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LONG ODDS ON PREDICTION

Ian Main discusses the current state-of-the-art in the prediction of earthquakes.

EARTHQUAKES and horse-racing are both complex phenomena where the prediction of individual events is inherently difficult, if not impossible. No one expects the bookmaker's favourite to win every time, but everyone expects the bookie to live well off an astute calculation of the odds. But the perception of the public, the media and many government funding agencies is that we should nevertheless go on betting heavily on the prediction of individual earthquakes, rather than spending money on a careful calculation of the odds - that is, estimation of the seismic hazard.

A useful earthquake prediction requires specification in advance of the location, magnitude and time of an individual event, within narrow limits, otherwise a programmed evacuation could not take place[1,2]. Prediction in this sense has proved elusive. In contrast, statistical estimates of the seismic hazard are based on a calculation of the likelihood of ground shaking from an understanding of the source mechanics of a population of earthquakes.

The thorny question of how to respond to the threat of earthquakes was at the core of a meeting* on the validation of schemes for earthquake prediction. Such schemes are sometimes based on a deterministic physical hypothesis, but more commonly on an empirical observation of geophysical or geochemical precursory 'anomalies'. The most cited physical hypothesis was based on the observation of dilatancy (an increase in sample volume due to microcracking) and associated precursors observed in laboratory tests, proposed in the 1970s (ref. 3). But the predicted anomalies failed to materialize, and the hypothesis was rejected - that is, the results failed to scale linearly over the spatial and temporal scales that separate laboratory tests and large earthquakes.

At the meeting, consensus emerged on several points. First, given the dynamic complexity of earthquake sources and the material heterogeneity of the Earth, there are no clear reasons why the reliable prediction of individual earthquakes is possible[4]. Second, we are not yet in a position to identify any significant and unambiguous earthquake precursors, even with the benefit of hindsight[5] ('past-posting' in betting terminology). Third, individual predictions, and prediction methods, should be stated so that their success or failure can be objectively and unambiguously determined.

Finally, in the absence of reliable prediction methods, we should concentrate on hazard mitigation based on a better understanding of earthquake source mechanisms, their statistical properties, the propagation of seismic waves and the response of individual sites, buildings and infrastructure to seismic vibration[5]. This lower-profile, statistical approach does not aim to give, say, a few hours' or days' warning for inhabitants of an area to leave it; rather, it results in guidelines for the construction of buildings and other structures that will withstand the forces earthquakes impose upon them. Most deaths and injuries from earthquakes are caused by collapse of buildings, or secondary effects such as ensuing fires, so this approach should save more lives, given the current state of knowledge[6,7].

Why have earthquakes proven so difficult or impossible to predict? There are two possibilities: either detectable and reliable empirical precursors do generally exist, but our instrumentation cannot measure them; or the physics of earthquakes is too sensitive to small fluctuations to produce reliable precursors. In fact, modern theories of earthquakes hold that they are critical, or self-organized critical, phenomena[8], implying a system maintained permanently 'on the edge of chaos', with an inherent random element and

* Assessment of Schemes for Earthquake Prediction, Royal Astronomical Society/Joint Association for Geophysics Discussion Meeting, London, 7-8 November 1996. Abstracts can be viewed at http:/www.seismo.demon.co.uk/Nov7th/second circular.html or are available by e-mail from russ.evans@bgs.ac.uk

Aftermath of the magnitude 6.8 Ms Kobe earthquake which devastated the city of Kobe on 16 January 1995. On current knowledge, individual earthquakes cannot be predicted in any reliable way. Hazard mitigation, based on a lower-profile statistical approach, remains the better prospect.

'avalanche' dynamics with a strong sensitivity to small stress perturbations. The notion of self-organized criticality is consistent both with the observed frequency-magnitude relation of earthquake populations, and the presence of '1/*f* (power-law) noise in almost all borehole spectra on a variety of rock types in different tectonic areas (P.Leary, Univ. Edinburgh).

Evidence of 'fracture criticality' has been inferred from observations of seismic anisotropy, using a new theory of stress-induced directionally dependent, contemporaneous crack opening and closure, which need not produce larger-scale dilatancy (S. Crampin and Z. Zatsepin, Univ. Edinburgh). Time-varying anisotropy due to stress changes may therefore be observable in the form of temporal changes in shear-wave polarization. This approach constitutes a middle course, where a full earthquake prediction is not possible, but the probability of possible events is temporarily elevated above the long-term seismic hazard[9].

