ISSN 0967-859X
THE SOCIETY FOR EARTHQUAKE AND CIVIL ENGINEERING DYNAMICS

SECED NEWSLETTER

Volume 9, No 2
Summer 1995

The Grevena-Kozani Earthquake (Greece) of May 13, 1996

Immediately following the destructive earthquake of 13 May in northern Greece a small team from Imperial College, Julian Bommer, Anargyros Alexandris and Eleni Protopapa, in conjunction with Dimitri Papastamatiou and colleagues from National Technical University of Athens (N.T.U.A.), visited the damaged area and studied different aspects of this earthquake. Subsequent field visits were made over a period of a few weeks. Here the preliminary findings and an overview of the earthquake are presented.

Plate 1: Collapsed two-storey house in Kalamitsi.

On 13th May 1995 at 11:47 local time, a strong earthquake struck the area of western Macedonia in northern Greece between the cities of Kozani and Grevena. The earthquake caused extensive destruction in many villages located in the epicentral region and limited damage in the major cities of the area. No fatal casualties were reported, which was mainly attributed to the fact that the earthquake was preceded by some strong foreshocks that alerted the population. Moreover, the earthquake struck on a Saturday morning when many of the heavily damaged schools and churches were empty and a large proportion of the population was outdoors.

According to the Laboratory of Geophysics of the University of Thessaloniki, the hypocentre of the mainshock was located at 40.16°N, 21.67°E, 20 km south of the city of Kozani, at a depth of 9km, and the surface wave magnitude was M_s=6.6. NEIC reported an almost identical epicentral location with the depth constrained to 13km and a body wave magnitude m_b=6.2 and a surface wave magnitude M_s=6.5. The moment magnitude was M_w=6.5

according to USGS and M_w=6.6 according to Harvard. The fault plane solution determination for the mainshock by Harvard suggests that the causative fault was normal, with a small component of dextral strike slip, striking N60°E and dipping at 31° to the north. The spatial distribution of the aftershock foci is in agreement with this solution and defines the dimensions of the fault, whose total length is estimated to be 30km (Papazachos *et al.*, 1995). Ground cracks were observed in the vicinity of Palaiochori village, whose orientation and displacement are consistent with this mechanism.

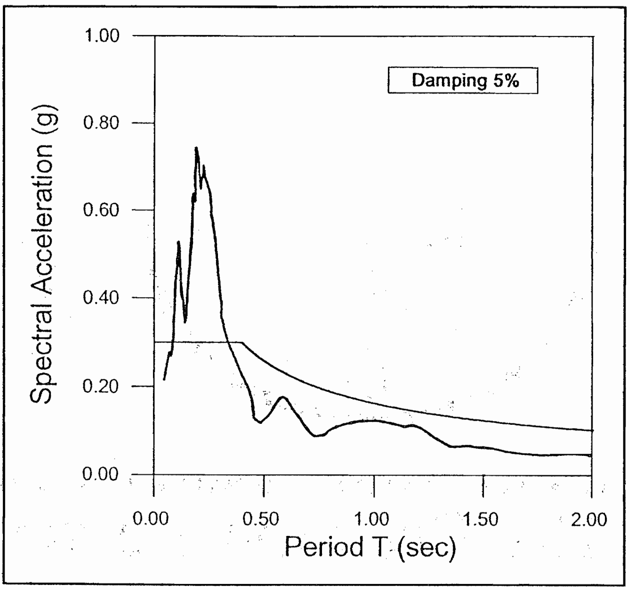

Figure 1: Horizontal acceleration response spectrum from the record of the main shock in Kozani, compared with the elastic design spectrum from the new code for rock sites in Zone I.

The area has been characterised by seismologists as being of low seismicity, and instrumental and historical data, which is limited for this area of Greece, do not show significant seismic activity. Seismic zonation for the new earthquake resistant design code in Greece has treated the area as an area of background seismicity where the assumption of a maximum magnitude 6.1 has been made (Papazachos, 1990). This seismic hazard analysis classified the region in the first and lowest seismic zone, where the basic horizontal ground acceleration used for design, which corresponds to a 10% probability of exceedance in 50 years, is 0.12g. The fourth and highest seismic zone requires effective accelerations three times larger. Most of the engineered buildings in the area have been designed to seismic coefficients specified in the previous code.

