2001 Technical Conference

"Future Directions: A Vision for Earthquake Engineering in New Zealand"

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NZSEE 2001 Conference

SESSION 1. CHAIR: KEVIN O'KANE

1.1 Retrofit of the William Clayton building using additional damping

Carden, L.P., Davidson, B.J., and Buckle, I.G.

. *Structural Evaluation & Retrofit, William Clayton, seismic isolation, near field, viscous damping, hysteretic damping*

ABSTRACT: The William Clayton building was one of the first buildings in the world to be designed with seismic isolation using lead rubber bearings (Megget 1979a). Associated with this unique design was the expectation that the building would be relatively undamaged during an extreme seismic event. Recent experiences, particularly from the 1994 Northridge and 1995 Kobe earthquakes, have shown that a large magnitude, long period pulse is often prevalent in earthquake records at sites within a few kilometres of the active fault during an earthquake. As the William Clayton building is located within a "near field" region in Wellington, it has been suggested that it may be vulnerable to a large magnitude near field earthquake for which it was not designed. Using numerical modelling, possible forms of retrofit for the William Clayton building are investigated by adding various forms of damping to the base of the structure. In optimising the performance of the building for both near field and far field "design level" earthquakes, it is concluded that linear viscous dampers added to the base of the structure can effectively control the response during large magnitude near field earthquakes with minimal impact on the design response. This conclusion is consistent with previous studies on models of other generic seismically isolated buildings.

1.2 Measurement of PGA and attenuation in Southeastern Australia

Brown, A., Gibson, G., Sinadinovski, C., McCue, K.

. *Engineering Seismology, PGA, attenuation, southeastern Australia*

ABSTRACT: Damaging earthquakes are frequent enough in Australia that design precautions are warranted, especially in majorurban areas and for critical facilities. One of the more significant contributors to the uncertainty in estimations of earthquake risk stems from our lack of knowledge of the earthquake process, in particular the attenuation of ground shaking with distance.After the Newcastle NSW earthquake of December 1989, the Joint Urban Monitoring Program was implemented to instrument major urban areas with accelerographs. Whilst no large earthquakes have yet been recorded, several earthquakes in the magnitude 3.0 to 5.2 range have triggered accelerographs in southeastern Australia over distances from 0 to 350 km.Overseas researchers have recently published attenuation relationships from earthquakes that include these low to moderate magnitudes. Comparison of local data with attenuation functions developed for North America is discussed.

1.3 Communities' understanding of earthquake risk in Hawke's Bay and Manawatu-Wanganui regions, in New Zealand

Ronan, K.R., Johnston, D.M., Paton, D.

. *Social Science, perceptions, preparedness, awareness, education, earthquakes*

ABSTRACT: This paper reviews the major findings from two recent studies that surveyed residents in the (a) Manawatu-Wanganui and (b) Hawkes Bay regions on levels of risk perception, preparedness and other human factors related to a future large magnitude earthquake. The overall findings indicated that the majority of respondents in Manawatu Wanganui and over one third in Hawkes Bay reported not hearing any general or specific information related to the next large magnitude earthquake in the region. These studies was also found that levels of risk perception were generally lower than expected though Hawkes Bay residents appear to have more realistic views. It therefore comes as no surprise that low levels of preparedness were generally indicated with some exceptions in Hawkes Bay. Those exceptions notwithstanding, the vast majority of residents in both regions reported not being prepared with regard to some major hazard adjustments (e.g., structural changes to homes). A number of factors were identified in those studies that predicted increased levels of preparedness. These factors are discussed in the context of community education programmes.

1.4 Planning and policy for earthquake hazards in New Zealand

Becker, J., Johnston, D.

. *Social and Economic Aspects, Planning, policy, earthquake hazards, local government, New Zealand*

ABSTRACT: Twenty-four district plans and regional policy statements from the Hawke's Bay, Waikato and Bay of Plenty regions were analysed in order to examine how councils plan for earthquake hazards. The results indicate that methods of accounting for earthquake hazards vary between different districts and regions. In general, plans and policy statements themselves contain very little information about the nature of earthquakes, the location of fault lines in the area or information on the possible effects of earthquakes. Earthquake hazards are in most part dealt with as part of an 'all hazards' framework, and are not specifically singled out for mention in plans or policy statements. Most of the objectives, policies, methods and environmental outcomes contained in plans or policy statements, are based on the 'all hazards' approach. Only three district plans in the regions studied have actual objectives, policies or methods that specifically mention earthquakes or make some attempt to plan for their specific nature. The majority of districts do not have any specific rules written in their plan for earthquakes, although many districts have rules for other hazards such as flooding, land instability, erosion and coastal hazards. Finally, a third of district plans make reference to the Building Act 1991 to reinforce the fact that buildings in the district must be built to specification in order to perform in an earthquake, but only three have any additional earthquake-specific policies.

