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NEWSLETTER

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Earthquake Engineering for Schools

A new Public Understanding project takes shape at Bristol University which aims to communicate the challenge and excitement of earthquake engineering research to school children

Earlier this year 20 pupils from Rednock School, a mixed comprehensive school in Gloucestershire, brought model buildings they had made to the University of Bristol's Earthquake Engineering Research Centre (EERC). They were taking part in a preliminary trial for a future national schools' competition in Earthquake Engineering. The pupils' models were shaken on the EPSRC shaking-table, an earthquake simulator, to find out which were the most efficient earthquake resistant models.

Dr Adam Crewe, Lecturer in Civil Engineering, and Dr Wendy Daniell, Research Fellow in Earthquake Engineering, from the EERC are leading the project, entitled Introducing and Demonstrating Earthquake Engineering Research in Schools (IDEERS). As part of a wider initiative to improve public understanding of science and engineering research, the Engineering and Physical Sciences Research Council (EPSRC) have awarded them a Partnership in Public Understanding Award of £29,000.

IDEERS aims to promote the understanding of earthquake engineering research to secondary school students through a web-based competition, which will involve constructing models of earthquake resistant buildings. Finalists' models will be tested with simulated earthquakes on the shaking-table at the EERC.

The IDEERS concept evolved through the EERC's regular participation in public understanding events, running public exhibitions for national initiatives promoting science and engineering and organising workshops in schools.

A popular feature of these events is a demonstration of the effect of earthquakes on buildings with model structures being shaken on a small portable shaking-table. However, it was observed that children were stimulated particularly by the workshop activity of making their own models and experimenting with them.

Building on this interest, Dr Daniell began planning a workshop specifically for children to make models from cheap materials, including medium density fibre (MDF) board, paper and string, for testing on the small shaking-table. In parallel, Dr Crewe wanted to develop the educational pages on the EERC website, as he receives regular enquiries from teachers about earthquake engineering. Their ideas were combined for this project which resulted in the production of a website

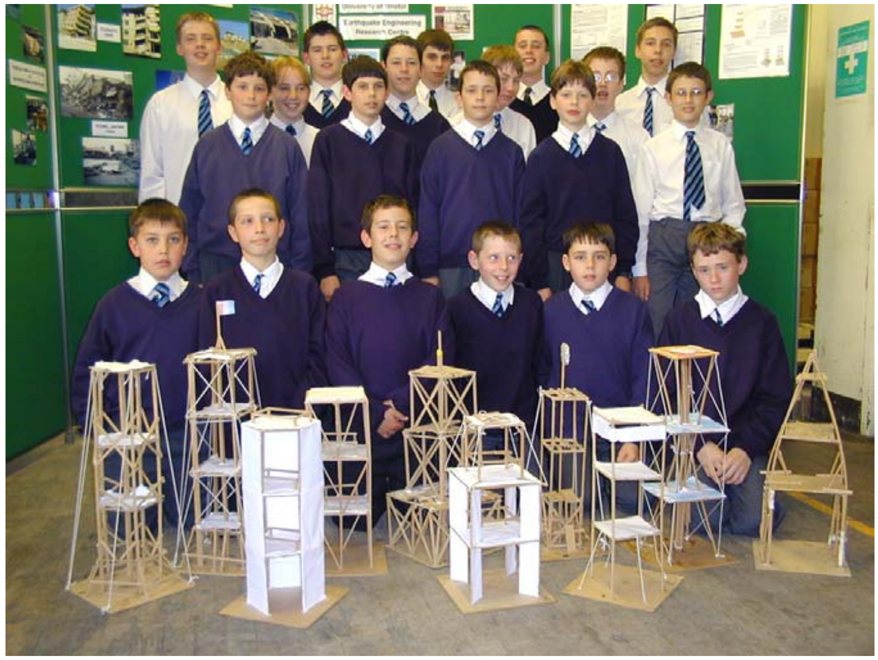
Rednock School pupils watch as their models are shaken on the shaking-table in Bristol University's Earthquake Engineering Research Centre

which provides a learning resource and running a national schools' competition for 11-16 year-olds of a range of abilities, to make the best models of an earthquake resistant building.

The web-site is currently under development and should be completed by the end of the year, and the first of three successive annual competitions will be launched in the summer of 2001. Competition prizes are being sponsored by the engineering consultants, EQE International, Ove Arup and WS Atkins, and by Texas Instruments.

The science of the project will cover basics of how buildings behave under gravity and earthquake loads and some basic concepts of dynamics. The maths will range from applying an understanding of dimensions, areas, and ratios to real problems, to the use of sine waves to describe real physical processes. Some of the issues associated with geography will include the nature of earthquakes, their effects on communities and how those effects can be minimised by careful design and construction of buildings. Skills learnt in technology will be directly applicable to the planning and making of the model building.

The EPSRC award requires researchers to communicate the challenge and excitement of their work. IDEERS will achieve this through the competition, encouraging children to simulate the earthquake engineering research process by developing and testing their models. The website will convey the research context by giving information on the effects of earthquakes, the need for earthquake engineering research, and some fundamentals on the seismic behaviour and design of buildings.



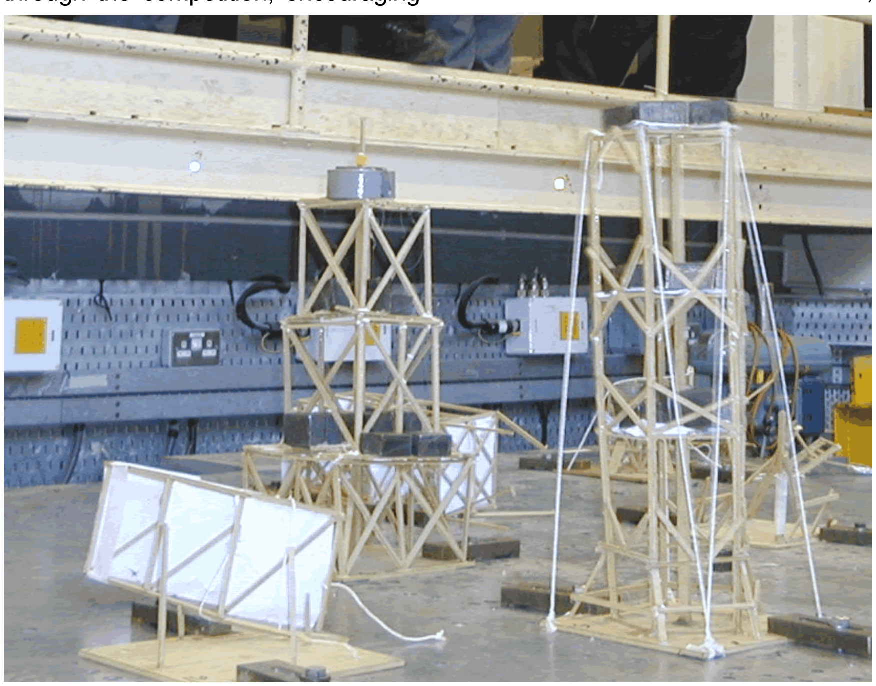
Rednock school pupils with their models

A major factor for the success of the project is the simple and effective communication of engineering principles to a young audience. To help with this side of the project, Professor Rosamund Sutherland, Professor of Education in the Graduate School of Education at Bristol, will be advising on the presentation of the website material. Her research team specialises in the teaching of science and maths and how young people interact with screen technology.

