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# SECED NEWSLETTER

THE SOCIETY FOR EARTHQUAKE AND CIVIL ENGINEERING DYNAMICS

July 1990, Vol. 4, No 3

## IN THIS ISSUE

Chris Browitt has now retired as chairman and his Annual Report delivered at the AGM on the 25th April has provided the first item in this Newsletter. I am sure the membership would wish to pass on a collective thanks to Chris for supplying so readily and efficiently all the additional effort which is demanded by the chairman's duties.

The Committee has now been reformed for the new season and we have used the occasion to provide a profile of the existing and new committee members in the Membership Notes item. Included also is a tribute by Dr. Brian Skipp to David Howells who was nominated as an Honorary Life Member of SECED at the recent AGM.

Committee news must also include a welcome to new chairman Mr. Edmund Booth and new committee members Joe Barr, Scott Steedman, Nigel Hinings and Matthew Raybould.

This issue also introduces an Earthquake News item which we hope will be a regular feature in the future. The item will be prefaced by a list of seismic events recorded by BGS during the quarterly periods which separate issues of this Newsletter. We would then hope to include under this heading reporting or reviews of such topical events. This time we have articles on the Romanian earthquake of May 1990 and the UK Bishops Castle event of April.

Special articles this quarter comprise a note by Dr. Roger Musson of BGS on the European review of the MSK-81 intensity scale and a note by chairman Ed Booth on ground motion parameters in Eurocode 8.



The Editor

The SECED Newsletter is published four times a year by the SOCIETY FOR EARTHQUAKES AND CIVIL ENGINEERING DYNAMICS and is available to all members of the society. Articles for inclusion should be sent to The Editor, SECED Newsletter, C.R.Sharman, Allott & Lomax, Fairbairn House, 23 Ashton Lane, Sale, Manchester, M33 1WP



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## ANNUAL REPORT FOR MAY 1989 - APRIL 1990

Dr. Chris Browitt, SECED Chairman 1988-1990

Over the past year the Society has maintained its now traditional vigour which is demonstrated by some of the highlights reported here. Membership has increased to a total of 196, including 23 student members who continue to be welcomed free of charge, and the income from subscriptions has increased by some 22%.

The programme of meetings started with the second of SECED's prestige Mallet-Milne lectures on 24th May 1989. Professor George Housner of CalTech addressed the Society and its guests at the Royal Institution on 'Coping with natural disasters: The International Decade for Natural Disaster Reduction'. His theme, using many illustrations from the field of seismology and earthquake engineering, also covered the wide range of other natural phenomena which form the total subject of the International Decade now upon us in the 1990s. His full text, with illustrations and Professor Geoffry Warburton's introduction. Dr. Frances D'Souza's response and Dr. Robert Muir Wood's sketch of Robert Mallet and John Milne, have been published by SECED.

The International Decade for Natural Disaster Reduction (IDNDR), as a cooperative programme to reduce natural hazards and their effects on mankind, was first presented by Dr. Frank Press at the Eighth World Conference on Earthquake Engineering in 1984. The idea spread slowly outwards from the earthquake engineering community and, in December 1987, the United Nations General Assembly passed a resolution designating the 1990s as a decade:

> "in which the international community, under the auspices of the United Nations, will pay special attention to fostering international cooperation in the field of natural disaster reduction".

On 22nd December 1989, the IDNDR was proclaimed by the United Nations with the objectives:

> "to reduce through concerted international action, especially in developing countries, loss of life, property damage and social and economic disruption caused by natural disasters, such as earthquakes, windstorms, tsunamis, floods, landslides, volcanic eruptions, wild fire, grasshopper and locust infestation, drought and desertification and other calamities of natural origin."

Of all the causes of natural disasters, earthquakes are one of the most significant with deaths often measured in tens of thousands and economic losses in $ billions. In the historical record, we only need to go back 15 years to record over 250,000 fatalities in the Tangshan earthquake to illustrate the point. As the primary UK forum for engineering seismology and earthquake engineering, SECED has a clear role to play in encouraging UK participation in the IDNDR. It has pursued this role, both formally and informally, with national institutions and Government but, despite these efforts, the UK is still behind most of the Developed World in supporting the IDNDR. There are some signs, however, that now the Decade has commenced, SECED's interests will find a focus in a committee to be jointly sponsored by the Royal Society and the Fellowship of Engineering and backed by the ODA Disaster Unit.

SECED has continued to support the Earthquake Engineering Field Investigation Team (EEFIT) which has sponsored a number of missions including California and Newcastle, Australia, during the year. Many participants in these missions are SECED members and a jointly sponsored meeting (also with Imperial College) was held on 10th January 1990 on the seismological and engineering effects of the Lima Prieta, California, earthquake.

Globally, the largest earthquake for over 10 years occurred on 23rd May 1989 in the Macquarie Island region, south west New Zealand. With a magnitude of 8.2 Ms, it just exceeded the Mexico

City earthquake in 1985 which caused approximately 10,000 fatalities. By contrast, the Macquarie event, with its epicentre in a remote oceanic region, caused little concern and no Media interest. It was felt only on Macquarie and Campbell Islands with a maximum intensity of V MM (below damaging).

The most publicised earthquake, which also resulted in many enquiries to UK engineers and seismologists from the Public and Media, was the 18 October Loma Prieta (initially called San Francisco) earthquake which caused damage in San Francisco and the Santa Cruz/Hollister area of California. With a magnitude of 7.1 ML it was slightly larger than the Armenia earthquake of December 1988 which caused 25,000 deaths. By contrast, the Loma Prieta earthquake caused only 62 fatalities as a result of the higher degree of earthquake preparedness in California. Nevertheless, this rupture of a 40 km section of the San Andreas fault resulted in over 3,000 injuries, 12,000 homeless and $6 billion of damage.

The Newcastle, Australia, earthquake north of Sydney, on 27th December 1989 caused 11 deaths. With a magnitude of only 5.5 Mb it is of a size which can occur infrequently in Britain. The buildings in this part of Australis were designed and constructed without provision for earthquake shaking as there is little evidence of such events in the history of the area. Seismograms recorded in the UK from seismic waves which travelled through the Earth's core have been used to provide an estimate of the depth of the earthquake of 10 km.

In East Germany, on 13th March 1989, a strong mining-induced earthquake occurred and was felt in West Germany, parts of France, Czechoslovakia, Switzerland and Austria. In the epicentral area, 80% of buildings were damaged by the event which is believed to be the result of a rockburst or pillar collapse following blasting at the Ernst Thaelmann mine near Merkers. The event had a magnitude of 5.4 Mb (4.5 Ms) and was, therefore, similar in size to the Newcastle, Australia, earthquake.

In the UK, small earthquakes have continued to be felt from the continuing aftershocks of the 1984 Lleyn Peninsular earthquake (5.4 ML). Earthquakes with magnitudes in the range 2-3 ML have been felt in the Doncaster/Sheffield area (8th February 1990), in Staffordshire (26th February and 4th March 1990), in Loftus (5th September 1989), in Milngavie (6th January 1990), in Glen Lyon (9th January 1990) and near Colonsay (26th January 1990). One of the largest earthquakes this century occurred south of Bishops Castle on the Welsh/English border on 2nd April 1990. With a magnitude of 5.0 ML, it was felt throughout Wales, most of England and into Ireland and southern Scotland. Some damage occurred, particularly to roofs and chimneys, in the epicentral area.

