



UNDER

THE COMMISSIONS OF INQUIRY ACT 1908

IN THE MATTER OF

**ROYAL COMMISSION OF INQUIRY INTO BUILDING
FAILURE CAUSED BY CANTERBURY EARTHQUAKES**

**KOMIHANA A TE KARAUNA HEI TIROTIRO I NGĀ
WHARE I HORO I NGĀ RŪWHENUA O WAITAHA**

**SECOND STATEMENT OF EVIDENCE OF ARTHUR JOSEPH O'LEARY IN RELATION
TO THE CTV BUILDING (AMENDED)**

HEARING BEGINNING: 25 JUNE 2012

Legal Services Unit, 53 Hereford Street, Christchurch 8013
P O Box 73013, Christchurch 8154
Telephone (03) 941 8999

INTRODUCTION

1. My full name is Arthur Joseph O'Leary. I am a retired structural engineer. I have had extensive design and design management experience of commercial buildings with emphasis on earthquake engineering during my professional career. That career has spanned some 40 years.
2. This is my Second Statement of Evidence. My relevant qualifications and experience were provided in my First Statement of Evidence (WIT.OLEARY.0001).
3. This evidence comments on the evidence of Dr Nigel Priestley, Ashley Smith and Murray Jacobs as provided to the Royal Commission.
4. I have read the Code of Conduct for Expert Witnesses and agree to comply with it. I confirm that all of the matters to be addressed in my evidence are within my areas of expertise.

Evidence of Dr Nigel Priestley

5. I have read the evidence of Michael John Nigel Priestly (WIT.PRIESTLEY.0001). I generally agree with his evidence, but I have some specific areas of disagreement and I comment further below.

Paragraph 15(a)

6. There is reference at paragraph 15(a) of Dr Priestley's evidence to the fact that he has little or no disagreement with the CTV report and Expert Panel report in relation to deficiencies in the design of the CTV Building, when considered against the code and *best practice at the time*.
7. For any consideration of non-compliance in relation to the CTV building, the bylaws and related standards are the governing criteria rather than some overriding consideration relating to best practice. There are in any event considerable difficulties in my view in determining what is best practice within the profession at any particular time. If it is relevant to consider such an issue, then in my view the enquiry should be as to the acceptable professional practice at the time.

Paragraph 15(b)

8. The critical vulnerabilities referred to in paragraph 15(b)(i) and (iii) of Dr Priestley's evidence are accepted. These two critical vulnerabilities are now seen as such, but at the time the interior columns may well have complied with the relevant standards, although it is unlikely that the columns on grid 'F' complied.
9. The question of "irregularities/lack of symmetry" (paragraph 15(b)(ii)) needs, in my opinion, to be put into the context of the understandings of the time and the understandable desire to have attractive and functional buildings. In my experience, structural engineers prefer regular buildings with minimal eccentricity between the centre of mass and centre of rigidity, but this is impractical for many buildings where layout functionality and associated considerations are major drivers behind the reasons for development.
10. As indicated in terms of paragraph 15(iii) and in my first statement of evidence, I have reviewed the diaphragm connection to the northern shear core and have concluded that the remedial work as designed would comply with NZS 4203 requirements in the North South direction but not in the East West direction.

Paragraph 16

11. I accept all the areas of disagreement Dr Priestley lists in paragraph 16 of his evidence, except I do not have an opinion on his item (h).

Paragraph 18-26, 43,-44, 63-71 and 75

12. I have a general level of agreement with much of Dr Priestley's evidence, but I take the opportunity below to note some issues that reinforce my own views:
 - (a) Paragraphs 18 to 26 of Dr Priestley's evidence relating to the ERSA analysis.
 - (b) Paragraph 43 and paragraph 44. From my review of the drawings of the spandrel panels, I have formed the view that they were too flexible

to provide much resistance to the interstorey drift along grid lines 1 and f.

