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A Summary of Earthquakes in 1997

David Galloway and Alice Walker present a summary of seismic activity during 1997

Overseas

The year 1997 was not exceptional in terms of worldwide earthquakes. There were no 'great' earthquakes (magnitude over 8.0), six 'major' earthquakes (magnitudes between 7.0 and 7.9) and 74 'strong' earthquakes (magnitudes between 6.0 and 6.9). These numbers are less than the long-term averages for these magnitude ranges, which are 1, 18 and 120, respectively. The number of people killed by earthquakes during 1997 was 2,919 against a long-term average of 8,700 (Table 1). This was mainly due to the larger 'major' earthquakes occurring in remote, sparsely populated areas (Figure 1).

The most disastrous earthquake during the year, with a magnitude of 7.3 Ms, occurred on 10 May in Northern Iran. It caused the deaths of at least 1,572 people, injured 2,300 more, destroyed or damaged over 16,000 homes and left over 50,000 homeless in the Birjand-Qayen area. Several landslides were reported from this same area. Damage was also reported from the Herat area of Afghanistan. Another earthquake, with a magnitude of 4.5 Ms, occurred three days later, 40 km to the south east, killing one person and destroying several houses in Khunik Sar. The most notable event in northern Iran, historically, was the magnitude 7.3 Dasht-e-Bayez earthquake of 1968, which resulted in the deaths of 12–20,000 people.

The year started off with a destructive earthquake, which caused extensive damage, on 9 January. It had a magnitude of 5.8 Ms and destroyed or damaged over 410 homes and buildings in the Dzhergetal area, Kyrgyzstan; no

Table 1. Earthquakes causing deaths in 1997

DATE	LATITUDE	LONGITUDE	MAGNITUDE	LOCATION	DEATHS
11 January	18.22 N	102.76 W	6.9 Ms	Mexico	1
21 January	39.47 N	77.00 E	5.8 Ms	Southern Xinjiang	12
04 February	37.66 N	57.29 E	6.8 Ms	Turkmenistan/Iran	88
27 February	29.98 N	68.21 E	7.3 Ms	Pakistan	60
28 February	38.08 N	48.05 E	6.1 Ms	Armenia/Iran	965
01 March	39.42 N	76.84 E	5.5 Ms	Southern Xinjiang	2
19 March	34.87 N	71.62 E	4.9 Mb	Pakistan	15
11 April	39.53 N	76.94 E	6.1 Ms	Southern Xinjiang	9
10 May	33.82 N	59.81 E	7.3 Ms	Northern Iran	1,572
13 May	33.47 N	59.89 E	4.5 Ms	Northern Iran	1
13 May	36.41 N	70.95 E	6.1 Mb	Hindu Kush region	1
21 May	23.08 N	80.04 E	6.0 Mb	Southern India	38
09 July	10.60 N	63.49 W	6.8 Ms	Venezuela	81
21 July	26.86 S	26.62 E	5.0 Mb	South Africa	15
26 September	43.05 N	12.88 E	5.6 Ms	Central Italy	5
26 September	43.08 N	12.81 E	6.0 Ms	Central Italy	6
28 September	3.78 S	119.73 E	5.6 Ms	Sulawesi, Indonesia	17
15 October	30.93 S	71.22 W	6.8 Ms	Chile	8
21 November	22.21 N	92.70 E	5.9 Ms	India/Bangladesh	23

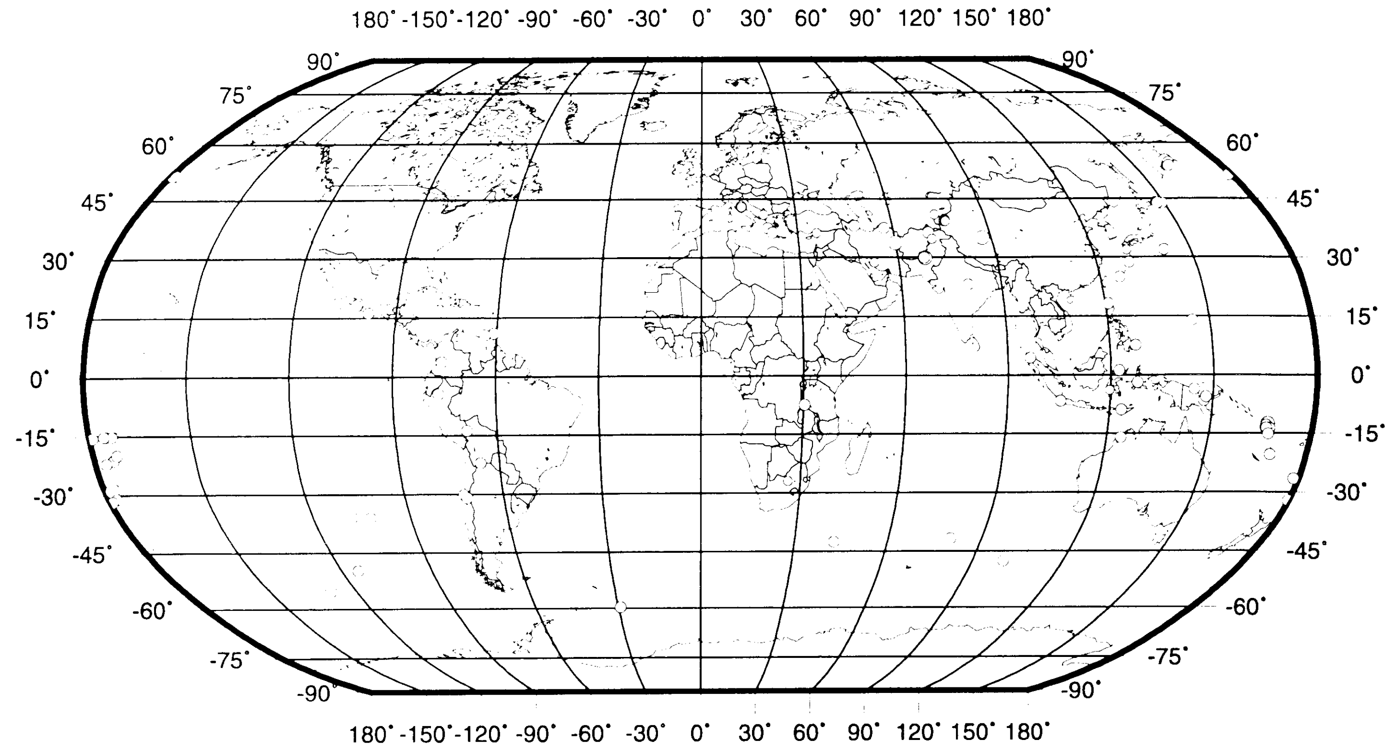


Figure 1. Notable world earthquakes of 1997

Magnitude Key

○ **7.0 to 7.9**

○ **6.0 to 6.9**

○ **4.0 to 5.9**

casualties were reported. Two days later, on 11 January, a magnitude 6.9 Ms earthquake killed one person and caused extensive damage in the Arteaga region of Michoacan, Mexico. It was felt throughout Michoacan and in Mexico City.

