13TH WORLD CONFERENCE ON EARTHQUAKE ENGINEERING

Vancouver, BC, Canada
August 1-6, 2004

A New Zealand delegation of 38 attended the 13th World Conference of Earthquake Engineering. The kiwis represented 1.56% of the total number of delegates at the conference. This was a fine showing from New Zealand, given the large number of countries represented there. The conference lasted a full five days from Monday 2 to Friday 6 August, with an official opening and icebreaker function on the night of 1 August. The conference venue was the spectacular Vancouver Convention and Exhibition Centre, also a terminal used by a great many Alaskan cruise liners during the course of the week.

As is typical for World Conferences, the presentations at 13WCEE covered a vast variety of topics of relevance to earthquake engineering. Plenary keynote presentations occupied the first part of each day, with keynote speakers being Liam Finn, Thomas O'Rourke and Jorge Gutierrez on the first day (earthquake engineering aspects of lifelines and vernacular buildings), Hugo Bachmann, Tsuneo Katayama on the second day (earthquake engineers and politics, and impact of the Kobe earthquake on earthquake engineering), Gail Atkinson and Shunsuke Otani on the third day (developments in seismic hazard analysis, and performance-based design code and state of practice in Japan), Chris Poland and Anil Chopra on the fourth day (performance-based engineering) , and Gian Calvi and Yuxian Hu on the fifth day (earthquake engineering in China, and innovative approaches in design and assessment of bridges). From a seismologist's perspective, interesting new bytes of information (or reminders of recent developments) that arose from the keynotes were:

Thomas O'Rourke's revelation that over 30 scenario earthquakes have been used in lifelines risk analysis in the Los Angeles area, allowing the risk analysts to estimate the probability of exceedance for certain numbers of houses being without power; Tsuneo Katayama's assertion that the Kobe earthquake hugely changed Japanese understanding of earthquake hazard and risk, more so than any other earthquake; Gail Atkinson's assertion that the biggest uncertainty in probabilistic seismic hazard assessment (PSHA) is the treatment of uncertainty itself, in that the distinction between aleatory (random) variability and epistemic (knowledge) uncertainty is still poorly understood.

The number and diversity of technical sessions were great. Again, from a seismologist's perspective I picked up the following highlights from the technical sessions I managed to attend at the meeting:

- Ian Buckle introduced the term "Collaboratory" to us in describing the working link between a number of earthquake engineering simulation laboratories around the USA.
- Peletes and Gulkan's analysis of the likely loss of life and property in the next North Anatolian Fault earthquake near Istanbul indicated that it is set to be the most disastrous earthquake to occur in modern times when it happens.
- Topographical site amplification of 3 for PGA and 2.7 for PGV for the top of a fluvial terrace relative to the bottom was shown by Toshinawa et al.
- Californian strong ground motions were shown to be higher than European and New Zealand motions because of the abundance of reverse-focal mechanisms in the CA data (Douglas).
- A paper by Abrahamson showed that the new criteria in the USA for the siting of nuclear power plants is a return period of 10e-8 years, which in PSHA results in physically impossible ground motions of (e.g.) 10-20g in PGA in low-seismicity areas like Yucca Mountain, Nevada. While Abrahamson showed that maximum ground motions have risen with time and methodology (1940-1970 ~ 0.5g, cf 1971-1994 ~ 1g, and 1994 to present ~ 2g) there needs to be upper limits defined that are physically viable.
- Many authors gave papers on analyses of damage probabilities for ancient structures such as Little Hagia Sophia Mosque in Istanbul.
- Park's paper on site effects in the Mississippi Embayment rocks showed the strong contrasts in site effects across the boundary of the embayment. Shear wave velocities went from less than 1000 m/s in the embayment to over 3000 m/s in the older rocks away from the Embayment.
- Stewart's paper showed basin depth to be very important for site amplification when an earthquake was directly underneath cf beside a basin. Also related to this was the very important finding presented by Somerville that ground motions for blind faults are systematically higher than for surface-rupturing faults. In another paper, Somerville's showed that ground motions systematically increase with distance into the centre of a basin, irrespective of the distance from the earthquake.
- A number of papers showed how uncertainty in PSHA (in particular attenuation uncertainty) is being reduced. Ricles et al. showed that site specific PSHAs result in a reduction of sigma by 0.2 (sigma is in natural log units of acceleration) as compared to simply applying regional PSHAs to a site. The site specific analyses therefore pay for themselves in the long run, as structures will not be over-engineered. It was a very important paper to show that the "cheap and nasty" approach is not financially sound. Kanla showed that synthetic seismograms for fault sources could be stacked to produce seismic hazard curves, therefore avoiding the large uncertainties associated with attenuation relationships.