- (c) Paragraphs 63 to 71 on torsional eccentricity and the infill masonry on line a.
- (d) Paragraph 75 on displacement capacity ERSA analysis.

Paragraph 77 and 78

- 13.** I do not agree with Dr Priestley's paragraph 77 and 78 to the extent that he measures details used in the building against "best practice to current state of knowledge". I have already commented on the difficulty in determining "best practice" in the profession. The design of the CTV building was only required to comply with the Council Bylaws. Further, a Council design reviewer was only required to review the design for compliance with such Bylaws and imposing a higher standard would not, in any event, be enforceable by the Council. I now comment on paragraphs (a) to (g) of paragraph 77 as follows.

Paragraph (a)

- 14.** NZS 3101: 1982 covered ductile detailing for columns and the standard was widely held as being appropriate in 1986. In the next version of NZS 3101 (NZ 3101: 1995) less rigorous requirements were introduced.

Paragraph (b)

- 15.** As above, the spacing of transverse reinforcement was covered by NZS 3101:1982 but made less rigorous in the subsequent version of the standard. This serves to illustrate the advancement of the 'normal practice of the profession' as standards were modernised.

Paragraph (c)

- 16.** This standard of cover to reinforcement of columns (as provided in the CTV building) is still allowed and it is still the normal practice of the profession.

Paragraph (d)

17. I do not consider that there were high levels of axial compression in the columns. The columns complied in that respect with the standards and in my view reflected normal practice within the profession at the time.

Paragraph (e)

18. This paragraph relates to a stated lack of transverse reinforcement. Again this is a matter relating to interpretation of NZS 3101. Up until a few years before 1986, this was not an issue that the profession had identified as being of concern. I was on an international committee in the early 1980's that was looking into the problem and as far as I can remember there was no basis for the design of beam column joints for shear even as late as the late 70's or early 80's. New Zealand researchers were right in the forefront of research into the problem of beam column joints in the late 70's and early 80's, and there were several PhD's undertaken at both Auckland and Canterbury Engineering Schools addressing the subject about that time.

Paragraph (f)

19. I accept that poor connectivity was a problem, but the CTV building would not have been far out of step with common practice in New Zealand at that time.

Paragraph (g)

20. I agree that lack of connection between floor diagrams and the North core was non-compliant, but the remedial work as designed would have brought it into compliance with NZS 4203 requirements in the North South direction but not in the East West direction. There has been work undertaken, and incorporated in the current seismic loading standard, NZS1170.5, that has shown that the standards current in 1986 (NZS4203, and NZS3101) were non-conservative in their approach to this issue.

Paragraph 78

21. Dr Priestley in his paragraph refers to a 1975 book authored by Park and Paulay. This text book was the basis for much of the contents of NZS

3101:1982. That standard had a predecessor (**NZS 3101P**) which was in common use from the early 1970's onwards. It was to the best of my knowledge a draft that was upgraded often, as new research became available. There may have been warnings about some issues in the Park and Paulay text book, but I believe that they would have been in the 1982 standard if they were thought important enough, especially given that Park and Paulay wrote extensive parts of the 1982 standard. There were even some issues where the requirements were relaxed in the 1995 version of 3101, including some aspects of column confinement.

Third Statement of Evidence of Ashley Henry Smith

22. I have read the third statement of evidence of Ashley Henry Smith (**WIT.SMITH.0003**). In paragraph 6 of Mr Smith's evidence, he notes differences between himself and his co-author of the Hyland Smith report, in the interpretation of NZS 4203 and NZS 3101. He further comments in the following paragraph 7 that members of the Expert Panel had differing interpretation of the standards in relation to column design.
23. As I have discussed earlier in my first statement of evidence, clause 3.2.1 of NZS 4203, which Mr Smith refers to in paragraph 11 of his evidence, is a general statement expanded upon in subsequent clauses. NZS4203 refers to the material standards for details. Clause 3.2.1 does not in my view stand in its own right. The concrete material standard NZS 3101 is more specific and in the sequence of standard clauses between NZS 3101 and NZS 4203, NZS 3101, must in my view take priority as it is more specific and quantitative.
24. Much of Mr Smith's reasoning is based on load reversal into the inelastic range. This does not, in my view, take into account clause 3.5.14 of NZS 3102:1982 which sets the limits around whether inelastic or elastic performance applies. If the member (in this case, columns) remains elastic at defined interstorey drift, then none of the post elastic (inelastic) criteria apply.
25. Mr Smith does not in his evidence address in any detail the implications of clause 3.5.14. He makes passing reference to this in paragraphs 35 and 36 of his evidence, but without discussion of the intent of the clause and its implications. In my view, his conclusion in the last sentence of paragraph 36 is