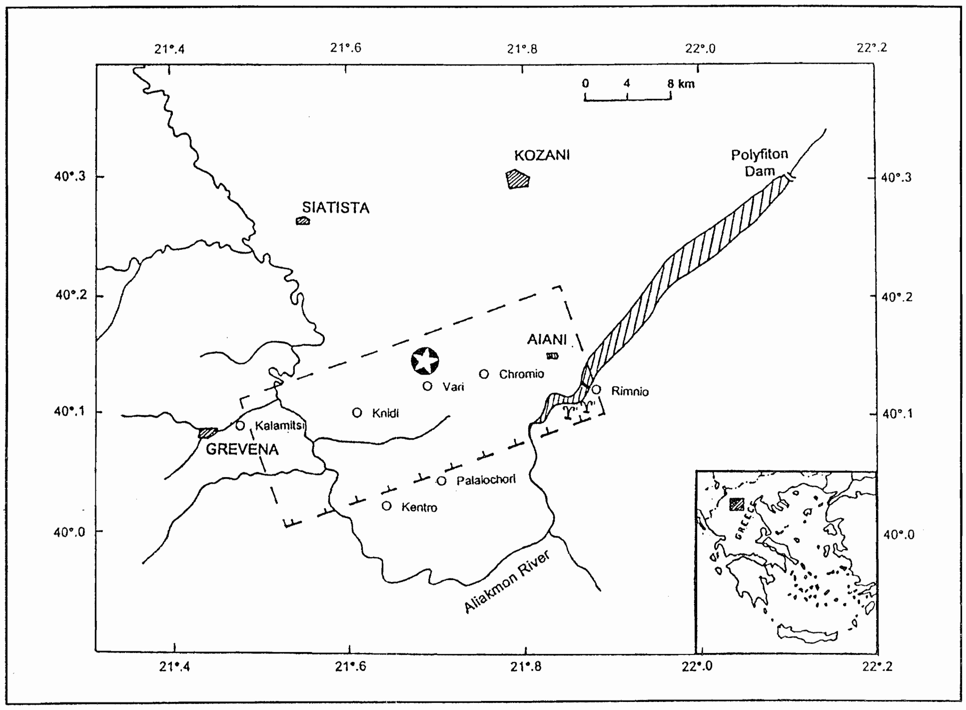

Figure 2: Location map of the epicentral area. Star shows main shock epicentre and dashed line the area of aftershocks. The barbed line indicates the possible location of the fault rupture at the surface. The sites of observed liquefaction are shown near Rimnio.

A strong motion instrument operated by the Institute of Engineering Seismology and Earthquake Engineering (ITSAK) in Kozani, 20km north of the epicentre, was triggered by the earthquake (Lekidis & Theodoulidis, 1995). The peak horizontal acceleration was 0.21g and the peak vertical acceleration 0.08g. The duration of the strong motion was about 7s and the predominant period was about 0.2s. The response spectrum of the record is presented in Figure 1, in comparison with the spectrum prescribed by the new code for a rock site. Other records were obtained from instruments operated by the Public Power Corporation (PPC) at the Polyfiton Dam 30km away from the source and at the Sfikia Dam further away. At Polyfiton Dam, peak horizontal acceleration was 0.025g and peak vertical acceleration 0.017g. No damage to the dam was reported and the operation of the hydro-electric power plant was not interrupted by the earthquake. After the earthquake many strong motion instruments were installed in the area by ITSAK and a large number of recordings from the aftershock sequence have been obtained.

Macroseismic observations are also in good agreement with the definition of the earthquake source. Intensity values have been evaluated based on a damage assessment survey of many villages in the affected area, where maximum values reach IX. Systematic measurements of the sliding of free standing marble blocks in the cemeteries of the area were taken to estimate the strong motion in the epicentral area quantitatively. The coefficient of friction of these blocks was estimated by simple field experiments and from the mean value a critical acceleration of k_c=0.32g was calculated. Maximum values of sliding were of the order of 45mm which corresponds to 0.50g peak horizontal acceleration, according to empirical relationships derived by Ambraseys & Srbulov (1994).

Structural failures

The greatest damage was observed in some of the villages lying in an east-west line, between the city of Grevena and the town of Aiani (Figure 2). The dominant construction systems in these villages are stone masonry, brick and adobe, and there are a few reinforced concrete frames, as well as composites of these systems. In the epicentral area nearly all the buildings suffered some damage and there was a large number of partial and total collapses. In most cases, the absence or inadequacy of lateral ties caused out-of-plane collapse of stone masonry or adobe load bearing walls. Many other stone masonry buildings suffered separation of the inner and outer skins of the wall due to the absence of "through stones" and sufficient bonding. Composite structures proved to be the most vulnerable. The addition of heavy reinforced concrete roof slabs in old stone masonry walls, produced very brittle and unstable structures (Plate 1).

The cities of Kozani and Grevena suffered less because they were located further away from the source. Only one collapse of a reinforced concrete building was observed: two kilometres outside Grevena, a three storey building lost its middle floor (Plate 2). Generally, in Kozani and Grevena only a few engineered buildings suffered localised structural damage and most showed no visible damage despite the strong shaking. Comparison of aftershock records in the southern and the northern parts of Kozani shows significant amplification of the ground motion in the southern part, which is attributed to the softer sediments that cover this part of the city (Lekidis & Theodoulidis, 1995). This is reflected by the fact that multi-storey buildings in the southern part showed more non structural damage, such as cracking of infill walls, than in the northern part.

In the town of Aiani, which is closer to the causative fault, many two and three storey buildings were damaged beyond repair. From measurements of sliding of

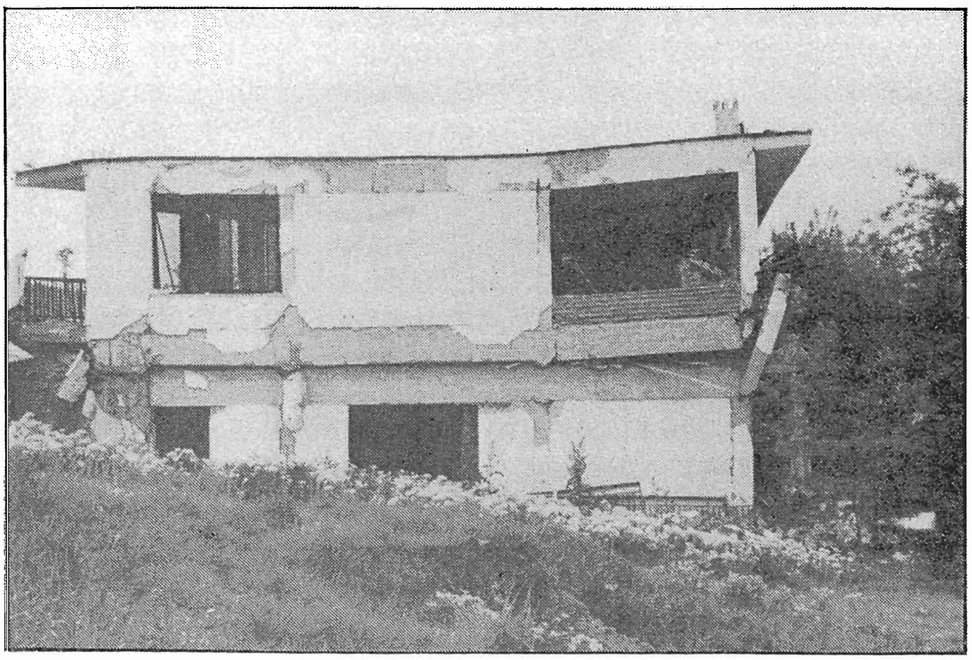

Plate 2: Collapsed middle floor of three-storey RC frame building outside Grevena.

