

REVIEW OF PUBLIC COMMENTS ON PROPOSED SEISMIC  
DESIGN CRITERIA\*

by

BNL-NUREG--42788

DE89 014191

A.J. Philippacopoulos  
Brookhaven National Laboratory  
Upton, New York 11973

S.K. Shaukat  
Engineering Issues Branch, Office of Nuclear Regulatory Research  
U.S. Nuclear Regulatory Commission, Washington, D.C. 20555

N.C. Chokshi  
Probabilistic Risk Analysis Branch, Office of Nuclear Regulatory Research  
U.S. Nuclear Regulatory Commission, Washington, D.C. 20555

G. Bagchi  
Structural & Geosciences Branch, Office of Nuclear Reactor Regulation  
U.S. Nuclear Regulatory Commission, Washington, D.C. 20555

**DISCLAIMER**

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

JMP

## INTRODUCTION

During the first quarter of 1988, the Nuclear Regulatory Commission (NRC) prepared a proposed Revision 2 to the NUREG-0800 Standard Review Plan (SRP) Sections 2.5.2 (Vibratory Ground Motion), 3.7.1 (Seismic Design Parameters), 3.7.2 (Seismic Systems Analysis) and 3.7.3 (Seismic Subsystem Analysis). The proposed Revision 2 to the SRP was a result of many years work carried out by the NRC and the nuclear industry on the Unresolved Safety Issue (USI) A-40: "Seismic Design Criteria." The background material related to NRC's efforts for resolving the A-40 issue is described in NUREG-1233 (Shaukat et al., 1988). Details pertaining to SSI issues are given by (Chokshi et al., 1989).

In June 1988, the proposed Revision 2 of the SRP was issued by NRC for public review and comments. Comments were received from Sargent and Lundy Engineers, Westinghouse Electric Corporation, Stevenson and Associates, Duke Power Company, General Electric Company and Electric Power Research Institute.

In September 1988, Brookhaven National Laboratory (BNL) and its consultants (C.J. Costantino, R.P. Kennedy, J. Stevenson, M. Shinozuka and A.S. Veletsos) were requested to carry out a review of the comments received from the above six organizations. The objective of this review was to assist the NRC staff with the evaluation and resolution of the public comments. This review was initiated during October 1988 and it was completed on January 1989. As a result of this review, a set of modifications to the above mentioned sections of the SRP were recommended by BNL and its consultants (Philippacopoulos, 1989). This paper summarizes the recommended modifications.

## GROUND MOTION

The main concerns expressed in the public comments with respect to the proposed Revision 2 to SRP requirements on ground motion are related to the following items:

- a) Power Spectral Density (PSD) criteria;
- b) Duration of input design time history;
- c) Number of time histories for multiple time history analysis; and
- d) Ratio of vertical to horizontal ground design spectra.

---

\*The USNRC has neither approved nor disapproved the contents of this paper. The views and conclusions contained in this paper are those of authors and should not be interpreted as necessarily representing the official position or recommendations of the USNRC.

From the above items, the public comments were particularly focused on the proposed PSD requirements. The basic objection was that it could force unnecessary conservatism in the design time history. It appears that the main source of the public reaction to the proposed PSD requirement is that the latter is based on a target PSD which produces response spectra which are much higher than the corresponding Regulatory Guide 1.60 spectra (especially at higher frequencies, i.e., greater than 10 cps). This causes the following problem: A design time history which matches closely the Regulatory Guide 1.60 spectra has to be subsequently modified so that its PSD meets a target PSD which in turn produces response spectra which lie much above the Regulatory Guide 1.60 spectra. This problem can be resolved by refining the PSD requirements of the proposed Revision 2 to the SRP so that they correspond to a minimum type PSD requirements. Minimum simply implies that they preserve (within reasonable limits) the level of conservatism associated with the design response spectra. By doing so, the primary role of design spectra is maintained in the design process, whereas the PSD requirement is of a complementary nature. As such, any time history which satisfies the design spectra should be able to pass the PSD check, unless there is a lack of ground motion energy at specific frequency windows.

