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# REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

## REGULATORY GUIDE 1.122
## DEVELOPMENT OF FLOOR DESIGN RESPONSE SPECTRA FOR SEISMIC DESIGN OF FLOOR-SUPPORTED EQUIPMENT OR COMPONENTS

### A. INTRODUCTION

Criterion 2, "Design Bases for Protection Against Natural Phenomena," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires, in part, that nuclear power-plant structures, systems, and components important to safety be designed to withstand the effects of earthquakes without loss of capability to perform their safety functions. Paragraph (a)(1) of Section VI, "Application to Engineering Design," of Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100, "Reactor Site Criteria," requires, in part, that safety-related structures, systems, and components remain functional in the event of a Safe Shutdown Earthquake (SSE). It specifies the use of a suitable dynamic analysis as one method of ensuring that the structures, systems, and components can withstand the seismic loads. Similarly, paragraph (a)(2) of Section VI of the same appendix requires, in part, that the structures, systems, and components necessary for continued operation without undue risk to the health and safety of the public remain functional in the event of an Operating Basis Earthquake (OBE). Again, the use of suitable dynamic analysis is specified as one method of ensuring that the structures, systems, and components can withstand the seismic loads.

This guide describes methods acceptable to the NRC staff for developing two horizontal and one vertical floor design response spectra at various floors or other equipment-support locations of interest from the time-history motions resulting from the dynamic analysis of the supporting structure. These floor design response spectra are needed for the dynamic analysis of the systems or equipment supported at various locations of the supporting structure. The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

### B. DISCUSSION

Nuclear facility structures can be approximated by mathematical models to permit analysis of responses to earthquake motions. Because of the large number of degrees of freedom that would be necessary and the possible ill-conditioning of the resulting stiffness matrix if the complete plant were treated in a single mathematical model, the plant is usually divided into several separate systems for analysis purposes. Thus it is usual that there are one or more mathematical models of supporting structures. Each supporting structure normally supports one or more systems or pieces of equipment. Also, different models of the same structure may be required for different purposes. For these reasons, the mathematical models used to generate the seismic excitation data for subsequent separate analyses of supported systems or equipment may not be suitable for the detailed localized analyses of the supporting structure.

Most equipment having a small mass relative to that of the supporting structure will have negligible interaction effects on the support structure and will need to be included only in the mass distribution of the mathematical model for that structure. For such equipment, a separate analysis will be performed using the floor design response spectra or time-history excitations at the equipment-support locations

*Lines indicate substantive changes from previous issue.

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Comments and suggestions for improvements in these guides are encouraged at all times, and guides will be revised, as appropriate, to accommodate comments and to reflect new information or experience. This guide was revised as a result of substantive comments received from the public and additional staff review.

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derived from the analysis of the supporting structure. This guide addresses the acceptability and development of floor design response spectra only. Time-history motions that will give results comparable to the floor design response spectra are also acceptable.

There are, however, other major equipment systems such as the reactor coolant system whose stiffness, mass, and resulting frequency range should be considered for inclusion in the model of the supporting structure to account for possible dynamic interaction effects. Such equipment can be analyzed by combining the complete equipment model with the model of the supporting structure and applying the proper excitation to the base of the supporting structure. With this method, no separate equipment-support excitations need be generated because the equipment will be excited directly through the structure. It should be noted that a combined model of the building and equipment must be formulated to perform such an analysis.

## 1. Floor Response Spectra

The two horizontal and the vertical response spectra can be computed from the time-history motions of the supporting structure at the various floors or other equipment-support locations of interest. It is important that the spectrum ordinates be computed at the natural frequencies of the supporting structure and at frequencies sufficiently close to produce accurate response spectra (see Table 1 for guidance). Spectrum peaks normally would be expected to occur at the natural frequencies of the supporting structure.