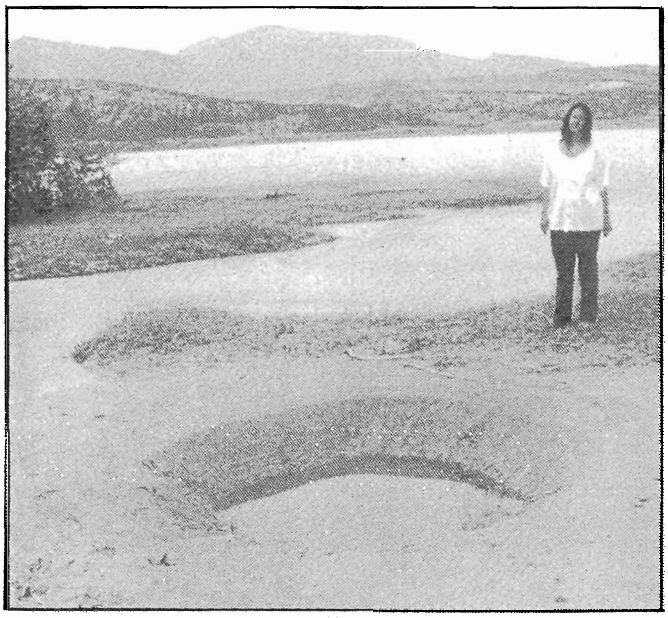

Plate 3: Sand boil and crater on south-eastern banks of Polifiton Reservoir.

marble blocks the peak horizontal acceleration in Aiani was estimated at 0.50g. In most of the cases of heavy structural damage, typical design shortcomings, such as short columns or structural asymmetry, as well as poor detailing, seemed to be the reasons for the failures. Well designed and properly constructed structures in the same town suffered little or no damage.

Geotechnical failures

The geotechnical failures induced by the earthquake include liquefaction, landslides and rockfalls. Extensive liquefaction occurred in the banks of the Polyfiton Reservoir, south-west of Rimnio village, where large sand boils were observed (Plate 3). This liquefaction is probably responsible for the lateral spreading failure of the approach embankment of the bridge that crosses the reservoir at this point. The failure produced extensive longitudinal cracks in the embankment, with vertical displacements of up to one metre and the crossing remained out of service for approximately 3 weeks.

Small landslides and local instabilities in road cuttings were very common in the epicentral region but failures were small enough not to interrupt traffic. A larger landslide, which crosses part of the village of Kentron, moved a few centimetres during the earthquake. It is not clear whether this was the cause of damage to houses situated close to the rear scarp. Only one kilometre away from the same village, another large landslide blocked a small stream and produced a lake. Other smaller landslides were observed in unstable slopes but none of these caused any damage to man made structures.

Further analysis of the data collected is currently being carried out at Imperial College in conjunction with NTUA and ITSAK. A comprehensive report of the findings will be issued in September, examining the implications of this earthquake for seismic hazard assessment and risk mitigation in Greece.

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SECED

SECED, The Society for Earthquake and Civil Engineering Dynamics is the UK national section of the International and European Associations for Earthquake Engineering and is an affiliated society of the Institution of Civil Engineers. It is also sponsored by the Institution of Mechanical Engineers, the Institution of Structural Engineers, and the Geophysical Society. The Society is also closely associated with EEFIT, the UK Earthquake Engineering Field Investigation Team. The objective of the society is to promote cooperation in the advancement of knowledge in the fields of earthquake engineering and civil engineering dynamics including blast, impact and other vibration problems.

For further information about SECED contact The Secretary, Institution of Civil Engineers, Great George Street, London SW1P 3AA, UK.

Dynamic Loads and Temporary Grandstands

Brian Ellis, Building Research Establishment, UK

Currently a major concern in the UK is the safety of temporary grandstands when subjected to dynamic loads. This is, in part, due to the fact that dynamic crowd loads are not included in the UK codes, hence grandstands are not designed to accommodate these loads. Attention has been focused on the problem by a number of incidents which have occurred, the most serious being the collapse of part of a temporary grandstand in Corsica which resulted in 17 deaths and 2587 injured. The subject was discussed at a SECED meeting on 25 January 1995, and some relevant information is presented here.

The Corsica grandstand collapse focused attention on the subject, and subsequent work led to the formation of an Institution of Structural Engineers working group which prepared an interim guidance note which was issued by the DoE to County and District Councils on 27 July 1994. The intention was that this interim guidance would be superseded by an I. Struct. E. guidance document to be issued in autumn 1995. At the same time the subject is being considered by the BS loading code committee, as the problem involves loads generated by crowds and is not simply restricted to temporary grandstands.

The interim guidance for temporary grandstands issued by the UK DoE said

"Where significant dynamic loads are to be expected, safety may be achieved by ensuring that the structure will withstand the dynamic loads or by avoiding resonance effects. A fundamental horizontal frequency above 4Hz when empty should prevent any significant horizontal response. Where it is necessary to prevent significant vertical response, the fundamental vertical frequency should be greater than 8.4Hz when empty."

The key points to note are:

- Dynamic loading is likely to be significant for co-ordinated crowd movement, especially for a highly motivated audience jumping, which is likely to occur in events like pop concerts.
- This loading is likely to be a problem if resonance occurs.
- The designer can either design the structure to withstand the loads or avoid the problem by providing sufficiently high resonance frequencies.
- The vertical frequency takes into account the third harmonic of the loading from jumping, 8.4Hz being 3x2.8Hz which is probably the highest frequency at which a crowd can jump in a co-ordinated manner.
- The horizontal frequency considers the fundamental mode for vertical loads being transferred into the horizontal direction, and considers jumping and stamping, thus the 4Hz limit covers the fundamental mode and takes into account any crowd-structure interaction.
- The relevance of the words 'empty grandstand' is that it means that the designer can actually determine these values, and does have to try to evaluate any interaction effects which are currently not documented.

