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The Indian Ocean Tsunami

Zygmunt Lubkowski reports on the joint SECED/ICE Maritime Board meeting.

Contents

At 0800 hours local time on December 26th a magnitude 9 earthquake struck off the island of Sumatra in Indonesia. This great earthquake generated a tsunami that has claimed more than 270,000 lives, displaced many more and destroyed whole communities across the region. The event has touched the lives of most countries around the world.

To try and answer some of the questions being asked after the event, SECED together with the ICE Maritime Board organised a half day meeting in London on 7th February 2005. The meeting was chaired by Professor John Burland, Imperial College and Vice President of the ICE, and addressed by a number of specialists in oceanography, earthquake engineering and disaster relief. Professor Burland explained that the purpose of the meeting was to bring together the experience and expertise of engineers and other specialists to share their knowledge and to educate the wider community. The information collected from this meeting would help to inform governments and other public bodies, would demonstrate the capacity of the profession to deal with these disasters and would raise the public profile of civil engineering.

The meeting was opened with a startling eye witness account by Steve Magenis, of Posford Haskoning who was on holiday in Phuket in Thailand and was actually sitting on the beach when the waves arrived. He ran back to safety in time. Interestingly two hours earlier he had felt the local earth tremor from the original earthquake some 400 miles away.

Initial reports from the Earthquake Engineering Field Integration Team were presented by Sean Wilkinson, University of Newcastle and Dr Navin Peiris, Arup, who had recently visited Thailand and the south west coast of Sri Lanka. Their observation was that the scouring of foundations was a serious problem and had caused the

Kalutara, Srilanka, 26th December 2004: Receding waters from tsunami. (Credit: DigitalGlobe) collapse of many buildings, railways and bridges. The collapse of bridges also caused the failure of service pipes attached to them such as water, telephone and electricity. Damage had extended from 400m to 1.5km inland by waves up to 9m in height. An initial report on their mission has been posted at www.eefit.org.uk .

Dr Clark Fenton, Imperial College, said the submarine earthquake off the coast of Sumatra was magnitude 9 and the fifth largest within the last 100 years. More severe earthquakes around the Pacific rim have occurred in Chile in 1960, magnitude 9.5, and in Prince William Sound in 1962, magnitude 9.2. Both of these events generated major tsunamis. Tsunami waves have also been created by submarine earth slides (e.g. Storegga, Norwegian Sea about 7000 years ago) and volcanoes (e.g. Krakatoa in 1883). (see http://www.nerc-bas.ac.uk/tsunami-risks/). Dr Fenton emphasised the need to understand the underlying science of submarine earthquakes and also to understand the difficulties in making predictions and hence the limitations of our methods.

Professor William Allsop, HR Wallingford explained how computer models can be used to demonstrate the generation and propagation of tsunamis. On 27th December 2004, the day after the Sumatra earthquake, Japanese engineers had modelled the event which showed that the major wave fronts were propagated to the east, to Thailand, and west to Sri Lanka and India. The waves to the north, to Bangladesh, and to the south were weaker. The westward wave had a speed of propagation of 200m per sec and a wavelength of 400m. Professor Allsop explained that the wavelength was a more important factor than the wave height in predicting the potential damage which the tsunami would cause when the wave reach the shore, and also showed that a tsunami wave is not always preceded by a trough when it reaches the shore.

Tsunami models work well to predict vertical displacements using shallow water equations and can be used to give practical guidance such as to identify safe areas. At Phuket bay the wave height had been measured by a Belgian yacht which happened to be anchored 1.2 km offshore in 12 m of water.

Dr David Ingram, Manchester Metropolitan University, identified the areas for future research in tsunami and inundation modelling. The different types of wave propagation need to be considered separately. Oceanic propagation is well understood but predicting the run-up wave is more difficult. The surface slope, roughness and degree of saturation of the surface need to be modelled accurately. Dr Ingram considered the Bousinesq equations were more accurate initially and should be used for the initial stages of wave propagation, and the shallow water equations could be used for the later stages.

The contribution from the British Geological Society was given by Dr Lars Ottemöller who explained how a tsunami early warning system could be established to respond to the detection and location of an earthquake. In developing a warning system for the Indian Ocean it is necessary to develop regional co-operation to improve the infrastructure and to tailor the system to meet the needs of the participants. The world wide net of seismic recording stations could detect the earthquake and locate its centre, and then the magnitude of the wave, its track and expected time of arrival needs to be determined. This would ensure the local warning could be issued in time.

Jeremy Larken, Managing Director of OCTO explained the practice of crisis and emergency management. A disaster is different from an emergency and requires performance under pressure. The first criterion is to save life and limb, even recognising that some lives may be lost. An important factor is to get information quickly. A disaster situation worsens rapidly and lack of information can reduce the time available to make a decision and reduce the likely success of the decision made. Leadership is also important and needs to replace consensus management in a disaster situation. Communication with the public is essential and need not be high-tec.

Zygmunt Lubkowski, Arup, discussed the possible ways in which a community can be protected from the consequences of such events. He highlighted the excellent guidance that is provided by the National Tsunami Hazard Mitigation Program (http://www.pmel.noaa.gov/tsunami-hazard/), which provides seven principles for planning and designing against tsunami hazards. These are:

- Understand the community's tsunami risk
- Avoid new developments in tsunami run-up areas
- Locate new developments to minimise future losses
- Design buildings to minimise damage
- Protect existing developments through redevelopment, retrofit and planning
- Take special precautions in locating and designing critical facilities
- Plan for evacuation

Greg Haigh, Arup and Chairman of the Maritime Board, concluded the meeting by summarising the key issues to be discussed with Government:

1. It was a very big event - low probability but high impact.
2. There was a negative wave before the positive wave to the east of the epicentre but no negative wave to the west. You can get a tsunami wave arriving without the water receding first.
3. A major tsunami will occur again somewhere, but it is highly unlikely that the next major natural hazard will be a tsunami.
4. Most historic development in most countries does not adequately take account of the risks of tsunami.
5. Need to improve assessment of risks from all natural hazards.
6. Governments and public have a limited knowledge of what the risks are and what solutions engineers can provide. Engineers need to create the demand.

