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 NGA WHARE I HORO I NGA RUWHENUA O WAITAHA**
AND IN THE MATTER OF	**THE CTV BUILDING COLLAPSE**

CLOSING SUBMISSIONS OF COUNSEL ASSISTING IN RESPECT OF THE HEARING INTO THE COLLAPSE OF THE CTV BUILDING

DATE OF HEARING: COMMENCING 5 SEPTEMBER 2012

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CLOSING SUBMISSIONS OF COUNSEL ASSISTING IN RESPECT OF THE HEARING INTO THE COLLAPSE OF THE CTV BUILDING

Introduction

1. In opening submissions delivered on 25 June 2012 the tragic consequences of the CTV Building collapse on 22 February 2011 were outlined and the evidence the Royal Commission could expect to hear was foreshadowed. This included the evidence of survivors and eye witnesses to that collapse. In the course of this hearing the Royal Commission has heard and witnessed first hand the searing memories that are still carried by many people.

2. Evidence given by the occupants who survived was able to provide an account of damage observed after the September earthquake and the Boxing Day aftershock. This information has contributed to an understanding of the various collapse scenarios and to the post-earthquake assessments of the Building.

3. One of the purposes of this hearing into the CTV Building collapse has been to enable the families and individuals directly affected by this tragic event to at least understand what led up to this collapse, as well as what happened on the day. Beyond this the principal purpose is to enable the Royal Commission to reach conclusions about the causes and make recommendations that will reduce the likelihood of such an event in the future.

4. What has become apparent in the course of this hearing is that much more is involved in the collapse of the CTV Building than the single event that occurred on 22 February 2011.

5. The opening submission of Counsel Assisting identified a number of questions that would need to be addressed in the course of the hearing and to the extent possible answered. They were:

    a. What was the origin of the CTV Building design and, in particular, the decision to locate the North Shear Core outside the walls of the Building?

    b. How did the structural design work come into Dr Alan Reay's firm and who within that firm had the principal structural design role?

c. If, as appeared likely, the principal structural designer was Mr David Harding, did he have the necessary experience and competence to carry out this work? If he did not, did his lack of experience and competence contribute to the collapse of the CTV Building?

d. If Mr Harding had neither the required level of experience or competence to be the principal structural designer for the Building without supervision, was he given an appropriate level of supervision by Dr Reay's firm and, if he was not, did Dr Reay act responsibly in giving the principal design role to Mr Harding?

e. If, as seemed likely, Mr Harding relied for a design template on the Landsborough House calculations and the ETABS input/output data that had been done by Mr John Henry when he was employed by Dr Reay's firm, who made the decision that this was an appropriate template for Mr Harding's work?

f. In relying on the calculations and input/output data for Landsborough House, did Mr Harding fall into error, through, either a lack of experience or competence, or both, in interpreting this material and, in particular, did he fail to accurately calculate the critically important inter-storey deflections that the CTV Building could be expected to undergo under lateral earthquake loads?

g. If Mr Harding did fail to accurately assess the inter-storey deflections, what consequences did this have for the design and might this have contributed to the Building's collapse?

h. Did the Christchurch City Council (**CCC**) issue a building consent for the CTV Building when it should not have done so because the Building did not comply with Bylaw 105 and the applicable New Zealand Standards (**the Code**)?

i. If the CTV Building was non-compliant when the building consent was issued, should these areas of non-compliance have been identified by the CCC reviewing engineer?

j. If the CCC did issue a building consent for a non-compliant building was this because Mr Bryan Bluck, the then head of the CCC Building Department, overruled the concerns recorded by his deputy, Mr Graeme Tapper in a letter dated 27 August 1986 to Dr Reay's firm, including a concern about the connections of the floor diaphragm and column stirrups?

k. If Mr Bluck did overrule Mr Tapper's concerns, was this because Dr Reay intervened directly with Mr Bluck and persuaded him that a building consent should be issued?

l. Were there any construction defects in the work carried out by Williams Construction Limited, and subsequently Union Construction Limited, that might have played a role in the collapse?

m. Were the inspections carried out during construction, by both Mr Harding as design engineer and the CCC as the responsible local authority, carried out to the expected standard?

n. When drag bars were installed in 1991 to address a critical structural weakness in the CTV Building that had been identified by Holmes Consulting Group (**HCG**) in January 1990, in respect of the connections between the floor diaphragms and the North Shear Core, was this retrofit work properly designed and installed; in particular, was the decision not to install drag bars on Levels 1 and 2 an appropriate one?

o. Did the decision made by Dr Alan Reay's firm not to install drag bars on Levels 1 and 2 contribute to the 22 February 2011 collapse?

p. Was a building permit required for the installation of the drag bars? If it was, why was none obtained?

q. Did the CCC properly exercise its statutory powers when deciding there had been no change of use of the Building when *Going Places* became a tenant in 2001? Did the CCC decision not to require any upgrade of the Building at that time play any part in the Building collapse?

r. Did the post earthquake assessments carried out by the CCC and by Mr Coatsworth under instructions from the Building owner (acting through Mr John Drew) meet the expected standards for these assessments?

s. What effect did the September and Boxing Day earthquakes have on the Building and did this contribute to the February collapse?

t. What contribution, if any, might under-strength concrete in the columns have made to the collapse?

u. Was the real cause of the collapse the high vertical forces to which the CTV Building was subjected on 22 February and would the collapse have occurred irrespective of any non-compliance with Bylaw 105 and the Code and irrespective of any inadequacies in design and detailing?

6. In the course of the hearing a further and even more critical question emerged: did Mr Harding have the knowledge and skill required to detail the pre-cast and in-situ structural components so that the Building as a whole was capable of transferring the gravity loads and seismic forces into the foundation? An aspect of this issue was touched on by Dr Reay in the course of his evidence. In answering a question put to him in cross examination about the deficiencies in the Building he said:

> The particular issues that I've mentioned, the first one is the potential issue of the connection of the floor diaphragms to the walls where there appears to have been an omission which was rectified in 1991. That is simply not following through load paths which is a fundamental part of structural engineering …[1]

7. In determining the Code compliance issues there is an overarching question. This is whether the Building was entitled to be designed as a largely non-ductile structure or whether it had to comply with the ductile requirements of the Code. While by the end of this hearing it was not disputed by any of the relevant experts that there were elements of the CTV Building that did not comply with Bylaw 105 and the Code at the date on which the building consent issued, the experts remained divided on the extent of the non-compliance. This, in turn, largely depended on the view taken on whether the CTV Building was entitled to be designed as a largely non-ductile structure.

8. It has become clear during the course of this hearing that the Codes in place at the time (NZS 3101:1982 and NZS 4203:1984) are not easy to follow and different interpretations of the ductility provisions were held by highly competent structural engineers. It is of itself a matter of serious concern that on such a significant structural design issue the Code did not speak clearly.

9. During the course of the hearing other suggested causes of the collapse have been put forward by witnesses called on behalf of Dr Reay and his firm. In particular:

a. Both Dr Reay and Professor Mander suggested a number of other collapse possibilities:

[1] TRANS.20120801.20, L28-33

Dr Reay:

i. Reinforcing strain hardening
ii. Vertical Acceleration
iii. The lateral load resistance of the south wall
iv. Building modifications, namely:
    - Drilling of holes into concrete beams during the 1990s (evidence of Daniel Morris)
    - Installation of internal staircase between CTV levels 1 and 2 in 2000
v. Understrength concrete
vi. Cumulative damage resulting from aftershocks

Professor Mander:

i. Column collapse in the lower storey from "Euler buckling" due to the overload effects arising from extremely high vertical ground motions and promoted from a deteriorated beam column joint.

b. In addition, in the course of cross examination by counsel for Dr Reay and Alan Reay Consultants Ltd (**ARCL**) it was suggested that:

i. Responsibility for any non-compliance with Bylaw 105 and the Code lay with the CCC because it should not have issued a building consent for a non-compliant building and Dr Reay and ARCL were entitled to assume the Building was Code compliant if a consent had been issued;

ii. The CCC also carried some responsibility for the collapse because it failed to properly exercise its powers when there is a change of use and did not give sufficient consideration to the additional live load being introduced into the Building by *Going Places* taking up occupancy in 2001;

iii. Holmes Consulting Group (**HCG**) deflected Dr Reay's firm from carrying out a more rigorous structural review of the CTV Building after HCG identified a critical structural weakness in January 1990, by stating in its report that the Building "generally complies with current design loading and materials codes".[2]

[2] BUI.MAD249.0130.5

10. In the course of a hearing that has run for nearly eight weeks and during which the Royal Commission has heard from more than 80 witnesses, it is submitted that the evidence the Commission has heard now enables a clear understanding of what has happened, from the initial design and construction of the CTV Building through to its tragic collapse. It is submitted that the evidence the Royal Commission has heard enables it to reach a conclusion on both the critical failings that have caused or contributed to the collapse and the responsibility for these failings. The evidence also allows important conclusions to be reached about lessons for the future.

11. The evidence has revealed failings and weaknesses at a number of levels. This includes the CCC regulatory processes in place at the time and the inadequacies of the post earthquake assessment processes carried out by the CCC. However, the principal and critical failings occurred during the structural design work carried out by Dr Alan Reay's firm. For this both Mr David Harding and Dr Alan Reay must carry the responsibility. The decisions they made about the structural design of the building are the primary cause of the CTV Building collapse. In critical respects the Building they designed was not Code compliant and was dangerously vulnerable to any earthquake that took the Building any distance beyond its elastic response state and into an inelastic range. There was no margin of safety provided for in the event that this occurred.

12. In the course of his evidence Dr Reay finally publicly acknowledged that his firm was responsible for any failings in the work carried out by Mr Harding. However, this is to acknowledge no more than the legal position that an employer is liable for the actions of its employee acting within the scope of employment. It is the submission of Counsel Assisting that the responsibility of Dr Reay is more fundamental than this. It was Dr Reay's decision to give Mr David Harding the virtually sole responsibility for carrying out the structural design for the CTV Building, in circumstances where he was on any objective view not competent to do this. Dr Reay then made a deliberate decision to provide no active supervision or mentoring for Mr Harding in the work he was doing and, in his own words, to leave it to Mr Harding to tell Dr Reay if and when he required assistance.

13. It is submitted that Mr Harding did not comply with the IPENZ Code of Ethics in acting outside his area of competence. One of the lessons to be learned from events that have occurred here is that both the IPENZ rule that applied in 1986, and the one that applies currently, which leave it to the engineer to determine when they might be working outside their level of competence, provide an inadequate restraint on when it is

appropriate for an inexperienced structural engineer to embark upon work never previously undertaken.

14. It is submitted that what has emerged from this hearing is that Mr Harding was not competent to take the principal responsibility for the design of the CTV Building and Dr Reay ought to have recognised this. There was then a serious failure by Dr Reay to provide the supervision Mr Harding required to carry out this work.

15. It has also emerged during the course of the hearing that Dr Reay had insufficient experience and competence in the design of complex multi-level structures. After John Henry left, Dr Reay's firm was not in a position to do the structural design for the CTV Building and ought to have turned the work away.

16. Dr Reay repeatedly made the claim that Mr Harding was better qualified to undertake the CTV design than he would have been because of his greater understanding of the Concrete Code (NZS 3101:1982) and it was also the basis for a line of cross-examination of Dr O'Leary by Mr Palmer. It was also on display in his answer to Mr Elliott when asked to look at the drawings for the CTV Building and identify the areas he thought were unsatisfactory. He identified only two – the connection to the North Shear Core and the failure of the contractors to build the reinforcing spirals shown on the column drawings so that they went up through the beam-column joint.

17. Dr Reay was right on the first point, although he was referring only to the drag bars and not the more fundamental design problems with the North Shear Core that have emerged during the course of this hearing. However, the second issue is no more than a minor issue in the context of the deficiencies in the CTV Building.

18. The result was a building with numerous design defects that was not compliant with Bylaw 105, nor with the applicable Code provisions, and which as a result was extremely vulnerable when the 22 February aftershock struck.

19. While the forces to which the CTV Building was subjected on that day were well above the design level earthquake, the vulnerabilities in the Building that resulted from the structural design do not cease to be critical structural weaknesses simply because of the unexpectedly high earthquake forces. The CTV Building is the only building in Christchurch, designed to the 1982 and 1984 Codes, that suffered a complete and catastrophic collapse on 22 February. Earthquakes search out the weaknesses in structures and there were a number of critical structural weaknesses in this Building

which the earthquake found. While the precise order of the collapse sequence continues to be a matter of debate, and it seems unlikely the Royal Commission will be able to reach a definitive view on this, the remaining uncertainty about this has no effect on the Royal Commission's ability to address the issues set out in the Commission's Terms of Reference (**ToR**). The consensus of the expert evidence is that there are several critical weaknesses that could have been the initiating event, but they are triggered in such quick succession, with only split seconds separating them, that if it was not one it would be another. A separation of the floor diaphragm from the North Shear Core continues to feature as a strong possibility and the most recent Non-Linear Time History Analysis (**NLTHA**) supports this, but it remains no more than one of several candidates.

20. In concluding that diaphragm disconnection was unlikely to have been the collapse initiator Dr Hyland, in particular, placed considerable weight on a photograph which shows the floors leaning against the North Shear Core.[3] Dr Hyland considered that this was inconsistent with diaphragm connection preceding column collapse.

21. Mr William Holmes, the Californian structural engineer engaged by the Royal Commission to conduct a peer review of the Hyland/Smith report, provided an alternative explanation for this configuration that was consistent with collapse initiation in that area:

    (a) The slab at Level 3 did not have drag bars. This led to large drifts in the middle floors which collapsed vertically, but was arrested by Level 2. As the collapse progressed the floors would have collapsed as seen in the photo.

    (b) Alternatively, the slab at Level 3, or partially a Level 4 or 5, disconnected from the North Core in tension causing increased drifts, but did not completely lose gravity support at the face of the North Core. The large drifts caused collapse away from the North Shear Core.

22. Another theory Mr Holmes suggested was that there was a partial disconnection at the higher floors that allowed increased drift of the columns causing failure.

23. Mr Holmes was surprised that there had not been more discussion about the fact that the North Shear Core had been relatively undamaged. He thought this could indicate

[3] BUI.MAD249.0189.297

that one or more slabs had detached from the North Shear Core earlier, causing a large drift which in turn caused column and/or joint failure.[4]

Forensic preservation of the Building debris

24. Professor Robin Shepherd, a consulting engineer specialising in forensic engineering, criticised the failure to properly preserve the collapsed remains of the Building for subsequent forensic analysis. He accepted that the Police had to deal with the rescue and recovery process and that this had to take priority over anything else and that in that process all of the Building remnants had to be turned over and moved.[5]

25. He agreed with Commissioner Carter that the trauma that resulted from a building where five layers of concrete collapsed on top of each other trapping and killing people was not conducive to forensic testing.[6]

26. It was fortuitous that Messrs Frost, Heywood and Trowsdale took it upon themselves to carry out the forensic analysis they did. That work has proved invaluable in providing a forensic basis for analysis of the collapse. Professor Shepherd accepted that this work was useful and the Royal Commission was lucky to have it.[7] However he was critical of the lack of any chain of custody which would have made it.clear where various elements such as columns came from in the Building. He was also critical of the fact that there was no attempt to preserve the North core or the South wall before they were demolished and that these things made it much more difficult for the Royal Commission to come to conclusions.

27. It is accepted that although criticisms of the failure to preserve the forensic scene can be validly made, the combination of the evidence of Messrs Frost Heywood and Trowsdale, together with other expert observations and the eye witness accounts, provide a reasonable and proper forensic basis for consideration of the relevant issues the Royal Commission has to address.

28. More could have been done, particularly in the later stages, but it has to be remembered that the Police and other authorities had to deal with what would have been an almost overwhelming situation.

[4] TRANS.20120710.144, L11-29
[5] TRANS.20120716.73
[6] TRANS.20120716.116
[7] TRANS.20120716.77

29. Professor Shepherd outlined efforts in the USA to standardise best practise for structural failure investigations, including by the National Academy of Professional Engineers **(NAFE)** and the American Society of Civil Engineers **(TCFE)** which had produced guidelines in 2003.

30. Such guidelines would be likely to be of assistance in New Zealand and should be investigated by the Ministry of Building Industry and Enterprise.

The Terms of Reference (ToR)

31. The Royal Commission's ToR, as they apply to the inquiry into the CTV Building collapse, were set out in the opening submission of Counsel Assisting. They warrant being set out again here because they define what the Royal Commission can and cannot inquire into in relation to the collapse.

32. The ToR direct the Royal Commission to establish:

    (a) Why the CTV Building failed severely;

    (b) Why its failure caused such extensive injury and death;

    (c) Why it failed severely while other buildings did not;

    (d) Whether as originally designed and constructed, and as altered and maintained, the CTV Building complied with earthquake-risk and other legal and best-practice requirements that were current, both in 1986 when the CTV Building was designed and constructed and on or before 4 September 2010;

    (e) Whether prior to 4 September 2010 the CTV Building had been identified as earthquake-prone or had been the subject of any measures to make it less susceptible to earthquake-risk and, if it had, the compliance or standards this had achieved;

    (f) The nature and effectiveness of any post earthquake assessments of the CTV Building and any remedial work carried out on it after the 4 September and 26 December 2010 events; and

    (g) Any other matters arising out of or relating to these issues that come to the Royal Commission's notice that it considers it should investigate.

33. It would not be surprising if some of the evidence that has emerged in the course of this hearing has triggered a strong reaction from some of the families of the bereaved. Much of the evidence must have been hard to bear. However, it is not within the jurisdiction of the Royal Commission to inquire into, determine or report on, any questions of liability. This does not foreclose an inquiry into, or a determination of, errors or failings in design, inspection, permitting or construction that might have contributed to or caused the collapse of the CTV Building and the consequent deaths and injury. This submission will certainly address these issues and urge on the Royal Commission the conclusions that should be drawn.

34. In order that there is no confusion over the role that Counsel Assisting is playing at this stage of the Inquiry, it needs to be emphasised that the submissions of Counsel Assisting are no more than that. They set out the views that Counsel Assisting have reached on the evidence. However, they play no greater role in this Inquiry than this. It is entirely a matter for the Royal Commission as to whether they are accepted or rejected, in whole or in part. The final decisions reached on the questions the ToR ask about the CTV Building are solely within the province of the Royal Commission itself.

The Design Issues

(a) The design layout

35. The CTV Building was a design-build project. Mr Michael Brooks, the former managing director of Williams Construction (Canterbury) Ltd (**Williams Construction**) described it as a "*… standard kind of speculative deal…".*[8] It had its origins in a proposal presented to Mr Neil Blair of Prime West Corporation by Mr Brooks. The site at 249 Madras Street was vacant. It was owned by Prime West Corporation. Mr Brooks knew Mr Blair and he approached him with a proposal. The proposal Mr Brooks put to Mr Blair was accepted. From the outset it included a floor plate very similar to the final design and Mr Brooks said it was his idea to have the North Shear Core at the back of the building and outside the exterior walls. The purpose of this was more rentable space.[9]

36. Prime West required the building to cost as little as possible, subject to it achieving its intended function and having a reasonable appearance.[10]

[8] TRANS.20120808.8, L20-21.
[9] TRANS.20120808.4, L9-25.
[10] TRANS.20120808.7, L4-6.

(b) The engagement of Alun Wilkie

37. Mr Tony Scott, who was at the time the Quantity Surveyor for Williams Construction, ran some numbers on the floor plan Mr Brooks had sketched and Mr Brooks then approached Mr Alun Wilkie to draw up preliminary architectural plans.[11]

38. Consistent with Mr Brooks' evidence, Mr Scott also says the shape of the Building had been largely decided before Mr Wilkie became involved in the project. Following Mr Wilkie's engagement, Mr Scott's recollection was that there was a meeting which involved Neil Blair, Alun Wilkie, Michael Brooks and himself. He said that the general practice of Williams Construction was to start off with the architect and he thought that the shape of the CTV Building was confirmed at that initial meeting, on the basis of input from both Neil Blair and Alun Wilkie. This appears to be supported by other evidence.[12]

39. Mr Scott referred to the preliminary architectural plans Mr Wilkie prepared as A2.[13] Mr Wilkie in cross examination also said they would have been at least A2.[14] The potential relevance of this is to what Dr Reay was likely to have seen at his initial meeting with Michael Brooks and Tony Scott, which seems likely to have been in February 1986.

40. The relatively small round columns that have been the subject of close scrutiny in the course of the evidence originated with the Contours Building. This had also been designed by Mr Wilkie. Mr Scott described the circular columns as a feature of Mr Wilkie's work and he thought that Neil Blair wanted the circular columns.[15] Mr Wilkie recalled that Michael Brooks had requested that the appearance of the Contours building be followed in the CTV design.[16]

41. Mr Wilkie accepted he probably also had input into the decision to use pre-cast beams because their smoother finish involved a design issue. Consistent with the evidence from Mr Scott that the decision to use Hi-bond flooring came from Williams Construction, Mr Wilkie said this would be a costing decision to be made by the contractor or engineer.[17]

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[11] TRANS.20120808.4, L27-30.
[12] TRANS.20120808.101, L28-32; 102, L1-4
[13] TRANS.20120808.50, L11-14
[14] TRANS.20120815.69, L9-12
[15] TRANS.20120808.109, L28-30; 110, L1-6
[16] TRANS.20120815.77, L27-31
[17] TRANS.20120815.78, L12-28

(c) The engagement of Dr Reay's firm

42. After Alun Wilkie was engaged to do the architectural work Alan Reay was approached by Williams Construction to do the structural design work.[18]

43. The decision to use Dr Reay apparently resulted from Williams Construction using him on the Aged Persons Welfare Building.[19]

44. The initial contact with Dr Reay involved a meeting between Dr Reay and Mr Scott. It seems likely that Mr Brooks was at that meeting as well. The meeting was probably at Dr Reay's offices.[20] Mr Scott thought he was introduced to David Harding at that meeting and that Mr Harding was asked to produce preliminary structural drawings from the A2 architectural sketches.[21] As the ARCL timesheets show the first time recorded for Mr Harding is in March 2006, this may not be correct. However it is also possible that Mr Harding was introduced to the Williams Construction team at that meeting, but would not have recorded time for an introductory meeting of this kind.[22] Mr Harding said he had no contact with the design build contractor,[23] however this is clearly not correct as he acknowledges contact once construction started.[24] However, in light of Mr Scott's evidence that after that initial meeting he only dealt with David Harding, and Dr Reay's evidence that he had no further contact with Williams Construction after that initial meeting, it seems likely that the contact was earlier than that and probably did commence at that initial meeting with Dr Reay.[25]

45. Dr Reay has time recorded in February 1986 (2 hours) on the CTV job and it seems likely that this relates to the initial meeting that Mr Scott describes. When asked about this Dr Reay said he had no memory of spending any time on the CTV building in February 1986 until he saw the time records, but while he did not recall any direct dealings with Williams Construction on the project he accepted that what Mr Scott had said would be correct.[26]

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[18] TRANS.20120808.101, L29-32; TRANS.20120808.102, L6-12
[19] TRANS.20120807.137, L19-32; TRANS.20120808.91, L30-33; .92, L1-2
[20] TRANS.20120808.102, L22-24
[21] TRANS.20120808.102, L10-12
[22] TRANS.20120808.102, L26
[23] TRANS.20120730.112, L23
[24] TRANS.20120730.45, L2-5; .86, L8-14;.112, L23; .113, L1; .126, L22-23; TRANS.20120731.15, L9-10
[25] TRANS.20120808.105, L11-17
[26] TRANS.20120801.40, L13-24; .42, L1-4; .43, L15-27

(d) David Harding's appointment as the principal structural designer

46. Mr Scott said that he thought there had been a fairly comprehensive discussion at that initial meeting with Dr Reay about the type of construction techniques that were to be used. This resulted in three options being proposed, with the decision ultimately being to use the third option, which included the use of Hi-bond flooring.[27]

47. Mr Scott also thought that at that meeting he was advised that David Harding had been assigned by Dr Reay to take charge of the project.[28] Mr Wilkie said he had no recollection of ever meeting with Mr Scott or Dr Reay. His contact was Mr Harding.[29]

48. It seems that following this initial meeting with Dr Reay and Mr Harding the Williams Construction people had little or no further contact with Dr Reay. Mr Scott assumed that Dr Reay, as the principal engineer in the firm, would be there in a checking role. However, he had no direct knowledge of whether Dr Reay was checking what David Harding was doing or providing any oversight. He simply assumed that he was.[30]

49. Dr Reay acknowledged that at this early stage of the project he was involved in checking the quality of the client, ensuring that Williams Construction had the knowledge and experience to undertake the proposed work and then verifying that David Harding considered himself capable and prepared to commit to the CTV job.[31]

50. Dr Reay also said he thought he would have ensured an appropriate structural draughtsman from the firm was made available to assist David Harding.[32] However the evidence given later in the hearing about the involvement of the firm's structural draughtsmen casts doubt on this. Terry Horn was the only draughtsman with experience of multi-level buildings and the evidence supports a conclusion that he did no more than the foundations. Mr Harding said he worked with Wayne Strachan and neither he nor Shane Fairmaid, the other possible candidate, had done any multi-level buildings at Dr Reay's firm.[33]

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[27] TRANS.20120808.103, L1-20; .104, L4-16
[28] TRANS.20120808.102, L15-24
[29] TRANS.20120815.76, L22-29
[30] TRANS.20120808.105, L2-32; .106, L1
[31] TRANS.20120801.44, L26-29; .45, L1-8
[32] TRANS.20120801.45, L9-17
[33] TRANS.20120806.27, L10-12 (Strachan); TRANS.20120815.93, L18-22 (Fairmaid)

51. Initially Dr Reay had said in a written brief of evidence that he believed David Harding had brought the CTV contract to the firm. In cross examination he said he no longer held that view.[34]

52. There seems to be no dispute that by the time Mr Harding was brought in on the project a number of important decisions had already been made about the design of the Building. In giving evidence Mr Harding assumed that these decisions had been made with input from Dr Reay and warmed to this theme in relation to the use of the Fletcher Brown Built Hi-bond,[35] first describing in detail how and why Dr Reay had made this decision, but subsequently acknowledging he was not privy to how that decision came about.[36]

53. In cross examination Dr Reay denied he had made the design and materials decisions Mr Harding attributed to him[37] and in light of the evidence from Michael Brooks and Tony Scott it seems likely that the design decisions were made by them in combination with Alun Wilkie and Neil Blair of Prime West, in part by carrying across design details from the Contours Building.