Under the editorship of Chris Sharman the SECED Newsletter has expanded during the year but contributions from the wider membership are needed for it to fully reflect the broad scope of interests of us all. If you haven't made a contribution this year, please let us have your views in a letter to the editor or an article, or send in a book review which would be particularly welcome.

The Society's Constitution has been revised

(i) to formally include representatives nominated to the Committee by ISE, IME and Geological Society as our links with those institutions have strengthened.

(ii) to include Corporate membership.

(iii) to permit re-election of retiring committee members.

(iv) to increase the proportion of elected members on the committee.

In addition, the opportunity has been taken to tidy-up some of the wording. The revised Constitution was accepted at an Ordinary General Meeting of the Society on 28th February 1990 and minor additional 'tidying' amendments are proposed for the April 1990 AGM.

Despite the increase in income from subscriptions during the year, the balance sheet is not healthy. This is the result of an increase in the commitments and business of the Society with an expanded Newsletter, free student membership and more discussion meeting and publications. In addition, the present subscription levels of £10 for individual and £50 for corporate membership have been held for 3 years and, consequently, reduced by inflation. It is, therefore, proposed to increase subscriptions, from January 1991, to £15 and £75, respectively.

As I am now retiring from the Chairmanship of SECED after my two-year term, I would particularly like to thank all members of the committee who, through their enthusiasm, ideas and endeavour, have made my term of office a pleasurable and relatively easy one. I extend my thanks to all members of the Society for their contributions through the Newsletter, correspondence and, particularly, in the discussion meetings. There, I have found a professionalism among the speakers resulting in punchy presentations and good time keeping and, on the floor, leading to a friendly but penetrating discussion and the exchange of information and ideas across the wide spectrum of our discipline.

I would like to, particularly, acknowledge the contributions of our now retired Secretary, Maurice Taylor, over many years, of James Dawson who has so ably taken his place (since July 1989) and, of course, Norman Tyler who is always there keeping everything running behind the scenes. In this year of 'engineering disruption' at the ICE, we have been indebted to a number of other organisations who have hosted our discussion meetings; namely, Imperial College, ISE, BRE, Heriot Watt university and, for a joint meeting, the Geological Society.

Finally, and with the greatest pleasure, I wish to announce that the Committee of the Society has nominated David Howells as the second Honorary Life Member of SECED. This nomination is made in recognition of his long association with the Society and the many contributions he has made as member, chairman and (the latest) as founder editor of the Newsletter. With it go our warmest thanks, best wishes and a certain knowledge that those contributions will continue.

## FIRST WORKSHOP ON UPDATING THE MSK-81 INTENSITY SCALE.

Reported by Dr. Roger Musson, British Geological Survey

The first Workshop on the updating of the MSK-81 intensity scale was held in the offices of Swiss Re, Zurich, on 7th-8th June 1990. This workshop was held under the auspices of the European Seismological Commission. The original MSK-64 intensity scale was updated to a minor extent in 1981; the intention is to continue to modernise the scale to keep it up to date with changes in the built environment, while maintaining consistency with earlier formulations and thus preserve the continuity of existing data sets. The workshop was chaired by Dr. G. Grunthal of the Zentralinstitut fur Physik der Erde, Potsdam, and was attended by fourteen representatives from seven European countries.

The most important conclusion of the workshop was that the 1990 revision of the MSK intensity scale would be a more major overhaul than the 1981 revision; in particular it was agreed (a) to take into consideration the specialised needs of earthquake engineers, engineering seismologists, historical seismologists, etc.; (b) to include overall guidelines on the use of the scale, complete with pictorial examples to illustrate the meaning of the various grades of damage, etc. The new version of the MSK scale will be modular in construction, comprising a "core" scale similar to that in use at present, together with various specialised modules which can be ignored by the general user if desired, but will give extra guidance on such topics as the response of engineered structures, soil mechanics, considerations for historical studies, and so on.

Because of the scope of the proposed revisions it was not possible to do any more than begin the process of revision in the two days allotted for the Zurich meeting. It is hoped that when the revision is complete, the new MSK scale will be a considerably more powerful and consistent tool than any other intensity scale in use.

The author has compiled a short report which is an unofficial account of the Zurich workshop for the benefit of any interested parties in the UK. Copies of this may be obtained on request from: Roger Musson, Seismology Group, BGS, West Mains Road, Edinburgh EH9 3LA.

## WORKSHOP ON GROUND MOTION PARAMETERS FOR EUROCODE 8

Edmund Booth

A weakness of the current draft of the seismic Eurocode, EC8, is that it gives almost no advice on the selection of appropriate design ground motions. It is a lack that the drafters are well aware of; last year, a German group was asked to prepare a model paper on seismic hazard analysis, which might serve as the basis for establishing a standard EC8 methodology.

A workshop was held in Lisbon at the beginning of July this year to discuss the German proposals, to present various other national approaches and to make progress towards establishing standard methods. About 30 engineers from ten different countries attended. There were 8 invited papers and I presented the one describing the situation in the UK.

Considerable common ground emerged and there was a general feeling that at least broad guidelines could be established, even if not a single unified approach. A committee was set up to do just this, drawing on the various papers given at the workshop. Progress is likely to be slow, however, since Euromoney for this sort of activity is scarce.

Please contact James Dawson at the ICE or myself if you would like a copy of the paper I presented and my more detailed report on the workshop.