Several fatal and damaging earthquakes occurred in Southern Xinjiang, China, during the year. The first, on 21 January, with a magnitude of 5.8 Ms, killed 12 people, injured 40 more, destroyed and damaged some 31,000 homes, left several thousand homeless and killed some 4,000 livestock in the Jiashi Area. The others occurred on 1, 5, 6 March and 11 April, with magnitudes of 5.5, 5.9, 5.8 and 6.1 Ms, respectively. A further 11 people were killed, 118 more were injured, thousands of buildings were destroyed leaving over 100,000 homeless and losses of over 11,000 livestock as a result of these earthquakes.

On 22 January, in the Antakya region of Turkey, a magnitude 5.4 Mb earthquake injured 5 people and damaged 10 houses in the epicentral area.

A 'strong' earthquake, with a magnitude of 6.8 Ms, occurred in the Turkmenistan-Iran border region on 4 February. It killed 88 people, injured 2,000 more and either destroyed or damaged over 16,000 homes in the Bojnurd-Shirvan area resulting in damage estimates of over $30 million.

On 27 February, the second 'major' earthquake during the year, with a magnitude of 7.3 Ms, occurred in Pakistan. Sixty people were killed, hundreds more injured, hundreds of cattle were killed and over 500 houses were destroyed, leaving thousands homeless in the Harnai-Sibi and Quetta areas. It was felt throughout much of central Baluchistan.

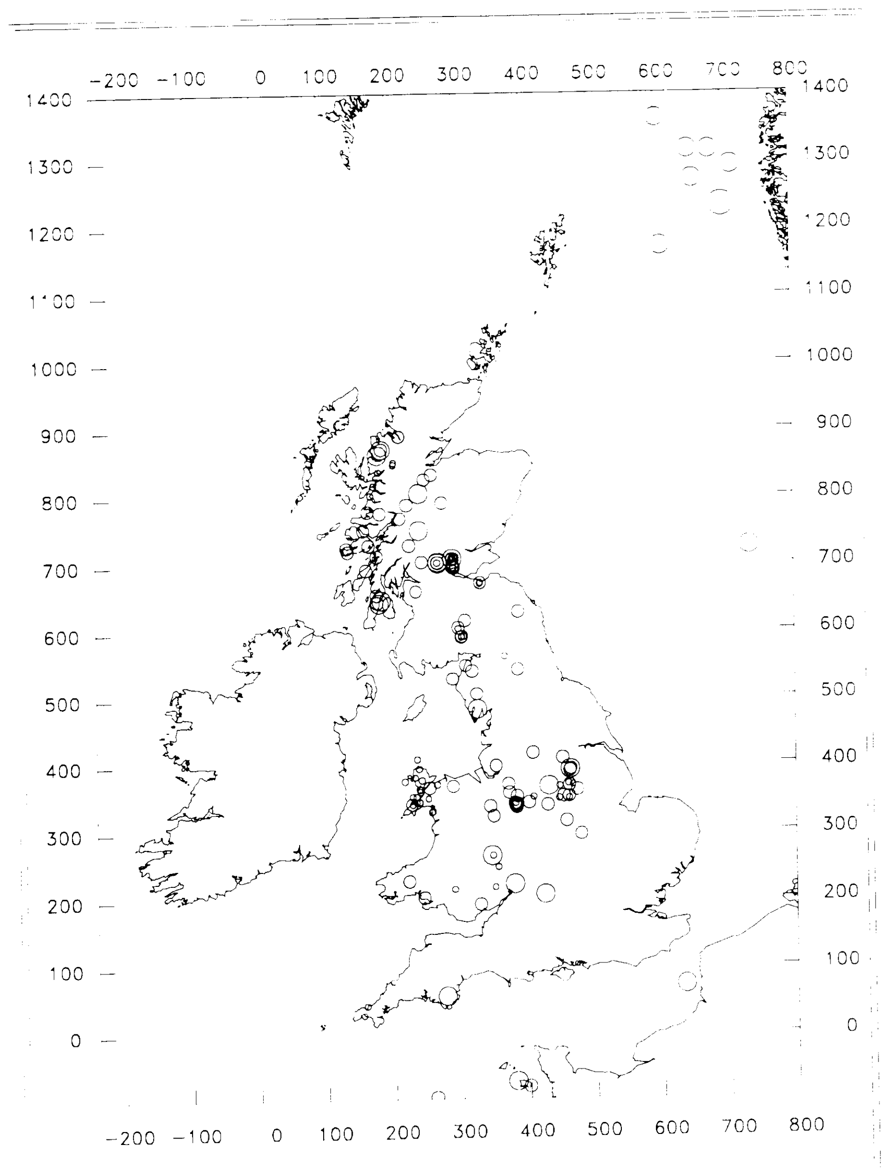
The next day, on 28 February, a magnitude 6.1 Ms earthquake occurred on the Armenia-Azerbaijan-Iran border and killed 965 people, and over 160,000 livestock in the Ardabil area of north-west Iran. It injured 2,600 and left some 12,000 homes damaged or destroyed and over 36,000 people homeless. Severe damage was caused to roads, electrical power lines, communications and water distribution systems in the epicentral area.

On 26 March, an earthquake, with a magnitude of 5.9 Ms, occurred in Kyushu, Japan. Twenty-two people were injured, many houses were damaged and railway services were interrupted in the Kagoshima Prefecture. Airports were temporarily closed at Kagoshima, Kumamoto and Tsuruda as a result of the earthquake.

In the Hindu Kush region (near the Afghanistan, Pakistan and Tajikistan border), on 13 May, an earthquake with a magnitude of 6.1 Mb killed one person and injured 11 more in the Malakand-Peshwar area, Pakistan. This earthquake was felt strongly throughout north-east Afghanistan, northern Pakistan and Tajikistan and was also felt some 1000 km away in Delhi, India.

On 21 May, 38 people were killed and more than 1,000 were injured as a result of a magnitude 6.0 Mb earthquake in the intraplate region of Jabalpur, southern India.

On 9 July, near the coast of Venezuela, an earthquake with a magnitude of 6.8 Ms caused



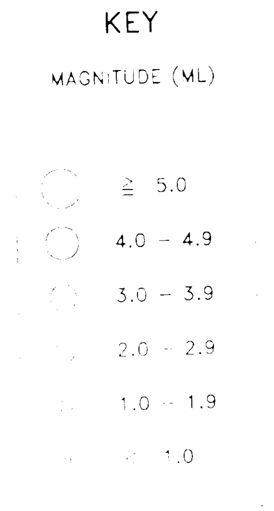


Figure 2. Epicentres of all UK earthquakes located in 1997 (from the BGS Bulletin of British Earthquakes for 1997)

extensive damage and disrupted power, telephone and water services throughout the Cariaco-Cumana area and on the Isla de Margarita and the Isla Coche. At least 81 people were killed and over 500 were injured. This earthquake was felt throughout north-east Venezuela, as far west as Maracaibo and on Trinidad and Tobago.

