

## Strengthening the link between earthquake engineering and architecture

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**ABSTRACT:** With reference mainly to the New Zealand scene, the paper reports on current initiatives to strengthen architects' understanding and engagement with issues of earthquake engineering. The situation at the three schools of architecture in New Zealand is reviewed with mention made of some recent developments including the introduction of earthquake structural design software and progress in integrating architectural and seismic design in studio projects. The paper notes a current earthquake engineering course organized and run by NZSEE and reviews the profile of earthquake engineering as represented in *Architecture New Zealand*. Overseas initiatives are also reported on. The paper concludes with recommendations for further strengthening the links between the professions.

### **INTRODUCTION**

Given the conference theme of 'Earthquake Engineering: getting the message across and moving ahead', this paper explores aspects of how the message of earthquake engineering is being communicated to architects. How strong are the links between these two allied disciplines currently, and how might they be strengthened?

First, we need to ask ourselves, why are strong links important? The answer, which probably needs recalling, lies in the value of close collaboration between architects and engineers during the design process, and especially in those very early stages of design when structural layout is largely determined. Decisions made during those feasibility or preliminary design stages affect the cost-effectiveness of the structure, can enable structure to integrate well with overall architectural intentions, and lead to an adequate and predictable seismic performance.

So, how strong are the links at present? The answer depends upon to whom you speak. While many excellent relationships between architects and engineers develop in the context of collaboration during design projects, one still hears anecdotes of architects having unrealistic expectations of the structure required to resist lateral loads, and also of structural engineers who need to work harder to help architects achieve their design concepts. Certainly our Society has tried for many years to arouse more interest and involvement in earthquake engineering by architects. NZIA nominates a representative onto our Management Committee each year, and architects are included as members of earthquake reconnaissance teams. These initiatives are important, but given the general lack of interest within the architectural community in earthquake engineering, we need to consider what else the Society might do to 'move ahead' in this area. We begin by looking at current initiatives within our schools of architecture.

### **CURRENT INITIATIVES**

### *Schools of Architecture*

New Zealand's three schools are the most strategic institutions for teaching earthquake engineering principles to future generations of architects. The extent of earthquake engineering taught in each school varies considerably as discussed below, but all schools have copies of RESIST, a student-friendly computer program that undertakes preliminary lateral load designs. The first DOS version of RESIST, written in the early 1990s (Charleson, 1993) was such a success with students that it has been superseded by a Windows version with attractive graphics features that makes it even more popular.

The Structures curriculum at Auckland University is unfortunately to be reduced in 2004. Structures will be taught in core courses to first and second year students only, in a total of 22 lecture-hours. A fifth year Timber Technology elective will be offered. Although the revised program is not yet finalized, probably about 3 lectures will address earthquake design issues. While fourth and fifth year students benefited from using RESIST previously it is hoped that RESIST can be introduced into a third year construction course. It is likely some earthquake design issues are introduced in some construction courses but details have not been confirmed.

UNITECH has also been restructuring its courses and emphasising the design studio as a teaching environment. For the first four years, architectural students have only four two-hour Structures lectures. Out of the total of 32 hours of Structures over the duration of their program, approximately 10 hours include aspects of earthquake engineering. Students also benefit from exposure to Structures in their design studio where on some projects they receive structural tutoring and feedback. A new staff member responsible for Structures courses has a real interest in earthquake engineering teaching and research.

The profile of Structures at the School of Architecture, Victoria University of Wellington is considerably higher than at the Auckland schools, partially as a result of Vic's greater emphasis on architectural technologies. The numbers of lecture-hours on structures for the first four years of the five year Bachelor of Architecture program are 6, 36, 36, and 18 respectively, giving a total of 96 hours. Of these hours, each year group has the following number of lecture-hours devoted exclusively and generally to earthquake engineering issues: 1, 4, 12 and 9 hours respectively, totalling 26 hours. For more detailed information refer to Charleson (1995). Approximately half of the assessment in years three and four Structures courses involves students producing structural reports on up to two of their architectural design projects. The reports must include output from RESIST that confirms their designs have adequate structure to resist lateral loads. Final year (fifth year) students must demonstrate slightly less rigour in their final design project but they are expected to size their lateral load resisting members using RESIST. Although there are no official structures lectures in their final year, students receive one-on-one structural tutoring throughout the duration of their projects. In 2002 a fourth year earthquake architecture studio program, to be discussed later in this paper, was taught for the first time.