- Irfanoglu introduced the concept of spectral intensity to describe the variation in intensity as a function of spectral acceleration.
- Irikura presented new scaling laws that use the combined asperity area of a fault to estimate the seismic moment of a potential earthquake. This work is recognising the importance of asperity areas in scaling laws for the first time, and will likely result in some demands on researchers to constrain the total asperity area on faults.
- Boroschek showed that the 2001 Southern Peru earthquake (Mw8.4) produced a very strong 30 second period pulse of energy, which is an unusually long period even for a subduction zone earthquake. I have considerable interest in this earthquake and the accompanying tsunami, after having led the 2001 reconnaissance trip to southern Peru after the event.

After the technical sessions of the day were put to rest, various social functions were held in the evening. On the Tuesday night the International Fair treated delegates to a truly global display of song, dance, and food, and on the Wednesday night the Enchanted Forest Banquet was similarly spectacular. Lastly, various field trips were held during the course of the week, and these were well attended.

Thanks to all who represented the Society and our strong Earthquake Engineering community in New Zealand. Your excellent presentations, networking and show of numbers at the conference has done us proud. I hope you will consider attending the next WCEE in Beijing, China in 2008.

Mark W. Stirling
President, NZSEE

THE FOLLOWING ABSTRACTS ARE BY NEW ZEALAND AUTHORS (NZSEE MEMBERS) WHO APPLIED FOR EQC PARTIAL FUNDING OF THEIR REGISTRATION FEES TO ATTEND 13WCEE. THE ABSTRACTS AND FULL PAPERS OF ALL PAPERS PRESENTED CAN BE FOUND ON THE 13WCEE CONFERENCE PROCEEDINGS DVD/CD.

SITE CLASSIFICATION FOR STRONG-MOTION STATIONS IN JAPAN USING H/V RESPONSE SPECTRAL RATIO

John X. Zhao[1], Kojiro Irikura, Jian Zhang, Yoshimitsu Fukushima, Paul G. Somerville, Akihiro Asano, Taketoshi Saiki, Hidenobu Okada and Toshimasa Takahashi

[1] *Institute of Geological & Nuclear Sciences, Lower Hutt, New Zealand, email: j.zhao@gns.cri.nz*

A reliable site classification scheme is vital in developing robust strong-motion attenuation models. We discuss a promising site classification scheme based on strong-motion data from Japan. We assigned site classes for those K-net sites where boreholes reached either to rock or to stiff soils with shear-wave velocity of 700m/s or larger, using four site classes defined by dominant site period. We used response spectral ratios of the horizontal and vertical components for records from the classified K-net sites to establish a site classification index. Using the index, we were able to classify a large number of strong-motion stations in Japan.

WATER SUPPLY AND EARTHQUAKES: DEVELOPING A MULTI-AGENCY APPROACH

D.R. Brunsdon[1] and J.L. Morrison[2]

[1] *Kestrel Group Ltd, Wellington, New Zealand*
[2] *Greater Wellington Water, Wellington, New Zealand*

Lifelines projects and related activities over the past decade have prompted the improvement of earthquake resilience of water supply networks in the Wellington metropolitan area. The greatest threat to water supply in this area comes from the Wellington fault, which has a mean return period of rupture of 600 years, and assessed time since last rupture of approximately 400 years. The bulk water supply to the metropolitan area (population of approximately 350,000) crosses the Wellington fault in six locations over a distance of approximately 50km from three source locations.

Efforts to mitigate both the bulk water system and local distribution networks (which are separately operated and administered) has focused on aspects such as the interconnection of zones, structural upgrading of reservoirs and addition of automatic shut-off valves, along with the progressive upgrade of brittle water mains. For some of the major fault crossings, attempts have been made to articulate and isolate adjacent sections of the bulk main. Greater emphasis has recently been placed on response preparedness, with particular reference to the development of repair strategies and the distribution of emergency water supplies to meet community needs following a major earthquake.