1.5 Earthquake Engineering Technology Business Cluster

Sharpe, R. and Pham, T.

NO ABSTRACT AVAILABLE

SESSION 2. CHAIR: DAVID MIDDLETON

2.1 Future directions in seismic design and performance-based engineering

Mander, J.B.

. *Structural Engineering, Performance Based Engineering, Damage control*

ABSTRACT: Based on the present state-of-the-practice in New Zealand, and a world-view of the state-of-the-art, it is argued that in order to make progress towards the building of seismic resilient communities, research and development activities should focus on two fronts: improved design methodologies; and new forms of construction. Performance-based design gives the engineer the ability to inform clients/owners of the expected degree of damage.. However, to achieve this it will be necessary to apply displacement-based design methodologies, rather than the current force-based design standards. Society can no longer afford structures that only maintain life-safety, a higher standard of performance is demanded by owners and clients. To improve the post-earthquake performance of structures, it is necessary that new forms of construction be implemented. Examples of two philosophical approaches are given that are referred to as Control and Repairability of Damage (CARD), and Damage Avoidance Design (DAD).

2.2 Avoidance of fault rupture hazard in New Zealand: Why we don't, and why we should

Nathan, S. and Van Dissen, R.

. *Engineering Seismology*

ABSTRACT: Although the Resource Management Act (1991 and amendments) gives both regional and territorial authorities responsibility for controlling land-use "for the avoidance and mitigation of natural hazards", there are no national standards or guidelines that clarify how this should be done. We illustrate the problems in this paper by considering the question of building across known active faults, which is the most easily avoided seismic hazard.
We consider that there is an urgent need for national consistency in the approach that local authorities take for the avoidance and mitigation of earthquake hazards. Alternative solutions include a Code of Best Practice, a National Policy Statement, or changes to legislation. This is an area where the New Zealand Society for Earthquake Engineering and the Geological Society of New Zealand can work together in a study group to develop national guidelines and procedures that will increase the resilience of our communities to earthquake hazards.

2.3 Presentation of strategic and financial plans for the future of the Society

Brunsdon, D.R., and King, A.B.

. *Strategic and financial plans*

NO ABSTRACT AVAILABLE

SESSION 3. **CHAIR: RUSS VAN DISSEN**

3.1 Envisioning earthquake architecture in New Zealand

Charleson, A.W., Taylor, M., Preston, J.

. *Structural Engineering Architecture, strengthening, seismic, earthquake, exposed, structure*

ABSTRACT: Earthquake architecture is an approach to architectural design that draws upon earthquake engineering design issues as a significant source of inspiration. After explaining earthquake architecture and exploring its possible benefits, the paper considers the current status of earthquake architecture in New Zealand. Two theoretical seismic strengthening case studies are then presented. They illustrate how an earthquake architectural approach can apply to existing buildings and also demonstrate how an expression of seismic resisting structure can add architectural richness. Strategies for realizing the vision of a more widely accepted earthquake architectural approach inevitably focus on architects. Structural engineers need to be the catalyst for the vision to be caught and progressed.

3.2 Modern multi-storey buildings and moderate earthquakes

Brunsdon, D.R., Clark, W.

. *Geotechnical Engineering,Moderate, earthquake, multi-storey, damage, non-structural*

ABSTRACT: Recent moderate earthquakes overseas have highlighted that the combined cost of direct damage and indirect effects of such events can be significant. In the case of multi-storey buildings, the non-structural damage is likely to be considerable, and will involve extensive occupancy disruptions. This paper summarises a recently completed EQC research project which examined the following aspects:

- The characterisation of moderate earthquakes in terms of engineering design parameters
- Quantifying the level of lateral drifts anticipated for modern multi-storey buildings under this level of ground shaking
- Highlighting the major process issues and likely durations associated with the damage assessment and repair

Analysis of a 13 storey moment resisting concrete frame building designed to NZS 4203:1984 under the corresponding response spectrum indicated that structural damage is likely, in addition to extensive non-structural damage. From the displacements determined from this analysis, it is suggested that the damage ratios that are commonly applied to modern multi-storey buildings for MM8 intensity shaking represent lower bound damage estimates only.