N.B. The many contributions from the floor included a request by Professor Robin Spence of the Department of Architecture at Cambridge University for eye witnesses of the tsunami to send him their reports.

Seismic Assessment of Existing Nuclear Structures: A Regulator's Viewpoint

Andrew Coatsworth, HMNII, publishes his closing comments, first given at the end of the BNES/SECED Symposium 26 May 2004. (These comments were largely in response to papers that Andrew Coatsworth had not seen until the symposium).

This article continues the series based on the SECED/BNES Symposium. The series will be concluded in the next newsletter.

This is not an attempt to fulfil the function of Rapporteur by providing a summary of the day's papers, but to provide brief comment on the presentations from a nuclear safety regulator's viewpoint, to note some regulatory issues, and to provide some preliminary findings from recent research conducted by HMNII in the subject of seismic assessment.

Peter Merriman in his introduction to the symposium referred to the need to consider seismic assessment as an integral part of the nuclear safety case, and I endorse that. He also referred to the need for nuclear site licensees to give a seismic strategy to contractors, and that the Nuclear Decommissioning Authority (NDA) will be seeking standardisation from the site operators. Indeed, HMNII would welcome sight of seismic assessment methodologies. Many years ago I was surprised to find no common methodology for the seismic assessment of the Magnox stations carried out as part of the Long Term Periodic Safety Reviews (LTSRs). Apart from the regulatory burden of assessing the several methodologies, I could not understand how a nuclear site licensee specified its requirements and compared tenders without such a methodology. At my urging this deficit was corrected for the Periodic Safety Reviews (PSRs) of the Advanced Gas Cooled Reactors (AGRs), but the lessons are in danger of being lost again.

I will now make brief comment on the earlier presentations.

A Review of UK Seismic Risk based upon the European Earthquake database – Chris Allen

Reiter (Reference 1) mentions the possible use of Cumulative Absolute Velocity (CAV). A recent search by HMNII had not found any such studies of CAV, so this study is very welcome.

The study into CAV is supported by recent attenuation research, but at first sight there appears to be a large extrapolation to 10^{-4} per annum non-exceedance level. The work makes welcome use of the BGS Network data.

CAV is one of several possible alternatives that may provide a better indication of damage than Peak Ground Acceleration, such as Effective Acceleration, A_{eff}, and maximum spectral displacement, a personal favourite of mine.

Whilst welcoming consideration of this possible new approach, I have two small caveats:

- The presentation refers to correlations of CAV with structural damage, but it is also necessary to assess the seismic capability of contained plant with a nuclear safety function;
- The presentation refers to correlations of CAV with damage to structures of good design and construction; unfortunately there are some, albeit a few, exceptions to such criteria to be found in the nuclear industry.

Perhaps Chris Allen could consider placing the study in the Nuclear Research Index to allow transparency.

Innovation in the seismic substantiation of existing nuclear facilities – Stewart Gallocher

Stewart Gallocher discussed the prescriptive detailing rules for reinforced concrete contained within Chapter 21 of ACI 349 (Reference 2). The assurance of structural ductility, rather than design against a seismic 'margin' event, is my preferred choice as a means of demonstrating that there is not a disproportionate risk from an event more severe than the design basis event. HMNII does not seek blind adherence to any design code, but expects those parts not adopted to be clearly identified and justified. However, regarding the prescriptive rules of ACI 349 Chapter 21, I do have a problem if a licensee appears to seek the cachet of a respected design code without implementing the most relevant reasons for adopting such a code in the first place, in this case the ductile detailing provisions. I recognize that ACI 349 is applied in regions of the USA with greater spectral displacement and longer duration than applicable in the UK, but for the time being it is probably the best standard we have for the design of reinforced concrete for nuclear facilities.

Elastic design at the Design Basis Earthquake (DBE) is not a HMNII requirement, except perhaps for containments, but may arise as a practical requirement to obtain secondary response spectra.

Performance based methods are welcome. Stewart Gallocher referred to the dependence of seismic analysis methodologies for existing structures upon the inventory of the nuclear plant; it is preferable where possible to use the consequences of failure rather than the inventory.

Pushover analysis has a value in understanding the structural behaviour in beyond design basis events, but if the objective is for more than conceptual understanding, then the justification of the assumptions in pushover analysis may be more onerous than conducting a more rigorous analysis.

Stewart Gallocher's presentation dealt with some seismic structural upgrade techniques such as carbon fibre wrapping, isolation etc. Base isolation protects the plant, as well as the structure, as graphically illustrated by the Olive View Hospital experiences.

It is a common misconception that HMNII is against innovation. Rather it recognizes that new techniques can improve nuclear safety, although non-routine techniques may require more justification.

Seismic assessment of the Dounreay Fast Reactor – Andrew Mair

Andrew Mair referred to the detective work required to obtain information on the design and construction of these existing nuclear facilities as part of the seismic assessment process. Indeed, I would extend the detective work to include maintenance and history of incidents. The need to understand the structural response, and not to depend on numerical analysis is clear. It would be of immense help to myself if seismic assessments stated the structural form and the load paths. Andrew Mair's messages seemed to be that a complex model may not be needed, and that intelligence is required in choosing the relevant design code for assessment, in this case elements of Highways Agency BD56 (Reference 3).

Appraisal of Nuclear Dock Structures – Robert May and Sandy Forshaw

A few years ago there was some discrepancy between the expectations of the Ministry of Defence's Nuclear Regulatory Panel (NNRP) and HMNII regarding beyond design basis seismic events, but as a result of collaboration between David Standerwick and myself, I believe this has been resolved. Recent research, which I will refer to later, has confirmed that design against a 40% seismic margin event is unlikely to reduce the risk to the broadly acceptable region.

The paper showed both the role of model testing – in this case centrifuge – and of displacement based seismic assessment. Jacob discussed centrifuge testing with myself before embarking upon it, and this shows the benefit of talking to the HMNII.

