EXPERIENCE WITH CURRENT USAEC CRITERIA FOR SEISMIC AND GEOLOGIC INVESTIGATION

By

P. C. Rizzo and S. D. Werner[I]

SYNOPSIS

This paper describes various aspects of the recent (1972) USAEC "Seismic and Geologic Siting Criteria for Nuclear Power Plants" so as to: (1) serve as a guideline for use of the criteria; and (2) stimulate thought regarding those aspects of the criteria that have required particularly careful consideration in past geologic and seismic investigations.

INTRODUCTION

In the site investigation and licensing phase for nuclear facilities both in Europe and the United States, our group has been following the guidelines set forth in the following two documents published by the United States Atomic Energy Commission (USAEC):

(1) "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," published February 1972 and October 1972.

(2) "Seismic and Geologic Siting Criteria for Nuclear Power Plants," published November 1971 in the Federal Register.

The latter document, which is a basis for a portion of the first document, is a result of the combined efforts of the USAEC, industry and consultants, and has been used by our group and others since 1968; therefore, considerable experience with its use has already been generated. It is the purpose of this paper to briefly outline the use of the USAEC criteria for specifying the seismic threat at the site and to comment on those areas of the criteria that have typically presented difficulties and required particular care in past nuclear plant investigations.

EXISTING PRACTICE FOR ESTABLISHING SAFE-SHUTDOWN EARTHQUAKE AT NUCLEAR PLANT SITES

As the name implies, the Safe-Shutdown Earthquake (SSE) is that level of earthquake ground motions for which operations of the nuclear plant can be shut down without danger to the surrounding area. This typically corresponds to the largest earthquake that can be conceived of ever occurring within 200 miles of the site. The step-by-step procedures used by our group and others to estimate the SSE according to USAEC requirements is as follows:(1)

A. Define the tectonics of the region, including faults and boundaries of seismo-tectonic provinces.

(I) Respectively, Vice President, Manager of Engineering and Project Engineer, E. D'Appolonia Consulting Engineers, Inc., Pittsburgh, Pennsylvania, USA.

B. Study the seismic history of the area and for those important earthquakes that have occurred within 200 miles of the site, assign intensity values and locate the epicenters.

C. Relate the epicenters to the faults or tectonic provinces in Step A.

D. Postulate a group of SSE'S by moving the epicenters to the location within the tectonic province or along the fault that is closest to the site.

E. Develop intensity versus distance attentuation curves for the region.

F. Using the results of Steps A and E, determine the SSE site Intensity.

G. Correlate the SSE site Intensity to the peak horizontal ground acceleration. The peak vertical ground acceleration is typically taken as some fraction (usually 2/3 or 3/4) of the peak horizontal ground acceleration.

H. Develop smoothed design response spectra based on the results of Step G.

I. Develop time histories of ground motion whose spectra envelope the design response spectra defined in Step H.

The above procedure is closely tied to a detailed geologic investigation of the area surrounding the site (see Step A above). In particular, the USAEC criteria requires the determination of the lithologic, stratigraphic, and structural geologic conditions and history of the surrounding area; the determination of geologic evidence of near surface faulting in the vicinity of the site; and the evaluation of whether or not these faults are active. An active fault is defined in the criteria as a fault that has exhibited movement at or near the ground surface at least once in the past 35,000 years or more than once in the past 500,000 years.

GENERAL DISCUSSION

The approach defined above has been successfully used for nuclear plant sites in the United States and around the world. From our experience, the main problem areas have been associated with:[2]

1. Definition of the seismo-tectonic provinces.
2. Variations in the correlations of intensity ratings over periods of time and from various regions around the world.
3. The determination of the peak horizontal ground acceleration from intensity data.
4. Age dating of faults and related tectonic events.

Usually, the technical disagreement between investigators and regulatory groups concerning seismo-tectonic provinces can be resolved in relatively short order, especially if there are no major problems with the regional tectonics. In the latter case, the SSE has been increased to help account for uncertainties in the tectonics. This is not entirely valid, especially if there is a question regarding fault activity or the age of the faults.

In order to show that a given fault in a relatively young area is in-active, various dating techniques are required. These may involve carbon dating of overlying segments, the use of sea level fluctuations, and the utilization of the stratigraphic displacements and changes in dip.[2] Since these methods are not totally reliable and often require a degree of imagination on the part of the investigator and regulatory groups, this aspect of the USAEC criteria has been a source of major difficulty.