The recent tests in May formed the first phase of the project where pupils from Rednock School trialed the competition specification. Between them they had made a variety of structural configurations for their models based on a specification prepared for them by the EERC.

Their models could be made only from 4x6 mm strips of MDF, paper, string and hot melt glue. The models had to have at least 3 storeys with a minimum floor area given. Constraints were placed on the overall plan dimensions, the amount of bracing on the outside face of the model and on minimum and maximum individual floor areas.

The models were tested on the shaking-table for an artificial earthquake. The motion selected was not representative of a real earthquake, but was designed to demonstrate some of the principles of the dynamic behaviour of buildings to the students. A single axis shake was employed and the “earthquake” comprised of a sine sweep from 10 Hz down to 1 Hz. (A range of typical frequencies for this type of model had already been determined by the

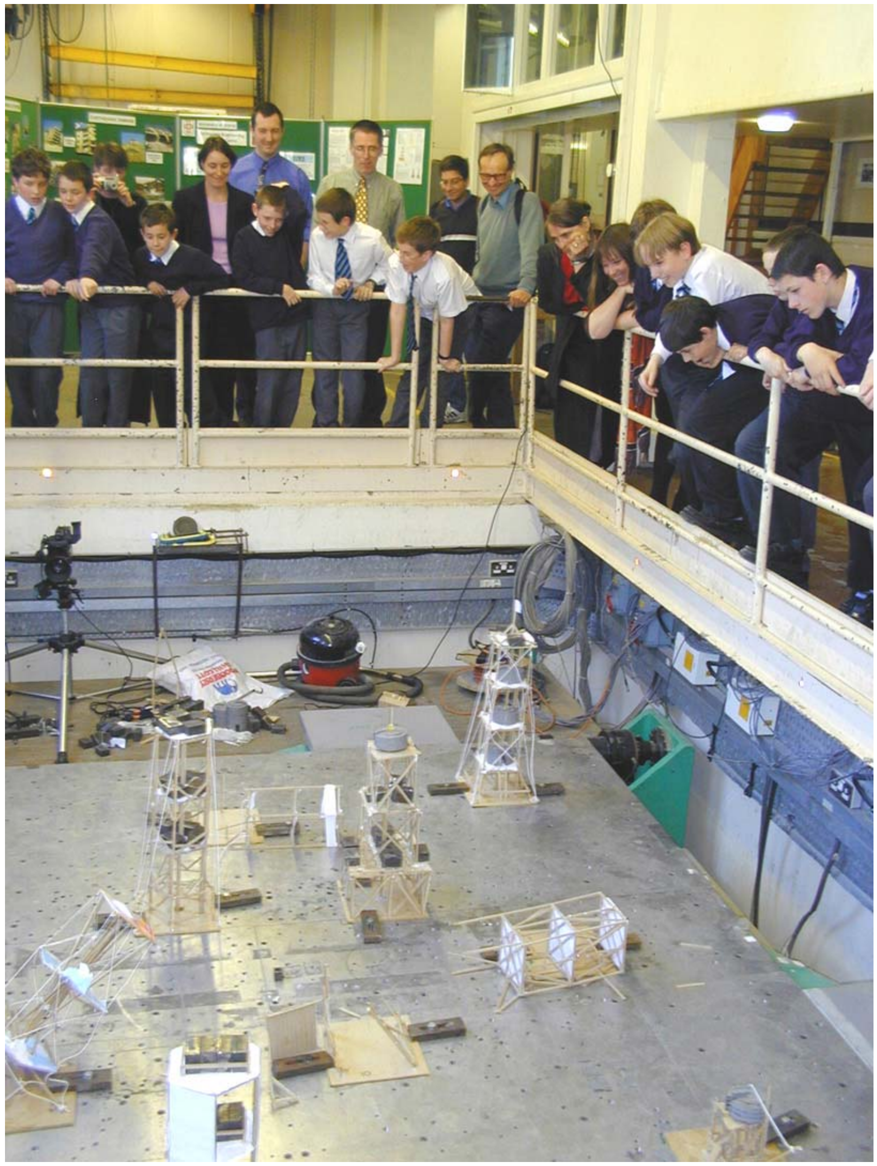


Some of the models made by Rednock school pupils being tested

EERC by running the competition as an undergraduate project in civil engineering.) Thus, the students could observe how buildings with different characteristics do not all respond similarly to the same ground motion. A low amplitude motion was used for the first shake and the amplitude was increased gradually until all of the models had been destroyed.

The winning model was not the last standing model. Instead, to demonstrate to the students, the concept of cost efficiency in designing buildings, the winning model was determined by considering its mass as well as the size of the maximum earthquake it resisted. The "most-efficient" model, the winning model, was the one with the highest "maximum earthquake resisted" to mass ratio.

Overall, the entrants had a good grasp of the idea of bracing their structure against lateral load. Models included MDF and string cross bracing, paper walls which act as tension bracing, and guy ropes. Excepting one entry, all the models survived the first few earthquakes. As would be the case for real buildings, the most carefully constructed models performed best and models with poor joint details and unsymmetrical construction performed less well. Generally, the models with string bracing systems or paper walls behaved best, but these were also some of the better constructed models.



By now many of the model buildings have failed under the gradually increasing earthquake forces

In response to a short questionnaire, some of the reasons for the students designs included "using triangles because they are strong", "copying a honey comb shape because it is strong" and "noticing that the Eiffel Tower was strong, so we built it in that design". All of the students said that the most enjoyable aspect of the project had been building the model, and some added experimenting with different support systems.

Typical building failure in an earthquake

Everyone enjoyed watching their models being shaken on the table and quite a competitive atmosphere developed with much cheering when somebody else's model failed.

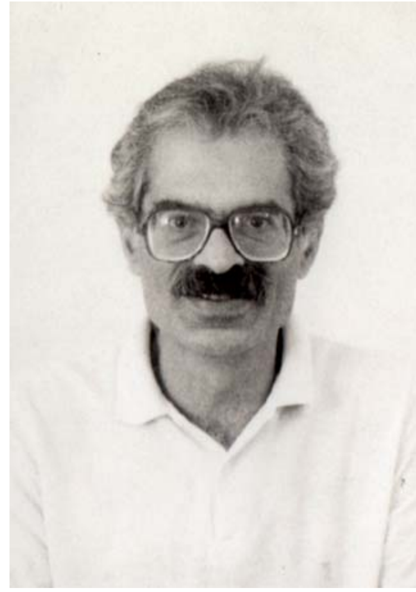
Next year, five Bristol schools have been invited to pilot the complete project, which will include the finished website.