Several questions were also raised in the public comments with respect to the minimum requirement of five time histories for the multiple time history analysis option. This requirement was found to be too high. In addition, it was suggested that specific guidelines be given in the SRP for acceptance of time durations for the design time histories used in seismic analysis. Finally, public comments suggested that the 2/3 rule for defining the vertical component of the design ground motion be included in the SRP acceptance criteria.

The following recommendations are made for resolution of the public comments on the proposed Revision 2 to the SRP areas dealing with ground motion requirements:

- a) First, the PSD criteria (target PSD function as well as requirements to meet the target PSD) of the proposed SRP Revision 2 should be replaced with the minimum PSD criteria given in NUREG/CR-5347. The SRP should also clarify that the design response spectra are the primary acceptance criteria while the PSD requirement is a secondary one. Secondly, the following items are suggested to be further investigated:
  - o PSD requirements for other types of generic broad-banded design spectra be developed.
  - o PSD requirements for both horizontal and vertical cases be specified.
  - o The purpose of PSD functions in seismic analysis be clarified, e.g., should PSD representations of input motion be also used in conjunction with other aspects of seismic analysis?
  - o The case of implementing power requirements directly at the level of the response spectrum be further investigated.
- b) The following provisions regarding the duration of ground design time histories are recommended:
  - o Strong motion duration: Minimum: 6 seconds  
Maximum: 15 seconds
  - o Total duration: 10-25 seconds

Shorter or longer durations should also be accepted on a case-by case basis.

- c) The minimum number of time histories required to perform a multiple time history seismic analysis should be reduced from five to four. At this time, sufficient basis does not exist for further reduction.
- d) The vertical ground design spectrum should be taken as 2/3 of the horizontal over the entire frequency range of interest provided that the epicentral distance of the design earthquake is more than 10 Km. For smaller epicentral distances the definition of the vertical ground design spectrum should be reviewed and accepted on a case-by-case basis. In addition, the 2/3 scaling rule should not be permitted for cases in which the horizontal ground design spectrum is generated using the site-specific approach described in Item 1 of SRP Subsection 2.5.2.6. In such cases, the same procedure should be followed for generating both the horizontal as well as the corresponding vertical ground design spectra.

## SOIL-STRUCTURE INTERACTION

The majority of the public comments on the soil-structure interaction (SSI) requirements of the proposed SRP Revision 2 were primarily focused on the following items:

- 1) Acceptance criteria for justification of fixed-base analysis.
- 2) Enveloping requirement of alternate 1 SSI analysis.
- 3) Requirements for variation of soil properties in SSI.
- 4) Limit of soil hysteretic damping to 5% of critical.
- 5) Limit on reduction of ground motion with embedment.
- 6) Acceptance criteria for composite modal damping in SSI.
- 7) Requirements for alternate 1 and 2 procedures of SSI.

These items are briefly discussed next.

A fixed-base analysis is usually justified for the case in which the underlying foundation material is of the rock type. The provisions of the ASCE Standard 4-86 on this issue seem to be appropriate and it is recommended that they should be accepted by the SRP for fixed-base frequencies of 10cps or less. On the other hand, it is appropriate to maintain in the SRP acceptance criteria the justification of fixed-base analysis in terms of fixed-base and interaction frequencies. The latter approach is more sound and should be the primary acceptance criteria in the SRP.

In the public comments it has been unanimously suggested that the requirement for enveloping the results of different analysis methods which are imposed by alternate 1 procedures of SSI, should be deleted. This subject has been carefully examined during the last ten years and at this time it is very important that the enveloping requirement be deleted since it is no longer necessary. No loss of conservatism is implied by such deletion. In fact, it will allow the design process to focus on the more important sources of conservatism which are usually hidden behind the enveloping requirement.

