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EARTHQUAKE ARCHITECTURE EXPLORATIONS

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SUMMARY

This paper describes and reviews a design studio undertaken by senior undergraduate architectural students to explore issues of earthquake architecture. After a brief initial phase of broad earthquake engineering literature research, in some cases supplemented by computer and physical modeling, students identified a wide range of earthquake related phenomena capable of providing the basis for generating earthquake architecture. From lists that included geotectonic processes, engineering technologies and human perceptions of earthquakes, students were encouraged to develop two design concepts robust enough to sustain subsequent architectural development. A suburban library and a multi-storey office building functioned as vehicles for the design process. The tested and developed ideas became primary design concepts, informing as many aspects of their designs as possible; guiding both architectural form-making and the resolution of design details. When integrated with site and programmatic requirements these ideas led to preliminary designs that, to various degrees of success, became examples of earthquake architecture.

While the research phase of the project highlighted the diversity of earthquake related ideas that can provide inspiration for designers, the design projects revealed the latent possibilities for further enriching our built environment through earthquake architecture.

INTRODUCTION

The 1851 Great Exhibition hall designed by Paxton marked an important moment in the development of modern architecture and modern architectural thinking. Here the problem of enclosing a large space was solved in a manner more closely allied to engineering than traditional architectural expectations. A vision for architecture was found at the intersection of structural mechanics and standardization. The legacy of this thinking being that engineering has a legitimate collaborative relationship to the making of contemporary architecture. Herman Muthesius [1] noted in a 1913 symposium on factory design that *"a good deal of engineering structure, bridges, station halls, lighthouses and grain silos, are good aesthetically."* Indeed the acceptance of engineering aesthetics, the display of 'gravity defying'

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engineering prowess and the elegance of the materialization of mathematical computation have lead to a number of works taking on iconic architectural status.

The shaping of architecture in response to engineering possibilities has almost exclusively been conducted on new structures, and to a lesser extent on the modification of existing buildings. But there is little evidence that seismic engineering has influenced the aesthetics of architecture, or lead to new paradigms for design. While sporadic examples of earthquake architecture may be found, particularly in Japan, California and New Zealand, very few notable buildings express ideas and concepts derived from earthquake effects or activities in their architecture (Arnold [2] and Charleson and Taylor [3]). Sometimes the visible presence of seismic strengthening systems is a desired outcome, but more often seismic load-resisting componentry is subsumed into the structural framework alongside gravitational and wind load structure. In these instances seismic engineering is simply there to prevent collapse and loss of life.

The contention of this paper is that earthquake engineering design issues can be used to influence a design aesthetic, or in other words, to generate earthquake architecture. The source of this includes geotectonic processes, engineering technologies, and human psychology and perceptions of earthquakes.

Earthquake architecture is taken to mean an approach to architectural design that draws upon earthquake engineering issues as its primary source of inspiration. It is not necessarily concerned with engineering economic solutions to the problem of seismic vulnerability, but instead investigates the design potential of seismic structural systems that is ‘other’ than concerned with overcoming seismic effects. Precedents naturally include projects in which gravitational structure (whether ornamented or not) are used in an explicit visual manner displaying qualities of technological achievement, as well as those that question the tectonic separation of structure and ornament.

The design studio’s other intention was to raise awareness that we are now in a period where professional barriers are no longer as rigidly defined as they once were. Conservative notions of the engineer as someone to add structure to a design are outdated and are becoming increasingly irrelevant. Witness the inspirational collaborations between Cecil Balmond of Ove Arup and Partners [4] and designers such as Liebskind, Koolhaus, Toyo Ito and UN Studio. It is evident that collaboration and multidisciplinary practice has given rise to many of the more interesting forms and spaces currently being constructed.

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 aimed at researching how notions of earthquake architecture could inform the design process. The course brought together the principal author (a structural engineer) and a practicing architect, but included only architecture students, as there are no tertiary engineering courses in Wellington. All students undertaking the course had a good understanding of seismic design principles obtained from earlier Structures programs within their architectural education. However, they were expected to go beyond the limitations of this earlier work and use the projects in this studio program to advance their architectural design skills.

The studio program was divided into three projects. The first invited students to research earthquake effects and actions and discuss them as architectural propositions. During this stage, students had to initiate and develop design ideas to be more fully resolved in the final two projects. The first 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 or propositions could emerge, of which two would become the guiding ideas for the two latter projects, and
- Study the work of several well recognized architects and engineers renowned for their expressive and innovative use of structure.

