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# Activities of OECD/NEA in the Fields of Seismic Hazard Assessment & Earthquake Engineering

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## 1 ABSTRACT

The Organisation for Economic Cooperation and Development (OECD)/Nuclear Energy Agency (NEA) established the seismic group to address high-level seismic safety issues from an international perspective, to provide information to member countries, and to help them in assessing their nuclear facilities. The seismic group supports the Working Group on the Integrity and Ageing of Components and Structures established under the Committee on the Safety of Nuclear Installations (CSNI) dealing with safety-related research and development aspects. The seismic group makes recommendations with the objective to exchange information, to overcome discrepancies, and to reach international consensus on technical issues. The group operates through annual plenary meetings and technical workshops and by issuing state-of-the-art reports and topical opinion papers. Among other items, the recent and planned activities of the group include the following:

- updating a strategic plan for seismic group activities for the next 5 years,
- conducting a meeting of specialists on seismic hazard assessment in April, 2008 in Lyon, France, with planned publication of the proceedings,
- publishing a report summarizing the main findings and conclusions of a series of OECD/NEA workshops and extracting the seismic information most relevant to current nuclear practices,
- discussing the worldwide implications on nuclear facilities of the July 16, 2007 Niigata-ken Chuestu-oki earthquake and its effects at the Kashiwazaki-Kariwa Nuclear power Station,
- supporting a benchmark, SMART 2008, being conducted in Saclay, France, on seismic design and assessment analysis for multi-story reinforced concrete buildings subjected to torsion and nonlinear effects, and
- supporting the IAEA extra-budgetary program on seismic safety of existing NPP's.

In April, 2008, the group held a workshop on seismic hazards assessments. The objective of this workshop was to address recent findings and issues in Probabilistic Seismic Hazard Analysis (PSHA) raised during the Specialists Meeting on Seismic Probabilistic Safety Assessment of Nuclear Facilities, held in Jeju, Korea on 6-8 November 2006. (The Jeju workshop was sponsored by OECD.) The Lyon workshop addressed the issues of: a. management of epistemic and random uncertainties, b. the issues associated with PSHA results for areas of low-to-moderate seismicity and of the difficulties with conducting a PSHA in such an area, and c. comparison of PSHA results to available observations, especially for return periods where records are available. The workshop was attended by over 60 participants from 15 countries, and 26 papers were presented, including five invited lectures and six panel discussions.

Annually about 25 high-level experts and specialists from 15 countries, representing safety authorities, research organizations, electric utilities, and other international organizations (e.g., the International Atomic Energy Agency and the European Union) participate in seismic group activities. During this annual plenary session, the group defines its programme of work and then presents it to the CSNI for approval. As conditions warrant, the CSNI provides top-down direction. The seismic group is

recognized as a forum to exchange technical information. It has no budget of its own, and activities are completed solely on in-kind contributions of its delegates.

As its first task, the seismic group developed strategic recommendations to describe its activities and identified the following topics or issues for the group to address:

- seismic analysis and design of piping,
- engineering characterization of seismic input,
- ageing effects, particularly as it affects seismic design,
- validation of analysis methods, and
- re-evaluation of existing facilities and assessment of margins beyond the design basis.

The seismic group has refined these topics for specific actions: to promote greater synergy between engineers and seismologists in the areas of probabilistic, performance-based, and reliability-based approaches to the above strategies, development of a proposal on better understanding of soil-structure interactions, and improvement of knowledge management .

This paper will detail some of the recent activities and products of the seismic group.

## 2 INTRODUCTION

The seismic group was formed about 14 years ago when the existing working group on metal components was expanded to include two new areas of expertise, one on concrete components and structures and another on the seismic behaviour of components and structures. The three groups constituted what is now the Working Group on the Integrity and Ageing of Components and Structures (WGIAGE or IAGE) under the Committee on the Safety of Nuclear Installations (CSNI) within the Organisation for Economic Cooperation and Development (OECD)/ Nuclear Energy Agency (NEA). The CSNI/IAGE has as a general mandate to advance the current understanding of those aspects of nuclear safety relevant to ensuring the integrity of structures, systems, and components, to provide for guidance in choosing the optimal ways of dealing with challenges to the integrity of operating as well as new nuclear power plants, and to make use of an integrated approach to design, safety, and plant life management.