The pilot project will be part-funded by the University's Widening Participation Strategy, which is supporting local state schools' involvement. The project will run from January 2001, with the final taking place at the University in April 2001. Dr Crewe and Dr Daniell will keep in touch with the participating schools during the trial, as they will be looking for feedback on the effectiveness of the website. They will also visit the schools in December with an introduction to the project. This will include a slide presentation of earthquake damage in regions they have visited, a working demonstration of how buildings behave during earthquakes using models and a hands-on activity for the students.

Anyone interested in promoting IDEERS in their local school can find

more details on the web-site at **http://www.ideers.bris.ac.uk**

Dr. Dimitri Papastamatiou



Dimitri Papastamatiou, a long-standing and prominent member of SECED, died in Athens on 4th July 2000, after a short illness. Dimitri was the second person to graduate with a PhD from the Imperial College Engineering Seismology Section (following Dr. S.K. Sarma), taking his doctorate in 1971 under the supervision of Professor Ambraseys. The subject of his thesis was "Ground motion and response of earth structures to strong earthquakes".

Dimitri left Imperial in 1974 and worked until 1980 as Senior Engineer in the Advanced Technology Group of Dames & Moore in London. During this time, he also acted as a UNESCO consultant to the Institute of Earthquake Engineering and Engineering Seismology in Skopje, Yugoslavia. He continued to undertake teaching and research in strong ground-motion and seismic hazard analysis and worked on applications in regional and site-specific seismic hazard assessment for nuclear power plants, industrial installations and residential complexes. Dimitri also participated in a number of field studies of destructive earthquakes in the Eastern Mediterranean.

Between 1980 and 1981, Dimitri was a Director of Geognosis Ltd., in London responsible for the development of numerical codes for static and dynamic analysis of continua. This work included applications in seismic fault studies in El Asnam, Algeria, following the destructive earthquake of 10 October 1980. In 1981, Dimitri established his own specialist consultancy, ***delta pi associates***, in London, of which he was Managing Director until 1988. His work included consulting for the Central Electricity Generating Board and then Nuclear Electric (as a Member of the Seismic Hazard Working Party), British Petroleum and Ove Arup amongst others. During this period, Dimitri was also a consultant to the recently formed Institute for Earthquake Engineering & Engineering Seismology (ITSAK) in Thessaloniki, Greece, and continued to engage in research in strong-motion data acquisition and analysis. He participated in field studies of destructive earthquakes in Greece, including the September 1986 Kalamata earthquake.

Dimitri left London in 1988 with his family to return to his native Greece to take up the post of Senior Lecturer in Engineering Seismology in the Civil Engineering Department of the National Technical University of Athens. In 1994, he was promoted to Associate Professor in the same Faculty, where his work included teaching and research in active tectonics, strong ground-motion recording and analysis, seismic hazard assessment and seismic response of classical monuments. One of his major enterprises at NTUA was the setting up of the Earthquake Field Laboratory, a compact borehole strong-motion array on the island of Cephalonia to collect ground response data in one of the most active seismic areas in Europe. In 1994, he was awarded the T.K.Hsieh award for the 1993 paper "Earthquake response at Grangemouth", published in Géotechnique (vol. 43: pp. 537-553, with co-authors J.W. Pappin, J.A. Richards and M. Sweeney). Dimitri's work also extended well beyond Europe: he participated in the reconstruction of Popayán in Colombia, following the destructive earthquake in 1983, and more recently in an EU-funded project on seismic hazard in El Salvador, to which he brought his unique experience on many aspects of the work, including the installation of a new strong-motion accelerograph network. Dimitri continued to be active in field studies of destructive earthquakes in Greece right up until the time he became ill, and nor did he neglect his connections with the UK, organising joint field trips with the MSc group from Imperial College and maintaining his many professional contacts, distance notwithstanding.

Dimitri Papastamatiou was born in 1941, a scion of a cultured family. His father had been Head of the Geological Survey of Greece and a pioneer in seismotectonics, and his late brother, Nicholas (who, too, sadly died early), was an eminent professor of physics at the University of Milwaukee. Dimitri himself was a combination of erudite engineer and perceptive scientist. Lateral thinking was a hallmark of his research - among his many publications, the 1980 Bulletin of the Seismological Society of America paper "Incorporation of crustal deformation to seismic hazard analysis" (vol: 70, pp. 1321 – 1335) and the 1988 Earthquake Engineering and Structural Dynamics paper "Physical constraints in engineering seismic hazard analysis" (vol 16: pp.967-984, co-author S K Sarma) are recognized by many as significant advances in post-Cornell seismic hazard assessment.

Dimitri leaves to mourn his wife Caroline, whom he met when they both worked for Dames & Moore, and two fine sons, Yannis and Alexis, of whom he was inordinately proud. At his funeral service in Athens, the head of the Civil Engineering Department told mourners that in five days time Dimitri was to have been made full Professor, a recognition he and his family would have treasured, and one that was fully warranted for this accomplished teacher and fine researcher. Just as his scientific thinking was often lateral, so too was his unique and special sense of fun. Many of us will have cherished memories of delightful post-meeting sessions at nearby pubs where, in former days, the indispensable Gauloise cigarettes would be produced, to go with that inimitable wry sense of humour, and the sudden, impulsive gale of laughter that was a special feature of his character. Dimitri was an exceptional human being, and such a thoroughly nice and charming person that he will be greatly missed by the multitude of colleagues and friends he had gathered over the years. The Society extends its heartfelt sympathy to his family in their sad loss.

"Seismic Design & Retrofit of Bridges"

David Doran reports on a seminar on the Seismic Design & Retrofit of Bridges held at Institution of Structural Engineers 22-23 June 2000. The Seminar was jointly sponsored by the French Association for Earthquake Engineering (AFPS), the American Concrete Institute (ACI) and Society for Earthquake and Civil Engineering Dynamics (SECED) and was held in association with the Institution and the l`Ecole des Ponts et Chaussées.

The London presentation followed a similar event held in Paris on 21/22 June 2000. The programme included lessons learnt by EEFIT (UK Earthquake Engineering Field Investigation Team) from recent field visits to Turkey, Taiwan and elsewhere.

The London seminar, which comprised three sessions, was introduced by **Peter Head OBE FREng** (Maunsell). He congratulated **Edmund Booth** for his enterprise in bringing such a major event to the Institution and emphasised the value of networking between like minded specialists. Peter mentioned IABSE conferences he had attended following the Kobe earthquake quoting the emotion aroused by Japanese engineers in admitting they had failed their people. He felt that much was now known about earthquakes and that, provided the lessons learnt were correctly applied, greater safety could be achieved.

SESSION 1: Chairman - Edmund Booth (Consultant)

In his opening remarks, Edmund highlighted the fact that French, American and UK engineers had come together to share their expertise and paid tribute to the particularly warm relationship between France and the UK which had led to the setting up of these seminars.