For this exercise students were provided with a number of course readings and were expected to study seven compulsory and ten optional texts for weekly seminar discussions during the initial four-week period (refer to the Bibliography). Design ideas were to be constructed as both digital and physical models, and students were expected to report on their four or five architectural issues worthy of design exploration in the second and third project. The outcomes consisted of written reports on their findings and twenty minute oral presentations. Some of the ideas presented were robust enough to form the basis of further design development, but others were discarded. A number of possible design ideas were identified at this stage, with many operating as metaphors of geological slippage and surface instability, as well as metaphors of collapse. Technological understanding also opened the possibility for innovative design ideas whereby technical requirements described design intention rather than being cast in the supportive role of satisfying engineering requirements. Students were encouraged and challenged in a total of six group and individual sessions though the four week period. Approximately thirty design ideas were identified, some of which are listed in Table 1.

Table 1. Potential design ideas listed under various headings.

Geology and seismology	Construction issues	General concepts or ideas not specifically related to earthquakes	Other earthquake-related ideas
Seismic waves	Propping	Healing processes like scabs that form after an injury	Temporary buildings for disaster relief
Faulting	Tying elements together	External forces acting on a building	Seismograph
Earthquake affected landforms	Post-earthquake ruins	Adaptability	Expression of structural actions
Contrast between geological and seismograph time-scales	Disassembly	Insecurity	Brittle behaviour
	Seismic resisting technology and componentry	Preparedness	Plastic behaviour
	Contrast between gravity and seismic load-resisting structure	Engineer and architect relationship	

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

Project Two required students to test these emerging ideas against a small institutional building—a suburban library. The project brief stated that the New Zealand Earthquake Commission (EQC) was partially funding the construction of the new library in the expectation that expressed seismic ideas would remind the community of seismic risk and therefore motivate it to take appropriate mitigation measures. The brief suggested that a clearly expressed earthquake architecture would enable the almost dichotomous relationship between a need for safety and the expression of the threat to that need to be reconsidered. The authors are aware that this is a contentious issue, particularly where architecture intersects with trauma, as it is not intended to 'glamorize' the tragedy of an earthquake.

After five tutorials over three weeks the students presented their schemes of which two are shown below. The design idea shown in Figure 1 utilizes metaphors of geological slippage and surface instability within the thinness of the earth's crust relative to the diameter of the earth. The literal rendering of this idea of crustal fracturing into tectonic plates sees the roof broken into varying shaped polygonal plates. The tilted and displaced roof planes provide opportunities for introducing natural light. The second design (Figure 2) addresses the visual and technical separation of gravity and seismic structures; a process occasionally undertaken with new building, but more often evidenced in retrofitting. For this project a glue-laminated timber grid-roof is supported on slender gravity-only steel columns. Spindle-shaped diagonal members brace the whole structure.

As with a number of projects students undertake in the school, RESIST, a preliminary structural design computer program for architectural students was used to size the seismic resisting structure (Charleson [5]).

While all student work was naturally limited by time and experience, much of the design work was of a high standard. However, it should be noted that the project was not concerned with the detail design of the library, but focused on architectural form and a general disposition of structure and spaces relative to the brief for earthquake architecture. Given more time, much of this work could have achieved more convincing and compelling architecture. Despite the intense teaching sessions, some students were less successful at communicating and contributing consistently throughout the process.