## EARTHQUAKE NEWS

### NOTABLE EARTHQUAKES APRIL - JUNE 1990

Reported by British Geological Survey

| DATE | LAT. | LON. | DEP. KM | MAGNITUDES ML | MB | MS | LOCALITY |
|---|---|---|---|---|---|---|---|
| 02.04.90 | 52.43N | 3.035W | 14 | | 5.1 | 4.5 | **BISHOPS CASTLE, SALOP** |
| | Felt from Newcastle to Cornwall, Kent to Dublin. Damage (Io=VI MSK) in Wrexham, Shrewsbury area. | | | | | | |
| 05.04.90 | 15.226N | 147.529E | 32 | | 6.5 | 7.5 | **MARIANA ISLANDS REG.** |
| | Felt IV MSK at Guam, no damage, small tsunami (24 cm) | | | | | | |
| 18.04.90 | 1.162N | 122.839E | 28 | | 6.2 | 7.4 | **MINAHASSA PENINSULAR, INDONESIA** |
| | At least 25 people injured, extensive damage in Gorontalo area. | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 26.04.90 | 35.961N | 100.227E | 33 | 6.6 6.9 | QUINGHAI PROVINCE CHINA |
| | At least 126 people killed, many injured, extensive damage and landslides. | | | | |
| 30.04.90 | 49.126N | 2.130W | 8 | 3.5 | JERSEY |
| | Felt throughout Jersey. IV MSK. No damage reported. | | | | |
| 20.05.90 | 5.041N | 32.109E | 7 | 6.6 7.2 | SUDAN |
| | Some damage in Juba area, felt throughout large parts of East Africa. Probably the biggest earthquake every recorded in Sudan. | | | | |
| 24.05.90 | 5.345N | 31.908E | 10 | 6.6 6.4 | NORTHERN PERU |
| | At least 135 people killed, over 800 injured and severe damage. | | | | |
| 30.05.90 | 45.873N | 26.666E | 90 | 6.7 | ROMANIA |
| | 13 people killed, over 700 injured and damage in Rumania, Moldavia (USSR) and northern Bulgaria. | | | | |
| 14.06.90 | 11.399N | 122.126E | 33 | 6.0 7.1 | PANAY, PHILIPPINES |
| | At least 4 killed, 15 injured in Culasi area, and considerable damage. | | | | |
| 20.06.90 | 37.047N | 49.384E | 10 | 6.4 7.6 | CASPIAN SEA/IRAN |
| | 50,000 dead, over 100,000 injured. 400,000 homeless. Extensive damage and landslides, felt in most of NW Iran and southern USSR. | | | | |

## THE 1990 ROMANIAN EARTHQUAKE

Reported by Stephen Ledbetter, EEFIT

On the 30th May 1990 a magnitude 6.7 earthquake occurred in the Vrancea region of Romania. This earthquake had a focal depth of 110 km and its effects were felt strongly throughout Romania and part of the Soviet Union. Eight people were killed although no buildings collapsed. Widespread damage was caused by the earthquake some of which was structural damage. This event is the third large magnitude earthquake in Vrancea in 13 years, the region having experienced a magnitude 7.2 in 1977 that killed 1500 people and a magnitude 6.8 in 1986. Damage from the 1986 earthquake had not all been repaired and there was at least one case of major structural damage not repaired since the 1977 earthquake.

Three members of the Earthquake Engineering Field Investigation Team (EEFIT) visited Romania. They were Stephen Ledbetter of Bath University and Andrew Coburn and Antonios Pomonis from the Martin Centre, Cambridge University. The team were in Romania for 7 days starting 15 days after the earthquake and were invited to Romania by INCERC the Romanian building research institute in Bucharest. The team spent 2 days in Bucharest before travelling with 3 members of INCERC to Buzau, Focsani and Ploiesti nearer to the epicentre. The final day was spent reporting back and discussing future collaboration between Romanian and UK engineers.

The initial shock occurred at 13.40 (local time) on Wednesday 30th May an aftershock of magnitude 6.3 occurred at 2.15 the following morning. The depth of the earthquake combined with the deep alluvial deposits of the Danube valley, 300m deep below Bucharest, give rise to long period ground motions that principally affect high rise buildings. Preliminary analysis of the strong motion records shows peak ground accelerations of 14% at Focaani, 25% at Buzau and up to 14% in Bucharest, with fundamental frequencies in the range 0.8-1.3 seconds.

Because of the uniform ground conditions and depth of the earthquake it was possible to study buildings over an area and have reasonable confidence that they had been subjected to similar ground motions. Comparisons were made between insitu concrete frames with masonry infill panels, insitu concrete columns with precast beams and slabs, load bearing apartment buildings of 5 to 12 storeys in height. Most damage was suffered by buildings with precast components. All structures are built with seismic movement joints. Most deaths were caused by masonry and concrete dislodged by pounding of the cladding at these joints. Current construction is of load bearing masonry for buildings up to 4 storeys or shear wall structures.

Following the 1977 earthquake a programme of strengthening works has been started for historic masonry buildings. These large structures built in the early years of this century are town halls, court houses, theatres and schools. The team were able to compare the behaviour of strengthened and as yet unstrengthened buildings. Recent strengthening with reinforced concrete elements had worked well but some of the early attempts at strengthening failed. This work is hampered by the limited technology available in Romania.

The team's visit was confined to epicentral region and central Romania. There were reports of damage to industrial chimneys, steel roofing on industrial plants and grain silos over a wide area extending to the southern Romanian border.

The Romanians are currently reviewing the seismic vulnerability of their building stock and considering methods for strengthening existing apartment buildings. A survey of vulnerability is to be completed later this year.

The field trip will be fully reported in a joint EEFIT-INCERC publication later in the year. The teams observations will be reported at an EEFIT meeting on Tuesday, 14th August at the Institution of Structural Engineers, 11 Upper Belgrave Street, London, Time: 4.00 pm. For further details please contact: Dr. Stephen Ledbetter, University of Bath, Tel. Bath 826880.

## BISHOPS CASTLE EARTHQUAKE

Report by Maureen Ritchie and Roger Musson, British Geological Survey

With a Richter magnitude of 5.1, the earthquake of 2nd April 1990 was one of the largest British earthquakes this century. The epicentre is near the village of Clun, in Shropshire, approximately 7 km SSW of Bishops Castle. Focal parameters are:

| | |
|---|---|
| Grid East: | 329.7 ± 1.0 km |
| Grid North: | 284.4 ± 1.0 km |
| Depth: | 14.3 ± 4.7 km |
| Time: | 13.46 and 34.20 sec GMT |
| Magnitude: | 5.1 ML |

Most of the high sensitivity seismic stations in Britain were saturated by the amplitude of the ground motion but eight low gain vertical seismometer recordings were available to calculate the Richter local magnitude.

The earthquake was felt over a large area from Ayrshire in the north to Cornwall in the south, Kent in the east, and Dublin in the west. Damage was minor and limited to the epicentral area, north to

Wrexham and especially Shrewsbury, which suffered most. It included cracks in chimneys, falls of part of chimneys, cracks in plaster and falls of small amounts of plaster. The British Geological Survey carried out a macroseismic survey after the mainshock which yielded over 6,000 responses, and, as a result, has assessed the epicentral (and maximum intensity) as 6 MSK.

While this earthquake does not have any direct precedent, so far as is known, it is comparable to other earthquakes in the general Herefordshire area, notably those of 6th October 1863, 27th December 1896 and 15th August 1926, which had Richter magnitudes of 5.2, 5.2 and 4.8 respectively. The epicentre of the 1926 event was near Tenbury Wells, about 40 km SE of the epicentre of the Bishops Castle earthquake. There have also been small events in the Clun area, notably the 15th April 1984 Newtown earthquake (3.2 ML) and the 31st May 1882 Knighton and 27th December 1768 Presteigne earthquakes. These last two had small magnitudes (based on felt areas) but appear to have caused relatively high intensities of up to 5 and 7 MSK, respectively.

Following the mainshock, a dense network of 11 stations was installed around the epicentre in order to detect possible aftershocks with station positions chosen to optimise the location accuracy and focal mechanism determinations. In the six weeks following the mainshock, only six aftershocks were detected with the largest magnitude, 1.5 ML, occurring the day after the mainshock. The local network, however, has provided improved control over aftershock location, with a corresponding reduction of the hypocentral errors to $\pm$0.4km in epicentre and to $\pm$0.2km in depth for the best cases.

