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APPLICABILITY OF BASE-ISOLATION R&D IN NON-REACTOR FACILITIES TO A NUCLEAR REACTOR PLANT

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ABSTRACT

Seismic isolation is gaining increased attention worldwide for use in a wide spectrum of critical facilities, ranging from hospitals and computing centers to nuclear power plants. While the fundamental principles and technology are applicable to all of these facilities, the degree of assurance that the actual behavior of the isolation systems is as specified varies with the nature of the facility involved. Obviously, the level of effort to provide such assurance for a nuclear power plant will be much greater than that required for, say, a critical computer facility.

The question, therefore, is to what extent can research and development (R&D) for non-nuclear use be used to provide technological data needed for seismic isolation of a nuclear power plant. This question, of course, is not unique to seismic isolation. Virtually every structural component, system, or piece of equipment used in nuclear power plants is also used in non-nuclear facilities. Experience shows that considerable effort is needed to adapt conventional technology into a nuclear power plant. Usually, more thorough analysis is required, material and fabrication quality-control requirements are more stringent as are controls on field installation. In addition, increased emphasis on maintainability and inservice inspection throughout the life of the plant is generally required to gain acceptance in nuclear power plant application.

It is expected that the increased efforts cited above are directly applicable to the use of seismic isolation in a nuclear power plant. In addition, the use of modern seismic isolation for any type of facility is relatively new and limited in scope, and there is a general lack of experience of seismically isolated structures to reasonably strong motion earthquakes. However, because it is an emerging technology, vigorous programs are in place worldwide to provide technical data ranging from measuring response of isolated buildings to actual earthquakes to tests and analysis of individual isolator elements.

This paper reviews the R&D programs ongoing for seismic isolation in non-nuclear facilities and related experience and makes a preliminary assessment of the extent to which such R&D and experience can be used for nuclear power plant application. Ways are suggested to improve the usefulness of such non-nuclear R&D in providing the high level of confidence required for the use of seismic isolation in a nuclear reactor plant.

INTRODUCTION AND PURPOSE

As the use of seismic isolation grows worldwide, it is becoming increasingly clear that considerable R&D is being carried out at a large number of facilities. It is equally clear that while the end use and related levels of risks of failure of the seismically isolated structures varies widely, the need for a common technology base for seismic isolation systems exists for virtually all applications. Therefore, it seems prudent to examine engineering data being generated for use of seismic isolation of such structures as hospitals, emergency centers, and computer facilities to see to what extent this information can be used to contribute to knowledge concerning the reliability and safety required for use of seismic isolation in a nuclear reactor facility.

The purpose of this paper is explore some of the questions associated with the use of non-nuclear seismic isolation data in the design and licensing of nuclear facilities. Some of the problems in adapting non-nuclear seismic isolation experience to nuclear plants will be identified, and suggestions will be made which might enhance the usefulness of such information.

TECHNICAL PROBLEMS ASSOCIATED WITH USING SEISMIC ISOLATION IN NUCLEAR REACTOR FACILITIES

Most, if not all, of the technical problems involved in using seismic isolation in nuclear facilities exist for seismic isolation application to other critical facilities such as hospitals and emergency centers. However, for obvious reasons, the level of understanding of isolation system behavior, the degree of performance assurance, and the assurance of safety margins is much greater in a nuclear reactor facility. The following listing presents some of the types of technical issues or problems that are of concern in the design and licensing of seismic isolation systems used in a nuclear reactor facility:

- lack of experience of the behavior of isolated structures in response to actual strong-motion earthquakes;
- need for large-scale to full-size tests of isolation system components;
- quality control in the fabrication and maintenance of isolation system components;
- required margins of safety for beyond-design-basis earthquakes;
- the need for vertical isolation;
- effects of long-period earthquake ground motions;
- consideration of the need for fail-safe designs;
- effects of traveling waves and inclined waves;
- long-term stability of isolator elements (aging effects);

- provision for differential movements between isolated and nonisolated structures on interconnecting systems (e.g., piping systems).

A large number of the issues listed above have already received considerable attention to support the use of seismic isolation for other critical facilities such as hospitals and emergency centers.

An excellent overview of worldwide experience and status of seismic isolation use in nuclear plants is given in Ref. 1. This overview includes a very good list of references which document the extent of analysis, testing, and building of seismic isolation systems which exist for both nuclear and non-nuclear applications. Reference 1 also includes a number of good papers on the use of seismic isolation for nuclear plants.

POTENTIAL USEFULNESS OF NON-NUCLEAR SEISMIC ISOLATION EXPERIENCE

In reviewing the types of issues given in the preceding section, two broad categories of concern are evident:

1. the response of seismically isolated structures (and their contents) to actual earthquake motions; and
2. the reliability and response characteristics of individual isolator bearing components (including data on materials used in these bearings).

