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NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

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TOPICAL OPINION PAPER

Apparent Discrepancies Between Nuclear and Conventional Seismic Standards

English - Or. English

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996), Korea (12th December 1996) and the Slovak Republic (14th December 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of 27 OECD Member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers. It was set up in 1973 to develop and co-ordinate the activities of the Nuclear Energy Agency concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety amongst the OECD Member countries.

CSNI constitutes a forum for the exchange of technical information and for collaboration between organisations which can contribute, from their respective backgrounds in research, development, engineering or regulation, to these activities and to the definition of its programme of work. It also reviews the state of knowledge on selected topics of nuclear safety technology and safety assessment, including operating experience. It initiates and conducts programmes identified by these reviews and assessments in order to overcome discrepancies, develop improvements and reach international consensus in different projects and International Standard Problems, and assists in the feedback of the results to participating organisations. Full use is also made of traditional methods of co-operation, such as information exchanges, establishment of working groups and organisation of conferences and specialist meeting.

The greater part of CSNI's current programme of work is concerned with safety technology of water reactors. The principal areas covered are operating experience and the human factor, reactor coolant system behaviour, various aspects of reactor component integrity, the phenomenology of radioactive releases in reactor accidents and their confinement, containment performance, risk assessment and severe accidents. The Committee also studies the safety of the fuel cycle, conducts periodic surveys of reactor safety research programmes and operates an international mechanism for exchanging reports on nuclear power plant incidents.

In implementing its programme, CSNI establishes co-operative mechanisms with NEA's Committee on Nuclear Regulatory Activities (CNRA), responsible for the activities of the Agency concerning the regulation, licensing and inspection of nuclear installations with regard to safety. It also co-operates with NEA's Committee on Radiation Protection and Public Health and NEA's Radioactive Waste Management Committee on matters of common interest.

FOREWORD

The CSNI Integrity and Aging (IAGE) Working Group deals with the integrity of structures and components, and has three sub-groups, dealing with the integrity of metal structures and components, the aging of concrete structures, and the seismic behaviour of structures. Ageing is also a primary consideration of the group.

The key features of nuclear and conventional codes, including trends for future codes, are summarised and the significant differences discussed. The options for addressing the discrepancies identified in the current implementation of the requirements for the seismic design and qualification of structures for nuclear use are considered and recommendations presented.

The complete list of CSNI reports, and the text of reports from 1993 on, is available on http://www.nea.fr/html/nsd/docs/

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EXECUTIVE SUMMARY

Summary

The differences between nuclear and conventional seismic standards are considered and their potential significance discussed.

1. The approach to the design of nuclear facilities is appropriately both more rigorous and conservative than that required by conventional seismic standards and codes.

2. For nuclear seismic design the requirements can be presented as assessment principles, e.g., NII SAPs or a safety guide e.g. IAEA; Seismic Design and Qualification for Nuclear Power Plants. Selection and use of appropriate codes and standards is to be justified in accordance with the seismic categorisation. As such, the codes, standards, and methods adopted to demonstrate seismic qualification are at the discretion of the designers, reviewers and assessors.

3. The adoption of novel methods or designs are required to be supported by appropriate research and development with the ability to cite a precedent within the industry being a powerful endorsement. The method adopted must reliably predict the seismic response of the item to be qualified, including the seismic response of attached or supported Structures, Systems and Components. (SSC's)

4. The traditional method adopted for seismic qualification by analysis has been based on linear elastic analyses. This is justified on the basis that the response is reliably predicted and realistic, provided that the elements remain elastic. The acceptance criteria are set accordingly, irrespective of the actual performance objectives established by the hazard assessment and safety functional requirements. A significant benefit of this approach is a high confidence in the calculation of secondary responses for (SSC's) supported by the civil engineering structures.

5. In contrast the benefit of ductile behaviour of conventional structures within the design envelope has long been recognised and used as the basis to justify significant reductions in the seismic demand. The reductions permitted are based on the generic structural type and the compliance with seismic detailing provisions intended to ensure ductile behaviour by full or partial implementation of the capacity design principles.

6. Provided the acceptance criteria are met, the SAPs do not preclude and the IAEA safety guide specifically permits non linear behaviour within the design envelope for category 1 items. This is confirmed by specific nuclear safety related codes such as ASCE 4-98 and ACI 349-97. To claim the benefit of ductility within the design basis envelope, the non linear behaviour of the item and the component elements must be explicitly justified. Increasing power and sophistication of computing hardware and software have enhanced the confidence in the modelling of material and geometric non linear behaviour and the use of complex non linear time history analyses to seismically qualify items and structures has a growing prevalence in the industry. However, the process can take considerable time.