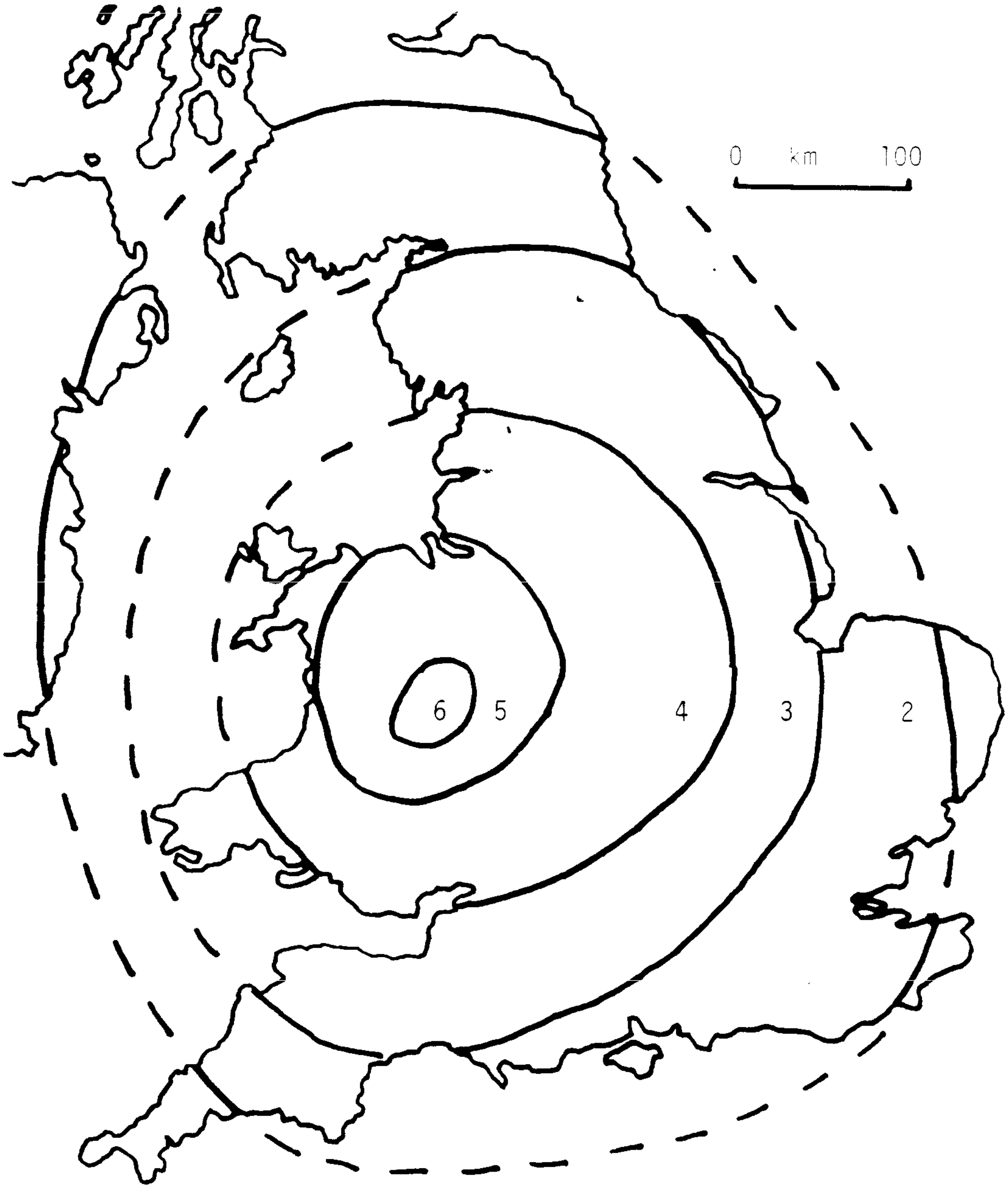
This small number of aftershocks contrasts with that for similar magnitude events in intraplate environments, worldwide, and especially when compared with the 19th July 1984 (5.4 ML) earthquake on the Lleyn Peninsula when 20 events per week with magnitudes greater than 1.0 ML occurred in the first 4 weeks. This lack of a substantial aftershock sequence at Bishops Castle suggests a relatively high stress drop which is consistent with the markedly higher frequency content of the mainshock when compared to that of the Lleyn event.

A focal mechanism obtained for the mainshock shows a dominance of strike-slip faulting with a component of thrust on either a N or WSW striking fault plane. The focal planes dip steeply west and SSE, respectively.

One aftershock, on 17th April with a magnitude of 0.7 ML, has also yielded a mechanism with focal planes similar in strike to the mainshock but with dips in the opposite sense and a dominant thrust component. The maximum compressive stress directions determined for both events are NW-SE.

In the absence of other evidence, the two possible focal planes defined by an earthquake mechanism analysis cannot be separated into the fault plane and the orthogonal auxiliary plane. Despite the small number of aftershocks, the accuracy of location provided by the dense local network of monitoring stations has permitted these few events to identify the N-S plane as that of the causative fault.

The surface structure of the area is dominated by the NE striking Welsh Borderland Fault System and no surface feature has characteristics that are compatible with either plane of the mainshock mechanism. There is, therefore, no surface expression of the causative fault of the mix-crustal Bishop's Castle seismicity which is the usual situation for intraplane earthquakes.




Provisional MSK isoseismal map of the 2 April 1990 Biship's Castle earthquake.

## ENGINEERING SEISMOLOGY OBSERVATIONS

N.N. Ambraseys, J.J. Bommer and A.Y. Eighazouli
Civil Engineering Department, Imperial College

Field observations in the epicentral area the day after the earthquake revealed that damage was very limited. From observations in Shrewsbury, Wrexham and Ruthin, the maximum observed intensity was estimated to be IV+ on the Modified Mercalli Scale. This assessment is made on the basis of selecting the modal observation, rather than the mean, median or maximum, (Richter, 1958), although some isolated observations may have corresponded to V or event VI, particularly human responses. For example, in the area around Dogpole in Shrewsbury, two chimneys were damaged and a decorative urn fell from the floor of St. Julian's church. The church is now used as a craft centre, and the occupants reported that none of the ceramics or glassware had been dislodged from tables and shelves. The team would conclude therefore that the damage that did occur was more closely related to particular vulnerability rather than a high level of shaking.

In London the earthquake was felt by a few people in favourable positions, such as those at rest on upper stories, which would correspond to an intensity of II. Taking London, Dublin and Carlisle as the limits of the II isoseismal gives an average radius of 230 km from the epicentre; using the equation derived by Ambraseys (1985b) for northwestern Europe, this gives a magnitude $M_s$ = 4.28. Using the Prague formula the surface-wave magnitude was calculated from 18 stations of medium to long period at distances from 3° to 13°; this was found to be $M_s$= 4.2 (±0.3) for a mean period of 13 seconds. The seismic moment calculated by NORSAR is $M_0 = 6.0 \times 10^{23}$ dyn-cm, which corresponds to a moment magnitude of $M_w$ = 4.5, (Ekstrom & Dziewonski, 1988).