On 21 July, an earthquake, with a magnitude of 5.0 Mb, killed 15 people and caused injury to 46 others at the Avgold's Hartebeesfontein mine near Stilfontein in the Republic of South Africa.

In southern Iran, some 850 km south-west of the devastating earthquake of 10 May, an earthquake, with a magnitude of 5.0 Mb, injured 67 people and damaged several buildings in the Firuzabad area on 24 August.

Two earthquakes, with magnitudes of 5.6 and 6.0 Ms, on 26 September in Central Italy, resulted in the deaths of 11 people and injury to over 100 more in the Marche and Umbria regions. Extensive damage was reported throughout the region including damage to the Basilica of Saint Francis at Assisi, some 40 km to the west. These events were felt in many parts of central and northern Italy from Rome (some 130 km away) to Bologna and Modena and were also felt in western and central Slovenia and as far as southern Karnten Province, Austria (400 km from the epicentre). Further earthquakes occurred in the area during September and October causing at least 25 further injuries and additional damage to the Basilica of Saint Francis.

In Indonesia, on 28 September, 17 people were killed and over 300 injured in the Parepare area of Sulawesi during a magnitude 5.6 Ms earthquake in the region.

On 15 October, an earthquake, with a magnitude of 6.8 Ms, killed 8 people, caused injury to 300 more and either destroyed or damaged over 22,000 houses in Central Chile. Numerous power and telephone outages and several landslides and rockslides were also reported from the epicentral area. The earthquake was felt throughout Chile, as far south as Buenos Aires, Argentina (some 1300 km away), and also in parts of Bolivia and Peru, some 1800 km to the north of the epicentre.

On 21 November, an earthquake, with a magnitude of 5.9 Ms, occurred near the India/Bangladesh border. It killed 23 people, injured 200 more and caused severe damage to several buildings, including the collapse of a five storey building, in Chittagong, Bangladesh. Houses were also damaged and old trees were uprooted at Alikadam, Bandarban, Lama and Nakhyaungcharipara.

Most of the severely damaging earthquakes during 1997 were in the 'major' or 'strong' categories. There

The EEFIT team that visited the regions effected by the Umbria-Marche earthquakes will be discussing in detail the performance of historic buildings in a future newsletter.

were, however, some notable exceptions. One of these was the magnitude 4.9 Mb Pakistan earthquake, on 19 March. This relatively small magnitude event caused the deaths of 15 people, injured several others and damaged numerous houses in the Bajaur region. Another exception was the magnitude 4.8 Ms earthquake, which occurred on 12 January in the Berat area of Albania. One person was slightly injured and minor damage was reported at Ura Vajgurope and at Berat, where over 70 houses were destroyed.

UK Earthquakes

The British Geological Survey detected and located some 235 earthquakes in the British Isles and surrounding continental shelf areas during 1997 (Figure 2). Of these, 33 had magnitudes of 2.0 ML and greater; 15 in this category were felt together with a further 22 smaller events, bringing the total to 37 felt earthquakes during the year. Twenty-one of the earthquakes, with magnitudes of 2.0 ML or greater, occurred onshore or near shore. The remaining 12 were located offshore in the North Sea and Norwegian Sea areas. No earthquakes were reported felt in the North Sea areas during the year.

The two largest offshore earthquakes, occurred on 18 March in the Norwegian Sea area (magnitude 4.0 ML) and on 13 May in the Northern North Sea (magnitude 3.4 ML).

During 1997, there were no earthquakes, onshore, in the magnitude 3.0 to 3.9 ML range, against the long term average of 2 or 3 per annum. In addition to this, the total number of events with magnitudes 2.0 ML or greater was also below average; 21 against 26 per annum.

The largest onshore UK earthquake during the year, occurred on 10 February, in the Chesterfield region of Derbyshire. The magnitude was 2.9 ML and it was felt in the Chesterfield areas of Ashgate, South Wingfield and Matlock with intensities approaching 4 EMS (European Macroseismic Scale). A fault plane solution of the event shows reverse faulting with a component of strike-slip motion on planes striking EW and dipping south or planes striking NE and dipping to the NW. Previous events in this area include the 10 September 1977 earthquake in Nottinghamshire (magnitude 3.5 ML) and the Doncaster earthquake of 8 February 1990 (magnitude 3.0 ML). The latter was felt with intensities of at least 4 EMS.

On 4 February, an earthquake, with a magnitude of 2.7 ML, was felt in the Rannoch Moor region of Tayside, Scotland. It was felt, with intensities of at least 3 EMS, in the Rannoch Moor, Appin and Bridge of Orchy areas. Felt reports described "a rumble like thunder", "the whole house shook and I was frightened" and "heard a loud bang".

On 19 May, an earthquake, with a magnitude of 2.8 ML, occurred near the town of Carterton, Oxfordshire. The event was felt throughout the villages of Carterton, Witney, Birford and Bampton. Felt reports described "felt like the foundations were lifted", "the light fitting rattled" and "the whole desk shook and items rattled", indicating a maximum intensity of 4 EMS in the epicentral area. This is an area where very few events have occurred in recent years.

An earthquake, with a magnitude of 2.2 ML, occurred on 22 June, approximately 2 km west of Grosnez Point, Jersey. Felt reports described "the floor vibrated for 15-20 seconds", the whole bungalow shook" and "like a plane crashing". A macroseismic survey was carried out and over 120 replies were received indicating a maximum intensity of 4 EMS close to the epicentre. This is the largest event in the area since the magnitude 3.5 ML, St Aubins Bay earthquake on 30 April 1990, which was felt on Jersey with intensities of 5 EMS.

On 8 October, an earthquake, with a magnitude of 2.1 ML, occurred in Ulverston, Cumbria. Several felt reports were received from places such as Ulverston, Kirkby-in-Furness, Broughton Beck and Bouth and they described the earthquake "like an explosion" and "a loud bang" indicating an intensity of at least 3 EMS. This is the largest event in the region since the magnitude 3.0 ML, Grange-over-Sands earthquake of 26 June 1993, which was felt over an area of 9,000 km^2 (isoseismal 3) and had a maximum intensity of 5 EMS.

On 16 October, an earthquake, with a magnitude of 2.8 ML, occurred approximately 10 km NW of Dartmouth, Devon. It was felt over an area of 1,400 km^2 (isoseismal 3) in the Dartmouth area. In order to better assess the felt reports, a macroseismic survey was initiated by placing questionnaires in local newspapers. Over 160 replies, from 25 towns and villages, were received and a maximum intensity of 4 EMS was assessed close to the epicentre. This earthquake locates approximately 12 km from the magnitude 3.1 ML Dartmouth event on 4 January 1886, which was felt with intensities of at least 5 EMS.