The specific elements of mandate of IAGE as articulated in the current operating plan for the CSNI are:

1. The Working Group shall constitute a forum to exchange views, information and experience on generic technical aspects of integrity and ageing of components and structures, and to review, as necessary, national and international programs concentrating on research, operational aspects and regulation
2. The Working Group shall stimulate, in relevant technical areas, new research, and recommend possible international co-operative projects.
3. The Working Group shall develop common technical positions on specific integrity issues for operating and new nuclear power plants, and shall identify areas where further work is needed.
4. The Working Group shall discuss the potential impact of ageing and other challenges to integrity on the safety, regulation, and operability of operating and new nuclear power plants.

The seismic group's responsibility under this broad mandate is to address the detrimental effects of vibratory ground motion on nuclear installations.

## 3 RECENT ACTIVITIES

Lyon PSHA Workshop

The Seismic group sponsored a workshop entitles, "Recent Findings and Developments in Probabilistic Seismic Hazard Analysis Methodologies and Applications," in Lyon, France on April 7 – 9 April 2008. It

was hosted by Electricité de France, in cooperation with the International Atomic Energy Agency. This was the third in a series of OECD/NEA meetings associated with seismic siting issues that began in Tokyo Japan in August 1999, followed by a second meeting in Jeju, Korea, in November 2006. The scope of both of the earlier meetings was broader, covering the whole range of methodologies that comprise Seismic Probabilistic Safety Assessment (SPSA) for Nuclear Facilities. This time, only the PSHA methodology, a subset of the larger group of SPSA methodologies, was covered.

The main objectives of the workshop were to discuss recent research and the regulatory, utility and industry issues associated with PSHA. The results of PSHA studies undertaken to date in regions with low to moderate seismicity exhibit large levels of uncertainty. Participants in the workshop discussed methods to improve knowledge and to reduce uncertainties associated with the paucity of strong-motion data needed to develop regional-specific attenuation relations. One specific objective was to compare the PSHA situation today with the situation at the time of the 2006 workshop in Korea, i.e., to discuss the findings and recommendations from 2006 that are relevant to PSHA, and to develop a set of findings and recommendations that would update those from that earlier workshop. Material presented in the 2006 workshop was used to support these discussions.

The deliverables and expected results from the Lyon workshop were as follows:-

- a description of state-of-the-art PSHA methodology including the management of epistemic and random uncertainties.
- a description of the issues associated with PSHA results and potential resulting difficulties, in particular differentiation between areas of low to moderate seismicity and areas of high seismicity.
- a comparison between PSHA studies conducted in different areas, including low to moderate and high seismicity areas.
- a verification of the consistency of PSHA results versus available observations, especially for return periods where records are available, in order to obtain an objective comparison and to improve the confidence in the results.
- a description of regulatory practice and the technical basis for safety standards in this area.

Information obtained as a result of this Workshop should provide the key to understanding and interpreting potential differences and discrepancies, from which methods to address them can be proposed.

The principal findings of the Lyon workshop are:

1. PSHA is now an established methodology that can provide great benefits when used properly.
2. A PSHA should be as realistic as feasible, and it should try to include consistency checks against available data.
3. It does not seem feasible to “validate” any PSHA study that examines earthquakes with frequencies much beyond the historical record. Using rigorous Quality Assurance procedures for all aspects of any PSHA is always important.
4. It is a healthy development that some nuclear regulatory agencies are moving ahead to use PSHA in their decisions. This development will surely lead to broader use and acceptance of PSHA worldwide.
5. The workshop participants emphasized the importance of providing feedback to all experts involved in any PSHA study about the ramifications of their expert input for the final results.
6. The application of Bayes’ classic theorem on updating prior information with newer information is not fully mature enough for routine use in PSHA without special care.