The implications of this guidance are two fold.

1. For temporary grandstands it won't really affect vertical response, however it will serve to increase the sway bracing which has been identified as the main problem. This will not necessarily involve extra costs, rather it will involve sensible design.
2. For large cantilevered grandstands (for which the guidance does not yet apply) vertical response is of concern and it may mean that they shouldn't be used for pop concerts which might create difficulties, however it is better to be aware of potential problems and to avoid them.

Although this guidance on avoiding resonance effects has been approved by various committees, any comments on the frequency limits or guidance would be welcomed. The alternative of allowing designers to calculate the dynamic response, means that the limiting frequencies are not sacrosanct, albeit the calculations are likely to be complex (see reference).

Reference

1. T Ji and B R Ellis. "Floor vibration induced by dance type loads - theory". Structural Engineer, Vol. 72, No 3, 1 February 1994, pp 37-44.

TECHNICAL REPORT ON ENGINEERING SEISMOLOGY

by Dr. Gordon Woo, EQE International

Gordon Woo is SECED's Technical Reporter for engineering seismology. This report, submitted in January before the Kobe earthquake, is still topical.

Any engineering seismology report communicated at the beginning of January should survey the prospect for the coming year, as well as review progress made in the year just passed. If only engineering seismology were more of a laboratory rather than observational discipline, this report might start by systematically listing the notable experimental milestones of the forthcoming year, instead of echoing the soothsaying of Nostradamus, or otherwise entertaining some speculation on the major earthquakes of engineering importance which may strike in 1995.

There was scarcely time for a rapporteur's ink to dry when the earthquake season started in earnest in 1994, with the Northridge earthquake of 17th January. This was the event which did for Blind Thrusts what the 1985 Coalinga earthquake did for Active Folds - popularise a geological expression which the fault-conscious US Geological Survey should have popularised long beforehand. The harsh truth is that the seismological and geological community would have been no better prepared for the event had it occurred at the end of 1994, rather than at the beginning.

Prior to the major advances in quantum field theory, it was once jested in the 1930's that the mathematical knowledge required of a theoretical physicist was reduced to a rudimentary acquaintance with the Latin and Greek alphabets. To be an engineering seismologist or geologist, does one need more than a pair of walking boots to carry one through a post-earthquake field mission? Can engineering seismology ever be more than just a phenomenological "wait - then go and see" discipline? Do we believe things only because we have seen them: e.g. 1g, 2g peak ground accelerations?

One of the publishing landmarks of 1994 was Cinna Lomnitz's treatise on the Fundamentals of Earthquake Prediction (John Wiley, Chichester). "Earthquake prediction is the best reason for becoming a seismologist", Lomnitz writes. Reason or excuse, it's hard not to seem a charlatan when told by a tabloid journalist that the Northridge earthquake has just occurred. Lomnitz' book is not about prediction in the narrow sense, but about engineering seismology in general: the social, commercial and political aspects as well as the technical. If you read it, remember: Lomnitz told you so.

At the 5th US National Conference on Earthquake Engineering in Chicago in July 1994, there was a heated discussion of the so-called Browning prediction of a Central US earthquake that never was. The state-of-the-art in earthquake science is not so advanced as to deter an articulate novice, such as Browning's daughter, from presenting a cogent argument for the prediction, and mesmerising the media away from the cohort of professional scientists.

As professionals, we may scoff at apparently misguided attempts to predict the time of occurrence of earthquakes. But how good are we at predicting the location of earthquakes, or the level and characteristics of ground motion? Why did some of the accelerograms recorded from the Northridge earthquake come as such a surprise? Can we explain the fractal clustering of building damage? The large element of uncertainty associated with seismic hazard estimation is a reflection of the complexity of these questions, and the disparity between expert judgements is a reflection of our difficulty in answering them.

Despite all the recent IDNDR effort on seismic hazard mapping, some of the open methodological questions seem to have been ignored in favour of maintaining rigid adherence to the Cornell-McGuire orthodoxy, which was established many computer generations ago. Existing procedures for seismic hazard evaluation have developed from crude medium to long-term earthquake forecasting tools. The far sharper short-term prediction tools will soon find their way to refining the methodology for seismic hazard analysis. Watch this space.

A leading proponent of the "walk-down" school of earthquake engineering has declared this subject to be an art rather than a science. His anonymity has been protected, but it needn't be: many practitioners share this view. Andy Warhol started his artistic career by making disaster pictures - so maybe this kind of art has a future.

Should seismic integrity be in the eye of the beholder? With ever-increasing libraries of earthquake strong-motion records, and supercomputer power for doing 3-D numerical simulations of ground motion and earthquake occurrence, the agenda for the late 1990's should turn towards establishing the foundations of engineering seismology as a rigorous quantitative discipline. The manifesto for the future should be this: don't guess it, calculate it.

Behaviour Factors for Building Frames

Professor A.S. Elnashai, Imperial College London
Dr B.M. Broderick, Trinity College Dublin

The SECED meeting on 22 February 1995 was given be Prof Elnashai & Dr Broderick at the Institution of Civil Engineers. The following is an article based on that presentation.

In accordance with observations on the response of structures during previous earthquakes, it is normal in earthquake-resistant design to apply design forces below that implied by elastic acceleration spectra. The degree to which the elastic forces may be reduced varies not only between design codes, but also between structural forms and material types within the same design standard. In Eurocode 8, the level of force reduction allowed is specified in terms of the behaviour factor, *q*. This factor, which is intended to represent the behaviour of the structure beyond its elastic range, includes for the effects of a number of relevant factors, including the redistribution of action effects, soil-structure interaction and three-dimensional response. Of greatest significance, however, is the ductility capacity of the structure, as it is this which most closely represents its energy dissipation potential.