Seismic appraisal versus qualification - Andy Campbell

Andy Campbell referred to the conservatism in the seismic hazard, to which I would respond is such conservatism unwarranted?

On the retention of conservatisms in design code based seismic assessments, I find the conclusions of such assessments implausible and rather unhelpful. The outcome of a design code based assessment for a PSR in stating that structural failure will occur at 0.1g or whatever and for seismic strengthening to be carried out almost invariably leads to decisions on whether to implement such recommendations to be made by staff who are not suitably qualified and experienced (SQEP) in seismic engineering. Derogation of the decision making process by civil engineers has its parallel in other areas, such as whether accountants or civil engineers are best qualified to do whole life costing of civil engineering projects. What both the HMNII, and I would have thought the nuclear site licensee, require is for the civil/structural engineers to make a judgment as to the probability of failure. Why have the Conservative Deterministic Failure Margin (CDFM) and High Confidence in a Low Probability of Failure (HCLPF) – both of which give a seismic capacity with about a 1% of failure – or indeed the stability based methods, all of which were introduced to the UK in the 1980s apparently fallen into disuse?

Andy Campbell referred to the use of Uniform Risk Spectra (URS) to give a better understanding of the range of performance. HMNII has accepted the principle of URS, but there are problems with all the actual URS that we have so far seen. In part these relate to the reduced sensitivity at low frequencies of the seismic detectors used to obtain early strong motion recordings, and in part to multi-modal response. It is HMNII policy to seek a seismic probabilistic risk assessment (PRA). I attended a summer school on seismic probabilistic risk assessment of structures held at the Rose School, University of Pavia, in 2003, and I am aware of the uncertainties. However, I do not believe that the uncertainties are greater than for other parts of the PRA, such as human factors.

Where a nuclear structure is found to have a low seismic capability, such that the risk from the facility is intolerable, our guidance states that this is still ALARP providing that adequate steps are being taken to reduce the risk. The legal duty remains to reduce the risk 'so far as reasonably practicable' (SFAIRP). There is a balance to be struck between the early retrieval of nuclear waste from legacy storage, and demonstrating whether or not the facility presents risks within the broadly acceptable region. HMNII is concerned by the risk of inaction or delayed action on legacy nuclear plants.

Dungeness A Boiler Cell - Pradeep Prakash

Pradeep Prakash gave a clear explanation of the structural behaviour and the need to strengthen part of Dungeness A. Such explanations are of great assistance to third parties in understanding safety cases. He also referred to the iterative nature of analysis and design for seismic upgrades due to the dynamic effects as modifications are introduced. This is probably recognized by all who have attempted to strengthen – and thereby stiffen – an existing nuclear structure.

The strengthening works are now complete.

Tricks of the Trade – Paul Doyle

Paul Doyle covered the need – and difficulty of understanding - the original design intent. As he showed the original designers may not have had access to finite element analysis, and may have used alternative structural theories to that of elasticity. Again the role of testing is evident.

Recent research by HMNII

I refer to recent work "Making Seismic Risk ALARP" by my colleagues Philip Brighton, John Donald and Peter Ford, supported by a number of external organisations. The report is currently awaiting HMNII agreement before being placed on our web-site. There are three preliminary findings which I would like to convey:

- The uncertainty in the seismic hazard due to the lack of data, noted by John Irving some twenty five years ago, has been replaced by uncertainty from scatter in the real data now available;
- The URS so far presented to HMNII may not be conservative;
- A design based on deterministic criteria may not be sufficient to achieve a broadly acceptable risk, even after application of a 40% margin; this supports the regulatory emphasis on ductility rather than a beyond DBE margin.

Closing comments

The objective of a PSR of an existing nuclear facility can be expressed as a comparison with how such a similar plant would be built and operated if built now. Shortcomings are to be expected, and the significance of the gap, and partial closure of the gap to meet ALARP requirements should be timely achieved.

Seismic assessment/improvement is not just a structural problem. Damage to nuclear safety related components may be expected, whether these be instrumentation, electrical systems, piping, valves, vessels or structures. I have placed the former list in approximate order of the likelihood of damage in the event of an earthquake, but with so much effort being devoted to the structural elements, while scant effort is given to other systems, I am provoked to ask if expenditure on seismic assessment and upgrading is in inverse relation to the probability of damage.

To illustrate the importance of giving attention to the non-structural seismic assessment I draw first to my personal experience on a foreign nuclear power station. Several million pounds had been spent on the seismic analysis of the structure and extensive strengthening had been commenced. However I quickly determined that the control cabinets in the main control room were not fixed to the floor and that cabling to the cabinets passed through sharp edged holes. Likewise the emergency cooling water tank rested on, but was not secured to, lightweight channel supports. Little imagination is required concerning the likely seismic performance of such systems, or whether the small effort to correct the deficiency would be justified under ALARP. Secondly I draw attention to a pre-operational inspection I recently carried out on a new UK plant designed to current seismic criteria. I found parts of a cooling system had not been bolted to the floor, although required as safety functional equipment following a 0.25g earthquake. In response to my finding, the nuclear site licensee determined that the plant installation had failed to follow the design in respect of anchorage of the equipment. I required the defect to be fixed.

There is a need not only to seismically qualify or assess nuclear safety related plant, but to also maintain that seismic qualification or assessment through continuing inspection and maintenance.

My perception is that emphasis of the nuclear industry in seismic research for twenty years has been on seismic hazard, not on seismic performance. A better balance is required.

Andy Roberts & John MacFarlane (Reference 4) identified the lack of UK national standards for nuclear structural design as a cause of undue conservatism. This shortfall has not been corrected.

I recognize that the seismic design or assessment criteria for facilities with low radioactive inventories – or more relevantly low consequences of failure – is a problem area. Our guidance to assessors currently seeks a minimum design peak ground acceleration of 0.1g, which is in keeping with IAEA expectations. There is a UK government ministerial indication that the UK will meet minimum IAEA expectations. This 0.1g minimum, subject to ALARP, has caused difficulties in some UK cases. However, performance is about design methodologies, as well as seismic hazard, and there may be scope for using design codes etc with a lesser safety classification for facilities with limited consequences of failure.