The formation in February 2002 of a multi-agency planning group has sharpened the focus on the full range of mitigation and preparedness measures. This group comprises emergency managers as well as water supply managers from each of the five local authorities involved, along with health sector, fire service and research representation. A multi-agency five-year strategy and action plan has been developed to focus and co-ordinate the range of activities, which include public communications messages to raise the level of stored water in individual households, medical centres and other essential community facilities.

The new Civil Defence and Emergency Management (CDEM) Act in New Zealand features the requirement for Lifeline utilities to actively engage with the emergency management sector in the development of regional and national plans. Implicit in this is the need for Lifeline utilities to give equal consideration to responding to and recovering from major emergencies as well as prior physical mitigation. .

This paper outlines the multi-agency emergency water supply strategy that has been developed for the Wellington Metropolitan Water Supply Area, and backgrounds the aspects of the New Zealand CDEM Act that relate to lifeline utilities.

EXPERIMENTAL DETERMINATION OF MODAL DAMPING FROM FULL SCALE TESTING

John BUTTERWORTH[1], Jin Hee LEE[2] and Barry DAVIDSON[3]

SUMMARY

Damping properties are of significant importance in determining the dynamic response of structures, and accurate prediction of them at the design stage, especially in the case of light-weight, wind-sensitive buildings, is very desirable. Unfortunately, damping parameters can not be deduced deterministically from other structural properties and recourse is generally made to data from experiments conducted on completed structures of similar characteristics. Such data is scarce but valuable, both for direct use in design and for furthering research into the phenomenon and modelling of damping.

This paper presents the results of an experimental investigation of the damping properties of an 11-storey reinforced concrete shear-core office building based on forced vibration tests. Excitation was by means of a rotating eccentric mass exciter driven by a precisely controlled electric motor with electromagnetic and resistive braking capabilities, allowing sinusoidal force amplitudes of up 40kN. Accelerometers were used to measure structural response. It proved possible to excite the structure in four distinct modes, two translational and two torsional. Amplitudes were constrained to avoid structural damage, but were large enough to induce motion sickness in some occupants, resulting in the testing having to be conducted when the building was empty. The acquired data was processed using both frequency and time-domain methods to arrive at modal damping ratios. The methods used included traditional ones such as free vibration decay and half-power bandwidth, with some adaptations, such as a direct application of the half-power method to the un-normalised spectrum, and a hybrid method based on experimental resonant response combined with modal data from an associated free vibration analysis. Damping for the lowest modes was around 1.5%, rising to approximately 6% for the 2nd translational mode. It was also observed that damping coefficients and resonant frequencies were amplitude-dependent.

[1] *Dept of Civil & Env. Engineering, The University of Auckland, NZ, jw.butterworth@auckland.ac.nz*

[2] *Graduate Student, Dept of Civil and Environmental Engineering, The University of Auckland, NZ*

[3] *Dept of Civil & Env. Engineering, The University of Auckland, NZ, bj.davidson@auckland.ac.nz*

DAMAGE-RESISTANT STEEL FRAMED SEISMIC-RESISTING SYSTEMS

G Charles CLIFTON[1], Raed ZAKI[2] and John BUTTERWORTH[3]

SUMMARY

For a building to resist a severe earthquake, it must exhibit dependable strength, stiffness and ductility. From the viewpoint of life safety, a building with relatively low strength and high ductility capacity may provide the same life safety protection as a building with higher strength and lower ductility capacity.

When subjected to a severe earthquake, however, the outcome in terms of structural damage sustained will be quite different. While both buildings will remain standing, the low strength/high ductility building is likely to require considerably greater structural repair than the high strength building. Such repair will at best require the building to be out of service for a period of time following the event, with associated occupant and business disruption.

However, with careful consideration, it is possible to develop building systems that achieve a high damage threshold without requiring design for elastic response. This can be achieved through the following:

- Use of semi-rigid joints that are rigid under normal operating conditions, rotate with dependable hysteretic characteristics under severe earthquake attack and become rigid again once the severe ground motion stops
- Use of isolation details to partially isolate each floor from the seismic-resisting systems at that level, thereby reducing the response of the floor to the lateral movement of the ground supporting the building.