3.3 Regional liquefaction study for Waimakariri district

Christensen, S.

. *Geotechnical Engineering, Waimakariri, Investigation, Liquefaction, Earthquake, Susceptibility*

ABSTRACT: A study has been undertaken to provide a better understanding of the liquefaction potential of the eastern side of the Waimakariri District in Canterbury, an area of historical liquefaction. Field investigations, including 26 boreholes, were used to supplement existing regional data. Two different earthquake scenarios (a nearby Foothills Earthquake and a more distant Alpine Fault Earthquake) were used to model the susceptibility to liquefaction. Using these two earthquake scenarios, liquefaction susceptibility was predicted using three different liquefaction models. It was found that the eastern side of the Study Region, which contains deep dune sand deposits, has a high susceptibility to liquefaction. This high susceptibility extends out to the western boundary of the Study Region in three locations and into the heart of the largest town in the Study Region, Kaiapoi. Level ground liquefaction settlements were also predicted for both earthquake scenarios. The extent of areas classified as having a high susceptibility to liquefaction is not significantly different to those in the eastern side of Christchurch and some other geologically young coastal areas around New Zealand.

SESSION 4 POSTER PRESENTATION

4.1 Damage ratios brick buildings in the 1942 Wairarap earthquakes

Dowrick, D. J., Rhoades, D. A.

. *Earthquake Lessons, Vulnerability, damage costs, non-domestic, low-rise*

ABSTRACT: An analysis of damage costs to low-rise non-domestic brick buildings in the MM8 intensity zone of the M_w 7.1 Wairarapa earthquake of 24 June 1942 has evaluated the vulnerability of such buildings in New Zealand for the first time. The buildings studied were mostly of unreinforced brick of average workmanship and material quality, i.e. the second most vulnerable class of New Zealand buildings. Approximate vulnerabilities were also determined for partly reinforced and partly retrofitted buildings, and of one and two-storey buildings. The costs of damage were derived from insurance claims and local government records. The indicators of vulnerability that were determined were the statistical distributions and mean values of damage ratios, and the percentage of buildings damaged. Comparisons have also been made with results from studies of other earthquakes.

4.2 Evaluation of earthquake risk buildings with masonry infill panels

Bell, D.K., Davidson, B.J.

. *Structural Evaluation & Retrofit, Infill, Masonry, RC, Analysis*

ABSTRACT: Structural frame buildings with masonry infill panels make up a significant portion of the buildings constructed in New Zealand prior to the development of comprehensive seismic design standards. These buildings may be regarded as 'Earthquake Risk' buildings, therefore an evaluation of their level of seismic performance may be required. There is however limited guidance in New Zealand on the seismic evaluation of infilled frame buildings. This paper reports on the evaluation of a reinforced concrete frame building with brick infill panels on the exterior walls. The evaluation uses an equivalent strut approach for modelling the infill panels. Reference is made to the provisions of international standards, including FEMA-273 and Eurocode 8. The evaluation includes sensitivity studies looking at the consequences of variations in modelling assumptions.

4.3 Seismic intensities derived from strong motion instruments in New Zealand –

Davenport, P.N.

. *Engineering Seismology, seismic intensity instrument, JMA, MMI*

ABSTRACT: Intensity of ground shaking during an earthquake has generally been estimated using scales based on felt effects at the time of the earthquake and on later observation of damage to the built environment. By their nature, these measures of felt seismic intensity are subjective and it requires a skilled observer to determine reliable values. An example of such a scale is the Mercalli scale and later adaptations. Where strong motion instrument recordings are available, it is desirable to have a way to determine a seismic intensity from them. Measures that have been used include the peak value of acceleration amongst others, and such measures have their drawbacks. In this paper, a seismic intensity measure developed in Japan is investigated and applied to strong motion records obtained in New Zealand. Comparisons with other measures of intensity are also reported.

4.4 Models for seismic hazard assessment in Australia

McCue, K., Sinadinovski, C.

. *Seismology, Australian Earthquake, Seismic Hazard, Seismic Model.*

Abstract**:** With a database of a century of recorded earthquakes in Australia, McFadden and others (2000) demonstrated that the pattern of epicentres is not representative of a random process at a high level of confidence. What then is the pattern and can it be explained by a simple physical process? We looked at possible correlations of epicentres with topography and geology, with potential fields such as gravity and geomagnetism reflecting deep and shallow crustal structure, and with interpreted crustal element boundaries, with no positive outcome.