(e) Dr Reay's knowledge of the Building design

54. Dr Reay said that he had not been aware of the basic layout of the floor plan, including the fact that the North Shear Core wall was located outside the floor plan of the Building. He claimed that the first drawing he ever saw was an architectural drawing and this led to a discussion in which he had asked David Harding about the shear wall layout.[38]

55. It is not entirely clear whether Dr Reay claims to have been unaware that the structural design of the Building was to be a shear wall protected, gravity load structure.[39] If he does this is contradicted by other evidence.

56. Any claim by Dr Reay that he was unaware of the basic layout of the floor plan prior to the discussion he says he had with Mr Harding over the south shear wall is not credible. Dr Reay has accepted that he was at the initial meeting referred to by Mr Scott. The A2 architectural drawings had been prepared before that meeting and the basic floor plan layout sketched by Mr Brooks had been done as well. It is

[34] TRANS.20120801.44, L1-8
[35] TRANS.20120730.112, L12-19
[36] TRANS.20120730.125, L1-3
[37] TRANS.20120801.46, L12-25; 47, L1-3; 50, L32-33; 51, L1-23, 52, L7-10; 53, L11-19
[38] TRANS.20120801.47, L14-19
[39] TRANS.20120801.50, L16-22; 51, L14-24; 71, L13-31; 72, L1-12

inconceivable that the basic floor plan was not described at that meeting when pricing issues and whether Dr Reay's firm would accept the work were key issues for discussion.

57. Dr Reay accepted that he would have been involved in deciding whether his firm would do the initial work on a no-job, no fee basis.[40] As only one meeting with Dr Reay has been identified it seems likely that this discussion would have occurred at that initial meeting. Although with the passage of 26 years, and Dr Reay's frequent failures of memory in the course of giving his evidence, it is entirely possible he does not accurately recall when he first learned of the intended plan of the Building and saw the A2 architectural sketches, it is submitted that from the time of this initial meeting Dr Reay was aware of the positioning of the North Shear Core and that the CTV Building was to be a shear wall supported gravity load system.

58. The closest Dr Reay came to acknowledging that he did know that the Building had a North Shear Core from a fairly early stage in the design process was in response to a question in cross examination which asked him whether a different structural design might have resulted if he had been more closely involved in what David Harding was doing. His answer was no, because he knew there was both a northern shear core and a southern shear wall and so that would not have changed.[41]

59. Further confirmation of Dr Reay's understanding of the structural design comes from the fact that he eventually acknowledged he had directed Mr Harding to the Landsborough House file for guidance in designing the CTV Building.[42] Landsborough House was a shear wall protected, gravity load system and it would have been relevant to CTV only because of this common feature.

60. Dr Reay also said during the design process he had asked David Harding about the layout of the shear wall because he was particularly interested in it.[43] He said this was the only issue with the structural design that concerned him.[44] He said that at that stage he was looking at architectural drawings, not structural drawings, and asserted that the shear wall layout was all he would have been interested in and all he would have looked at.[45] This is despite saying that the reason he could remember the discussion with Mr Harding about this issue was because the shear wall layout was an

[40] TRANS.20120801.43, L22-24
[41] TRANS.20120712.133, L29-32; .134, L1-3
[42] TRANS.20120815.25, L8-10
[43] TRANS.20120801.48, L1-3
[44] TRANS.20120801.47, L28-29
[45] TRANS.20120801.48, L6-7

important issue to him and he wanted to satisfy himself that Mr Harding was not about to progress with something that was going to be a problem.[46] Again, it is inconceivable that he would not have noticed the positioning of the North Shear Core.

61. When questioned on this issue by Justice Cooper he said the reason for his concern was that the CTV Building had a bigger floor plate than Landsborough House and as he had thought that Landsborough House was getting near the limits for having a shear core without a wall on the opposite side of the Building, he wanted to assure himself that Mr Harding did have a wall on the opposite side.[47] Dr Reay's concern about Landsborough House being near to its limits is likely to have been because of concerns Mr Henry had expressed to him during the design of that building, a matter Mr Henry referred to in his evidence.[48]

62. It is submitted that these various points lead to the conclusion that from the date of the first meeting with the Williams Construction personnel Dr Reay was aware of the basic layout of the building, including the fact that initially the contractor and the architect wanted the services area located outside the floor plate of the Building, and he knew it would be designed as a shear wall protected gravity load structure. Whether Dr Reay's recollection, or Mr Harding's recollection, is correct on the precise circumstances in which Dr Reay came to ask about the south wall layout is probably not a matter that needs to be resolved, although it will be dealt with in more detail later in this submission. It is submitted that Dr Reay wanted to see the shear wall layout because he was aware of the floor plan that was originally proposed by Mr Brooks and Mr Wilkie and knew enough about what was going on to have at least a residual concern about how Mr Harding was dealing with that design.

(f) David Harding's assumption of responsibility

63. Mr Harding gave evidence that prior to rejoining Alan Reay's firm in late 1985 he had had no multi-level building experience which required the use of ETABS.[49] In oral testimony he expanded on this and agreed that he had had no multi-level experience at all.[50] He said that when Dr Reay approached him Dr Reay *"understood"* this lack of experience.[51]

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[46] TRANS.20120801.49, L17-19
[47] TRANS.20120801.49, L26-30
[48] TRANS.20120801.132, L25-29
[49] TRANS.20120730.23, L19-21; TRANS.20120731.18, L7-8
[50] TRANS.20120730.94, L9-11
[51] TRANS.20120730.23, L19-21

64. Immediately prior to rejoining Dr Reay's firm he had designed a four-storey residential building for the Hospital Board. This had been done at the request of Dr Reay when Dr Reay apparently found himself short-handed.[52] Whether or not this building qualifies as multi-level experience similar to what was involved in the CTV Building, and it is submitted that it did not, it did not involve any use of ETABS. It was done by using the equivalent static method with which Mr Harding said he was familiar.

65. The opportunity that Mr Harding was being offered at Dr Reay's firm was principally for the design of multi-level buildings, including those that would involve the use of ETABS. Dr Reay had found himself with no-one with the skills and experience to do this work after Mr John Henry left the firm in late 1985. Mr Harding says that when he was approached by Dr Reay to see if he would rejoin the firm, Dr Reay specifically held out the opportunity of getting multi-level experience in the firm as well as the prospect that he would be made an associate.[53]

66. At the time that Mr Harding was approached by Dr Reay he was working as a civil engineer with the Waimairi District Council. He said in evidence that he was concerned that he was being directed into a future as an administrator rather than a practicing engineer, which he did not want.[54] As a result the approach from Dr Reay was welcomed as a way out that would get him back into consulting engineering work after *"…not doing structural design for a long time".*[55]

67. In cross examination he made it clear that he would not have been interested in coming back to Dr Reay's firm had it not been for the opportunity to get experience with multi-level work. He said that even if he had been involved in cutting edge tilt slab work he would have had no interest.[56] It was his aspiration to gain experience in multi level work that he repeatedly referred to.[57]

68. Mr Harding's evidence that he had no prior experience in multi-level work and that Dr Reay held out to him the opportunity to learn this work was not shaken by Mr Rennie QC's cross examination.[58]

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[52] TRANS.20120730.23, L25-33; .24 L1-4
[53] TRANS.20120730.23, L11-23; TRANS.20120731.39, L27-32; .40, L14-15, 24-28; .41, L18-20
[54] TRANS.20120730.94, L2-11
[55] TRANS.20120731.14, L21-24
[56] TRANS.20120731.38, L13-16; .39, L29-32
[57] TRANS.20120731.14, L21-32
[58] TRANS.20120730.93, L27-33

69. Mr Harding resisted the suggestion that an associate position in the firm was the lure.[59] However, he acknowledged that he saw the associate position as a way of avoiding being in the position that he had been in when he first worked for Dr Reay's firm, which he described as being a "*backroom number muncher*".[60] He did not want to go back to that.

70. It is submitted that the conclusion to be drawn from this is that the associate position was an important element of the offer for Mr Harding. Whether it was a lure in itself or it was important because of the type of work he thought it would lead to does not need to be resolved. What is important is that for Mr Harding to achieve his ambitions in the firm it would have been necessary for him to prove he was capable of doing the multi-level work for which he had been hired. While in the course of cross examination Dr Reay claimed that whether Mr Harding was able to do this work made absolutely no difference to Mr Harding's advancement to an associate position, this is not credible.[61]

71. The Commissioners have observed Mr Harding during the several times he gave evidence and will have formed their own view of him. It is submitted that despite his claims that he would not have felt able to do the structural design work for the CTV Building had he been on his own, and only took responsibility because he believed that Dr Reay was reviewing what he was doing, neither his confident demeanour nor the evidence supports this. When Dr Reay brought the CTV job to his desk Mr Harding described it as *"… giving me the opportunity to do one.*[62]

72. Although in the course of cross examination on Day 66 Mr Harding referred to needing to know there was a review process in place because when you are designing something for the first time you don't know what you don't know,[63] there is little or no evidence that supports Mr Harding's claim that he had any doubts about his ability to work on his own.

73. At one stage in response to a series of questions put to him by Mr Rennie QC, he said.[64]

> Q. … the elements of structural design they were in fact all matters within your skills and expertise?

[59] TRANS.20120731.38, L4-6
[60] TRANS.20120731.38, L9
[61] TRANS.20120815.61, L24-31
[62] TRANS.20120730.81, L20-21
[63] TRANS.20120731.43, L18-19
[64] TRANS.20120730.125, L17-32; 126, L1-4

A. There was nothing new…
Q. But at the time you considered that you were confident, you were competent to do it, didn't you?
A. I was competent to do it provided there was someone reviewing it.

74. Despite this reference to a need to know someone was reviewing his work, his evidence provided no basis for any reasonable belief on his part that he was being reviewed by Dr Reay and he referred to only one occasion on which he specifically discussed with Dr Reay any aspect of the Building's design. This was over the south wall. In the course of questioning Mr Harding moved away from supervision by Dr Reay to include the structural draughtsmen in the firm as people from whom he might obtain guidance and agreed that the oversight he thought he was getting was principally by Dr Reay checking the work of the structural draughtsmen.[65] He also agreed that he was not "*calling out*" for supervision or review.[66] In replying to a series of questions from Justice Cooper on this issue he agreed that the only issue he ever raised with Dr Reay related to the south wall.[67]

75. It is submitted that although Mr Harding was working beyond his level of competence, a fact that he accepted,[68] the evidence is that he was confident he could do the work, in part encouraged by his confidence that he could follow the work that Mr Henry had done on Landsborough House and to which he had been referred by Dr Reay.[69]

Q. You've said in your evidence that you found the Landsborough House documentation that you were given clear and easy to follow, that's correct?
A. I wouldn't say easy, but methodical…
Q. So within the engineering world, at any rate, these were materials that were clear and easy to follow?
A. Clear to follow.
Q. Yes, but you were confident that you could follow them?
A. Well I was giving it a go…
Q. … to what extent could it be described as following the dots…
A. Well, no I don't think you could call it following the dots
Q. How would you describe it?
A. Oh, by looking at the method, at the, at the identification of which structural elements are doing the work and which are along for the ride. Which ones you need to include in your modelling and which you don't. What the relevant criteria

[65] TRANS.20120731.41, L31, 42, L23; 47, L22-28
[66] TRANS.20120731.83, L27
[67] TRANS.20120730.131, L1-4
[68] TRANS.20120731.70, L17-22
[69] TRANS.20120731.45, L7-29

> are in terms of deflection perhaps or any number of other criteria such as shear and axial load.

76. However, in response to a question from Commissioner Fenwick he said with reference to using the ETABS programme from Landsborough House:

> …it was just a case of following the dots with the ETABS programme.[70]

77. He also said:

> Q. …so you see the CTV building as in effect a watershed building where you learned the skills that you needed to do the other buildings?
> A. Very much so … I think it was really self taught by going through John Henry's calculations for the previous job …[71]

78. He also knew that the culture of the firm was one where, if he was to progress, he needed to prove that he could do this work.[72]

79. He referred to the culture as one that required high levels of performance and which did not offer you a lot of hand holding. This was a culture he acknowledged he knew from his previous period with the firm, which he knew he was coming back to and which he said he was comfortable with.[73]

80. Even when confronted in cross examination with the serious design deficiencies in the Building that had been identified by a number of expert witnesses, including the critical structural weakness that Holmes Consulting Group (**HCG**) identified in the connection of the floor diaphragm to the North Shear Core in February 1990, Mr Harding was never really prepared to admit any problems with what he had done. When he was asked by his counsel, to comment on the long list of criticisms Professor Nigel Priestley had directed at his work, which Professor Priestley said failed to meet best practice by the standards of the day, including known structural engineering knowledge, Mr Harding rejected every one of those criticisms.[74]

81. In the course of cross examination Mr Harding was invited to comment on a number of opinions Professor Mander had expressed about the Building's compliance with best practice standards. Mr Harding agreed:

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[70] TRANS.20120731.87, L1-2
[71] TRANS.20120730.106, L26-32
[72] TRANS.20120731.41, L21-30; 45, L3-6
[73] TRANS.20120731.37, L12-17
[74] TRANS.20120730.70, L15; 77, L27

a. The seating sill on the west wall was not well anchored;

b. It was a Building with a significant number of problems;

c. The responsibility for compliance lies with the designer not the Council and in part he regarded himself as the designer (he regarded Dr Reay as the other designer);

d. Whatever the vertical acceleration forces were on the Building they were likely to have exacerbated existing structural weaknesses and there were a significant number of structural weaknesses.[75]

82. As he always did, however, he refused to accept that any of these problems were responsible for the Building's collapse. In his view this was solely attributable to exceptionally high vertical accelerations.[76]

83. Mr Harding was then questioned at length by Commissioner Fenwick about the way in which he had gone about his design for the CTV Building.[77] If it was not clear before this, it was patently clear following this exchange that Mr Harding was seriously out of his depth in the work that he had done on the CTV Building and in some critical areas he was completely unaware of calculations that he should have made and Code provisions he needed to take into account.

84. Because Mr Harding acknowledged that he had not reviewed his calculations before giving evidence on that occasion, he was questioned again on some of these issues by Commissioner Fenwick at a later stage of the hearing.[78]

(g) Dr Reay's examination of the SCSW

85. Mr Harding and Dr Reay gave different accounts of the single occasion on which Mr Harding says he sought advice from Dr Reay and the single occasion on which Dr Reay says he checked any aspect of the structural design.

86. Ultimately which account is preferred appears to have little direct significance. On either view Dr Reay looked at this issue and approved it in circumstances where his review was superficial and inadequate. If he looked at it only in the architectural drawings, as he says he did, he can properly be criticised for not asking at a later date to see the

[75] TRANS.20120731.78, L16; 79, L25
[76] TRANS.20120731.80, L3; 82, L5
[77] TRANS.20120731.85, L4; 97, L12
[78] TRANS:20120807.49, L27; 50, L33

structural drawings, given the importance he acknowledged he had attached to confirming the shear wall arrangements. If it was brought to his attention by Mr Harding after Mr Harding had concluded a south wall was needed to address the excessive deflections his early ETABS runs had identified, Dr Reay would have been much more closely involved in, and better informed of, the structural design than he admitted.

87. Because Mr Harding's recall of events was largely premised on his contention that the issue would need to be discussed with the owner and architect, and Dr Reay had to do this because this was not something he was in a position to do, his version of events is to be doubted. It is clear on the evidence that Mr Harding was the principal contact for the Williams Construction team and on a design-build project such as this that would have been the logical first stop for any required discussion over a south shear wall.

88. Mr Harding says he discussed the excessive inter-storey deflections with Dr Reay and recommended to him that an additional shear wall on the south should be added to help resist torsional rotation. Mr Harding said that Dr Reay was concerned that as this additional wall was not on the Contours building it might not be acceptable to the client and Mr Harding believed Dr Reay discussed it with the owner and architect before confirming that the wall could be added but it had to be limited in size such that it could be concealed behind the fire-escape stairs.[79]

89. Mr Harding was referred to his 1986 seminar notes which he said showed a layout of walls very similar to the CTV Building and said that was one of the reasons he had proposed the south shear wall.[80] However he said that if he had a choice he would have made the wall the same length as the North Core Shear wall so that it was symmetrical. He said he had made that point to Dr Reay in their discussions on the issue.[81]

90. This evidence contrasted starkly with that given by Dr Reay on the issue. Dr Reay said that the conversation about the south shear wall came up when he, having become aware that Mr Harding had received the architectural drawings, asked him about the structural lateral load system or as he put it in cross-examination, "the shear wall layout" .Dr Reay said that when he saw it had the additional wall on the south he considered it more stable than the Landsborough House design.[82] Dr Reay claimed that this was the first drawing he had seen and before that he had not been aware it

[79] TRANS.20120730.34, L9 - .35, L5
[80] TRANS.20120730.119 L25-31
[81] TRANS.20120807.73, L10 -.74, L8
[82] TRANS.20120731130, L6-11

originally only had a single shear core.[83] As has already been submitted, this cannot be correct.[84]

(h) Dr Reay's decision to give David Harding the lead designer role

91. Dr Reay's evidence was that Mr Harding was well capable of doing the work, he was keen to do it and was responsible for it, subject only to being able to ask Dr Reay if he needed help:

> He was the one who said that he wanted to do the job and believed he could accomplish it … I had confidence in his ability… If he couldn't I expected him to come to me and tell me he couldn't … he would have found out fairly quickly if he thought he, if he found he had difficulty doing it I believe.[85]
>
> I would've gained some confidence from reviewing the Westpark Building in terms of Mr Harding which may have influenced me in relation to the CTV Building.[86]
>
> He handled [Westpark] satisfactorily in my view and from there he undertook, he wanted to undertake the design of the next building and he was confident that he could do it, and I accepted that.[87]

92. What stands out from these passages, and from Mr Harding's own evidence, is the extent to which Dr Reay judged whether it was appropriate to give Mr Harding the responsibility for this Building by relying on the fact that Mr Harding wanted to do it and believed he was capable of doing it. In other words, Mr Harding's self assessment largely governed the decision.

93. It is submitted that, viewed objectively, there was no defensible basis on which Dr Reay could have considered that Mr Harding was appropriately qualified to be given the sole responsibility for the structural design of the CTV Building. In the first place Mr Harding was being brought in to do work that had previously been done by Mr John Henry. Dr Reay was well aware of the high level of experience and skill that John Henry had in this type of work. It was impossible to rationally conclude that Mr Harding could take over the level of work that Mr Henry had previously been doing unless there was appropriate supervision and mentoring by someone else within the firm who had the requisite level of skill and competence.

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[83] TRANS.20120801.47, L14-22
[84] TRANS.20120807.100, L29 - .101, L5
[85] TRANS.20120801.30 L4-12
[86] TRANS.20120801.33, L15-17
[87] TRANS.20120807.96, L27-30

94. This was never made available and by the end of the hearing it was apparent that Dr Reay did not have the required levels of skill and experience to provide appropriate supervision and mentoring even if he had been willing to do so.

95. It is also clear from the evidence that Dr Reay did not bother to conduct anything approaching a careful interview with Mr Harding before offering him a position that was to fill the gap left by Mr Henry's departure. He was unclear, when asked, about what Mr Harding had done at Hardie and Anderson.[88] He had a sufficient understanding of what he had done at the Waimairi District Council to know that it was almost entirely civil work, not structural engineering.[89] He seems to have proceeded on the basis that he had a need and Mr Harding was willing to fill it.

96. What Dr Reay continually harked back to was that Mr Harding was a Registered Engineer, he had ten years experience since registration (at one stage astonishingly suggesting that he had more years of experience than John Henry and implying he was, as a result, better qualified than Mr Henry to undertake this work),[90] and it is part of being a Registered Engineer and being in a senior position that you take on responsibility.[91] In effect Dr Reay was saying David Harding was expected to have the ability unless he put up his hand and said, I don't have it.

97. In the end the only two buildings that Dr Reay was able to point to as ones that might possibly have provided some justification for his decision that Mr Harding was appropriately qualified to take the sole responsibility for the CTV Building structural design were the four storey hospital residential building Mr Harding designed just before he rejoined Dr Reay's firm and the involvement he had in the Westpark building.

98. The work on the Westpark design was commenced by Mr Henry before he left the firm.[92] During the course of his evidence Mr Henry was shown a copy of the calculations for the Westpark building and asked to comment on the extent to which the work he had already done would have assisted Mr Harding when he was asked to take over the work. Mr Henry said that the building was a uniform one with essentially the same properties on the top and bottom floors. Not only was the building itself a regular one, but this made the ETABS work very straightforward. Mr Henry had already set up

[88] TRANS.20120801.103, L16; 104, L13
[89] TRANS.20120801.2, L16-25
[90] TRANS.20120815.57, L10-11
[91] TRANS.20120731.103, L7-9; TRANS.20120801.22, L3-6; TRANS.20120815.21, L25-29; 60, L21-24
[92] TRANS.20120802.62, L28-31; .63, L1-11

the ETABS programme and done the first run of it to get the basic forces and do the preliminary design.[93]

99. When asked how much assistance Mr Harding would have derived from the work already done he said:

> … the model would be there sitting ready to go. If he'd wanted to change anything it would be straightforward enough to change the data that's already there so the – it would have been very helpful to him to have that model sitting there. You could have amended it, edited it, and run it again without having to set it up…[94]

100. When asked whether doing ETABS on the Westpark building was the equivalent to doing it on the CTV Building his answer was emphatic:

> No, no definitely not.[95]

101. Dr Reay also referred on several occasions in the course of his evidence to the fact he believed Mr Harding was more familiar with the Concrete Code than he was.[96]

102. Dr Reay's justification for putting Mr Harding into the principal designer role for the CTV Building was usefully captured in an exchange with Justice Cooper.

> Q. ….the question I really want you to answer is whether you think you did everything, you did anything wrong other than relying on Mr Harding?
>
> A. Well the difficulty is I believe I was right to rely on him at the time, but it was clearly the wrong decision.
>
> Q. And am I right, you thought that you were right to rely on him at the time, because of his years' standing as a registered engineer and because of work he had done with you on the Westpark Tower. Are they the main reasons?
>
> A. Oh, and the other buildings that he had designed, small, albeit smaller ones, they had – they all have features that require code analysis and – or compliance with the code. I – and he'd been through the same education and training system that I had and I guess I expected, well I would have anticipated that he would he would have had a similar level of knowledge to myself, or in fact in terms of concrete

[93] TRANS.20120802.64, L29-32; .65, L1-10
[94] TRANS.20120802.65, L16-20
[95] TRANS.20120802.65, L21-22
[96] TRANS.20120731.105, L26-27; TRANS.20120815.30, L23-24; .57, L21-23

> design he was more au fait with the codes and with the latest, later thinking than I was in terms of buildings of this type. [97]

103. The uncomfortable conclusion is that if, as Dr Reay said, Mr Harding was more qualified to design the CTV Building than he was, this might well have been an accurate self assessment. In response to questions from both the Commissioners and various counsel, what emerged was that with a very limited number of exceptions, Dr Reay's career had been built exclusively around one and two level tilt-slab concrete industrial and commercial buildings and some cold form steel structures.[98]

104. Dr Reay also acknowledged, in answer to questions from Justice Cooper, that he was not involved in the design of the Aged Persons, Bradley Nuttall or Landsborough House buildings, all of which were designed by Mr Henry. Dr Reay said that because he was the lead consultant for each of these three jobs he was involved with Mr Henry in liaising with him and with the architect. As a result to some degree he was involved in understanding the basis of what was being done. However, beyond understanding the principle that the structures had been designed for he relied entirely on Mr Henry for whether the buildings complied with the applicable standards, including the Concrete Code. He said he had not taken time to familiarise himself with the Code provisions because he was fully committed on other work and it was Mr Henry's responsibility to deal with those issues in the senior position he had been employed in.[99] This is largely consistent with Mr Henry's evidence about Dr Reay involvement in these jobs.[100]

105. It is submitted that the consequence of Mr Harding's lack of experience and structural engineering understanding, and the lack of any adequate supervision or mentoring for the work he was undertaking, resulted in a building with a number of significant structural weaknesses and a completely inadequate load path, that led directly to the collapse that occurred on of 22 February.