To be attractive to owners and investors, such systems must add little cost to that of traditional seismic-resisting system construction.

HERA and the University of Auckland are involved in the development of moment-resisting steel framed (MRSF) seismic-resisting systems with these attributes. One system incorporates semi-rigid joints that are designed and detailed to withstand high rotation demand without structurally significant degradation. The second incorporates simpler semi-rigid joints between the beams and columns and a partial floor isolating detail, that is easy to fabricate and erect and reduces demand on the seismic-resisting system. This paper gives an overview of the systems developed and references sources of further information.

[1] *HERA Structural Engineer, Manukau City, New Zealand. Email: structural@hera.org.nz*

[2] *HERA Assistant Structural Engineer, Manukau City, New Zealand. Email: structural@hera.org.nz*

[3] *Deputy Head, Dept of Civil & Environmental Engineering, University of Auckland.*

ANALYSING AND MODELLING RECORDED EARTHQUAKE INDUCED STRUCTURAL RESPONSE

Jonas Thor SNÆBJORNSSON [1], Athol J. CARR [2] and Ragnar SIGBJORNSSON [3]

SUMMARY

Earthquake induced acceleration data has been systematically collected in two reinforced cast-in-place concrete buildings over periods of 14 and 5 years respectively and the database from the two buildings presently contains 870 records from 107 events ranging from magnitude 2½ to 6½ with acceleration amplitudes of up to 34% g. This data is used to examine structural behaviour and system parameters and their dependence on excitation conditions. The system identification based on the sampled data serves both as a baseline for damage identification as well as calibration for further structural modelling of the buildings. Visible damage is slight, but the system parameters reflect structural changes. There are clear indications that the system parameters are amplitude dependent, even for relatively small response amplitudes. Inelastic dynamic analyses were also carried out on one of the structures to investigate the reliability of the analytical models and to estimate the capacity of the building to sustain future earthquake events. The results show that the model does represent the structure and although it came through the recent earthquakes with no damage the structure has limited capacity to withstand any event that would be larger than those experienced to date.

[1] *Research Scientist, Earthquake Eng. Research Centre, Univ. of Iceland, Email: jonas@hi.is*
[2] *Reader in Civil Eng., Univ. of Canterbury, NEW ZEALAND, Email: a.carr@civil.canterbury.ac.nz*
[3] *Professor in Civil Eng., Faculty of Eng., Univ. of Iceland, Email: Ragnar.Sigbjornsson@afl.hi.is*

INELASTIC RESPONSES OF LONG BRIDGES TO ASYNCHRONOUS SEISMIC INPUTS

Jiachen Wang, A. Carr, N. Cooke & P. Moss

Department of Civil Engineering, University of Canterbury, Christchurch, New Zealand.

ABSTRACT

It has been recognized for some time that the spatial variability of the ground motion has an important effect on the seismic responses of extended structures, however it is not known just how much the responses will be affected. The study outlined herein sought to gain insight into the effect of asynchronous inputs on the inelastic response of long bridges in order to improve their earthquake resistant design. In particular, the influence of two effects of the spatial variation of seismic ground motions, viz. the wave-passage effect and the geometric incoherence effect, on the responses of long bridges was considered. Analyses were carried out to produce time-history responses of long bridges with the seismic motions acting in the transverse direction of the bridge and travelling along the bridge in the longitudinal direction. The asynchronous seismic inputs were generated by using the conditional simulation method with a natural earthquake record specified at one abutment. Three different bridge models and three different earthquake records were employed to carry out parameter studies. The response parameters investigated were the maximum pier displacements, the maximum pier shear forces and the maximum section curvature ratios of the piers. The variation of bridge responses with the travelling wave velocity and the degree of the geometric incoherence were determined. The analysis results show that the spatial variation of seismic ground motion significantly influences the response of long bridges through the pseudo-static components of the response. The response changed with the travelling wave velocity and the degree of the geometric incoherence effect. The analyses showed that the responses of long bridges to asynchronous seismic inputs can sometimes be more critical than those under synchronous seismic inputs. When the geometric incoherence effect was large, the variation of the bridge responses with the travelling wave velocity became unpredictable.