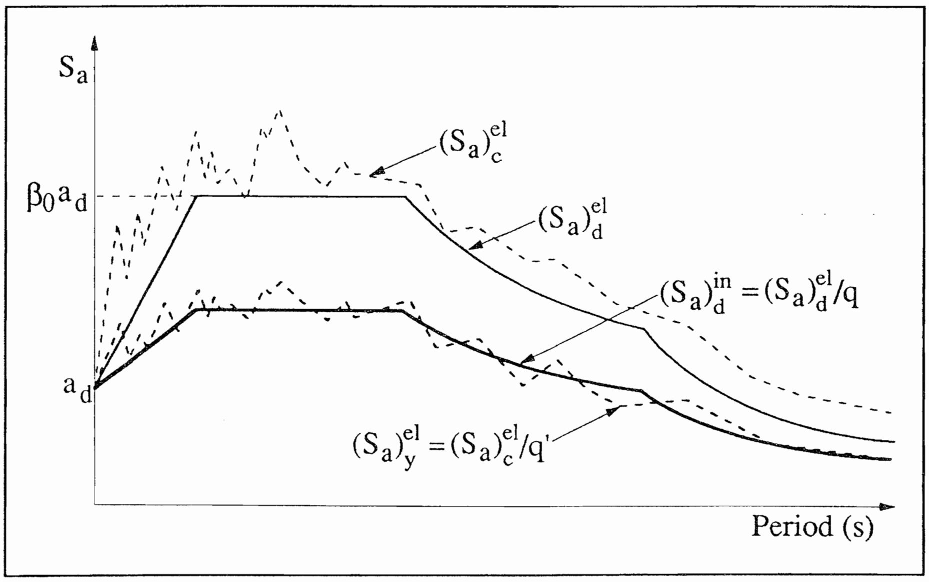
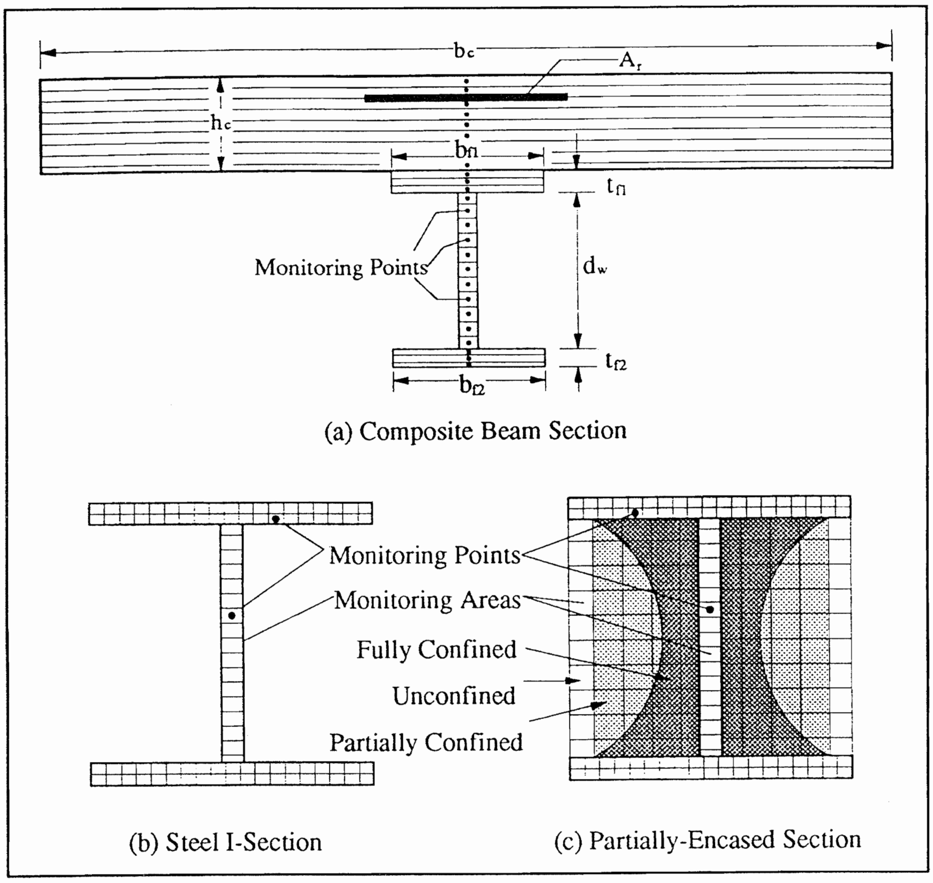


Figure 1: Design, collapse and yield acceleration spectra

Although constituting the single most significant variable in the seismic design of a building, there exists no universally accepted definition of the behaviour factor; neither is there a commonly accepted basis on which it should be evaluated. From the code provision however, it is possible to determine their effect on the design process and proceed accordingly. In Figure 1, the elastic and inelastic design spectra are compared with yield respectively. While the code-specified behaviour factor, *q*, is the ratio between the two design spectra, the *actual* behaviour factor of the structure, *q*, is the ratio between the yield and collapse spectra. This value will vary not only from structure to structure, but also with the ground motion record applied.