not supportable because it is not based on the clear intent of clause 3.5.14.3 of NZS 3101.

26. Mr Smith at paragraphs 48 and 49 of his evidence briefly refers to beam-column joints. There is a limited discussion of the beam column joint detailing contained in the Hyland Smith report. Mr Smith's reference to clause 6.4.7 of NZS 3101, and as to what it means, is incomplete, as it does not include a discussion of compliance with clause 6.4.7(b), although he uses the more general reference of clause 6.4.7 to justify his opinion on confinement after quoting clause 9.8.4 of NZS 3101:1982. The columns complied with clause 6.4.7(b) of NZS 3101 if they were not required to be designed for earthquake loading.

Evidence of Murray Lionel Jacobs

27. I have also read the evidence of Murray Lionel Jacobs (WIT.JACOBS.001.1). I comment on his evidence as follows.

Paragraphs 11 and 12

28. Dr Jacobs concludes at paragraph 12 of his evidence that the building did not comply with clause 3.1.1 of NZS 4203 relating to symmetry. In considering this issue, it is useful to refer to the commentary section. C3.1.1, which is about mathematical methods, is particularly relevant. It says "... notwithstanding the availability of modern computers, considerable uncertainty exists in selecting a mathematical model representing the true behaviour of complex arrangements such as combinations of geometrically dissimilar shear walls ...".
29. Clause 3.1.1 is the introductory clause to Part 3 'Earthquake Provisions' of NZS 4203, and in my view does not raise a specific standard compliance issue. This needs to be considered under clause 3.4.7.1. I have concluded in my first statement of evidence at paragraphs 32 and 33 that clause 3.4.7.1(b) was relevant to the CTV building.

Paragraph 14

30. Dr Jacobs refers to clause 3.4.7 of NZS 4203. In my view and as noted above the relevant clause for compliance purposes is clause 3.4.7.1(b) of NZS 4203.

I disagree that clause 3.4.7.1(c) is the applicable clause for the reasons given in my first statement of evidence.

Paragraphs 15 and 16

31. Dr Jacobs refers to clause 3.2.1 of NZS 4203 and reaches the conclusion that the columns in the CTV building do not comply with that provision. I have considered this issue at paragraphs 48 to 55 of my first statement of evidence.

Paragraph 18

32. I refer to my comments relating to paragraph 16 of ~~Mr~~Dr Jacobs' evidence above. In my view, if the columns did not require to be designed as ductile, then the spiral complied except possibly through the beam column joint.

Paragraphs 18 and 19

33. In my view, the anchorage of spirals is covered by 3101 clause 5.3.29.3 of NZS 3101. I refer also to clause 5.4.1.2 of NZS 3101 (non-seismic design) where anchorage for non seismic design is set out. I have examined drawing S14 and do not consider that there is significant congestion in the joint as the spiral for the joint and column above would start immediately above the bottom layer of reinforcing in the beam.

Paragraph 20

34. Dr Jacobs refers to clause 1.1 of the standard NZS 3101 Part I at page 15. I have addressed the minimum level of design expected earlier in this statement of evidence at paragraphs 7 and 13.