At Victoria University, students in construction courses also learn about the need for seismic separations of glazing, claddings, of buildings from boundaries, and the need for

suspended ceilings and partitions to be braced. At least three lecture-hours cover these topics. RESIST is also used in some construction design projects where students have to design and size lateral load resisting systems. While there is no postgraduate research to report, several staff members have been active in research (Taylor, 2002). The Earthquake Hazard Centre, a NGO that disseminates earthquake engineering information to developing countries is also based at Victoria University. Further information is available at [www.ehc.arch.vuw.ac.nz](http://www.ehc.arch.vuw.ac.nz).

#### *Professional activities*

There is little earthquake engineering input into practising architects at present. However, at the New Zealand Institute of Architects (NZIA) CPD Refresher Course 2003, held in the main centres and attracting a total audience of approximately 1000 architects, Chris MacKenzie of Holmes Group presented a talk on 'Architects and Engineers: can we design it? – yes we can.' As part of a general overview of structure in architecture, Chris mentioned briefly key seismic design principles, including base-isolation.

Our Society started planning a more extensive three-hour CPD recognized seminar for architects last year. During March/April 2004, seminars focusing entirely upon earthquake engineering for architects will be held in the three main centres initially. Depending on the level of interest, the seminars may be taken to other regions.

#### *Initiatives in other countries*

A research project funded by FEMA and administered through the Earthquake Engineering Research Institute began in October 2003 and concludes in April 2004. Its aim is to discover what architects need to know concerning seismic design in order to participate in an increasingly important role on the design team in the implementation and execution of seismic standards that exceed code minimums. An outcome will be the updating of a 1970s seismic design handbook. The first phase of the research is to conduct a telephone survey of school of architecture staff to ascertain what students in the U.S.A. are being taught. This will be followed by a second survey of architects, structural engineers and client representatives who are expert in performance-based seismic design.

### **EARTHQUAKE ARCHITECTURE STUDIO PROGRAM**

In 2002 a group of eight Victoria University of Wellington School of Architecture fourth year students participated in an architectural design course to explore notions of earthquake architecture. Earthquake architecture is taken to mean an approach to architectural design that draws upon earthquake engineering design issues as a significant source of inspiration. The idea behind the project was to create an interest in earthquake architecture that would help bridge the gap between Structures courses and Architectural Design studios and facilitate the integration of the two disciplines. The course represented one-sixth of the students' workload for the year. Two tutors, a practicing architect and the author, ran the course. The students had already completed all core Structures courses in the school and so had a good understanding of seismic design principles.

The course was divided into three projects which were sequenced to achieve a progression of learning and challenge. In the first project, essentially research, students had to initiate and develop design ideas that had the potential to be more fully resolved in their final two projects. The project's three aims were to:

- Increase student knowledge and understanding of seismic effects,
- Expose students to a large number of ideas from which approximately five key architectural questions and concepts could emerge, two of which would become the guiding ideas for the other two projects, and
- Study the work of well recognized architects renowned for their expressive architectural style that might be relevant to a student's approach to earthquake architecture.

Students were given photocopied articles to read and also expected to study seven compulsory and ten optional readings. They were also encouraged to use the internet as well as computer and physical modelling. The outcomes consisted of written reports on their findings and twenty-minute presentations in which students reported on their lists of four or five architectural issues worthy of design exploration in the next phases. Students were encouraged and challenged in a total of six group and individual tutorial sessions through the four week period. Thirty design ideas were identified, a few of which are listed below:

- Waves
- Propping
- Faulting
- Expression of seismic technology
- Insecurity
- Flexibility
- Crumple zones
- Protection.

Some of their ideas were robust enough to form the basis of a design concept, but many others were discarded.