NEURAL NETWORK ANALYSIS OF SEISMIC INTENSITY FROM INSTRUMENTAL RECORDS

Peter DAVENPORT

Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand

ABSTRACT

Seismic intensity is a qualitative or quantitative measure of the severity of ground motion at a specific site during an earthquake event. Over the years, various subjective scales of what is often called *felt intensity* have been devised. These scales assess the felt effects by observers present during the shaking, or the evidence, usually damage, which can be observed after the event. Such intensity scales are classifications of the strength of shaking and are essentially qualitative. The Modified Mercalli Intensity (MMI) scale is the most common felt intensity scale in use and is used to indicate seismic hazard and level of damage.

This felt seismic intensity is one of the least-satisfactorily explained components of seismic hazard because, unlike a quantity such as peak acceleration, it cannot be directly measured, but must be estimated based on the observation of damage from the effects of shaking. It does, however, have the very great advantage of being defined in terms of, and therefore directly linked to, damage.

More qualitative, physically based, information has become available with the advent of strong motion recording instruments. The use of the recorded time history of the shaking should potentially provide engineering parameters such as peak ground acceleration, velocity and displacement, spectral values and other measures as a more objective measure of seismic intensity. Numerous researchers have attempted to estimate the seismic felt intensity from strong motion records. Some of the simple methods which are reported try to fit a linear relationship between the variables, but the process of assessing seismic felt intensity from damage is highly non-linear in nature. Many researchers have emphasized the need for accurate estimates of intensity in risk or loss modelling studies. This requirement could be addressed through better models which address the inherent non-linearity in the process. Further, there is a requirement for methods which consider only a few variables, since estimates are often needed where limited data only is available.

Artificial neural network (ANN) based methodology is not new, but has not been extensively applied to engineering seismology problems. This technique essentially uses large quantities of data to train a model which can then be used to explore the relationship. The ANN models allow complex and nonlinear behaviour to be tracked. This study investigates the relationship between parameters derived from the strong motion records obtained in New Zealand and the felt intensity information. The major objective was to evaluate the potential of ANNs for estimating seismic felt intensity from parameters derived from strong motion records. The motivation for this is to determine if there is some function of the parameter derived from the strong motion records which could be used as an analogue of seismic felt intensity. In previous studies of United States and Japanese data there has been strong interest in the peak acceleration. The focus here is also on this parameter derived from New Zealand strong motion records.

Use of "Controlled rocking" in the Seismic Design of Bridges

Alessandro Palermo [1], Stefano Pampanin [2] and Gian Michele Calvi [3]

Traditional seismic design of ductile reinforced concrete structures implies the non-linear behavior of the system to be accommodated through the formations of flexural plastic hinges in structural elements (i.e. top and/or bottom of piers in the case of bridge systems). As a consequence of the inelastic structural response, a significant level of damage is thus expected and has so far been accepted.

Recent developments in the design of precast reinforced concrete buildings (under the U.S. PRESSS Program) have resulted in the definition of innovative typologies of "jointed ductile systems", for both frame and wall systems, as alternative to equivalent "cast-in-place" or "emulation of cast-in-place" solutions. Pure precast elements are connected through unbonded post-tensioning techniques; the inelastic demand is accommodated within the connection itself (beam to column, column to foundation, wall to foundation critical interfaces) while very limited damage is expected in the structural elements which are maintained in the elastic range. A particularly promising efficiency and high flexibility have been shown by the hybrid systems, where unbonded post-tensioning tendons/bars with self-centering properties are adequately combined with longitudinal mild steel or additional dissipation devices which can provide an appreciable energy dissipation. As a result, a sort of "controlled rocking" motion occurs: an adequate ratio of self-centering and energy dissipation contribution, which characterizes the "flag-shape" hysteresis behavior, can guarantee limited maximum displacements with no residual/permanent displacements. The critical role of residual deformations as an additional and complementary indicator of damage (thus repairing costs), when appropriately defining the seismic performance of a structure, has been recently emphasized in literature.