Paragraph 31

35. I have considered Dr Jacobs' comments at his paragraph 31 relating to the reduced wall section of the north shear wall. I agree that this particular shear wall has a notch at level 1 so that it could possibly be classed as a slender wall, ~~but given that it is only one of a group of four walls in the N-S direction it would be inappropriate in my view to class the group as slender on the basis that only one of them could have that characteristic.~~ The question of whether a wall is

stiff involves considering whether it is stiff or slender in relation to the frames in the same direction. There were only two frames spanning north/south which are quite flexible because of the long beam spans and flexible columns. On this basis I consider the walls spanning north/south should still be classified as stiff because they are relatively stiff compared to the frames on Grid A and Grid E.

Paragraph 36

36. Dr Jacobs concludes at his paragraph 36 that the critically important columns were not secondary elements. I disagree because the columns meet the definition of a secondary element in clause 3.5.14.1 of NZS 3101. I refer to paragraphs 38 to 43 of my first statement of evidence.

Paragraphs 39 and 40

37. The requirement in clause 5.3.32 is for shrinkage and temperature effects and not for diaphragm action. It is inappropriate to apply clause 5.3.32 to diaphragm action. There is a system of flooring 75mm thick that, according to clause 5.3.32, requires approximately half the reinforcing area that 664 mesh provides. Therefore that flooring system would have complied with clause 5.3.32 based on Dr Jacobs' reasoning. Yet as a diaphragm, it would have been required to transfer the same diaphragm forces as the floor installed in the CTV building. In addition, I note that it complied with the manufacturer's recommendations as indicated in paragraph 41 of Dr Jacobs' evidence

Paragraph 47

38. At paragraph 47 of his evidence, Dr Jacobs refers to clause 7.3.4.3 of NZS 3101 when discussing the minimum shear reinforcing in the column. He does not refer to clause 7.3.4.1 which has an exception to the requirements of clause 7.3.4.3 members, for where the shear stress is less than half of the shear that can be resisted by the concrete alone. The exemption in clause 7.3.4.1 is in my view satisfied for the interior columns. I refer to my paragraphs 56 to 58 in my first statement of evidence.

Paragraph 50

39. I agree with Dr Jacobs at paragraph 50 that the beam-column joints are unlikely to comply. However, if the columns could have been designed as non ductile, then 9.5.1 of NZS 3101 would not apply.


Paragraph 53

40. I refer to Dr Jacobs's paragraph 53 where he summarises where the CTV building design did not comply with the loading and concrete standards that applied at the time. I discuss each issue in turn as a summary of my evidence in terms of design compliance issues:
- (a) The issue of symmetry of the building layout is not in my view a question of compliance. There is no absolute requirement for symmetry. The building would in my view have been classed as a reasonably regular structure of moderate eccentricity. To this end, it was required to comply with clause 3.4.7.1(b) of NZS4203 which allowed two dimensional modal analysis of the structure. I refer to my first statement of evidence at paragraphs 70 to 72.
 - (b) I believe that subject to assumptions and qualifications stated in my third statement of evidence the internal columns were not generally required to be designed for seismic loading (ductility). The columns on grid line 'f' however were required to be designed for seismic loading. I refer to my first statement of evidence at paragraphs ~~70 to 72~~ 48 to 55.
 - (c) I do not comment elsewhere on this topic but it does not in my view cause a compliance issue.
 - (d) The size and longitudinal reinforcing in the columns did comply with NZS3101. The discussion relating to the columns being too small and too heavily loaded is not supported by the standard.
 - (e) Some of the columns did comply with the minimum shear reinforcing of the standard, but unfortunately not all of them. My calculations lead me to believe that the interior columns did comply but those on grid 'f' did not comply. I refer to my first statement of evidence at paragraph 58.

- (f) I agreed that the diaphragm (slab) connection to the north shear walls did not comply with NZS4203 when the building was constructed, but as indicated in paragraph 10 above, the design for the remedial work would bring it into compliance with NZS 4203 in the North South direction, but not in the East West direction.

Dated: 8 August 2012

Signed by:


Name: Arthur Joseph O'Leary