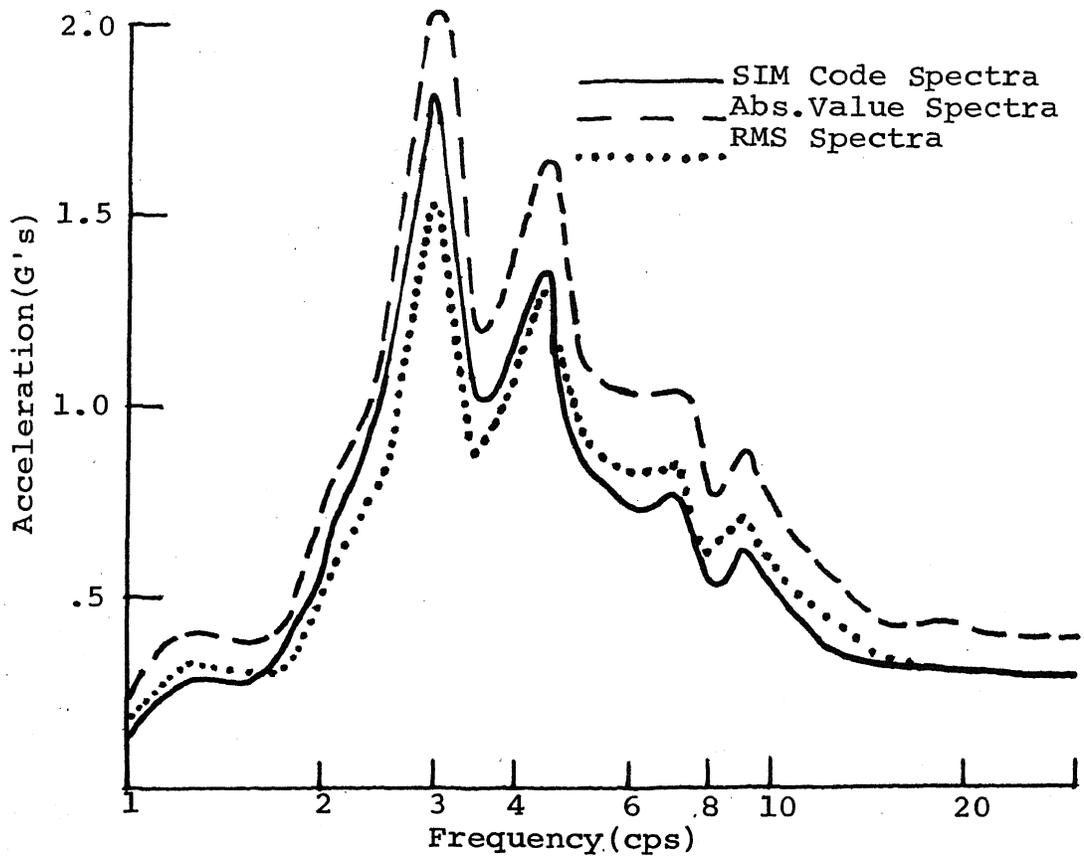


Fig.2 Point "X" Spectra from C.G. Spectra

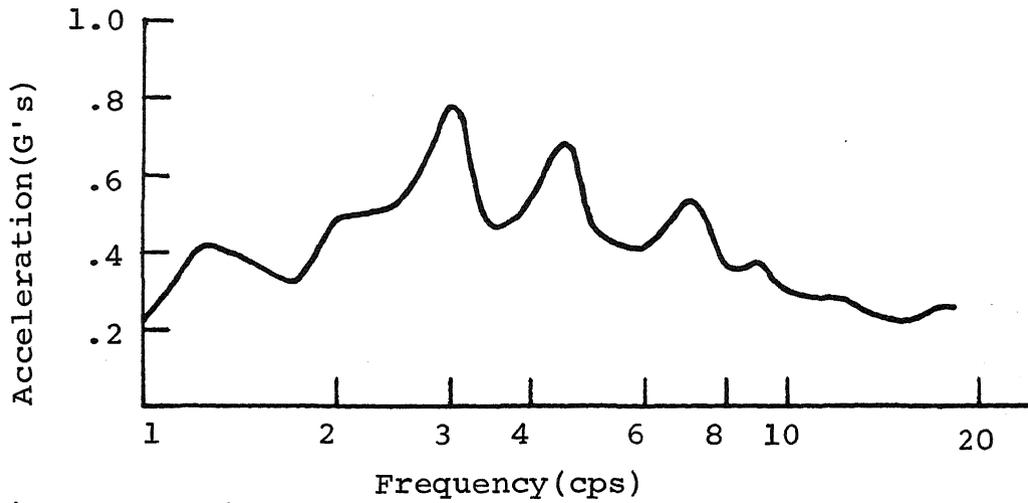