According to one view, it is "highly unlikely" that reliable precursors exist (R. Geller, Univ. Tokyo). Indeed, no single precursor satisfying the validation criteria developed by the International Association of Seismology and Physics of the Earth's Interior has ever been observed unambiguously (D. Booth, British Geological Survey). These criteria include a precise definition of the anomaly, an explicit statement of the signal-to-noise ratio, detection at more than one site, and a full publication of negative as well as positive evidence[5].

There are many reported 'anomalous' electrical signals in earthquake zones, recorded as voltage oscillations between two electrodes coupled to the ground and separated by relatively long distances. Case studies of such observations were presented for Japan (Y. Enomoto, Mechanical Engineering Laboratory, Tsukaba, Japan) and Crete (F. Vallianatos, Chania, Crete). However, as in other descriptions of the same techniques, there is no clear-cut statistically significant correlation with individual earthquakes during the recording period.

In analysing such signals, it is also essential to be able to identify a plausible physical meaning for them - for instance, assignment of many electric precursors to events preceding an earthquake, notably by P Varotsos *et al.* (the VAN group) in Greece, violates the principle of energy conservation (P Bernard, Inst. Physique du Globe, Paris). It is an indication of mistaken priorities that earthquake 'prediction' as advocated by this group absorbs more funding than research programmes to improve building design practice in Greece (S. Stiros, Inst. Geology and Mineral Exploration, Athens).

Vague 'predictions', with loose limits on their magnitude, and time and place of occurrence, can also give spurious success rates, even for a purely random process (Bernard). This theme was taken up by several advocates of rigorous statistical testing and evaluation of the significance of reported precursors and predictions (Y. Kagan, Univ. California, Los Angeles; F. Mulargia, Univ. Bologna; P. Stark, Univ. California, Berkeley). For example, a prediction scheme should perform better than a naive rule, such as predicting that large events will have aftershocks (Stark, Mulargia). When this is done, with full access to the facts (successes - hits; and failures - misses or false alarms), it is hard to be optimistic about the prospects for reliable prediction. In contrast, methods already exist for assessing long-term hazard from combining instrumental, historical, geological and geodetic data (Y. Kagan; ref.10).

Why is it hard to get this 'negative' conclusion, based on our experience of prediction, across? Speaking with the conviction of a prophet outside his adopted country of Japan, Geller laid into the sloppy practice and publicity-seeking activities of a minority of scientists and even non-scientists. We have had more than 100 years of failure in attempts to predict individual earthquakes, and "the public, media and government authorities must be clearly informed that earthquake prediction in its popularly understood sense is impossible at present, that all attempts to predict earthquakes to date have been failures, and that there are no reasonable prospects for prediction in the near future".

Given the current state of knowledge, the best bet with a guarantee of return in reducing the threat from earthquakes is on hazard mitigation. Even then, it is likely that there will continue to be some failures. The next best bet, perhaps in the form of an each-way flutter, seems to be on the establishment of the possibility of a seismic hazard that may be time-dependent. In the absence of past-posting, the prediction of individual earthquakes remains a long shot.

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1. Wood, H. O. & Gutenberg, B. Science **82**, 219-220 (1935)
2. Mecelwane, J.B. Bull. Seismol. Soc. Am. **36**, 1-4 (1946)
3. Scholz, C.H., Sykes, L.R. & Aggarwall, Y.P. Science **181**, 803-810 (1973)
4. Main, I.G. Rev. Geophys. **34**, 433-462 (1996)
5. Wyss, M. (ed.) Evaluation of Proposed Earthquake Precursors (Am. Geophys. Un., Washington DC, 1991)
6. Reiter, L. Earthquake Hazard Analysis (Columbia Univ. Press, New York, 1991)
7. Press, F. et al. Confronting Natural Disasters (Natl Acad. press, Washington DC, 1987)
8. Bak, P. & Tang, C.J. Geophys. Res. **94**, 15635-15637 (1989)
9. Keilis-Borok, V.I. & Gossubov, V.G. Phys. Earth Planet. Inter. **61**, 73-83 (1990)
10. Main, I.G. Nature **357**, 27-28 (1992)

Meeting Report: 26 February 1997

JOINT SECED / OES TECHNICAL MEETING:

ALTERNATIVE METHODS FOR BLAST ANALYSIS OF STRUCTURES

This meeting attracted an almost capacity audience to the Godfrey Mitchell lecture theatre to hear three speakers describe different aspects of designing structures to resist the damaging effects of pressures generated in gas or vapour cloud explosions. The meeting was chaired by Dr Alan J Watson of SECED and Dr Peter Blair Fish of OES.