Surprisingly a simple artistic exercise presented us with a pattern of seismic zones which seemingly accounts for more than 90% of epicentres of magnitude 4 or greater earthquakes. In addition, all known and prehistoric Recent fault scarps are within the delineated zones as are the only two known regions of Recent Volcanism in north

Queensland and the Newer Volcanics in the Victoria - South Australia border region. For more than a half a century geologists have commented on the existence of continent-scale lineaments, many of which parallel or coincide with our seismic zones.

A simple physical model that we have termed the Coulomb model seems to account for this pattern of intraplate seismicity.A simple physical model that we have termed the Coulomb model seems to account for this pattern of intraplate seismicity.

4.5 Preliminary results of the detailed microtremor zonation of Newcastle, New South Wales

Sinadinovski, C., Stewart, D., Jones, T.

Lessons derived from earthquakes, Risk assessment, microzonation, seismicity.

ABSTRACT: In the area of Newcastle and Lake Macquarie, NSW, where most of the damage occurred during the ML5.6 1989 earthquake, around 450 sites were selected for AGSO's microzonation study 2000. This study is part of an earthquake risk assessment of the Hunter region undertaken jointly by AGSO, local and state government, industry and the University of Newcastle. Ambient vibrations were recorded and the spectral ratio of horizontal to vertical components, along with geotechnical and geological information, was used to help determine the seismic amplification of sediments.The preliminary results of the maximum natural period for Newcastle correlate extremely well with the geology map and show that in most of the cases the sites with higher values coincide with the depths of the sedimentary layers between 10 m and 40 m. The inferred site classifications, amplification factors and hazard estimates will be compared with the Australian Earthquake Loading Standard to generate various earthquake shaking scenarios for risk assessment.

4.6 The Akatarawa Fault: a newly discovered active fault in the Wellington Region, and implications for increased hazard on the Wellington fault

Van Dissen, R. J., Begg, J. G., Robinson, R.

. *Earthquake Geology, Active faulting, earthquake hazard, Wellington*

ABSTRACT: The active Akatarawa fault extends northeastward for ca 18 km from its junction with the Wellington fault near the Whakatikei terraces area of Upper Hutt to its junction with the Moonshine and Otaki Forks faults at Cloustonville in the Akatarawa valley. Geomorphic mapping and trenching of the fault trace in the Akatarawa valley indicate that the Akatarawa fault has a minimum dextral slip rate of 0.4 mm/yr, and a maximum average earthquake recurrence interval of ca 9000 yrs. However, given dating and measurement uncertainties, the actual slip rate may be considerably higher, and the recurrence interval may be considerably less. Coulomb failure stress modelling of the Wellington and Akatarawa faults suggests that rupture of the Wellington fault enhances the likelihood of rupture of the Akatarawa fault. An important implication, given the Akatarawa fault's sense of slip and geometry relative to the Wellington fault, is that the hazard posed by the Wellington fault south of its junction with the Akatarawa fault may currently be underestimated.

4.7 What earthquake would be amplified more at a soil site?

Yu, J., Taber, J. J.

. *Seismology, ground motion, amplification, coherence, modelling*

ABSTRACT: To understand what earthquake would be amplified more in a Quaternary sedimentary basin, ten earthquakes recorded at the Parkway basin, Wainuiomata, New Zealand, were studied. The ground motion amplification in the basin of an earthquake was quantified using spectral ratios of recordings from soil sites to rock sites. The spatial coherence of seismic waves was also calculated for each event. The results demonstrate that there is a correlation between the amplification and the coherence of the seismic waves at the fundamental resonant frequency -- the more coherent the waves, the greater the ground motion amplification in the basin. This observation was supported by three-dimensional modelling of the ground motion in the basin. The modelling showed that coherent SH or SV incident waves were amplified significantly more than randomly incident waves. This suggests that ground motion in a basin will be amplified more for an earthquake when the waves of the earthquake are more coherent.

4.8 The rotation of asymmetric plan structures

Castillo, R., Carr, A.J., Restrepo, J.I.