Darius Amir-Mazaheri then spoke about the *Different Strategies in Seismic Design of Bridges* in which he defined two systems:

- Elastic
- Energy dissipating

The first required modifications, for example, to the geometry, flexibility and material properties of the structure; the latter relied on mechanical damping, sliding systems and the development of plastic hinges. He also emphasised that post-earthquake feed-back often revealed deficiencies in detailing, the most common of which was probably unseating due to insufficient bearing area.

Marcel Cheyrezy, Louis Marracci and **Pierre Loic Veyron** then described the *Saint-Andre Viaduct* in Savoy in SW France. This is a 902m segmental prestressed concrete box girder structure comprising 11 spans varying from 38m to 95m. For architectural and other reasons the 5m dia pier supports are relatively short (max 15m). The continuous, jointless deck is supported on neoprene elastomeric bearings on central piers and sliding pot bearings elsewhere; six visco-elastic damping devices are provided on each abutment. Piers are supported on 4x2500mm dia bored piles; piling was preceded by removal of up to 15 large boulders at each pile position. A design peak ground acceleration of $1.5m/s^2$ was used in the seismic analysis; five accelerograms compatible with the French seismic code spectrum were applied separately in two horizontal directions.

The *Rion-Antirion Bridge*, currently under construction in the Gulf of Corinth, was described by **Jean-Paul Teyssandier, Jacques Combault** and **Alain Pecker.** The basic design parameters for the 2.5km bridge were:

- large water depth (up to 65m)
- deep soil strata of weak alluvium
- strong seismic activity
- possible tectonic movements

The Patras region is highly active so the seismic design is associated with a 6.5 to 7.0 magnitude earthquake originating at a fault 10km away. The response spectrum at seabed level represents a peak ground acceleration of 0.48g; additionally the bridge must accommodate fault movements up to 2m in any direction (i.e. both horizontally and vertically). The chosen solution was to use a cable-stayed central section of five composite steel spans (305m to 560m) and approach viaducts of 378m (Rion side) and 252m (Antirion side) of prefabricated prestressed concrete beam construction. After much debate it was agreed that the four pylons would be supported on the sea bed through a large concrete substructure 90m in diameter and 65m high which would distribute all forces to the soil. Below this structure the weak soil will be improved by 25m/30m long steel tube inclusions driven at regular spacings into more competent ground below. The tops of the tubes are covered with a layer of compacted gravel which acts to restrict the seismic forces transmitted to the structure, by allowing a limited amount of sliding. There is no direct connection between the inclusions and the soffit of the concrete substructure.

In the dynamic analysis the following were considered:

- non-linear hysteretic behaviour of the reinforced soil
- possible sliding of the pylon bases on the gravel beds.
- non-linear behaviour of the reinforced concrete of the pylon legs (including cracking and stiffening of concrete due to confinement)
- non-linear behaviour of cable stays
- non-linear behaviour of the composite bridge deck (including yielding of steel and cracking of RC slab)
- second order effects (or large displacements if any)

SESSION 2: Chairman - Jo Coke (past president, ACI)

Associate Professor David Sanders spoke on *Policy and Methods in a Large Seismic Region (California).* Damage to highway bridges had initiated changes to design and had required substantial retrofit programmes. Whilst major changes could be traced back to the 1930s, the San Fernando earthquake of 1971 started the retrofit programme and amended design procedures. Further changes followed the 1989 Loma Prieta quake. A major feature of retrofit measures was to prevent deck structures from falling off hinge seats and supports.

Investigation of San Fernando revealed that columns contained very little transverse reinforcement and that short dowels had often been used to link main vertical steel to footings. New regulations required improved confinement levels, continuity of main column steel, increased seat lengths and design forces. In the retrofit programme efforts were made to transmit seismic loads to abutments rather than support columns, tall steel rockers were replaced by elastomeric pads and steel plates were installed to provide continuity in steel girders.

After the 1987 Whittier Narrows event (Mag 5.9) Caltrans identified 400 single column bridges as candidates for retrofitting. Many were provided with steel jacket column enhancement and some footings were reinforced. However, before completion of the programme Loma Prieta occurred. A Seismic Retrofit Inventory (SRI) revealed 12000 local and 12000 state bridges at potential risk; on reassessment these were reduced to 4000 and 7000 respectively as candidates for retrofitting. High risk bridges were identified as those:

- with rigid outrigger bents
- with leased space below
- spanning faults
- on critical routes or spanning critical routes

The Californian prioritisation method takes into account 12 factors (e.g. vulnerability, abutment type, seismicity, traffic exposure, etc) and each factor is assigned a value between 0 and 1. Each is then multiplied by a fixed weighting factor and added together to determine the risk value. To economise construction cost/bidding, detours and delays, bridges were clustered together before evaluation.

The 1994 Northridge event (Mag 6.6) caused further damage although bridges retrofitted since Loma Prieta performed well. However AASHTO and Caltrans were under renewed pressure to accelerate retrofit programmes and improve design procedures.

Nigel Priestley then spoke on *Seismic Evaluation & Retrofit of Bridges.* For concrete columns he illustrated techniques for steel and concrete jacketing and the use of composite materials. It was more effective to encase square or rectangular columns by circular or oval shaped jackets. Vertical reinforcement should be securely doweled into footings. Jacketing could significantly increase stiffness but link beams constructed between columns could also enhance strength and stiffness. Prior to jacketing it was essential to check that existing reinforcement was not fractured, buckled or significantly deformed; that crack widths were not excessive and that core concrete was intact.

Column to beam joints were often badly detailed and could be relieved by joint force reduction or enhanced by prestressing and/or jacketing. In extreme cases it was necessary to replace joints. Movement joints could have seat extensions built or restrainers applied; consideration could also be given to applying prestress to lock the joints completely. With footings it might be necessary to accept some rocking or to enhance with linked piling to prevent uplift. Footing sizes could be increased by overlays (with or without new piles) and forces reduced by the addition of grade link beams.

Dr Frieder Seible completed this session by giving a presentation on the *Design and Retrofit of Long Span Toll Bridges.* There were 10 existing and 3 proposed major toll bridges in California; the Golden Gate Bridge (1937) being the most famous. The proposed retrofit measures for Golden Gate included:

- strengthening saddle/cable connections
- strengthening tower bases with additional steel plates/angles
- confinement of concrete pier tops with prestressed steel tendons
- installation of dampers at several locations along the deck
- strengthening of pylons by internal reinforcement
- strengthening of cable anchorages by internal reinforcement to housings

Amongst other things the Benicia-Martinez bridges will have bearing replacement and pier strengthening.

A new facility at the University of California, San Diego (UCSD) has been commissioned for the testing of large bearings. This can provide six degrees of freedom and can apply force in the longitudinal (8.9MN), transverse (4.5MN), and vertical (53.4MN) directions.