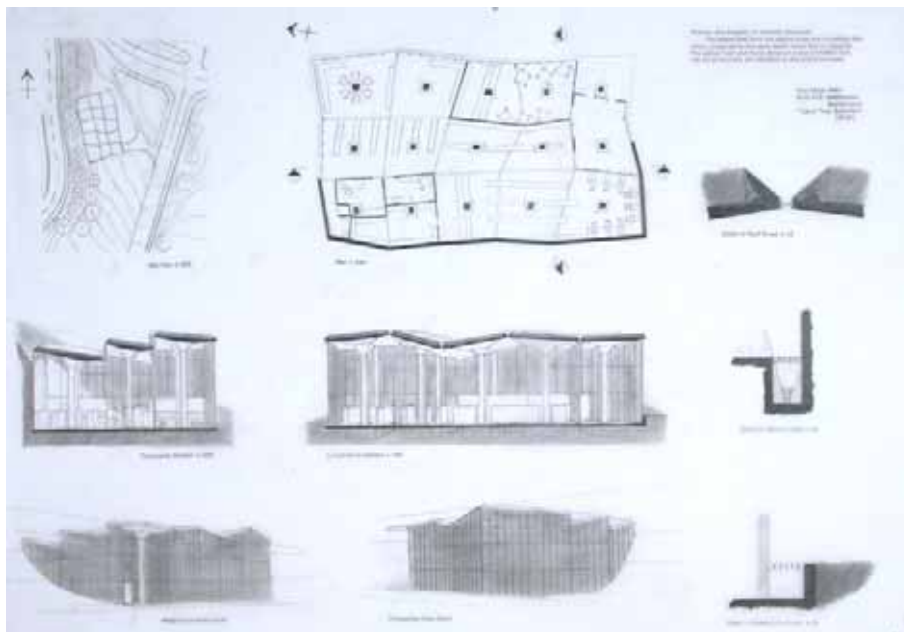
During the next stage, students chose from a list of architects who successfully express various ideas and concepts in their work. The intention was for students to discover suitable precedents within the works of these architects that might help them develop their own designs. Possibly due to pressures of other courses, this phase did not appear to be very successful.

Having generated a short-list of architectural ideas that were to inspire their subsequent designs, the students began their first design project – a suburban library. Each used a different existing library in Wellington to develop a brief and a site. The goal for the students was to design a new building in such a way as to express their seismic design ideas. The Wellington City Council was assumed to be the primary client and the brief stated that EQC was also providing funds. Its expectation was that expressed seismic ideas would remind the community of seismic risk and motivate it to take its own

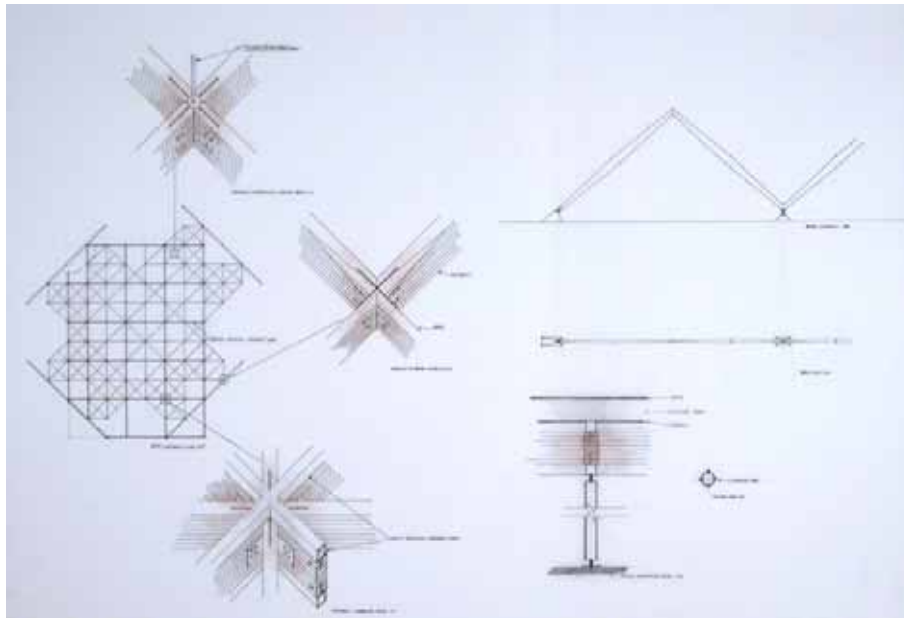
appropriate mitigation measures. After five tutorials over three weeks the students presented their schemes of which two are shown below.