TABLE 1

SUGGESTED FREQUENCY INTERVALS FOR CALCULATION OF RESPONSE SPECTRA

| Frequency Range (hertz) | Increment (hertz) |
|---|---|
| 0.2– 3.0 | 0.10 |
| 3.0– 3.6 | 0.15 |
| 3.6– 5.0 | 0.20 |
| 5.0– 8.0 | 0.25 |
| 8.0–15.0 | 0.50 |
| 15.0–18.0 | 1.0 |
| 18.0–22.0 | 2.0 |
| 22.0–34.0 | 3.0 |

## 2. Smoothing Floor Response Spectra and Broadening Peaks

To account for uncertainties in the structural frequencies owing to uncertainties in the material properties of the structure and soil and to approximations in the modeling techniques used in seismic analysis, it is important that the computed floor response spectra be smoothed and peaks associated with each of the structural frequencies be broadened. One acceptable method for determining the amount of peak broadening associated with each of the structural frequencies is described below.

Let $f_J$ be the Jth mode structural frequency that is determined from the mathematical models. The variation in each of the structural frequencies is determined by evaluating the variation due to each significant parameter such as the soil modulus, material density, etc. The total frequency variation, $\pm\Delta f_J$, (see Fig. 1) is then determined by taking the square root of the sum of squares (SRSS) of a minimum variation of $0.05f_J$ and the individual frequency variations, $\Delta f_{Jn}$, as described in regulatory position 1.

Figure 1 shows a sample of a smoothed floor response spectrum curve. Note that the broadened peak is bounded on each side by lines that are parallel to the lines forming the original spectrum peak.

## 3. Floor Design Response Spectra

Nuclear power plant facilities are designed for three-component earthquakes, as indicated in Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants." When a structural seismic analysis is performed separately for each direction (two horizontal and one vertical), and in the case of unsymmetric structures, the structural motion in a given direction at a given location will contain contributions from the vertical and the two horizontal excitations. In such cases, the contribution from each individual analysis will generate a response spectrum at a given location in each of the three directions. It is important that the ordinates of these three response spectra for a given direction be combined according to the SRSS criterion and that the resulting response spectrum then be smoothed and the peaks broadened to predict the floor design response spectrum at the location of interest and for the given direction. In the case of symmetric structures, there will be only one significant floor response spectrum in each of the three directions. The smoothed versions of these floor response spectra will be the floor design response spectra. In those cases in which the mathematical model is subjected simultaneously to the action of three statistically independent spatial components* of an earthquake, the three computed and smoothed floor response spectra at a given location will be the floor design response spectra.

# C. REGULATORY POSITION

The following procedures for combining and smoothing the floor response spectra (with peaks broadened) to obtain the smoothed floor design response spectra are acceptable to the NRC staff.

*See Regulatory Guide 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis."