(i) The appropriate standard of supervision and review

106. During the course of the hearing a number of structural engineers were questioned about the supervision their firms provided for less experienced employees. This involved structural engineers from firms across a range of sizes, from the one principal firms such as Dr Reay's was in the 1980s, through to much more substantial national practices such as HCG and Beca Carter. Not one of the witnesses questioned

[97] TRANS.20120807.139, L1-17
[98] TRANS.20120807.137, L1-5; TRANS.20120815.58, L32-34
[99] TRANS.20120815.56 L12; 57, L5
[100] TRANS.20120802.15, L17; 17, L26; 19, L13-20; TRANS.20120802.94, L24; 95, L2

considered it appropriate to have allowed structural drawings to go out for permit without a review by a senior and experienced member of that firm. Most of them went much further, saying that the culture within their firms was one where there was constant discussion and review and in most cases a deliberately structured form of mentoring and supervision.[101]

107. At times questioning by counsel for Dr Reay and his firm seemed to be suggesting that as Dr Reay was practising as the sole principal in the firm he could not be expected to provide that sort of supervision and checking. However it was Dr Reay's choice to practice in this way and if he was not able to conduct a safe practice on his own he ought to have taken steps to either change the structure of his practice, or arrange for external peer reviewing when the firm decided to take on complex multi-level work. Mr Falloon, who gave evidence on the installation of the stairway in the CTV Building, was a sole principal and he referred to checking and supervision as his responsibility.[102]

108. After deciding to abdicate all responsibility for supervision of the work Mr Harding was doing on the CTV Building, Dr Reay by his own account took no steps to check the drawings before they were submitted for permitting.[103] No other structural engineer the Royal Commission has heard from on this topic would have allowed this. Even though Dr Reay may not have had a sufficient understanding to identify all of the defects in the Building, it seems clear he was capable of identifying the problem with the connection between the floor diaphragms and the North Shear Core that HCG identified in January 1990. In the course of cross examination on the issues arising from the HCG report he acknowledged as much and described Mr Harding's error as "*fundamental engineering*".[104]

(j) Reliance on Landsborough House as a design template

109. In designing the CTV Building Mr Harding used the Landsborough House calculations and the input output data for the ETABS as a "design template" for the CTV Building. This is not disputed. What is disputed is how it was that he came to use the Landsborough House material for that purpose and the role that Dr Reay played in this.

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[101] TRANS.20120801.115, L5; 119, L13 (Mr Henry referring to the several different firms in which he has worked); TRANS.20120814.86, L8-21; 102, L1-31; 103, L1-7; (Mr John O'Loughlin); TRANS.20120813.72, L15-31; 73, L12; 74, L4 (Dr O'Leary); 74, L22; 75, L20 (Mr Palmer cross examining Dr O'Leary); TRANS.20120710.109, L8-29 (Mr Rob Jury)
[102] TRANS.20120725.88, L5-9
[103] TRANS.20120817.120, L31-32; .121, L17-29
[104] TRANS.20120817.123, L1-4

110. Mr Harding's position on this was initially set out in paragraph 15 of his first brief of evidence.[105]

111. Although Dr Reay finally agreed without reservation that he had referred Mr Harding to the Landsborough House materials and said that he had referred him to this to look at so he could understand the principles of that particular project,[106] his starting position was that he "*wouldn't necessarily have given them to him – he was familiar with … the filing systems*".[107]

112. As his evidence on this issue evolved Dr Reay then said that he would have directed Mr Harding to the calculations for Landsborough House, but not just that. It would have been the entire job drawings that were in there.[108] The primary purpose was to assist Mr Harding with ETABS and Landsborough House was an example of a design process and drawings that would be helpful to him in understanding how that work would be undertaken.[109]

113. What is also apparent is that before referring Mr Harding to the file and the job drawings for Landsborough House, Dr Reay had not checked the file to see what was in it. Dr Reay said the drawings would have been useful and he would have expected David Harding to have looked at them.[110] However Mr Harding says that no drawings were given to him and he never saw the drawings. Nor did he seem to regard them as relevant, which is surprising.[111]

114. In his reply brief Dr Reay criticised Mr Henry for not having in the file all of the information that Mr Harding would need to follow what Mr Henry had done on Landsborough House and seemed to suggest that Mr Henry could be blamed for the fact that, as a result, Mr Harding made some significant errors in his work.[112] He also seemed to be contending that Mr Henry should have set up his work on Landsborough House as though he was responsible for the supervision and mentoring of Mr Harding.[113]

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[105] TRANS.20120730.28, L9; 29, L2
[106] TRANS.20120815.25, L8-10
[107] TRANS.20120801.8, L32; 9, L2
[108] TRANS.20120801.24, L3-5; TRANS.20120731.140, L8-11; TRANS.20120801.8, L32; 9, L2; 39, L31-32; 63, L16-23; 72, L23-25; TRANS.2012.0815.25, L8-10
[109] TRANS.20120801.25, L8-9
[110] TRANS.20120731.140, L8-11; TRANS.20120801.24, L3-14; TRANS.20120801.25, L8-9.
[111] TRANS.20120730.114, L28; 115, L5
[112] TRANS.20120731.124, L8-15.
[113] TRANS.20120731.124, L12-15; TRANS.20120802.20, L28; 21, L12

(k) Errors made by Mr Harding in following the Landsborough House "template"

115. During the course of his evidence Mr Henry expressed concern that Mr Harding had been doing the CTV design and that he had been placing such a high level of reliance on the Landsborough House calculations without any experience in doing buildings of this kind.[114] He was also very concerned about the design Mr Harding had produced. This included the low level of confinement in the CTV columns when compared to those in Landsborough House, which he described as only about 20% of the typical ties used in Landsborough House,[115] and a very significant error that had been made in calculating the corner deflections of the CTV Building.[116] He also observed that there were some significant differences to the way he would have interpreted the Code for determining the design earthquake loading and the application of the structural type factors, including the Building period and the relevant scaling factors[117].

116. On the issue of corner deflections Mr Henry's evidence was that at the time the ETABS model was used by Mr Harding it did not provide output results that could be used directly to interpret the deflections of the Building. Mr Henry said it was essential to calculate the inter-storey drifts by hand, because ETABS calculated deflections at the centre of mass of the Building only.[118] He said he had examined pages S15 and S16 of Mr Harding's calculations, which is where he said he would have expected to see the maximum corner deflections addressed, and found no working of this in the calculations.[119]

117. For the purpose of preparing his evidence Mr Henry had done his own preliminary check on corner deflections, which indicated significantly larger deflections at the south wall than the deflections that Mr Harding had calculated and he dealt at some length with the differences between the corner deflections he had calculated and those calculated by Mr Harding in both the North-South and East-West directions.[120]

118. Mr Henry concluded this section of his evidence by saying:

> In this respect I believe that the eccentric and unbalanced structural configuration of the CTV Building and the characteristics that I have described in my evidence, made it susceptible to increase lateral deflection under severe earthquake loading in the east-west direction.

[114] TRANS.20120802.20, L10-15.
[115] TRANS.20120802.33, L25; 34, L8
[116] TRANS.20120802.34, L25-30
[117] TRANS.20120802.34, L10-16
[118] TRANS.20120802.34, L18-24
[119] TRANS.20120802.34, L26-30
[120] TRANS.20120802.35, L1; 51, L24

119. In both his evidence in chief and under cross examination Mr Harding acknowledged a number of the concerns that Mr Henry had expressed. In particular he acknowledged that at the time he used ETABS to calculate the deflections to the CTV Building he was unaware that it was calculating deflections only at the centre of mass. He admitted he did not know that in order to determine the corner deflections there needed to be a separate hand calculation. He also said that while it was apparent, when he thought about it in the course of being questioned, that deflections are typically going to be greater at the corners of buildings than they are at the centre of mass, at the time he was doing the calculations he did not think of this because he was too busy trying to get the computer program to work and to get any kind of result. He said:

> When it gave one that was below the code I was grateful.[121]

120. Mr Harding also acknowledged that he had not checked for corner deflections and accepting that if he had done this he was likely to have ended up with a bigger number.[122]

121. In explaining how he had used ETABS he said:

> My recollection is that there were standard input data sheets. I had seen how John had taken it from his calculations and how that had translated into putting the data on these input sheets and I used his situations as a template and basically filled the sheets out the same way.[123]

(l) The consequence of Mr Harding's failure to accurately assess the inter-storey deflections

122. The inter-storey deflections that were calculated by Mr Harding for the CTV Building were critical to answering the question of whether the Building could be designed as a non ductile building. If the inter-storey deflections for the CTV Building had been properly calculated they would have shown, at best, that the deflections were right at the edge of the permitted deflections. While Mr Harding's failure to accurately assess the inter-storey deflections, based in turn on Mr Harding's lack of understanding of the ETABS model he was working with, was not the only serious design error that he made, it has resulted in a design weakness that the Hyland/Smith report for the Department of Building and Housing (**DBH**) identified as a likely initiator of the Building's collapse. This error in the calculation of inter-storey drifts was a direct result

[121] TRANS.20120731.69, L12-13
[122] TRANS.20120731.69, L14-27
[123] TRANS.20120730.98, L26-29

of Mr Harding's inexperience with ETABS and the fact that he was working outside his level of competence without adequate supervision.

123. The Foreword to the Commentary to NZS 4203:1984 cautions the designer about the uncertainty of the precise properties of materials and structural elements and uncertainty about the interaction between building elements; design involves a level of imprecision. If the calculations had been done correctly by Mr Harding for the inter-storey drift then even if they had shown the inter-storey drifts were within the Code prescribed deflections they would at best have only been just within those limits. To have then proceeded to design the building without either greater ductility or greater strength and rigidity would have been to disregard this caution and not act in a way in which a competent and responsible engineer should have acted.

124. All of the different collapse analyses that have been carried out, including by the DBH and most recently in the second NLHTA directed by the Royal Commission, have identified the very low level of confinement in the columns, and their inability to sustain significant deflections without collapse, as a potentially initiating event in the collapse sequence. It is now also generally agreed by the experts the Royal Commission has heard from that the columns at Line F did not comply with Code at the date on which a permit was issued because there was inadequate confinement for the anticipated deflections.

(m) The lack of an adequate load path

125. A related but more fundamental failing in Mr Harding's design for the CTV Building was its failure to provide an adequate load path through the Building. Ultimately this may have played the principal role in its collapse.

126. The fundamental concept for structural design is that any force or load that is applied to a structure must have a load path that transfers that force through the structure to the foundation soils. The force flow through this load path must satisfy the requirements of equilibrium and compatibility.

127. In designing for the transfer of seismic inertial forces in the east west direction between each floor and the North Shear Core Mr Harding did not allow for the in plane bending moments induced in the floors associated with the shear transfer between each floor and the wall on Line 5. The critical bending moment associated with this action occurred on the south side of beam on Line 4, in the location between the finger walls

on Lines C and C/D. Ignoring this action resulted in a load path that did not satisfy the equilibrium and compatibility requirements that are fundamental to structural design.

128. Many of the beam column connections also show a lack of appreciation of the need to track loads through the details. Anchorage of bars is left dependant on the direct tensile strength of concrete, which is contrary to design practice for reinforced concrete structures. The details that were used were also likely to have been major contributors to the premature collapse of the Building.

129. The forces required to connect the floors to the structural walls were also incorrectly determined. These should have been found using either the parts and portions force criteria in NZS 4203:1984, or the forces associated with capacity design and over-strength actions. Instead Mr Harding used the equivalent static values which were very much smaller than the design actions specified by NZS 4203:1984.

130. In respect of this issue and others, Mr Harding proceeded blindly unaware of the risks in the design for which he had taken responsibility.

(n) The South Coupled Shear Wall (**SCSW**)

131. Mr Harding also demonstrated an inadequate understanding of the design issues involved in the SCSW. Several times during the course of his evidence he referred positively to the lack of diagonal cracking in the SCSW when in fact this was evident that the SCSW had not responded in the way it ought to have done.

132. The diagonal coupling beams were in fact overstrength and this prevented the SCSW acting as Mr Harding would have intended it to. As a result it was not able to dissipate as much seismic energy as it should have and most of the yielding was forced into the bottom section. This would be seen in some of the photos put into evidence by Mr Frost.

133. The inadequate design of the SCSW may well have had some effect on the performance of the Building on 22 February.

134. The SCSW was the one area Dr Reay acknowledged he had looked at in the course of the design. By his own account he was satisfied simply by seeing that there was a shear wall on the south side of the Building.

The building permit

(a) The CTV Building did not comply with Bylaw 105 and the Code at the date of permitting

135. The aspects of the design that were non-compliant are analysed in detail in the next section of this submission. The extent of non-compliance is affected by both the extent to which the CCC Bylaw 105 modified NZS 3101:1982 and NZS 4203:1984, the two New Zealand Standards relevant to the CTV Building, and by the answer to the question of whether the Building had to be designed as a ductile building. The only elements of the CTV Building that were designed to be ductile were the North Shear Core and the South Coupled Shear Wall.

136. The concept of a shear wall protected gravity load structure has been discussed at various points in this hearing. It was based on treating the columns as secondary elements and designing them, and the beam-column connections, using the non-seismic provisions of NZS 3101:1982.

137. Mr John Henry gave evidence that the design of Landsborough House was based on the concept, although he took the step of designing additional reinforcement in some parts of the columns which exceeded the non-seismic provisions of the Code. Mr John Hare gave evidence that other engineers working in Christchurch at the time had also designed buildings using this interpretation of the Code.

138. The failure of the columns and beam-column connections was integral to the collapse of the CTV Building. Professor Priestley said that if the seismic provisions of NZS 3101:1982 had been applied '*the displacement capacities would have exceeded that predicted in the time history analysis and therefore the time history analysis would not have predicted failure.*'[124] Seismic detailing of the columns and beam-column connections may have prevented many deaths.

139. For this reason, the concept of a shear wall protected gravity load system and whether this did comply with Bylaw 105 needs to be considered. It is submitted that the application of this approach to the design of the CTV Building did not comply with Bylaw 105.

140. The concept is not referred to in the applicable Codes, at least in those terms. Nor is the expression 'gravity only columns' used. NZS 3101:1982 contains provisions regarding elements designed for seismic and non-seismic loading. There are provisions

[124] TRANS.20120712.4, L4-8

relating to members, such as columns that are not designed for seismic loading, but no reference to the term 'gravity only.'

141. The Codes refer to shear wall structures and also to ductile frames. NZS 3101:1982 also refers to ductile hybrid structures.[125]

142. The shear wall protected gravity load structure was, in effect, a hybrid structure. Professor Mander gave evidence that the CTV Building comprised a dual system made up of the shear walls and the frames.[126]

143. There is no guidance on the design of such a structure in either the Park and Paulay text or in the seminar attended by Mr Harding in 1986, the seminar that Dr Reay referred to as one of the grounds for his confidence that it was appropriate to give Mr Harding responsibility for the CTV Building structural design.

144. None of the papers from the 1986 seminar disclose assistance for a designer of a shear wall protected gravity load structure building. If anything, the papers demonstrate why the design should not have been used and why Mr Harding and Dr Reay should not have been attempting to use it.

145. There was a paper entitled 'The Design of Ductile Reinforced Concrete Walls for Earthquake Resistance' by Professor Paulay.[127] Had Mr Harding applied the principles set out in that paper he would have realised that the wall configuration on the CTV Building was flawed. The warnings as to variable wall response are well covered[128] and they contain the same diagrams and cautions from the 1980 paper by Paulay and Williams referred to by Dr Jacobs.

146. However, the paper specifically states that the structural contribution of other Building elements is not examined in this study. While the paper gave guidance on the design of walls, it gave no assistance on the behaviour of frames within a hybrid structure.

[125] Clause 3.5.8.1: ENG.STA.0016.26
[126] TRANS.20120724.84, L10-25
[127] BUI.MAD249.0519.98
[128] BUI.MAD249.0519.101

147. There was another paper entitled ‘The Capacity Design of Reinforced Concrete Hybrid Structures for Multistorey Buildings’ by Paulay and Goodsir.[129] This makes a number of pertinent points:

> When lateral load resistance is provided by the combined contributions of ductile multistorey frames and structural walls, the structure is often referred to as a 'hybrid structure.' In North America, the term 'dual system' is used. These structures combine the advantages of their constituent components. Because of the large stiffness of walls which are provided with adequate restraints at the foundations, excellent storey drift control may be obtained. Moreover, suitably designed walls can ensure that storey mechanisms (soft storeys) will not develop in any event. Interacting ductile frames on the other hand, while carrying the major part of the gravity load, can provide, when required, significant energy dissipation, particularly in the upper storeys.
>
> ...
>
> The traditional procedure of designing for earthquake resistance, utilising elastic analysis techniques and equivalent lateral static loads, is well-established. The resulting distribution of lateral load resistance over the height of Buildings with ductile frames, or structural walls, is generally accepted as meeting satisfactorily actual earthquake load demands. There was little evidence to indicate that this would be the case also with hybrid structures. One source of concern for possibly drastic differences between ‘elastic-static’ and ‘elasto-plastic dynamic’ responses of hybrid structures stems from the recognition of fundamental differences in the behaviour of beam-column frames and structural walls. These differences stem from dissimilar deformation patterns when subjected to the same lateral load... Frames and walls, while sharing in the resistance of shear forces in the lower storeys, oppose each other in the storeys near the top of the Building.[130]

148. The paper also notes:

> In the majority of reinforced concrete multi-storey Buildings, lateral load resistance is assigned to both ductile space frames and cantilevered structural walls.

149. The paper sets out a 19 step process relating to the capacity design of a hybrid shear wall-ductile frame structure.

[129] BUI.MAD249.0519.140
[130] BUI.MAD249.0519.140

150. The paper concludes by saying:

> (9) It is believed that the methodology proposed is logical and straightforward. It should provide Buildings so designed, and carefully detailed, with excellent seismic performance capability.
>
> (10) Using engineering judgement, the approach is capable of being extended to other structural configurations not covered in this paper, but only by consistent application of capacity design principles.
>
> (11) The excellent seismic behaviour of well-balanced interacting ductile frame-wall structures, particularly in terms of drift control and dispersal of energy dissipation mechanisms throughout the structural system, should encourage their extensive use in reinforced concrete Buildings.[131]

151. The absence of guidance in relation to a non-ductile frame/wall structure, together with the warnings set out in the article, illustrate:

    a. The incompatibility of such a structure with the obligations of avoiding collapse and minimising injury and death.

    b. The novelty of what Mr Harding was attempting to achieve; and

    c. The extent of his lack of competence to design such a Building.

(b) Should the areas of non-compliance have been identified by the CCC reviewing engineer

152. There is no longer any real dispute that when the CCC issued a building permit for the CTV Building it did not comply with Bylaw 105 and the Code. Any dispute is over the extent of the non-compliance.

153. During the course of the hearing the CCC took the position that most of the areas of non-compliance that had been identified were not ones that a CCC reviewing engineer could reasonably have been expected to identify. Both Dr O'Leary and Mr O'Loughlin were called by the CCC to support this.

154. Dr O'Leary's evidence was that the non-compliant parts of the CTV Building would have been difficult to pick up in the time available to the checking engineer and essentially would have required an extensive peer review which it was not able to do.[132]

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[131] BUI.MAD249.0519.154 and 155
[132] TRANS.20120813.21, L20 - .23, L6

155. Mr O'Loughlin took a similar position, describing the checking engineer's role as "*a scrutineer to look that the proper processes have been followed through*", not the designer.[133] His opinion was that the scope of a CCC reviewing engineer's role in the 1980s was limited, that for them to review drawings and calculations in detail was impractical and that their task was to check in general terms that matters had been dealt with by the designer.[134] They could be expected to pick up basic structural issues about the Building when they looked at it and that it was a shear wall protected gravity load system.[135]

156. In Mr O'Loughlin's opinion, this meant in the case of the CTV Building a CCC reviewing engineer could not have been expected to have identified any of the areas of non-compliance in the Building design which have now been identified, with the exception of the diaphragm connection.[136] Even then he did not consider that the review process could have been expected to pick up Mr Harding's clear error in dropping a zero in S57 of his calculations because a line by line review would not be carried out.[137]

157. Dr O'Leary agreed that the imbalance between the south shear wall and the North Core was something that a CCC reviewing engineer could be expected to note and that would then lead on to looking at the drawings and the calculations to see whether it was adequately accounted for in the design. He also agreed that one of the further enquiries that might follow was to look closely at the connection of those shear walls to the rest of the Building because that was a fundamental issue. In the case of the CTV Building the inadequacy of the connection between the diaphragm and the North Core would, if viewed closely, have been apparent.[138]

158. Mr O'Loughlin, describing the CTV Building as pioneering, said:

> …it would have stretched the capacity of the Council staff to fully understand how that building was working.[139]

159. Dr Reay by contrast repeatedly said:

    a. As a small firm he relied on the Council review process.[140]

[133] TRANS.20120814.113, L25-31
[134] TRANS.20120814.71, L1-6
[135] TRANS.20120814.88, L12-18
[136] TRANS.20120814.69, L12-27
[137] TRANS.20120814.69, L28 - .70, L4
[138] TRANS.20120813.42, L21-31
[139] TRANS.20120814.85, L30-33
[140] TRANS.20120731.111, L1-2

b. He expected the CCC to scrutinise ARCE's permit applications and relied on this.[141]

c. Because the CCC issued a building permit for the CTV Building it must have considered that the building complied with the relevant Codes/bylaws at that time…[142]

160. It is accepted that not all of the areas of non-compliance that this submission identifies in the next section are ones which a CCC reviewing engineer could reasonably have been expected to identify from the permit drawings and calculations. However, it is submitted that what could properly be expected and required of a CCC reviewing engineer at the time is considerably more than the CCC appeared to be contending, both by its reliance on the evidence of Mr O'Loughlin and by the line of questioning conducted by its counsel. As a matter of law, it was the CCC's obligation not to issue a permit for a non-compliant building, an issue that was the subject of a careful line of questioning by Justice Cooper.[143]

161. It is accepted that the responsibility for ensuring that a building is compliant with Code and with the CCC Bylaw No. 105 was principally on the structural designer and it would not be expected that a CCC reviewing engineer, would be involved in the fine detail of the design, particularly in the 1980s when the *evidence was that the CCC Building Department did not have its own computer systems that would enable it to check computer designed calculations. However, it is submitted that what can properly be expected of a CCC reviewing engineer was a high level of understanding of the way in which buildings work, an ability to read plans and understand calculations and to identify actual or potential areas of non-compliance, or uncertainty about compliance. In any areas of uncertainty the reviewing engineer would then be expected to refer matters back to the structural designer with a requirement that issues of concern be satisfied before a permit is issued.

162. In relation to the CTV Building it is submitted that this should have involved the CCC reviewing engineer identifying the following issues:

a. The asymmetry resulting from the location of the design of the North Shear Core and South Coupled Shear wall.

[141] TRANS.20120807.105, L1-2
[142] TRANS.20120815.19, L28-30
[143] TRANS.20120814.112, L2 - .114, L8

b. The inadequate connections between the diaphragms and the North Shear Core in both North-South and East-West directions, including all of the areas of non-compliance set out in the Code compliance section in relation to diaphragm connections.

c. The absence of complete calculations relating to the diaphragm connection and the error in which Mr Harding dropped a zero on page 557.

d. The fact that the Building was prone to torsion and the dangers resulting from this including unpredictable and excessive inter-storey drifts.

e. The inadequacy of non-seismic columns and beam-column connections to meet the requirement of Bylaw 105 in relation to this Building and the incorrect treatment of the columns as secondary elements.

f. The fact that the columns and beam-column connections were a risk to life in the event of failure.

g. The absence of sufficient calculations relating to the determination of v delta and whether the columns would be elastic at v delta.

h. The fact that, even if this could be properly treated as secondary elements, the columns and beam-column connections should have been designed with the seismic provisions of the Code as drift levels were likely to be excessive.

163. The CCC reviewing engineer for the CTV Building was Mr Graeme Tapper. Far from failing to recognise concerns with the CTV Building it is a matter of record that Mr Tapper did identify a number of issues, including most significantly a concern with the diaphragm connection to the North Shear Core. It was accepted in cross examination by both by both Dr Reay and Mr Geoff Banks that the issue regarding the diaphragm connection that Mr Tapper had identified in a letter of 27 August 1996 to Alan Reay Consulting Engineer would have been the issue that HCG identified in its January 1990 report.[144] This issue was in turn accepted by both Dr Reay and Mr Banks as what would now be referred to as a critical structural weakness.[145]

164. Mr Tapper also identified in that letter a concern with the “stirrups” on drawing, which is an issue with the rectangular columns on the west wall, an area that Professor Mander identified as a potential contributor in one of his collapse scenarios.