7. Both the current nuclear practice and the current conventional seismic standards can be classified as "force based". Design to the conventional codes is founded primarily on one or two ultimate limit states and is often combined with a check on displacement to ensure that damage is limited and that second order P-Delta effects are not significant. It is noted that the version of EC 8 that is to be adopted in the near future may include an annex on displacement based approaches.

8. The displacement based approach, also referred to as performance based engineering (PBE), has been developed as a powerful tool in the evaluation and seismic retrofit of existing structures. This approach could be equally valid to the design of new structures and can be used to represent elastic or non linear behaviour although the full benefit will only be realised in the latter case. National guidelines for the seismic rehabilitation of buildings (FEMA 273 & 274, ATC 40) have already been produced. It is anticipated that PBE may form the basis of the next generation of seismic codes and standards. The ongoing debate among the opinion formers relates mainly to the type of the displacement based analysis.

9. PBE shares many common features with the nuclear ideals, namely:
   - Defining the performance objectives specific for a particular structure;
   - Ready evaluation of multiple limit states;
   - Seeking to predict real behaviour as closely as feasible by considering the combination of soil and foundation effects, cracking and stiffness and strength degradation etc. and permitting the tracking of the development of mechanisms;
   - Enhancing the understanding of the seismic response by the identification of redistribution between load paths and the identification of the potential and probable controlling mechanisms;
   - Enabling the provision of a consistent level of protection against reaching a specified limit state.

10. An initial evaluation of the relevance of displacement based methods to nuclear power plant structures has been undertaken by the U.S. Nuclear Regulatory Commission. They concluded that the approach has no advantages over force based methods for the design where the response is required to remain within the linear elastic range. They also identified advantages over the use of non linear time history analyses in the evaluation of seismic margin and the production of fragility curves. Their report recommends that additional studies would be required to establish the relevance to structures with both material and geometric non linearities, to define the scope of problems that could be reliably addressed. Further development of the coefficients appropriate for nuclear use would be required if the displacement based method of FEMA 273 is adopted.

11. The displacement based methods require explicit consideration of many previously implicit or hidden assumptions. They therefore may have the appearance of being more reliant on engineering judgement. Initially there may be a potential lack of SQEPs to handle major projects.

Recommendations

12. The reluctance of the nuclear industry to adopt the displacement based analysis and design methods is identified as a significant discrepancy between current nuclear practice and the conventional design methods that are available. The options available are:

1. Continue with present force based methods;
2. Change completely to PBE and displacement methods;
3. Wait for the nuclear industry to recognise the benefits and adopt appropriate use of displacement methods;
4. Encourage use of PBE and displacement based analysis and design where appropriate and support nuclear industry focussed research on methodologies.

13. Option one is not defensible in light of changes to modern standards and option two is considered unrealistic given the need for a transition between approaches. Option three imposes the additional burden of justifying a novel method on a limited number of initial projects and is likely to delay the introduction of the method and the potential benefits in the enhanced understanding of the seismic response. The ideal and recommended course of action is option four.

14. The development of guidelines on the appropriate use of PBE and displacement methods would encourage the adoption of the approach. Before guidelines could be developed and agreed, studies and research to assess the various displacement based analysis methods available and to demonstrate that the methodologies would be sufficiently robust to yield reliable outputs, particularly for SSC's would be required. The initiation of these studies would provide evidence of a change in approach by nuclear industries and that the change was being undertaken in a measured and thoughtful manner. The US NRC report is a step in this direction. The US approach of determining the performance criteria based on the categorisation of the facility, rather than the safety function of the particular structure, appears to be an additional obstacle that is not present in the European context.

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APPARENT DISCREPANCIES BETWEEN NUCLEAR AND CONVENTIONAL SEISMIC STANDARDS

1. INTRODUCTION

The key features of nuclear and conventional codes, including trends for future codes, are summarised and the significant differences discussed. The options for addressing the discrepancies identified in the current implementation of the requirements for the seismic design and qualification of structures for nuclear use are considered and recommendations presented.

2. SCOPE

The scope of this paper is limited to the seismic design and qualification of new civil structures for nuclear use. European nuclear design practice can be represented by a number of references, including, for example, NII SAPs (Reference 1) and the IAEA Safety Guide "Seismic Design and Qualification of Nuclear Power Plants" (Reference 2).

3. GENERAL DESIGN STRATEGY

The classification, seismic loading definition, performance criteria and seismic design philosophy are considered.