. *Structural Engineering, Torsion, Asymmetric response, Ductility*

ABSTRACT:
A recent study on the torsional response of ductile structures indicated the need for improvements in current seismic design provisions (Paulay, 1997). This is because most standards deal with the torsion problem using concepts based on elastic response. These provisions may be satisfactory at the serviceability limit state but are generally irrelevant for ductile structures.

The objective of this paper is to promote an understanding of the dynamic response of asymmetric structures. It is illustrated how the mass rotational inertia plays an important role in the response of asymmetric structures. It is shown how strength eccentricity and distribution of mass affect the rotation of the system.

It is suggested that the strength distribution to elements of a system be such as to reduce or eliminate strength eccentricity. This generates a reduction of the system rotation and allows the structure to be modelled as an equivalent single degree of freedom, ESDOF, system. Thus, the system displacement ductility capacity becomes a simple function of the displacement ductility capacity of the critical element.

4.9 Direct displacement based design - a definition of damping

Judi, H.T, Fenwick, R.C., Davidson, B.J.

. *Seismic design, DDBD, FBD, Substitute damping, Equivalent damping*

ABSTRACT.The response of a range of structures with different hysteretic rules was investigated for a variety of strong earthquake ground motions. It is shown that the use of substitute viscous damping, instead of equivalent viscous damping, with the direct displacement based design approach, improves the accuracy and generality of the method, and gives predictions which are marginally better than those obtained with force based design. Analyses of a wide variety of earthquake records show that the values of substitute viscous damping are relatively insensitive to the type of earthquake but they vary with the structural period, ductility level and hysteretic form.

4.10 Determination of inelastic seismic response and evaluation of seismic performance for building structures using pseudo dynamic analysis method

Lee, D.G., Choi, W.H., Lee, J.W.

. *Seismic Analysis and Earthquake Resistant Design, Nonlinear seismic response, Nonlinear static analysis, Lateral load pattern, Pseudo dynamic analysis method, Evaluation of seismic performance*

ABSTRACT: For the performance based seismic design, nonlinear static analysis is usually applied to evaluate the seismic capacity of a building structure effectively. This is a simple and practical analysis method to estimate the stability limit of a structure considering the load redistribution in the inelastic range. However, evaluation of the seismic performance of high-rise buildings or irregular buildings based on the nonlinear static analysis results may have shortcomings because the effects of the higher modes on the structure are not considered. In this study the story force obtained by the pseudo dynamic analysis method was used in the nonlinear static analysis, and the results were compared with those of the nonlinear time history analysis in terms of the plastic hinge formation, and interstory drift. The seismic responses predicted using the proposed method turned out to represent the nonlinear seismic response of a structure more accurately than those by other lateral load patterns

4.11 Efficient seismic analysis of high-rise buildings considering the basements

Lee, D.G., Kim, H.S.

. *Sructural analysis, seismic analysis, basement, partial rigid diaphragm*

ABSTRACT: Many high-rise buildings are designed with basement. In general, we assume that a building is fixed at the ground level. Therefore, the basement of the building is not included in the analysis and only gravity loads are considered in designing the basement. However, the basement may introduce flexibility to the structure resulting in larger lateral displacements and longer vibration periods. The seismic loads applied to a building structure will affect the member forces in the basement. Thus, it is recommended to include the basement in the analysis of high-rise building structures. The effect of the basement is investigated based on the seismic response of high-rise buildings and an efficient analysis method to account for the effect of the basement was proposed in this study. Most of the degrees of freedom in the basement are eliminated by the matrix condensation procedure using a rigid diaphragm for each floor in the basement in part or in full. When a 20-story building structure was subjected to static lateral loads,

the displacements of the roof were 13.8cm and 12.7cm for the cases with and without the basement. And the period of the building with the basement was about 10% longer than that of the building without the basement. Therefore, it is recommended to use the proposed method to get more accurate results in the analysis of building structures with basement

4.12 Dynamic analysis of RC frames including buckling of longitudinal steel reinforcement

Potger, G.M., Kawano, A., Griffith, M.C., Warner, R.F.

. *Structural Dynamics, non-linear analysis, bar buckling, reinforced concrete, collapse, ground motion*

ABSTRACT: The overload behaviour and mode of collapse of a reinforced concrete frame is strongly influenced by the ability, or otherwise, of critical regions in the beams and columns to undergo plastic deformations. In some circumstances outward buckling of the compressive reinforcing bars can follow spalling of the compressive cover concrete and lead to local failure and overall system collapse. In this paper compressive bar buckling is treated in a simplified manner by modifying the constitutive relations for the bar. This simplified treatment is incorporated into a finite-element based analysis procedure which predicts overload behaviour and collapse of concrete frames under severe dynamic loads.