The first speaker, Dr Philip Cleaver in place of the indisposed Mr Mike Johnson, British Gas Plc, Research and Technology, discussed both the mechanisms by which pressure is generated and the factors which can influence the magnitude of peak pressure, following the combustion of a cloud of flammable gas or vapour formed after an accidental release into the atmosphere. It was pointed out that although confined explosions of fuel mixture can produce peak pressures up to 8 bar and flame speeds of over 100m/s, structural failure will often occur at lower pressures and the subsequent venting and expansion of the hot gases limits the maximum overpressure to values much less than 8 bar. For unconfined explosions the generation of over pressure is associated with flame speed and the analysis of such incidents as Flixborough indicates a type of damage produced by overpressures associated with higher flame speed than normally occur in unconfined conditions, possibly 200 m/s in Cyclohexane. Several slides and video clips were shown of British Gas experiments to demonstrate the dramatic increase in flame speed, and therefore over-pressures, that occur when the flammable cloud engulfs regions of congestion, formed by repeated obstacles such as process pipework. Research has identified several important factors such as the geometry of the module, the location of the point of ignition, the ignition strength and the fuel type and concentration, which influence the severity of the effects from gas and vapour cloud explosions. Also discussed were the methods which can be used to prevent or control and mitigate the severity of the explosion. One control technique to achieve explosion suppression is to use the spray produced by conventional offshore fire deluge systems. The break-up of relatively large water droplets in the spray into much smaller droplets, as a result of their acceleration in the high speed flow of gases ahead of the flame, increases the surface area of water and increases the extraction of heat from the flame. A controversial aspect of this technique however, is whether or not the operation of a gas detection water spray system has a potential to ignite the gas cloud. Finally predictive models available for explosive overpressures were briefly described, including the computational fluid dynamics models which most accurately follow the physical processes by solving fluid flow equations, and experimental scaling techniques recently developed to estimate large scale behaviour.

The next speaker, Dr Richard Yeung, Kvaerner Earl and Wright, demonstrated a non-linear progressive collapse analysis recently performed for a topside design. The analysis was used to assess the reinforcement required to strengthen the structure in order to resist a module blast overpressure ranging from 0.5 to 4 bar. The weight increase in the structural members required to resist increasing blast overpressures, were obtained. The analyses were performed using an ABAQUS finite element analysis of the entire structure. A deck floor blast analysis using strain hardening and strain rate and negative pressure effects, identified lateral buckling as a major cause of reducing the load bearing capacity. Another blast analysis described by Dr Yeung was that of a temporary refuge firewall, part of a safety case submission, identifying the failure mode of buckling in a diagonal column.

The final speaker, Mr Rob Harwood, Shell UK Exploration and Production, spoke about the difficulties of idealising the measured pressure-time pulse originating from a real explosion, into a shape more useful for a response calculation. The idealisation must be such that the characteristics of the structural response are adequately captured. An example was given where the use of a triangular pressure-time idealisation using a least squares fit, could include more impulse and overpredict the response by a factor of three. It was also pointed out that the jagged edge sometimes measured in a pressure function might be due to the characteristics of the pressure gauges and so is not really part of the true response function. Since the predicted structural response depends on the interaction of the explosive load with the characteristics of the structure, any error in either will influence the accuracy of the modelling system. The other point made strongly by Rob Harwood, is the importance of identifying membrane action as a significant mechanism by which a structural element supports an applied load. A case study of design for an explosion which produced peak pressure from 6 - 8 bar, showed that a yield line analysis gave a slab capacity of 2 bar, but a non-linear analysis predicted 4 bar when membrane effects were included, allowing deflections ten times larger than the elastic deflection. Some thoughts were presented on the future design of compliant blast walls, failing at the welds, which would not respond to all the small peaks and oscillations of pressure that occur in a real bast wave.

The meeting ended with a useful discussion period chaired by Dr Blair-Fish where some in the audience questioned the use of simple methods of analysis when the blast wave and the structural element have such a complicated interaction. It was agreed that the simplest methods gave useful preliminary design concepts but the finalisation of the design needed more complicated analysis.