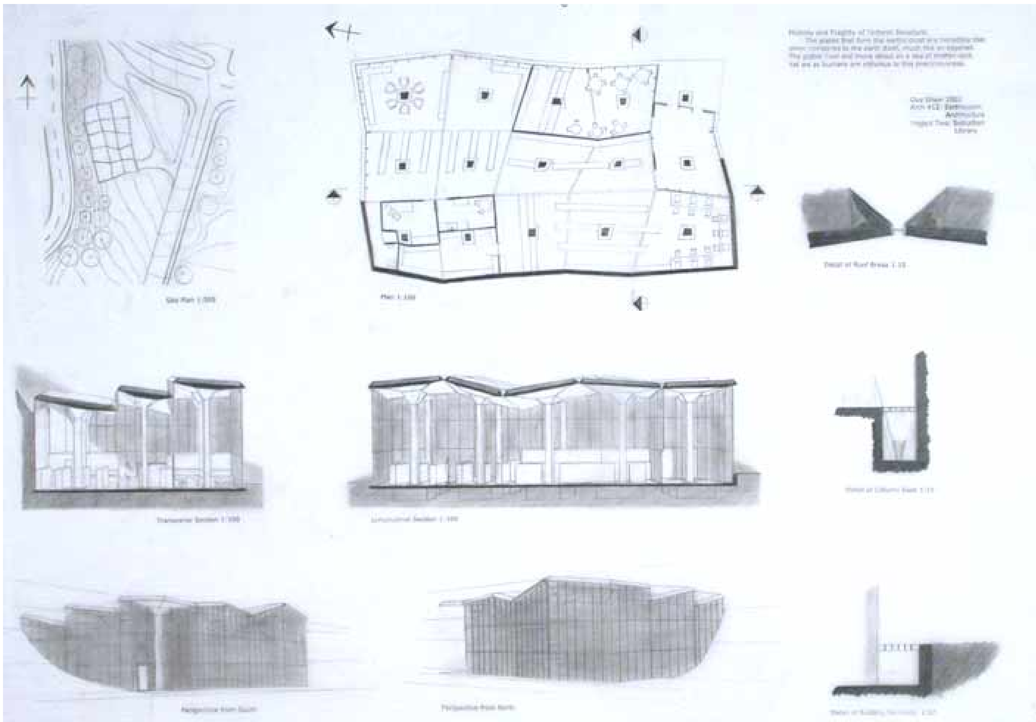

Figure 1. Design concept expresses the thinness of the earth's crust and its fracturing (G. Shaw)

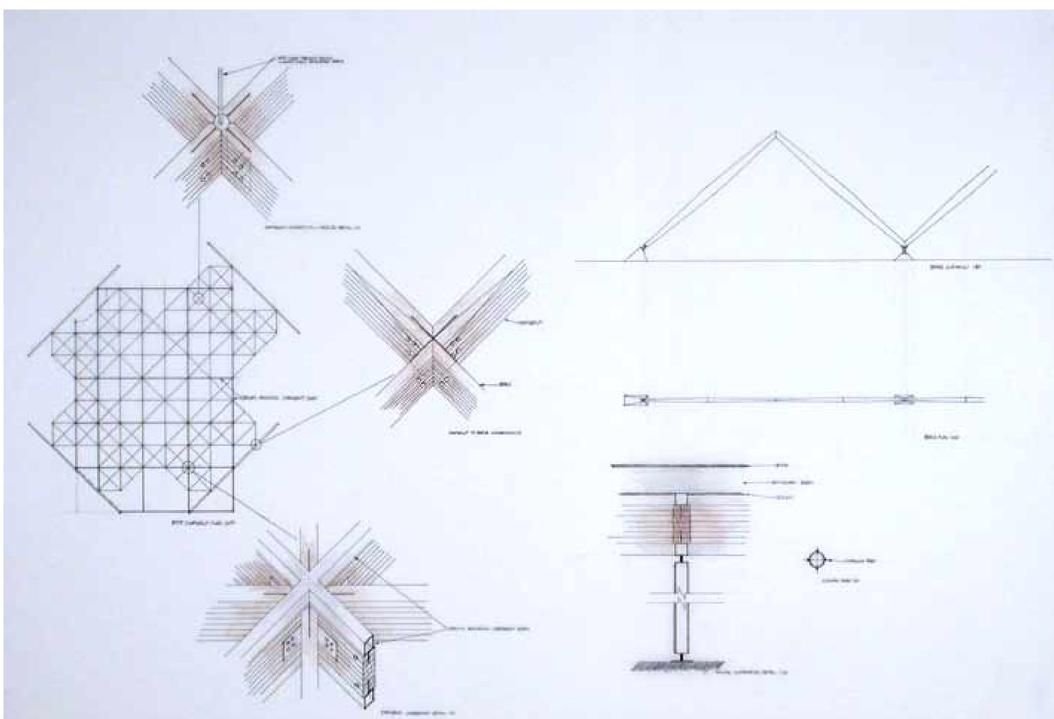

Figure 2. Library roof plan and details showing separation of gravity from lateral load resisting systems (K. Leong)

For the third project the students had to design a more complex building. Once again they had to adopt another of their ideas from the first project and trace its potential for architecture. The brief required a medium-rise building on an urban corner site to accommodate purpose-designed offices for Earthquake Engineering New Zealand (EENZ). It was assumed that due to unprecedented success in winning international earthquake engineering contracts, EENZ was in a position to build a Cluster flagship. Being acquainted with New Zealand's impressive earthquake engineering expertise, many existing and potential international clients will visit it. The Client therefore wanted not only to showcase the very best earthquake engineering and architectural design practice, but also to express the building's purpose of accommodating professionals who work on the cutting edge of earthquake disaster mitigation. The project called for a seven storey building with roof level plant-room, a number of individual office suites and social/exhibition spaces.