4.13 Two new semi-rigid joints for moment-resisting steel frames –

Clifton, G. C., Butterworth, J. W., Pantke M.

. *Structural Engineering, Earthquakes, Structural Steel, Semi-rigid Connections, Bolted Joints, Beam-Column Joints*

ABSTRACT: HERA and the University of Auckland are engaged in a long-term research project aimed at developing innovative new semi-rigid joints for moment-resisting steel framed seismic-resisting systems (MRSFs). Two joints are under development, both of which can undergo rotation during a design level severe earthquake and beyond, while suffering minimum structural damage under the design level event.
The first of these joints, termed the *Flange Bolted Joint* (FBJ) is simple to fabricate and erect and is intended for low levels of design ductility demand. The second joint, termed the *Sliding Hinge Joint* (SHJ) is also simple to fabricate but is more complex to erect. It is intended for higher levels of design ductility demand.
Design and detailing provisions for the FBJ are summarised in this paper. The current status of the SHJ in terms of research and design development are also presented, along with the intended future research and design procedure development planned for 2001/2002.
Both these semi-rigid joints offer considerable advantages over traditional rigid jointed MRSFs and have the potential to set the future direction for MRSF seismic-resisting system application in New Zealand.

SESSION 5. CHAIR: PETER MOSS

5.1 The seismic assessment of building contents combining force and displacement principles

Lam, N., Wilson, J.

. *Engineering Design Criteria, Displacement Based Design, Building Contents*

ABSTRACT: Existing procedures for assessing the seismic performance of building contents are mainly founded on force-based principles wherein the maximum seismic force is estimated in accordance with the predicted peak floor acceleration. Such force-based procedures tend to be over-conservative when adapted to determine the minimum base width requirement to prevent overturning instability of unrestrained (free-standing) objects, as the capacity of the object to displace without overturning has not been accounted for. The displacement capacity of a free-standing object can be checked against the peak floor displacement in situations where it is safe to rock. This paper introduces a new procedure which combines both the force and displacement principles to check overturning stability. Results obtained from this approach indicate that objects with a base width exceeding 300mm will not overturn for most seismic regions of Australia based on a 500 year return period.

5.2 Study group on earthquake risk buildings – 1999/2000 report

Brunsdon, D.R., Hopkins, D. C.

ABSTRACT: This report summarises the recent and current activities of the Society's Earthquake Risk Buildings Study Group. Work over the past year has focused on completing the document *An Initial Evaluation Process For Identifying Buildings Not Safe in Earthquake*, which was released in draft form via a series of seminars in August 2000. Subsequently, the Study Group has been significantly expanded to tackle the task of producing Detailed Procedures for assessing and improving the structural performance of earthquake risk buildings.

5.3 Practical considerations for implementing legislative change - an architect and a communicator's view

Pynenburg, R., Killip, R.

. *Legislative change, practical considerations, earthquake prone, communication*

ABSTRACT: The proposed changes to the earthquake prone provisions of the Building Act that are currently before the Minister of Internal Affairs will have significant implications for building owners, territorial authorities and professional advisers. These changes will see the scope of these provisions widened from only applying to unreinforced masonry buildings to those of any construction that can be shown to be not safe in earthquake.
From a regulatory perspective, the key feature of the proposed changes is that they are not mandatory. Individual territorial authorities will be able to develop their own strategies and time frames for firstly carrying out engineering assessments and secondly requiring physical mitigation for those buildings where structural improvement is found necessary. Clearly a structured risk-based approach will be required.
One of the biggest issues for all parties involved in this process is the development of a rational timeframe for individual buildings to be assessed and have physical improvements implemented where found necessary. There is a need to balance the opposing considerations of:
(i) Giving owners adequate warning and timeframe to react in; and
(ii) Reflecting the opportunity that significant alterations represent to carry out structural improvements that will reduce the earthquake risk
This paper reviews and comments on the key provisions of the proposed changes, and considers the process and communication issues.

SESSION 6. **CHAIR: CRAIG STEVENSON**

6.1 Future earthquake loading standards

King, A. B., Jury, R. D.