We have compared the $M_s$ value of this event with that of the North Wales earthquake of 19th July 1984 using the same stations. We find that for this latter event $M_s$ = 4.5 (±0.2) and that $M_0 = 8.5 \times 10^{23}$ dyn-cm, or $M_w$ = 4.7; that is that the 1984 earthquake was somewhat larger and its magnitude was also compatible with the macroseismic observations. Of similar magnitude was the shock of 15th August 1926 ($M_s$ = 4.4), (Ambraseys, 1985a).

The Bishop's Castle earthquake highlights the importance of defining uniformly the size of UK earthquakes and the need for a proper calibration of local magnitude scales.

Ambraseys, N.N. (1985a) Magnitude assessment of northwest European earthquakes. Earthquake Engineering & Structural Dynamics, vol. 13, pp.307-320.

Ambraseys, N.N. (1985b) Intensity-attenuation and magnitude-intensity relationships for northwest European earthquakes. Earthquake Engineering & Structural Dynamics, vol. 13, pp.733-778.

Ekstrom, G. & Dziewonski, A.M. (1988) Evidence of bias in estimations of earthquake size. Nature, vol. 332, pp.319-323.

Richter, C.F. (1958) Elementary Seismology. W.H. Freeman.

## SECED MEETINGS

### DESIGN CRITERIA FOR NUCLEAR STRUCTURES
### ONE DAY SEMINAR HELD AT UKAEA RISLEY
### TUESDAY, 16TH JANUARY 1990

Report by Peter Merriman, British Nuclear Fuels

The meeting was held in conjunction with the Institution of Structural Engineers and was attended by over 110- delegates representing a broad spectra of the nuclear industry. Six speakers gave presentations ranging from 30 to 45 minutes.

1. G. Jordan - BNFL

"Design of BNFL Safety Related Structures"

Mr. Jordan outlined the overall role of his firm in the nuclear fuel cycle covering, the production of fuel pellets, the reprocessing of uranium from spent fuel and the waste management strategy. Improved standards for extreme hazards had led to experimental studies to support the design criteria for cladding and the wind effects on the Sellafield site. In addition, dropped flask loads had been modelled to substantiate the containment philosophy on the inlet pond of the Receipt and Storage Building. He explained that the seismic design criteria was to design for a 0.25g Design Basis earthquake with the requirement to consider that there would be no sudden collapse of the structure if the earthquake increased to 0.35g (Cliff Edge). Design criteria had been developed to restrict the containment barriers to an elastic behaviour during the earthquake and to permit plastic behaviour in the supporting administration areas. He felt that there was a need to be continually aware of the developments in Design codes in seismic practice with the Euro Code 8, New Zealand and American Codes being updated as more technical information was made available. Possible development areas mentioned were:

a) the application of three dimensional programmes to give a better understanding of soil/structure interaction effects.

b) the damage assessment of existing facilities to meet the higher safety standards required.

2. Professor J. Eibl, University of Karlsruhe "Core Melt - Proof Containment for PWR - Reactors".

Prof. Eibl described how risk is commonly defined as the produce of probability of occurrence of accident and the cost of consequences of failure. At the present time, he felt that this approach was not acceptable to the public because for nuclear power plants the first factor approaches zero at its extreme limit while the second factor tends to infinity. Therefore his team were investigating designs to provide core melt-proof containment.

The following conditions had to be considered:

a) Internal Pressure in the Containment (Hydrogen Explosion, Deterioration).

| | | |
|---|---|---|
| - | static | 3.0 MPa |
| - | Dynamic | 23.0 MPa per 5ms |

b) Failure of Pressure Vessel

- Melt through under High System Pressure 16 MPa
- Steam Explosion after Core Melt (220 M J Kinetic Energy)

c) Removal of Heat

d) Enclosure of Molten Core

e) Tight Closure of all Penetrations

Prof. Eibl outlined the key features of the design to meet these requirements - 80 "chimneys" about 60m high being located in between the concrete ribs to passively remove most of the after heat by natural draught.

- a core catcher below the reactor vessel
- a small gap between the steel shell and the outer pressed concrete shell which is closed when the steel containment yields under high pressures.

Actual prices on the last PWR showed that Civil Engineering costs represented 17% with 4% for the Reactor Building. He estimated that these additional safety features would increase the civil cost by 30%. With long term energy demands in mind, he felt that these costs could be incurred if it meant regaining public acceptance in the industry.

3. G. Kessler - Karlsruhe Institute of Neutron Physics and Reactor Technology

"Design Criteria for Future Pressure Water Reactors"

Mr. Kessler defined the ultimate objectives of his team's work as

a) the containment of the radioactivity within the reactor in the very improbable case of a core melt.

b) any release of radioactivity to the environment should be almost zero or at least extremely small.

c) the outer containment shell retains its integrity and tightness.

He outlined the specifications for his R & D programme.

1. Melt through of the Pressure Vessel under low pressure.
2. Melt through of the Pressure Vessel under high pressure.
3. The Problem of $H_2$ Deterioration in the Reactor Containment.
4. Steam Explosions
5. Basement Erosion by Molten Core Material.

When completed these studies will provide more confidence that the possibility of a core melt down can be designed for.

4. Professor Soane - Bingham Blades

"Seismic Implications"

Prof. Soane outlined the methods of analyses available to the designer. From the equivalent lateral force (ELF), for regular structures to determine preliminary member sizes to the use of modal analysis on irregular structures. Explicit Dynamic Analysis was applied on very complex structure where response spectra were required - he emphasised that this was very costly compared to modal analysis. From personal experience of the San Francisco earthquake he drew attention to the large cost of financial damage over 10 billion dollars, and the personal tragedies 65 killed and over 13,000 made homeless. A large percentage of the damage away from the epicentre was due to high amplification on soft soils - the measured acceleration at a comparable distance being three times greater on the soft soil (artificial fill Bay Mud or Alluvium). Slides illustrated that in many cases, failures were due to inadequate detailing - the Interstate 880 possibly collapsing over a length of 1.3km due lack of transverse links at hinge positions. From experience base information, it was apparent that if mechanical equipment well anchored, then a large percentage would be functional after the event.

5. A. Mann - Allott and Lomax

"Structural Steelwork in nuclear structures"

Mr. Mann explained that the major effects of improved safety standards had been the increased costs due to the connection detailing for seismic requirements and the better quality of steel required to meet the extreme temperature conditions. The key features to obtain the overall response modification factors were outlined:

a) It was beneficial if the hinges formed should be sequential rather than at the same time.

b) The greater number of hinges (redundancy) that are required to be formed before the structure becomes a mechanism - the higher the response modification.

c) The need to consider the structural form - where possible the hinges should be spread throughout the structure so increasing energy absorption.

d) In large portal frames the plastic hinges could extend up to metres in length and should not be considered at a discrete point - lateral restraint being provided for the compression flanges.