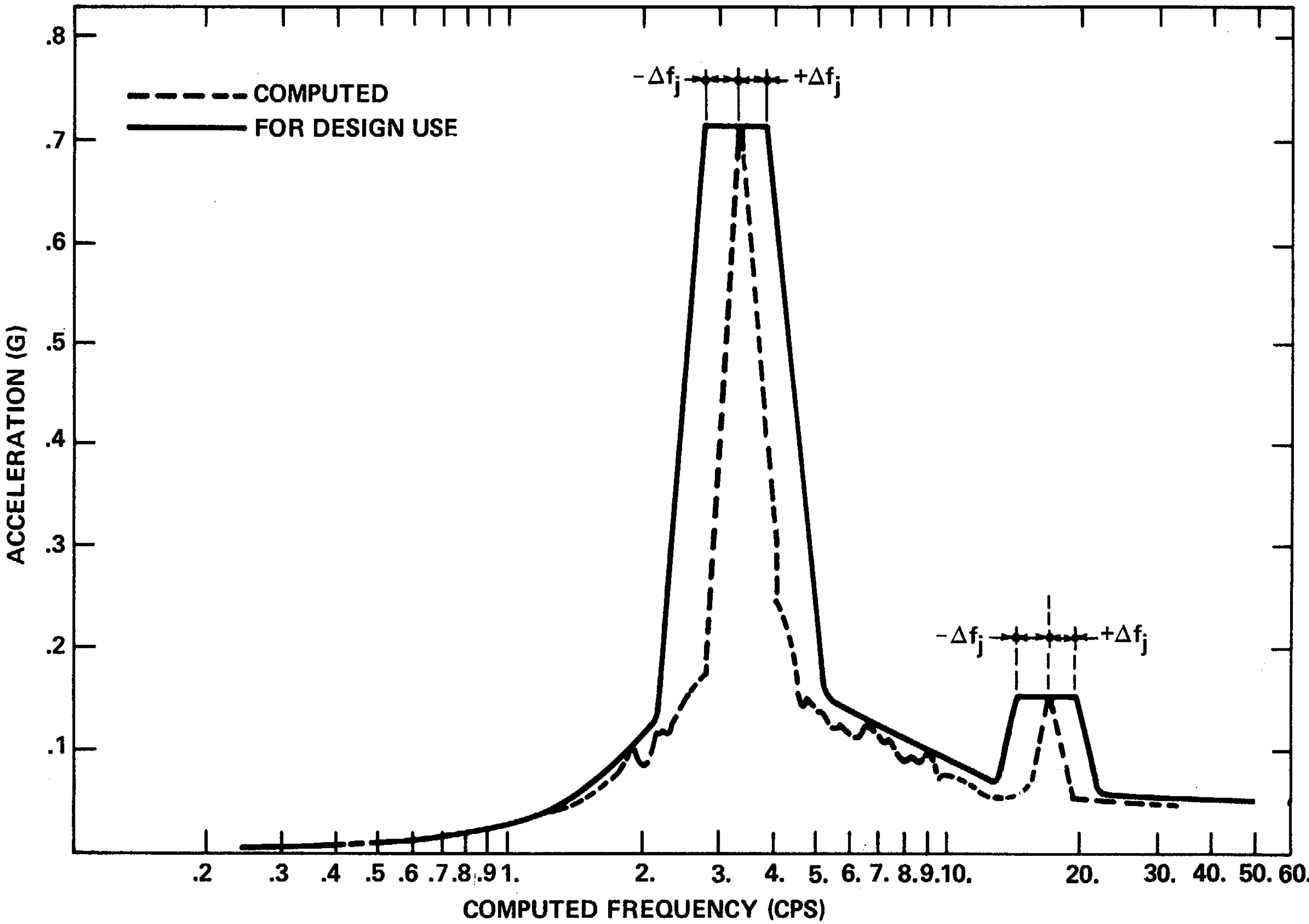


Figure 1 Response Spectrum Peak Broadening and Smoothing

1. When the seismic analysis is performed separately for each of the three directions, and in the case of unsymmetric structures, the ordinates of the floor design response spectrum at the location of interest and for a given direction should be obtained by combining the ordinates of the three floor response spectra for that direction according to the SRSS criterion. The resulting response spectrum should be smoothed with peaks broadened. In the case of symmetric structures, the floor design response spectrum for a given direction will be the smoothed floor response spectrum for that direction.

2. To account for uncertainties in the structural frequencies owing to uncertainties in such parameters as the material properties of the structure and soil, damping values, soil-structure interaction techniques, and the approximations in the modeling techniques used in seismic analysis, the computed floor response spectra from the floor time-history motions should be smoothed, and peaks associated with each of the structural frequencies should be broadened (see the sample in Figure 1) by a frequency, $\pm\Delta f_J$, where

$$\Delta f_J = \left[ (0.05 f_J)^2 + \sum_{n=1}^{P} (\Delta f_{Jn})^2 \right]^{1/2} \nless 0.1 f_J$$

where $\Delta f_{Jn}$ denotes the variation in the Jth mode frequency, $f_J$, due to variation in parameter number n, and P is the number of significant parameters considered. A value of $0.1f_J$ should be used if the actual computed value of $\Delta f_J$ is less than $0.1f_J$. If the above procedure is not used, $\Delta f_J$ should be taken as $0.15f_J$.

3. When the mathematical model of the supporting structure is subjected simultaneously to the action of three spatial components of an earthquake, the computed response spectrum in a given direction with peaks broadened and smoothed will be the floor design response spectrum in that direction.

## D. IMPLEMENTATION

The purpose of this section is to provide information to applicants regarding the NRC staff's plans for using this regulatory guide.

This guide reflects current NRC staff practice. Therefore, except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein is being and will continue to be used in the evaluation of submittals for construction permit applications until this guide is revised as a result of suggestions from the public or additional staff review.