New bridge designs would require:

- clear identification of inelastic mechanisms
- to be inspectable and repairable without traffic interruptions
- large scale proof testing to validate inelastic response of all potential mechanisms
- capacity protection of all other elements

Design checks on existing and proposed bridges should include:

- An independent global response analysis
- A Caltrans design review
- An independent seismic safety review
- A value analysis on concepts and construction

Dr Seible concluded by presenting a summary of the Caltrans Bridge Seismic Safety Programme the main points of which were:

- 4662 bridges of a population of 25000 had been identified in need of retrofitting at a potential cost of $6073million
- the estimated completion date was August 2003

SESSION 3 Chairman - David Mackenzie (Flint & Neill Partnership)

Joe Barr reviewed *Recent Advances in Earthquake Engineering* by listing the following:

- analysis input: better understanding of regional seismic characteristics (shaking and fault/tectonic movements)
- boundary conditions: better understanding of soil and soil/structure response
- soil improvements: past failures have driven the development of better techniques to control loss of shear strength during earthquakes
- structural design: better understanding of structural response and the need for

robustness, ductility and for a clearly defined chain of strength (capacity design)
- detailing: failures have emphasised the importance of detailing
- maintenance: commitment to maintenance of design assumptions to avoid changing the structure or its boundary conditions

He stressed the need to support organisations such as EEFIT and the Earthquake Field Training Unit (EFTU) so that feed-back could be improved. Joe also emphasised the fact that recent events (e.g. Kobe, Northridge & Taiwan) had revealed some devastating surprises. In particular he described how the Duzce event in Turkey (1999) had caused an inactive fault to break beneath a 2.5km viaduct, opening a 1.5m-2m displacement across the fault.

Alain Capra, Peter Whatling, and Marc Wastiaux then spoke about the completed 17.3km *Second Tagus Crossing* in Portugal for which earthquake considerations have played a major part. The main structure is a cable-stayed bridge of 420m span with side spans of up to 72m. Because of the high level specified earthquake motion (0.5g peak ground acceleration) it had been necessary to install special devices such as:

- hydraulic dampers
- elasto-plastic dampers
- shock transmission units
- large displacement expansion joints
- large displacement sliding bearings

The 150m high H-shaped pylons to the cable-stayed span were founded on large caissons designed to resist ship impact; the caissons in turn, were supported on 44 No 2.2m dia piles. The 31m wide deck consists of 2.6m deep RC beams supporting 4.5m deep transverse steel beams. The deck is not connected to the pylons in order to increase the natural period of vibration of the bridge.

Zygmunt Lubkowski and **Mike Oldham** then made a presentation of the design competition winning proposal for the *Metsovitikos Bridge* in Greece. This is an elegant (557m) span suspension bridge with splayed hangers which crosses a steep sided valley. The supports for the main cables reflect the complex geological conditions on either side and provide a mixture of gravity and rock anchor systems. Potential landslips required the SW anchor to be relocated. In the seismic design a 235 year return period was used for the Functional Evaluation Event (FEE) (elastic design, minimal damage) and a 1139 year return period for the Safety Evaluation Event (SEE) (elastic design, repairable damage). The bridge is designed for a 120 year design life.

Peter Whatling made the final presentation featuring the design studies for the proposed *IZMIT Bay Bridge* in Turkey. This forms part of a planned 47km section of the Istanbul to Izmir motorway. The employers requirements were not specific and bidders had to develop their own detailed design criteria. In addition to the normal operational loading criteria the bidding consortia investigated;

- earthquakes
- ship impact
- wind climate

Two levels of earthquake resistance were considered:

- a FEE corresponding to a SLS representing an event with a high probability of occurrence during a 120 year design life. This was chosen to be a 50 year return period event, and elastic behaviour with minor structural damage was required.
- a SEE corresponding to an ULS representing an event with a low probability of exceedence during the design life. A 1000 year return period event was chosen, and the requirement was to maintain structural integrity, albeit with significant structural damage.

Studies in conjunction with Professors Erdik and Aydinoglu of Bogazici University, Istanbul had deduced values peak ground accelerations for the design return periods of 50 and 1000 years as 0.18g and 0.65g respectively.

The chosen structure was a long span suspension bridge (main span 1688m) with 560m side spans. This structure offers advantages, including inherent ability to resist earthquakes, minimal obstruction to shipping, minimal number of supports and low impact on the marine environment.

Design studies were carried out for the following:

- ship impact - 155000 DWT @ 4knots; 80000DWT @ 10knots: global point load of 175MN and a local effect of 350MN on an area of 3mx3m -for which a heavy robust structure was required
- seismic effects - for which a minimum weight structure was desirable with small submerged volume to minimise hydrodynamic mass

This led to a proposal for a pylon structure using a 1.5m thick RC shell acting compositely with a ring beam-stiffened structural steelwork inner lining.

Because of legal and political difficulties it was uncertain if or when the scheme would proceed.

The seminar concluded with a round table discussion chaired by **Roger Lacroix** in which several participants expressed hopes and ideas for the future. French and American engineers spoke about revisions to their procedures that should ensure greater safety to both life and structure in the event of future earthquakes. It was announced that another joint US/French/UK seminar on some aspect of the seismic design of bridges would be held in the USA during 2003, and suggestions for topics were invited.

During the course of the seminar many questions were raised from the floor including:

- detailing of seatings
- steel versus concrete bridges
- welding failures
- brittle castings
- buckling of piers
- groundwater effects
- cost and levels of damping
- friction pendulum systems
- embankment failures
- costs of remediation versus replacement
- cost benefits of better detailing
- excessive and unrealistic length of return periods
- jacketing of square and rectangular columns
- liquefaction
- design criteria for isolators
- Caltran/AASHO retrofit code

- pier replacement
- out-of-plane suspension bridge hangers

The seminar ended with mixed feelings of optimism (that the state of the art was advancing) but caution that new events continued to surprise seismic specialists. There were, however, strong feelings that with good attention to detail (particularly confinement to concrete and provision of generous deck seatings) and more frequent use of 'displacement based' analysis methods (which account explicitly for the extent and distribution of inelastic deformations) then the worst of problems could be avoided.

In his concluding remarks **Edmund Booth** warmly thanked all participants. He thought the two venue event had been a success and echoed the remarks of others that a follow up seminar should be held in 3 years time. He also stated that the printed proceedings would be available in the autumn and referred to the on-line discussion facility that all are welcomed to join.

An online discussion on this seminar has been set up by SECED on http://www.mailbase.ac.uk/lists/seismic-bridges/ SECED members (and their colleagues) are cordially invited to use this facility to exchange ideas on the seismic design and retrofit of bridges.