In this contribution, the concept of hybrid systems or controlled rocking is extended to bridge piers and whole systems. The self-centering contribution of each pier will be provided by axial load plus additional post-tensioned cables, while the energy dissipation contribution can be provided by longitudinal steel bars passing through the critical section and/or external dampers/energy dissipation devices at the top/bottom of the pier.
A concentrated plasticity analytical model, which relies on a simplified procedure to develop a complete moment-rotation behavior at the critical section in presence of unbonded tendons, has been adopted to investigate, through cyclic push-pull and non-linear time-history analyses, the seismic response of bridges piers (S.D.O.F.) and of bridge systems (M.D.O.F.) both in the longitudinal and transverse direction. The effects of initial prestressing, unbonded length, axial load ratio, re-centering (unbonded tendons plus axial load) and energy dissipation (mild steel or devices) contributions on the hysteresis flag shape and on the expected overall response will be examined. Comparisons with the performance of traditional cast-in-situ reinforced concrete solutions, based on maximum and residual displacement, will be critically discussed.
Preliminary suggestions for the seismic design (displacement-based) of bridges with hybrid or controlled rocking solutions will be provided, with focus on both the local (single pier behavior) and the global (bridge system) response, when irregularities (i.e. different geometrical and mechanical properties of the piers) are considered.

Contact Author: Alessandro Palermo, alessandro.palermo@canterbury.ac.nz
Session:

[1] *Fixed-Term Lecturer, University of Canterbury, Christchurch, New Zealand*
[2] *Senior Lecturer, University of Canterbury, Christchurch, New Zealand*
[3] *Full Professor, University of Pavia, Italy*

SEISMIC DESIGN AND RESPONSE OF BUILDINGS INCLUDING RESIDUAL DEFORMATIONS

C. Christopoulos, *University of Toronto, Canada, cchristo@ecf.utoronto.ca*
S. Pampanin, *University of Canterbury, New Zealand, stefano.pampanin@canterbury.ac.nz*
M.J. Nigel Priestley, *ROSE School, Pavia, Italy, nigel.priestley@unipv.it*

ABSTRACT

Reports from past earthquake reconnaissance observations, from shake table tests, as well as results from analytical studies indicate that most structures designed according to current codes will sustain residual deformations in the event of a design-level earthquake, even if they perform exactly as expected. Residual deformations can result in the partial or total loss of a building if static incipient collapse is reached, the structure appears unsafe to occupants or if the response of the system to a subsequent earthquake is impaired by the new at rest position of the structure. Furthermore, they can also result in increased cost of repair or replacement of non-structural elements as the new at-rest position of the building is altered. Despite this reality, little consideration is currently given to residual deformations when assessing the seismic performance or in the design of seismic resistant structures. To gap this apparent discrepancy between the real final state of a structure and current performance evaluation, a framework for a more comprehensive performance-based seismic design and assessment approach of frame structures has been recently proposed by the authors. Residual local and global deformations of structures are explicitly taken into account, by introducing a residual deformation damage index (RDDI) as a complementary indicator of damage and by adopting a performance-based matrix as combination of maximum deformations/displacement and residual deformation/displacement parameters.

In this contribution, the framework described above is further extended to the seismic design of new frame structures. A direct displacement-based design approach which includes an explicit consideration on the expected residual deformations is proposed. The design considerations are also extended to current force-based design procedures that are part of most modern seismic provisions.

The response of SDOF systems is first studied through extensive numerical analyses and then extended to MDOF RC and steel structures to identify the parameters influencing residual deformations. Simplified methods for estimating residual deformations are then proposed and are used in the design procedure. Hysteretic characteristics, post-yielding stiffness as affected by P-□ effects, as well as maximum ductility were found to greatly influence residual deformations. More importantly, systems exhibiting fuller hysteretic responses with little stiffness degradation and pinching were found to be more susceptible to sustain larger residual deformations. Significant differences in the final deformed state (and therefore the overall seismic performance) are found when comparing the response of steel and RC concrete buildings that are designed according to current code provisions, for similar performance levels.