. *Engineering Standards & Design Criteria, Loading, Earthquake Actions, Future trends, NEHRP, Eurocodes*

ABSTRACT: The draft joint Australian/New Zealand earthquake loadings standard, which has recently been out for public comment, is described. This standard is intended to be a verification method within the general framework of the New Zealand Building Code. This paper summarises the principal aspects of the draft standard and the major differences between the proposed provisions and those in the current standard.
Comment is also made as to the future direction of overseas and international loading standards and the implications of such changes for New Zealand, particularly with regard to the building regulations applicable here and their application to international structural standards

6.2 Ductile moment-resisting connections in glulam beams –

Moss, P., Buchanan, A., Wong, N.

. *Structural engineering, ductility, epoxy, glulam, steel, timber*

ABSTRACT: This paper describes an experimental investigation into the use of epoxied steel bar connections in glulam beams. The tests confirm that high strength moment connections can be achieved with threaded steel rods epoxied into the end-grain of glulam timber, bolted to steel brackets. For ductile seismic design with the epoxied steel rods designed to yield in tension, a displacement ductility of 3 was achieved, but brittle failures occurred at larger displacements. Ductile behaviour of glulam frames is better designed with yielding of the steel connecting brackets rather than yielding of the epoxied rods.
The main factor limiting the strength and ductility of these connections is longitudinal splitting caused by shear forces near the beam-to-bracket interface. Shear strength can be enhanced by providing transverse steel rods epoxied through the full depth of the beam. Threaded bars arranged at an angle to the grain are not recommended, because they result in premature shear failures.

6.3 Lateral resistance of shallow foundations

McManus, K.J. and Burdon, N.R.

. *geotechnical engineering, lateral load, shallow foundation, interface friction, passive pressure, wedge failure*

ABSTRACT: Three shallow foundations each 4.25 m wide x 4.6 m long consisting of a 100 mm thick slab “on-grade” with two foundation beams 600 mm wide embedded 450 mm were constructed in coarse granular material. Each was tested by shoving back-and-forth by a powerful hydraulic actuator with several cycles of quasi-static lateral loading. These tests were supplemented with several, simpler interface sliding tests were performed on 2 m wide x 3 m long concrete slabs constructed “on-grade” using one or two layers of polymer damp-proof membranes.
Lateral loading of the slab and beam foundations caused a wedge type of failure mechanism with significant passive soil pressures acting against the vertical faces of the foundation beams. The passive soil wedge developing against the trailing beam lifted one side of the structure vertically leaving hollow space beneath the floor slab. For the somewhat narrow structures tested, significant rotations of the structure occurred.
A simple method of analysis was developed and found to give good predictions for the experimental results while accounting for all of the main parameters. The analysis predicts that lateral load capacity is highly sensitive to the eccentricity (height above ground) of the applied lateral load.

6.4 Joint hazard of earthquake shaking at two or more locations

Rhoades, D. A., McVerry, G. H.

. *Lifeline Systems, Earthquake hazard, attenuation, lifelines, uncertainties,*

ABSTRACT: The continuation of a system, activity or lifeline after an earthquake may depend on one or all of several critical facilities at different sites remaining operational. Hence the joint hazard of earthquake shaking at two

or more locations in the same earthquake is of much interest. The joint hazard from either a single earthquake source or multiple earthquake sources can be estimated using a random effects attenuation model, which distinguishes the within-earthquake and between earthquake components of variability. The ratio between the joint and individual hazards can vary widely, and this calls into question the common "scenario" approach adopted in some lifeline studies. To illustrate this point, estimates of joint hazard are compared with the results of a lifelines study in Auckland in which the scenario approach was adopted.

6.5 Improvement of traditional masonry wall construction for use in low-rise/low-wall-density buildings in seismically prone regions

Toranzo, L. A., Carr, A. J., Restrepo, J. I.

. *Earthquake Engineering, rocking, wall, masonry, seismic-design, performance-based*

ABSTRACT: The current trend of designing structures to meet performance-based demands could severely limit the use of some traditional construction materials and systems. Masonry construction, used in conjunction with reinforced concrete frames, as used extensively in Latin America, is among those affected. This limitation is due to the poor performance of conventional masonry systems in past earthquakes. This paper discusses the option of using reinforced concrete frames infilled with masonry, acting together as a series of rocking walls providing a desired performance level. Such system may be used in buildings with a low density of elements where the demand expected in conventionally built masonry walls might result in structural damage in moderate earthquakes. Rocking walls can be designed to rock while ensuring no damage will occur anywhere else in the structure. During the rocking process the system has a much lower equivalent stiffness than before rocking is triggered. Most often this means that the inertial forces are reduced as the response is shifted into a less demanding region of the acceleration spectra. The softening of the system also lets other flexible elements participate in the response. Triggering of the rocking may be set for levels of excitation greater than frequent earthquakes for which the element can be designed to behave as a fixed-base wall. Rocking also allows the use of hysteretic energy dissipators at the base of the wall. It was found that these energy dissipators could add up to 20% of equivalent viscous damping to the system.