3.1 Nuclear practice

The key current requirements for the seismic design and qualification of nuclear plants, are summarised as follows:

- Seismic classification of nuclear structures is based on the safety function;
- Seismic loading definition for nuclear design is based on the risk identified by hazard analysis;
- Specific performance criteria are defined for each individual nuclear structure as part of the development of the safety case. These are often not strength based;
- Allowance for ductility is not included in the seismic loading definition for nuclear structures. Any reliance on non linear response/behaviour within the design envelope must be fully justified;
- Identification of potential and controlling mechanisms is required;
- ALARP requirement is applicable irrespective of performance criteria;
- Multiple limit states are considered for nuclear designs;
- Qualification methods adopt a force based analysis/design approach;
- Analysis of nuclear structures is more rigorous and sensitivity to possible variables is considered, including input motion;
- Justification/qualification is based on reliable predictions of the seismic response;
- Modern standards and codes are used for the assessment;
- Adopted codes and standards are to be justified;
- Novel designs and methods are to be suitably researched and justified.

Typical past practice has been to design nuclear structures based on an elastic response to seismic excitation, irrespective of the identified performance criteria. This has been justified on the basis of predictability, both of response and design of the civil structures and for the secondary response inputs to supported SSC's. It also reflects the reliability and capacity of the hardware and software that was readily available for analysis. The approach appears to be endorsed by the US NUREG provisions rather than the present European requirements.

3.2 Conventional standards

The current conventional standards are force based with the exception of the possible incorporation of an annex to Eurocode 8 (Reference 2) covering displacement based methods. The design strategies underlying the current conventional codes have the following characteristics:

- Life-safety or collapse prevention are the non-specified underlying performance criteria of the majority of conventional codes;
- Seismic demand is reduced assuming adequate ductility based on the generic structural type and compliance with the detailing rules prescribed for typical structural types;
- The detailing rules are based to a greater or lesser extent on capacity design procedures;
- Rules are prescribed to ensure that the simplified analysis methods are only applied to regular structural forms;
- A "black box" prescriptive approach is adopted with no requirement to understand or identify the potential and controlling mechanisms.

One or two limit states are generally considered with a check on displacements using factored results from elastic analyses to ensure adequate separation between adjacent structures and to check that second order P-delta effects are not significant. Typically, cracked concrete section properties are only required to be used when P-delta effects are expected to be significant.

3.3 Future conventional standards

Performance based engineering (PBE) using displacement based analysis methods is identified as the approach favoured by the opinion formers as the basis for the next generation of codes and standards (Reference 4). The PBE approach has been developed over the past decade for the seismic assessment and retrofit of existing structures. It is equally applicable to the design of new structures. The key features of the approach are as follows:

- Selection of performance requirements that are appropriate for the intended use;
- Increasing realism in the modelling of the behaviour of structural systems, encouraging modelling of subgrade, foundation and stiffness degradation and variation in damping with increasing demand;
- Use of displacement based analysis methods;
- Consideration of multiple limit states.

The current debate relates to the type of displacement based analysis that should be endorsed.

National handbooks produced by the US Federal Emergency Management Agency, FEMA 273/274 (References 5 and 6), give details of PBE as applicable for the assessment and retrofit of existing structures. These documents contain information relating to displacement limits for conventional structures and individual elements based on type, materials, and the adopted performance criteria. Other handbooks and papers give alternative displacement based analysis methods.

The potential benefits of the PBE, and the displacement methods in particular, are summarised below (Section 0).

3.4 Significant differences

Nuclear practice rightly adopts a more rigorous approach particularly with respect to the definition of the seismic loading, the performance criteria and the treatment of ductility/non linear behaviour.

However the nuclear designers, reviewers, regulators and operators do not appear to have recognised the similarities in the objectives or the full potential of the benefits available with the application of PBE approach and in particular, the displacement based analysis methods.

4. ANALYSIS

4.1 Nuclear practice

ASCE 4 (Reference 7) presents much of the US nuclear industry best practise, although it is noted that it is not endorsed by USNRC. This document specifically defines the degree of rigour required of force based analyses for the qualification of structures for nuclear use, e.g. SSI, sensitivity assessment etc. Non linear behaviour within the design envelope is not precluded.

The past preference has been for the qualification of safety related structures based on elastic analysis irrespective of identified performance criteria as noted above. The predictability is ensured by limiting the demands on elements to within the appropriate stress range.

Enhancements in computing power enable the representation of increasing realism in the modelling of the seismic response of structures using more sophisticated techniques and analyses. With due care, time history analyses can reliably represent material and geometric non linear behaviour under transient loading.

ASCE 4 permits a conservative interpretation of the simplified static equivalent method. IAEA, however, recommends that the application of simplified methods be limited to checking.