DEVELOPMENT OF TESTS FOR PROBABILISTIC SEISMIC HAZARD MODELS FROM HISTORICAL AND PREHISTORICAL DATA

Mark W. STIRLING[1], Edward (Ned) FIELD, Rasool ANOOSHEHPOOR and Mark D. PETERSEN

We compare predicted rates of seismic hazard (felt intensities or peak ground accelerations) from the national seismic hazard models for New Zealand and the USA against the historical rate of exceedance for specific felt intensity levels at towns and cities in the two countries. The comparisons reveal a tendency for the probabilistic seismic hazard (PSH) models to slightly overestimate the historical hazard at about 30 towns and cities in New Zealand, and to significantly underestimate the historical hazard at a similar number of centres in southern California, and across the continental USA. The discrepancies in the USA are most marked in the areas of lowest seismicity and seismic hazard, and where strong site response is likely to be observed during large earthquakes. The results of these comparisons are preliminary, and future work is expected to be geared towards determining the reasons for and statistical significance of the discrepancies observed in southern California/continental USA, the difference in result between southern California/continental USA and New Zealand, standardising the procedure for the three areas, and introducing constraints on ground motions provided by ancient precariously-balanced rocks to the overall analysis.

[1] *Institute of Geological and Nuclear Sciences, Lower Hutt*

ATTENUATION MODELS FOR RESPONSE SPECTRA DERIVED FROM JAPANESE STRONG-MOTION RECORDS ACCOUNTING FOR TECTONIC SOURCE TYPES

Toshimasa Takahashi, Akihiro Asano, Taketoshi Saiki, Hidenobu Okada, Kojiro Irikura, John X. Zhao[1], Jian Zhang, Hong K. Thio, Paul G. Somerville, Yasuhiro Fukushima and Yoshimitsu Fukushima

[1] *Institute of Geological & Nuclear Sciences, Lower Hutt, New Zealand, Email: j.zhao@gns.cri.nz*

A spectral acceleration attenuation model for Japan is presented. It accounts for effects of tectonic source type and the faulting mechanisms for crustal earthquakes. Site class terms are used based on a recent study on site classification for strong motion recording stations in Japan. For crustal and interface earthquakes, a simple form of attenuation model is able to capture the main strong motion characteristics and achieve unbiased estimates. For subduction slab events, a simple distance modification factor is employed to achieve plausible and unbiased prediction. Effects of source depth, tectonic source type, and faulting mechanisms for crustal earthquakes are significant.

SEISMIC RESPONSE OF GRAVITY-LOAD DESIGNED FRAME SYSTEMS WITH MASONRY INFILLS

G. Magenes[1] and S. Pampanin[2]

[1]*University of Pavia, Italy*
[2]*University of Canterbury, New Zealand*

ABSTRACT

Special attention has been recently given to the investigation on the seismic vulnerability of existing reinforced concrete frame buildings, designed for gravity only as typically found in most seismic-prone countries before the introduction of adequate seismic design code provisions.
Comprehensive experimental-analytical studies has confirmed the expected inherent weaknesses of these systems. As a consequence of poor reinforcement detailing, lack of transverse reinforcement in the joint region as well as absence of any capacity design principles, brittle failure mechanisms are expected at both local and global level.
Different damage or failure modes can occur in beam-column joint panel zone depending on the typology (exterior or interior joint) and of the adopted structural details (i.e. use of plain round or deformed bars, alternative bar anchorage solutions), which ultimately affect the efficiency of the shear transfer mechanisms in the joint region (post-cracking non-linear behavior). As a result, global response mechanisms given by the combination of "shear hinges" (non-linear behavior of joint panel zone regions) and plastic hinges in the structural elements can be developed.
Moreover, the interaction between unreinforced masonry infills and r.c. frame can lead to unexpected or peculiar effects on the global seismic response, as compared with the response of the bare frame, depending on the mechanical properties and distribution along the elevation of the infills.

In the present contribution the seismic response of gravity load designed buildings, typical of older construction practice, is investigated through pushover and non-linear time-history analyses using a simplified but reliable analytical model based on a concentrated plasticity approach.
The non-linear behavior of the joint panel zone is modeled through an equivalent rotational spring, suggested by the authors in previous works and based on principal tensile stresses considerations. Equivalent strut-model with appropriate hysteresis rule, available in literature, is adopted to represent the cyclic behavior of under-reinforced masonry infills.
The experimental-analytical validation on quasi-static tests on as-built beam-column subassemblies as well as on pseudo-dynamic tests on a series of one-storey infilled frame systems and on a five-storey frame with infills is briefly presented.

The effects of infills properties (mechanical characteristics and distribution) and joint damage on the seismic (2-D) response of multi-storey frame systems is discussed. Limit states, based on interstorey drift and related to joint or infills damage levels are tentatively suggested.