A J Watson

Meeting Report: 29 January 1997

REPAIR AND STRENGTHENING OF CONCRETE STRUCTURES FOLLOWING AN EARTHQUAKE:

The SECED Meeting on 29 January 1997 on "Repair and Strengthening of Structures following an Earthquake" comprised of two presentations:

"Repairs and upgrading for masonry structures in seismic areas" by Dr Dina F. D'Ayala , Lecturer, University of Bath
"Repair and Strengthening of Concrete Structures Following an Earthquake" by Dr Kypros Pilakoutas, Lecturer, University of Sheffield

The following article based on the latter presentation gives a summary of the various techniques for the strengthening and repair of damaged concrete structures.

Redesign Strategy

The retrofit of damaged structures due to earthquakes requires an approach of re-design rather than an ad-hoc intervention. The following steps should be therefore be followed before a correct redesign strategy is adopted:

- Accurate assessment of 'as built' capacity
- Re-estimation of loading
- Use of improved analysis techniques

The structural intervention options available are:

- Elimination of conceptual or construction errors
- Selective repair
- Strengthening following re-analysis and redesign

Repair

The repair options, given below, aim in general not to increase the structural strength or stiffness, but to restore the structure or element to its originally intended state.

- Resin Injection
- Patch repair
- Shotcreting
- Welding of fractured reinforcement
- Replacement of damaged infills
- Partial Jacketing
- Plate bonding

Strengthening

Strengthening of a structural component can have an effect not only on the strength but also on the stiffness and ductility. In many instances, the most economic solution may not be the enhancement of strength of the structure, but rather the ductility.
The various strengthening options available to engineers are briefly discussed below:

Strengthening of the Reinforcement

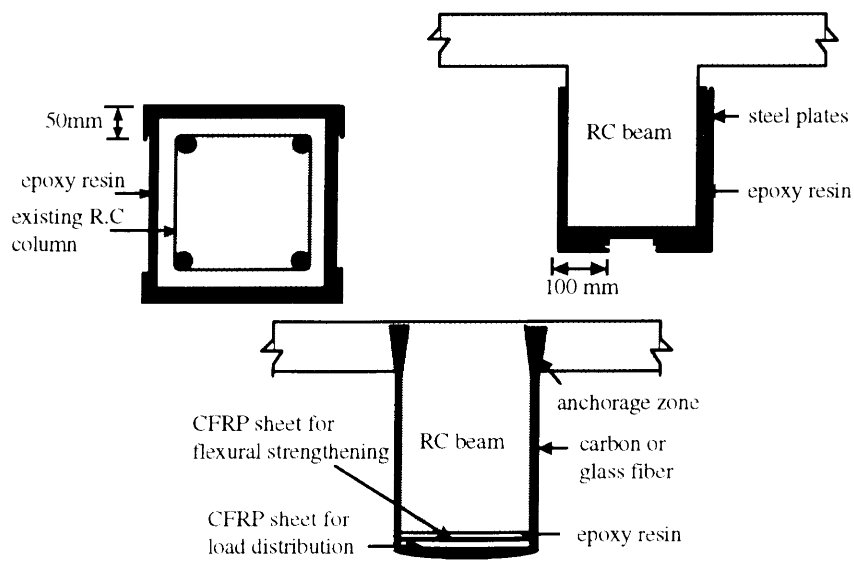
Inadequate or corroded reinforcement can be replaced by additional reinforcement, by post-tensioning or by externally bonded structural plates. The amount of strengthening to be achieved depends to a large extent on the properties of the existing element. Under-reinforced elements can be strengthened substantially, usually at the expense of ductility, whilst over-reinforced elements can not be helped much without the addition of concrete overlays.

Strengthening with Reinforcing Bars and Jacketing

This method requires the unloading of the element to be strengthened, and the removal of the concrete cover. Sufficient new reinforcement can be added in parallel to the existing one by suitably designed lapped splices, welding, or suitable coupling devices. Care has to be taken when welding, since the high temperatures induced may damage the concrete or adhesives.
The addition of new bars usually results in the jacketing of part or the entire member. This method, is very effective for enhancing the strength, stiffness and ductility of a member and is recommended for severely damaged elements.