BLADE – Bristol Laboratory for Advanced Dynamic Engineering

Bristol University wins £15m to allow the development of a unique, cross-disciplinary laboratory for large scale, multi-axis, structural dynamics experiments

The Faculty of Engineering at Bristol University has recently been awarded £15m to form the Bristol Laboratory for Advanced Dynamic's Engineering (BLADE) in the Queen's Building. The award came from the Higher Education Funding Council for England, the Office for Science and Technology and the Joint Infrastructure Fund, against competition from other Universities. The total funding given to Engineering and Materials research in the UK through this scheme has only been £59m and Bristol is clearly delighted to have received over a quarter of the national funding. The awards have been made, "To enable world class UK scientists to remain at the leading edge of research". The initiative at Bristol has already attracted international interest and will provide a unique Dynamics Research Facility in the UK.

The concept for BLADE is to provide the essential research infrastructure for the development and application of sound principles in non-linear dynamics. This will be achieved by integrating and advancing the state-of-the-art in materials, component and structural assemblage testing. Using Bristol's acknowledged world-class research in the control of dynamic sub-structuring experiments, BLADE will enable real engineering components, ranging from large sections of bridges, buildings, aircraft fuselages and wings, through to complete helicopter rotor assemblies, small electro-mechanical devices and material specimens, to be subjected to accurate laboratory representations of in-service dynamic loads.

BLADE will greatly enhance an ongoing programme of research to reduce world-wide suffering and economic loss arising from engineering performance failures. Amongst the most significant problems encountered are in machine failure and the impact of earthquakes upon man-made structures. Key to this research is the accurate modelling and testing of the inherently non-linear dynamic behaviour of materials, machines and structures at large and prototype scales.

BLADE will involve the reconfiguring and refurbishment to modern standards of the Faculty of Engineering's Queen's Building, which dates from 1951, but was designed in the 1930's. Two inner courtyards will be roofed over to create 4-storey test halls. One test hall, called the Structural Dynamics Laboratory, will accommodate an adaptable structural dynamics test facility orientated towards smaller to medium sized testing of components ranging from aircraft wing boxes and automotive 'bodies-in-white' to the instrumentation cubicles used in earthquake zones. The second test hall will be equipped with a strong floor and reaction wall for general dynamic testing of large structures, for example a whole helicopter airframe or reservoir intake tower. This second hall will also include the Earthquake Engineering Laboratory, into which the EPSRC Earthquake Simulator (shaking table) will be relocated from its current position in a low headroom laboratory in the building. The simulator's new accommodation will be on a par with other laboratories in Europe, the USA and Japan. Between the two test halls, reflecting its central unifying role, will be a new Advanced Control and Test Laboratory (ActLab). This will supply the advanced experimental control techniques to be employed in the two test halls. Encompassing all these laboratories will be the refurbished and reorganised Materials Test Laboratories. The overall reorganisation will integrate the current separate laboratories of the Aerospace, Civil and Mechanical Engineering departments at Bristol in keeping with the growing integration of their research activities in the materials, control and structural dynamics fields. It will also rationalise the supporting workshop facilities, and create new space to accommodate cross-disciplinary research staff.

The new facility will be equipped with modular test rigs and actuation devices. This will allow as much flexibility as possible for the testing of non-homogeneous materials and multi-degree of freedom systems where single axis loading does not exhibit the cross coupling effects demonstrated by these complex systems. The importance of creating new facilities for this type of testing can best be seen when considering the issues surrounding performance-based engineering design.

The essence of performance-based design is to ensure that the capacity of the structure exceeds the performance demands placed upon it, with suitable allowances being made for uncertainties and acceptable risks. The capacity of a structure depends on material properties, component strengths, and how the structural configuration distributes the load through the structure. In dynamic cases, the demand is not only dependent on the external loading mechanism, but also on how the structure responds to that loading. The structural response is also a function of the material properties and structural configuration, which therefore feature on both sides of the capacity versus demand equation. This gives the design engineer the opportunity to control both the capacity *and* the demand through the conceptual and detailed design of the structure.

Design procedures for elastic structures are well established. The demand is controlled by the natural frequency of the structure, which is readily determined from a knowledge of the latter's mass, stiffness and damping. By ensuring that the natural frequency is located well away from the dominant frequencies of the input forces, and that the dynamic response is limited through appropriate and achievable levels of damping, the knowledgeable engineer can confidently control the design and produce an effective, economic solution.

In contrast, design procedures are not well established for non-linear problems. Currently, engineers are armed with very powerful dynamic analysis tools, such as finite element and finite difference computer codes, with which they can predict the non-linear response of very complex structures to very complex loadings. However, the value of such predictions is questionable in many cases, since our understanding of non-linear dynamic behaviour is not as mature as the available analytical tools might suggest. The implementation and interpretation of non-linear response analyses using these tools often tend to be extrapolated from elastic analysis practice. However, such practice does not cater for the effects of phenomena such as bifurcations and chaos in the dynamic response. These can lead to unpredictability due to small parameter variations that are within the tolerances of measured material properties and the like, especially for earthquake and other types of extreme loading. So far, theoretical non-linear dynamics research has tended to study these phenomena using grossly simplified structural systems subjected to regular, periodic loads, which are rarely encountered in engineering practice. Many useful fundamental features of these phenomena have been identified through such studies, the most important of which, from a design point of view, is parameter sensitivity. However, few fundamental non-linear dynamics studies have addressed real engineering structures in order to ascertain how the findings from simplified structures translate to them. This has left a major gap in our knowledge that must be bridged if engineers are successfully to exploit non-linear dynamic behaviour in design. BLADE will help researchers at Bristol to build this bridge through the observation of actual engineering components and materials as they respond to accurate simulations of in-service dynamic loads. These observations, in turn, will lead to the development and validation of reliable analytical and design techniques.

Typical non-linear mechanisms of prototype structures in many branches of engineering are usually associated with material behaviour under high stresses, and frictional and lack-of-fit effects in joints. The latter are often the main sources of damping. Such mechanisms and conditions cannot, in general, be reproduced accurately at small model scales. Therefore, small scale modelling of complete structures has severe limitations with respect to its application in engineering design. On the other hand, dynamic testing of complete civil engineering, aerospace or large mechanical structures to extreme loads is at best very expensive, if indeed it is feasible at all. Nevertheless, accurate dynamic testing at large to prototype scales is essential if modern numerical analysis computer codes, and the models based on them, are to be validated for safe, non-linear, design.

Dynamic sub-structuring offers a viable and effective solution to this problem, by enabling a material specimen, component or sub-assembly to be loaded as if it were installed in the complete structure. The remainder of the structure is modelled numerically in the computer control system of the test rig, which calculates the correct interaction forces to be applied to the test specimen in real-time. True dynamic sub-structuring creates the opportunity to investigate the physical non-linear dynamic behaviour of parts of real engineering structures under realistic extreme loadings at prototype or very large scales. It can never fully recreate in-situ prototype conditions, since it relies, in part, on an abstract numerical model, but, provided that model is properly validated, the dynamic sub-structuring approach can be a powerful tool.