Finally, HMNII staff will attempt to give advice as to a likely regulatory position. It is a statutory duty under the Health and Safety at Work Act (1974). So, talk to us.

Acknowledgement

The author thanks the Chief Inspector of Nuclear Installations of the Health and Safety Executive for permission to publish this paper. The views expressed are those of the author and do not necessarily represent those of HMNII.

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Selection of Earthquake Time Histories for Analysis of Structures

Philip Cooper reports on the SECED meeting held on 24th November 2004.

The meeting was chaired by **Dr Paul Greening**, UCL with addresses from **Dr Julian J. Bommer**, Reader in Earthquake Hazard Assessment, Imperial College and **Chris Rogers**, CREA Consultants Ltd.

Julian Bommer made a presentation entitled "Seismological and Engineering Criteria for Using Accelerograms in Design Analysis". The presentation opened with a statement that thousands of real accelerograms are now easily and freely available from a number of Internet sites (Bommer & Strasser, 2004) but that guidance on how to select and scale accelerograms for use in engineering analysis is limited, incomplete and as often as not based on 'folklore' rather than research.

A key issue is that whenever accelerograms are required, there will generally already be an acceleration response spectrum defined for the design and one of the key issues, from both seismological and engineering perspectives, is therefore to obtain accelerograms that in are compatible with this spectrum. Dr Bommer described the use of spectrum-compatible artificial accelerograms obtained from white noise as problematic and strongly recommended that their use be discontinued, since if spectrum compatible records were required – in order to reduce the number of analyses required to obtain stable estimates of inelastic response – then these are better obtained by modification of real accelerograms.

In particular Dr Bommer pointed to techniques based on wavelets, currently being developed by Imperial College researcher Jonathan Hancock in collaboration with Dr Norm Abrahamson, as being particularly promising in allowing engineers to achieve a very good degree of spectral compatibility whilst retaining many of the features of real earthquake ground motion. Sometimes such records have been referred to as 'intelligent artificial' accelerograms.

The main thrust of Dr Bommer's presentation was to provide an overview of the options available for selecting (Figure 1) and scaling (Figure 2) accelerograms for use in design, and finding the optimal balance between seismological

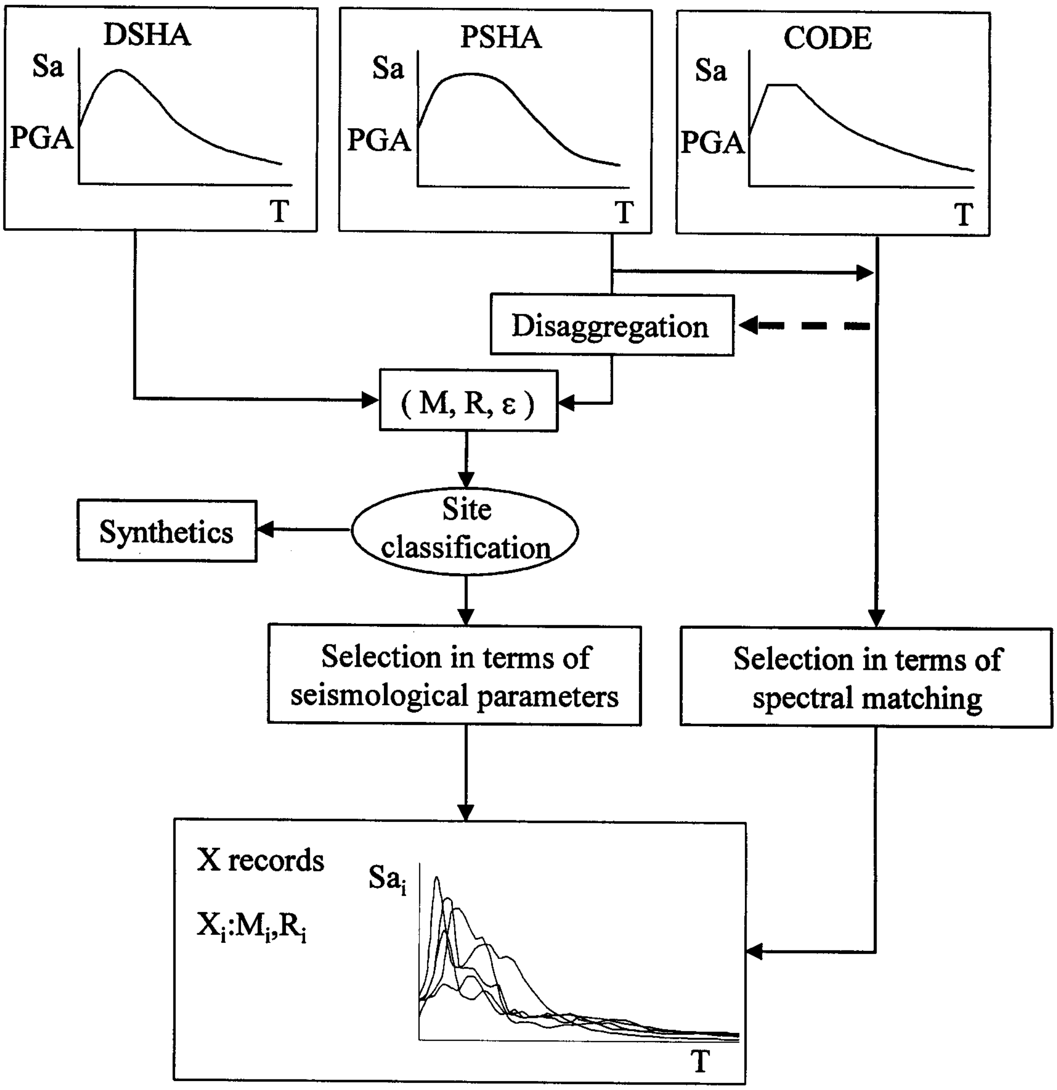

Figure 1 Overview of the options available for selecting accelerograms for use in engineering analysis and design (Bommer & Acevedo, 2004)

criteria (obtaining the most realistic representation of the expected ground motions at the site) and engineering criteria (obtaining robust estimates of inelastic response within a reasonable time frame). The approaches to selecting real accelerograms can be broadly grouped under three headings, the first being to select according to the parameters (magnitude, site classification, source-to-site distance, etc.) that define the design earthquake scenario. The second being to search directly for records that match the shape and/or amplitude of the target spectrum, as proposed by Naeim et al. (2004). Dr Bommer suggested that the ideal method is to combine these two approaches, first selecting records from broadly similar scenarios – but with a reasonably good match in terms of magnitude – and then to search within these records for those records with the smallest deviations from the shape of the design spectrum. Dr Bommer pointed out that such searches can be performed using the second CD-ROM of European strong-motion data (Ambraseys et al., 2004). The third approach, currently being developed by Dr Norm Abrahamson at the University of California at

