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CTV Building

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Overview

- Forensic Engineering practice;
- The evolution of Seismic Design Standards;
- Cumulative Earthquake Damage;
- Seismic excitation of the Building site;
- Dynamic Analyses including Non Linear Time History analyses.

Forensic Engineering Practice

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- Best practice structural failure investigations
 - National Academy of Professional Engineers
 - Technical Council of Forensic Engineers

- A structural failure investigation should attempt to answer:
 - (1) **HOW** the building failed; and
 - (2) **WHY** the building failed.
- “Failure” means state or condition not meeting desirable or intended objectives.

- **HOW** did the CTV Building fail?

- **WHY** did the CTV Building fail?

Review of collapse investigation reports

- DBH efforts (through Hyland/Smith) cannot be considered conclusive.
- By failure to abide by the generally accepted open-minded approach to a Failure Analysis investigation, too many avenues of possible enquiry were neglected.

Evolution of Seismic Design Standards

- Early seismic resistance codes;
- Development of strong ground motion measuring instruments;
- 1940 El Centro earthquake;
- Introduction of “risk” considerations;

Evolution of Seismic Design Standards

- Stepwise developments in code requirements has meant the production of a stock of buildings with variable seismic resistance capabilities.
- In general the newer structures respond more closely to their intended behaviour than do older ones.
- The current trend is to focus in the future on the performance aspects of a proposed structure and to provide a reasonable assurance that serious injury and loss of life will be avoided, that critical facilities will continue to function and that, wherever practicable, repair costs will be minimized.

Cumulative Earthquake Damage

- Reports from reconnaissance teams dispatched by California based Earthquake Engineering Research Institute to damaging earthquakes around the world.
- When members are subjected to successive excursions each causing plastic deformations, but with insufficient deterioration to cause structural collapse, the structure as a whole is clearly weakened.
- Progressive weakening may lead to greater damage in multiple events as the more flexible structure better matches the input excitation

- The CTV Building may have been damaged more seriously in the September 2010 earthquake than was appreciated immediately following the event.
- More serious damage could have been consistent with the Compusoft NTHA analyses. For example, see the draft Hyland/Smith report dated 7 December 2011:
“First impressions are that the maximum strains suggest a level of damage somewhat higher than the minor 0.3mm wide cracks that were reportedafter the 4 September Darfield Earthquake”.
- The authors elected to assume that these column cracks had not deteriorated the columns to the extent that they were less able to resist failure in the February 2012 event.

- Hyland/Smith draft report, Appendix D, Conclusion # 4:
 - *“it has been difficult to reconcile the damage predicted by the analysis with reports of damage by others after the Darfield earthquake. The analysis generally indicated a higher level of damage than was reported”*
- Hyland/Smith final report, Appendix D, Conclusion #6:
 - *“overall the output of the NTHA analyses was not inconsistent with the reported condition of the building after 4 September 2010. The limited available evidence of the building condition after 4 September 2010 leaves room for a range of interpretations of the likely maximum displacements in the 4 September 2010 event. However the conclusions drawn from the analyses are not particularly sensitive to the level of demand assumed by the NTHA, with indications that collapse could have occurred at lower levels of demand.”*
- The modification of wording between the draft and the final reports could be interpreted as recognition of the problem of forming consistent conclusions based on the generally imprecise nature of quantitative results of NTHA analyses.

Seismic excitation at the CTV Building Site

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- On the basis of study of past strong motion earthquake records, a "rule of thumb" evolved in which the expected peak vertical acceleration would be of the order of one-half to two-thirds of the peak expected horizontal acceleration.
- Actual records from the 22 February 2011 event showed that at several sites in the CBD the maximum vertical peak ground accelerations were of the order of 1.0 g.
- In the absence of any records from the CTV Building site, the actual vertical excitation experienced by the CTV structure can only be a matter of conjecture. However, it is clear that it was great enough to apply loads significantly in excess of those typically anticipated in code compliance seismic design.
- The Hyland/Smith report does not specifically address the possible effect of the exceptional vertical accelerations on the CTV columns.

Dynamic Analyses

- The limitations on the size of the model used for the computer analyses in the Hyland/Smith report prevented a comprehensive "global" investigation that would have involved all components of the CTV structure being simulated to the maximum degree of sophistication.
- This restriction required a judgmental choice to be made of the most probable vulnerable components, which were then modelled in detail, whilst much of the rest of the structure was not subjected to such refinement.
- The result is that the computer analyses appear to have been made to prove a certain hypothesis rather than to investigate all collapse possibilities without prejudice.

- There are numerous disclaimers and/or qualifiers throughout the Hyland/Smith report, for example:
 - *“Variability and uncertainty in physical properties and analysis procedures do not allow a particular (collapse) scenario to be determined with confidence.”*
 - *“It has been difficult to identify a specific collapse scenario with confidence.”*
 - *“Estimating the effect on the structure of the very significant ground accelerations is subjected to considerable uncertainty.”*

- Despite the authors' clearly expressed reservations, they chose to focus on a particular scenario at the exclusion of in-depth investigations of alternatives.
- In doing so they called into question the value of their conclusions.

General Comment - redundancy

- The term “redundancy” as used in structural engineering is possibly open to misunderstanding. Its general definition of “the state of being no longer needed or useful” could mislead if applied to buildings. Aeronautical engineers have typically preferred “fail safe design” rather than structural “redundancy”.
- Encouragement should be given to the use of the wording used in the Final Report, Department of Building and Housing “Technical Investigation into the Structural Performance of Buildings in Christchurch” which defines alternative load paths or “back up” mechanisms as the preferred manner of preventing disproportionate collapse in the case of failure of a single load bearing element.

General comment – expert panels

- NTHA and ERSA panels have been convened and the results of further analyses are awaited with interest.
- Further comment may follow completion of these processes.