Near the village of Doune in the Central region of Scotland, ten earthquakes occurred during the year, with magnitudes ranging from 0.9 to 2.7 ML. The two largest (both with magnitudes of 2.7 ML) occurred on 6 October and 30 November and were reported felt throughout the epicentral region with intensities of at least 4 EMS.

A swarm of 49 events was detected in the Blackford area of Tayside during the year with magnitudes ranging between –0.2 ML and 2.4 ML; five were reported felt. The largest, with a magnitude of 2.4 ML, occurred on 30 July and was reported felt throughout the Blackford area with intensities of at least 4 EMS.

The coalfield areas of Central Scotland, Northumberland, Yorkshire, Staffordshire, Derbyshire and Nottinghamshire continued to experience earthquake activity of a shallow nature, which is believed to be mining induced. Over 60 coalfield events, with magnitudes ranging between –0.6 and 2.0 ML, were detected and located during the year, 17 of which were felt. During January, February and early March, a series of 17 events occurred in the Musselburgh/Newcraighall area, to the east of Edinburgh and represent a continuation of the activity which started in October 1996. The largest events this year, with magnitudes of 1.7 ML, occurred on 9 and 11 January and were felt in the Musselburgh area with intensities of at least 4 EMS. Four events in this series were felt by local residents who described "the whole house shook and rumbled" and "there was a loud bang". The pattern (most events occurring in the working week) and location of the activity were a consequence of mining at Monktonhall colliery. The two most likely causes of these events are: the undermining and subsidence of old workings with void and pillar collapses and shearing in strained rock layers; or the bridging, and subsequent breaking during subsidence, of a strong rock layer between the mine and the surface (in this case, 900 metres above). Following the closure of Monktonhall Colliery in March 1997, no further events have been detected.

Other notable UK earthquakes in 1997, include the magnitude 2.5 ML Loch Maree, Highland, event of 8 November, the magnitude 2.3 ML Fort Augustus event of 8 December and the magnitude 1.2 ML Caernarfon, Gwynedd, event of 19 December. All three were reported felt in the epicentral areas with intensities of at least 3 – 4 EMS.

__David Galloway__ and __Alice Walker__ are both members of the Global Seismology and Geomagnetism Group of the British Geological Survey.

The "**Bulletin of British Earthquakes 1997**" edited by A Walker will be published in March 1998. Copies of this and previous years' bulletins can be obtained from the Global Seismology and Geomagnetism Group secretaries and from BGS bookshops. For further details contact: Alice Walker, Global Seismology and Geomagnetism Group, British Geological Survey, Murchison House, West Mains Road, EDINBURGH EH9 3LA, Scotland, UK.

Meeting Report: 26 November 1997

SEISMIC ASSESSMENT OF EXISTING STRUCTURES

This meeting held at the ICE attracted a record 80 people. It was championed by Andreas Kappos and chaired by Edmund Booth. The following article is based on the presentations made by the three speakers at the meeting.

Introduction

The vast majority of the *existing building stock* all over the world consists of structures which were either built before the introduction of a seismic code, or were built according to the provisions of a rather out-of-date code, wherein ductile detailing was hardly an issue. Fortunately, not all existing buildings would prove inadequate when assessed in the light of modern seismic performance requirements, because in many cases good selection of the structural configuration and (over)conservatism in design have resulted in a significant *overstrength* of these older structures, which to a certain extent compensates for the lack of adequate ductility.

The meeting focused on current trends in the evaluation of seismic performance, usually called *assessment*, which constitutes an invaluable tool in situations such as that of existing structures that should possibly be strengthened to avoid collapse and minimize structural damage in future earthquakes.

The use of statistical methods for vulnerability functions in loss estimation studies

A. Pomonis, Director, Cambridge Architectural Research Ltd.

Estimation of damage and loss to a region prior or immediately after an earthquake occurrence is of primary importance for disaster planning, preparedness, mitigation and insurance risk calculations. The subject of this presentation was to present a methodology to derive loss estimates based on statistical interpretation of a large worldwide damage database assembled at the University of Cambridge, discuss its uses and present new evidence on the vulnerability of engineered buildings after the experiences of the 1994 Northridge and 1995 Kobe earthquakes.

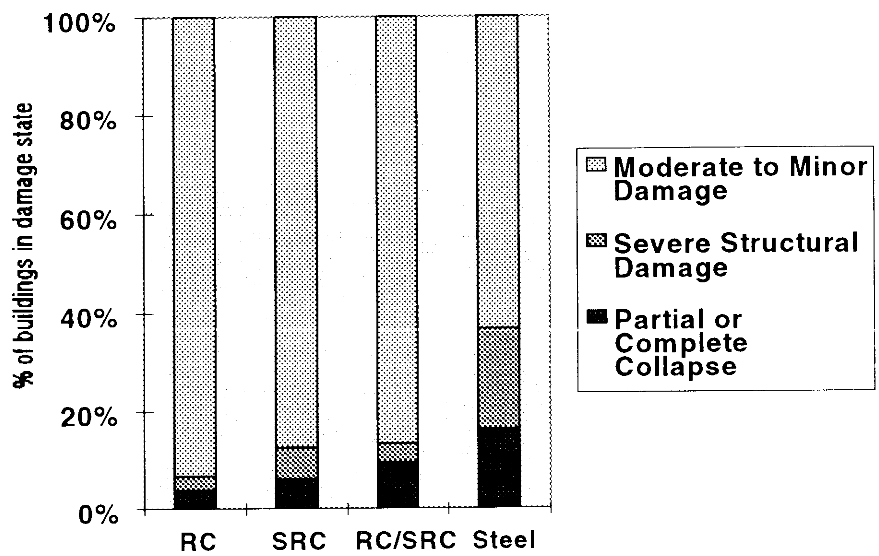


Figure 1. The comparative performance of the four main structural types during the 1995 earthquake in Kobe in the 7 worst affected wards of the city (RC: reinforced concrete shear wall; SRC: steel reinforced concrete composite; RC/SRC: mixed RC and SRC structures; Steel: Steel Framed structures).

From early-on experience of earthquake damage, following major earthquakes, pointed-out that various building types perform differently under the same ground motion. This experience has lead to the historical development of intensity scales like the MM and MSK scales, which are mostly based on damage experience to low-rise residential buildings of unreinforced masonry or timber frame construction.

Modern cities around the world now contain a large variety of structural types, including engineered buildings built under continuously updated earthquake code regulations. Statistical methods of analysing post-earthquake damage experience have therefore been developed in order to derive vulnerability functions for a variety of commonly encountered building types.

A brief historical review of the worldwide damage database assembled at the University of Cambridge was made. It was shown that this has been used to obtain a number of vulnerability functions for the most common building types across the intensity spectrum. The vulnerability functions are mathematically described by a cumulative normal distribution curve and are independent of the traditionally estimated seismic intensity. These in turn were correlated to actual ground motion parameters like peak ground acceleration, spectral acceleration, spectral intensity and others based on detailed damage surveys in the vicinity of strong motion recording stations triggered during major destructive earthquakes around the world during the last 15 years.