Fig.3 Free Field Spectra

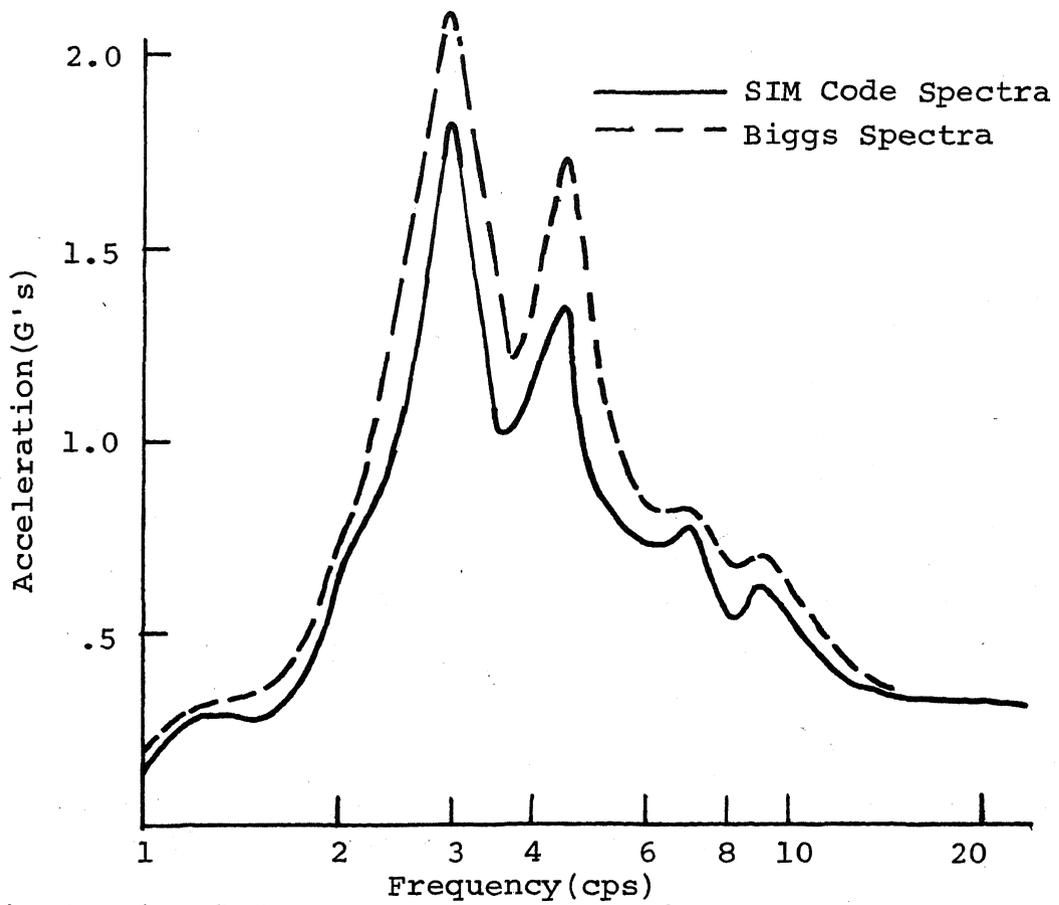


Fig.4 Point "X" Spectra from Free Field Spectra