6.6 Report from working party on integrated response planning

Brunsdon, D.R.

. *Earthquake, response, engineers, agreement, critical facilities*

ABSTRACT: This report summarises the recent and current activities of the Society's Working Party on Integrated Planning For Earthquake Preparedness. The focus of the Working Party is on promoting the need for key organisations to be better prepared to respond following a major earthquake, and in particular highlighting the pre- and post-event roles of Society members. This work involves liaison with the Ministry for Emergency Management, the Earthquake Commission, the Building Officials' Institute of New Zealand and a range of territorial authorities.

SESSION 7. **CHAIR: KEVIN MCMANUS**

7.1 Seismic design of storage tanks study group – 1999/2000 Report

Whittaker, D.

. *Engineering Standards & Design Criteria, Seismic Design Storage Tanks*

ABSTRACT: The NZSEE Study Group on Seismic Design of Storage Tanks is working towards publishing a revision to the 1986 Red Book incorporating an amended procedure for determining seismic loads on tanks. Industry Funding from interested parties is being sought to assist the Study Group to complete its work.

7.2 Modelling the seismic response of light timber framed buildings

Deam, B., Moss, P.J.

. *Structural Engineering, Timber, shaketable, pushover analysis, time-history analysis, building*

ABSTRACT: Timber-framed buildings have become the focus of extensive research following their poor response in the Northridge and Kobe earthquakes. A series of research projects are being conducted by the California Universities for Research in Earthquake Engineering (CUREe) to improve the hazard mitigation for these buildings. In the past, a variety of analytical models have been developed to predict the seismic response of timber-framed buildings. Their accuracy is being assessed as part of an international benchmark, which is comparing their (blind) predictions of the response of a full-scale two-storey residential building tested on a shaketable.
This paper presents the method and results of the static and time-history modelling of the CUREe benchmark building. The building deformations were found to be similar to those expected for New Zealand buildings subjected to design level earthquakes.

7.3 Tell it like it is – How to communicate your future vision for earthquake engineering to clients and building owners.

Killip, R.

. *Communication, neuro linguistic programming, techniques*

ABSTRACT: The current seismic design philosophy for reinforced concrete structures in New Zealand is based on the concept that it is generally uneconomical to design a building to ensure elastic response in a large earthquake. An implication of this concept is that structural damage is accepted, as long as collapse is prevented in a major earthquake. For this reason standards allow the use of design forces that are generally smaller than those required for elastic response. This requires the critical regions of the structure to be adequately designed for ductility and for energy dissipation. In New Zealand, ductile design has been achieved since 1976 by selecting a suitable mechanism of plastic deformation and ensuring, through capacity design, that the mechanism can develop and be maintained.

7.4 New generation of structural systems for earthquake resistance –

Restrepo, J.I., Mander, J., Holden, T. J.

. *Structural Engineering, Performance Based Design, Reinforced Concrete, Capacity Design, Damage Control*

ABSTRACT: The current seismic design philosophy for reinforced concrete structures in New Zealand is based on the concept that it is generally uneconomical to design a building to ensure elastic response in a large earthquake. An implication of this concept is that structural damage is accepted, as long as collapse is prevented in a major earthquake. For this reason standards allow the use of design forces that are generally smaller than those required for elastic response. This requires the critical regions of the structure to be adequately designed for ductility and for energy dissipation. In New Zealand, ductile design has been achieved since 1976 by selecting a suitable mechanism of plastic deformation and ensuring, through capacity design, that the mechanism can develop and be maintained. Experience gained from earthquakes abroad indicates that the cost of repair of buildings designed for ductile response has not been insignificant. This prompts the need to develop structural systems that have large displacement capacity and perform essentially damage-free, even when subjected to large earthquakes. This paper covers design aspects of a new generation of structural systems aimed at minimizing damage. The paper briefly discusses the results of a test programme on precast/post-tensioned structural wall systems being conducted at the University of Canterbury.

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