A typical use of dynamic sub-structure testing in the field of earthquake engineering research is the test of a structure where soil-structure interaction must be included. Currently such a test would require the modelling of a structural model on a large soil deposit. Performing such a test at a large enough scale to realistically model the structure is likely to be difficult, if not impossible. However, with dynamic sub-structure testing the large soil deposit would be modelled within an FE programme which is incorporated within the control of a shaking table. A bedrock earthquake motion can then be applied to this FE model and this FE model then controls the motion of the shaking table. The table therefore behaves is if it were at the top of the soil deposit applying the appropriate motion to the structure mounted on the table. Force transducers under the model provide the foundation force feedback into the soil model to complete the soil-structure interaction. In this way a larger scale test of the structure is possible.

For more information about BLADE, or other research and development facilities within the Faculty of Engineering at Bristol please contact the BLADE Project co-ordinator David.Smith@bris.ac.uk

An artists impression of one of the new testing halls that will be available for large-scale dynamics testing within BLADE

Graduate School in Seismic Engineering

A new international postgraduate school in Earthquake Engineering will open in January 2001. The school will be based at the University of Pavia in northern Italy and will offer both Masters and Doctorate degrees in Earthquake Engineering. The idea behind the international school is to bring together leading academics in Earthquake Engineering within a single programme, with intense courses running consecutively rather than schedule of parallel courses running for full semesters. Courses will run over six weeks with two-week overlaps.

The faculty of the International Graduate School come from Universities throughout the world, including the University of Illinois at Urbana-Champaign, MIT, the University of California at San Diego, Stanford University, the University of Tokyo and the Tokyo Institute of Technology, as well as Imperial College from the UK. Amongst the illustrious names in the faculty are Professors Abrams, Faccioli, Fardis, Kawashima, Nakashima, Priestley, Sieble and Veneziano. The Director of the School is Professor Michele Calvi from the University of Pavia.

Tuition fees for the Masters Course have been set at € 6,000 per year. Subsidised accommodation is offered at the Collegio Volta in single rooms with bathrooms for € 250/month, including meals. A limited number of scholarships is being offered by the Graduate School for applicants to the Masters course.

Information regarding the Graduate School, which has the acronym ROSE (Reduction of Seismic Risk) can be obtained from the Secretariat at ROSE School, Collegio Alessandro Volta, Via Ferrata, 27100, Pavia, Italy. Tel: +39-0382-548735, Fax: +39-0382-528422, email: rose@gndt.unipv.it, web site: http://spadino.unipv.it/rose.htm.

Julian Bommer

Membership of ICE Opens Up

SECED, as all of our members know, is an Associated Society of the Institution of Civil Engineers, one of 14 such learned societies that operate with the support of the Institution and a base at One Great George Street in Westminster. The Associated Societies of the ICE, including the Wind Engineering Society, the British Dam Society, the British Geotechnical Association, the British Nuclear Engineering Society and the Transport Planning Society, represent professionals working in specialised areas that a few years or decades ago may have been considered beyond the scope of Civil Engineering. The ICE is currently effecting important changes in its operation that reflect the growing awareness of the fact that Civil Engineering is a very broad profession, encompassing all those working in the built environment and its interface with the natural environment. The Institution now defines the profession as "*engineering the quality of life for a developing global population*".

In changes that are taking place within the ICE are aimed at opening up Membership to include many professionals who would previously have been excluded by the narrower definition of the Civil Engineering profession. One group of professionals who in particular will now find it possible to obtain Membership of the ICE are those within the Associated Societies, not least amongst them members of SECED. The ICE has produced a booklet, entitled "Developing today's professionals for tomorrow's challenges", to explain the changes and the new routes to Membership. The cover of the new booklet declares that "*Civil engineering has no boundaries*". Copies can be obtained by writing to Institution or by calling the Membership Division Help Desk on 020-7665-2200/2135. Alternatively, send an e-mail request to membership@ice.org.uk or visit the Institution's web site at http://www.ice.org.uk.

Julian Bommer

"An Introduction to Wind and Earthquake Dynamics"

More than 35 attended this short course held at the IStructE on 20 June 2000 to learn about modern methods of dynamic structural analysis.

A broad spectrum of people from many different backgrounds attended this course, sponsored by SECED, WES and the IStructE, which introduced the basic principles of wind and earthquake engineering. The course was based on the SECED / WES guide "*Dynamics – An Introduction for Civil and Structural Engineers*" and covered the basic concepts and methods in structural dynamics as well as applications in wind and earthquake engineering. Analysis methods, codes of practice, and design concepts were all well covered and the course included various examples of the practical analysis of structures.

After a short introduction by Edmund Booth, Dr Martin Williams outlined the basic concepts of structural dynamics. Professor Tom Wyatt then discussed the various issues surrounding the aerodynamic stability of bridges and chimneys, and delved into the field of stochastic analysis of wind loading.

In the afternoon, Edmund Booth and Martin Williams introduced the principles behind earthquake engineering and seismic analysis.

At the end of the course all participants were given an extensive list of references and other source material for further study.

The course was enjoyed by all who attended and we were given an excellent insight into the work of specialists in the fields of wind and earthquake engineering.

Stephen Bright
Bristol University

MCEER report links rapid construction to devastation in last year's Turkish earthquake

Upsurge in development may have compromised effectiveness of modern seismic building codes

Rapid population growth and resulting development in Turkey's Kocaeli province were main factors in the large-scale devastation and loss of life in last year's earthquake, according to a report by the University at Buffalo's Multidisciplinary Centre for Earthquake Engineering Research (MCEER). Population in the earthquake region grew by 26 percent between 1990 and 1997, resulting in an upsurge in construction and unregulated building, says the report.

The August 17, 1999 earthquake killed more than 17,000, and injured almost 44,000 people. It damaged 214,000 residential units and 30,500 business units, displacing more than 250,000 people, according to official Turkish government estimates.

"Rapid development in the Marmara region overwhelmed government's ability to monitor construction, and led to unregulated building, resulting in inadequate lateral force systems in buildings," says Charles Scawthorn of EQE International, Inc., the report's editor. This, he says occurred in spite of Turkey's "very modern" building code, which contains requirements for earthquake-resistive construction.

The finding underscores the influence of societal factors on the implementation of effective earthquake engineering and construction principles.

The 190-page report, titled "The Marmara, Turkey Earthquake of August 17, 1999: Reconnaissance Report," details findings from field investigations by several MCEER researchers, following the magnitude 7.4 earthquake. It represents an interim earthquake engineering assessment of the natural, built and social environments following the earthquake.

It contains observations on the earthquake and its impact, including the seismology of the region, geotechnical failures, damage to industrial, commercial, and residential structures; damage to electrical, gas, water and transportation systems; emergency response and search and rescue operations; and post-earthquake restoration efforts.

It also includes a section titled "The Marmara Earthquake: A View from Space," detailing high-level reconnaissance investigations exploring the use of advanced technologies such as satellite imagery, differential global positioning systems and in-field GPS-GIS interfaces for post-earthquake damage assessment and disaster management.