Externally Bonded Structural Plates

Steel plates and more recently Carbon Fibre Reinforced Plastic (CFRP) plates are bonded externally on concrete elements by using epoxy resins. This technique is very effective in reducing deflections and crack widths. The concrete surface should be well prepared and steel plates need to be sand-blasted and cleaned just prior to the epoxy application. Epoxies can be 'buttered on' or injected under



Use of externally bonded structural plates to strenghten beams and columns pressure. One limit to the strength enhancement that can be achieved by this technique is the strength of the surface concrete, since peeling failures take place within the surface of the concrete. Creep of the adhesive is also a concern and that is why the adhesive layer should be kept to a minimum. The main advantage of this technique is the achievement of minimum increase in the size of the section after strengthening. The thickness of the plate is limited (< 8 mm), (CEB, No162, 1983) mainly because of the strength of its bonding, but can be increased if special anchorage systems are used.

Gluing of thin steel sheets on damaged elements by using epoxy resin laid onto the steel sheets and concrete surfaces, is shown in the figures opposite. The steel sheet is placed in position and fastened using clamps for at least 24 hours. However, this technique is not recommended for structures subjected to earthquake action due to their cyclic nature (UNIDO, 1983).

The advantages of using CFRP sheets relative to steel plates are; their high tensile strength, low weight, no sandblasting is required, and resistance to corrosion. The main drawback is the high material cost which can be counteracted with the reduction of the labour cost involved in the technique. Pre-tensioned CFRP sheets is another alternative of strengthening (Meier, 1992). The pre-tensioned material, carbon or glass fibres, is wrapped around the cross-section on one side and anchored on the opposite side in the compression zone. The above procedure allows for the effective strengthening of the shearing force areas without the use of steel.

Strengthening with longitudinal Post-tensioning

Post-tensioning of high strength materials is an effective way of utilising them structurally. Both bonded and unbonded tendons can be used. Strengthening by post-tensioning can be designed by using the conventional post-tensioning design procedures. Care should be taken to limit anchorage slip and to protect the tendons against fire and corrosion. Anchorages and deviators can be placed at suitably designed ends, at additional supports, at existing diaphragms or at new ground anchorages.

Strengthening with Lateral External Post-tensioning

A new technique patented by the University of Sheffield, involves lateral post-tensioning high strength strip around existing RC elements. This confines the concrete and, hence, has the potential of increasing the ductility, as well as the strength of the element. This technique is particularly useful in the repair and strengthening of elements in seismic zones.

Another new seismic retrofitting and repair technique utilises a hybrid of high strength fibres, saturated with a special epoxy formulation, which allows them to be wrapped round any shape of column. The unstressed HSFC jackets proved to enhance ductility and increase shear strength of columns to the extent that brittle shear failures are converted into ductile deformation modes. The stiffness increase provided with the technique is less than that of steel or concrete jacketing.

Infill walls

Infilling of existing frame bays by the addition of reinforced concrete, masonry and prefabricated infill panels, is considered to be the most effective technique of increasing the lateral strength and stiffness of the structure as a whole. Two of the main disadvantages of the infill walls are the increase in the mass of the structure which may result in the increase of the dynamic forces during earthquakes and the likely brittle failure of infills.

Steel Bracing

Steel bracing is more effective when there is a need to dissipate energy from a strong earthquake or high winds and there is a requirement to increase the stiffness of a structure. The main advantages of the technique are the small dead loads of the materials used and the speed of application. The main disadvantage of this technique is the lack of dissipating capacity of the whole structure when the steel bracing is in the elastic range. This is the case during weak and sometimes moderate intensity earthquakes.

Steel Jacketing

This technique is based on fixing thin steel full plates (steel encasement) or tie plates (steel cage) around the whole of the column. Steel angles are placed at each of the corners of the column and are clamped onto the concrete. The plates are then welded onto these angles. Proper tightening of the sheets can be ensured by means of heat tensioning. A cast-in-place concrete jacket or a gunite jacket is finally added. Enhancement in strength, stiffness and the shear capacity can be achieved.

Adding new reinforced concrete/concrete layers

Two types of concrete overlays exist; concrete or reinforced concrete compressive overlays and reinforced concrete tensile overlays . The majority of the data available is experimental (CEB, 1983) and the analytical solution is restricted to define correction factors γ_n to account for the degree of "monolithicity" between the new and the old layers (Tassios, 1981).

General Problems Remaining and Conclusions

There are few generally accepted models for re-design and non-linear analysis which is required to be carried out is expensive and not widely used by designers. Hence, in many countries the practice of repair and strengthening at the moment is more of an art rather than a science.

