SECED

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THE SOCIETY FOR EARTHQUAKE AND CIVIL ENGINEERING DYNAMICS

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DAMPING VALUES USED IN THE NUCLEAR INDUSTRY

Two letters have been received stoutly supporting the damping values currently used for structural analysis in the nuclear industry. Recent studies of this subject have not been widely circulated and Newsletter would welcome the opportunity to print an annotated reading list of the publications thought by the contributor to be authoritative. The meeting of the 16th March is likely to present a step forward to a valid approach to the use of viscous damping to represent energy absorption in structural behaviour.

SHAKING IN SPACE AND LOS ANGELES, SECED Meeting, 21st October 1987
by Professor Bruce A. Bolt, Professor of Seismology,
University of California, Berkeley

Report by Dr. Bryan O. Skipp

Professor Bruce Bolt of the University of California, Berkeley, one of the most distinguished seismologists in the world lectured at the Institution of Civil Engineers on October 21st and brought with him the latest news of the recent Los Angeles earthquake which like every new earthquake has its new features. The shock which had a magnitude of 6 and caused damage estimated at $200m had its epicentre a few km north east of the northern extremity of the mapped Whittier fault in a region of en echelon folding. The focal depth of the main shock was about 10km deep and the aftershock cluster extended downwards to about 15km as well as upwards with a few events as deep as 20km. The main aftershock M=5.5 seems to have had a different focal mechanism from the thrusting of the primary event being of a strike slip character.

Free field peak horizontal ground acceleration of 0.45g was recorded 8km from the epicentre and rehabilitated masonry buildings in the city of Whittier were devastated.

Another earthquake occurring in an area without a known fault (viz Coalinga), in a region of folds and flexures has set some questions for the hazard mappers of Los Angeles.

Professor Bolt went on to the main theme of the evening - 'The application of spatial variability of strong ground motion'.

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Newmark had recognised that all points at the base of a large foundation were not excited simultaneously and had introduced his T factor to take this into account. The requalification work for the Diablo Canyon NPP had given an opportunity for the phenomenon of near source coherence (or non-coherence) of travelling waves to be further assessed and its implications explored in a ground-structure interaction problem.

In the near field of an earthquake strong motion does not show clearly identifiable wave types - P waves, S waves but there is present a proportion of energy which is transmitted coherently, with regular phase. Coherence can be regarded as 'likeness', that is, the wave at one point is 'like' the wave at another point. Coherence is denoted on a scale of 0 to 1. When coherence is 1 the motion can be treated deterministically as harmonic input but as coherence reduces towards 0 stochastic procedures become more applicable.

The factors which introduce incoherency are the different travel paths from the different source elements on a rupturing fault surface, the different scattering which the waves may suffer on different paths and the phase distortion involved when waves from different source positions having different path lengths are seen with an apparent surface velocity.

The first strong motion array in Taiwan (SMART 1) had collected some 50 events from all directions with epicentres in the distance range 4-30km and peak ground surface accelerations up to 0.4g. Using procedures of array seismology ('steering', time domain cross co variance) it had been shown that coherence diminished rapidly above 2-3Hz.

At Diablo Canyon artificial earthquakes caused by offshore explosions were used to study the largely path related incoherence of low level signals with a view to substantiating the estimates of T adopted in the original seismic design. Coherence versus frequency and coherence versus spatial separation at different frequencies was established. This permitted an evaluation of the effect on multiply supported facilities to be made.

The Diablo Canyon work had indicated that random motion input would be appropriate for the NPP vessel with a fundamental frequency of 8hz and that by taking account of the coherency-incoherency for particular pathways the peak ground acceleration can be reduced by 10-15%.

EARTHQUAKE FIELD MISSIONS, SECED Meeting 25th November 1987
Speakers from EEFIT and Imperial College

Report by Chris Sharman (Allott & Lomax)

Dr Roy Kunar, in the chair, declared that under the umbrella of the EEFIT organisation, the object of the meeting was to provide updates upon the information provided by a number of recently occurring earthquakes. All speakers had been in close contact with teams researching the events and in the case of the San Salvador earthquake, EEFIT had sent its own team to investigate. Dr. Kunar considered that it is only after a considerable lapse of time that sufficient information upon the events becomes available. This view was subsequently confirmed by the general conclusions of the speakers that followed.

Dr. Kunar handed the meeting over to SECED Committee member E. Booth to provide a brief introduction to the workings of EEFIT and the topics to be discussed. EEFIT is composed of members from UK Industry and Universities and to-date has investigated four earthquakes with the results of the latest (San Salvador) earthquake having just been published. EEFIT are at present reviewing their constitution and method of working and hope to extend their activities to include a wider circle of influences.