The Marmara earthquake struck early on the morning of August 17, 1999, along the Anatolian fault in the north-western region of Turkey. Epicentered approximately 11 km south-east of the industrial city of Izmit, the earthquake lasted 45 seconds and was felt over thousands of square miles in the country's most densely populated region. Commercial and residential buildings from Adapazari to Istanbul collapsed.

Estimates of property losses range from $3 to $6.5 billion, the equivalent of 1.5 to 3.3 percent of Turkey's Gross National Product.

The report is available from the Multidisciplinary Centre for Earthquake Engineering Research (MCEER), University at Buffalo, Red Jacket Quadrangle, Buffalo, New York 14261; Tel: 716-645-3391, ext. 126; fax: 716/645-3399; Email: mceer@acsu.buffalo.edu; or via the centre's Web site at http://mceer.buffalo.edu. Cost is $35.00 (U.S. funds), plus shipping and handling.

MCEER is a nationwide consortium on earthquake engineering research, headquartered at the University at Buffalo. Funded principally by the National Science Foundation (NSF), the state of New York and the Federal Highway Administration, the centre was established by the NSF in 1986 as the National Centre for Earthquake Engineering Research. The centre's mission is to reduce earthquake damage and losses through multidisciplinary team research and the application of advanced technologies that improve engineering, pre-earthquake planning and post-earthquake recovery strategies.

The Earthquake Engineering Research Centre (EERC) at the University of Bristol achieves recognition as a Marie Curie Training Site in Earthquake Engineering.

In its fifth Framework Programme (2000-2003) the European Commission (DGXII) has recognized EERC Bristol as a Marie Curie Training Site in earthquake engineering. Within the awarded contract, opportunities are provided for researchers working for a higher degree in a university or equivalent institution of a Member or Associated State, to spend between 3 and 12 months at EERC Bristol as part of their higher degree studies. A subsistence allowance of 1200 Euro per month will be paid for the researcher, plus a travel allowance of 100 Euro per month. There will be no charge for the use of experimental and other facilities at EERC Bristol.

Candidates for these Marie Curie training awards must be less than 35 years of age, an allowance being made for compulsory military or civil service or for childcare. A policy of equal access opportunities will be applied between men and women.

It is suggested that intending candidates for these awards should first consult their research supervisor/advisor, for information about the facilities which EERC can offer, in particular whether experience of these facilities can enhance the quality of their proposed research.

Further information can be obtained from either

Prof. R T Severn or Dr C A Taylor at the
Earthquake Engineering Research Centre,
Queen's Building, University Walk,
Bristol BS8 1TR,
Tel: +44 (0)117 9287708, Fax: +44 (0)117 9287783,
E-mail Colin.Taylor@bristol.ac.uk or Janet.Davies@bristol.ac.uk
Web-site: http://www.cen.bris.ac.uk/civil/research/eerc/index.html

Pacific Earthquake Engineering Research Centre (PEER) News

The Pacific Earthquake Engineering Research Centre have informed us that they will no longer be able to continue sending copies of the PEER Centre News for distribution to SECED members. The Newsletter is however available on-line at www.eerc.berkeley.edu/

If any SECED members would still like to receive a printed copy of the Newsletter they can submit their request to the publications department by
fax (510) 231-9471.

NOTABLE EARTHQUAKES JANUARY - MARCH 2000

Reported by British Geological Survey

YEAR	DAY	MON	TIME UTC	LAT	LON	DEP KM	MAGNITUDES ML	MB	MS	LOCATION
2000	07	JAN	22:16	55.09N	3.63W	10	1.8			DUMFIES, D & G
			Felt Tinwald with an intensity of 2 EMS							
2000	08	JAN	11:59	23.19S	69.99W	33		5.8	5.9	NORTHERN CHILE
			Power outages occurred throughout Calama. Felt throughout northern Chile.							
2000	08	JAN	16:47	17.02S	174.22W	183		6.5		TONGA
2000	14	JAN	23:37	25.60N	101.10E	33		5.6	5.9	YUNNAN, CHINA
2000	19	JAN	13:56	6.38S	148.81E	33		6.0	7.0	NEW BRITAIN REG, P.N.G
			Five people were reported killed, approximately 1,500 people injured and 31,000 houses were damaged or destroyed in Yaoan County.							
2000	26	JAN	20:55	24.27N	103.78E	33		5.1	4.4	YUNNAN, CHINA
			At least two people were injured and houses and roads were damaged in the epicentral area.							
2000	28	JAN	14:21	43.01N	146.88E	62		6.7		KURIL ISLANDS
2000	02	FEB	22:58	35.25N	58.18E	33		5.3	5.3	NORTHERN IRAN
			One person was killed, at least 15 were injured and damage occurred throughout the Bardeskan-Kashmar area.							
2000	06	FEB	11:33	5.66S	150.88E	33		6.6	6.6	NEW BRITAIN REG, P.N.G
2000	12	FEB	08:51	55.91N	5.31W	9	2.7			KAMES, STRATHCLYDE
			Felt throughout Kames with maximum intensities of 5 EMS.							
2000	20	FEB	09:31	56.20N	4.10W	5	2.3			DOUNE, CENTRAL
			Felt throughout Doune with maximum intensities of 4 EMS.							
2000	25	FEB	01:43	19.57S	173.83	33		6.2	7.1	VANUATU ISLANDS REGION
2000	26	FEB	08:11	13.83N	144.74E	122		6.1		MARIANA ISLANDS
			Several people were slightly injured on Guam. Minor damage occurred at Santa Rita.							
2000	26	FEB	18:24	9.49N	78.64W	65		5.7		COAST OF CENTRAL CHILE
			Felt strongly throughout Panama City.							
2000	03	MAR	22:09	7.31S	128.64E	140		6.4		BANDA SEA
			Felt throughout Darwin Australia.							
2000	03	MAR	22:22	6.77S	143.75E	10		6.3	6.6	PAPA NEW GUINEA
			Felt in the Lake Kutubu area.							
2000	21	MAR	05:26	3.10N	128.08E	103		6.1		HALMAHERA, INDONESIA
2000	28	MAR	11:00	22.36N	143.68E	119		6.8		VOLCANO ISLANDS REGION

Issued by Bennett Simpson, British Geological Survey, April 2000

Forthcoming Events

27 September 2000
Non-linearity and Earthquake Engineering
ICE 5.30pm

25 October 2000
Seismic Evaluation of Dams

29 November 2000
Seismic Behaviour of Buried Pipelines and Structures

31 January 2001
Performance Based Design

28 February 2001
Seismic Upgrade of Industrial Plant

28 March 2001
Probabilistic Safety Assessment in the Nuclear Industry

25 April 2001
This Year's Earthquake

23 May 2001
The Mallet-Milne Lecture : James Jackson
"*Living with Earthquakes: Know Your Faults*"

Contents

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. Copy typed on one side of the paper only 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. Diagrams and pictures may also be sent by Email (GIF format is preferred).

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 Geophysical 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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