Special care should be taken to ensure the continuity of new members with existing ones. This is a particular problem when trying to anchor additional bars or reinforcement plates. Welding of reinforcement which could lead to an effective connection of reinforcement has its own problems due to the unsuitability for welding of existing reinforcement or the residual stresses developed as a result of heat generated during welding.

Many repair and strengthening techniques are quite intrusive and can lead to the disturbance of the function of the structure for long periods during the works. The cost of such structural interventions is usually high, which means that many times the owners either prefer to reconstruct or do patch repairs, masking the real problems. Hence, there is still the need for new repair and strengthening techniques which are not only efficient but also quick and cheap to apply. The use of FRP reinforcement is emerging as a new technology which shows some promise, but it is still prohibitively expensive for ordinary applications.

Code provisions for strengthening and repair of buildings

A number of useful publications for undertaking the redesign of structures necessary for the strengthening and repair of buildings are given in the following:

- Repair and Strengthening of Reinforced Concrete, Stone and Brick-Masonry Buildings (UNIDO, 1983)
- Assessment of Concrete Structures and Design Procedures for Upgrading (Redesign) (CEB 162, 1983)
- Repair and Strengthening of Concrete Structures (FIP, 1991)
- Redesign, Repair and Strengthening of Buildings in RC Regions (Tassios, 1981)
- Guideline for Seismic Retrofitting (Strengthening, Toughening and/or Stiffening), Design of Existing Reinforced Concrete Buildings (Sugano, 1980)
- Eurocode 8 Part 1-4 (1995)

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EURODYN'96:

Tianjian Ji reports on the third European conference on structural dynamics.

The third European Conference on Structural Dynamics (EURODYN'96) was held in Florence, Italy between 5-8 June 1996. The first two EURODYN conferences took place in Bochum, Germany (1990) and in Trondheim, Norway (1993). These major conferences on structural dynamics are held every three years and attract engineers, research workers, university lecturers and others to present their work on structural dynamics, exchange information and discuss subjects of mutual interest. As well as the general lectures and the keynote lectures, 144 papers were selected from more than 200 originally submitted to the conference.

The conference was opened by the Mayor of Florence, Mario Primicerio, who is also well known among scholars in Mechanics. Two general lectures were arranged in the opening section and were given by Prof. E Benvenuto, University of Genova, Italy and Prof. JM Thompson of University College, London. Between them they gave an account of the past and future of structural dynamics. Prof. Thompson's talk in particular concentrated on non-linear dynamics and chaos which he demonstrated with the aid of many graphics. It was an interesting experience sitting in the huge hall that was built in the 16th century when little was known about mathematics and mechanics, listening to a lecturer on the "growth of structural dynamics between 19th and 20th century".

As a start to the morning and afternoon sessions on the following days, five keynote lectures were given on different branches of structural dynamics. The 144 papers were divided into twelve themes which were presented in three parallel sessions. These together with the number of papers in each subject were:

- Earthquake Engineering (20)
- Wind Engineering (17)
- General dynamics and numerical methods (19)
- Non-linear material behaviour (6)
- Structural control (13)
- Structural systems and elements (15)
- Bridges and large structures (12)
- Masonry and historical structures (5)
- Experimental dynamics (9)
- Structural identification and damage estimation (10)
- Soil dynamics and soil-structure interaction (13)
- Vehicles and machines (5)

The conference was organised by Prof. Giuliano Augusti and his colleagues, and the two volumes of proceedings are currently available from the organisers. There were increasing numbers of delegates from Eastern European countries and it is expected that the number will further increase as it is likely that the next conference will be held in Prague, Czech. Rep. in 1999.

Tianjian Ji, UMIST

Current State of ENV 1998: Design provisions for earthquake resistance of structures (Eurocode 8)

Pre-standard No	Ratified by SC	Published by CEN	Enquiry Launch	Present Situation
ENV 1998-1-1	DEC 93	OCT 94	(JAN 97)	In ENV period 2 yr Enquiry Jan 97
ENV 1998-1-2	DEC 93	OCT 94	(JAN 97)	In ENV period 2 yr Enquiry Jan 97
ENV 1998-1-3	DEC 93	FEB 95	(JAN 97)	In ENV period 2 yr Enquiry Jan 97
ENV 1998-1-4	JUNE 95	JAN 96	(AUG 97)	In ENV period
ENV 1998-2	JUNE 94	DEC 94	(JAN 97)	In ENV period 2 yr Enquiry Jan 97
ENV 1998-3	JUNE 96	(NOV 96)	(NOV 98)	Post-vote editing
ENV 1998-4	(JAN 97)	(APR 97)	(APR 99)	Drafting
ENV 1998-5	JUNE 94	OCT 94	(JAN 97)	In ENV period 2 yr Enquiry Jan 97

NB Dates in Brackets are current forecasts

EARTHQUAKE-RESISTANT CONCRETE STRUCTURES

Edmund Booth reviews a new book by George G. Penelis and Andreas J. Kappos.