The talk commenced with a review of the Greek earthquake in Kalamata by Dr. Elnashai of Imperial College. Dr. Elnashai and colleagues have carried out research and a recent field trip since their presentation to SECED last January. Their review has included literature searches, strong motion records, Design Spectra/Code requirements, damage statistics and examination of damaged structures, causes of damage and repair techniques.

The University is also engaged upon a research programme into the response of shear wall structures under monotonic, cyclic and shake table loading.

Kalamata is in Zone II of the Greek Building Code and the earthquake on 13th December 1986 was reported as providing Ms = 6.2 for the main shock, located 11 km off-shore from Kalamata, and 5.4 for the main aftershock centred 1 km from the town, two days later. However, Dr. Elnashai confirmed that records from 19 stations gave mean values of Ms = 5.7 and 4.7 respectively.

The older, northern part of the city composed of traditional adobe structures suffered considerable damage. Reinforced concrete structures also suffered considerable structural and non-structural damage. However, only a few cases of total collapse were reported, with 20 fatalities.

The duration of the event was some 6 secs. with strong motion (above 0.1g) lasting for 2.5 secs. Maximum horizontal ground acceleration was recorded at 0.27 with the vertical component of 0.18g at a predominantly higher frequency than the horizontal motion. The Horizontal Response Spectra (5% damping) provided a concentrated response between periods of 0.2 to 0.7 secs. with a peak of approximately 1.5g at 0.4 secs. The vertical response spectrum provided significant responses for a number of periods (between 0.1 to 0.4 secs.) with a maximum of 0.8g. The distinctive peak of 1.5g in the 5% damping acceleration spectrum was not however observed on all of the published spectra for different digitisations. It was hence felt that it was safer to comment upon the peak of 0.9g which was common amongst all the available response spectra. Even this level of acceleration is some six times greater than the maximum allowed for by the 1959 Greek Code. Hence if purely elastic response is considered then significant damage would have been expected.

Mr. Pilakoutas of Imperial College, then introduced by Dr. Elnashai, gave details of damage statistics and it was evident that load bearing masonry structures had fared the worst. Heavy structural damage to RC framed structures, where it did occur, was concentrated in ground floor column zones with compression and shear failures close to joints. Beam/slab failures were rare. Damage resulted from design/detailing errors and construction errors. Design errors included strong beam/weak column concepts, torsional effects (with 'corner column' distress) and lack of drift control. It was noted that the 1959 edition of the Greek Code did not consider drift control.

Detailing and construction errors were a selection of a now familiar list; shear failures at construction joints, lack of confining link reinforcement and lack of reinforcement continuity with embedded drainage pipes causing unexpected effects. Material defects in one case included unwashed marine aggregates in the concrete.

The third speaker from Imperial College, Mr. Lefas, confirmed the superior behaviour of RC structures and in particular the ability of wall structures to limit displacements. Irregularity in the distribution of stiffness was a major cause of inadequate behaviour[1] and it was noted that whilst the 1959 Building Code addressed the necessity for symmetrical layouts, no proper guidance was given upon desirable seismic detailing.

Cost of repairs to existing housing stock amounts to some £11m although progress has been slow with virtually nothing done in the old area of the town. Finance is limited and it is expected that a complete repair programme will extend over a five to ten year period. 80% of the schools are in bad condition with little repair work completed. It is evident that morale is low with trade being reduced by some 40%.

A report covering the geology of the area and its tectonic activity, past earthquakes and a detailed assessment of structural behaviour has been issued[2].

The San Salvador Earthquake of the 10th October 1986, introduced by Dr. Ledbetter of Bath University, was of moderate magnitude Ms = 5.4, similar to the Kalamata incident in being at shallow depth with a high frequency vertical component. Dr. Ledbetter together with Mr. Bommer of Imperial College had visited the site ten days after the earthquake and had stayed for fifteen days. Some 70 buildings has suffered serious damage. Detailed information on the visit is now available in the team's Report[3] and Dr Ledbetter's talk concentrated upon the more general problems encountered in obtaining the necessary information. Problems with communication, lack of street plans and unreliable information sources were included in the problems which hindered the team.

The work of loss adjustors unfortunately is not published and hence such valuable information was not available. However, videos taken some three to four days after the major shock had been obtained from such sources and were shown by Dr. Ledbetter during the course of his talk.

Filmed records from the local television stations which were viewed by the team showed more immediate reactions of the populace. The taking of photographic slides as the only record meant that practically only locally selected areas of the structures could be recorded and that inevitably items got missed.