If the ground accelerations sufficient to cause both yield and collapse in a building frame can



(a) Composite Beam Section

(b) Steel I-Section

(c) Partially-Encased Section

Figure 2: ADAPTIC composite beam and column sections

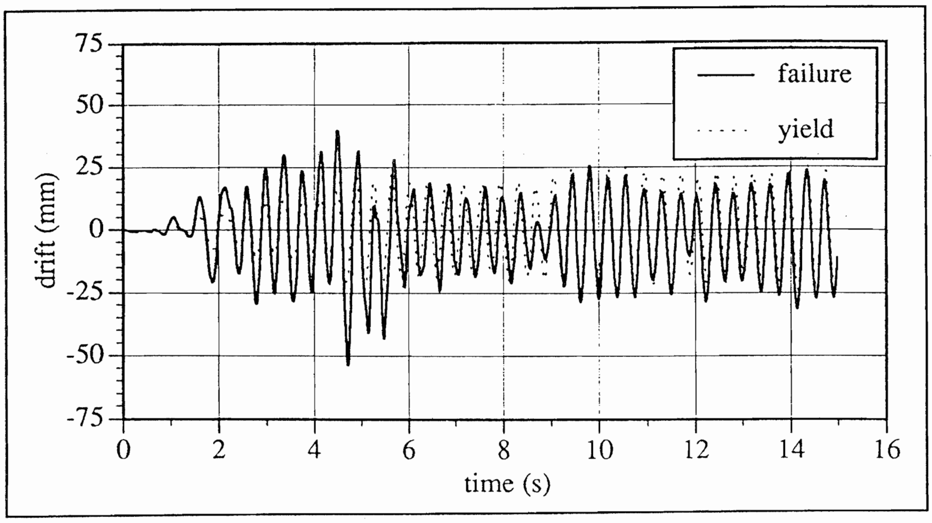


Figure 3: Response of a building frame to the 1940 El Centro earthquake

be found, then the ratio between these will give the true behaviour factor, q`. If this task is performed for sufficiently large and wide ranges of structures and ground motions, the lower bound on the identified behaviour factors can be employed as a reliable design value. For this to be done however, an analytical facility capable of determining the transient response of the frame well into the inelastic range must be employed.

The ADAPTIC program developed at Imperial College has been used to evaluate the behaviour factors of a number of reinforced concrete and composite moment-resisting frames. The member element cross-sections used in the program are illustrated in Figure 2, in which their subdivision into a number of monitoring a reason shown. These allow the local stress-strain response to be determined in addition to that on the global member and structural level. If throughout a time history analysis, these responses are continually compared with a number of criteria representing structural yield and failure, then successive scaling of the earthquake record will identify the yield and collapse ground accelerations (Figure 3), from which the behaviour factor can be evaluated.

The results from the performed analyses show the variation in the evaluated behaviour factors with ground motion record, structural type and construction material. Overall, the values specified in Eurocode 8 appear to somewhat conservative, especially in the case of composite frames where no account is currently taken of the benefits of composite action. Here, the evaluated behaviour factors all exceeded $7\alpha_u/\alpha_1$, compared to the value of $5\alpha_u/\alpha_1$ stipulated by the code - a 40% increase.

The feasibility of performing this type of evaluation has been confirmed, given the correct analytical tool. Future developments in this direction should include for an assessment of the influence of bidirectional motion, soil-structure effects and inelastic response periods.

Professor Bruce Bolt

An Introduction by Robin Adams

Professor Bruce Bolt gave the Fifth Mallet-Milne Lecture at the Institution of Civil Engineers to a packed lecture theatre on 24th May 1995. Introducing the speaker Robin Adams gave the introduction. The article following is based on what he said.

This evening Bruce is to address us on the very relevant topic "*From Earthquake Acceleration to Seismic Displacement*". We shall hear Bolt the engineering seismologist - there may well be some among you who wonder if he is the same man as Bolt the mathematician or Bolt the statistician - for, once, an astronomer, a seismologist and a statistician were discussing there latest developments in their fields, when they looked at each other and said "but is YOUR Jeffreys the same man as OUR Jeffreys". Like the late Sir Harold Jeffreys, our speaker this evening has contributed to many fields of the mathematical and physical sciences.

Bruce Bolt is by training an applied mathematician. He completed his first degrees in the University of Sydney; B.Sc., M.Sc. and Ph.D. in quick succession. At Sydney, Bolt studied under Profession K E Bullen, who himself had worked with Sir Harold Jeffreys in Cambridge in the 1930s and produced the Jeffreys-Bullen seismological tables still used as the global standard 60 years later.

Bullen's overriding research interest was the internal constitution of the Earth, so it was natural that the young Bolt's interest should also turn to seismology, bringing new techniques to bear. For example, early in the 1960s he demonstrated to the staff of the International Seismological Summary in England, the first use of a least-squares computer program to locate earthquakes. A demonstration that at that time met with some scepticism!

It was shortly afterwards at the early age of 33 that Bruce was appointed Professor of Seismology and Director of the Seismographic Stations at the University of California, Berkeley, one of the most prestigious seismological posts in the United States. Bruce helped to revitalise seismology throughout California, and he continues as one of its leading and most active exponents, even after his reputed retirement a few years ago.

It was at Berkeley that I first met Bruce a few days after the great Alaskan earthquake of April 1964 - I found him unreeling a long paper microbaragraph record the whole length of the corridors of the Earth Science building, in the process of finding the first recording of atmospheric waves following an earthquake.

Bruce was by training a mathematician, and he helped develop new techniques such as finite element analysis which he and his students applied to a variety of problems ranging from the deep structure of the Earth to detailed response of soils and structures.

In California, however, it is difficult to remain a purely theoretical seismologist, and he quickly developed interests in the practical problems of recording and analysing strong ground motion, and its effect on structures, for which he has become so well known. In particular, he has become involved with the dense array of strong-motion recorders in Taiwan - SMART - which has resulted in much greater understanding of details of strong earth motion.

But he also never neglects the practical side of earthquake studies. Immediately after the major San Fernando earthquake in Los Angeles in 1971 I had the privilege of joining him in a two-day field study, in which we were the first to find and recognize the fault rupture that traversed the town.