[144] TRANS.20120817.74, L16-17, 23-26 (Banks); TRANS.20120807.126, L5 - .127, L16
[145] TRANS.20120817.46, L2-3 (Banks); TRANS.20120807.120, L15-16 (Reay)

165. The general approach to review that was being taken by the CCC Building Control Department in the 1980s is known to the Royal Commission because Mr Peter Nichols, who gave evidence to the Royal Commission and was himself a CCC reviewing engineer during the 1980s, was able to provide an internal memorandum from Mr Bryan Bluck, who was at the time the head of the Building Control Department. It directs the CCC reviewing engineers on how they were to approach their task:

> "You are entitled to rely upon the recognized (sic) expertise of a Professional Designer who is prepared to certify under his signature that a specific design for a conventional or innovative structure (or detail), complies in all respects with the intent of the provisions of NZS 1900 Chapter 8."[146]

166. John Henry, who had also worked in the CCC building department between 1992 and 1995, gave evidence about the interplay between Bryan Bluck and Graeme Tapper and their respective positions on any challenge to building consents applications that was consistent with the approach set out in Mr Bluck's memorandum:

> So Bryan, his general way that he operated, and he always had operated was our job was to review. If you see something you are not happy with you're to query it. You get the answer back and you essentially if its reasonable leave it at that… and so you had Graeme Tapper who you might say was, not stubborn but wanting to stick to his guns, and Bryan saying, "You've got to live and let live and keep things moving through and get things issued, get these building consents out", 'cos holding them up was big pressure. And so that's the sort of difference in the way that they saw their roles. And as I say, both trying to do their best under the circumstances.[147]

167. While the general approach set out in Mr Bluck's memorandum is neither surprising nor a matter of concern, what is known of its application in the case of the CTV Building permit does raise concerns. This includes both the fact that it does not appear that Dr Reay's firm was required to provide a Design Certificate and Mr Henry's evidence that one of the considerations influencing Mr Bluck's approach was a response to "big pressure" if consents were held up.

168. Both Dr O'Leary and Mr O'Loughlin also made reference to the pressure that went onto the CCC checking staff in the 1980s as a result of the property boom. Mr O'Loughlin referred to the CCC being busier than normal and appeared to accept that this would

[146] BUI.MAD249.0267.1
[147] TRANS.20120802.56, L14 - .57, L4

have shortened the time that the reviewing engineers could have given to each job and this was to be accepted in setting the standard of review to which the CCC reviewing engineers were to be held. Mr O'Loughlin also referred to time being of the essence for developers who were borrowing at high rates of interest and who were in turn pushing their engineers to put pressure on the CCC to move permits through without delay.[148]

169. In addition to the evidence of the standards *actually* applied by Mr Tapper, which it is submitted sets an appropriate benchmark for the *expected* standard, at least in relation to identifying compliance issues, the Commission also heard from Mr Peter Nichols, about the CCC's checking standards in the 1980s. This evidence described a situation where, despite the time constraints and not having a computer system, the reviewing engineer was competent to look at a design and note areas of concern that warranted further investigation or justification by the designer.

170. Mr Nichols gave evidence of the process he followed, in identifying critical points in the structure that needed to be isolated for an independent check. He said that with experience he began to develop an "*intuitive familiarity*" for different building designs and those which were innovative or contained unfamiliar features would need to be enquired into further.[149]

171. Of particular interest, when he looked at the structural drawings of the CTV Building for the purpose of preparing his evidence he was very quickly struck by "*a complete mismatch in terms of load sharing*" between the North and South Shear walls.[150] This was something he said he would have been really concerned about had he been checking the design.[151]

172. Mr O'Loughlin also agreed under questioning that a good reviewing engineer would pick up the imbalance between the north and south shear walls and that would be enough for him to ask questions of the designer about what had been done in the design to address this.[152]

173. The evidence on the role of the reviewing engineer also addressed the use of Design Certificates as a basis for the CCC issuing a permit.

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[148] TRANS.20120814.97-98; TRANS.20120802.107-108 (Mr John Henry)
[149] TRANS.20120806.61, L7-12
[150] TRANS.20120806.78, L21
[151] TRANS.20120806.79, L7-8
[152] TRANS.20120814.92, L19 - .93, L30

174. Rather surprisingly the approach of the CCC at the time was to treat receipt of a Design Certificate or calculations as alternative ways of satisfying the reviewing engineer.[153] This can be seen in the letter of 27 August 1986 from Mr Tapper. The rationale for this was not made clear during the course of the hearing, and they seem to impose responsibility in entirely different places. The designer in the case of a Design Certificate and the reviewing engineer in the case of calculations. It is not clear why they would have been seen as alternatives

175. Mr Nichols confirmed that during his time with the CCC, if the design was certified by way of a Design Certificate, this was usually relied on and a permit issued.[154] No Design Certificate has been located for the CTV Building. Dr O'Leary stated that the way for the CCC to have met its obligations under Bylaw 105 was for it to have required a Design Certificate.[155]

176. Evidence was given that the CCC's position on whether it would accept a Design Certificate or require the calculations to be provided depended on who the design engineer was. Mr O'Loughlin's evidence was that the CCC recognised the strengths and weaknesses of various designers and modified its attitude towards Design Certificates on that basis. He thought this would take into account the checking systems within those offices to produce designs which were compliant with Bylaw 105.[156]

177. What has emerged from the evidence of how the CTV Building permit was dealt with is a number of unsatisfactory processes. The public might almost wonder why the CCC carried out a structural review of building designs at all, given the low level of skill it appeared to attribute to its own staff and their ability to identify design deficiencies or areas of non-compliance. The extent of the review which could be expected, as put forward by Dr O'Leary and Mr O'Loughlin, defended the CCC's failure to pick up most of the Code faults in this Building.

178. The CCC's decision to issue a permit for the CTV Building when it should not have done so has a number of significant flow on consequences during the period prior to the collapse. A number of subsequent decisions about the CTV Building were made on the flawed basis that the Building was compliant at the time of permitting. For example, the building consent application for *Going Places* in 2000, which triggered a Change of

[153] ENG.CCC.0044A.72
[154] TRANS.20120806.61, L18-25
[155] TRANS.20120813.23, L7 - .24, L4; TRANS.20120813.76, L11-17
[156] TRANS.20120814.100, L15 - .101, L4

Use under the Building Act 1991, was determined on the summary basis that the CTV Building was a "*relatively modern building*" and presumably complied with the Code.[157] When Madras Equities purchased the Building in 1990 Mr Ibbotson said that one of the reasons no structural review of the Building was commissioned prior to the purchase was that the Building had been built recently and signed off by the CCC.[158] When HCG did its 1990 report it to seemed to assume that apart from the one identified problem, it had been permitted and built to Code.[159] Finally, Dr Reay, Mr Harding and Mr Banks also claimed to have been reassured by the fact that a building permit had been issued.

179. It is apparent from a letter dated 27 August 1986 from Graeme Tapper, who was at the time was the Council's Deputy Building Engineer that a number of concerns had been identified by Mr Tapper as the reviewing engineer. This included a concern about the floor diaphragm connection that both Dr Reay and Mr Geoff Banks accepted would have been the floor diaphragm – North Shear Core connection that HCG identified in January 1990 as a weakness that could cause the Building to effectively separate in the event of an earthquake. Mr Tapper recorded these concerns in the 27 August letter following his receipt of information provided to the CCC with a permit application lodged on 17 July 1986.

180. Mr O'Loughlin gave evidence that it was not uncommon during the "boom" period of the mid 1980s for permit applications to be put in before all of the required documentation was completed in an effort to more rapidly progress the application and this appears to be what occurred with the CTV Building. It appears that it was not until after the permit application went in that the structural drawings were lodged with the CCC. These were received by the CCC on 26 August 1986 and Mr Tapper's letter of 27 August was a response to these.

181. A Document Transfer Form dated 5 September 1986 from Alan Reay's firm (signed by Mr Harding) to Mr Tapper records that the Council had been sent the structural drawings S1 to S39.[160] In addition calculations were provided relating to the Bondek structure. This is related to a fire rating issue that had become a matter of contention. Pages G78 and G79 were also forwarded to the CCC.

[157] BUI.MAD249.0151C.37
[158] TRANS.20120817.152, L12-18
[159] BUI.MAD249.0130.5
[160] BUI.MAD249.0141.1

182. On 10 September 1986 the structural design for the CTV Building was signed off by the CCC.[161] Mr Tapper initialled the structural sign off. A permit was then issued on 30 September 1986.[162]

183. Some of the concerns identified in Mr Tapper's letter had been dealt with by the time the permit was issued. This can be seen by reviewing the permit drawings. For example, S39 provided a number of the design details that Mr Tapper was asking for in his letter. However it is clear that not all of them were dealt with. In particular the concern Mr Tapper had expressed about the diaphragm connection shows no difference between the drawings Counsel Assisting received from Alan Reay and the permit drawings received from the CCC. Mr Tapper also referred to an issue with the stirrups in the columns and if, as seems likely, this was a concern about the level of confinement that did not change either.

184. Why then did Mr Tapper sign off on the structural design when one and possibly two significant issues of concern had not been addressed?

185. The Commission heard evidence from Mr Peter Nichols and from Mr Tapper's widow, Mrs Patricia (Pat) Tapper. The Commission also heard evidence from Mr John Henry, largely based on his experience while working as a CCC reviewing engineer from 1992 to 1995, regarding the interactions between Mr Tapper and Mr Bluck, who was the head of the Building Department and Dr Reay's dealings with Mr Bluck.

186. It is submitted that the effect of the evidence was that Dr Reay had gone over Mr Tapper's head to Mr Bryan Bluck and had convinced him it was appropriate for a building permit to issue for the CTV Building.

(c) 27 August 1986 letter from Graeme Tapper

187. Mr Tapper was the reviewing engineer on the CTV permit application. It is apparent from his letter of 27 August 1986 that he had a number of concerns with the CTV Building design, at least as shown in the documents lodged with the permit application which was put in on 17 July 1986. These concerns included a question about the floor diaphragm connection that both Dr Reay and Mr Geoff Banks accepted would have

[161] BUI.MAD249.0141.8
[162] BUI.MAD249.0141.6

been the floor diaphragm – North Shear Core connection that HCG identified in January 1990.[163]

188. Mr John O'Loughlin gave evidence that it was not uncommon during the boom period of the mid 1980s for permit applications to be put in before all of the required documentation was completed.[164] This was in an effort to more rapidly progress the application and this appears to be what had occurred with the CTV Building permit. It appears that it was not until 26 August 1986 that Mr Tapper received the structural drawings and his letter of 27 August was a response to his review of them.

189. A Document Transfer Form dated 5 September 1986 from Alan Reay's firm, which was signed by Mr Harding, was sent to Mr Tapper.[165] It records that the CCC had been sent the structural drawings S1 to S39. In addition calculations had been provided relating to the Bondek. This related to a fire rating issue that had become a matter of contention. Pages G78 and G79 were also forwarded to the CCC at the same time.

190. On 10 September 1986 the structural design for the CTV Building was signed off by the CCC.[166]

191. Some of the concerns identified in Mr Tapper's letter had been dealt with by the time the permit was issued. This can be seen by reviewing the permit drawings. S39 provided a number of the design details that Mr Tapper had asked for in his letter. The areas where it would appear changes were made in the permitted drawings were:

    a. Notes had been added to S9;

    b. Details of the stirrups had been added to columns noted on S14;

    c. Asbestos rope had been added for fire resistant rating purposes on S17;

    d. The size of fixing A on S23 is detailed on S39;

    e. The notes for S23 are referenced to S18;

    f. The reinforcing for the spandrel panels appears on S25;

    g. The fixing details for S25 appear on S39;

[163] TRANS.20120817.74, L16-20 (Banks); TRANS.20120807.124, L23- .127, L16 (Reay)
[164] TRANS.20120814.97- .98
[165] BUI.MAD249.0141.1
[166] BUI.MAD249.0141.8

h. There is additional information as to how the web is welded on S28;

i. Details of the weld plate size and type are on S39.

192. However not all of Mr Tapper's concerns had been met. In particular, the concern Mr Tapper had expressed about the diaphragm connection have not been addressed. In relation to this issue there is no difference between the drawings Counsel Assisting received from Alan Reay and the permit drawings received from the CCC. It is submitted that this is the issue that led Mr Tapper to make the comment that Mrs Tapper referred to in evidence, that the Building was an earthquake risk.[167]

193. The likelihood that Mr Tapper would have identified this issue and been alarmed by it is supported by the evidence from Mr Peter Nichols, who said that when he reviewed the permitted drawings in the course of preparing his evidence he was astonished at the weak appearance of diaphragm connection with 664 mesh and D12s at 400 centres, which he likened to the reinforcing for a house rather than a multi-storey office building.[168] Mr Nichols said he was not surprised that Graeme Tapper was concerned. Mr John Henry also said that the diaphragm connections caused him concern.[169]

194. Why it is that Mr Tapper signed off on the structural design, when at least one significant issue of concern to him had not been addressed, has raised an important issue in this hearing.

195. It is submitted that the answer to this lies in the evidence the Royal Commission has heard from Mr Peter Nichols, from Mr Tapper's widow Mrs Patricia (Pat) Tapper, and also from John Henry, Terry Horn, Leo O'Loughlin, Shane Fairmaid and Dr Reay. That evidence helps to put the evidence of Mr Nichols and Mrs Tapper into the context of the wider relationship between Graeme Tapper and Bryan Bluck, Graeme Tapper and Dr Reay and Bryan Bluck and Dr Reay.

196. It is submitted that the effect of this evidence all supports a submission that after receiving Mr Tapper's letter of 27 August 1986, with its indication that Mr Tapper was likely to hold up the issuing of a permit, Dr Reay went directly to Mr Bluck and persuaded him that it was appropriate for a building permit to be issued.

[167] TRANS.20120802.78, L1-4
[168] TRANS.20120806.65, L18-25
[169] TRANS.20120802.61, L21-23

197. The letter from Mr Tapper was addressed to "*Alan Reay Consulting Engineer*". Mr Harding gave evidence that all correspondence into the firm went through Dr Reay.[170] This was confirmed by both John Henry and Terry Horn.[171] Dr Reay said that mail coming into the firm was opened by a secretary and the letter might have been passed direct to David Harding, or if he had been given it he might simply have passed it on to David Harding himself without reading it.[172] However, it is unlikely that it would have been handed to David Harding by a secretary as David Harding's name was not listed in the letter as an addressee. It also seems unlikely in light of the evidence given by his staff regarding the control he exercised in the office and is inconsistent with the evidence about his reaction to designs from his office being questioned by Graeme Tapper.

198. Neither Dr Reay nor David Harding recalled the letter, but we know Mr Harding did see it because he put the notation on the top right hand corner of the letter "2503 rec'd 1/9/86" [173], 2503 being the file number allocated within the firm to the CTV matter. Mr Harding said he thought the letter would have been passed on to a draughtsman to address because he regarded the matters raised by Mr Tapper as draughting details that were missing. However this evidence was based on his normal practice and he did not have any memory of what happened after this particular letter was received.[174]

199. The fact that Dr Reay had no recall of receiving this letter or intervening direct with Mr Bluck is not surprising. There were many matters during the course of the hearing that Dr Reay was unable to recall. He was questioned on how he usually remembered things and this would not have stood out for him. It was clear from both his own evidence and that of others that he routinely dealt directly with Mr Bluck and went over the heads of Mr Tapper and other Building Department staff.

200. The letter from Mr Tapper has gone back to the CCC following receipt by Alan Reay Consulting Engineer. We know this because it was the CCC that provided Counsel Assisting with the original of that letter with the handwritten notation by Mr Harding that has just been referred to. Mr Harding could not explain how that happened and said that any dealings he had with the CCC were either by phone or by letter.[175]

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[170] TRANS.20120807.63, L10-18
[171] TRANS.20120802.67, L27- .68, L18 (Henry); TRANS.20120806.9, L29-30 (Horn)
[172] TRANS.20120807.88, L28- .89, L19; 103, L26- .104, L7; 117, L29-31
[173] TRANS.20120807.54, L17-21
[174] TRANS.20120807.54, L29- .55, L5; .65, L4 - .66, L11
[175] TRANS.20120807.67, L24-29; .68, L17-18

201. The evidence of both Mr Nichols and Mrs Tapper is hearsay. Under the Commissions of Inquiry Act 1908, section 4B(1), the Royal Commission has power to admit such evidence as it considers appropriate. However, because of the significance of this evidence for both the CCC and Dr Reay, it is appropriate to consider the way hearsay evidence is treated in the Evidence Act 2006. While the approach that a court would take under that Act is not binding on the Royal Commission it is a helpful guide.

202. The fundamental principle for the admissibility of evidence is that all relevant evidence is admissible: section 7. This includes hearsay evidence. Evidence is relevant in a proceeding if it has a tendency to prove or disprove anything that is of consequence to the determination of the proceedings: section 7(3)

203. Even if evidence is relevant a judge must still exclude it if its probative value is out-weighted by the risk that the evidence will have an unfairly prejudicial effect on the proceeding: section 8(1) The other limbs of section 8 are not relevant here.

204. Hearsay is dealt with specifically in sections 16, 17 and 18. Section 17 says that a hearsay statement is not admissible except as provided for in sub part 1 of Part 2 of the Act.

205. The general principle on the admissibility of hearsay statements is set out in section 18. A hearsay statement is admissible if the "circumstances" relating to the statement provide reasonable assurance that the statement is reliable: section 18(1)(a). The other provisions dealt with in section 18 are met here because both Mr Tapper and Mr Bluck are dead.

206. The meaning of the word "circumstances" as it used in section 18 is defined in section 16. Relevant "circumstances" in considering whether they provide a reasonable assurance that the statement is reliable are:

    (a) The nature of the statement;

    (b) The contents of the statement;

    (c) The circumstances that relate to the making of the statement;

    (d) Any circumstances that relate to the veracity of the person, and

    (e) Any circumstances that relate to the accuracy of the observation of the person.

207. The statutory list of "circumstances" will be examined more closely after considering the relevant evidence.

208. The evidence from Mr Nichols relevant to this issue begins at Transcript.20120806.61, L30. He says that at the time in question he was working for the Riccarton Borough Council. He heard through the engineers' grapevine that a new building in Christchurch had been the subject of some contention over the issuing of a building permit. He heard that Graeme Tapper and Bryan Bluck had been involved in what he described as a "…*particularly trenchant … fracas*"[176] concerning the issuing of a building permit. Mr Nichols said he was curious to know what the issue was and, as a result, one day when he was in the central City, he went to take a look at the CTV Building. This was about six months after he had first heard about this row between Messrs Bluck and Tapper.[177]

209. Mr Nichols said that he was standing on the footpath looking at the Building when Bryan Bluck came up to him. Mr Nichols said he commented to Mr Bluck that he had been studying the building and trying to understand how its structural mechanism worked because it was not a system he was familiar with and, in his opinion, it superficially appeared to lack substance. Mr Nichols said he commented to Mr Bluck that the Building appeared to lack any substantive lateral load restraint system in the south wall vertical plane.[178]

210. Mr Nichols said that in response Mr Bluck said that when he first saw the concept on the plans he had shared the concerns that Mr Nichols was expressing. He said it still gave that superficial appearance as the construction proceeded. According to Mr Nichols Mr Bluck then said that the building design incorporated a novel technological approach and while he had initially had misgivings about aspects of the design he had been convinced by Alan Reay that his reservations were unfounded.

211. Mr Nichols was very firm that Bryan Bluck had specifically mentioned Alan Reay.[179]

212. This evidence was not challenged in cross examination.

[176] TRANS.20120806.62, L5
[177] TRANS.20120806.62, L14-25
[178] TRANS.20120806.63, L13-24
[179] TRANS.20120806.63, L25-33

213. In cross-examination by Mr Rennie QC Mr Nichols said he understood that the "novel technological approach" to which Mr Bluck had referred was the way in which the shear wall gravity protected load system had been used in this building.[180]

214. The evidence from Mrs Tapper begins at TRANS.20120802.76, L20. She said:

a. Her husband was a person who never talked about his work at home. The one exception was the CTV Building. She acknowledged that at the time she was referring to it was not known as the CTV Building, but she believed that is the building that her husband was referring to.[181]

b. She said her husband had gone on and on about the CTV Building and while she had first thought this was because of Alan Reay, where there was a personality clash between Dr Reay and her husband, she came to realise that he was actually unhappy about the Building itself.[182]

c. She said he was never happy with the Building. His view was that there were earthquake risks in Christchurch, it was not a matter of if but when and when that happened he was concerned the CTV Building would not prove to be strong enough.[183]

d. Mrs Tapper said he also told her that he had not wanted to sign off the building, but he was under huge pressure to sign it off from Bryan Bluck and he was concerned about his job.[184]

e. Mrs Tapper also said she thought that the date on which her husband had this discussion with her was in 1986.[185] She also said that the building was in Madras Street and near the church they were married in.[186]

f. Finally she said her husband had told her that the building he was concerned about had been designed by Dr Alan Reay[187] and as he went out the door he had said to her he was going to a meeting and he might not have a job when he came home that night. She knew the meeting would be with Bryan Bluck and she

[180] TRANS.20120806.73, L10-31
[181] TRANS.2010812.77, L23-26
[182] TRANS.20120802.77, L28-31
[183] TRANS.20120802.78, L1-4
[184] TRANS.20120802.78, L6-9
[185] TRANS.20120802.80, L12
[186] TRANS.20120802.78, L25-26; .84, L5
[187] TRANS.20120802.79, L4-8

surmised that it was also going to be with Alan Reay, although she did not know this.[188]

215. In cross examination by Mr Rennie QC Mrs Tapper said that the events she had been describing covered only a week or so.[189] She also said that after her husband returned from the meeting that day he just nodded when she asked him whether he still had his job, but after that day he never really mentioned the issue again.[190]

216. Evidence was also received from Mr David Hutt which, it is submitted, puts to bed any possible doubts there might have been about whether Mr Tapper was referring to the CTV Building in his exchanges with his wife. Mr Hutt examined all possibly qualifying buildings in Madras Street in 1986 and the only one that could meet the description was the CTV Building

217. The evidence about the relationships between Mr Tapper, Mr Bluck and Dr Reay provide the background to, and, it is submitted, corroboration for, the evidence of Mr Nichols and Mrs Tapper.

218. The Commission heard evidence from Mr Henry, largely based on his experience while working as a CCC reviewing engineer from 1992 to 1995, regarding the interactions between Mr Tapper and Mr Bluck.

219. Mr Henry said it was not uncommon for ARCL's designs to be closely queried by Mr Tapper and that Dr Reay and ARCL did not like Mr Tapper's close scrutiny of their work.[191]

220. Mr Henry said Mr Tapper maintained high professional and ethical standards and had little tolerance for consulting engineers who submitted poor details or incomplete work. This, he said, would often result in difficult situations which Mr Bluck then had to deal with.[192]

221. The situation Mr Henry described was one that he said was existing when he joined the CCC in 1992.[193]

[188] TRANS.20120802.80, L1-7
[189] TRANS.20120802.81, L21
[190] TRANS.20120802.81, L24-26
[191] TRANS.20120802.52, L20-24
[192] TRANS.20120802.59, L18-21
[193] TRANS.20120802.57, L13

222. Mr Leo O'Loughlin gave evidence that he had heard "heated debate on the pros and cons of jobs" between Messrs Tapper and Bluck.[194]

223. Mr Henry described the stand-offs that occurred between them in much more graphic terms and that Mr Tapper would sometimes have to go to the sick bay afterwards to recover.[195]

224. In relation to how Dr Reay would deal with issues which Mr Tapper might raise, evidence was given by Mr Henry and Mr Horn of their experiences.

225. Mr Henry said it was not uncommon for Dr Reay to go over Mr Tapper's head to Mr Bluck when he could not get Mr Tapper's approval for a building consent.[196]

226. Mr Bluck would come in agitated from communications with Dr Reay which resulted in very heated arguments.[197]

227. Mr Horn described how Dr Reay's frustration with Mr Tapper led him to refer to Mr Tapper as the "Colonel". He said Dr Reay had a practice of resolving issues with Mr Tapper by effectively going over his head to Mr Bluck. He recalled this as a general occurrence.[198]

228. It should be noted that Dr Reay said that he could not recall the conversation with Mr Bluck to which Mr Nichols referred and did not believe it could have occurred as if he had spoken to Mr Bluck he would have taken Mr Harding with him.[199]

229. It is submitted that the evidence of the various relationships referred to above, together with the evidence of Mr Nichols and Mrs Tapper supports the following conclusions:

    a. Designs were likely to receive close scrutiny from Mr Tapper, particularly those from Dr Reay's office.

    b. Mr Tapper raised an issue in relation to the connections between the North shear core and the floor slabs which had a direct bearing on the gravity protected shear wall load protection system used by the building.

[194] TRANS.20120802.41, L19
[195] TRANS.20120802.56, L1-4
[196] TRANS.20120802.52, L24-26
[197] TRANS.20120802.55, L17- .57, L5; TRANS.20120802.58, L25-29
[198] TRANS.20120806.10, L1-28
[199] TRANS.20120807.113, L13-15, 25-28

c. That issue was not resolved as the lack of connection is apparent on the permitted plans.

d. Given the significance of this issue, it is unlikely to have been accepted by Mr Tapper without substantial resistance.

e. Such an issue is therefore likely to have resulted in the involvement of Dr Reay who, on the evidence, would have seen the "Tapper letter".

f. We also know from the fact that the "Tapper letter" provided to the Royal Commission by the CCC is the original (with Mr Harding's writing on the top right-hand corner) that it must have been taken from ARCE's office to the CCC subsequent to its receipt.

g. The only likely candidates for delivery of that letter are Dr Reay or Mr Harding.

h. Mr Tapper's resistance to signing off the permit was likely to have been met by intervention from Mr Bluck.

i. That intervention would, on past history, have come about from Dr Reay's involvement.

j. It would only have been as a result of Mr Bluck putting pressure on Mr Tapper, that Mr Tapper would then have signed off the permit application.

k. Mr Bluck's acceptance of assurances from Dr Reay would be consistent with the memorandum to which Mr Nichols referred.