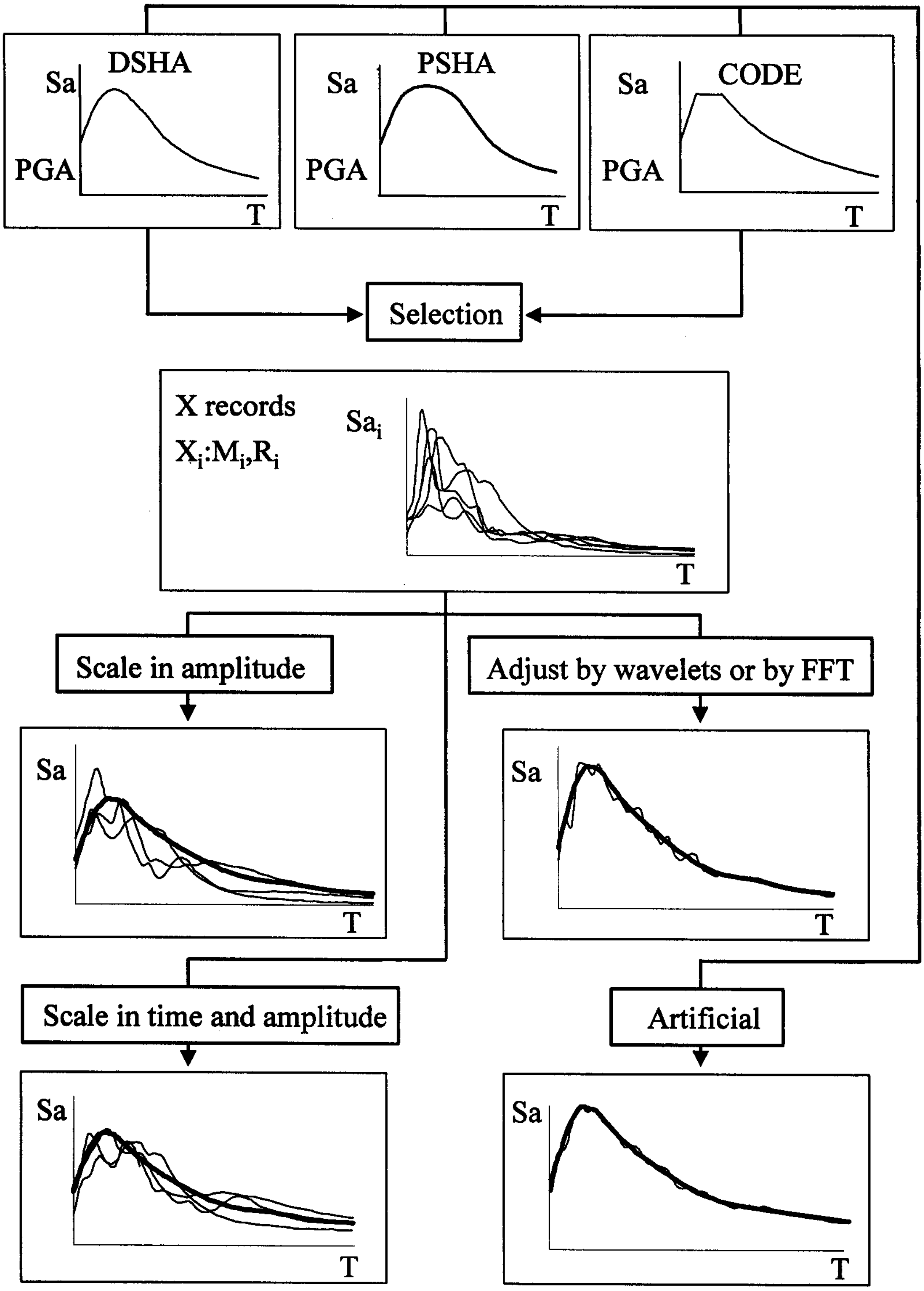

Figure 2 Overview of the options available for scaling accelerograms to the elastic design spectrum (Bommer & Acevedo, 2004)

Berkeley, is to directly select accelerograms that have characteristics (duration, root-mean-square acceleration, peak velocity, etc.) that have been previously found to produce stable median estimates of inelastic behaviour. This work is being developed for simple geotechnical (sliding block) models and will shortly be extended to SDOF oscillators by Jonathan Hancock.

A number of pitfalls and fallacies in current practice were highlighted. Foremost amongst these is the fact that if the target response spectrum is defined by probabilistic seismic hazard analysis (PSHA), then the variability in the ground motion is already accounted for and should not be double-counted by being also included in the suite of selected and scaled records; therefore, records should be individually rather than collectively scaled to the design elastic response spectrum. When the ground motion is to be defined in two horizontal directions, then the scaling must take account of the definition of the horizontal component of motion (larger or geometric mean) employed in derivation of the design spectrum. In scaling the two horizontal components from each accelerogram, any polarization should be preserved, so for example if the ground-motion prediction (attenuation) equation used to derive the spectrum were based on the larger component of motion, then the smaller component of the accelerogram should be below the target spectral ordinates. A serious fallacy, dating back to work carried out in the 1970s, is that records should not be scaled by a factor of more than 4 or even 2. The shape of the acceleration response spectrum, over the range of periods usually of interest to engineering design, is very insensitive to distance whereas the amplitude of the spectral ordinates decays very rapidly with distance, hence it is often possible to scale records by factors as high as 10 without creating unrealistic ground motions.