Public comments suggested that some clarifications be given for the SRP acceptance criteria related to soil properties variations employed in the SSI analysis (Section 3.7.2). BNL and its consultants also recommend that this area needs to be improved. First of all, it should be spelled out what is meant by low shear strain soil properties. As such, the  $10^{-4}$  percent shear strain should be defined as the low shear strain for the purpose of SSI analysis. Second, the SRP should clarify that the soil shear modulus and the damping (hysteretic) used in the SSI analysis are not necessarily those corresponding to low strains. Specifically, it should be made clear that these values should be consistent with the strains obtained in the soil profile through the free-field analysis of the design earthquake. Finally, certain changes should be made in this section of the SRP so that the best estimate, lower and upper values for soil variations

cases be better defined especially in terms of soil shear strain. Specifically, the following clarifications are recommended:

- o The upper bound shear modulus at low strain can be taken as twice the best-estimate value while the lower bound shear modulus can be defined as one-half this value, provided that this range of variability suitably encompasses the scatter typically found in the site investigation program. The average shear modulus degradation ( $G/G_{max}$  vs effective shear strain) and hysteretic damping ratio ( $D$  vs effective shear strain) curves, as defined in ASCE Standard 4-86 can be determined from the laboratory testing program, together with typical data available for similar soil. These curves can then be used in the iterative pseudo-linear analyses to determine shear moduli and hysteretic damping ratios compatible with the effective shear strains computed in the free-field for the input seismic motions for all soil layers for each of the three cases of interest. These properties can then be used directly in the SSI computational model.
- o The lower bound shear moduli should not be less than the moduli required for an acceptable foundation design, that is, lead to static settlements much greater than considered acceptable for normal foundation design. Secondly, the upper bound shear moduli should not be less than the best estimate shear moduli defined at low strain ( $G_{max}$  defined at  $10^{-4}$  percent effective shear strain) for all soils.

Public comments suggested that the requirement of 5% maximum hysteretic soil damping is too low and it should be raised to 15% which was also recommended in NUREG/CR-1161. BNL and its consultants concur with this recommendation since such arbitrary limit on soil damping is not consistent with experience from soil data. Furthermore, the SRP should also provide a definition of the hysteretic damping since different definitions currently exist in the SSI literature. The ASCE Standard 4-86 gives a clear definition of the hysteretic soil damping and SRP should refer to it.

The subject of reduction of motion with embedment received considerable attention by the public comments. The positions taken ranged from those questioning the advisability of adopting a limit on the reduction to those suggesting that the SRP should adopt the ASCE Standard 4-86 provisions on this subject. It is realized that this issue is particularly difficult and cannot be completely resolved at this time. A sufficiently rational approach for establishing acceptance criteria for the reduction of motion with depth is described below:

- o Reduction of the translational components of the ground motion with embedment should be permitted in SSI analyses provided that the relevant rotational components are accounted for. This is supported by physical considerations of the problem as well as by recorded data.
- o At this time, it is appropriate to impose a limit on the reduction of the ground motion with embedment. This will guard against the uncertainties associated with the spatial variation of seismic motion.
- o The reduction should refer to the difference between the surface translational motion and the corresponding motion in the free-field at the foundation level. This form of reduction has primarily two advantages: a) the reduction can be conveniently applied to both the direct as well as the substructure method of SSI analysis and b) the reduction can be directly measured with field data.
- o The amount of reduction should be reasonably taken in the range of 30-40%, with the 30% limit being considered as very conservative.

- o The reduction should refer to the envelope (best estimate, lower bound and upper bound cases) of the free-field spectra at the foundation level. This will allow the analyst to meet the reduction criteria by enveloping the results of the three soil property variation cases.