It was evident that Dr. Ledbetter was confident that valuable information could be obtained from video records and suggested that this method should receive careful consideration from future teams.

The video pictures that were shown at the meeting included the Ministry of Agriculture building, a four storey structure standing astride a ground dislocation. The concrete frames supporting the first three storeys had performed well but the top storey, which was of steel, suffered significant structural damage. The ten storey tower of the Hospital was also illustrated; of RC frame and shear wall construction, the greatest damage occurred in the region between adjacent shear walls forming the ends of the building. This region was composed of a masonry and glass infills extending the full height of the building. The walls performed well as independent elements but the masonry panels as an infill medium had failed at every storey.

No return visit to the site is at present envisaged but Dr. Ledbetter confirmed that a University Student now visiting San Salvador has been asked to provide a report upon return to the U.K.

Mr. Bommer, introduced by Dr. Ledbetter, confirmed that now the Report had been issued, future actions would include detailed study of the strong motion records together with a detailed seismicity study in connection with the Spanish Authorities.

Dr. Brian Hawkins of Bristol University, whilst modestly claiming only to having 'made a brief visit and taken a few slides' then took the floor to give an entertaining and informative review of the local geology and after effects of the New Zealand Edgecumbe earthquake of 2nd March 1987.

The Australian plate, with the Pacific Plate subducting, is moving at the rate of some 50 to 60mm per year. Edgecumbe, a small town of a few thousand population is located on alluvium inland of the Bay of Plenty. It is adjacent to the Taupo Volcanic Zone which in 1886 had an earthquake on the same trend.

The event of 2nd March commenced with a foreshock of Ms = 5.2 at 13.36 hrs. followed by a main shock of Ms = 6.2 at 1343 hrs. The main shock, located 7-8 miles north of the town, was of shallow depth (10-12 km) and resulted in ruptures 7km long.

Between 13.43 hrs and 19.05 hrs., four aftershocks occurred exceeding Ms = 5.0. Eyewitnesses reported 'rolling' ground surface waves 0.75m high. Displacements varied over the 7 km length of main fault but reached the order of 2m. Downthrow, which was to the NW, affected a zone 3-4m wide with a depth (as revealed in trenches) of 3-4m. The trenches exposed two probable previous undetected movements believed to have occurred in the last 2000 years. The slides shown by Dr. Hawkins clearly indicated a spectacular fault scar.

Some data were provided in connection with the Mathahina Dam located 11 km from the main rupture. The dam 79m high, which is composed of a clayey gravel core experienced a period of shaking for some 10 secs. Horizontal acceleration at the base was recorded at 0.33g with a vertical component of 0.14g. At the crest, maximum horizontal acceleration was 0.43g. Maximum recorded horizontal displacement was 250mm and vertically 100mm.

Since the area is lowland, there were few natural slope failures, only small scar movements on the surface. There were significant failures of man made slopes, and slides shown, indicated typical ground surface compressional movement resulting in severe distortions of railway tracks and road cracking and misalignment. One slide showed that a 67 ton diesel engine which had been stationary outside Edgecumbe Station, had toppled over during the event.

Bridges on the whole had suffered little damage but some 50 houses had suffered significant structural damage. Other slides showed toppling of milk storage tanks and electrical transformers. Over 400 breaks occurred in water/sewage pipes. Of particular interest was a high pressure gas pipe which had stretched and deformed but not fractured; it was considered that liquefaction of the ground induced material flow around the pipe and effectively limited the damaging motions of the ground. Extensive areas of the sandy alluvium had suffered liquefaction and air photographs clearly showed 'sand boils' which had emerged along the downthrow of the fault.

At the conclusion of Dr. Hawkins' talk, Dr. Adams (ISC) suggested that as the Matahina Dam has a soft layer of sediment beneath the harder rock upon which the dam is supported it was this feature that had determined the response of the dam.

Mr. Booth from the audience wished to confirm a remark made by Dr. Hawkins to the effect that the damage that had occurred to the bridges had been due to settlement rather than ground shaking. Dr. Hawkins replied that this had been the impression.

Dr. Robin Spence of Cambridge University Department of Architecture, the final speaker of the evening, gave a review of the Ecuador earthquake which occurred on the 5th March 1987. Dr. Spence confirmed that he had not had the opportunity of visiting the site himself but was in contact with those that had. His talk therefore was not to be considered as a field report but rather as a review of the interesting features associated with this particular earthquake.

The earthquakes occurred in a remote part of rural Ecuador, not previously thought to be in an earthquake area. There were two incidents, the first event of Ms = 6.1 happened at 21.00 hrs. and the second two hours later of Ms = 6.9. The earthquake triggered a large number of mud and rock slides, Mercalli scale intensity registering between 8 and 9.