Earthquake-resistant concrete structures, George G. Penelis and Andreas J. Kappos.
E&FN Spon, 1997. (£65.00)
ISBN 0-419-18720-0 (572 pp)

For many years, the classic work by Park & Paulay "Reinforced concrete structures", published in 1975, was the main source of textbook information on the seismic design of concrete structures. Recently, however, three new, and in many ways complementary, texts have appeared on this subject. Tom Paulay's new book (ref. 1), written with Nigel Priestley, comes from the master himself, and covers reinforced masonry as well as concrete. That by Booth (ref. 2) is more eclectic, covering New Zealand, US and Japanese practice, as well as providing sections on foundations and base isolation. The book by Penelis and Kappos is the most recent of the three. Although Andreas Kappos is now based at Imperial College London (and is a member of the SECED committee), the main work on the book was done from the University of Thessaloniki and is rooted in the very strong Greek school of reinforced concrete. The authors therefore write from a firmly European point of view and one of the attractive features of the book is that it provides an insight into the concrete clauses of the new European code, Eurocode 8 (EC8, ref. 3), as well as, in some cases, a critique of them.

The book is aimed at post-graduate students and practising engineers, as well as final year students specialising in earthquake engineering. The first 150 pages provide a general review of the principles of earthquake resistant design, covering seismology, dynamic analysis and design principles. These may serve as a useful reminder or introduction to the subject, but it is the remainder of the book, concentrating on the seismic behaviour of reinforced concrete, where the main value lies. There is an extensive section on the fundamental properties of reinforced concrete under cyclic loading, and then sections on the design of the principal types of structural elements, including beams, columns, walls, beam-column joints and floor diaphragms. Numerical design examples to EC8 are provided. The main emphasis therefore is on European practice, which draws quite strongly on New Zealand methods but differs markedly from the essentially empirical provisions of US codes or the quite distinct practice of Japanese engineers.

A very interesting chapter follows, based on research by Kappos, which reports the seismic performance of ten-storey buildings designed to a close precursor of the current version of EC8, as evaluated from non-linear time history analysis. The chapter covers buildings designed to all three ductility classes allowed by EC8, namely high, medium and low. Generally, EC8 comes out well, but the authors find that the confinement requirements for columns are excessive and the shear requirements for beams and walls (particularly in the low ductility class) may not always be sufficient. Of equal interest is the finding that although the low ductility class building has no obvious cost advantage over the others, it offers significantly the least protection against earthquakes greater than the design basis event, while the high ductility building offers the most. Since EC8 (unlike the Californian UBC code) currently permits all classes of ductility in regions of high seismicity, this is a significant finding. The chapter is not the final word on the subject, since it only relates to 10 storey buildings, but it is an important contribution to an ongoing debate.
The next two chapters draw on the authors' experience of post-earthquake field missions in Greece, describing the nature of damage experienced by concrete buildings in past earthquakes, and setting out procedures for emergency post-earthquake damage inspection and evaluation. The final chapters treat repair and strengthening, discussing both design strategies and practical techniques. Once again, this is a firmly European view of a subject where there has also been an extensive American research effort recently.

The seismic response of concrete structures is a highly complex, as well as fascinating, subject; the increasing proportion of earthquake damage represented by the failure of concrete buildings makes it a very important one, too. The book is a very welcome addition to the literature on the subject, particularly in its exposition of the European state-of-the-art in the subject.

A shortened version of this review appeared in Engineering Structures: the journal of earthquake, wind and ocean engineering.

1. Paulay T and Priestley MJN. Seismic design of reinforced concrete and masonry buildings. Wiley, 1992.

2. Booth E (editor). Concrete structures in earthquake regions. Longmans, 1994.

3. Eurocode 8 (ENV 1998): Design provisions for earthquake resistance of structures. Part 1.3.2: Specific rules for concrete buildings. CEN (European Centre for Standardisation) Brussels, 1995.