He emphasised the need to distinguish between local ductility for individual members and the response modification factor which was for the overall system. Other factors were the effects of strain hardening on the upper bound yield stress, the weak beam/strong column approach for multi storey buildings and the future developments in the Eurocode where two different types of joints were identified.

6. J.C.W. Smith, Nuclear Design Associates

"Techniques used in the Design and Analysis of the Sizewell B Reactor Building.

Mr. Smith described the prestressed concrete containment shall for the reactor building with its three buttresses running vertically from the top of the base to 60° up the dome. At these buttresses the 37 No. 15.2mm diameter compacted 'strands' are stressed to a maximum of 80% of their ultimate capacity of 11.2 Mn - each hoop tendon covering 240° of the circumference.

The main requirement is that the ultimate internal pressure load capability is twice the design pressure. On the analytical side, initial static analyses were carried out on PAFEC - the seismic ones on MSC/NASTRAN. To simulate, the variation of material properties with strain - the non-linear Code ADINA was used to cater for the cracking behaviour of concrete. A 1% limiting strain on the hoop tendons restricted the pressure to 0.72 Mpa which was 2.09 times the design pressure. All programmes were extensively verified against themselves and standard solutions.

To validate the non-linear analysis a 1/10 scale model of the structure has been constructed and tested to failure. The loading for safety reasons was applied by water - there being a gradual reduction in incremented loads as the test approached the required pressure of twice the design one. Some 'tuning' of the non linear elements was required to match the analytical and practice results. Overall, however, the test confirmed the design assumption and validated the non-linear assessment.

## 'AN OVERVIEW OF THE LOMA PRIETA EARTHQUAKE' JOINT MEETING WITH SECED AND EEFIT INSTITUTION OF CIVIL ENGINEERS 30TH MAY 1990

Report by Peter Merriman, British Nuclear Fuels

Peter Yanev gave an entertaining and informative talk supported by slides on the field studies and case histories carried out by EQE after the earthquake.

### General Features

He explained that it was not the expected "Big One" - being relatively small to the San Francisco one of 1906:- Magnitude 7.1 Richter compared to 8.3, a short duration time of 15 secs to 60 secs and a fault rupture of 31 miles to 270 miles. From the early 70's there had been extensive monitoring of the San Andreas fault. This had led to predictions that there was a 90% probability of there being an event of magnitude 6.0 at Parkfield to the South within the next thirty years. Closer to San Francisco, there was a small probability 20% of a magnitude 7.0 event on the Hayward fault. Confidence had been gained by the high probability 30% of a magnitude 6.5 event in the Loma Prieta region being confirmed. He warned that the latest studies indicated a 20% probability of a 7.0 event in the next five years close to the heavily populated areas - San Francisco and Oakland.
Damage was generally observed in areas where the peak horizontal acceleration exceeded 0.25 g. The maximum acceleration was 0.60g near the epicentre reducing to 0.10g at 60 miles away on rock in accordance with standard curves. Where there was artificial fill, bay mud and alluvium layers above rock, there were large amplications 2 - 3.5 times higher than on rock at the same distance

### Bridges

Peter showed the collapse of the upper deck of the Bay Bridge - a fifty year old structure consisting of a long suspension bridge with long simply supported side approaches up to 150 metres. He commented that it was very unwise for the major artery of the transport system not to have been reappraised by modern computer techniques. The failure due to large longitudinal movement at an expansion joint may have been predicted.

On the Cypress Bridge Interstate 880 where 31 people died there were two causes of failure.

i. the natural frequency of the soft esturine mud was close to the frequency of the transverse portal frames supporting the viaduct causing increased resonance.

ii. the inadequate detailing of the confining reinforcement at the key hinge positions.

At present, no firm decision had been taken on a similar structure at the Embacadero - still standing with minor damage - on whether to reinstate or demolish. There were three proposals considered:

i. jacketing the column with steel plates.
ii. enlarging the existing columns.
iii. providing additional columns.

In California, most public buildings including school designs had to be assessed by independent engineers - this had not occurred on the bridges as they were part of a very large government department and were not subject to these regulations. Peter recommended the use of an independent review to improve engineering standards and avoid similar disasters.

Structures

In the Marina district, the failure had been on those houses with a soft storey at ground level - the outside walls being modified to cater for garages. An insurance study highlighted that the maximum damage occurred on the areas with largest depth of fills and on corner buildings where two external walls may have altered, thereby making them very susceptible to torsional effects. An interesting feature was the small damage to unreinforced masonry houses. Site surveys showed that they had many internal walls in both directions, thereby forming a relatively stiff structure which did not resonate with the soft soil below.

After the earthquake, several houses were shored up to first floor level to prevent further collapse. These have now been jacked up to the vertical position for reoccupation. In several cases, a heavy concrete slab has been constructed at ground floor level to minimise possible differential settlement due to liquefaction and increased stiffness provided by steel bracing or wooden shear walls using stiffened plywood panels.
On commercial buildings, there had been no damage to steel framed structures in San Francisco. From damage observed - some on retrofitted buildings - he stressed that more attention should be made to non-structural elements. In one, many of the internal partitions had fallen down while all the three main services - ventilation, electricity and water were still operational. Where movement joints had been provided in accordance with standard regulations, pounding often occurred at floor levels. This had led to the compressive failure of concrete floors in one case - Peter felt that an analysis of the structures would have increased the joint from 100 to 300 mms.
He emphasised the need for care in providing seismic details - poor examples shown were:

i. a pipe crossing an expansion joint without a flexible section.

ii. inadequate ties at roof level between the wooden roof beams and side concrete walls.

iii. undersized washers on one base plate allowing the vessel above to topple over onto an adjacent structure.

iv. In one retrofitted building large crossed struts had been provided in the same plane. At their cross-over point, they had been detailed so that there was very small resistance to buckling - additional plates had increased the capacity.

There was a marked contrast between the telephone exchange at Watsonville near the epicentre and a new one in Oakland. The older building which was stiff, with large shear walls had its equipment well anchored with the supports for the batteries properly braced. When the electricity supplies went down - the standby diesel generators were able to take over without any loss of service. The modern structure was subjected to high torsional modes and suffered damage to the shear wall at ground level. It was observed that the shear walls had been split down the middle - the two "reinforced" sides being split apart by the high compressive stresses - Peter hinted that more links between the faces may be required in future on shear walls. There was extensive damage to the Terra Cotta and the remedial work has been estimated at 40 million dollars.

The major failure at Moss Landing Power Plant was that the reserve batteries on the turbines were unable to provide sufficient power to lubricate the machine after four hours. There were several cases of minor damage to pipework.

For the data base, the effects of relay chatter on control systems had been monitored in detail. Although there had been erroneous signals - there had been no affect on safety.
There had been a case where mechanical plant had been severely damaged by the uplift due to sloshing effects. This may lead to a reappraisal of the present method of estimating the effect in open tanks.
Lastly he warned of the potentially damaging effects that a damaged sprinkler system can have on equipment. Where they are required, care must be taken in their design and position to ensure that damage will not cause water spray onto electrical equipment for fire prevention purposes.