119. It is submitted that the relevant circumstances do provide a reasonable assurance that the statements are reliable in terms of sections 16 and 18 of the evidence:

a. The circumstances for both Mr Nichols and Mrs Tapper were such that the conversations were clearly recalled.

b. Mr Nichols had heard about a disagreement between Messrs Tapper and Bluck and had decided to look at the building he understood to have been the cause of this disagreement. It was as he was doing this that Mr Bluck appeared and the conversation occurred.

c. Mrs Tapper said her husband never discussed his work at home and the CTV Building was the only exception to this. He mentioned it a number of times because of the particular concerns he had.

d. There was no issue taken with the veracity of Mr Nichols or Mrs Tapper.

e. There did not appear to have been any suggestion of embellishment in the recounting of the conversations.

The collapse causes: ARCL's theories

230. The various collapse causes identified by counsel for Dr Reay and his firm, and put forward by witnesses called on their behalf, were outlined in the introduction to this submission, at paragraph 9. They have been considered in the process of reaching the conclusions on the defects in the Building, and the contribution they may have made to the collapse, that have already been set out. They require no more consideration, apart from two specific issues that will be dealt with momentarily.

231. Five collapse scenarios were referred to by Dr Reay when he first gave evidence.[200] In the course of cross examination he accepted he was putting them forward as no more than possibilities.[201] He had done no research or analysis on them himself.[202] It appeared he was looking to the Royal Commission to do that work itself. To the extent they warranted this, the Royal Commission has heard evidence on them and given close attention to them. For example, the issue about the lateral load resistance of the SCSW. In respect of other matters such as the vertical accelerations to which the CTV Building was subjected on 22 February, an issue on which both Mr Harding and Dr Reay and a number of the witnesses called by his legal team sought to place principal responsibility, while those vertical forces may well have had a contributing role, the exact vertical forces to which the Building was subjected are not known. Particular features of the Building would have had an affect on this even if these vertical forces had been able to be precisely measured, which they were not.[203] What is known is that the serious design defects in the Building made the Building vulnerable and this was accepted by most of the expert witnesses who dealt with this issue.[204]

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[200] TRANS.20120712.102,L21 - .106, L15
[201] TRANS.20120712.114
[202] TRANS.20120712.113, L10-19
[203] TRANS.20120724.49, L15 - .51, L18
[204] TRANS.20120711.50, L6-12 (Professor Nigel Priestley); TRANS.20120724.49, L8-14 (Professor John Mander); TRANS.20120725.7, L24-29; - .8, L7-17 (Dr Brendon Bradley)

232. Professor Mander's interesting hypothesis on Euler buckling and related issues identified several of the critical structural weaknesses that have been dealt with in this submission, including beam-column joints which he regarded as particularly significant.[205] These submissions have not taken a position on whether his Euler buckling hypothesis is correct because is has not been necessary to do so. Professor Mander agreed in the course of his evidence that it was just another theory.

233. The only four remaining issues that need to be addressed is the evidence from Daniel Morris alleging the drilling of holes in the CTV Building concrete beams during the 1990s, the installation of an internal staircase between CTV levels 1 and 2 in 2000, the change of use involved in *Going Places* going into occupancy in 2001 and the issue of understrength concrete.

(a) The evidence of Mr Morris

234. One of the theories proffered by Dr Reay was that the structural integrity of the CTV Building could have been compromised as a result of holes drilled in its beams. If this had been correct, this theory may have gained some traction. Instead it simply provided some light relief at the hearing.

235. The theory rested on the evidence of Mr Daniel Morris, a former concrete cutter. Unfortunately the evidence lacked all credibility. On Mr Morris' own admission, he could not provide any firm detail about the supposed holes that may have been drilled. This lack of all credibility and reliability was best illustrated in a question put to Professor Nigel Priestley by Mr Hugh Rennie QC:

> … there is some evidence suggestive that an unknown number of holes of an unknown number of dimensions were drilled on dates not precisely known in the late 1990s in the floor and/or the beams for cabling purposes.[206]

236. There is no need to say anything further about this theory.

(b) The Internal Staircase

237. Another contributor to the collapse suggested by Dr Reay was the installation in 2000 of an internal staircase between Levels 1 and 2 at the south end of the Building. Dr Reay noted that the structural drawings, done by Falloon and Wilson Limited, showed that the staircase was installed by cutting through floors at the eastern end of the South

[205] TRANS.20120723.63, L21-22
[206] TRANS.20120712.51, L13-16

Coupled Shear Wall and expressed concern about the potential effects on the south wall and on the overall structure.[207]

238. Mr David Falloon, the principal of Falloon and Wilson who signed the Design Certificate provided to the CCC for this work, gave evidence that he reviewed the design for vertical loads and carried out calculations to determine the size of the steel trimmer beams required to support the edges of the floor around the opening, but did not perform any calculations to check the lateral load paths from the floor diaphragm because the area cut out for the stair opening was only a small proportion of the total floor area. Mr Falloon considered that the remainder of the floor diaphragms available to transfer lateral loads to the shear walls was sufficient and, in any event, Level 2 would not attract as much lateral action through the floor as the upper levels.[208]

239. Mr Ashley Smith, in his reply evidence, said that the internal staircase penetration was modelled in the original NLTHA prepared for the DBH report and was considered adequate to transfer seismic forces into the shear wall.[209]

240. The Royal Commission's international peer reviewer Mr William Holmes undertook a review of the effect of this work by carrying out full calculations and concluded that the installation of the staircase at Level 2 and the required penetration to the floor slab at Level 2 had no effect on the transfer of seismic loads to the south wall.[210]

241. Mr Holmes' evidence was not challenged by counsel for Dr Reay and his firm. It is submitted that this is another issue that does not require any further consideration by the Royal Commission.

(c) Change of use

242. Dr Reay also suggested the CCC's failure to properly address the change of use when *Going Places* went into the Building in 2001 was another contributor to the collapse. Dr Reay contended that the seismic and gravity loading requirements for the CTV Building had increased since the Building was designed, although this was disputed by Dr O'Leary[211].

[207] TRANS.20120712.105, L22-25
[208] TRANS.20120725.81, L25- .82, L3
[209] WIT.ASMITH.0006.15
[210] WIT.HOLMES.0001.5
[211] WIT.OLEARY.0003.2-4

243. In its Opening Submissions, the CCC said:

> It seems clear that there would have been increased loading standards for the building compared to a new one built at the same site, but the risk factor itself did not on the basis set out above, increase with the change of use.[212]

244. The *Going Places* tenancy was treated by the CCC as a change in use from office to school. The effect of section 46(2) of the Building Act 1991 was that the use of the Building should not have been changed unless the CCC was satisfied on reasonable grounds that the Building would in its new use comply with structural requirements "*as nearly as is reasonably practicable to the same extent as if it were a new building*".[213]

245. In 2001 when the CCC considered this issue there was a different loadings code to that applicable in 1986. There were also increased minimum requirements for the transverse reinforcement of columns. In addition, although the CCC was unaware of this, the Building was non-compliant in a number of respects. This included the critical structural weakness in the diaphragm connection to the North Shear Core.

246. As a result the Building did not comply with the Code to the same extent as a new building would have done at the date on which the *Going Places* occupancy was being considered by the CCC. Accordingly the question for the CCC was whether it could satisfy itself on reasonable grounds that the Building complied "*as nearly as is reasonably practicable*". The submission is that the CCC did not meet this requirement.

247. Counsel for the CCC said in opening:

> There is no contemporaneous record as to how the Council addressed this particular issue apart from the Council structural checklist.[214]

248. There is no reason to conclude that this checklist, which is the only contemporaneous record, is anything other than an accurate record of the basis on which the CCC made its decision.

249. According to the checklist, the reason for the CCC reaching its conclusion that the Building complied as nearly and as reasonably practicable was, "*reasonable (sic) modern 1986…shear wall building – OK*."[215]

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[212] TRANS.20120806.OS.21
[213] ENG.NZP.0001.20
[214] TRANS.20120806.OS.21
[215] BUI.MAD249.0151C.37

250. Mr McCarthy said in evidence that buildings built after 1976 were considered to be equivalent to two-thirds of the applicable design code in 2000[216], although that rule relied on the Building being compliant at the time it was designed and built. It was accepted by Dr O'Leary that in 1995 the Loadings Code introduced a new requirement for transverse reinforcement in columns, but no alteration to the CTV Building's columns was required in 2000.

251. Mr McCarthy's evidence was that the CCC engineer considering this application would have been aware of this but this is entirely speculative and no weight should be given to it, particularly when there is a contemporaneous record.[217] Equally his contention that the decision recorded in the checklist would have included consideration of the fact that the CCC did not *require* anything to be done at that time, to upgrade to the new loading standard.

252. It is submitted that the CCC did not have reasonable grounds to conclude that the Building would in its new use comply with structural requirements as nearly as is reasonably practicable to the same extent as if it were a new building. There is no evidence of any consideration other than what is recorded in the checklist and this is limited to the age and general type of building.

253. There was no evidence that the CCC considered:

    a. Differences between the applicable Codes at the time of the permit and those at the time of the application for change of use and the relevance of these changes to the proposed new activity (here *Going Places*).

    b. The way these differences might impact on the performance of the Building in an earthquake.

    c. The ways in which these differences could be addressed. In particular, there is no evidence that the CCC considered the possibility of strengthening the columns.

254. Mr Rennie QC described the CCC process for the *Going Places* application as a "*missed opportunity in the history of this unfortunate building*".[218]

[216] TRANS.20120807.21, L19-22
[217] TRANS.20120807.21, L28-32
[218] TRANS.20120709.158, L22

255. In one sense this is correct. In hindsight it takes on a significance it would not have been seen to have had at the time, but it is another event in the history of this Building that highlights the on-going consequences of issuing a permit to a non-compliant building. Assumptions continued to be made about the expected performance of the Building based on the erroneous assumption that it had been Code compliant in 1986.

256. However, the irony of Dr Reay and his firm seeking to raise the CCC's failure to deflect responsibility should not be overlooked. By 2001 Dr Reay knew that there was a critical structural weakness in the Building and it would not have been Code compliant in 1986. If a building consent had been sought for the drag bar retrofit in 1991 the CCC would have been aware of this and it is quite likely that it would have dealt differently with the change of use.

(d) Understrength concrete

257. Although the issue of concrete strength in the columns is one that assumed considerable importance in the Hyland-Smith report, before the Royal Commission it has dropped away. Dr James MacKechnie, the independent expert engaged by Counsel Assisting to consider this issue, largely agreed with the conclusions reached by the experts engaged by Dr Reay and his firm with regard to the methodology that had been followed by Hyland and Smith for testing. This meant that on the evidence then available to the Royal Commission it would not be possible to reach a firm conclusion on concrete strength.

Code Compliance and Best Practice

258. The Royal Commission's ToR require it to consider the following issue in relation to the CTV Building:

> (i) whether the CTV Building (as originally designed and constructed and, if applicable, as altered and maintained) complied with earthquake-risk and other legal and best-practice requirements (if any) that were current-
>
> (A) when those Buildings were designed and constructed; and
>
> (B) on or before 4 September 2010...

259. This section of the submissions will address the question of whether the CTV Building complied with legal and best practice requirements relating to earthquake risk.

260. In *summary, it is submitted that:*

a. There are three crucial respects in which the Building did not comply with legal requirements:

i. Building symmetry.

ii. Connections between the diaphragms and the North Shear Core.

iii. Reinforcement of columns and beam-column connections.

b. There are other respects in which the Building did not comply with legal requirements.

c. The Building did not comply with these legal requirements at the time a permit was granted.

d. Notwithstanding the retrofit in 1991, the Building did not comply with these requirements on or before 4 September 2010.

e. The Building did not comply with best practice at the time of design in a number of ways. Of greatest concern is that it did not provide an adequate load path to transfer earthquake forces into the foundations and then dissipate them into the ground.

261. Compliance with legal and best practice requirements will be addressed in the following order:

a. Part 1: The applicable legal requirements at the time the permit was granted:

i. Bylaw 105.

ii. The status and effect of NZS 4203:1984 and NZS 3101:1982.

iii. The interpretation of clause 11.1.5(d) of the Bylaw.

iv. Some important design principles:

1. Ductility.

2. Capacity design.

b. Part 2: Non-compliance with Bylaw 105:

v. Areas of particular relevance to the collapse.

vi. Areas of less relevance to the collapse.

c. Part 3: Non-compliance with best practice

Part 1: Legal Requirements at the time the permit was granted

(a) Summary of applicable legal requirements

262. The first section of these submissions addresses the legal requirements applicable at the time the CTV Building was designed and permitted.

263. *In summary, it is submitted that the legal position at the time was*:

a. *Bylaw 105 set out the legal requirements applicable to the design of the CTV Building.*

b. *The most fundamental and important legal obligations Mr Harding faced were set out in clause 11.1.5(d) of the Bylaw:*

vii. *Collapse shall be avoided.*

viii. *The probability of injury or loss of life shall be minimised.*

c. *NZS 4203:1984 was a means by which compliance with these requirements could be deemed to have occurred, subject to proof to the contrary.*

d. *NZS 4203:1984 contained provisions which, if followed, would have led to compliance with clause 11.1.5(d):*

ix. *The requirement for symmetry.*

x. *The requirement that the Building as a whole and all of its elements that resist seismic forces or movements, or that in case of failure were a risk to life, were required to be designed to possess ductility.*

e. *These requirements as to symmetry and ductility were in the Bylaw as well. This is significant, because not every part of NZS 4203 was given legal force in this way.*

f. *NZS 3101:1982 was a means of compliance with Part 8 of the Bylaw, which related to the design of concrete elements. However, NZS 3101:1982 was not a means of compliance with requirements relating to the general structural design method set out in clause 11.1.5.*

g. *To the extent that NZS 4203:1984 or NZS 3101:1982 contradicted or failed to fulfill the critical requirements of clause 11.1.5(d), compliance with the Codes was not sufficient to comply with the Bylaw.*

264. It was not sufficient for an engineer to just ‘follow the Code’ without giving any consideration to the requirements of the Bylaw.

(b) Bylaw 105

265. The obligations of an engineer at the time of design of the CTV Building are a question of law. The applicable law is set out in Bylaw 105.

266. The CCC made Bylaw 105 (1985) using the powers vested in it under the Local Government Act 1974 and the Standards Act 1965. The Bylaw came into force on 1 December 1985.

267. Clause 5 of the 'Introduction' said:

> **Acceptance means of compliance with the provisions of this bylaw**
> Proof of compliance with the specifications, standards and appendices named in the second schedule shall be deemed to be in the absence of proof to the contrary sufficient evidence that the relevant degree of compliance required by this bylaw is satisfied.
>
> Specifications, standards and appendices named in the second schedule are not part of this Bylaw.

268. The substance of the Bylaw was contained in the First Schedule, in which there were 12 Parts.

269. Part 11 was entitled, 'General Structural Design and Design Loading.'

270. Clause 11.1.3 stated:

> In this bylaw the word "shall" indicates a requirement that is to be adopted in order to comply with the bylaw.

271. Clause 11, which was entitled 'Objective and Application,' included the following:

> 11.1.5 The general structural design method (as distinct from detailed design appropriate to particular construction materials as required elsewhere in this Bylaw) and the design loadings shall be recognised as appropriate upon achieving the following:
>
> (a) All loads likely to be sustained during the life of the Building shall be sustained with an adequate margin of safety.
>
> (b) Deformations of the Building shall not exceed acceptable levels.

(c) In events that occur occasionally such as moderate earthquakes and severe winds structural damage should be avoided and other damage minimised.

(d) In events that seldom occur, such as major earthquakes and extreme winds, collapse and irreparable damage shall be avoided, and the probability of injury to or loss of life of people in and around the Building shall be minimised.

11.1.6 General structural design and design loadings complying with NZS 4203 shall be approved as complying with the requirements of clause 11.1.5.

272. Clause 11.2.5.2, which was entitled 'Earthquake Provisions,' included the following:

11.2.5.1 Symmetry

The main elements of a Building that resist seismic forces shall, as nearly as is practicable, be located symmetrically about the centre of mass of the Building.

11.2.5.2 Ductility

(a) The Building as a whole and all of its elements that resist seismic forces or movements, or that in the cause of failure are a risk to life, shall be designed to possess ductility; provided that this shall not apply to small Buildings having a total floor area not exceeding 140m2 and having a total height not exceeding 9m.

(b) Structural systems intended to dissipate seismic energy by ductile yielding shall have "adequate ductility".

(c) "Adequate ductility" in terms of clause (b) shall be considered to have been provided if all primary elements resisting seismic forces are detailed in accordance with special requirements for ductile detailing in the appropriate material Code.

273. The Interpretation Act 1999 applies to 'enactments.[219] An 'enactment' is defined as 'the whole or a portion of an Act or Regulation.[220] The definition of 'regulation' includes bylaws.[221]

274. The Interpretation Act 1999 therefore applies to the interpretation of Bylaw 105.

(c) The Codes

275. Schedule 2 of Bylaw 105 included the following Codes:

a. NZS 4203:1984- *Code of Practice for General Structural Design and Design Loadings for Buildings*.

[219] Section 4
[220] Section 29
[221] Section 29

b. NZS 3101 Part 1:1982- *Code of Practice for the Design of Concrete Structures*.

c. NZS 3101 Part 2:1982- *Commentary on the Design of Concrete Structures*.

276. Clause C1.1 of NZS 4203:1984 (which was a commentary clause) stated:

> This standard aims at setting down minimum requirements for the general run of Buildings…[222]

277. Pursuant to clause 5 of the Introduction to Bylaw 105, compliance with these and other Codes was deemed, in the absence of proof to the contrary, to be sufficient evidence of compliance with the Bylaw.

278. The result is a clear distinction between the Bylaw and the Codes. The Bylaw set out the law, while the Codes set out a means of compliance. Although compliance with the Codes was deemed to be compliance with the Bylaw, it was subject to proof to the contrary.

279. The effect of this is that the Codes did not prescribe the law. The Bylaw did this. Any provisions of the Codes which conflicted with the Bylaw were incapable of satisfying the Bylaw.

(d) Compliance with NZS 3101:1982 as a means of compliance with the Bylaw

280. Part 8 of the Bylaw was entitled 'Concrete.' Clause 8.4 was entitled 'Means of Compliance,' and included the following:

> **8.4.1 Design**
>
> Concrete elements designed in accordance with the requirements of NZ 3101 or a recognised equivalent standard shall be deemed to comply with the requirements of this bylaw.

281. Clause 11.1.5 in Part 11 of the Bylaw identified a distinction between, 'the general structural design method' and 'detailed design appropriate to particular construction materials as required elsewhere in this bylaw.' It is submitted that the design of concrete elements dealt with in Part 8 fell into the latter category. Dr Jacobs agreed with this.[223]

[222] ENG.STA.0018.16
[223] TRANS.20120809.57, L15-29

282. This distinction assumes particular importance given that Dr Reay now relies upon the columns being defined as 'secondary elements.' Secondary elements are not to be found in NZS 4203. They appear in clause 3.5.14 of NZS 3101:1982.

283. It is submitted that NZS 3101:1982 was a means of compliance with the requirements of Part 8 of the bylaw in relation to the design of concrete elements. However, compliance with NZS 3101 was not a means of satisfying the general structural design methods and requirements set out in clause 11.1.5. This is confirmed by:

    a. Clause 11.1.6 in which the general structural design and design loadings complying with NZS 4203 would be approved as complying with that requirement.

    b. Clause 1.1.1.1 of NZS 4203:1984, which stated:

> This standard sets out requirements for general structural design (as distinct from detailed design appropriate to particular construction materials) and design loadings for Buildings, and is approved as a means of compliance with the relevant requirements of NZS 1900.

(e) Relationship between the Codes

284. In interpreting the two Codes that applied to the CTV Building, NZS 3101:1982 and NZS 4203:1984, an understanding of the origin and structure of the two codes is an important aid to interpretation.

285. The Codes are the result of ongoing research and industry discussion. As a result, various Codes would leapfrog each other in recording what was considered to be required practice from time to time. For example, NZS 3101:1982 applied for a period of time during which NZS 4203:1975 was current. The latter was then superseded by NZS 4203:1984, which applied at the time the CTV Building was designed.

286. Importantly, C1 .1 of NZS 4203:1984 stated:

> Pending the revision of various other New Zealand standards, this standard should be regarded as the "master document" with other standards, where appropriate, subject to it.

287. The Foreword to NZS 4203:1984 included the following note:

> This edition incorporates Amendment No 3. Among the Amendment's more significant contributions is an upgrading of the section dealing with

> earthquake provisions. It also irons out any parts of the Loadings Code that happened to conflict with the various materials Codes.
>
> Rather than merely issuing an amendment slip, it was decided the extent of Amendment No 3 warranted a reprint of NZS 4203.

288. The Foreword to NZS 3101:1982 stated that section 3 (which set out General Design Requirements) had a particular importance because it established the relationship between the 1982 Code and the 1984 Code. It also stated:[224]

> It should be noted that some provisions in this Code are based on proposed amendments to NZS 4203 which at the time of publication are being finalised.

289. Clause C3.5 of the Commentary to NZS 3101:1982 stated:

> The earthquake loading, principles of seismic design, recommended analysis procedures and several other aspects of earthquake structural engineering are documented in detail in NZS 4203. Therefore the commentary of NZS 4203 should also be consulted when applying this Code.

290. It is submitted that these provisions establish the principle that in interpreting the two Codes NZS 4203:1984 is to prevail over NZS 3101:1982 where there is inconsistency. This seems unsurprising where NZS 4203:1984 is concerned with general loading standards that apply to all of the materials codes and NZS 3101:1982 is concerned only with the use of concrete. Some parts of the 1982 Code were apparently made in anticipation of the 1984 Code, and the 1984 Code was then stated to be a 'master document.'

291. Both the 1984 Code and the 1982 Code contained the following:

> …the word "shall" indicates a requirement that is to be adopted in order to comply with the standard, while the word "should" indicates a recommended practice. [225]

(f) Clause 11.1.5(d) of Bylaw 105

292. The interpretation of Bylaw 105 and the extent to which compliance with the Bylaw might have been effected by application of the Codes assumes particular importance in relation to clause 11.1.5 (d) of the Bylaw.

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[224] 1982 Code, page 12
[225] Clause 1.1.2.1 of the 1984 Code and clause 1.2.1 of the 1982 Code

293. This clause set out a central and fundamental obligation in relation to the design of a Building. The clause stated:

> In events that seldom occur, such as major earthquakes and extreme winds, collapse and irreparable damage shall be avoided, and the probability of injury to or loss of life of people in and around the Building shall be minimised.

294. Clause 11.1.6 said:

> General structural design and design loadings complying with NZS 4203 shall be approved as complying with the requirements of clause 11.1.5.

295. Clause 11.1.5 included two key requirements namely:

a. Collapse shall be avoided.
b. The probability of injury or loss of life shall be minimised.

296. Use of the word 'shall' makes it clear that the requirements were mandatory.

297. Section 5(1) of the Interpretation Act 1999 states:

> The meaning of an enactment must be ascertained from its text and in the light of its purpose.

298. It is submitted that the text of clause 11.1.5 (d) demonstrates a very clear purpose. In particular, the clause made it clear to designing engineers that:

a. They must be conscious of the possibility of building collapse.
b. They must design the building so that collapse was avoided.
c. They must be conscious that injury or loss of life could occur to those inside and outside a building.
d. They must minimise the probability of such injury or loss of life occurring.

299. NZS 4203 included a number of provisions by which these objectives could be achieved. They included:

a. The requirement of symmetry in clause 3.1.
b. The requirement of ductility in clause 3.2.
c. The definition of ‘primary elements,’ which directed the designer’s attention to certain important parts of the Building:

> PRIMARY ELEMENTS means elements forming part of the basic load resisting structure, such as beams, columns, diaphragms, or shear walls necessary for the Building's survival when subjected to the specified loadings.

d. The use of capacity design.

300. It should be noted that the loads the Building would have been subjected to on 22 February 2011 exceeded the maximum Code loads. However, this does not mean that collapse would have been inevitable. Compliance with clause 11.1.5(d) could have led to design decisions which prevented catastrophic collapse.