As well as actively running a recording network and a research school, Bruce has found time and energy to hold so many administrative and advisory posts that I cannot possibly mention them all, but let me enumerate a few:

In California:-Chairman,
Academic Senate, University of California, Berkeley,
President, Seismological Society of America, and Editor of its Bulletin,
President, Board of Trustees,
California Academy of Sciences
Chairman, California Seismic Safety Commission

Here in Britain he is an Overseas Fellow of Churchill College, Cambridge, and has been honoured by giving the Harold Jeffreys Lecture to the Royal Astronomical Society.

Internationally, Bruce has also made tremendous contributions - he was on the executive Committee of the International Association of Seismology and Physics of the Earth's Interior for no less than sixteen years, four of them as President, and has continued as Chairman of its Commission for Strong Ground Motion and is still Chairman of its Commission for the International Decade for Natural Disaster Reduction. But his contribution to international affairs is not just administrative - he travels and is known and respected in all continents - wherever seismology and earthquake engineering are practised.

The text of Professor Bolt's lecture is being printed and will be available from SECED in the near future.

Colloquium/ Colloque

SECED-AFPS

PERMANENT SOIL DEFORMATIONS AFTER EARTHQUAKES - IMPLICATIONS FOR DESIGN

DEFORMATIONS PERMANENTES DE SOL APRES SEISMES IMPLICATIONS POUR DESSIN

London (near Waterloo International Terminus), UK
Monday 18th December 1995

Organisers/ Organisateurs
SECED
Edmund Booth (Ove Arup & Partners: tel ([+44] 171 465 2232, fax 465 2150)
Scott Steedman (Sir Alexander Gibb & Partners: tel ([44] 1734 261061)
AFPS
Denis Aubry (Ecole Centrale Paris: tel ([+33] 1 41 13 13 21)

Following the highly successful joint AFPS/SECED colloquium in Paris in 1993, a second one day meeting in the general field of seismic soil structure interaction will be held in London this December. Six recognised experts in the field will make presentations, with a final session devoted to general discussion and short contributions from the floor. The aim is to exchange and discuss the state-of-the-art in our two countries in this important and rapidly developing field

In order to contain costs, and in recognition of our French colleague's superior language abilities, the conference language is English, and no simultaneous translation facility will be provided. Technical queries should be addressed to the Organisers listed above.

5th SECED CONFERENCE

EUROPEAN SEISMIC DESIGN PRACTICE

26-27 October 1995

at the Moat House, Chester, UK

The Organising Committee of the 5th SECED Conference has the pleasure of inviting you to participate in a two-day meeting on European seismic Design Practice (Research and Application). In view of the advancement of Eurocode 8 and the recent establishment of several pan-European nerworks in the field of earthquake engineering, this is an important and timely meeting that will have the benefit of acquainting the engineering community in Europe and further afield with the diversity of projects currently underway and the extent to which EC8 is being developed and applied.

Contact: Rachel Coninx or Jacqueline Morris, The Conference Office, Institution of Civil Engineers, Great George St, LONDON, UK
Phone: +44 (0) 171 839 9807

Notable Earthquakes January - June 1995

Reported by British Geological Survey

YEAR	DAY	MON	TIME	LAT	LON	DEP	MAGNITUDES			LOCATION
		UTC				KM	ML	MB	MS	
1995	01	JAN	16:20	52.57N	1.55E	6	2.7			REEDHAM, NORFOLK
1995	06	JAN	22:37	40.23N	142.24W	57		6.7		HONSHU, JAPAN
				At least 20 people injured in the Hachinohe area and about 5,000 homes lost water and sewer services in the region.						
1995	16	JAN	20:46	34.55N	135.00E	16		6.4	6.8	KOBE, JAPAN
				Five thousand two hundred ninety one people confirmed killed, 27,000 injured, 6 missing and extensive damage in the Kobe area and on Awaji-Shima. Over 90 percent of the casualties occurred along the southern coast of Honshu between Kobe and Nishinomiya. At least 28 people were killed by a landslide at Nishinomiya. About 310,000 people were evacuated to temporary shelters. Over 109,464 buildings were damaged or destroyed. Numerous fires, gas and water main breaks and power cuts occurred in the epicentral area.						
1995	19	JAN	15:05	5.08N	72.92W	18		6.4	6.6	COLOMBIA
				Five people were killed, several injured and at least 20 major buildings damaged in the Bogota area. One person was also killed at Manizales and another at Miraflores. More than 500 houses were damaged or destroyed. Landslides blocked several rivers and streams in Colombia. Felt throughout much of Colombia and western Venezuela as far as Caracas, Venezuela.						
1995	02	FEB	08:43	57.96N	0.38E	11	3.2			CENTRAL NORTH SEA
1995	08	FEB	18:40	4.16N	76.64W	69		6.3		COLOMBIA
				At least 40 people killed, 400 injured and over 2,00 buildings damaged or destroyed in the Cali-Pereira area. Landslides blocked two roads in the epicentral area. Damage occurred at Armenia, Calarca, Cali, La Union, Manizales, Pereira, Trujillo and many parts of western Colombia.						
1995	20	FEB	01:59	53.03N	2.20W	2	2.5			STOKE-ON-TRENT
				Felt throughout Stoke-on-Trent, Newcastle-under-Lyme, Hanley, Norton and Tunstall.						
1995	21	FEB	23:15	53.02N	2.18W	2	2.2			STOKE-ON-TRENT
				Felt Stoke-on-Trent, Chesterton and Newcastle-Under-Lyme.						
1995	22	FEB	07:51	52.97N	2.27W	2	2.3			NEWCASTLE-UNDER-LYME
				Felt throughout north Staffordshire and Newcastle-under-Lyme.						
1995	22	FEB	21:15	53.03N	2.19W	2	2.3			STOKE-ON-TRENT
				Felt throughout Stoke-on-Trent, Newcastle-under-Lyme, Hanley, Norton and Tunstall.						
1995	22	FEB	23:40	53.03N	2.21W	3	1.7			STOKE-ON-TRENT
				Felt at Stoke-on-Trent.						
1995	23	FEB	01:27	53.01N	2.21W	4	1.8			STOKE-ON-TRENT
				Felt at Stoke-on-Trent.						
1995	23	FEB	21:03	34.98N	32.25E	33		5.8	5.8	CYPRUS REGION
				Two people were killed and five injured in the Paphos district. Buildings were damaged in 25 villages as far away as Lefka. Felt in much of Cyprus and in northern Israel.						
1995	24	FEB	10:31	53.02N	2.19W	1	2.2			STOKE-ON-TRENT
				Felt throughout Stoke-on-Trent and Newcastle-under-Lyme.						
1995	04	MAR	23:23	1.29N	77.30W	5		4.4		COLOMBIA
				At least 8 people killed, 10 injured and 8 houses damaged in the Pasto area.						
1995	19	MAR	23:53	4.15S	135.09E	33		6.3	7.2	IRIAN JAYA, INDONESIA
				Some minor damage to buildings in the Ayam, Nabire and Fakfak areas. Felt in the Jayapura, Paniai and Tembagapura areas. Also felt along the south coast of Irian Jaya.						
1995	01	APR	03:49	37.92N	139.18E	11		5.8		E HONSHU, JAPAN
				At least 39 people were injured and 504 buildings were damaged or destroyed in Niigata Prefecture, mostly in the Niigata area.						
1995	07	APR	22:06	15.19S	173.59W	31		6.7	8.0	TONGA ISLANDS
				Felt at Apia, Western Samoa.						
1995	21	APR	00:30	11.90N	120.57E	33		6.3	7.0	SAMAR, PHILIPPINE ISLES
1995	21	APR	00:34	12.06N	125.93E	23		6.2	7.3	SAMAR, PHILIPPINE ISLES
				Some damage occurred at Borongan and Sulat. Felt at Butuan, Mindanao, Masbate, Cebu and at Cagayan deOro, Mindanao.						