4.2 Conventional standards

Conventional standards are currently force based, with the exception of a possible annex to EC 8, and generally share the following characteristics:

- Correct modelling of relative stiffness is sufficient to reliably predict the distribution of demand. The use of gross section properties may therefore be justifiable;
- The static equivalent method, based on the assumption that the first mode is dominant, is widely used for regular structures;
- Elastic spectra are modified based on assumed ductility to produce the seismic design envelope;
- There are limited codified requirements for modal and time history analysis.

4.3 Future conventional standards

It is expected that future conventional standards will move towards displacement based analysis and design methods (Reference 4). This approach is based on the assessment of absolute displacements. It therefore requires a more realistic representation of behaviour of the full system including the influence of the foundation and the subgrade (SSI), combined with the realistic variation of stiffness and damping with increasing deformation.

Displacement based analysis methods have been evolving over the past decade. These have been driven mainly by the assessment of the seismic behaviour of existing structures and the development of realistic retrofit schemes. These methods are equally applicable to new structures. The current debate centres on the adoption of the various displacement based methods that are available. The potential benefits are summarised below, but it is recognised that not all of these benefits are easily realised:

- They are equally applicable for linear elastic and non linear behaviour. The advantages are primarily with the assessment of non linear behaviour;
- A number of the assumptions made in the current force based analysis and design procedures are assessed explicitly for each case. Currently these assessments may be based on engineering judgement;
- Redistribution of demand between load paths can be tracked;
- Multiple limit states are readily assessed;
- Potential and probable mechanisms can be identified;
- Rotational demands at individual hinge locations can be evaluated;
- Quick evaluation of alternative strategies is possible, i.e. assessing the effect of increasing or decreasing strength, stiffness or ductility individually or in combination;
- The margin of safety provided is readily demonstrated allowing adjustment to ensure a consistent level of protection against reaching a specified limit state.

Some difficulties with these new approaches revolve around the availability of suitably qualified and experienced engineers. A further difficulty lies in the calculation of reliable secondary responses which can be applied to SSC's within structures analysed and designed using displacement based approaches.

4.4 NRC study

The US Nuclear Regulatory Commission (NRC) have reported (Reference 8) on an assessment of the relevance of the FEMA 273 displacement based analysis method to nuclear plant structures. The results from the displacement analysis for two selected cases are compared with those from the traditional analysis approaches. The selected cases are presented as representative of a typical shear wall with material non linearity and a structure with combined non linear material and geometric behaviour respectively.

For the non linear material case, the results from a time history analysis, a linear response spectrum analysis using ductility factors and the displacement method were comparable.

The case representing the combination of material and geometric non linearity is an example of impact or pounding between two adjacent structures with a natural frequency ratio of approximately 1:2. The deformations predicted by the displacement method were about 30% greater than the mean value from a series of 25 time history analyses. The scatter in the time history results was significant. The displacement analysis permitted tracking of a complex redistribution of demand between lateral load paths with increasing lateral deformation. They give a valuable insight and understanding of the behaviour and the development of the controlling mechanism.

The NRC however concluded that the displacement method "is not applicable for the design of nuclear power facilities since the [current] acceptance criteria are force based and all responses are required to remain in the linear elastic range." The next sentence notes that "While the displacement based approach could be used in this area, it offers no advantages [for structures remaining in the linear elastic range] over forced based methodologies currently in use for evaluating design adequacy."

NUREG practice is to design Category I Structures, Systems and Components (SSC) to remain within the elastic limit. The conclusion of the NRC report does not appear to adequately address the application to the evaluation of existing structures or the design of Category II structures and other components where inelastic/non linear behaviour within the design envelope could be accepted.

The study did recognise the potential benefits over time history analyses in the assessment of the seismic margin and recommends that:

- Additional studies are needed to define the scope of the application of displacement methods in the nuclear context for systems with both material and geometric non linearities;
- If displacement methods are to be applied on a wide scale to nuclear facilities there is a need to develop coefficients and drift limits appropriate for the importance of the structure.

The latter may offer an opportunity to use the performance criteria for individual structures derived from the safety case rather than adopting generic criteria developed for application to all nuclear structures of a similar categorisation.

4.5 Differences

As noted above (Section 0) the philosophy of PBE is similar to that of the current nuclear practice in that the performance requirements are defined for each individual structure. The difference is that displacement based analysis is used for the design and assessment with the PBE approach while the current nuclear practice is to use force based analysis.

