Presentation at the 8th International Conference on "STRUCTURAL MECHANICS IN REACTOR TECHNOLOGY," Brussels, Belgium, 8/19-23/85

THIRD-PARTY REVIEW OF HISTORICAL DATA USE FOR EQUIPMENT SEISMIC SCREENING

by

The Senior Seismic Review and Advisory Panel (SSRAP)

Paul Ibanez, ANCO Engineers, Inc., Culver City, CA, USA
Robert Kennedy, Structural Mechanics Associates, Newport Beach, CA, USA
Anshel Schiff, Purdue University, Lafayette, IN, USA
Walter Von Riesemann, Sandia National Laboratories, Albuquerque, NM, USA
Loring Wyllie, H.J. Degenkolb Associates, San Francisco, CA, USA

Abstract

The five-member Senior Seismic Review and Advisory Panel (SSRAP) was retained in June 1983 to make an independent assessment of whether certain classes of equipment in operating nuclear power plants have demonstrated sufficient seismic ruggedness in past earthquakes so as to render an explicit seismic qualification unnecessary. The SSRAP served as an independent review of positions suggested by a utility group (Seismic Qualification Utility Group - SQUG) and under review by the USNRC. Within certain limitations, the SSRAP agreed with the use of this generic seismic ruggedness approach.

1. Introduction

This assessment was primarily based upon past earthquake performance data for eight classes of equipment provided to the SSRAP by SQUG through its consultant, EQE Incorporated. Detailed reviews were conducted by EQE on the performance of these eight classes of equipment at:

1. several conventional power plants (Valley Steam Plant, Burbank Power Plant, Glendale Power Plant, and Pasadena Power Plant) and the Sylmar Converter Station subjected to the 1971 San Fernando earthquake (magnitude 6.5);
2. the El Centro Steam Plant subjected to the 1979 Imperial Valley earthquake (magnitude 6.6); and
3. pumping stations and petrochemical facilities subjected to the 1983 Coalinga earthquake (magnitude 6.7).

After a detailed and careful review of the full range of the available experience data base, the SSRAP conclusions for these eight classes of equipment are

1. Equipment installed in nuclear power plants is generally similar to and at least as rugged as that installed in conventional power plants.
2. This equipment, when properly anchored, and with some reservations, has an inherent seismic ruggedness and a demonstrated capability to withstand significant seismic motion without structural damage.

3. For this equipment, functionality after the strong shaking has ended has also been demonstrated, but the absence of relay chatter during strong shaking has not been demonstrated.

Therefore, with several caveats and exclusions as discussed in subsequent sections, it is the SSRAP judgement that for excitations below certain seismic motion bounds (typically, about .3 g), it is unnecessary to perform explicit seismic qualification of existing equipment in these eight classes for operating nuclear power plants to demonstrate functionality after the strong shaking has ended.

The data base is insufficient to preclude the possibility of an inadvertent change of function (breaker trip, etc.) due to causes such as relay chatter. This does not mean that the SSRAP expects these inadvertent changes to occur. It simply means that their preclusion has not been demonstrated by the available data base. The data base does demonstrate that breakers can be properly reset, and the equipment functions properly after the earthquake.

The SSRAP is particularly concerned with equipment anchorage and feels that any attempt to justify equipment for acceptable seismic performance must ensure adequate engineered anchorage. There are numerous examples of equipment sliding or overturning in earthquake exposure due to lack of anchorage or inadequate anchorage.

2. Background

The Seismic Qualification Utility Group (SQUG) was formed in 1982. Currently, it has over 24 nuclear utility members. Concerned by the potentially large cost of response to the USNRC A-46 unresolved safety issues by standard seismic evaluation techniques, SQUG, assisted by their consultants, KMC and EQE Inc., proceeded to collect historical data on eight selected classes of equipment (Pilot Study). They presented their conclusions to the USNRC, which received them with interest and, understandably, many questions. The USNRC proceeded to evaluate the approach their conclusions represented along with several other alternative requalification approaches. In time, the use of historical data appeared to be one of the most useful methods.