The presentation by **Chris Rogers** on the generation of time-histories to comply with ASCE 4-98 was intended to raise questions as much as to inform. ASCE 4-98, Reference 1, is an update to the previous code, ASCE 4-86. In terms of the generation of spectrum matching artificial time-histories, the revised rules at ASCE 4-98 mean that any time-history generated to comply with ASCE 4-86, does not necessarily comply with ASCE 4-98.

The presentation examined the characteristics of an artificial motion that are important in the selection of time-histories for analysis: the target spectrum; the intensity envelope; the power spectral density; and statistical independence. In addition to the requirements of ASCE 4-98, it is also necessary to be aware of the frequency content and the integration time step size. It was noted that any given generated time-history may not be suitable for all structures or all analysis types, it is necessary for the engineer or analyst to be fully aware of the time-history's characteristics with respect to the structure being analysed.

Spectrum matching time-histories can be generated as a single compliant record, or a set of records. If a set of time histories is generated, (usually sets of three or five), then the average of the response spectra for the records in the set should comply with the ASCE 4-98 spectrum matching requirements. If a single record is used, then its spectrum must satisfy the requirements without any adjustment. Thus, for elastic analysis running multiple time-histories is not a necessity.

If multiple time-histories are used in analysis, then ASCE 4-98 allows averaging of the results to obtain design values. However, it was suggested that this may not be a sensible approach for non-linear analysis. As non-linear analysis is path dependent, all time-histories in the set may not trigger the non-linearities in the same order. Therefore, for non-linear analysis enveloping may still be the necessary post-processing approach. ASCE 4-98 requires that more than one set of time histories are used for non-linear analysis.

The new requirements for time-histories at ASCE 4-98 were discussed, primarily these are the generation of Power Spectral Density (PSD) functions and new rules for long-period response structures. The PSD requirement is that the PSD should show a smooth variation of power over the frequency range. It was argued that ASCE 4-98 is inconsistent in its treatment of the PSDs for a set of time-histories. In one part of the code it suggests that PSDs should only be averaged where suites of real time-histories are being assessed, but elsewhere it is suggested that averaging is allowed for synthetic records as well. Averaging appears logical for the selection of real time-histories, as it provides a good method of identifying a sufficient set. However, for synthetic time-histories, then averaging shouldn't be necessary as the time-history will tend to be frequency rich.

The new requirement for long-period response structures (not to be confused with long period ground motion, although there is a clear link), is that if the structure responds at frequencies below 1Hz, then the spectra for all time-histories in a set must exceed the target below 1Hz. That is, it is not permissible to rely on the averaging process below 1Hz.

It was indicated that these two new rules are sensible in that they ensure good time-histories from an analytical point of view.

The presentation touched on the frequency content of synthetic time-histories. There are several different time-history generation techniques, each resulting in different numbers of frequencies being used in the generation. Frequency content is of particular concern in non-linear analysis. For instance, an analysis with gap and/or friction interface elements is going to be sensitive to high frequencies. Therefore, a time-history that uses higher frequencies to achieve the spectrum match may cause unnecessary solution problems. Therefore, the understanding of the analysis and the input is of importance.

Two questions were asked, intentionally without answer, with respect to the use of ASCE 4-98 for UK projects. The first is the use of the intensity function for time history generation. When compared to the UK seismic specification for nuclear structures, the ASCE 4-98 intensity function appears to be too strong. The ASCE 4-98 intensity functions all have a definite strong motion period, whereas the UK specification has no such zone. Secondly, ASCE 4-98 demands a higher vertical response above 5Hz, with this now being equal to the horizontal response. However, the UK specification is very strong in its conclusion that a two-thirds ratio between horizontal and vertical is suitable at all frequencies. The question raised is: Can the UK specification be treated as a local site specification in terms of ASCE 4-98?

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Third Bled Workshop: Performance-Based Seismic Design Concepts and Implementation

At the end of June 2004, a Workshop on *Performance-Based Seismic Design: Concepts and Implementation* (bled2004.ikpir.com) was held in the beautiful lakeside town of Bled in Slovenia. Participants came from around the world to present current research and practice in performance-based seismic design and to discuss future directions in this area. Invited participants came from Europe, Japan and the USA; the UK was represented by past Chairmen of SECED, Edmund Booth and Julian Bommer.

This was the third such workshop held in Bled; the second workshop was held in 1997 and resulted in a book that has been very widely distributed and is frequently cited in earthquake engineering literature: *Seismic Design Methodologies for the Next Generation of Seismic Codes*, edited by P. Fajfar and H,. Krawinkler, and published by Balkema (ISBN 90 5410 928 9). The papers presented at the third Bled workshop have now also been published: *Performance-Based Seismic Design: Concepts and Implementation*, Proceedings of an International Workshop Bled, Slovenia, June 28-July 1, 2004, edited by P. Fajfar and H. Krawinkler, PEER Report 2004/05, Pacific Earthquake Engineering Reserach Center, Richmond, CA, USA September 2004 (548 pages, soft cover).

The publication contains 44 papers by leading practitioners and researchers from Europe, North and South America and SE Asia. It also contains the recommendations of four working groups investigating ways of promoting the use of performance based concepts in seismic design practice. The four workshops covered:

- Loss Estimation, Fragilities and Vulnerability, and Impact on Risk Management;
- Implementation of Performance Based Earthquake Engineering in Engineering Practice;
- Performance-Based Design Concepts;
- Harmonization of Experimental and Analytical Simulations.

The proceedings are published by Pacific Earthquake Engineering Research Center as report PEER 2004 and can be purchased for $45 (plus postage for overseas orders). Requests should be addressed to:

PEER Reports Orders
Pacific Earthquake Engineering Research Center
1301 South 46th Street
Richmond, CA 94804
Tel: 00 1 510-231-9403
Fax: 00 1 510-231-9461
info@nisee.berkeley.edu

Copies of the proceedings can be found in the libraries of both the Institutions of Civil and Structural Engineers in London.