The design concept of the scheme shown in Figure 1 is based on the thinness of the earth's crust relative to its diameter and crustal fracturing into tectonic plates. The key feature is the roof which is broken into different shaped polygonal plates. Their tilting and relative vertical displacements evoke the movements associated with tectonic plates and provide opportunities for introducing natural light. In Figure 2 the roof plan and details reflect a design idea that involved visually articulating separate gravity and lateral load resisting systems. A glue-laminated grid roof is supported on slender steel columns, with the whole structure braced by spindle-shaped diagonal members. RESIST was used to size the seismic resisting structures for all projects.

As a general comment on the student work, although much of their design work was of a high standard, the students could have pushed their ideas further, perhaps achieving more compelling architecture. We also found in some cases that the design ideas did not come through the work very clearly. This was certainly the case when students' design concepts were rather fuzzy to begin with.



**Figure 1 Design concept expresses the thinness of the earth's crust and its fracturing (Guy Shaw)**



**Figure 2 Library roof plan and details showing separation of gravity from lateral load resisting systems (Kieran Leong)**

The final project was similar to the second, but this time the students had to design a more complex building. Once again they had to adopt from their first project another of their design concepts. It was applied to a medium-rise office building for the site currently occupied by Rostrevor House, opposite the School of Architecture in Vivian Street, Wellington. The brief assumed that due to unprecedented success in winning international earthquake engineering contracts, Earthquake Engineering NZ decides to build its own purpose-designed office facility. The building is to be the Cluster flagship. Many existing and potential international clients will visit it, being acquainted with NZ's impressive earthquake engineering expertise. The Client therefore wants not only to showcase the very best earthquake engineering and architectural design and practice, but to express the building's purpose of accommodating professionals who work on the cutting edge of earthquake disaster mitigation.

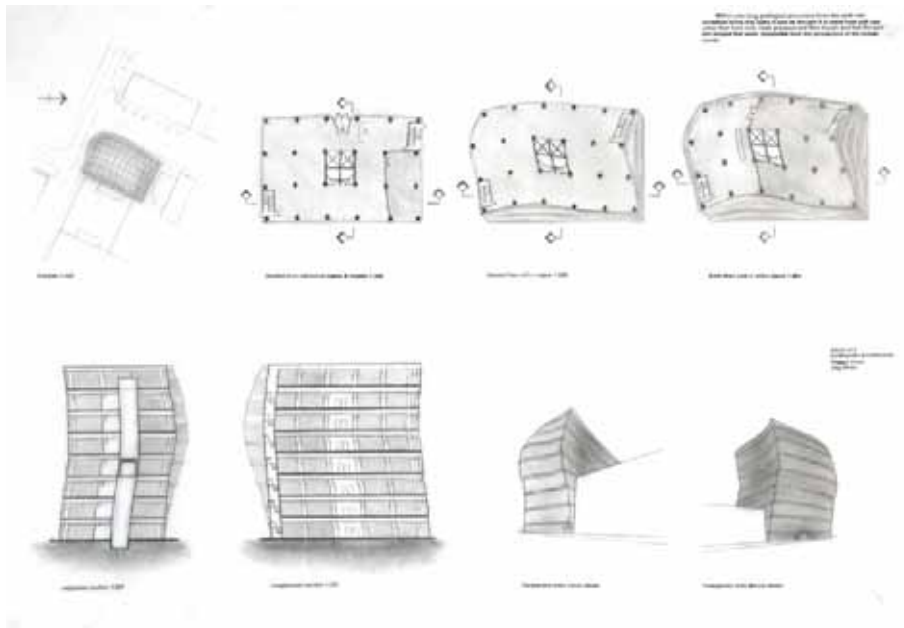
The building is seven storeys high with a plant room at roof level. As far as the brief was concerned, the ground floor is required for a reception and display area. Six floors of offices are stacked above, with the top floor occupied by offices and a café cum meeting-space. Offices on the uppermost floor house Cluster employees, while all remaining floors are leased to New Zealand consulting firms who are key Cluster members.