(g) Ductility

301. The requirement for ductility was a prominent feature of Bylaw 105 and NZS 4203:1984. The importance of ductility was emphasised by Park and Paulay in the *Reinforced Concrete Structures,*[226] for example:

> It is important to ensure that in the extreme event of a structure being loaded to failure, it will behave in a ductile manner. This means ensuring that the structure will not fail in a brittle fashion without warning but will be capable of large deformations at near-maximum load carrying capacity. The large deflections at near-maximum load give ample warning of failure, and by maintaining load carrying capacity, total collapse may be prevented and lives saved...[227]

302. Clause 11.2.5.2 of the Bylaw stated:

> **11.2.5.2 Ductility**
>
> (d) The Building as a whole and all of its elements that resist seismic forces or movements, or that in the case of failure are a risk to life, shall be designed to possess ductility; <u>provided that this shall not apply to small Buildings having a total floor area not exceeding 140m2 and having a total height not exceeding 9m.</u> *(underline added)*
>
> (e) Structural systems intended to dissipate seismic energy by ductile yielding shall have "adequate ductility".
>
> (f) "Adequate ductility" in terms of clause (b) shall be considered to have been provided if all primary elements resisting seismic forces are detailed in

[226] Park T and Paulay T, John Wiley & Sons, 1975
[227] Page 7

> accordance with special requirements for ductile detailing in the appropriate material Code.

303. Clause 11.2.5.2 is identical to clause 3.2 of NZS 4203:1984 except that the underlined passage does not appear in the latter and the following appears in its place:

> …provided that this shall not apply to small Buildings complying with clause 3.4.8.1 designed in accordance with clause 3.4.8.2 nor to tied veneers (item 3 (b) of table 8) and unreinforced or partially reinforced walls and partitions (item 4 of table 8) designed in accordance with clause 3.4.9

304. Although there is reference to clause 3.4.8, that clause was actually deleted from NZS 4203:1984.[228]

305. Ductility was defined in clause 1.1.3.1 of NZS 4203:1984 as:

> The ability of the building or member to undergo repeated and reversing inelastic deflections beyond the point of first yield while maintaining a substantial proportion of its initial maximum load carrying capacity.[229]

306. There was disagreement between members of the DBH expert panel about the meaning of ductility, especially given that the Commentary to clause 3.2 of NZS 4203 contains a lengthy discussion of the ductility requirement.[230] It is submitted that there is no need to engage in this debate as the Bylaw, and not the Code, sets out the legal requirements for ductility.

307. It is accepted that it could be argued that the 'members not designed for seismic loading' set out in NZS 3101:1982 contained some degree of ductility. However, this was nowhere near the level of ductility provided by the seismic provisions of the Code.

308. It is submitted that clause 11.2.5.2 of the Bylaw makes it clear how much ductility the CTV Building was required to possess. The Building was designed to dissipate seismic energy by ductile yielding. It was therefore required to have 'adequate ductility.' Adequate ductility would have been provided where the special requirements for ductile detailing in NZS 3101:1982 (i.e. the seismic loading provisions) were met. They were not.

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[228] ENG.STA.0018.54
[229] ENG.STA.0018.17
[230] ENG.STA.0018.38

309. Another issue implied by some questioning of witnesses by counsel for Dr Reay and the Council was why NZS 3101 contained provisions for 'non-seismic' columns if it was impermissible for a designer to use them at all.

310. It is submitted that the answer to this question is also provided by clause 11.2.5.2 of the Bylaw. The ductility requirements applicable to Buildings did not apply to small buildings. 'Non-seismic' columns would have been permissible in such a building. Mr Smith agreed with this.[231]

(h) Capacity Design

311. *Capacity design was not a requirement of the Bylaw. However, it was referred to in both NZS* 4203*:1984 and NZS 3101:1982 and was an important means by which to achieve the objectives set out in clause 11.1.5(d) of the Bylaw.*

312. *Capacity design is based upon the principle of an engineer 'telling a building what to do' in an earthquake. The designer considers how the building will perform and designs it in such a way that, if it does fail, the failure will occur at identified points in the building. These points can be selected to ensure that the building will not suffer a catastrophic collapse. Hence the objective of minimising the probability of injury or death can be met.*

313. Capacity design was *described* in clause 3.3.2.2 of NZS 4203:1984:

> Buildings designed for flexural ductile yielding or for yielding in diagonal braces, shall be the subject of capacity design. In the capacity design of earthquake resistant structures, energy dissipating elements or mechanisms are chosen and suitably designed and detailed, and all other structural elements are then provided with sufficient reserve strength capacity to ensure that the chosen energy dissipating mechanisms are maintained throughout the deformations that may occur.

314. Clause 3.5.1.3 of NZS 3101:1982 said:

> Wherever the requirements of a capacity design procedure apply, the maximum member actions to be expected during large inelastic deformations of a structure shall be based on the overstrength of the potential plastic hinges.

[231] TRANS.20120809.88, L20-23

315. The effect of these clauses is that the designer of a Building subject to capacity design was required to identify the points of energy dissipation (plastic hinge regions) and design the remaining structural elements to be stronger than those plastic hinge regions.

316. The fact that Dr Reay and Mr Harding failed to comply with the requirements of capacity design in a number of important respects is developed more fully later in this submission.

Part 2: Non-Compliance with Bylaw 105

317. Part 1 addressed the applicable legal requirements at the time the CTV Building was designed and permitted. This part of the submissions deals with the ways in which the design of the Building did not comply with these requirements.

318. In summary, the areas of non-compliance with Bylaw 105 at the time of permit were:

a. *Asymmetry.*
b. *Connections between the diaphragms and the North Shear Core.*
c. *Non-seismic detailing of columns and beam-column connections.*
d. *Shear reinforcement of columns.*
e. *Anchorage of spirals on columns.*
f. *Adequacy of R60 @ 250mm spirals in cranked splice regions of the columns.*
g. *Minimum transverse reinforcement of beam column connections.*
h. *Diaphragm design.*
i. *Spandrel panel seismic gap.*

319. One of the most fundamental design flaws of the Building was the inadequacy of the load paths. Load paths were required to transfer earthquake forces through the Building, into the foundation and then to dissipate them into the ground. The inadequacy of the load paths was a consequence of the failure to comply with the principles of capacity design as well as poor connections between diaphragms and walls, beams and columns and beams and walls.

(a) Asymmetry

320. *In summary, it is submitted that the design violated the symmetry requirement in clause 11.2.5.1 of the Bylaw and consequently violated clause 11.1.5(d). Although the*

requirement was subject to practicability, there was no impracticability sufficient to justify departure from the mandatory requirement.

321. Clauses 11.2.5.1 of the Bylaw and 3.1.1 of NZS 4203:1984 stated:

> The main elements of a Building that resist seismic forces shall, as nearly as practicable, be located symmetrically about the centre of mass of the building.

322. The effect of these clauses is:

a. The requirement for symmetry was mandatory.
b. The only exception to this mandatory requirement was if it were not practicable to achieve it.

323. The Commentary to clause 3.1.1 stated:[232]

> It is recognised that the aim to achieve structural symmetry is frequently in conflict with the purpose and architectural design of a building. For high buildings, symmetry is one of the most basic requirements in achieving a structure of predictable performance. Simple geometry is essential for obtaining symmetry in practice. 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 and unsymmetrical combinations of shear walls and frames. Geometrically dissimilar resisting elements are unlikely to develop their plastic hinges simultaneously, and ductility demand may also be increased by torsional effects.

324. These comments are relevant to the CTV Building, in particular the final sentence.

325. The main elements of the CTV Building designed to resist seismic forces were the North Shear Core and the South Coupled Shear Wall. Dr Murray Jacobs said:

> The primary resisting elements in this structure are asymmetrical in the East West direction. In the North South direction the eccentricity is less. The main resisting element is the concrete core wall between lines 4 and 5 situated completely outside the main floor plate envelope (North Shear Core). There is a smaller much less stiff coupled shear wall on the south side of the Building on line 1 (coupled shear wall).

[232] ENG.STA.0018.38

> The diagram shown below, taken from the Hyland/Smith report, shows the large separation of the centre of mass from the centre of stiffness and consequently rotation. The Building will rotate about the centre of stiffness during an earthquake and place a greater demand on some of the columns, especially those further away from the centre of stiffness. [233]

326. Dr Jacobs expanded upon this in his evidence in reply.[234] He stated that the problem of two unequal walls in the same direction was well known at the time of the design of the CTV Building. He referred to a paper published in the *Bulletin of the New Zealand National Society for Earthquake Engineering* by T Paulay and RL Williams which stated:

> …as in all structures in seismic areas, symmetry in structural layout should be aimed at... Deliberate eccentricity should be avoided, if possible, because uneven excitations may aggravate eccentricity and this in turn may lead to excessive ductility demand in lateral load resisting elements situated far away from the centre of rotation.

327. Under cross-examination, Mr Harding agreed that the walls were not located symmetrically about the centre of mass in the East West direction.[235] He acknowledged that, as a result of this, the centre of stiffness of the designated primary seismic resisting elements were significantly eccentric to the centre of mass.[236]

328. However, Mr Harding defended this on the basis that it was not practicable for the walls to be located symmetrically given that:

> … the architectural requirement for the location of the walls wouldn't have allowed a shear wall the same as the one on the north side to be located on the south.[237]

329. On the other hand, Dr Reay considered that the walls were located symmetrically about the centre of mass, although he agreed that the centre of stiffness was significantly eccentric to the centre of mass.[238]

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[233] TRANS.20120809.7, L18-32; TRANS.20120809.8, L1-3
[234] WIT.JACOBS.0002.4, para16-19
[235] TRANS.20120814.126, L13-29
[236] TRANS.20120814.127, L9-16
[237] TRANS.20120814.127, L2-4
[238] TRANS.20120815.36, L6-20

330. Dr Reay's position was that there was no absolute requirement of symmetry in the Code.[239] Dr O'Leary adopted the same position and even went as far as to say that this provision could just be 'set aside' because there was no practical way to apply it.[240]

331. Even if it is accepted that there is room for an exercise of judgment in applying the words, 'as nearly as practicable' to the requirement for symmetry, it is disturbing that Mr Harding's position seemed to be that an objection from the architect was sufficient to justify a conclusion that symmetry was not 'practicable.' It was even more disturbing that Dr O'Leary's view was that this provision could simply be ignored.

332. The torsional effects from a lack of symmetry about which the Code warns would have contributed to the excessive inter-storey deflections resulting in the capacity of some columns being exceeded at Code loads.

333. It is submitted that clauses 11.2.5.1 of the Bylaw and 3.1.1 of NZS 4203:1984 should be interpreted as follows:

    a. They should be regarded as an important means by which the obligations to avoid collapse and minimise the probability of injury and death were to be achieved.
    b. They set out a mandatory requirement that Building elements must be located symmetrically about the centre of mass.
    c. The designer could only move away from this requirement for very good reason and only after exploring ways of retaining symmetry.
    d. Even when moving away from the requirement, there was still an obligation to achieve symmetry as nearly as practicable, and to ensure that the overarching obligations to avoid collapse and minimise injury and death were met. This would make it even more important to ensure that the building satisfied ductility requirements and had adequate load paths.

334. Neither Dr Reay nor Mr Harding could point to any impracticability sufficient to justify the exclusion. Mr Harding said it was an architectural issue.241 However, Mr Wilkie gave evidence that there was no architectural impediment to a wall being located anywhere along the south of the Building.[242]

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[239] TRANS.20120815.36, L23
[240] TRANS.20120813.7, L31 - TRANS.20120813.9, L8
[241] TRANS.20120731.49, L14 - 50, L10
[242] TRANS.20120815.75, L19 - 76, L3

335. The design failed to comply with clauses 11.2.5.1 and 11.1.5(d) of the Bylaw.

(b) Diaphragm Connections

Absence of Connections at Lines D and D/E

336. The connections between the diaphragm and the North Shear Core at Lines D and D/E did not comply with the Codes.

337. *To summarise the position:*

a. *The structure was required to be designed using capacity design.*

b. *The required loads for the connection at the North Shear Core using capacity design would likely have been greater than the loads prescribed by clause 3.4.9 of NZS 4203:1984.*

c. *If clause 10.5.6.1 of NZS 3101:1982 was followed, loads for the diaphragm connection were required to be no less than those set out in clause 3.4.9 of NZS 4203:1984. Clause 3.4.5.3 of NZS 4203:1984 also required that clause 3.4.9 was to be used.*

d. *Mr Harding did not apply clause 3.4.9. As a result, he under-calculated the required loads of the North Shear Core connection. The underestimation applied in relation to connections to the South Coupled Shear Wall as well.*

e. *The connection of the diaphragm to the North Shear Core did not have sufficient capacity to meet the minimum required loads.*

f. *The absence of sufficient connections at lines D and D/E was both a product of this error and a failure to provide a suitable load path between the diaphragm and the North Shear Core.*

g. *The design as permitted did not comply with clause 11.1.5 (d) of the Bylaw or with the Codes.*

h. *Both Mr Harding and Mr Banks should have used capacity design to calculate the loadings at the connections. A higher level of required loading is likely to have resulted than that which was based on clause 3.4.9.*

i. *The failure to apply capacity design can be explained by clause 10.5.6.1. However, that clause is inconsistent with the objective of the Bylaw set out in*

> *clause 11.1.5 (d) because capacity design was the most effective means by which to avoid collapse and minimise the probability of injury and death.*

338. The Hyland Report said:

> No specific reinforcing steel was specified connecting the lift shaft walls of the North Shear Core into the slabs on DENG Dwg S15 and 16.[243]

339. The Hyland Report and the DBH Panel Report described this as an 'omission.'

340. HCG described it as 'a vital area of non-compliance with current design Codes.[244] It said in its report in January 1990:

> Connections to the walls at the north face of the Building are tenuous... in the event of an earthquake, the Building would effectively separate from the shear walls well before the shear walls themselves reach their full design strength.

341. Mr Harding did not accept that the building was non-compliant in this respect.[245] Dr Reay accepted that the diaphragm connection was a 'possible' area of non-compliance.[246] Mr Banks said it was an area of non-compliance.[247] An attempt was made to address it with the retrofit work in 1991. The retrofit issue will be addressed later in these submissions.

342. Mr Harding's calculations at the time of the original design did not include any calculation of the loadings applicable to the North Shear Core connections in a North-South direction. He gave evidence that he believed there were additional calculations which were not part of the set which the Commission has.[248]

343. Mr Harding did carry out calculations of the loadings for this connection in an East-West direction.[249] However, he used forces derived from either the equivalent static method or the dynamic analysis.[250]

344. Clause 3.4.6.3 of NZS 4203:1984[251] stated:

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[243] BUI.MAD249.0189.143
[244] BUI.MAD249.0005.11
[245] TRANS.20120814.147, L17-30
[246] TRANS.20120815.34
[247] TRANS.20120817.63, L15-27
[248] TRANS.20120815.5, L1-10
[249] BUI.MAD249.027265 and 66
[250] TRANS.20120814.145, L20-24
[251] ENG.STA.0018.53

> Floors and roofs acting as diaphragms and other principal members distributing seismic forces shall be designed in accordance with clause 3.4.9. Allowance shall be made for any additional forces in such members that may result from redistribution of storey shears.

345. Mr O'Loughlin said in evidence that the effect of clause 3.4.6.3 was that the loadings for diaphragm connections must be calculated using clause 3.4.9.[252] Mr Banks used loads derived from clause 3.4.9 when he calculated the required loads for the connection prior to the retrofit in 1991.

346. Mr Banks' calculation of the applicable loadings for the North Shear Core connection in an East-West direction using clause 3.4.9 was 724 kilonewtons. Mr Harding's figure was only 300 kilonewtons, less than half the required load.

347. If capacity design was applied, the loads which the diaphragm connections would have been required to bear would have been greater than the loads required to cause yielding in the plastic hinge regions of the walls. Mr Harding agreed with this.[253]

348. Mr Harding accepted in evidence that he did not make any calculations to determine the required loadings of the diaphragm connection based upon capacity design.[254] Neither did Mr Banks.[255]

349. Clause 10.5.6.1 of NZS 3101:1982 provided:

> Diaphragms, intended to transfer earthquake induced horizontal floor forces to primary lateral load resisting elements or which are required to transfer horizontal seismic shear forces from one vertical primary lateral load resisting element to another, shall be designed for the maximum forces that can be resisted by the vertical primary load resisting system, or for forces corresponding with the seismic design coefficients specified by NZS 4203 for parts or portions of Buildings, whichever is smaller.

350. The effect of this is that the minimum loadings required for diaphragm connections were those specified by clause 3.4.9.

351. However, this interpretation is inconsistent with clause 11.1.5(d) of the Bylaw and the requirements of capacity design. It is submitted that capacity design should have been

[252] TRANS.20120814.107, L5-8
[253] TRANS.20120814.145, L5-12
[254] TRANS.20120814.144, L8-11
[255] TRANS.20120817.82, L29 – 83, L2

used to determine the loadings of the connections between the diaphragm and North Shear Core.

352. In response to questions from Commissioner Fenwick, Dr Reay accepted that capacity design required that the connections between the floor slabs and the wall should be capable of developing the maximum possible strength of the wall. He also accepted that it did not make sense to use the forces derived from the parts and portions section of the Code and not those derived from capacity design.[256] This is because the forces derived from the parts and portions section of the Code would have been less than those derived from capacity design.

Non-compliance in the East-West direction

353. *The Building was non-compliant in the East-West direction both at the time of permit and* after *the retrofit in 1991. It remained non-compliant in this respect as at 22 February 2011.*

354. The point has already been made that clause 3.4.6.3 of NZS 4203:1984 required that floors acting as diaphragms were to be designed in accordance with clause 3.4.9 and Mr Banks' calculation of the applicable loadings for the North Shear Core connection in an East-West direction using clause 3.4.9 was 724 kilonewtons. Mr Harding used a figure at the same location of 300 kilonewtons.

355. In response to questions from Commissioner Fenwick, Mr Banks agreed that:[257]

a. All of the East-West shear had to go on the area between wall C and wall C/D.

b. That shear would have come from the floor and would be resisted by the wall on line 5 together with the finger walls going the other way.

c. The contact connection force was 700 kilonewtons (in fact it was 724).

d. That connection force would have acted on line 5 and generated a shear which was virtually constant over the distance between line 4 and line 5, which was about four and a half metres.

e. This would have generated a bending moment of 3000-3500 kilonewton metres, on the assumption that the north wall was free to warp (the transcript says 'not

[256] TRANS.20120815.44, L9-25
[257] TRANS.20120817.100, L20 – 103, L21

free,[258] but it is submitted this was either an error in the transcript or a misunderstanding).

356. As Mr Banks accepted, by using the forces derived from clause 3.4.9 and then considering the equilibrium of forces just south of line 4, the required design strength was a shear of approximately 700 kilonewtons and a moment of at least 3000 kilonewton metres.

357. Clause 4.2.1 of NZS 3101:1982[259] required that structures and structural members be designed to have dependable strengths at least equal to the required strengths. Clause 4.3.1.1 of NZS 3101:1982[260] set out the requirements for the design dependable strength of a member.

358. Mr Banks said that he had calculated the flexural capacity at that point as being in the order of 1800 kilonewton metres.[261]

359. The design strength (1800 kilonewton metres) was therefore less than the required strength (at least 3000 kilonewton metres).

360. For these reasons, the Building was non-compliant in this respect both at the time of permit and after the retrofit in 1991. It remained non-compliant up to when it collapsed.

361. Neither John Hare from Holmes Consulting Group nor Geoff Banks from ARCL identified this deficiency in 1990/1991.

362. In evidence, Mr Banks acknowledged that the floor was overloaded. He said he did not consider this given that he directed his attention to the issue raised by HCG.[262]

363. In addition to these issues, Dr O'Leary gave evidence that the diaphragm connection was non-compliant in the East-West direction even after the retrofit for reasons set out in calculations provided to the Commission by the CCC.[263]

364. Mr Banks did not accept that the Building was non-compliant in this respect.[264]

365. This issue will need to be resolved by the Commission.

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[258] TRANS.20120817.101, L9
[259] ENG.STA.0016.30
[260] ENG.STA.0016.30
[261] TRANS.20120817.102, L3-4
[262] TRANS.20120817.100-.103
[263] TRANS.20120809.131, L6-8
[264] TRANS.20120817.85, L5 - .88, L33

(c) Non-seismic detailing of columns and beam-column connections

366. *Four grounds emerged in the course of the hearing as to why the seismic provisions of NZS 3101:1982 should have been applied to the design of the columns and beam-column connections in the CTV Building. Any one of these grounds, if accepted, would be sufficient to justify this conclusion. The grounds are:*

a. Capacity design required that they be designed in this way.

b. Failure of columns was a risk to life.

c. It was not open to the designers to treat the columns as 'secondary elements'.

d. If the columns were secondary elements, the prescribed drift limits were exceeded.

367. The columns and beam-column connections should have been designed using the seismic loading provisions of NZS 3101:1982 and in particular:

a. Clause 6.5.4.3 for the columns.[265]
b. Clause 9.5.6.1 for the beam-column connections.[266]

368. The primary reason for this is that in the design of the CTV Building, the legal obligations to avoid collapse and to minimise the probability of injury and death were served by the use of these provisions. Conversely the use of non-seismic provisions did not serve these obligations.

369. It is anticipated that counsel for Dr Reay will argue that these objectives only apply in the context of a 'design-level' earthquake and the use of non-seismic provisions met this objective, as evidenced by the performance of the Building on 4 September 2010.

370. Clause 11.1.5(d) of the Bylaw refers to a 'major earthquake,' not a 'design-level earthquake.' Even if it is accepted that 'major' means 'design-level,' neither the Bylaw nor the Codes allow the designer to design on the basis that a Building is only required to withstand an earthquake at 'design level' but to collapse in an earthquake only marginally stronger.

[265] ENG.STA.0016.53
[266] ENG.STA.0016.72

371. An approach based upon just meeting a performance requirement is not compatible with maximising performance. There was an obligation to not only address the risk, but to minimise the probability that it would eventuate.

372. As Park and Paulay noted in *Reinforced Concrete Structures*, it is impossible to accurately predict the characteristics of the ground motions that may occur at any given site.[267]

373. The Bylaw sets out fundamental design requirements. The underlying purpose of these requirements is clear. Collapse is to be avoided and the probability of injury and death is to be minimised. This purpose cannot be met if the designer seeks to draw a line beyond which collapse and death are virtually certain.

i. Capacity design required that columns be designed using seismic provisions

374. The CTV Building was required to be designed using capacity design. Dr Reay and Mr Harding should have considered the behaviour of the structure as a whole in an earthquake and identified an acceptable ductile failure mechanism and designed the Building with this in mind. Professor Mander said that capacity design required the use of the seismic provisions of the code for columns and beam column connections.

375. Mr Harding applied a structural type factor of S=1 for the north wall and S= 0.8 for the South Coupled Shear Wall.[268] Mr Smith gave evidence that, as a consequence, clause 3.5.1.1(a) of NZS 3101:1982 applied.[269] This included the requirement that:

> Ductile structures shall be subject to capacity design...

376. Dr Reay and Mr Harding both gave disturbing evidence about their interpretation of the requirements of capacity design.

377. Mr Harding applied capacity design solely to the walls, but gave no consideration to the structure as a whole and what an acceptable ductile failure mechanism would be. This was highlighted in questioning from Commissioner Fenwick:

> Q. When you did your capacity design, what was your critical ductile mechanism that you had assumed?

[267] Page 600
[268] TRANS.20120814.131, L2-6
[269] TRANS.20120809.90, L14-20

> A. A plastic heading at the base of the vertical shear walls and in the coupling beams and at the base of the coupled shear wall.
>
> Q. So in the north-south direction you get the forces from the floor slabs going into the north core, pulling it over?
>
> A. Yes.
>
> Q. So the fundamental requirement of capacity design is what? What do you have to do to design, you're wanting a plastic hinge to form at the base of that-
>
> A. I accept what you're saying Sir-
>
> Q. – floor?
>
> A. – that the diaphragm force in the floor should've been greater than that required to cause the plastic bending at the bottom and I accept that it wasn't that high.
>
> Q. Yes, you didn't check that out?
>
> A. No I didn't think far enough to include that as part of capacity design.[270]

378. Dr Reay on the other hand said that capacity design applied only to the walls, while the frames were to be treated as elastically responding structures.

379. Dr Reay's evidence contrasted starkly with the evidence given by Professor Mander, an expert witness who was called by Dr Reay and his firm. Professor Mander provided a telling analysis of the CTV design:

> In the failure of structures, there exists a strength hierarchy, where the failure generally originates within the weakest link in the chain of resistances. In the context of a normal seismic design of frame structures, the strength hierarchy (from weakest to strongest) is normally:
>
> 1. Beam bending (flexure). Beams are chosen to be the weakest link in a chain of resistance because in a Building there are many plastic hinge regions at the ends of beams that serve as the hysteretic energy dissipation system and the large sway reversals.

[270] TRANS.20120731.90, L11-20

2. Column bending (also called column flexure). Columns are generally designed to be stronger than beams and deliberate strength enhancement is typically 100% or more.

3. Joint shear. Joints are protected from failure by the presence of tightly wound spirals or closely spaced groups.

4. Foundation capacity. The substructure is normally designed to be stronger than the superstructure, as damage is difficult to observe and/or appear when below ground.

In the case of the CTV Building, under an E-W sidesway analysis for the type of substructures presented in Figure 2.5 above, the strength hierarchy (from weakest strongest) is:

1. Joint shear

2. Column flexure

3. Beam flexure

4. Wall capacity

There are several reasons that beam-column joints in the CTV Building were the weakest and thus most vulnerable elements....[271]

380. Professor Mander gave the following evidence under cross-examination:

Q. So if capacity design applied to the structure, just to summarise the position, you agree that the designers of the Building would have been required to consider the behaviour of the Building as a whole, when exposed to earthquake loads, that's right?