Notable Earthquakes January - June 1995 (continued)

YEAR	DAY	MON	TIME	LAT	LON	DEP	MAGNITUDES			LOCATION
			UTC			KM	ML	MB	MS	
1995	**28**	**APR**	**16:30**	**44.06N**	**148.05E**	**29**		**6.6**	**6.9**	**KURIL ISLANDS** Felt on Kunashir, Iturup and Shikotan.
1995	**02**	**MAY**	**06:06**	**3.85S**	**76.96W**	**103**		**6.5**		**NORTHERN PERU** Felt at Andoas, Moyobamba, Tarapoto and along the Peru-Ecuador border.
1995	**02**	**MAY**	**23:14**	**53.09N**	**2.19E**	**2**	**3.4**			**SOUTHERN NORTH SEA**
1995	**05**	**MAY**	**03:53**	**12.62N**	**125.31E**	**33**		**6.2**	**7.0**	**SAMAR, PHILIPPINE ISLES** Felt on Catanduanes, Leyte ane Masbute. Also felt in southern Luzon.
1995	**13**	**MAY**	**08:47**	**40.14N**	**21.68E**	**13**		**6.2**	**6.5**	**GREECE** Twenty five people injured and substantial damage in the Kozani area. The earthquake and aftershocks destroyed 5,000 homes and damaged 7,000 others with preliminary damage estimated at 450 million US dollars. Felt at Thessaloniki.
1995	**15**	**MAY**	**08:42**	**62.29N**	**2.33E**	**14**	**3.4**			**NORTHERN NORTH SEA**
1995	**16**	**MAY**	**20:12**	**23.01S**	**169.89E**	**33**		**6.8**	**7.7**	**LOYALTY ISLES REGION**
1995	**27**	**MAY**	**13:03**	**52.56N**	**142.81E**	**33**		**6.6**	**7.6**	**SAKHALIN ISLAND** At least 1,989 people killed, nearly 450 injured and extensive damage in the Neftegorsk area. Felt strongly at Aleksandrovsk-Sakhalinskiy, Nysh, Nyvrovo and Okha.
1995	**15**	**JUN**	**00:15**	**38.51N**	**22.24E**	**14**		**6.0**	**6.5**	**GREECE** Twenty six people killed and 60 injured in the Aiyion area. Extensive damage occurred at Aiyion and Eratini. Damage also occurred at Corinth, Patras and Pirgos. Preliminary estimate of damage was placed at 660 million US dollars. Felt at Athens, Ioanuina, Kalamata, Kardhitsa and Kozani. Also felt on Kefallinia.
1995	**20**	**JUN**	**21:22**	**61.58N**	**3.63E**	**17**	**3.2**			**NORTHERN NORTH SEA**
1995	**28**	**JUN**	**05:48**	**59.05N**	**1.77E**	**15**	**3.7**			**NORTHERN NORTH SEA**

Issued by Bennett Simpson, British Geological Survey, April & July 1995

Forthcoming Events

4-8 September 1995
18 Seminaire Regional European de Genie Parasismique, L'Ecole Centrale Lyon

26-28 September, 1995
International Symposium 'Non-Destructive Testing in Civil Engineering'., BERLIN.

26-27 October 1995
SECED Conference - European Design Practice, Chester, UK

14-16 November 1995
1st Int. Conf. on Earthquake Geotechnical Engineering, Tokyo, Japan

20-22 November 1995
Pacific Conf. on Earthquake Engineering PCEE'95, Melbourne, Australia

5-8 June 1996
EURODYN '96 Third European Conference on Structural Dynamics, Florence, Italy

23-28 June 1996
11WCEE: 11th World Conf. on Earthquake Engineering, Acapulco, Mexico

3-5 July 1996
Joint DTA/NAFEMS & SECED Conference 'Structural Dynamics Modelling - Test,Analysis, Correlation & Updating'

Contents

SECED Newsletter

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