Overall, the class found this project more difficult due to the urban design issues involved. While several students were not forceful enough in expressing their concept architecturally, both on the exterior and in the interior of their buildings, other projects showed a lot of promise. The students explored the following architectural ideas:

- Relative movement between buildings
- Plastic deformation of geological forms
- Seismic waves

- Differentiation of gravity and seismic loads
- A seismometer
- Expression of seismic resisting structure
- Earthquake damage patterns in buildings.
- Tying a building together.

Two schemes shown in Figures 3 and 4 explore plastic deformation and building earthquake damage respectively. In each project, the design concept can be discerned from the building forms.



**Figure 3 Cross-sections and building perspectives (Guy Shaw)**



**Figure 4 Exterior of a building that expresses earthquake damage to building form (Luke Allen)**



Given this design studio was the first to investigate earthquake architecture it was considered reasonably successful. It not only gave the students opportunity to further develop their architectural skills, but it also showed the potential for earthquake issues to lead to expressive and fine architecture and therefore to contribute to the richness of our built environment.

## DISCUSSION

Earthquake engineering is being taught at very different levels of intensity within the Structures curriculum in the three Schools of Architecture. Aspects of its content and its delivery can be improved. In some schools, steps can be taken to increase the amount of Structures (and earthquake engineering) taught, while in others, lecturers might appreciate some sort of support – ranging from an outside person or organisation taking an interest in their work to financial support to purchase a video, books or some other teaching aids. A recent University of Technology Sydney staff member described his philosophy of teaching in part as ‘to entice, enthuse, embrace and empower the student.’ We who teach a less popular subject like Structures in a school of architecture, need to employ similar methods to engage with our students. We would welcome interest and modest offers of support from the Society. It is very much in the Society’s interest to nurture and encourage this work among our future architects.

Although the Society has taken a big step forward by initiating its own seminar program for architects, it is difficult to communicate with practising architects. Perhaps the Society could target the annual NZIA CPD Refresher course. Another way of moving ahead might be to prepare written articles for architectural publications.

The bi-monthly journal *Architecture New Zealand* is a possible vehicle for communicating earthquake engineering matters to architects. However, if its 2003 journals are typical, earthquake issues rarely surface. If the journal is likened to a seismograph, barely a micro-tremor is recorded, and an overseas reader could be forgiven for not realizing the severity of the seismic threat faced by New Zealand. During last year many prominent new buildings were reviewed. Even though several featured strongly expressed external bracing, comments about seismic matters were limited to a note in one article informing us that facilities in the proposed new hospital lie ‘within an earthquake protected environment.’ Another mention of earthquake engineering occurred in a discussion of American architect, Frank Lloyd Wright’s San Francisco area buildings. It was noted that the Hanna House ‘was closed for several years after suffering severe damage in the 1989 earthquake, but has now been repaired and strengthened.’ The final instances of earthquake engineering, and potentially the most effective, are one or two full-page advertisements for Seismic 300 and 500 reinforcing steel by Pacific Steel, even though one wonders why architects would be targeted for this information!

The Society would do well to make a goal of supporting or soliciting and publishing say two articles each year on earthquake engineering themes. The material would have to entice and engage the architectural readership.

There are many possible reasons there is no discussion of earthquake engineering in *Architecture New Zealand*. The most likely is the number of other issues architects must address, of which earthquake design is but one. The attitude that this issue can be left to consulting engineers to sort out may also be prevalent. This is a topic for further research.

Finally, we need to acknowledge that much of what practising architects know about earthquake engineering has been learnt from consulting engineers in the course of collaborating on projects. How can we, in our individual practices, and in our day-to-day dealings with architects share our passion and concern for earthquake engineering? How can *I* better entice and enthuse?

## CONCLUSIONS

While the Society and some of its members are ‘getting the message across’, there is plenty of room for improvement. Progress can be increased if the Society continues its current initiatives and offers support to Structures programs in schools of architecture (and polytechnics). Targeting *Architecture New Zealand* might also be strategic. Society members should take it upon themselves to share their enthusiasm for earthquake engineering with architects so they too catch the vision.

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