A. Yes.

Q. You've agreed that designers of the Building would have assumed or should have assumed that the columns would be called upon to resist lateral earthquake loads in at least the east-west direction.

A. Yes.

Q. And that the designers should have regarded the columns as being a risk to life safety in the event of failure.

[271] BUI.MAD249.0446.30

A. Yes.

Q. And shouldn't the designers have identified the ends of columns, as you've done, as potential plastic hinge regions?

A. Yeah I think they should have.

Q. And, in fact, they should have assumed that reversible plastic hinges would form in those parts of the columns in a severe earthquake.

A. Yes.

Q. So it's true, isn't it, that they should have specified the transverse reinforcement set out in the Code for those plastic hinge regions?

A. I believe so.

Q. And they should also have designed for the same confinement in the beam column connections.

A. Yes.[272]

381. It is submitted that Professor Mander's evidence should be accepted. Capacity design required that the seismic loading provisions set out in clauses 6.5.4.3 and 9.5.6.1 should have been used. They were not, and this amounted to a failure to comply with the Code and with clause 11.1.5(d) of the Bylaw.

ii. Failure of columns was a risk to life

382. *Bylaw 105 required that the elements of a building which were a risk to life in the case of failure must be designed to possess ductility. The failure of the columns of the CTV Building was a risk to life, but were not designed to possess ductility.*

383. Clause 11.2.5.2 of the Bylaw is re-stated for ease of reference:

(a) The Building as a whole and all of its elements that resist seismic forces or movements, or that in the case of failure are a risk to life, shall be designed to possess ductility; provided that this shall not apply to small Buildings having a total floor area not exceeding 140m2 and having a total height not exceeding 9m.

(b) Structural systems intended to dissipate seismic energy by ductile yielding shall have "adequate ductility".

(c) "Adequate ductility" in terms of clause (b) shall be considered to have been provided if all primary elements resisting seismic forces are detailed in accordance with special requirements for ductile detailing in the appropriate material Code.

[272] TRANS 20120724.101, L26 – 102, L16

384. It is submitted that there are two limbs to clause (a):

a. Elements that resist seismic forces or movements.
b. Elements which may not resist seismic movements, but which pose a risk to life in the event of failure.

385. Even though the word 'or' appears, building elements could fall into both categories. In both cases, such elements are required to be designed to possess ductility. Ductility must not be just a consequence of the design.

386. 'Ductility' must mean an appropriate level of ductility to address the risk which is contemplated by the Bylaw.

387. In the case of the CTV Building, the columns resisted seismic forces. The failure of the columns in the CTV Building also presented a risk to life. Dr Jacobs held this view. Professor Mander agreed. It is also self-evident from the manner of the collapse. The Building 'pancaked' and the floor slabs, which were the heaviest part of the structure, ended up in layers. The structural element holding these up was the columns. The beam-column connections were crucial as well. Their failure could only have led to injury or death.

388. Even if only one column failed, injury and death could have resulted, although as Professor Priestley pointed out, catenary action would have likely led to multiple column failures even if one internal column failed.[273]

389. Clause (b) states that a structural system intended to dissipate seismic energy by ductile yielding shall have 'adequate ductility.' The CTV Building was intended to dissipate seismic energy in this way.

390. The effect of clause (c) is that, once clause (b) was triggered, all of the primary elements resisting seismic forces, and not just the North Shear Core and South Coupled Shear Wall, were to be detailed using the seismic provisions of NZS 3101:1982. The definition of 'primary elements' in NZS 4203:1984 included beams and columns.

[273] TRANS.20120711.52

391. Counsel for ARCL, Dr Reay and Mr Harding may argue that the definition of 'secondary elements' in clause 3.5.14 of NZS 3101:1982 overrides or modifies the definition of primary elements in NZS 4203:1984. However, for the reasons already given, in the event of inconsistency or ambiguity between the two Codes, NZS 4203:1984 is to prevail. In addition, clauses 11.2.5.2 and 11.1.5(d) of the Bylaw are the dominant provisions.

iii. *The columns should not have been treated as 'secondary elements'*

392. *ARCL, Dr Reay and Mr Harding argue that the columns satisfied the definition of secondary elements in clause 3.5.14 of NZS 3101:1982. However, it is submitted that the columns did not satisfy this definition. They cannot be regarded as secondary elements and should have been designed using the seismic provisions of NZS 3101:1982.*

393. It became clear in an exchange between Commissioner Fenwick and Mr Harding that Mr Harding was unaware of clause 3.5.14 at the time he designed the CTV Building.[274]

394. Clause 3.5.14 of NZS 3101:1982 is entitled 'Secondary Structural Elements.' Clause 3.5.14.1 begins:

> Secondary elements are those which do not form part of the primary seismic force resisting system, or are assumed not to form such a part and are therefore not necessary for the survival of the Building as a whole under seismically induced lateral loading, but which are subjected to loads due to accelerations transmitted to them, or due to deformations of the structure as a whole...

395. There appear to be two key aspects to this clause:

a. Secondary elements are those which do not form part of the primary seismic force resisting system.

b. Secondary elements may also comprise those which 'are assumed' not to form such a part and are therefore not necessary for the survival of the Building as a whole.

[274] TRANS.20120731.65-66

396. The effect of the 'assumed' status appears to allow something to be treated as a secondary element when it should not have been, but nonetheless be Code-compliant. It appears that Mr Harding ultimately has to fall back on this interpretation to justify the columns as secondary elements although it is submitted that this interpretation is not tenable. This obviously unsatisfactory possibility has been removed by the equivalent provision of NZS 3101:2006.

397. In the end, any contention by Dr Reay or Mr Harding that the columns could have been treated as secondary elements can only be sustained under the phrase 'are assumed not to form such a part.' However, although the clause is very poorly worded, when interpreted in light of both text and purpose it is submitted that any such assumption must be consistent with the element not being necessary for the survival of the Building as a whole. The clause does not allow columns to be treated as secondary simply because the designer mistakenly assumed that they were.

398. This interpretation of the clause is supported by Bylaw 105 and its controlling requirement of life safety and collapse avoidance.

399. Professor Mander similarly gave evidence that, when the Building was exposed to design level shaking, the frames, consisting of beams and columns, the beam column connections, the North Shear Core and South Coupled Shear Wall would all have been called upon to resist earthquake loads,[275] which on his view could not have been secondary elements.

400. Dr O'Leary accepted that beams, columns, diaphragms and shear walls were included in the definition of primary elements because they are the parts of the structure which would be exposed to earthquake loads in an earthquake.[276]

401. Professor Mander was asked to consider those parts of the CTV Building that were necessary for the survival of the Building as a whole under lateral seismic loading. He was asked to treat 'survival' as meaning there would be no full or partial collapse. He said that the columns, beam column connections, North Shear Core and South Coupled Shear Wall would all have been necessary for the survival of the Building as a whole.[277]

[275] TRANS.20120724.85, L10-19
[276] TRANS.20120813.47, L5-11
[277] TRANS.20120724.86, L3-18

402. Professor Mander described clause 3.5.14.1 as a 'loophole.' In response to questioning from His Honour Justice Cooper, he said that he did not agree with the approach of using clause 3.5.14 as a loophole.[278]

403. It is submitted that the columns and beam-column connections of the CTV Building did not satisfy the definition of secondary elements set out in clause 3.5.14.

404. Dr Jacobs was the only expert engineer who expressed the view that the columns were not properly classified as secondary elements.

405. By contrast, it was implicit in the evidence of Dr Hyland, Mr Smith, Mr Jury (giving expert evidence on behalf of the DBH panel which included Professor Priestley, Professor Pampanin and Mr Thornton), Dr O'Leary, Mr O'Loughlin, Mr Henry and Mr Hare that it was permissible to categorise columns as secondary elements.

406. However, it is submitted that this does not assist Dr Reay or Mr Harding for the following reasons:

    a. Compliance with the Bylaw is a question of law. Opinions expressed by these experts are not definitive.

    b. The fact that engineers generally appear to have adopted an approach inconsistent with that which the Royal Commission is invited to accept does not prove that it was lawful.

407. It is further submitted that the Royal Commission need not be concerned about reaching a conclusion which could have the wide-ranging consequence of determining that a number of existing buildings are not compliant:

    a. The minimum provisions for seismic detailing of columns were increased in 1995. As a result, the only buildings affected by the Royal Commission accepting this submission would predate that time.

    b. The Department of Building and Housing Expert Panel Report recommended:

> Buildings designed before NZS 3101:1995, and especially those designed prior to NZS 4203:1992 (which increased the design drift demand) with non-ductile gravity columns may be unacceptably

[278] TRANS.20120724.105, L8 – 107, L2

> vulnerable. They should be checked and a retrospective retrofit program considered.[279]

c. The Panel recommended that the Department review these and other concerns as 'a matter of priority and importance.'

d. The Department of Building and Housing indicated when it released the Hyland/Smith and Panel reports that it was pursuing an enquiry to identify buildings which had been constructed in this way across the country.

408. Far from it being a cause of concern if the Royal Commission was to accept the submission from Counsel Assisting on this point, a finding from the Commission that the treatment of columns as secondary elements did not comply with Bylaw 105 or any equivalent by law that has been adopted by other local authorities around New Zealand is likely to assist in a process of requiring building owners to carry out structural upgrades.

iv. *If columns were secondary elements, drift limits were exceeded and columns should have been designed for ductility*

409. In summary*:*

a. *Dr Hyland and Mr Smith determined that a number of columns would have exceeded their elastic deformation limit at the prescribed drift limits. On this basis, they said that columns were required to be detailed using the additional seismic design provisions of NZS 3101:1982. The DBH Expert Panel endorsed this conclusion. Dr O'Leary expressed a similar view in relation to the columns on Line F.*

b. *Mr Latham, who was called as an expert witness by Dr Reay, gave evidence that the columns did not exceed their elastic limit. However, it became clear during Mr Latham's evidence that he was not expressing an opinion about whether the columns and beam column connections were compliant with the applicable Codes. He was doing no more than presenting an alternative approach.*

c. *It is submitted that the conclusions expressed by Dr Hyland and Mr Smith and Mr Jury should be accepted. The columns exceeded their elastic deformation limit at the prescribed drift limits and were required to be detailed using the additional seismic design provisions of NZS 3101:1982*

[279] BUI.VAR.0056.55

410. If the columns in the CTV Building were secondary elements, the question of whether they were required to be designed to meet the seismic or non-seismic provisions of NZS 3101:1982 was determined by identifying 'V delta' and assessing whether or not the columns would remain elastic at that point. If they did remain elastic, the seismic provisions would not apply. If their behaviour was inelastic below this point, the seismic provisions requiring full or limited ductility would apply.

411. There is a preliminary issue which arises from the application of capacity design. Clause 3.5.3.2 of NZS 3101 3.5.3.2 provided:

> Structures classified in 3.5.1.1(a), such as ductile frames composed of beams and columns with or without a shear walls, and also cantilever or coupled shear walls and bridge piers, shall be assumed to be forced into lateral deformations sufficient to create reversible plastic hinges by actions of a severe earthquake.

412. Where capacity design applied, this clause required the designer to assume the columns would be inelastic rather than elastic, in which case the seismic provisions would apply.

413. If this interpretation of clause 3.5.3.2 is not correct, the designer would have been required to calculate V delta and assess the capacity of the columns at that drift level.

414. The ETABS analysis Mr Harding carried out was for the purpose of calculating the building drift if the columns remained elastic. Mr Harding did not calculate the capacity of the columns to determine whether they would actually remain elastic at V delta. If the columns did remain elastic at V delta, it would only have been a lucky coincidence for Dr Reay and Mr Harding.

415. As part of their investigation into the issue of Building compliance, Dr Hyland and Mr Smith carried out an Elastic Response Spectra Analysis, a modern equivalent of the ETABS analysis Mr Harding carried out.

416. By deriving drift limits from this and using the modification factor specified in clause 3.8.1.1 of NZS 4203:1984, Dr Hyland and Mr Smith identified V delta. They then carried out an assessment of column capacity. They determined that identified columns did not remain elastic at V delta and the columns should have been designed with the seismic

provisions of the Code. This finding was endorsed by the Department of Building and Housing expert panel.[280]

417. Dr O'Leary also gave evidence that, in his view, the columns at Line F would not have behaved elastically at V delta and should have been designed using the seismic ductile provisions of the Code.

418. Other experts who gave evidence on this issue were unanimous that the columns and beam-column connections were non-compliant, although there was some divergence on the extent of the non-compliance.

419. After conferring at the direction of the Royal Commission, all of the experts except Mr Douglas Latham agreed that the ERSA analysis prepared by Dr Hyland and Mr Smith was appropriate. Mr Latham alone considered a further ERSA should be carried out.

420. Mr Latham subsequently carried out an ERSA and expressed the opinion that column capacity did not exceed V delta. However, it became clear during Mr Latham's evidence to the Royal Commission that he was not expressing an opinion about whether the columns and beam column connections were compliant with the Code. He was doing no more than saying, 'if one adopts this alternative approach then one could arrive at a point where they could assert that they are compliant.[281] While Mr Latham put an approach based upon 'an alternative set of assumptions,[282] it did not amount to an expert opinion that the columns and beam-column connections in fact complied.

421. The effect of this is that no expert witnesses gave evidence that the Building was compliant in this respect.

422. It is submitted that the columns and beam-column connections should have complied with the seismic provisions of NZS 3101:1982 and the Royal Commission should find that they did not.

v. Column/Beam Connections

423. If the Royal Commission concludes that the columns of the CTV Building should have been designed using the seismic provisions of NZS 3101:1982, it must follow that the

[280] BUI.MAD249.0192.52
[281] TRANS.20120814.54, L15-19
[282] TRANS.201208.14, L30

beam column connections should also have complied with the seismic provisions set out in clause 9.5.6 and were non-compliant.

424. This is because the effect of clause 9.5.6.1 is that the horizontal transverse reinforcement in the beam-column connections was required to be no less than that in the columns. Dr Reay accepted this.[283]

(d) Shear reinforcing of the columns

425. The design of the columns did not comply with NZS 3101:1982 in two respects:

a. It required a minimum area of shear reinforcement of columns: clause 7.3.4.3.
b. It specified spacing limits for shear reinforcement in columns: clause 7.3.5.4.

426. According to the Hyland/Smith Report:[284]

a. Minimum spacing of the spiral reinforcing was required to be approximately 150 millimetres.

b. Spiral reinforcing of R6 @ 90 mm centres approximately or R10 @ 150 mm centres, with the same steel properties as those specified would have been required.

c. The spiral reinforcement detailed was R6 @ 250 mm centres, which was insufficient to meet these requirements.

(e) Anchorage of spirals on columns

427. Clause 5.3.29.3 NZS 3101 required anchorage of spirals. Mr Smith gave evidence that he saw no indication in the drawings of any anchorage.[285]

428. Dr Reay gave evidence that he had seen a column in which the required anchorage was present and he subsequently, at the request of Mr Elliott, produced a photograph of a single column that showed this.

429. As the drawings did not require this anchorage, it is submitted that a single photograph of an unidentified column has little evidentiary value. As the drawings did not specify anchorage, this is irrelevant to Code compliance at the date of the permit.

[283] TRANS.20120815.48, L16-32
[284] Hyland/Smith Report, page 110
[285] TRANS.20120809.99, L9-12

(f) Adequacy of the R6 @ 250 mm spirals in the regions of the cranked splices in the columns

430. According to the drawings, there was a region in the columns in which splices were to be cranked.

431. Clause 5.3.27.1 NZS 3101:1982 related to 'Special details for columns and piers.' It specified that ties or spirals were to be placed no more than 150mm from the point of bend.

432. Spirals of R6 @ 250 mm were insufficient to meet this requirement in the cranked splice regions.

(g) Minimum (non-seismic) transverse reinforcement of beam-column connections

433. Clauses 9.4.2, 9.4.5 and 9.4.6 of NZS 3101:1982 provided:

a. Design forces acting on a beam-column joint should be evaluated from the maximum stresses generated by all members meeting at a joint, subjected to the most adverse combination of loads, with the joint in equilibrium.

b. Joint shear shall be assumed to be resisted by a concrete mechanism plus a truss mechanism comprising horizontal and vertical stirrups or bars.

c. Equations applicable to horizontal joint shear reinforcement.

434. Transverse reinforcement of R6 @ 250 mm was insufficient to meet these requirements.

435. The Hyland/Smith report said:

> The beam-column joints had no specific spiral or hoop reinforcing detailed to provide confinement or shear strength, and to hold the beams into the joint.
>
> This level of detailing is indicative of the joints having been considered to be required to satisfy only the non-seismic design requirements of the concrete structures standard NZS 3101:1982.
>
> The R6 @ 250 mm centres column spiral reinforcement would have been difficult to achieve in practice. As an integral part of the columns, the joints

would also have been required to be designed using the additional design requirements of NZS 3101:1982.[286]

436. Clause 9.4.8 of NZS 3101:1982 specified that spiral reinforcing in the beam-column joints was to be spaced at no more than 200mm. Transverse reinforcement of R6 @ 250mm was insufficient to meet this requirement.

(h) Diaphragms

437. Clause 10.5.6.2 and 5.3.32 of NZS 3101: 1982 required the diaphragm to be reinforced in both directions with not less than minimum reinforcement required for two-way slabs.

438. Dr Jacobs gave evidence that the 664 mesh did not meet these requirements.[287]

439. Clause 3.4.6.3 NZS 4203:1984 required diaphragms to be designed using the loadings set out in parts and portions section of NZS 4203:1984 (clause 3.4.9). The point has already been made that the loadings set out in this section were not used for diaphragms or diaphragm connections.

440. Dr Jacobs also gave evidence about weaknesses in the slabs.[288]

i. Spandrel panel

No seismic gap was specified in the drawings for the spandrel panels.

Part 3: Best Practice

441. The *Codes do not always reflect the most current research and information about the safest way to design buildings. For this reason, designers must be aware of ongoing developments and ensure that they comply with best practice.*

442. The design of the CTV Building did not comply with best practice at the time of design in a number of important respects.

443. Professor Priestley gave evidence that many of the details in the structural drawings submitted for permit in 1986 failed a test of 'best practice to current state of knowledge:[289]

[286] BUI.MAD249.0189.142
[287] WIT.JACOBS.0001.14, paras 38-43
[288] TRANS.20120809.12, L24 – 20, L8

> Q …where does this concept of best practice, the current state of knowledge, sit in your view in relation to the obligations that the design engineer has?
>
> A. Well in my mind it is extremely important. We are obliged to design to Codes and it is recognised that Codes provide a minimum level of safety and we also know the Codes are, can lag behind the current state of knowledge. So if there is information that is available but is not codified then I believe that the designer has a duty to incorporate that information. It may not be a legal requirement but I'm sure that the public expects us to use best practice not just to design to the Code.
>
> Q. Thank you
>
> A. And I would say that that has always been taught in my knowledge in structural engineering at the universities. This is a well-established principle that you don't just take the Codes.[290]

444. Dr Reay's position was that he did not understand what was meant by best practice, but whatever it meant it would be satisfied by compliance with Code.[291] The Royal Commission is urged to reject that view for the reasons given by Professor Priestley.

445. It is submitted that the following matters amount to a failure to comply with best practice current at the time of design.

(a) Diaphragm connection

446. Professor Priestley referred to the connection between the diaphragm and North Shear Core as, 'clearly inadequate to achieve a sufficient connection.[292] He said that the lack of design connection between floor slabs and wall at lines D and D/E was 'very remarkable.[293]

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[289] TRANS.20120711.64, L30
[290] TRANS.20120711.65, L2-15
[291] TRANS.20120815.51, L23
[292] WIT.PRIESTLEY.0001.17, para 53
[293] WIT.PRIESTLEY.0001.17, para 54

447. Professor Mander gave evidence that the connection certainly did not amount to best practice.[294] He said it was 'remarkable.'[295]

448. It is submitted that the Royal Commission should conclude that the design of the diaphragm connection, and in particular the absence of an adequate connection at lines D and D/E, failed to comply with best practice.

(b) Robustness

449. According to Dr Hyland and Mr Smith, robustness means the ability of the structure to sustain damage without causing progressive damage to the building as a whole.[296] They said that the secondary beam and column frames lacked the level of robustness expected of frames designed to cope with the cyclic drift of earthquakes and that the seismic design provisions of NZS 3101 would have improved robustness:[297]

450. This view was supported by Mr Jury.[298]

451. Once again, Dr Reay resisted any suggestion that robustness imposed an additional or desirable requirement above the Code standards.[299]

(c) Redundancy

452. It is submitted that the building should have been designed to have redundancy, that is, if one part, such as the columns or beam-column connections failed, it should not have resulted in collapse. It was not.

(d) Column detailing

453. Professor Priestley said:

> Of particular concern to me is the poor detailing of the columns, combined with the high axial load levels. Park and Paulay "Reinforced Concrete Structures" Wiley, 1975, clearly identifies this as dangerous (Section 6.4, pp217-221). This book was published some 10 years before the CTV Building was designed and was widely referred to by NZ designers using reinforced concrete as "the bible". It is inconceivable, in my view, that Alan

[294] TRANS.20120724.34, L11-17
[295] TRANS.20120724.37, L6-11
[296] BUI.MAD249.0189.143
[297] BUI.MAD249.0189.144
[298] TRANS 20120710.79, L18
[299] TRANS.20120815.52, L8-23

> Reay Consultants was unaware of this information. Designers have a duty to design not only to the Code, but also to the state of accepted knowledge applicable at the time of design.[300]

454. It is submitted that the warnings given in the Park and Paulay text are clear. Reference has already been made to the paper at the 1986 conference highlighting the dangers of adopting a non-ductile frame-shear wall hybrid approach.

455. Professor Mander gave evidence that the non-seismic detailing of the columns was not best practice.[301]

(e) Excessive cover to reinforcement of columns

456. Professor Priestley gave evidence that excessive cover to reinforcement of columns resulted in inadequate compression strength of the concrete core in the event of spalling of the cover concrete.[302]

457. It is submitted that the level of cover did not comply with best practice. Mr Harding sought to defend it by reference to an alleged need to weatherproof the exterior columns, apparently unaware that the internal columns had the same amount of cover.[303]

(f) Excessive spacing of transverse reinforcement

458. Professor Priestley gave evidence that the spacing of transverse reinforcement in the columns was excessive and not best practice.[304]

(g) Beam column connection

459. Professor Priestley referred to a lack of transverse reinforcement in the beam-column joints, which he considered did not comply with best practice.[305]

460. Professor Mander also gave evidence that the low level of transverse reinforcing steel in the beam-column connections was not best practice.[306]

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[300] TRANS.20120711.68, L30
[301] TRANS.20120724.38, L1-15
[302] WIT.PRIESTLEY.0001.23, para 77
[303] TRANS.20120815.1, L13-29
[304] TRANS.20120711.68, L2
[305] TRANS.20120711.68, L20 - .69, L9

(h) Connectivity between pre-cast beams and columns

461. Professor Priestley considered that poor connectivity between pre-cast beams and columns was a failure to comply with best practice.[307]

(i) Anchorage/Connections

462. There were a number of instances of poor anchorage and connections in the building, all of which failed to comply with best practice:

Detailing of East-West beam connection at western wall

463. Professor Mander gave evidence that the seating sill on the western wall was only about 20 millimetres, was not well anchored, and was quite poor.

464. He said that the lock in details of the East-West beams into their seats on the western wall probably failed to comply with best practice at the time of design.[308]

Anchorage of bars to walls and beam-column connections

465. Clauses 5.3.7.1 (Development length of deformed bars and deformed wire in tension) and clause 5.13.5.1 (Standard hooks in tension) of NZS 3101:1982 set out requirements in relation to anchorage.

466. These clauses were not satisfied to fully develop the tension strength of the embedded bars.

Connection to the South Coupled Shear Wall

467. Mr Holmes gave evidence that the edge beams on line 1, acting as drag beams, were connected to the South Coupled Shear Wall by 4-H24 bars with 700mm embedment and that the connection was potentially compromised by having less than the required embedment (700mm vs. 1250mm).[309]

(j) Design of the South Coupled Shear Wall

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[306] TRANS.20120724.41, L18-19
[307] TRANS.20120711.68, L20 -.69, L9
[308] TRANS.20120724.44, L1-13
[309] WIT.HOLMES.0001.4

468. A structural type factor of 0.8 should not have been used for the south wall. It resulted in a disparity between the North Shear Wall and South Coupled Shear Wall which would have led to the latter yielding before the former. This would have caused inter-storey drifts to increase further than anticipated, as Mr Smith said.[310]

469. In addition, the coupling beams in the South Coupled Shear Wall were stronger than they should have been. The effect of this was that they could not have served their purpose as coupling beams.

470. Once again, it is submitted that this amounted to a failure to comply with best practice.

(k) Inadequate load paths

471. One of the most serious consequences of some of the failures to comply with the Bylaw and best practice was the inadequacy of load paths in the CTV Building. This was due to the failure to apply capacity design, the under-calculation of required loads to diaphragm/wall connections and poor anchorage and detailing at walls and beam-column connections throughout the Building.