SECED DIRECTORY OF PRACTITIONERS, 1997 EDITION

SECED is now preparing to update the corporate directory, from the 1995 (5th) edition to a new 1997 (6th) edition. A print run in excess of 1000 is envisaged, distribution being to selected clients, consultants, contractors, researchers, academics, libraries and others. In addition, the 1997 directory will be distributed to delegates at the next SECED Conference.
You are hereby invited to make an entry or renew your existing entry in the directory. Please telephone or write to John Maguire at address shown opposite for a proforma for the new edition. The new directory will be produced for SECED by Lloyd's Register in a similar format to the 1995 version.

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NOTABLE EARTHQUAKES JANUARY - MARCH 1997

Reported by British Geological Survey

YEAR	DAY	MON	TIME UTC	LAT	LON	DEP KM	ML	MB	MS	LOCATION
1997	07	JAN	20:29	55.94N	3.08W	2	1.1			MUSSELBURGH, LOTHIAN
			Felt in the Musselburgh, Newcraighall, Joppa and Portobello areas of Lothian.							
1997	09	JAN	18:53	55.94N	3.08W	2	1.7			MUSSELBURGH, LOTHIAN
			Felt in the Musselburgh, Newcraighall, Joppa and Portobello areas of Lothian.							
1997	11	JAN	04:41	55.94N	3.09W	2	1.7			MUSSELBURGH, LOTHIAN
			Felt in the Musselburgh, Newcraighall, Joppa and Portobello areas of Lothian.							
1997	11	JAN	20:28	18.22N	102.76W	33		6.5	6.9	MICHOACAN, MEXICO
			One person killed and extensive damage in the Arteaga area of Michoacan.							
1997	18	JAN	09:09	56.23N	4.47E	15	3.1			CENTRAL NORTH SEA
1997	21	JAN	01:47	38.97N	75.03E	33		4.9		XINJIANG, CHINA
1997	21	JAN	01:48	39.27N	77.26E	33			5.8	XINJIANG, CHINA
			At least twelve people killed, 27 injured 2,500 houses damaged or destroyed.							
1997	29	JAN	17:13	55.94N	3.09W	2	0.6			MUSSELBURGH, LOTHIAN
			Felt in the Musselburgh, Newcraighall, Joppa and Portobello areas of Lothian.							
1997	04	FEB	22:12	56.61N	4.57W	8	2.6			RANNOCH MOOR,TAYSIDE
			Felt in the Appin and Orchy Bridge areas of Rannoch Moor.							
1997	06	FEB	00:36	53.50N	1.04W	4	1.5			RANSKILL, NOTTS
			Felt throughout Ranskill, Nottinghamshire.							
1997	10	FEB	23:09	53.20N	1.52W	11	2.8			CHESTERFIELD, DERBYS
			Felt throughout the Ashgate, South Wingfield and Matlock areas of Derbyshire.							
1997	27	FEB	21:08	29.90N	68.10E	33			7.3	PAKISTAN
			At least 35 people killed, many injured and damage occurred in towns and villages.							
1997	28	FEB	12:57	38.10N	48.80E	33			6.1	IRAN
			At least 500 people killed, 2000 injured and 35,000 people left homeless.							
1997	01	MAR	06:04	39.35N	76.80E	22			5.5	XINJIANG, CHINA
			At least two people killed, six injured and 4,000 houses destroyed.							
1997	18	MAR	05:53	66.12N	3.02W	15	3.9			NORWEGIAN SEA
1997	19	MAR	19:57	34.77N	71.65E	33		4.8	4.1	PAKISTAN
			At least 15 people killed, several injured and damage occurred throughout the Bajaur region.							
1997	23	MAR	05:56	53.41N	1.04W	4	2.0			BLYTH, NOTTS
			Reported felt in Blyth, Nottinghamshire by one person.							
1997	26	MAR	08:31	31.91N	130.53E	10		5.6	5.9	KYUSHU, JAPAN
			At least 22 people injured, damage occurred to houses throughout Kagoshima.							

Issued by Bennett Simpson, British Geological Survey, March 1997

Forthcoming Events

21 May 1997
Mallet-Milne Lecture "Structural Response Prediction using Experimental Data" ICE 5pm

24 September 1997
Recent Research Topics in Soil Foundation Dynamics

29 October 1997
Recent Developments in Shaking Table Control and Testing

26 November 1997
Seismic assessment of existing structures

26 to 27 March 1998
The Next SECED Conference: *Seismic design practice into the next century - research and application.*

Contents

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

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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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