Future SECED Meetings, both immediately (July - September) and those planned for the new season are given below:

**WHAT'S ON JULY ———— SEPTEMBER 1990**

| Date/Time | Title | Speaker | Venue |
|---|---|---|---|
| 14/8/90<br>16:00 p.m. | The 1990 Romanian Earthquake - A Field Report | S. Ledbetter<br>A. Coburn<br>A. Pomanis | I.Struct.E |
| 26/9/90<br>17:30 p.m. | Seismic Resistance of Masonry | Dr. R. Spence<br>Dr. J. Menu | I.Mech.E |

FORTHCOMING SECED MEETINGS

| | | | |
|---|---|---|---|
| 31.10.90<br>17.30 p.m.<br>ICE | Introduction to Non-Linear Transient Dynamics | Dr. R. Keene | |
| 28.11.90<br>17.30 p.m.<br>I.Mech.E | Assessment of Seismic Hazard and Risk in the UK | Dr. Pappin | |
| 30.1.91<br>17.30 p.m.<br>ICE | Earthquake Protection Planning in Mexico City | Dr. Coburn | |
| 27.2.91<br>17.30 p.m.<br>ICE | Reports from the Field on recent Earthquakes in Algeria | | Joint with EEFIT/ EFTU |

| | | |
|---|---|---|
| 27.3.91<br>14.30 p.m.<br>ICE | Understanding Earthquake Source Processes and their Implications for Engineers | Prof. B. Bolt |
| 24.4.91<br>17.30 p.m.<br>Warrington | Soil Structure Interaction | ½ Day Workshop introduced by Dr. Skipp |
| 29.5.91<br>17.30 p.m.<br>ICE | Mallet Milne Lecture<br>Reduction of Vibrations | Prof. G. Warburton |

## CONFERENCE CALENDAR

| Title | Date | Location | Organiser |
|---|---|---|---|
| 9th European Conference on Earthquake Engineering | Sept.1990 | Moscow | Soviet Comm. on Earthquake Engineering |
| 2nd International Conference on recent 15.3.91 advances Geotechnical Earthquake Engineering and Soil Dynamics | 11.3.91 | St. Louis USA | University of Missouri - in Rolla |
| Earthquake, Blast and Impact (Measurement and Effects of Vibration) 3rd SECED Conference | 18-20 Sept 1991 | UMIST Manchester | SECED |

## BOOK REVIEWS

The following review is printed by kind permission of the Institution of Structural Engineers.

Design Guide on the Vibration of Floors

T.A. Wyatt (Ascot: Steel Construction Institute, 1989) 43pp.

This short publication provides a straightforward method of assessing the vibration sensitivity of floors in steel framed structures. The need for this document has been brought about by the trend towards lightweight long-span floor systems which are often susceptible to vibrations caused by pedestrian traffic. Human beings are very sensitive to vibration and although the live load stresses may be well within safe bounds, the feeling of vibration in floors is sometimes a nuisance to users of a building and should, therefore, be controlled.

The author succeeds admirably in the task of deriving a concise method of calculation which should ensure that vibration problems may be avoided. The procedure is in three stages: (a) the natural frequency of the floor is calculated; (b) the floor response is determined according to whether it has a 'low' natural frequency (less than 7 Hz) or a high frequency, in which case impulsive excitation is considered; and (c) the response is compared with a criterion for annoying vibrations culled from the relevant literature. The guide contains a brief introduction to the theory of structural dynamics and the author explains carefully the background to the three stages of the assessment.

The document will be a valuable resource to many structural engineers who are finding it increasingly necessary to pay attention to vibration phenomena. The relatively complex issues of human response to vibration are dealt with sympathetically. Readers with no knowledge of vibration theory may find the section on modes and natural frequencies a bit difficult at first. However, the rules provided are sound and can be applied with confidence as long as the units are used consistently.

Finally, it should be said that there is currently no British Standard covering floor vibrations for buildings and therefore this volume fills an important gap in the literature on serviceability criteria.

## MEMBERSHIP NOTES

A past member is remembered by Dr. B. Skipp and the new committee is introduced by chairman Ed. Booth.

### THANKS TO DAVID HOWELLS - from Dr. B. Skipp

DAVID ASHTON HOWELLS MA(Cantab), CEng, FICE

D.A. Howells was Chairman of SECED from 1979 to 1982, he had joined in 1962 and served on the Executive Committee from 1969 to 1984.

David is out of the Cambridge stable, and this shows in his predilection for a basic analytical approach to problems. He became a Member of the Institution of Civil Engineers in 1947 and Fellow ten years later. Much of his working life was with Howard Humphries but he was introduced to earthquake engineering with Babcocks when designing for the Tokai Mura nuclear power station. Subsequently he had five years with Sir William Halcrow and Partners and he has lectured and published on tunnel design. David has been particularly engaged in the design of dams for earthquakes; his contribution to a quantitative assessment of the migration of pore pressure down fault apertures and induced seismicity is notable. He took the lead in organising and editing the proceedings of two significant conferences: "Dynamic Waves in Civil Engineering" Wiley Inter-science 1971 and "Dams and Earthquake" ICE 1980. A frequent participant in the informal meetings of SECED in the 70's his more recent work has been connected with differential excitation of bridge like structures.

When in 1984 he retired from the Executive Committee he took on the arduous task of editing the new Newsletter until 1988 and the Society is indebted to him on this count. With his quiet if sometimes sardonic style David has had to overcome disabilities and illness and in doing so has contributed substantially to the profession, the Society and the Institution. Now fully retired he must be gratified with the current standing and influence of SECED to which he has contributed so much.

### The SECED Committee - Edmund Booth

The smooth running and success of a society like SECED depends to a large extent on the enthusiasm of its committee, but this is often a somewhat faceless body having little contact with the membership. We have decided to try and rectify that by at least showing you what we look like and, briefly, telling you a little about ourselves. You now have no excuse for not buttonholing a suitable member of the committee at the next SECED meeting and giving him your ideas on what the Society should be doing.

The committee is a large one, consisting of 18 members. 8 are elected by the membership for a

Society) and a further 4 are co-opted each year to cover specific areas of the Society's work. The committee meets 5 times a year; however, much of the work is done by the 8 sub-committees, listed below. Despite its large size, I can honestly claim that there are no passengers on the committee; debate is always lively, ideas flow freely and everyone makes a significant contribution. Some of Britain's most distinguished earthquake engineers and seismologists from both academies and industry have given dedicated service for many years (I think it is true to say they love the Society) but equally encouraging is that four new members have joined this April and are bringing in fresh ideas and approaches. We are also well served by the Institution of Civil Engineers, which provides us with a secretariat, meeting spaces, lecture rooms and much else besides. James Dawson has recently joined us as secretary and gives invaluable and efficient support.

Chris Browitt's report on last year, reproduced elsewhere, shows that SECED enters the nineties in good shape. We intend to maintain that progress and strengthen the Society still further. The backbone of SECED is its evening meetings; this year's programme we believe to be varied, stimulating and of essential interest to the profession. We will be spending much time preparing for the third Mallet-Milne lecture next May and for our three day conference in September 1991. We are preparing a proposal to host the Tenth European Conference on Earthquake Engineering in 1994 and we intend to continue to play a part in promoting the UN's International Decade for Natural Disaster Reduction.