Another source of difficulty is with the use of intensity data to estimate peak horizontal accelerations. The intensity of an earthquake is a measure of its effects on structures, people, etc., and as such, it is dependent on the quality of construction, the temperament of the individuals interviewed, and the population density of the region. As a result we have found that intensity estimates are highly variable not only between different regions of the world within a given time span, but also between different time spans. Furthermore, available correlations between intensity and acceleration are typically based on data obtained recently for the few regions of the world where strong motion acceleration measurements are available, such as California. Therefore, these correlations can not always be reliably applied to sites in regions whose construction practices, earthquake source mechanisms, geology and tectonics differ widely from the region in which the correlation was obtained.

PROPOSED ALTERNATE PROCEDURE

The smooth, straight line design response spectra developed according to the existing practice mentioned above are typically utilized as input to a mathematical model of the structure for purposes of determining floor response spectra and equipment design criteria. Alternately, an ensemble of artificial time history records can be developed that matches or envelopes one of the damped spectra provided. Floor response spectra and equipment design criteria are then obtained from time history analyses of the structural model.

The above time history and response spectrum procedures are both based on the smoothed design spectrum shapes developed from the seismicity and geologic study of the site. These spectrum shapes are derived from a limited number of existing strong motion records, generally measured on deep, firm alluvial deposits.[3] These strong motion spectra have been developed by highly qualified and experienced engineers and, especially in view of the lack of time history measurements presently available, represent an important and valuable basis from which to derive the SSE design spectra for the site. However, since nuclear plants may be constructed on sites quite different from those at which the above strong motion records were obtained, the use of the strong motion spectra by themselves may not always provide an adequate representation of the effects of local soil conditions on the strength and frequency content of the earthquake motions at the nuclear plant site.

In view of this, an alternate approach for developing site dependent earthquake motions should be considered. This approach would utilize a linear or nonlinear multi-degree of freedom filter to represent the stiffness and damping characteristics of the soil layers at the nuclear power plant site. Input motions to this filter would consist of an ensemble of real earthquake records, artificial records, or band-limited white noise whose strength, duration, and frequency content are judged to be consistent with the seismic and tectonic properties of the region. The computed ensemble of motion time histories at the surface could then be used directly as input into the structural analysis. In addition, response spectra could be computed from each of these motion time histories and smoothed to obtain the design spectra for the site.[4]

The above approach has the advantage of providing design spectra that are consistent with the seismicity, tectonics, and local soil conditions at the site; in this sense, the approach is consistent with many building codes around the world.[5] However, the approach also has a number of drawbacks. First, the relative scarcity of ground surface records and the lack of subsurface records for strong earthquakes make it difficult at this time to assess the validity of the input motions for this approach and the scaling rules for this motion. Secondly, there are uncertainties inherent in the selection of appropriate numerical parameters for representing the soil properties at the site. Nevertheless, with proper judgment exercised in the selection of soil parameters and subsurface input motions, we have found that this approach can serve to yield meaningful results, as evidenced by a number of prior successful applications of the method in analyzing earthquake motions at actual sites. Therefore, it is our opinion that seismic design criteria based on local soil conditions, as well as existing strong motion measurements, can be developed and utilized for nuclear power plants.

LIST OF REFERENCES

1. E. D'Appolonia Consulting Engineers, Inc., Geology, Seismicity, Soil Mechanics and Foundation Engineering, Preliminary Safety Analysis Report, Sections 2.4, 2.5, 2.6, Almaraz Nuclear Power Station, Units 1 and 2, Almaraz, Spain, Prepared for Gibbs & Hill, Inc., New York, New York, May 1972.

2. Rizzo, P. C., "Seismologic/Geologic Criteria and Considerations for Siting Surface and Underground Nuclear Plants," Talk presented at Specialist Meeting on Antiseismic Design of Nuclear Power Plants, Pisa, Italy, October 1972.

3. Newmark, N. M. and W. J. Hall, "Seismic Design Criteria for Nuclear Reactor Facilities," Proceedings, Fourth World Conference on Earthquake Engineering, Santiago, Chile, January 1969.

4. Werner, S. D., "A Study of Earthquake Ground Motions for Seismic Design," Agbabian-Jacobsen Associates Report No. 6914-925, Prepared for U. S. Atomic Energy Commission, Division of Reactor Standards, Washington, D. C., June 1970.

5. Whitman, R. V., "Effect of Soil Conditions Upon Damage to Structures; Caracas Earthquake of 29 July 1967," Report to Presidential Commission for Study of the Earthquake, Caracas, Venezuela, 1969.