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Safety Significance of Near Field Earthquakes
An IAEA Co-ordinated Research Program

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ABSTRACT

The purpose of this paper is to introduce a Co-ordinated Research Program (CRP) of the International Atomic energy Agency (IAEA). The title of the CRP is: Safety Significance of Near Field Earthquakes (NFE). The rationale for such a CRP is the well-known technical finding that the usual engineering practices in seismic design of Nuclear Facilities result in a poor estimate of safety implications of near field earthquakes. This is clearly illustrated by experimental results (CAMUS experiment) that will be used in the frame of this CRP in order to conduct a benchmark on the damaging capacities of near field versus far field seismic inputs on a typical shear wall structure. It is expected that this research will result in a proposal for an evolution of the relevant engineering practices. 17 IAEA Member States are involved in this CRP, which is funded both by the IAEA and the European Union.

KEY WORDS: IAEA, nuclear safety, earthquake, near field, vulnerability, damage indicators, displacement-based approach, research program, benchmark, CAMUS experiment.

INTRODUCTION

Technical Background

It is a well-known technical finding that the usual engineering practices in seismic design of Nuclear Facilities result in a poor estimate of safety implications of near field earthquakes. In some cases (small or medium magnitudes) the effects are unduly over-estimated while in other cases (large magnitudes) they are dangerously under-estimated. This issue is much more critical for existing nuclear facilities than for new ones.

Recent developments in earthquake engineering, basically developed for non-nuclear facilities, provide tools to cope with this difficulty. The CRP aims to determine to what extent these developments can also be recommended for the assessment of nuclear facilities subjected to near field earthquake inputs. For this purpose the CRP is organized so that Member States share the most recent developments in earthquake engineering and that the basis of an appropriate engineering practice be established and described in an IAEA document.

Inputs for the CRP

The IAEA Member States (MS) were requested to inform the Agency about their available input suitable for the envisaged CRP. The answers were presented and discussed in December 2001, at a technical meeting held in Vienna, where 15 MS were represented. The delegates concurred on the selection of the following inputs:

- Results of experiments on shaking table, with inputs representative of NFE, provided by France, [1] & [2]
- Database of NFE records provided by Japan, [3]
- Assessment of the relevance of displacement based methods, provided by USA. [4]

Outlines of the CRP

In the wake of the above-mentioned background, the purpose of the CRP is to focus on the assessment of the vulnerability of structures. Due to the available experimental input and to the specific rules related to site selection of NPPs, the considered NFE are related to low-moderate magnitude earthquakes. The specific objective of this CRP is to adapt for nuclear engineering and to use for the evaluation of the seismic vulnerability of nuclear facilities the best available engineering practices on near field earthquakes. In view of this objective, the purpose of the CRP is to:

- Carry out a benchmark on NFE effects on a shear wall structure,
- Concur on the principles of an updated engineering practice.

BENCHMARK ON A SHEAR WALL STRUCTURE

The CAMUS experiment

The CAMUS experiment [1] consists of 2 similar shear walls, installed on a shaking table and subjected to horizontal seismic input motions. This is a mock-up at the scale 1/3 of typical shear walls. The total mass of the mock up is: 36 tons (5 floors x 6 tons). The stress in a wall under static load is: 1.60 MPa. The main characteristics of the walls are as follows: height: 5.10 m (5 storeys x 0.9 m); length 1.70 m; thickness: 0.06 m

Two types of input motions were used: the “Nice input” motion (artificial ground motion), representative of a far field motion, and the “San Francisco input” motion (natural ground motion) representative of a near field input. In the frame of the benchmark the outputs of the following 4 runs have to be interpreted:

Run1	Run2	Run3	Run4
Nice 0.24g	San Francisco 0.13g	San Francisco 1.11g	Nice 0.41g

Run 1 can be considered as a typical design input motion. Runs 1 and 2 can be regarded as rather “low level” inputs. Runs 3 and 4 are damaging level inputs. However, as an illustration of the above “background situation analysis”, the core of the issue to be clarified by the CRP is the following one:
According to the classical engineering approach (*), Run 3 was expected to be approximately 4 times more damaging (**) than Run 4. But this was not confirmed by the experiment (the damages induced by the two runs were comparable).

(*) description of the input motion by its response spectrum, modelling of the structure as an elastic body, modal analysis
(**) for instance, the displacement at the top can be regarded as an indicator of damage.

Interpretation of the experimental results
The participants will:

a) model the CAMUS mock-up and compute the response to the above mentioned input motions. The expected output will principally consist of:
   - displacements at the top of the walls,
   - bending moments and forces in the walls,
   - description of the damage in the walls (strains in R-bars, cracks, etc… according to the type of modelling used by each participant).
b) carry out an interpretation of the experiment as per the engineering practice:
   - traditional response spectrum approach,
   - innovative approaches including the displacement based approach,

and discuss and clear up the predictive performances of these methods.

Japanese NFE inputs

In a second step of the benchmark, the participants will carry out numerical simulations of responses to a set of seismic input motions (2 or 3 accelerograms, provided by Japan) representative of NFE and examine the outputs of engineering methods on these examples.

The reference [3] presents a list of 13 recent events in Japan for which near field records are available. From this database, Yoshio Kitada proposes a first screening of the candidate input motions from the following earthquakes: 1995 Hyogo-ken Nunbu (Kobe) earthquake (Mw 6.9), 1997 Kagoshima-ken earthquake (Mw 6.0) and 2000 Tottori-ken Seibu earthquake (Mw 6.6). presented in the hereunder table from [3]. A second screening resulted in the selection of Gashyo Dam and Shin-Kobe Substation records. At the moment this paper was written, the selection of the Japanese input motions was not yet finalized.