Internal review by the USNRC and ongoing discussions with SQUG continued to expand the data base (evolved by EQE) for the new approach. By late 1982, the need arose for an independent third-party review by a panel of knowledgeable individuals with broad industry background (national laboratories, private consultants, test laboratories, academia, architectural firms, etc.). Hence, the Senior Seismic Review Advisory Panel (SSRAP) was formed (and constituted of five members—the authors).

While recognizing a number of caveats and exclusions to these conclusions (discussed in their report), it was the SSRAP's judgement that for excitations below certain seismic motion bounds (approximately .3-g free field), it is unnecessary to perform explicit seismic qualification of existing equipment in these eight classes for operating nuclear power plants to demonstrate functionality after strong shaking has ended. These conditions and the general approach have been presented many times to the technical community at a variety of conferences and meetings. Presentations have also been made to the Advisory Committee on Reactor Safeguards (ACRS) and the Electric Power Research

Institute (EPRI). The latter is beginning related efforts to use existing laboratory test data and to create effective techniques for anchorage review.

Based on efforts to date, it appears that the USNRC will soon approve the use of these data for generically establishing the seismic adequacy of certain classes of equipment. Undoubtedly, additional review and discussion by several groups will continue for some time. Efforts are also underway to extend the eight classes and the spectral acceleration levels.

3. Technical Basis and Issues

The earthquake data base was compiled by EQE primarily from the above-mentioned three historical earthquakes. In addition, limited reviews (largely looking for negative evidence) were performed for the following earthquakes:

- M 5.9 - 1973, Point Mugu, California
- M 5.1 - 1978, Santa Barbara, California
- M 8.4 - 1964, Alaska
- M 7.7 - 1952, Kern County, California
- M 7.4 - 1978, Miygai-Ken-Oki
- M 6.5 - 1976, Friuli
- M 6.2 - 1972, Managua

The eight classes of equipment included in the SQUG Pilot Program were:

- Motor Control Centers
- Low-Voltage (480-V) Switchgear
- Metal-Clad (2.4- to 4-kV) Switchgear
- Unit Substation Transformers
- Motor-Operated Valves
- Air-Operated Valves
- Horizontal Pumps
- Vertical Pumps

The eight classes of equipment were not judged to be equally capable. This is not to imply that they had unequal capacity or that the capacities quoted were, in fact, their ultimate capacity. Rather, the response spectra stated are the largest spectra that could be justified <u>on the basis of available historical data.</u> Efforts are being made to collect more data so as to increase the allowable spectra.

Typical allowed spectra, as suggested by SSRAP, are shown in Figure 1. These were based on the average (of two directions) horizontal ground, 5%-damped response spectra from actual ground motions divided by a factor of 1.5. (Types A, B, and C refer to different earthquakes and were applied to different equipment classes, depending on the available data base.) Judgement had to be used in smoothing the spectra and in extrapolating instrumental recording of ground motion to the data base plant locations.

It was also judged conservative (in most cases) to ignore the soil-structure interaction effects at the data base (conventional plants). Lastly, the SSRAP decided to address only the horizontal component since the vertical was present in appropriate amounts in the data base plants.

The 1.5 factor was included to account for amplification of ground motion (e.g., soil-structure interaction effect) at the nuclear plant. It was judged that below 40 ft above containment grade, less than a 1.5 amplificiation factor on the free-field motion would occur (for these classes of equipment). Hence, comparison of nuclear plant free-field spectra to the spectra of Figure 1 would be conservative (as they had already been divided by a factor of 1.5). The SSRAP felt that above 40 ft more significant amplification could occur and that properly calculated floor spectra must be compared to the spectra of Figure 1 multiplied by a factor of 1.5. The ability to compare to the free-field spectra below 40 ft is of great assistance to the utilities as this does not require the computation of floor spectra nor the use of floor spectra previously calculated by methods now considered overly conservative. Most equipment of concern lies below the 40-ft level.