I hope you will enjoy your membership of the Society and gain professional benefit from it in the coming year. Please give us what support you can and persuade your colleagues to join. A growing membership is our greatest strength.

## THE NEW COMMITTEE 1990-91

Edmund Booth (Chairman) — Ove Arup & Partners
Dr. Amr Elnashai (Vice Chairman) — Imperial College

Secretary

J. Dawson — ICE Secretariat

### Elected Members

| | | |
|---|---|---|
| Dr. W.P. Aspinall | - | Mass Data Systems |
| Dr. R.S. Steedman | - | BEQE |
| Dr. J.R. Maguire | - | Lloyds Register |
| Dr. P. Merriman | - | BNFL |
| J. Barr | - | Rendel, Palmer and Tritton |
| N.P. Hinings | - | Allott & Lomax |
| M. Raybould | - | Nottingham University |
| D.J. Mallard | - | CEGB |

Representatives

### Institution of Civil Engineers

Prof. H.A. Bucholdt - Polytechnic of Central London

### Institution of Mechanical Engineers

Prof. G.B. Warburton - University of Nottingham

Institution of Structural Engineers

| | | |
|---|---|---|
| Dr. D. Key | | CEP Research |

Geological Society

| | | |
|---|---|---|
| Dr. B. Skipp | - | British Geological Society |

Immediate Past Chairman

Dr. C. Browitt

Co-Options

| | | |
|---|---|---|
| Dr. R. Kunar | - | BEQE |
| Dr. B. Ellis | - | Building Research Station |
| Dr. R.D. Adams | - | International Seismological Centre |

ORGANISATION OF SUB-COMMITTEES

| | | |
|---|---|---|
| Steering Committee | - | Mr. Booth, Dr. Elnashai, Dr. Browitt, Mr. Mallard and Dr. Ellis |
| Mallet-Milne | - | As Steering Committee, helped by Drs. Skipp and Kunar as necessary. |
| 1991 SECED Conference | - | Dr. Maguire (Chairman), Mr. Barr and Drs. Kunar, Steedman, Browitt (Treasurer), Merriman and Elnashai |
| 1994 EAEE Conference | | Mr. Booth and Drs. Elnashai and Skipp |
| Newsletter | - | Mr. Hinings and Dr. Aspinall |
| IDNDR | - | Drs. Adams, Aspinall and Browitt (Brief to monitor and promote SECED's interest and support for the IDNDR). |
| Membership | - | Dr. Elnashai and Mr. Raybould |
| Research & Education | - | Mr. Booth and Drs. Key and Elnashai |

NEW COMMITTEE MEMBERSHIP PROFILE

Edmund Booth (Chairman) is with Ove Arup & Partners, where he specialises in the earthquake resistant design of building and industrial structures. A special interest is improving links between the research community and industry.

Dr. Amr Elnashai (Vice Chairman) is Lecturer in Earthquake Engineering and co-ordinator of Earthquake Engineering Research at Imperial College, London. He is also visiting Professor at the University of Southern California, Los Angeles, and is the technical co-ordinator for BSI on Eurocode 8: seismic.

Dr. Robin Adams was formerly a seismologist in New Zealand. Since 1978 he has been at the International Association of Seismology and Physics of the Earth's Interior.

Dr. Willy Aspinall; formerly Senior Research Fellow, Univ. of the West Indies (1970-1983); now Principal Consultant, Aspinall and Associates; Director, Mass Data Systems Ltd. Interests: earthquake seismology, volcanology and cricket.

Joe Barr, of Rendel Palmer and Tritton, has specialised in earthquake resistant design of bridges, and was a member of the EEFIT team which visited California following the Loma Prieta earthquake in 1989.

Dr. Christopher Browitt is head of the Global Seismology Unit at the British Geological Survey in Edinburgh. He is responsible for maintaining the UK seismic monitoring network and is active in a number of aspects of seismological research.

James Dawson (Secretary)
A graduate from the University of Edinburgh, worked for a year as a research in the House of Commons before joining the Institution of Civil Engineers.

Dr. Brian Ellis joined the Building Research Station in 1974; presently Head of the Structural Dynamics Section within the Structural Design Division; involved with full-scale testing and structural response to vibration, wind loading and explosions. Member of various national and international committees concerned with dynamics and serviceability.

Dr. David Key is a partner of CEP Research, Managing Director of Bristol Earthquake Engineering Laboratory and a Research Fellow at Bristol University. Author of a book on earthquake resistant design, he has over 30 years experience in civil and structural engineering practice.

Nigel Hinings is a Principal Engineer with Allott & Lomax Special Projects Group involved in dynamic analysis and earthquake resistant design of building and civil engineering structures.

Dr. Roy Kunar, Managing Director of BEQE Limited, past Chairman of SECED. Specialist in earthquake engineering and structural dynamics. Served on the SECED Committee for nearly 10 years. Author of over 25 publications.

John Maguire (Lloyd's Register, Civil & Structural Department) is a Chartered Civil/Structural Engineer, interested in structural dynamics, and also serves on BSI and NAFEMS Committees

David Mallard, Nuclear Electric plc. Currently a member of the Steering Committee. Particular interests are seismic hazard assessment and the dynamic properties of soils and rocks.

Dr. Peter Merriman is a principal engineer in the Structural Assessment section of British Nuclear Fuels, and has been involved in many aspects of the analysis and structural design of earthquake resistant facilities.

Matthew Raybould is a lecturer in the Department of Civil Engineering, University of Nottingham. His major research interests are the cyclic loading of soils and he is currently investigating the behaviour of clay contaminated silt.

Dr. Bryan Skipp graduated from Birmingham, was introduced to geotechnics at Imperial College and joined Soil Mechanics Limited from the NCB in 1986, becoming a Consultant in 1981.

Dr. R. Scott Steedman, Manager, Engineering Division, BEQE Cambridge; Fellow, St. Catherine's College, Cambridge. Technical background in modelling and analysis of geotechnical problems and dynamic and earthquake soil-structure interaction.

Geoffrey Warburton, Professor in the Department of Mechanical Engineering of the University of Nottingham, 1961-1969. Editor of the Journal, Earthquake Engineering and Structural Dynamics, since 1971. Author of many papers and a book on structural dynamics.

## SECED MEMBERSHIP APPLICATION FORM

Name (block capitals please) :
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Name & Address of organisation with whom employed (block capitals please) :

Decorations, Degrees, Diplomas, Membership of Professional Bodies :

Date of birth :

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Home Address (block capitals please) :

Telephone :

Name (block capitals please) :
Home Address (block capitals please) :

Telephone :

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## STUDENT MEMBER

Name (block capitals please) :
Home Address (block capitals please) :

Telephone :

Confirmation of student status : (To be signed by tutor or supervisor)
I confirm that this applicant is currently a full-time student
Date ________ Signature
Institution and position

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