Edmund Booth & Julian Bommer

Earthquake Engineering on the Internet: Earthquake Catalogues

By Roger Musson, BGS, Edinburgh

In the first article of this series about Internet resources for engineering seismology, on strong-motion data, Bommer and Strasser (2004) surveyed the main Internet sites from which users can download accelerograms. While the situation is now rather good for those who need to access strong-motion data online, it is not nearly so good with regard to those interested in obtaining earthquake catalogues that might form the starting point for a seismic hazard study. It is not so much that online earthquake catalogues cannot be found – there are many; the problem is rather that the pitfalls for the unwary user of such files are numerous.

The great difference between strong-motion data and earthquake catalogues is that, while an accelerogram is data, in the sense of information acquired directly from nature, an earthquake catalogue is an artifice of interpretation. We may speak loosely of a list of earthquakes as seismicity data, but it is highly processed from the actual raw material, which might be seismograms or macroseismic data. How well the catalogue reflects reality may be far from discernable to the student who simply downloads the numbers from an Internet site and begins to process them.

The situation is certainly good with respect to catalogues of recent seismicity. Apart from an increasing number of sites that provide near-real-time bulletins such as the European Mediterranean Seismological Centre (EMSC) at http://www.emsc-csem.org/, the three principal catalogue resources are the PDE (preliminary determination of epicentres) lists from USGS, the ISC (International Seismological Centre) catalogue, and the Harvard CMT catalogue. These each have their own strengths. The PDE catalogue, which can be accessed at http://wwwneic.cr.usgs.gov/neis/epic/epic.html, runs from 1973 up to a few days ago, and so is the source to use for the very most recent events. The ISC catalogue, at http://isc.ac.uk, is usually about two years in arrears, but ISC locations are generally considered to be more definitive. The importance of the Harvard catalogue, at www.seismology.harvard.edu/CMTsearch.html, is that while it is less complete than the PDE and ISC catalogues, it contains centroid moment tensor solutions for each event.

A number of national agencies also have online catalogues for recent seismicity; too many to list here, but the excellent Seismo-surfing page (http://www.seismo.ethz.ch/seismosurf/seismobig.html) is a good place to start.

However, for seismic hazard assessment, recent seismicity (effectively the last 40 years) is generally insufficient as a basis, being too short a time period to sample the seismic cycle effectively, even in most high-seismicity regions. What is needed for hazard studies is a historical earthquake catalogue for the area of interest that pushes the record as far back in time as possible, and this is where the problems start.

Obviously, there will be large variations in different parts of the world simply because of historical factors; a European country will generally have a longer historical record than a New World country. But simple availability also varies greatly. For some countries, one can easily find the most recent historical earthquake catalogue online, as for example, in the case of Italy, at http://emidius.mi.ingv.it/CPTI/. Other countries may not only keep their national catalogues off-line, the catalogues may be unpublished and regarded almost as a state secret.

In fact, one needs to operate with caution. Because a catalogue is an interpreted work, it is subject to intellectual property rights in a way that a seismogram or accelerogram is not. Being able to download an earthquake catalogue is not a guarantee that one is entitled to use it. In most cases there should not be a problem, but this is a point that may increasingly bear watching in the future. The recent Central and North European catalogue by Grünthal and Wahlström (2003) is downloadable (http://seismohazard.gfz-potsdam.de/projects/catalogues/EEC_CNNW.html), but pointedly as a pdf file, not an ASCII file for reading into applications.

If one lacks a national catalogue for the region of interest, there are still some global catalogues that can be sampled, the best-known being the USGS/NEIC resource, again at http://wwwneic.cr.usgs.gov/neis/epic/epic.html. This gives one access to various databases, some regional (especially for the Americas) and one global ("Significant worldwide earthquakes 2150 BC-1994 AD"), which is a composite of various catalogues and resources, produced by NOAA (Dunbar et al 1992).

However, composite catalogues are prone to all sorts of problems. These include duplicate events due to careless merging of component catalogues, inconsistent magnitude values between the component parts, and a range of other possible problems due essentially to the fact that the catalogue editor probably has little familiarity with the events being dealt with. As a simple example, for the Arab region, one sometimes finds earthquakes listed twice, once with the correct date, and once with the Anno Hejira year treated as an Anno Domini year.

Downloading a dataset from the Internet in a casual fashion will be sufficient to determine the general seismicity of a region, but unless the data are reviewed by a seismologist, one uses them for quantitative purposes at one's peril. Other problems often encountered are the unwitting inclusion of fake earthquakes (see the discussion in Musson 2005), events flipped across the Greenwich meridian by treating west as east or vice versa, and sometimes completely wrong magnitudes caused by inappropriate conversion formulae. In one recent published hazard study that I have seen, a catalogue file was used that contained explosions as well earthquakes – something that would have been spotted at once if a seismologist with appropriate experience had gone over the file before it was incorporated into the analysis.

Parametric entries for earthquakes may also have spurious levels of accuracy. Once one has a line of numbers giving epicentre and magnitude, it is too easy to trust these more than one ought. In the recent BEECD (Basic European Earthquake Catalogue and Database) study, entries in European earthquake catalogues were graded according to the supporting information. In surprisingly many cases, entries were simply copied from previous parametric catalogues, and it was impossible to trace the earthquake back to any actual original source material. The report of this study is well worth reading with care, and can be found at http://emidius.mi.ingv.it/BEECD/. It shows how much work is still to be done before one can claim to have a reliable, homogeneous earthquake catalogue even for Europe.

The resources mentioned above are of necessity only a small selection; a critical listing of all the online earthquake lists and catalogues, for all the regions of the world, would be a major task. While it is something of a truism to remark that quality control is something often lacking in Internet sites, it has to be borne in mind that, of all the types of information one may need to process in earthquake engineering and seismology, the parametric earthquake catalogue is probably the most subject to fantasy and error. Yet exaggerated and false catalogue entries can be quite difficult to detect. The Internet earthquake catalogue is truly a case of caveat lector.