The devastating effects on reinforced concrete and steel buildings during the Kobe earthquake were also discussed. The comparative performance of such buildings during the Kobe, Erzincan, Kalamata and Mexico earthquakes was shown with damage histograms correlated to average response spectra of the areas of highest intensity in each earthquake. It was pointed-out that in Kobe steel and steel reinforced concrete composite buildings, experienced higher losses than reinforced concrete buildings (Figure 1). However, if these structures are grouped by age, the older RC structures (pre 1971) show similar percentages of failures to the steel frames. It was also pointed out that the Kobe earthquake was a rare event of intensity 10 or higher affecting a very large number of modern buildings, thus supplying us with many lessons, that are of primary importance in many cities around the world expected to experience such intensities in the future.

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Probabilistic Analytical Assessment of Reinforced Concrete Structures

A. J. Kappos, M. K. Chryssanthopoulos & C. Dymiotis, Imperial College, London

Probabilistic seismic assessment of RC structures relies on appropriate modelling of the uncertainties involved in the strength and ductility of RC members, both properties varying with the level of confinement. The findings presented have resulted from an ongoing study wherein material properties, namely concrete strength, steel yield strength and steel ultimate strain, are modelled as random variables and their effect on section behaviour assessed through fibre modelling and the Response Surface Methodology. The latter involves the derivation of approximating functions based on fibre model analyses for various combinations of the random variables. Simple expressions were derived for estimating strength and ductility parameters.

Monte Carlo simulations showed that significant variability exists in both the strength and ductility of confined RC sections. The variability in ductility is greatly increased if model uncertainty is taken into account (Figure 2). The uncertainty involved in the estimation of the latter using various models for confined concrete was examined using experimental data. Similarly, the uncertainty concerning fibre modelling was also investigated but was found to be of much lesser importance. With regard to strength, the variability was assessed for parameters defining key points on the interaction diagram. A significant amount of variability, especially above the balance point, exists primarily due to variations in f_c (Figure 3). Furthermore, the provisions set by EC8 for estimating section strength and ductility have been assessed. Although strength prediction is always conservative, the predicted ductility becomes unconservative as the level of axial load decreases.

A pilot probabilistic assessment of a three-bay ten-storey RC frame has been done. Dynamic analyses were carried out using a modified version of DRAIN-2D/90 whereby the strength and resistance of members was estimated using the derived equations.

Another novel feature is the possibility to model beam failure whenever the rotational or shear capacity is exceeded, defining failure at global level on the basis of first column failure or limiting interstorey drift. The frame is subjected to a number of input motions and its inelastic response evaluated, accounting for variabilities in member strength and ductility. From the foregoing analysis, the probability of failure for various earthquake intensities can be estimated. Initial analyses showed that the response is highly sensitive to the material properties of the first storey. A probability of failure of 27% was

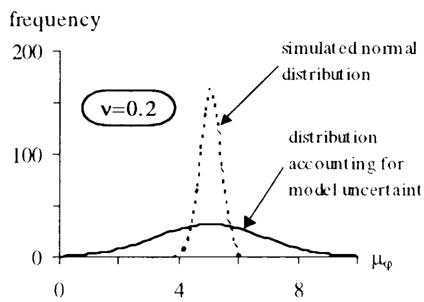

Figure 2. Typical distributions of curvature ductility with/without model uncertainty.

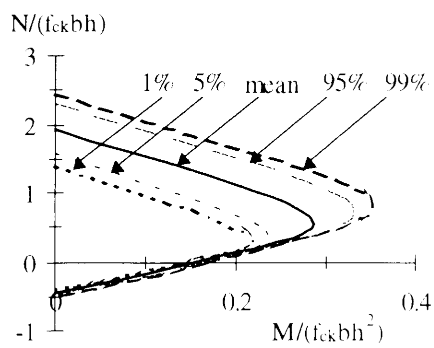

Figure 3. Typical column interaction diagram at five levels of reliability.

estimated for the survival earthquake (A=0.5g). Global failure was always due to a column failure on the first storey, mainly as a result of a low model uncertainty factor leading to low available ductility; the limiting interstorey drift of 3% was never critical. In all cases extensive beam damage had occurred prior to column failure, with beam failures on storeys 1 to 8.

Further studies on frame response influenced by uncertainties are currently under way. It is expected that the results outlined above will be useful in assessment as well as code development.

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The hybrid approach to vulnerability assessment

A. J. Kappos, Imperial College, London

A procedure for seismic vulnerability assessment, which combines the statistical approach with the analytical one, was presented and discussed. It involves supplementing existing damage (loss) data for a single intensity with results of inelastic dynamic analysis of appropriate models. According to this procedure the damage probability matrices (DPMs) are derived as follows:

Construction of the parts of each damage probability matrix for which statistical data from past earthquakes are available, using the standard procedure of dividing the cost of repair by the replacement cost and using an appropriate damage state classification scheme, such as that suggested by ATC-13. It is pointed out that the DPMs suggested by ATC-13, which are based on California data may be significantly different from those derived from local data.

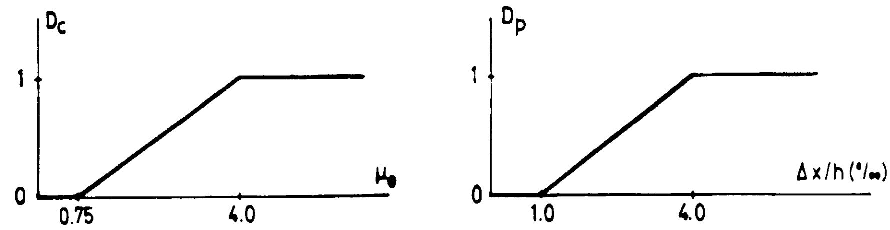

Figure 4. Normalised economic damage indices for (a) R/C members; (b) Brick masonry infill walls.

The remaining parts of the DPMs are constructed based on results of inelastic time-history analysis of models, simulating as closely as practicable the behaviour of each building class, subjected to input motions that have been derived for the site under consideration, taking local soil conditions into account. As dynamic analysis typically provides structural response quantities (such as ductility factors, displacements etc.) an appropriate model correlating structural parameters to loss, expressed in terms of cost of repair, is required at a post-processing stage; this is shown in Figure 4 (Kappos et al. 1996). In determining the DPM terms, in particular those referring to very low or very high degrees of damage, some judgement is commonly required for smoothing local peaks resulting from the output of the time-history analysis (and also, quite often, from the available statistical data mentioned in the previous step).

An essential part of the suggested procedure consists of correlating damage estimates derived from available statistical data with corresponding estimates based on the aforementioned time-history analysis, at specific areas. This permits the evaluation of the reliability of the analytical technique, which inevitably is susceptible to numerous uncertainties.