Overall, the class found this project more challenging due to the urban design issues involved. Although the better projects showed promise, several students were not forceful enough in representing their ideas as regulators of seismic activity, but instead offered more literal expressions of technical expertise and achievement. The students explored the following architectural ideas related to geological and technical metaphors:

- 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, and
- Tying a building together.

Two schemes shown in Figures 3 and 4 explore plastic deformation and building earthquake damage respectively.

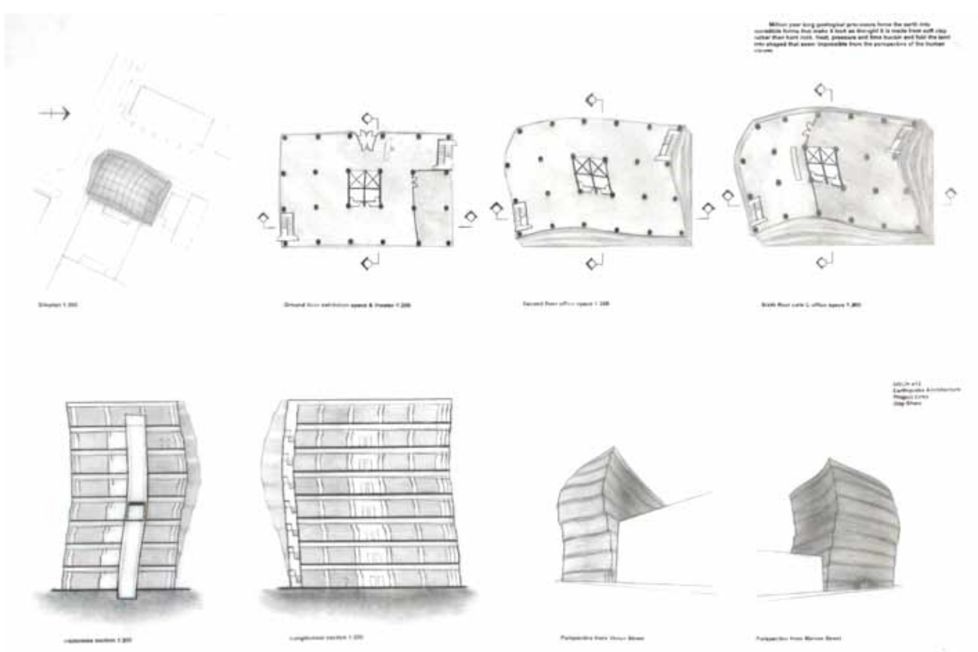

Figure 3. The concept of plastic deformation informs cross-sections and building perspectives (G. Shaw)

Figure 4. Exterior of a building that expresses earthquake damage to the building form (L. Allen)

Given this design studio was the first in the school to investigate earthquake architecture it was considered reasonably successful. Most importantly, it 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 the built environment.

CONCLUDING COMMENTS

In this design studio we anticipated students would have a good understanding of seismic design principles enabling an engagement with the concept of earthquake architecture. We were aware that being new to the idea, emphasis would be placed on the process and quality of thinking, rather than a fully resolved formal outcome. However it became clear that some students had difficulty with the conceptual leap from engineering to architecture, or indeed blurring their architectural intentions with engineering. This is perhaps partly due to architectural educational paradigms and curriculum stratifications that place engineering separate and supportive of design teaching. As a deliberate challenge to this pedagogy the studio forced continuous design exchange between the two disciplines.

Many projects utilized metaphors associated with earthquake effects, processes and tectonics. Some tended towards a literal interpretation, whereas others abstracted the idea to provide more complex readings. From our perspective more critical discussion of design ideas and digital/physical models would have alleviated some ‘fuzzy’ thinking that tended to hamper development. Overall students were supportive of the studio, both formally and informally, commenting that the opportunity to engage with two complementary disciplines was invaluable.

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