In view of the public comments, BNL and its consultants recommend that the SRP should place a limit on the composite modal damping used in SSI analyses based on modal superposition. This limit should be reasonably set to 20%. Finally, they also recommend that the current distinction of alternate 1 and 2 procedures of SSI analysis should be deleted from Section 3.7.2 of the proposed SRP Revision 2. In summary, the following are recommended by BNL and its consultants with respect to soil-structure interaction requirements:

- o It is recommended that the definition of rock-like materials per ASCE Standard 4-86 be adopted in the SRP.
- o It is recommended that the ASCE Standard 4-86 provision for fixed-base assumption be accepted in the SRP for fixed-base frequencies of 10 cps or less.
- o It is recommended that the enveloping requirement of results from different SSI methods be deleted from the SRP.
- o It is recommended that the following clarifications/criteria be given in the SRP with regard to soil property variations:
  - o The shear modulus and the soil damping of hysteretic type used in the SSI analysis should be compatible with the effective shear strains (65% of corresponding peak values) associated with the free-field analysis of the design ground motion.
  - o The low strain best estimate shear modulus should be defined at  $10^{-4}$  percent shear strain. The lower and upper bound shear moduli at low strain should be defined as half and twice this value respectively.
  - o The lower bound shear moduli should not be less than those required for an acceptable foundation design.
  - o The upper bound shear moduli should not drop at any shear strain below the value of the best estimate at low strain.
- o It is recommended that the current 5% limit on soil damping of hysteretic type be changed to 15%. Furthermore, the ASCE Standard 4-86 definition of hysteretic damping or other equivalent be specified in the SRP.
- o The translational components of the free-field motion at the foundation level should not be less than 60% of the corresponding surface motion. This provision should be:
  - a) allowed only when the associated rotational components are accounted for; and
  - b) applied in terms of the envelope of the best estimate, lower and upper bound soil property variation cases.
- o It is recommended that when modal superposition is used in the SSI analysis, the modal damping be limited to 20%. If the composite modal damping is higher than 20%, then acceptable methods should be:

- a) time domain analysis based on solution of complex eigenvalue problem;
  - b) frequency domain analysis; or
  - c) direct integration.
- o It is recommended that alternate 1 and 2 procedures of SSI analysis be deleted from SRP Section 3.7.2 and their design philosophy be associated with the specification of the vibratory ground motion (Section 2.5.2).

#### OTHER ISSUES

Additional issues which were included in the public comments are:

- 1) Requirements for modal combination.
- 2) Correlation of damping with stress levels.
- 3) Greater use of professional standards by the SRP.

The following recommendations were made by BNL and its consultants on these issues:

- o It is recommended that the algebraic sum method in modal combination be accepted in the SRP by appropriately revising Regulatory Guide 1.92 to that effect.
- o It is recommended that the provisions of the ASCE Standard 4-86 on correlation of damping with stress levels be an acceptable procedure in the SRP.
- o It is recommended that the SRP make greater use of available standards of professional societies and other organizations.

#### CONCLUSIONS

As a result of the review of the public comments, BNL and its consultants recommended major changes on the proposed SRP Revision 2 which primarily affect the particular SRP areas dealing with a) ground motion requirements and; b) soil-structure interaction requirements. These changes will advance the licensing process in view of the developments over the last two decades in the seismic area and on the other hand they will provide an improved accountability of conservatism in the seismic design review process.

#### REFERENCES

- Philippacopoulos, A.J. (1989), Recommendation of Resolution of Public Comments on USI A-40, "Seismic Design Criteria," NUREG/CR-5347.
- Coats, D.W. (1980), Recommended Revisions of Nuclear Regulatory Commission Seismic Design Criteria, NUREG/CR-1161.
- Shaukat, S.K., Chokshi, N.C., Anderson, N.R., (1988) Regulatory Analysis for USI A-40, "Seismic Design Criteria," NUREG-1233, Draft Report for Comment.
- Chokshi, N.C., Shaukat, S.K., Anderson, N.R., (1989), The Proposed Soil-Structure Interaction Licensing Criteria-Resolution of USI A-40, "Seismic Design Criteria," SMIRT 10.