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Adobe Buildings: International Seminar - SismoAdobe2005

The Catholic University of Peru (PUCP), Proterra (a Research Project of CYTED), the Earthquake Engineering Research Institute (EERI), and the Getty Conservation Institute (GCI), are organizing SismoAdobe2005, an International Seminar of Architecture, Construction and Conservation of Earthen Buildings in Seismic Areas. This event will take place on the PUCP campus, from 16-19 May 2005.

This event will include keynote conferences from international experts, oral and poster presentations, and technical demonstrations at the Structures Laboratory of the PUCP, where full-scale seismic simulation tests of adobe dwellings will be performed.

The topics to be covered are:

- Seismic effects on earthen buildings
- Research analysis and experimentation
- Earthquake-resistant design and construction concepts
- Seismic reinforcement for safety
- Code provisions
- Conservation and restoration of monuments
- Dissemination and application of appropriate technologies.

For further information, please visit the website: http://www.pucp.edu.pe/eventos/SismoAdobe2005

NOTABLE EARTHQUAKES OCTOBER – DECEMBER 2004

Reported by British Geological Survey

YEAR	DAY	MON	TIME UTC	LAT	LON	DEP KM	ML	MB	MS	LOCATION
2004	**7**	**OCT**	**21:46**	**37.13N**	**54.48E**	**35**		**5.6**		**NORTHERN IRAN**
			At least 60 people were injured in Golestan.							
2004	**18**	**OCT**	**22:11**	**25.07N**	**99.17E**	**30**		**4.8**		**YUNNAN, CHINA**
			Twelve people were injured and more than 20,000 houses were damaged or destroyed in the Baoshan area.							
2004	**23**	**OCT**	**08:56**	**37.23N**	**138.78E**	**16**		**6.4**	**6.3**	**HONSHU, JAPAN**
			At least 40 people were killed, 3,183 people were injured and 6,000 buildings were destroyed or damaged.							
2004	**3**	**NOV**	**13:34**	**55.19N**	**3.14W**	**5**	**2.7**			**ESKDALEMUIR,D&G**
			Felt with maximum intensities of 3 EMS.							
2004	**11**	**NOV**	**21:26**	**8.15S**	**124.87E**	**10**			**7.3**	**KEPULAUAN ALOR**
			At least 34 people were killed and approximately 400 people were injured.							
2004	**15**	**NOV**	**09:06**	**4.69N**	**77.51W**	**15**			**7.1**	**COLOMBIAN COAST**
			Several people were injured and numerous buildings damaged or destroyed.							
2004	**24**	**NOV**	**22:59**	**45.63N**	**10.56E**	**17**		**5.3**		**N. ITALY**
2004	**26**	**NOV**	**02:25**	**3.61S**	**135.40E**	**10**			**7.2**	**PAPUA,INDONESIA**
			At least 32 people were killed and approximately 130 people were injured.							
2004	**28**	**NOV**	**08:11**	**55.21N**	**3.14W**	**5**	**2.9**			**ESKDALEMUIR,D&G**
			Felt with maximum intensities of 4 EMS.							
2004	**28**	**NOV**	**18:32**	**43.06N**	**145.19E**	**39**			**6.7**	**HOKKAIDO,JAPAN**
			At least 24 people were injured.							
2004	**1**	**DEC**	**17:42**	**36.85N**	**3.45E**	**10**		**4.5**		**NORTHERN ALGERIA**
			At least 15 people injured and minor damage occurred to some buildings.							
2004	**5**	**DEC**	**08:30**	**36.87N**	**3.42E**	**10**		**4.5**		**NORTHERN ALGERIA**
			Forty-six people were injured in the Zemmouri area.							
2004	**23**	**DEC**	**14:59**	**50.15S**	**160.36E**	**10**	**8.1MW**			**N OF MACQUARIE IS**
			Felt throughout Tasmania, Australia and the South Island, New Zealand.							
2004	**26**	**DEC**	**00:58**	**3.30N**	**95.96E**	**30**	**9.0MW**			**OFF N SUMATRA**
			This is the fourth largest earthquake in the world since 1900. The tsunami caused more casualties than any other in recorded history. In total, more than 220,272 people were killed, 22,352 are still listed as missing and 1,076,350 were displaced in South Asia and East Africa. At least 173,981 people were killed by the earthquake and tsunami in Indonesia. Affected areas include Thailand, Sri Lanka and other coastal areas of the Bay of Bengal, which have all reported wide scale damage and deaths.							

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Non British Earthquake Data supplied by: The United States Geological Survey

Forthcoming Events

27 April 2005
This Year's Earthquake (Tsunami) and AGM
ICE 5.00pm

28 May 2005
10th Mallet-Milne Lecture: Prof. Liam Finn
"A study of piles during earthquakes: issues of design and analysis"
ICE 6.00pm

28 September 2005
Seismic Vulnerability of a Housing Project

SECED Newsletter

The SECED Newsletter is published quarterly. Contributions are welcome and manuscripts should be sent on a PC compatible disk or directly by Email. Diagrams, pictures and text should be in separate electronic files.

Copy typed on paper is also acceptable. Diagrams should be sharply defined and prepared in a form suitable for direct reproduction. Photographs should be high quality (black and white prints are preferred). Diagrams and photographs are only returned to the authors on request.

Articles should be sent to:

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SECED

SECED, The Society for Earthquake and Civil Engineering Dynamics, is the UK national section of the International and European Associations for Earthquake Engineering and is an affiliated society of the Institution of Civil Engineers.

It is also sponsored by the Institution of Mechanical Engineers, the Institution of Structural Engineers, and the Geological Society. The Society is also closely associated with the UK Earthquake Engineering Field Investigation Team. The objective of the Society is to promote co-operation in the advancement of knowledge in the fields of earthquake engineering and civil engineering dynamics including blast, impact and other vibration problems.

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SECED Website

Visit the SECED website which can be found at http://www.seced.org.uk for additional information and links to items that will be of interest to SECED members.
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