EXPECTED EVOLUTION OF ENGINEERING PRACTICE

It is quite clear for most of the researchers involved in the analysis of NFE effects that the poor predictability capacity of the current engineering practice is related to the frequency content of the NFE inputs: relatively high frequencies that lead to relatively high accelerations, associated to relatively small displacements.

Apart from the case of NFE, the respective roles played by accelerations and displacements in the classical earthquake engineering are questionable. In the last decade, several authors have proposed to replace the classical approach by a displacement-based approach. This topic was particularly developed at the 11th European Conference on Earthquake Engineering [5].

The relevance of these new-developed methods for the case of nuclear facilities is discussed in the reference [4]. In the frame of this CRP, the specific case of the NFE, which is not addressed in this document, will be discussed. The objective is to concur on the main features of an appropriate methodology to realistically account for the effects of NFE and their safety significance.

ORGANIZATION OF THE CRP

Participating Member States and Institutions

The CRP was launched at a meeting held in Istanbul, 14-16 October 2002. At that moment 21 institutions from 17 Member States (Armenia, Bulgaria, Canada, China, France, India, Italy, Japan, Korea, Pakistan, Portugal, Romania, Russia, Slovakia, Spain, Turkey and USA) were involved in the CRP. During the meeting, 2 extra institutions expressed their interest for joining the CRP: the UK HSE and the US NRC. In between, Finland expressed also its interest. Institutions and team leaders are listed in the appendix.

Funds and organizing committee

The CRP is funded by the IAEA and by the European Union that supports institutions from MS candidates to the EU accession. A memorandum of understanding was signed in this regard between the IAEA and the European Commission. Developed countries fund their respective contributions.

As well as the IAEA and the EU, France, Japan and USA, which have provided inputs to the CRP, are represented at the Organizing committee. There is also a representative of the participants and a representative of the OECD/Nuclear Energy Agency (NEA)[1]. (see the appendix)

Schedule

The CRP was approved in the Agency at spring 2002 and the contracts/agreements with the MS were finalized before the above-mentioned kick-off meeting (Istanbul, 14-16 October 2002). Each participant is deemed to provide the Agency with an interim progress report by 1st September 2003. The participants should share the final results of the benchmark at a Research Committee Meeting, to be held at spring 2004. The conclusions in terms of engineering practices are expected to be drawn in 2004 and to be presented in an IAEA Technical Document.

Networking

As already mentioned, the European Union is deeply involved in this project. Other organizations are also involved in the R&D on N.F.E. Contacts will be established or maintained for the delivery of the CRP:

- The cases of small magnitude near field earthquakes were identified in a 1997 OECD/NEA report (NEA/CSNI/R(96)11) as “the most significant issue” in the field of engineering characterization of seismic input motion. The IAEA activities in earthquake engineering are strongly co-ordinated with the NEA activities. The IAEA participates in the NEA working group and workshops dedicated to these questions, particularly in periodic workshops on “exchanges between seismologists and engineers”. The agenda and the venue of the last workshop were co-ordinated with the kick-off meeting of the CRP.
- A NATO project “Characterization of N.F.E. seismic motion for earthquake design” is currently running. This project and the proposed CRP are complementary to the extent the CRP proposes to address the engineering approach of the design against N.F.E. input motions, not the characterization of these input motions.

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[1] The IAEA and the NEA strongly co-ordinate their activities in the field of earthquake engineering.

APPENDIX: PARTICIPANTS AND ORGANIZING COMMITTEE

Member State	*Institute*	*Team leader or representative*
Participants		
Armenia	ANRA	Mr. Paruyr Zadoyan
Bulgaria	BAS	Mr. Marin Kostov
Canada	AECL	Mr. Medhat Elgohary
China	BINE	Mr. Wei Liu
France	CEA	Mr. Pierre Sollogoub / Mr Christophe Pédron
France	INSA Lyon	Mr. Pierre-Alain Nazé
France	IRSN	Mr. Nebojsa Orbovic
India	AERB	Mr. Prabir Basu
Italy	Polyt. Di Milano	Mrs Gabriella Mulas / Mr. Luca Martinelli
Japan	NUPEC	Mr. Yoshio Kitada
Korea	KOPEC	Mr. Yong Il Lee
Korea	KINS	Mr. Chang-Hun Huyn
Pakistan	PAEC	Mr. Hamid Mahmoud
Portugal	University Porto	Mr Rui Faria
Romania	Univ. Bucharest	Mr. Ovidiu Coman
Russia	CKTI vibroseism	Mr. Victor Kostarev
Slovakia	SAS	Mrs. Emilia Juhasova
Spain	IDOM	Mr. Francisco Beltran
Turkey	TAEA	Mr. Ayhan Altinyollar
Turkey	METU	Mr. Polat Gülkan / Mr. Ahmet Yakut
USA	BNL	Mr. Nikolaos Simos
Organizing Committee		
France	CEA	Mr. Pierre Sollogoub
Japan	NUPEC	Mr. Yoshio Kitada
USA	NRC	Mr. Andrew Murphy
Turkey	METU	Mr. Polat Gülkan
IAEA		Mr. Pierre Labbé
European Union		Mr. Vito Renda
OECD/NEA		Mr. Eric Mathet