Experience and R&D carried out for non-nuclear use of seismic isolation can be of benefit to nuclear applications. The extent of such usefulness depends on certain conditions. For example, information obtained on the response of isolated structures to actual earthquakes will generally be useful, since most isolated structures are reasonably instrumented to obtain such data. Actual response can be compared with predicted behavior and, if necessary, the original design can be more fully characterized with the latest analytical tools. On the other hand, ownership of the building may have changed and/or the required inspections and maintenance of the isolation bearings may not be as complete as planned or they may be inadequately documented. In addition, most of the isolation bearings in use today have been tested as a condition of their acceptance by local building codes.

The potential in the near future for large enough earthquakes to cause beyond-design-basis motions is rather low. Therefore, most of the data obtained for actual earthquakes will be within the design limits used for those structures. There are, however, increasing numbers of isolated structures in seismically active parts of the world, such as Japan, and eventually there will be recorded responses to large seismic events. In any event, it is almost a certainty that any significant field experience will be widely reported in the open literature. Every effort should be made to encourage the original designers and owners to keep good records of bearing conditions and response to seismic events.

For most important structures, the characterization and response of individual seismic isolator bearings has been determined by testing and is generally well documented. Because of its newness, local building authorities require a considerable amount of bearing testing as well as extensive structural analysis of the whole system. The literature on such tests is large and growing. One possible drawback to the use of these data is that the actual materials and precise fabrication processes for the bearing elements may be proprietary and not specifically available to the design community. This is partially offset, however, by the growing numbers of large- to full-size bearing tests completed and under way funded by governmental agencies, which has resulted in more information being available on actual response behavior of isolated bearings (as well as on the analysis of the isolated structures). There may be problems, however, both within a given country (between competing design organizations and/or bearing fabricators) and between countries on obtaining full information. There are some international cooperative programs under way, but more such arrangements are needed.

SUGGESTIONS TO ENHANCE USEFULNESS OF DATA FROM NON-NUCLEAR R&D

First, it must be recognized that a large amount of research data and experience is available now. For example, the USA has had a basic research effort in seismic isolation under way for over 20 yr, most of which was funded by the National Science Foundation (NSF). These data are generally available in open literature. Reference 2 is an excellent example of the scope of material available to designers and researchers concerned with seismic isolation. Reference 2 also contains a wide range of papers given at a 1986 seminar and workshop on seismic isolation and includes, among other topics, the following types of papers:

- current technology overviews;
- measurements/analysis of response of isolated structures to actual (modest) earthquakes;
- experience of use of seismic isolation in actual nuclear plants;
- aging effects on the elastomer materials;
- quality assurance/control of fabrication for high-damping rubber isolation bearings.

Second, national engineering societies have initiated new technical committees to study seismic isolation [e.g., the American Society of Civil Engineers (ASCE) in the United States] and have held technical sessions at national meetings (e.g., NSF-sponsored seminars/workshops and the ASME Pressure Vessel and Piping Conference). These activities are important, since they bring together technical people experienced in non-nuclear applications of seismic isolation to work together with engineers/researchers facing the demands anticipated for application of seismic isolation to nuclear reactor facilities. Such efforts should be continued and intensified, since personal interaction is perhaps one of the best ways to utilize the non-nuclear design, testing, and fabrication experience that exists.

Organizations considering the use of seismic isolation for a nuclear facility should examine literature available on existing non-nuclear facilities which are isolated to see if additional analysis, testing, instrumentation, or better documentation would enhance the usefulness of information obtained from those structures. In this regard, the NSF has been effective in helping to improve information exchange on seismic isolation use in the USA.

SUMMARY AND CONCLUSIONS

The use of seismic isolation for a nuclear reactor facility will require very high levels of assurance that the isolation system is adequately characterized, the system's performance is reliable, and safety margins exist that can be shown to be equivalent to those determined for conventionally designed nuclear facilities.

The use of isolation in a nuclear facility requires considerable additional research and development. A large amount of information exists, however, from R&D performed for non-nuclear application of seismic isolation and from the existence of new structures with isolation systems. These data can be used as a basis for the nuclear application R&D program. Measured performance of isolated structures during actual earthquakes can be of considerable use to the nuclear program, particularly if the original design and fabrication records are complete and inspection and maintenance procedures have been implemented on the actual isolation system.

Some non-nuclear data may lack adequate backup documentation, and some information may be proprietary. Since the use of modern seismic isolation is relatively new, however, a considerable amount of data is well documented and open-literature publications are growing rapidly.

While considerable use can be made of the non-nuclear applications experiences in seismic isolation, there is a need for more and better documented tests and analysis, large-scale dynamic testing of isolators, and shake table tests of model systems. Significant increases in international cooperative programs and exchange agreements are very much needed.

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