7. It was recognized that the practitioners of deterministic seismic hazard assessments (DSHA) studies are generally cognizant of the underlying uncertainties, and try to account for them pragmatically in the analysis.

8. The workshop participants discussed the important benefits that arise from involving the sponsoring organisation for any PSHA in technical discussions at the beginning of the study and during its execution, rather than waiting until the end.

9. One of the major potential uses of a PSHA study is to support technical decision-making at the design stage for a specific facility. It does not now make sense (and perhaps it never will) either to allow routine use by practicing design engineers of probabilistic methods in design itself or to incorporate such methods as mandatory requirements in the industry-wide codes that these designers use. However, there are obvious advantages to using insights developed in either a site-specific or a regional PSHA to inform how a design is undertaken, or to inform how a given engineering design code is formulated.

The Workshop participants developed the following recommendations from the above set of findings.

1. PSHAs are usually large complex studies that can be very complicated and expensive at SSHAC Levels 3 and 4 and therefore great care is needed in their execution.

2. A "procedures guide" that would provide more detailed guidance than the guidance now available in the SSHAC report itself is needed. Funding agencies should consider supporting the development of such a guide as high priority.

3. Guidance on how to develop robust quantitative and realistic descriptions of uncertainties should be a major part of any broader PSHA "procedures guide".

4. There needs to be continuing emphasis on reducing uncertainties. This will require both research to provide guidance, and the use of care whenever a PSHA study is undertaken.

5. Guidance on consistency checks should also be a major part of any broader PSHA "procedures guide."

6. Regulatory agencies in other countries should make an explicit effort to follow closely the activities in those few countries that are moving more rapidly toward using PSHA explicitly. These agencies should try to be active rather than only passive observers, so that the full regulatory benefits of PSHA can be realized worldwide, while avoiding the possible pitfalls of implementing PSHA in regulation inappropriately.

7. It is recommended that every PSHA study take care to provide adequate feedback to the experts who are involved. This helps to assure that misunderstandings of the expert input by the study team will not distort the study's results.

8. Using Bayesian updating methods can be of important value, but further work (both research work and applications) in this area is to be encouraged.

9. The incorporation of uncertainties explicitly into DSHA studies is a way to enhance them. This can provide benefits that are not easily obtained from the more usual use of sensitivity studies in DSHA.

10. Because every PSHA study involves large uncertainties in its results, it is recommended that each study begin with technical discussions with the sponsoring organization, and that such discussions continue during study execution.

11. The results of any PSHA, like the results of any other analysis dealing with nuclear plant risk, need to be communicated to the public in a way that faithfully communicates what was done, what was learned, and what it means.

12. Among the subjects within the scope of this workshop was the issue of the comparisons between PSHA studies performed in regions of high seismicity and other studies performed in regions of moderate or low seismicity. This was also an explicit recommendation of the earlier workshop in Jeju, Korea, in 2006. However, only one paper was submitted to the Lyon workshop on this topic, and very little discussion took place about such comparisons. It is recommended that this subject be given special attention at a future NEA workshop.

13. One of the major potential uses of a PSHA study is to support technical decisions at the design stage for a specific facility, but the infrastructure supporting its use in this manner is not mature enough currently without careful use. It is recommended that this area be considered as the subject of a future workshop.