Analytical estimations of loss are subsequently checked against empirical data for the reference intensity and then used to construct damage probability matrices for various typologies of buildings. Probability damage matrices derived using this methodology are incorporated in a cost-benefit model tailored to the problem of estimating the feasibility of seismically rehabilitating the existing stock of reinforced concrete buildings in Thessaloniki, Greece. Results of the case study (Figure 5) indicate that benefit/cost ratios for this class of buildings are quite low, hence it appears that a pre-earthquake strengthening programme is not economically justifiable.

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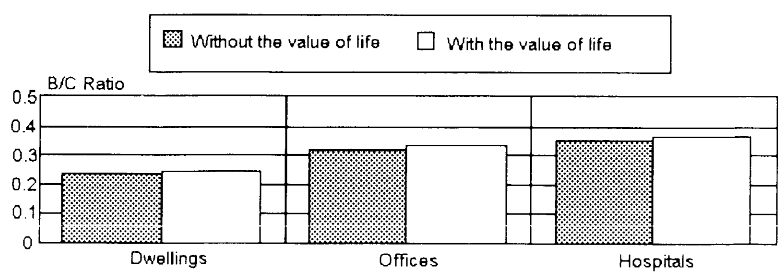

Figure 5. Benefit-cost ratios for RC medium-rise frame structures, for various uses

IMPROVING ACADEMIC-INDUSTRIAL INTERACTION IN EARTHQUAKE ENGINEERING

A Workshop on Mechanisms of Academic-Industrial Interaction in Earthquake Engineering was held at the Institution of Civil Engineers on Wednesday 4 February. The Workshop was organised by the SECED Research and Education Sub-Committee.

A total of 25 participants attended the Workshop, including two representatives from the EPSRC and Professor Jean-Georges Sieffert on the Ecole Nationale Superierue des Arts et Industries de Strasbou rg, who was representing the AFPS. The other participants included 14 academics (representing Birmingham, Bristol, Cambridge, Nottingham and Oxford Universities, Imperial College, the University of East London and the British Geological Survey) and 8 industrial participants (representing British Nuclear Fuels, GIBB, W.S. Atkins, Gifford and Partners and Ove Arup and Partners, as well as two independent consultants).

The event was opened was Dr. Julian Bommer (Imperial College), Chairman of the Research and Education Sub-Committee, who explained that the initiative for the organising the Workshop had come from the theme of interaction and exchange between academics and practitioners being raised many times at short course, conferences and technical meetings. The mission of the Sub-Committee is stated in its brief to be "To advise the SECED Committee on matters relating to research and education in earthquake and civil engineering dynamics, and to implement initiatives in this area, with particular emphasis on promoting links between research and practice", and hence the organisation of such meetings was fully in accordance with the raison d'être of the Sub-Committee.

The keynote speech was delivered by Dr. Scott Steedman, who is perfectly qualified to address the subject having spent 7 years as an academic at Cambridge and now being Director of Engineering at GIBB. Dr. Steedman said that he was very pleased to see this meeting actually happening since he and others had been discussing the need for such an initiative for at least 10 years. Dr. Steedman spoke both of the possibilities that exist for mutual benefit to industry and to academia from closer collaborations and presented some examples of very successful collaborations. At the same time, Dr. Steedman pointed out the challenges that are presented by trying to foster closer interaction between the worlds of research and practice and particularly the need for attitudes to change on both sides. According to Dr. Steedman, industry needs to take the role of academics in engineering projects seriously and academics need to make a serious commitment to these projects and understand industry deadlines and reporting standards.

Written contributions on the issues of industrial-academic interaction were then summarised in presentations made by Edmund Booth (consulting engineer), who presented the views of industrial participants, and Dr. Peter Merriman (BNFL), who presented the views of academic participants. A number of interesting and challenging ideas were put forward by both of the speakers. At this point, a brief presentation was made by Prof. Sieffert on the experiences of an AFPS Working Group, which he had chaired and that had produced a report on research needs in earthquake engineering in France. The report had been submitted to various French government ministries.

After the formal presentations, the participants split into three Working Groups to discuss different aspects of industrial-academic interaction:

(A) Mechanisms of academic response to industrial requirements in earthquake engineering research. (WG Chair: Dr. Robin Spence).

(B) Mechanisms of communication of earthquake engineering research results to industry. (WG Chair: Professor Roy Severn).

(C) Mechanisms of industrial involvement in the course of earthquake engineering research. (WG Chair: Graham Roberts).

After discussions lasting more than an hour, the conclusions and recommendations of each Working Group were presented by the three rapporteurs:

(A) Dr. Ahmed Elghazouli,

(B) Zygmunt Lubkowski and

(C) Dr. Robert May.

These presentations were followed by a lively discussion, which focused particularly on improving the communication of research findings to industry. The possibility of establishing research networks with EPSRC funding was also discussed, as was the need for industry to provide support for postgraduate training from which it benefits in terms of trained personnel. A full report on the Workshop, including all of the written contributions and summaries from the Working Group and general discussions, will be produced by the Research and Education Sub-Committee in the near future.

Julian Bommer

THE NEW OXFORD STRUCTURAL DYNAMICS LABORATORY

The new Structural Dynamics Laboratory at the University of Oxford was officially opened by the Head of the Oxford Engineering Science Department, Professor David Clarke, on Tuesday 9 December 1997, at a ceremony attended by senior industrialists and academics.

Delegates at the opening ceremony saw a range of practical demonstrations which highlighted the laboratory's capabilities. The ability to provide large dynamic loads to full-scale test specimens was illustrated by a test to failure of a steel beam. Figure 1 shows the test set-up, with the beam bolted into a large test frame and loaded vertically at its centre by two 250 kN actuators, via a transverse loading beam. The displacements of one actuator were slaved to the other to preserve the symmetry of the test set-up. Figure 2 shows the deformation of the test beam when subjected to an acceleration record taken from the 1994 Northridge earthquake.

Other demonstrations illustrated the capacity of the system to provide prescribed loadings over a wide range of frequencies and amplitudes, and the way in which actuators can be made to mimic structural systems using real-time control algorithms. The latter was demonstrated by coupling an actuator in real time to a model of a variable mass-spring-damper system, so that it underwent damped oscillations when set in motion by an external load. There was also a presentation of some of the analytical and graphical software being developed for use in conjunction with the tests.

The new facility has been developed by Dr Tony Blakeborough and Dr Martin Williams, both Lecturers in the Department of Engineering Science at Oxford. Funding of approximately £660,000 has been provided by the Wolfson Foundation, EPSRC, the Leverhulme Trust, Instron Ltd (who manufactured much of the dynamic testing equipment used in the laboratory) and from sources within Oxford University.

The laboratory has been designed as a flexible dynamic testing facility, with the aim of studying structural behaviour under a wide variety of dynamic load types, including earthquakes, wind and ocean waves. Tests are performed on a large strong floor, which also acts as an isolation block, preventing excessive vibration transmission into other parts of the building. Loads are applied by hydraulic actuators (capacities of ±10 kN, ±100 kN and ±250 kN are available) driven by a 270 litre/min power pack. A bank of accumulators can be used to boost the maximum flow rate by approximately 50% for short tests. This set-up enables dynamic loads with frequency contents representative of loadings such as earthquakes, wind and waves to be applied to large-scale structural models, or to full-scale structural components.