Note that considerable discussion was required to define the limits to the various equipment classes and the reasonableness of generic conclusions. Class "membership" was subject to a number of caveats. These include limits on, for example, cut-out size in cabinets, mass-to-height ratios on valves, shaft lengths on vertical pumps, etc. The limits were specified so as to keep the class membership within a "space" defined by the data base. These conclusions were made only after research indicated that the variations one would expect from plant to plant and model year to model year were within the data base variations. This assured sufficient similarity between the data base equipment and the nuclear plant equipment. Judgement had to be exercised as to the sensitivity of seismic fragility levels to these variations and the "density" of data points in the data base. Tens to hundreds of data base points (pieces of equipment surviving the historical earthquake) were required to support this judgement.

In addition to the "membership" caveats, the SSRAP (and subsequently the USNRC) noted certain others. For example, the data base is insufficient to preclude the possibility of an inadvertent change of function (breaker trip, etc.) due to causes such as relay chatter. This does not mean that the SSRAP expected these inadvertent changes to be caused by design earthquake motion. It simply means that their preclusion has not been demonstrated by the available data base. The data base does demonstrate that breakers can be properly reset, and the equipment functions properly after the earthquake. The SSRAP was also particularly concerned with equipment anchorage, concluding that any attempt to justify equipment for acceptable seismic performance must ensure adequate engineered anchorage.

The nature of these caveats and their effect on the required reevaluation effort (from a small effort to none at all) is currently being discussed.

4. Conclusions

The word judgement has been used a number of times in this paper. Indeed, judgement is required in all engineering fields, and its further recognition in the nuclear industry is overdue. Judgement backed by generic, historical experience should allow us to raise the seismic level for which specific analysis or testing is required to a value higher than that previously used and possibly eliminate the need for most of the reevaluation for escalating criteria. Of course, this approach must be used with judgement and by knowledgeable engineers.

Numerous other generic examples exist of the applicability of this approach in the nuclear industry, including 1) evaluation of plastic capacity of piping systems during historical earthquakes and by high-level generic shake table testing and 2) generic shake table tests of cable trays and conduit raceways to demonstrate high damping and ductility. Much benefit can be gained from further study of these newer approaches to seismic qualification of plants subjected to escalated criteria.

Bibliography

1. "Use of Past Earthquake Experience Data to Show Seismic Ruggedness of Certain Classes of Equipment in Nuclear Power Plants," January 1985, by the Senior Seismic Review Advisory Panel.

2. CHANG, T., "Seismic Qualification of Equipment in Operating Nuclear Power Plants," draft NUREG 1030, 1984.

3. YANEV, P.I., and SWAN, S.W., "Pilot Program Report Summary: Program for the Development of an Alternative Approach to Seismic Equipment Qualification," prepared for Seismic Qualification Utilities Group by EQE Incorporated, San Francisco, CA, September 1982.

4. YANEV, P.I., and SWAN, S.W., "Volume I: Pilot Program Report, Program for the Development of an Alternative Approach to Seismic Equipment Qualification," prepared for Seismic Qualification Utilities Group by EQE Incorporated, San Francisco, CA, September 1982.

5. YANEV, P.I., and SWAN, S.W., "Volume II: Pilot Program Report Appendices, Program for the Development of an Alternative Approach to Seismic Equipment Qualification," prepared for Seismic Qualification Utilities Group by EQE Incorporated, San Francisco, CA, September 1982.

6. "Seismic Experience Data Base - Data Base Tables for Seven Types of Equipment," prepared for Seismic Qualification Utilities Group by EQE Incorporated, San Francisco, CA, November 1983, draft.