The potential benefits offered by displacement based analyses methods do not appear to have been recognised for the design, assessment and qualification of nuclear safety related structures. As outlined above (Section 0) the benefits would assist in the understanding of the seismic response, the assessment of sensitivities and the available margin, and the demonstration of ALARP, all of which are recognised objectives of the current nuclear guidelines.

Displacement methods may give the impression of over reliance on engineering judgement but do identify a number of previously implicit assumptions and allow rational assessment of same.

It is recognised that displacement based analyses do have limitations. While they will generally provide an enhanced understanding of the non linear behaviour of a structure, the qualification for nuclear use may require that they are supplemented by time history analyses. The NRC study has shown that the displacements predicted may not be sufficiently reliable where impact or geometric non linearity occurs. The limitations on the application need to be understood and guidelines developed.

5. DESIGN

The demand on individual elements is typically assessed against capacities based on ULS principles for design of both nuclear and conventional structures.

Currently the adequate non linear behaviour of conventional structures is typically assured by application of the prescribed seismic detailing provisions for key individual elements based on the overall or structure ductility assumed in the derivation of the seismic loading component. The seismic detailing provisions are based to a greater or lesser extent on capacity design principles. The actual ductility demand on the individual sections or elements is not considered explicitly.

ACI 349-97 (Reference 9) requires the application of seismic detailing provisions for nuclear safety related concrete structures irrespective of imposed stress limits i.e. the seismic detailing provisions are applied to structures that are assumed to remain elastic both within the design envelope and at the margin.

In contrast, the non linear behaviour of individual elements and sections is explicitly modelled in the displacement based analyses. The displacement analysis method presented in FEMA 273 models potential hinge positions using non linear moment/rotation relationships appropriate for the section detailing and the anticipated axial load. At rotations beyond the ductile capacity of the hinge, the residual moment resistance is typically reduced to a nominal percentage of the ultimate strength. The overall performance of the structure can therefore be assessed in a rational manner and the development of mechanisms tracked as the capacity of individual members is exceeded. In comparison with the methods prescribed by the current conventional codes, the insight provided by the displacement methods significantly enhances the designer's understanding of the potential seismic response.

The development and justification of suitable moment/rotation relationships and acceptance criteria would be required prior to use of displacement analysis and design methods for the qualification of nuclear structures. The potential benefits are summarised in section 0.

6. MATERIALS AND CONCEPTS

The adoption of new concepts and materials is limited by the ability to reliably predict the performance over the full life of the structure including the decommissioning period.

Concepts and the associated analysis methods proven in the design for non nuclear use, such as base isolation, have been adopted in the nuclear industry to limit the seismic demand on critical items.

7. DISCREPANCIES: OPTIONS AND RECOMMENDATIONS

The apparent reluctance to adopt the full PBE approach and displacement based analysis and design methods in particular as a part of nuclear design practice is identified as a growing discrepancy between current nuclear practice and the conventional design methods that are available.

The options are therefore to:

1. Continue with the present nuclear practice;

or to address this discrepancy by:

2. Changing completely to PBE and displacement methods;
3. Waiting for the nuclear industry to recognise the benefits and propose/adopt appropriate use of displacement methods;
4. Encouraging the use of PBE and displacement based analysis where appropriate.

The first option is not defensible given the requirement to assess using modern standards and the potential benefits of the displacement methods.

The second option is not realistic given that there are likely to be limitations to the use of PBE and other approaches could be more applicable. There would also be significant transition difficulties, particularly for prescriptive regulatory regimes where the regulatory bodies would need to develop robust codified approaches.

The third option places the burden of justifying a novel method on the initial users. The benefit to a particular project may need to be substantial to justify the additional time and cost of developing and justifying a ‘novel’ approach. Initially the results from the displacement methods may need to be confirmed by more rigorous approaches, such as time history analyses, to establish the necessary confidence.

The fourth option appears to be the ideal and is the recommended course of action. The US NRC assessment of displacement based methods is a step in this direction. However, the current US position appears to differ from European nuclear practice of design based on performance criteria developed from the safety requirement for each structure as part of the safety case. The European approach therefore shares many of the objectives of PBE. The seismic categorisation determines the approach to the qualification but not the specific performance criteria.

In contrast the US approach is more prescriptive. The performance criteria appear to be based on the categorisation of the facility rather than the specific safety function or performance objective associated with a particular structure.

The development of guidelines on the appropriate use of PBE and displacement methods within the nuclear environment would encourage the adoption of the approach. This would require an assessment of the various displacement based analysis methods available and the development or endorsement of robust methodologies which yield suitably reliable outputs for Structures, Systems and Components. Studies to undertake this assessment of methods could constitute research which could be sponsored by OECD.

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