Control software being developed will enable a full-scale dynamic test of a critical part of a structure to be coupled in real time to a finite element model of the remainder of the structure. The system is shown in schematic form in Figure 3. A physical model of the critical component (in this illustration, a short, diagonal knee element) is mounted in a test frame. External loads are input to a finite element model of the remainder of the structure, which calculates displacements at the interface with the test element. These displacements are then applied to the specimen by the actuators, and the forces generated are fed back into the finite element model as part of the input for the calculation of the next timestep. For the correct loading to be applied in real time, this control loop must be completed within the time interval between load increments (typically 0.01 seconds).

This technique, known as real-time substructure testing, combines the best features of existing techniques and eliminates some of the disadvantages. Unlike pseudo-dynamic testing it allows dynamic amplifications and strain rate effects in the test specimen to be correctly modelled, and it eliminates the complex scaling problems involved in shaking table testing of small scale models. The substructure testing system is being developed by a Leverhulme Trust Research Fellow, Dr Antony Darby, and an EPSRC-funded D.Phil. student, David Williams.

A major project currently being undertaken in the laboratory is the large scale seismic testing of knee-braced steel frames. A typical frame configuration is shown in Figure 3; diagonal braces are connected to the midpoints of the short knee elements which span across the beam-column joints. During an earthquake energy

Figure 1. Dynamic test of a steel I-beam (load is applied two vertically acting 250 kN actuators via a short transverse beam element).

is dissipated by yielding of the knee elements, which act sacrificially, protecting the main structural members from damage. The damaged knee elements can then be replaced relatively easily. The feasibility of the knee bracing technique has been demonstrated by Dr Blakeborough using small-scale model tests on the University of Bristol shaking table, but there is a need for larger scale testing to provide more comprehensive validation, and for the development of detailed design guidelines.

Testing at Oxford is being carried out in two phases. First, full-scale cyclic load tests are being performed on individual knee elements in order to establish an optimal element design, which will remain stable under repeated excursions into the plastic regime. This design will then be incorporated into a large scale model of two knee-braced bays, representing the lower two storeys of a multi-storey knee-braced frame. This will be tested using the real-time substructure approach outlined above. The work on knee braced frames is being carried out by an EPSRC-funded Research Assistant, Neil Woodward.

Delegates to the Sixth SECED Conference, being held in Oxford in March 1998, will have the opportunity to visit the laboratory as part of the programme of events on Wednesday 25 March, the day before the main conference. The tour will leave from the St Cross Building at 11.00 am. There is no charge for the tour and a free sandwich lunch will be provided for those who book in advance. Please book by contacting Mrs N H Houliston at the Department of Engineering Science, Oxford University – Tel: (01865) 273162, Fax: (01865) 283301, Email: nicola.houliston@eng.ox.ac.uk.

Figure 2. Failure of the test beam under simulated earthquake loading.

The facility is available for research supported either by research organisations or industry. Enquiries should be directed to Dr Martin Williams (Tel: 01865 273102, Email: martin.williams@eng.ox.ac.uk) or Dr Tony Blakeborough (Tel: 01865 283442, Email: tony.blakeborough@eng.ox.ac.uk).

Martin Williams

Lecturer, University of Oxford, Department of Engineering Science

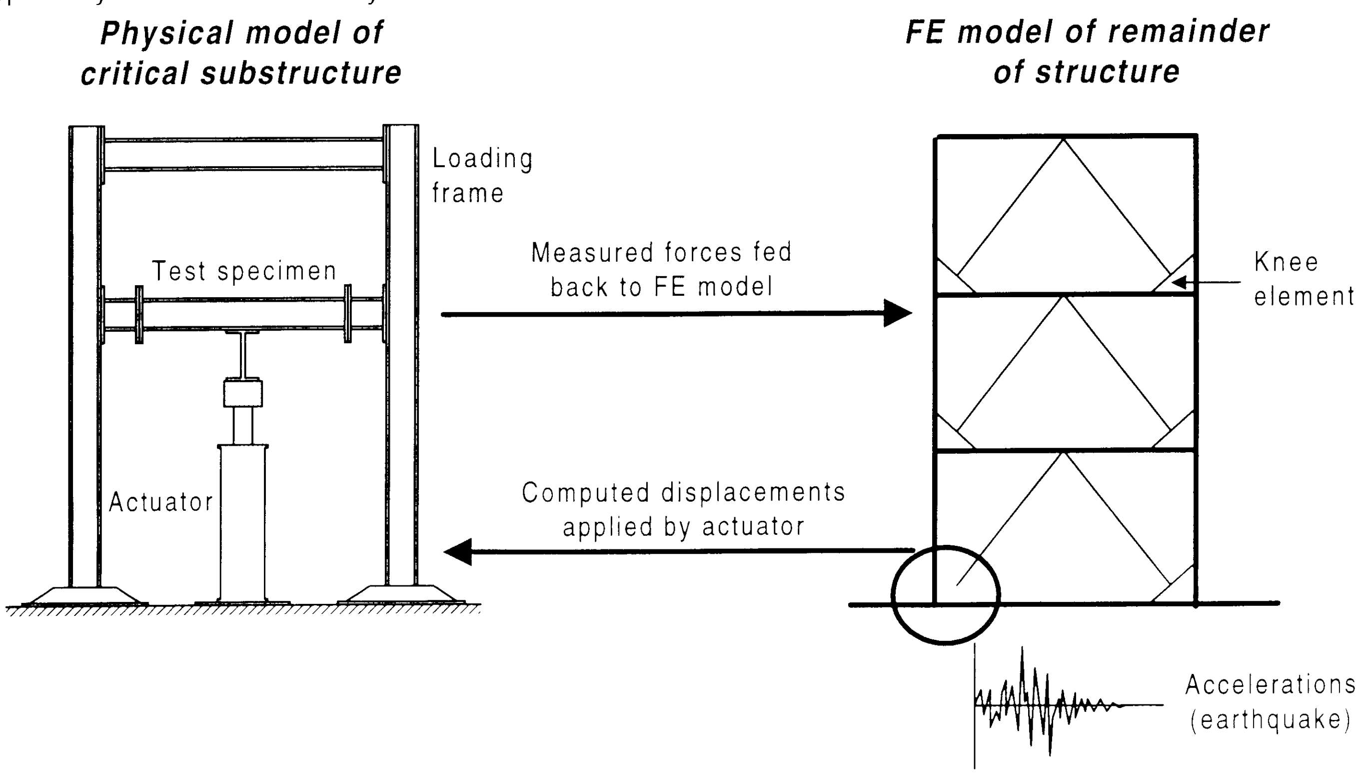

Figure 3. Real-time substructure testing – a schematic view of a substructure test on a knee element from a knee-braced frame.