What is considered to be the largest pipeline loss in history occurred over a long length in the El Reventador Volcano area, the slides displayed by Dr. Spence showing lengths of totally buried pipeline. The loss in oil revenues which followed caused a reduction of some 60% in foreign exchange earnings for Ecuador and the cost of repair to the pipeline was estimated at 1.0 to 1.5 billion dollars.

Dr. Spence probably echoed the thoughts of many in the audience in questioning what thinking lay behind not only the original siting of the pipeline at the base of the steep slopes of a volcano, but the decision to reconstruct along the same route.

Professor Tom O'Rourke and colleagues of Cornell University are carrying out a full report of the failure for the U.S. Earthquake Engineering Research Institute.

Full details are not yet available but it is estimated that 1000 to 2000 lives were lost with the loss of many of the traditional 'rammed earth' dwellings. Typical timber structures performed on the whole better than the small number of RC buildings in which infill partitions/walls fell away from often intact frames. The earthquake again confirmed the vulnerability of large masonry structures, a construction typical of the principal churches which in certain instances suffered total collapse.

Information and practical assistance in the aftermath of the incident was provided by a British architect Mr. Eric Dudley, working with Centro Sinchagnasin, a local rural development organisation. With the object of improving hazard resistance, he was able to assist in developing small though important changes in the methods used in constructing the typical rammed earth dwellings. It is hoped that Mr. Dudley will come to Cambridge University to research further into traditional building methods.

Junta Nacional de la Vivicuda, a government agency was also commendably swift in response to the situation and within a month of the earthquake had produced suggested construction details for the traditional rammed earth and abode buildings.

Since time was short at the conclusion of the talks, only a brief discussion was possible.

Mr. Booth was interested to know whether anyone wished to comment upon Dr. Ledbetter's suggestion of video records for future investigating teams.

Dr. Elnashai in response considered that whilst they might form an interesting record, the precision obtained was not really adequate from a technical point of view.

A question was raised regarding damage to bridges since none of the speakers had made much reference to these structures.

Dr. Elnashai replied that no significant bridges existed in Kalamata and Mr. Bommer confirmed that bridge damage that did occur in San Salvador was of no real account.

Responding to an enquiry regarding what recommendations Imperial College intended to make to the Greek Authorities following the Kalamata event, Dr. Elnashai confirmed that the present design spectra be increased by 50% together with general revisions to the building Code.

Attendance at the meeting was counted at 37.

(1) Author's note;
See also, The Structural Engineer, March 1986, Vol. 64A No.3 'Design of concrete structures for seismic loading, with emphasis on the use of analytical and physical models'. Discussion on lecture by Prof. T.P. Tassios.

(2) The Kalamata (Greece) Earthquake of 13 September 1986.
A.S. Elnashai and K. Pilakoutas
Engineering Seismology and Earthquake Engineering Report No.ESEE 86/9 December 1986 (price £8.00)

(3) The San Salvador Earthquake of 10th October 1986. A field report by EEFIT. Rendel Palmer and Tritton. EEFIT Sept. 1987 (price £10.00)

THE EARTHQUAKE RESISTANT DESIGN OF LOW-RISE BUILDINGS

A draft document entitled "Guidelines for the Earthquake Resistant Design of Low-Rise Buildings" has been made available to the ICE's Working Party on Eurocode 8 (Common Unified Rules for Structures in Seismic Regions). It is proposed that this is adopted as the starting point for the preparation of a Handbook to be issued for use with the Eurocode when it becomes available in 1991.

It takes into account the first draft of Eurocode 8, Part 2 of BS 5628, (for reinforced masonry) and various documents used internationally, including some on low cost housing.

The document was intended to represent a consensus view of the subject when it was written by Scott Wilson Kirkpatrick & Partners in 1985, but international practice was found to vary considerably and where recommendations differed an assessment has been made of the best approach.

The Guidelines presently cover reinforced concrete, masonry and steelwork construction. Special consideration is given to infilled frames which constitute by far the most common form of new construction in areas as far apart as Greece, Turkey and the Middle East on the one hand and Latin America on the other. It includes a few novel features, for example damp proof courses, which with some materials constitute a potential slip plane.

Copies of the Guidelines are available to anyone with views or information on the subject, who would like to contribute to its development. This is a field in which there is much scope for initiative in development of new design techniques, new building materials and new components.

DR. JOHN H. MILLS

Dr. John Mills has been appointed a Director of Consulting Engineers, Allott & Lomax. He will be the Director responsible for work involving advanced engineering analysis and computing services.