7. SMITH, P., and DONG, R., "Correlation of Seismic Experience Data in Non-Nuclear Facilities With Seismic Equipment Qualification in Nuclear Plants," NUREG CR-3017, Lawrence Livermore Laboratories, CA, 1983.

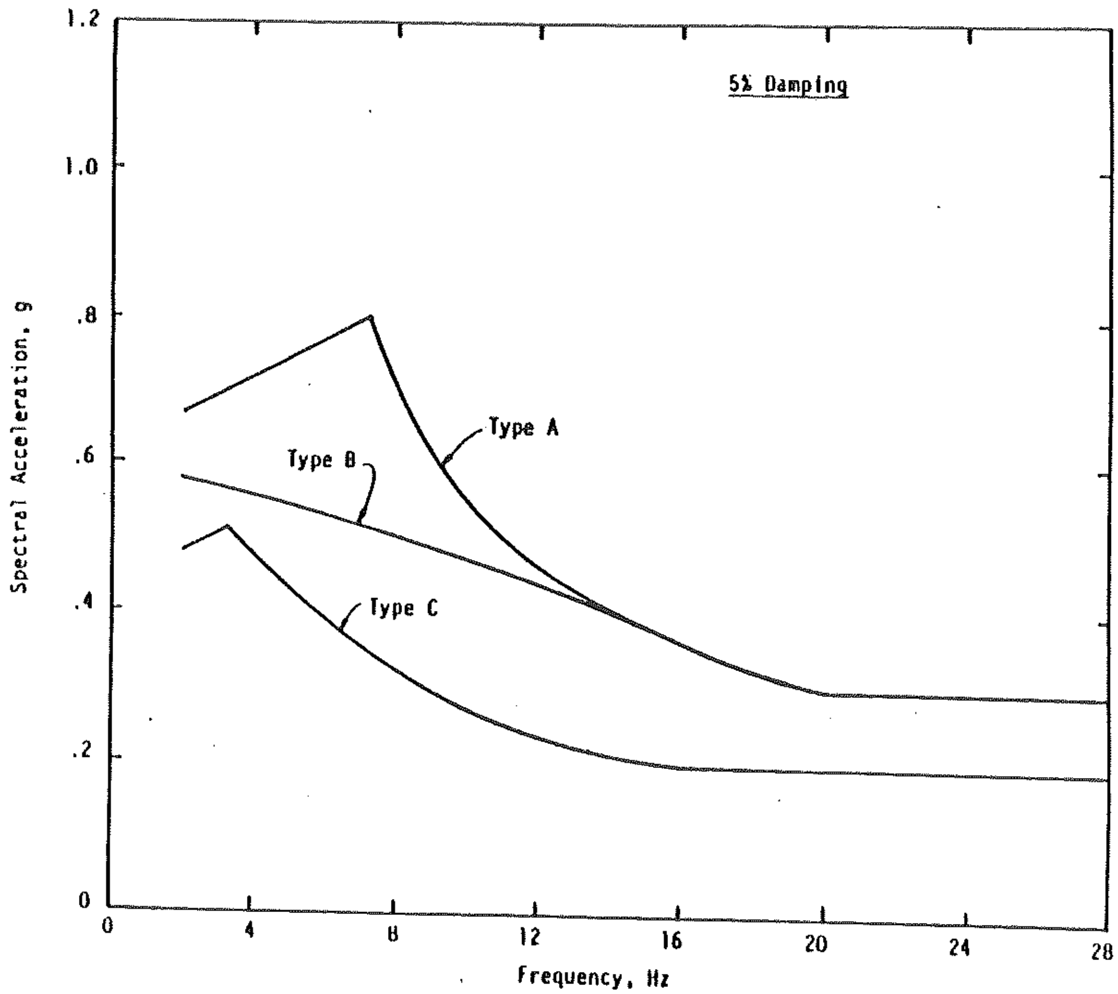

Figure 1. Smoothed Average Horizontal Ground Response Spectra