YOUR OPPORTUNITY TO INFLUENCE THE REDRAFTING OF EUROCODE 8

3.00pm, Wednesday 25th March 1998, University of Oxford

The Centre for European Standards (CEN) has asked its member nations to authorise the conversion of Parts 1 and 5 of Eurocode 8 (Design provisions for earthquake resistance of structures) from a Prestandard (equivalent to a BSI draft for development) into a full European Standard. The conversion process is scheduled to take two years, starting mid-1998, and will be done by four Working Groups.

At 3.00pm on Wednesday March 25th, 1998, a SECED meeting entitled 'Eurocode 8: a case for minor revision or radical reform?' will be held at the St Cross building, Oxford University, as part of the run up to SECED's conference, which starts the next day. The four UK engineers who will participate in the conversion Working Groups will address the meeting, which will be chaired by David Lazenby, chairman of the main CEN Eurocode co-ordinating committee. The meeting will finish at 5.30pm.

BSI have negotiated a delay in their response to CEN on the conversion enquiry, so that this meeting, and the conference that follows, can be used to inform the relevant BSI committee more fully of UK opinion on Eurocode 8, before it responds to CEN. During the SECED meeting on 25th March, there will be ample opportunity for discussion and debate; short formal contributions from the floor (up to 5 minutes) are also being sought. This is therefore a most important event, and all with an interest in the conduct of seismic engineering in the UK are strongly encouraged to attend.

For further details of the meeting (which is free and open to all), please contact Alison Bullen, SECED Secretary, at the Institution of Civil Engineers (phone: +44 171 665 2238 /fax: +44 171 799 1325 /e-mail: bullen_a@ice.org.uk). Please contact Alison if you wish to make a formal contribution from the floor.

SIXTH SECED CONFERENCE: SEISMIC DESIGN PRACTICE INTO THE NEXT CENTURY

UNIVERSITY OF OXFORD, 26TH - 27TH MARCH 1998

Final preparations are in hand for SECED's conference at the end of the March, which looks set to become the best attended in SECED's history. A wide technical range is covered in the 8 keynote and 55 other papers to be presented, covering the latest developments in seismic design and analysis, codes of practice, dynamic testing and seismic response control. These are contained in the published proceedings, which will be available to delegates at the time of the conference, and will be on sale to non-delegates for about £67.50. The published papers will be supplemented by around 15 'Work-in-Progress' posters, giving up-to-date details of current innovative design and research projects.

The conference bursary scheme, generously funded by the Commission of the European Communities, Allott & Lomax, Nuclear Electric, Technology Transfer Associates and from SECED's own funds, is extending the opportunity to attend the conference to a dozen delegates from the Soviet Block and an equal number of students and researchers. Currently registered delegates comprise 60% from industry and 40% from academia, with a strong minority representation from many centres of excellence in seismic engineering overseas, so there is fertile ground for well represented debate.

The social side of the conference has not been neglected. Oxford and its surroundings provide many places of great interest and beauty, and walking tours of the university will be available at a small charge for delegates and their partners. The conference banquet takes place in the magnificent setting of Magdalen College, and the guest of honour is Paul Back, Royal Academy Visiting Professor in Civil Engineering Design at Oxford. Musical entertainment will be provided during the meal by the barber shop quartet 'Chord in the Act'.

Further information on the conference can be obtained from the Thomas Telford website http://www.t-telford.co.uk/co/conf40.html or from Rachel Coninx at the Conference Office (tel +44 171 233 1743, fax +44 171 665 2314 E-mail coninx_r@ice.org.uk.)

EARTHQUAKE PREDICTION COMPETITION

Taking place at the SECED AGM on the 29th April

At the SECED AGM on 29th April, the earthquake competition will take place once again asking:
Where will the next magnitude 2.5 event be located by BGS onshore UK?
The answer will be available and the winner will be notified as soon as the earthquake occurs.

NOTABLE EARTHQUAKES OCTOBER - DECEMBER 1997

Reported by British Geological Survey

YEAR	DAY	MON	TIME UTC	LAT	LON	DEP KM	MAGNITUDES ML	MB	MS	LOCATION
1997	06	OCT	06:21	56.20N	4.10W	3	2.7			DOUNE, CENTRAL
				Felt throughout the Doune and Thornhill areas of Central Scotland.						
1997	13	OCT	13:39	36.38N	22.07E	24		6.2	6.6	SOUTHERN GREECE
				Minor damage occurred throughout southern Peloponnisos. Felt strongly throughout Athens and Crete.						
1997	14	OCT	09:53	22.10S	176.77W	167		6.7		SOUTH OF FIJI ISLANDS
1997	15	OCT	01:03	30.93S	71.22W	58		6.8	6.8	COAST OF CHILE
				Eight people killed, more than 300 people injured and 5,000 houses destroyed.						
1997	16	OCT	00:19	50.39N	3.73W	10	2.8			DARTMOUTH, DEVON
				Felt throughout Devon, with maximum intensities of 4 EMS in the epicentral area.						
1997	28	OCT	06:15	4.37S	76.68W	112		6.6	6.3	NORTHERN PERU
1997	08	NOV	04:47	57.67N	5.57W	10	2.5			LOCH MAREE, HIGHLAND
				Felt throughout the village of Gairloch, with maximum intensities of 4 EMS.						
1997	08	NOV	10:02	35.07N	87.33E	33		6.2	7.9	XIZANG
1997	30	NOV	00:59	56.20N	4.10W	5	2.7			DOUNE, CENTRAL
				Felt throughout the Doune and Thornhill areas of Central Scotland, with maximum intensities of 4 EMS.						
1997	05	DEC	11:26	55.00N	161.9E	33			7.7	EAST COAST OF KAMCHATKA
1997	08	DEC	23:56	57.10N	4.60W	7	2.3			FORT AUGUSTUS, HIGHLAND
				Felt reports received throughout the village of Fort Augustus, with maximum intensities of 4 EMS.						

Issued by Bennett Simpson, British Geological Survey, January 1998

Forthcoming Events

25 February 1998
Base Isolation of Large Tanks - a LNG case study. *ICE 5.30pm*

25 March 1998
EC8 - a case for minor change or major overhaul. *Oxford University 3.00pm, St Cross Building*

26 to 27 March 1998
The Sixth SECED Conference: Seismic design practice into the next century. *Oxford University*

29 April 1998
Accidental Explosions. *ICE (proceeded by AGM at 5pm including the 1998 earthquake prediction competition)*

27 May 1998
Are vertical earthquake ground motions important? *ICE 5.30pm*

Selected extracts from previous SECED Newsletters can now be found on the World Wide Web at the Institution of Civil Engineers:

http://www.ice.org.uk/public/seced.html

Comments are welcomed and should be sent to: A.J.Crewe@bristol.ac.uk

Contents

SECED Newsletter

The SECED Newsletter is published quarterly. Contributions are welcome and manuscripts should be sent on a PC compatible disk. 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.

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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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