## Current Activities

### SMART-2008 Benchmark

The seismic group is sponsoring and has recommended that its member countries participate in a blind benchmark competition of a model three-story reinforced concrete (RC) structure organized by Commissariat a' l Energie Atomique (CEA) and Electricite de France (EDF). Because three-dimensional (torsion) effects and nonlinear response are a concern in the field of earthquake engineering research and building regulation, CEA and EDF have organized and supported this benchmark competition. A three-story RC structure at ¼ scale was built and placed on the AZALEE shake table at the CEA laboratory in Saclay, France. The aim of the proposed benchmark is to compare and validate various approaches used by the international participants to model the dynamic response analysis techniques for RC structures subjected to simulated earthquakes and exhibiting both three-dimensional (torsion) and nonlinear behaviour. This analysis includes evaluation of loads induced by internal equipment, quantification of margins in design methodologies, and conducting realistic methods to quantify variability to produce fragility data.

The blind benchmark competition has the following two objectives:

- assess design methods for structural dynamic response analysis and floor response evaluation
- compare best-estimate methods for structural dynamic response analysis and floor response evaluation including various practices, depending on participants' experiences:
    - linear equivalent approaches
    - nonlinear approaches

CEA and EDF envisioned a two-phase program with the first phase being associated with pre-test activities, such as:

- design and construction of the ¼ scale model,
- dissemination of the model parameters/specification,
- participant analysis of model and prediction of its behaviour under test conditions, and
- delivery of blind predictions to CEA and EDF.

Phase two would encompass:

- actual model testing and recording of the test data,
- comparison of the blind predictions to the test data,
- comparison of the blind prediction by individual analysis technique, and
- development of lessons learned.

Phase one has been completed and initial testing of the model to a simulated 0.2 g acceleration on the Saclay shake table, AZALEE, occurred in July, 2008, and the participants' predictive analyses are under review.

### Strategic Plan

The current strategic plan of the seismic group's activities covers 2006 through 2010 and begins with a review of the previous plans adopted following the subgroup's organizational meeting in 1996. At that meeting, the organisers outlined the following five areas for action:

- piping analysis and design,
- engineering characterisation of seismic input,
- ageing effects and the seismic behaviour of structures and components,

- validation of analysis methods, and
- re-evaluation of existing nuclear facilities and assessment of beyond design basis.

The group has been able to work on specific products for four of the five areas and is addressing the fifth of the previous plan. Under the current strategic plan, the subgroup has addressed the following topics:

- The group, in conjunction with a group from IAEA, is collecting a database of nuclear facilities that have experienced an earthquake; the group is considering the analysis that should be applied to the database rather than simply making the data available. The subgroup is also examining the potential for using the data to develop or propose a better indicator of damage than peak ground acceleration.
- Soil-structure interactions for the new and advanced reactors are an area for activity, including consideration of new fully embedded structures.
- The role of performance-based or reliability-based approaches to the use of probabilistic techniques in regulation and regulatory guidance is a definite area in need of more complete characterization. The issues raised during the Jeju workshop on seismic probabilistic risk assessment mentioned earlier in this paper are topics for further research and discussion.

At the 2009 annual meeting of IAGE, the seismic group discussed its accomplishments under the current strategic plan and initiated preparations for the strategic plan to cover 2010 through 2015. Three items included:

- soil-structure interactions related activities, such as a workshop or a state-of-the report,
- analysis of the earthquake experience data base,
- participation of Member States in the SMART-2008 and K-KNPS benchmarks, and
- toward the end of the plan timeframe, a re-examination of the experiences with PSHA in areas of low-to-moderate seismicity.

Collaborative Activities

The International Atomic Energy Agency (IAEA) initiated a seismic program entitled, “Extra-Budgetary Project on Seismic Safety of Existing Nuclear Power Plants” in 2007. Several facets of the project involve interactions with the Japanese nuclear regulator and the owner-utility of the Kashiwazaki-Kariwa Nuclear Power Station (K-KNPS), which experienced a beyond-design earthquake on July 17, 2007. Two international benchmark studies have been initiated using actual data obtained from the earthquake and the properties of K-KNPS. One benchmark is on piping and other equipment response; another is on structural and soil-structure interaction response to the earthquake. IAGE developed an arrangement with IAEA for OECD Member States to participate in this important series of benchmarks.

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