Current seismic retrofit research in New Zealand

Dr Jason Ingham, Associate Professor at the University of Auckland, and corresponding member of the IStructE Research Panel reports on some of the work

A collaborative research programme considering seismic retrofit solutions appropriate to New Zealand's unique earthquake risk building stock is currently under way as a joint effort between the University of Auckland and the University of Canterbury.

The project is focussed predominantly on multi-storey and non-residential structures, as the majority of single-level dwellings in New Zealand are expected to perform satisfactorily in a major earthquake due to their comparatively long period and inherent resilience.

The Structural Engineering Society of New Zealand has formed a 'Seismic Retrofit Research Board that acts in an advisory capacity to assist in defining the seismic retrofit research needs of the New Zealand structural engineering community, thereby directing the focus of the research programme. Board members represent practising structural designers, manufacturers, local government building officials, and independent researchers.

The project is funded by New Zealand's Foundation for Research Science & Technology, and has a 6-year duration from the start in July 2004. The project details are shown schematically in Fig 1 and described in the sections below.

Background

New Zealand's seismicity is comparable to many nations such as Taiwan, Japan, Pacific coast USA and Turkey, which have all had major earthquakes in the recent past, and whose citizens are therefore keenly aware of the seismic hazard to which they are subjected. However, New Zealand's last major earthquake was in 1931. This absence of a recent major earthquake in New Zealand has led to a substantially reduced awareness of the seismic hazard amongst the general public, and a comparative lack of attention by building owners to the need for seismic retrofitting of their structures. Furthermore, seismic assessment and retrofit is not currently taught in New Zealand's structural engineering degree programs and there is no useful national technical resource for structural designers wishing to execute seismic retrofits. Consequently, this research programme seeks to address these issues.

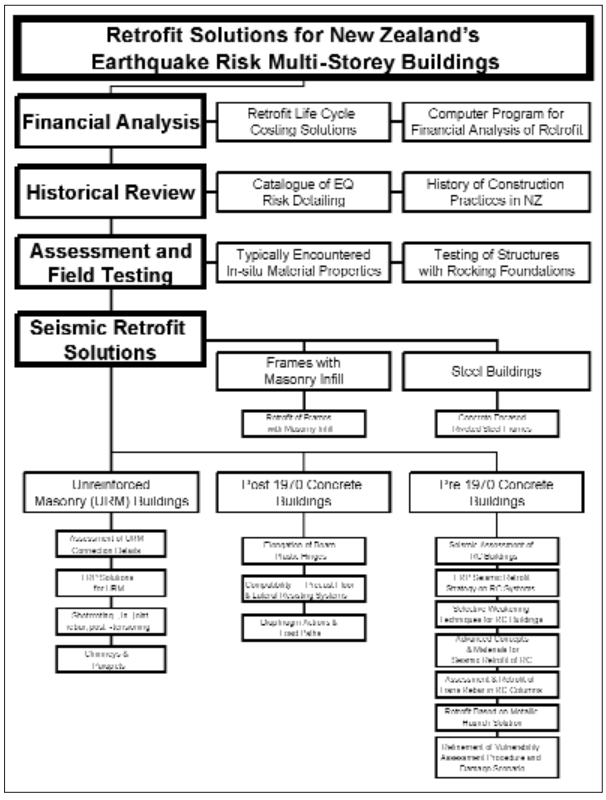

Fig 1. Retrofit solutions for New Zealand's earthquake risk multi-storey buildings – project overview at April 2006

Financial analysis of retrofit intervention

This component of the study is focused on providing costing software for different degrees of retrofit intervention, and correlating these costs on a life-cycle costing basis against the expected seismic performance and associated financial implications for the unretrofitted structure.

The analysis will seek to account for aspects such as human injury, reduced insurance premiums, building damage costs, and the impacts of down-time on the performance of businesses resident in the structure. The intention is to demonstrate a financial motivation for seismic retrofit implementation.

Historic review

This component of the research programme seeks to catalogue the changing design documents and the recognised detailing and construction practices for different eras. One important aspect of the study is to determine the source and characteristics of early building materials, such as where structural steel and steel reinforcement were imported from before they were manufactured in New Zealand, and where clay bricks and cement were manufactured. Also important is whether there were regional trends in material properties and construction typology, or whether practices were commonplace nationwide.

Field testing

The focus of this study is to acquire data to improve the ability of designers to accurately assess the performance of structures that may be candidates for retrofit. The first part of the study will involve obtaining data on typical material properties for *in situ* steel, masonry and concrete, accounting for strength gain and/or deterioration since the structure was built.

The second part of the study seeks to provide excitation to existing structures scheduled for demolition in a manner that will induce inelastic deformations, allowing characteristics such as strength, stiffness, damping, torsional and higher modes and structure-foundation interaction to be studied. The influence of secondary structural elements and of redundancy will also be quantified.

A primary focus of this component of the study will be to develop assessment guidelines for structures on shallow foundations, where rocking of the structure may be an effective seismic isolation method.

Infilled frames

The impact of infills on the sway response of moment frames is well documented. This topic will be explored by adopting and adapting international best practice and latest research findings to New Zealand's unique building typology. One important aspect of the study will be to acquire experimental data on the actual performance of infills typically encountered in New Zealand, for implementation into assessment tools.

Structural steel

The form of steel construction most urgently requiring research attention is concrete encased riveted steel framed

structures. These structures are typically large, such as town halls and train stations, with the cover concrete often being very weak and having uncertain bond characteristics. The performance of the riveted joints also needs investigation.

It has been noticed previously that when such structures have been demolished their strength has been much greater than expected based on conventional assessment techniques. An example of such a structure during construction in 1932 is shown in Fig 2. The second form of steel construction to be explored is the performance of early welded steel connections.

Unreinforced masonry

Unreinforced masonry diminished in popularity following the 1931 Napier Earthquake, but was not abolished until 1965. Studies have shown that unreinforced masonry structures represent the most vulnerable structural form in New Zealand.

This study will first focus on a critique of international best practice in the assessment of unreinforced masonry with appropriate modification to account for detailing and material properties typical in New Zealand. Testing of sub-assemblages such as wall-diaphragm connections will help designers to improve their ability to determine the likely performance of the unretrofitted structure. Conventional solutions such as post-tensioning, shotcreting and fibre reinforced polymer overlays will be proof tested and published in a form facilitating use by New Zealand designers.

Fig 2. 1932 construction of a Napier building having a riveted steel frame encased in concrete, during reconstruction following the 1931 Napier Earthquake (*Credit: Fletcher Building Archives*)

Structural concrete

This component of the study is by far the largest, with 50% of the resources assigned to this topic. The subject is divided into pre-1970 and post-1970 construction, primarily based on changes to loadings codes and design philosophies at about this time.

For pre-1970 structures the issues are predominantly associated with: poor reinforcement detailing; the use of plain rather than deformed reinforcement; inadequate lap length and poorly located laps; inadequate transverse reinforcement; no joint shear reinforcement; poor quality concrete and non-ductile reinforcement.

For more recent concrete construction, one important issue is the accommodation of beam plastic hinge elongation, and the implication on deseating of precast concrete floors. A parallel concern is the often neglected beam overstrength that occurs due to cast *in situ* concrete floors acting compositely with beam. Both beam elongation and composite beam-floor action tend to generate additional loading on the adjacent columns, generating potential for soft storey sway mechanisms.

Numerous projects under this subject heading are underway including:

- the development of improved assessment techniques;
- proof testing of retrofit interventions such as post-tensioning and the use of fibre reinforced polymers and shape memory alloys;
- effective techniques for intentional weakening of structural components;
- ongoing studies related to the interaction of concrete moment frames and diaphragms.

Further information

Additional details and selected publications from the research programme are available from the project website: (www.retrofitsolutions.org.nz). se