472. The effect of this was that the Building was incapable of carrying load through its structural elements, to the walls and then to the foundations.

473. This inadequacy may have been one of the most fundamental reasons for the collapse.

(l) Conclusion

474. There were a number of faults in the design of the CTV Building. Some were major and others minor. Some amounted to non-compliance with legal requirements. Others which may have satisfied minimum legal requirements fell short of best practice. Some made the Building susceptible to collapse, while others may not have made a difference to the outcome on 22 February 2011.

475. All of the faults illustrate why Dr Reay and David Harding and Dr Reay's firm should not have accepted the contract to do the structural design for the CTV Building.

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[310] TRANS.20120809.92, L5

Building Assessments

476. The ToR require the Royal Commission to inquire into the nature and effectiveness of any assessment of the Building and of any remedial work carried out on it after the September earthquake and the Boxing Day aftershock.

(a) Post September earthquake

477. Following the September earthquake there were two CCC initiated assessments; a Level 1 rapid assessment on 5 September 2010 and a Level 2 rapid assessment on 7 September 2010.

478. An engineering inspection on behalf of the building owner was carried out by David Coatsworth on 29 September 2010 and a follow up inspection on 19 October 2010.

(b) Post Boxing Day aftershock

479. Following the Boxing Day aftershock there was a CCC Level 1 rapid assessment on 27 December 2010 and a USAR Damage Reconnaissance inspection on the same day.

480. Although Jo-Ann Vivian, a manager with Relationship Services, the tenant on Level 6, contacted the CCC in early January to arrange an inspection of the building,[311] she later withdrew that request after she had spoken to John Drew, the Building Manager.[312] There was therefore no further CCC inspection after Boxing Day, nor was there any further engineering inspection initiated by Mr Drew.

(c) Remedial work

481. Although Mr Drew was in the process of obtaining quotations for the repair of concrete cracking, by 22 February 2011 no remedial work had been carried out, other than cosmetic repair and painting.

(d) Level 1 rapid assessments

482. It is accepted that it is appropriate to do the brief external inspection that is involved in a Level 1 rapid assessment, as part of a triage process. However, for a multi-level building there has to be something more. The New Zealand Society of Earthquake

[311] TRANS.20120702.106, L 21-26
[312] TRANS.20120702.108, L 5-9

Engineering (NZSEE) Guidelines provide that Level 2 assessments should be performed on multi-story buildings.[313]

483. There was what purported to be a Level 2 rapid assessment following the September earthquake. However, because of the way it was conducted it was not in fact a Level 2 assessment.

484. However, following the Boxing Day aftershock, as no state of emergency had been declared and because of the limited resources available in the Christmas holiday period, the CCC never intended to carry out a further Level 2 assessment.

485. As there was no owner initiated inspection following the Boxing Day aftershock either, the only inspection after Boxing Day was the Level 1 rapid assessment.

486. Given the proximity of the Boxing Day aftershock to the CBD a more detailed inspection was required, either in the form of a Level 2 rapid assessment or a further inspection by the owner's engineer Mr Coatsworth; preferably by both. This is an issue which the Commission may need to address in the Building Management hearing on 3 September 2012.

(e) Reliance on the Green Placard

487. It became apparent during the hearing that there was a perception amongst occupants of the Building, also held by Mr Drew as building manager, that the green placard indicated the Building was "safe to occupy". [314]

488. Mr Drew, although he indicated that he placed significant reliance on the fact the Building had been green placarded, did understand that it was recommended an owner obtain its own inspection.[315] However this is not a legal requirement of an owner and if a private inspection had not been obtained by the owner, occupation of the Building could have resumed on the basis of the green placard placed on the Building following the September 2010 Level 2 assessment.

489. Mr Drew should have obtained a further inspection by Mr Coatsworth after Boxing Day, but it appears that Mr Drew continued to place reliance on the green placard.[316] It would appear that some of the occupants did as well.[317] Assurances created by the reliance on the green placard may have created a situation that cost some people their lives.

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[313] ENG.CCC.0002F3.73
[314] TRANS.20120625.90, L 33 - .34, L3(Kulpe); TRANS.20120625.101, L14-15 (Cammock); TRANS.20120625.104, L7-9; (Cammock); TRANS.20120702.9, L13-23 (Drew)
[315] TRANS.20120702.13, L24-29
[316] TRANS.20120702.56, L18-20
[317] TRANS.20120625.91, L1-3 (Kulpe); TRANS.20120625.101, L14-15 (Cammock); TRANS.20120625.104, L7-9 (Cammock)

490. This highlights the need for consideration of a more detailed assessment following a significant earthquake or aftershock and reconsideration of the green colour of the placard and the impression this conveys. These are also issues that the Commission will have to address in the Building Management hearing.

491. Brian Kehoe, a Californian structural engineer who gave expert evidence, noted that there had been concern in the USA over the interpretation of green stickers by the public and that the wording had been changed from "safe to occupy" to "inspected".[318]

(f) Lack of training/understanding of the assessment process

492. It became apparent from the evidence of Messrs Calvert, Flewellen and Simson, the three CCC building inspectors who carried out the Level 2 rapid assessment on 7 September 2010, that they were relying on the briefings conducted each morning at the Emergency Operations Centre. Mr Simson said that they "*were left to second guess and use [their] combined experience as to what was safe or otherwise*".[319]

493. This lack of training was highlighted by the different understandings each of these three building inspectors had regarding the nature of the Level 2 assessments they were supposed to carry out.

494. It was apparent from the evidence of Mr Kehoe that, although New Zealand has guidelines from the NZSEE, there does not appear to be the more detailed information that is available in the USA to assist in the assessment of buildings, such as FEMA 306 or the ATC-20 Field Manual.[320] This needs to be addressed.

(g) Level 2 assessment: no engineer involved

495. The NZSEE Guidelines state that an engineer should conduct all Level 2 assessments. For a high-rise structure such as the CTV Building, with some structural complexity, an engineer's input was necessary.

496. The evidence of Stephen McCarthy, the Environmental Policies and Approvals Manager for the CCC, was that, as far as he was aware, the Level 2 assessment carried out on the CTV Building, where no engineer was present, was the only exception to this requirement.[321] It appears, however, that there were other occasions

[318] TRANS.20120705.35, L19-28
[319] TRANS.20120628.89, L5-11
[320] TRANS.20120705.17, L13 - .18, L30
[321] TRANS.20120703.24, L 26-33

when this occurred. The evidence of Marie Holland, the building inspector who carried out the Level 1 rapid assessment after Boxing Day, was to the effect that there were other Level 2 assessments carried out without an engineer.[322]

497. There appeared to be some inconsistency between the evidence of Mr McCarthy and Mr Flewellen regarding the instructions Mr McCarthy said he gave to the three building inspectors on the morning of the inspection. However, once they knew a Level 2 assessment was required, it appears that Messrs Calvert, Flewellen and Simson knew that inspection by an engineer was necessary.[323]

498. Although they knew this they were content to rely on an assurance from the man whom they understood to be the "Building Manager" of the CTV Building, that an engineering inspection would be arranged.[324] This reliance was inappropriate and potentially dangerous.

499. Despite knowing that an engineer should have inspected the CTV Building they proceeded to carry out an internal inspection of a very limited portion of the Building and then assigned the Building a green placard. This did not comply with the NZSEE or CCC guidelines, yet it would have effectively been understood by the occupants of the Building as a more detailed inspection which had resulted in a green placard, giving them further comfort in the "safety" of the building.

500. Within an hour of the inspection Murray Wood, the then CTV Manager, in an email to CTV staff, wrote "*We have just had an internal inspection of the building from 3 engineers and they have found that this building is in good condition and is deemed habitable*".[325] Mr Wood died in the collapse and there is no way of knowing why he described the three CCC building inspectors in this way.

501. The Level 2 assessment form completed by Mr Calvert did not indicate that there had not been an engineer present. Nor did it indicate there should be a follow-up engineering inspection, which would have been appropriate in the circumstances.[326]

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[322] TRANS.20120702.91, L1-8
[323] TRANS.20120628.34, L16-21 (Calvert); TRANS.20120628.67, L31 - .68, L3 (Flewellen); TRANS.20120628.99, L20 - .100, L15 (Simson)
[324] TRANS.20120628.33, L30 - .34, L2 (Calvert); TRANS.20120628.80, L30 - .81, L19; TRANS.20120628.101, L29 - .102, L6 (Simson)
[325] BUI.MAD249.0388.1
[326] BUI.MAD249.0137.1

The CCC's records would have simply shown a Level 2 assessment by "3 senior officials".

502. Mr McCarthy said that the Level 2 assessment was "superseded" by Mr Coatsworth's subsequent inspection.[327] Although it is correct to say that Mr Coatsworth's inspection was a more detailed one, the Level 2 assessment was not superseded and it still raises concerns; in particular, the failure of the three building inspectors to appreciate that the Building should not have been green placarded on the basis of their inspection. This green placard created a false sense of security on the part of occupants. This can be seen in the email sent by Mr Wood.[328]

503. The fact that there was a later engineering assessment done by Mr Coatsworth did not mean that the CCC green placard became irrelevant. Rather it combined with the later engineering assessment to give the Building occupants an even greater sense of security. It was also the sole basis on which occupancy was allowed to continue in the period prior to Mr Coatsworth's report on 6 October 2010. Fortunately for the CCC an earthquake with the force of 22 February did not strike then.

(h) Inadequate information systems

504. Further problems with record keeping by the CCC are highlighted by the fact that when the three building inspectors were sent out on 7 September 2010 they and Mr McCarthy were unaware of the fact that there had already been a Level 1 assessment of the CTV Building two days earlier.[329] Mr McCarthy said that he would not have sent the men to the Building if he had known that it required a Level 2 assessment.[330]

505. Similar problems were highlighted in the evidence of Jo-Ann Vivian. When she rang the CCC on 5 January 2011 to request an inspection of the building she was told that it was not in the area to be inspected by the CCC.[331] This, despite the fact that a Level 1 assessment had been carried out on 27 December 2010.

[327] TRANS.20120703.34, L13-18
[328] BUI.MAD249.0388.1
[329] TRANS.20120628.34, L13-15 (Calvert); TRANS.20120628.52, L2-17 (Flewellen); TRANS.20120628.90, L30 – 91, L1(Simson)
[330] TRANS.20120703.26, L6 - .27, L1-8
[331] TRANS.20120702.106, L21-24

506. It is imperative that an adequate information system be implemented quickly and effectively following an earthquake. It is anticipated that this is an issue that will be addressed in the Building Management hearing.

(i) Inspection by David Coatsworth

507. David Coatsworth, a CPEng engineer, provided a proposal to Mr Drew to conduct a visual inspection of the Building and determine whether there was any pattern to the damage observed that would explain any deficiencies in the performance of the Building following the September earthquake.[332]

508. At that stage the proposal did not include the removal of internal linings or the performance of a structural analysis. Mr Coatsworth explained that those things would have followed if he had observed significant structural damage.[333]

509. The inspection proposed by Mr Coatsworth and subsequently carried out on 29 September 2010, was, a "damage based" inspection.[334] The nature of "damage based" inspections has been examined in previous hearings. This type of inspection was being carried out by most engineers in the aftermath of the September earthquake, certainly as an initial inspection.

510. As a damage based inspection the inspection carried out by Mr Coatsworth was a reasonably thorough and competent one. However there are lessons to be learned for the future which largely relate to the inherent limitations involved in damage based inspections and the way in which those limitations are communicated to the public. There is also an issue about whether Mr Coatsworth adequately communicated to Mr Drew these limitations on the assessment he was proposing so that Mr Drew knew what he was accepting.[335] Mr Drew, as a lay person, was entitled to rely on the expertise of Mr Coatsworth to advise him on the appropriate inspection and in advising Mr Drew that only a damage based assessment was needed, at least initially, he should have clearly explained what that would and would not include.

[332] TRANS.20120704.5, L9-13
[333] TRANS.20120704.8, L2-5
[334] TRANS.20120704.5, L9-13; TRANS.20120704.78, L8-12
[335] TRANS.20120704.79, L8 - 30

511. In cross examination there was criticism of both Messrs Drew and Coatsworth that a more detailed engineering evaluation, including a structural analysis, was not carried out.[336]

512. Although a damage based assessment may have been considered appropriate by engineers at that time, it has since become clear that damage based assessments essentially proceed from the assumption that the building is Code compliant. In the case of the CTV Building this assumption was dangerously wrong. This raises the important issue of access to and perusal of structural drawings in any post earthquake inspection.

(j) Structural drawings

513. Mr Coatsworth asked Mr Drew if structural drawings were available and indicated that these would have been helpful in understanding the structural systems within the Building.[337] Mr Drew did not have the drawings. He said that he had put a request into the CCC for the Building file, but had been told it might be some eight weeks before it was available[338].

514. Mr Coatsworth said in evidence that he telephoned the CCC and was told that the files were not available because of the disarray in the filing system following the September earthquake[339]. Mr Coatsworth said that although he considered the structural drawings would have been useful to familiarise himself with the structural systems in the Building in advance of his visual inspection, he did not think the drawings were required for him to be able to conduct a meaningful inspection of the Building. That remained his position.[340]

515. Mr Coatsworth also said that after his inspection and subsequent report he did not make any further attempts to obtain the drawings as he had not observed any significant structural damage. Had he found any significant structural damage he would then have recommended the drawings be obtained as they would have been necessary to perform any subsequent quantitative structural analysis of the Building.[341]

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[336] TRANS.20120704.75, L5-20; TRANS.20120702.60, L32 - .61, L23
[337] TRANS.20120704.7, L5-8
[338] TRANS.20120702.18, L32 - .19, L2
[339] TRANS.20120704.5, L30-33; .6, L18-24
[340] TRANS.20120704.7, L5-12; .80, L19-22; .81, L18-28
[341] TRANS.20120704.7, L12-19

516. Mr Coatsworth did not consider it necessary to contact the CCC again to see if the drawings were available before he completed his report on 6 October 2010. After receiving the report Mr Drew received notification from the CCC that the Building file was available and he perused the file at the CCC offices and noted that the structural drawings were on the file. However, he did not contact Mr Coatsworth to advise him of this. He said this was because he had received Mr Coatsworth's report and concluded that if Mr Coatsworth had needed the drawings to prepare his report he would have followed that up[342].

517. Mr Drew can properly be criticised for not contacting Mr Coatsworth. Mr Drew was the Building Manager. He knew from both the initial enquiry Mr Coatsworth had made of him, and the comment made in the report, that Mr Coatsworth had wanted to see the structural drawings and had not obtained them. It would have been a simple matter for him to have left a message for Mr Coatsworth telling him that the structural drawings were now available.

518. On the other hand it is unfortunate that Mr Coatsworth did not either qualify his report by making clear the significance of his inability to assess the drawings, or ask Mr Drew to advise him if he learned that the drawings had become available. Mr Coatsworth accepted that the inadequate connections between the North Shear Core and the floor slabs would likely have been picked up by him had he viewed the drawings.[343] He did not say how quickly this might have been done, but this issue was picked up quickly by each of John Hare, Grant Wilkinson, Murray Mitchell and Geoff Banks when they looked at the drawings.[344]

519. Mr Coatsworth said that he had expressly looked for cracking in the area of connection between the North Shear Core and floor slabs as he knew of the importance of these connections in the shear wall system,[345] but he had found none.

520. The difficulty with this solely visual inspection of the North Shear Core connection is highlighted by what Professor Priestley said in evidence. He said that if the reinforcing mesh in the floor slab had cracked in the September or Boxing Day earthquakes, and he thought it entirely possible that it had, the crack might only have been 2mm. This

[342] TRANS.20120702, L26-29
[343] TRANS.20120704.90, L10
[344] TRANS.20120816.52, L10-15 (Hare) TRANS.20120816.119, L3-9 (Wilkinson); WIT.MITCHELL.0002.3, p6 (Mitchell); TRANS.20120817.3, L5-10 (Banks)
[345] TRANS.20120711.69, L28 - .70, L3

would not have been observable on a visual inspection without removing floor linings.[346] Mr Kehoe accepted that a crack of 2mm may not have shown up through the vinyl floor covering. [347] If Mr Coatsworth had obtained and reviewed the drawings it seems quite likely that he would have identified a concern with the connection to the North Shear Core and realised that either a more invasive inspection of that area, or a structural analysis, was required.

521. Mr Kehoe gave evidence in support of Mr Coatsworth's inspection and conclusions. He said that such an inspection did not necessarily require access to structural drawings, although he agreed that if they had been available for the CTV Building they would have shown Mr Coatsworth that his assumption that the beam-column joints were constructed in the standard fashion with steel reinforcing through the joint was incorrect. They would also have shown him that there were issues with the connection between the North Shear Core and the floor slabs. Although he expressed the view that this might not have changed Mr Coatsworth opinion, Mr Kehoe agreed that it would be a good idea to require perusal of structural drawings in post earthquake inspections.[348]

522. It is accepted that the majority of engineers in Mr Coatsworth's position at that time would have proceeded in the same way that he did. However it is submitted that in future all inspections of multi-level buildings, that are owner initiated and outside the emergency response period, should be required to include a review of the structural drawings. In the case of CCC Level 2 assessments this would also be highly desirable and all structural drawings should be available electronically in order to facilitate this.

523. A possible alternative to the need for inspecting engineers to access structural drawings would be to implement the type of system Mr Kehoe said was becoming common on a voluntary basis in California. This involves a pre-earthquake 'desk-top' assessment of the building by an engineer who can then, after an earthquake, quickly assess and placard the building on a well informed basis.[349]

524. Such a "desk top" analysis would also provide some degree of structural analysis of the building and thereby avoid the situation where an engineer inspecting a building following an earthquake has no way of knowing how that building would perform in an

[346] TRANS.20120711.69, L28 - .70, L3
[347] TRANS.20120705.14, L3-8
[348] TRANS.20120705.15, L1 - .16, L13
[349] TRANS.20120705.16, L14 - .17, L11

aftershock which might be larger than the original earthquake, as was the case with the CTV Building and most of the other buildings in the CBD. [350]

525. Again, these are issues which the Royal Commission may have to address at the Building Management hearing.

(k) Inspection of Beam-column joints

526. Mr Coatsworth examined all of the exterior beam-column joints and those interior beam-column joints that were not covered by linings (Level 2). However he only looked at one internal beam column joint above Level 2.[351]

527. It would have been preferable for Mr Coatsworth to have looked at more beam-column joints in the upper floors. Mr Kehoe accepted that Mr Coatsworth could have done so, although he did not necessarily think that Mr Coatsworth would have come to any different conclusions if he had.[352]

528. The beam-column joints that were inspected by Mr Coatsworth were the ones on which there was greater axial load. As a result, if there had been significant structural damage to beam-column joints as a result of the September earthquake it seems likely it would have been to the beam-column joints examined by Mr Coatsworth.

(l) Recommendations not carried out

529. In his report of 6 October 2010 Mr Coatsworth made two recommendations for further investigation. These were the removal of the pin board lining on the south wall on Level 1 and a check of the western wall. The more important is the first of these.

530. Mr Drew said that the pin board lining was not removed because he had received a negative reaction from Mr Woods, the CTV Manager, about the upheaval that would be involved in having to remove electronic equipment in that room. Mr Drew also said that he had not been under the impression that there was any urgency to Mr Coatsworth's request and as CTV was expected to move out at some stage the inspection could be done after this.[353]

[350] TRANS.20120704.33, L1-4
[351] TRANS.20120704.52, L9-24
[352] TRANS.20120705.26, L1-7
[353] TRANS.20120702.28, L1 - .29, L33

531. It would have been preferable for Mr Drew to have expeditiously carried out the recommendation, but Mr Coatsworth acknowledged that he did not suspect serious damage and assumed that his recommendation would be investigated "in time". He said that if he had suspected that there was serious damage he would have removed the lining himself at the time of his inspection.[354]

532. In evidence Mr Coatsworth said that on or about 1 October 2010, following his initial inspection, he telephoned Mr Drew and advised him that a security fence should be erected around the bottom of the fire escape on the south face of the Building to prevent injury to people walking beneath those stairs should plaster fall from the beam-ends.[355]

533. This recommendation was not complied with by Mr Drew. He said that he could not recall receiving such advice from Mr Coatsworth. It is understood that some of the families of the bereaved are critical of Mr Drew for not addressing this issue because a compromised fire escape might have led to the CCC closing the Building. However even if this had occurred any closure would almost certainly have been of short duration. It is very unlikely that it would have resulted in an empty building on 22 February

(m) Vertical cracks in the lift shaft

534. Graeme Smith, a qualified engineer and concrete repairer, visited the Building in early February to provide a quotation for repair of the cracks identified in the Coatsworth report.

535. Mr Smith inspected the inside of the lift shaft and observed horizontal cracks which corresponded to the cracking that Mr Coatsworth had observed in the stairwell. Mr Smith also observed two vertical cracks that ran down the length of the inside of the north wall of the lift shaft. Although they were not referred to in the Coatsworth report, Mr Smith said these cracks did not concern him.[356] Mr Coatsworth had not examined the inside of the lift shaft on his inspections. In evidence he said he thought the vertical cracks might have been construction joints or blemishes in the form-work.[357] The photographs Mr Coatsworth produced indicate this is unlikely.

[354] TRANS.20120704.99, L5-26
[355] TRANS.20120704.23, L27 - .24, L21
[356] TRANS.20120702.117, L1 - .118, L29
[357] TRANS.20120704.38, L 13-19

536. It is unfortunate that Mr Coatsworth did not inspect the lift shaft. As he was aware of the significance of the North Shear Core to the overall integrity of the Building this might have provided him with more information about potential damage to this area. He may also have observed the drag bars and examined their performance.

(n) Communication between engineers and the public

537. There is an issue that arose with Mr Coatsworth's inspection that has also been an issue with other buildings the Royal Commission has inquired into. This is the language used by engineers and how that is understood by the public. As Mr Coatsworth said, it is not possible for an engineer to say that a building will be safe in all circumstances. [358] Mr Coatsworth properly accepted that by concluding that the Building was structurally sound he was in effect conveying the message that it was "safe to occupy". It is clear that what engineers mean by this and what the general public understands by this is not the same. This and earlier hearings have underscored the need for there to be clarity in the language used by engineers to ensure it is understood by the public.

538. Clarity is also required when communicating the extent of an inspection. In this case Mr Coatsworth accepted that what he carried out was essentially governed by what he proposed to do rather than what he was asked to do. [359] Mr Kehoe agreed that it was desirable to state clearly in a report that it is not a structural assessment and to include necessary qualifications. [360]

(o) GNS Information

539. Mr Coatsworth, in common with many other engineers, was aware of the likelihood of aftershocks, but not that they might have the accelerations of the February earthquake. He was not in receipt of any information from GNS or any other source about the likelihood, location and extent of further aftershocks.[361]

540. Although GNS could not have predicted the accelerations of the February earthquake, it is vital that in the future systems are put in place to ensure that as much information as possible is provided to engineers carrying out post earthquake inspections.

[358] TRANS.20120704.31, L16 - .32, L2
[359] TRANS.20120704.43, L13-21
[360] TRANS.20120705.33, L26 - .34, L4
[361] TRANS.20120704.33, L4-14

(p) Red-stickering by fiat

541. Professor Mander said that "*it can be argued that with the level of observed as well as hidden damage, CTV building should have been red-stickered following the Darfield earthquake*".[362] He went on to contend that even without inspection by the CCC, because the September earthquake had been a design level earthquake the Building should have been red-stickered by fiat without the need for any inspection.[363]

542. Mr Kehoe did not agree with this argument. He considered that buildings normally will have more strength than that they were designed for, so that the fact that they may have experienced a design level event did not necessarily mean that the event had caused the level of damage which might be expected when the building reached its capacity.[364]

543. In relation to the contention that the Building should have been red stickered without inspection, Mr Kehoe said this was not something that applied in the United States and he had never heard of it being promoted or applied. He made the point that in order for it to be applied, inspectors carrying out a Level 1 inspection would need to know what the design level earthquake was for every building they inspected. He did not see this as a practical solution.[365]

544. Professor Mander also raised the issue of eyewitnesses reporting on what came to be referred to as the Building's "liveliness". In his view this should have served as a signal and confirmation to inspecting engineers that the Building had sustained some hidden damage.[366]

545. Mr Coatsworth acknowledged that he spoke to a number of occupants of the Building when he inspected it on 29 September 2010 and took into account their observations. He did not go back to the Building after 19 October 2010. However he did comment on the issue of "liveliness", saying "*I think those sort of comments are very hard to assess, people's impression of movement after an earthquake I think became much more heightened*".[367]

546. The whole basis of the assessment conducted by Mr Coatsworth was that any significant structural damage that was "hidden" would still be apparent from visible damage to the structure or linings. This is the test that was generally applied following

[362] TRANS.20120723.12
[363] TRANS.20120723.116, L12-16
[364] TRANS.20120705.9
[365] TRANS.2012075.10
[366] TRANS.20120723.18
[367] TRANS.20120704.95

the September earthquake and, as was apparent from Mr Kehoe's evidence, the test that is applied in the United States. Although one cannot be certain that there was no "hidden" damage, there were no indications of this to Mr Coatsworth. Given the thoroughness with which he conducted his visual examination the chance of such hidden damage being of significance would appear to be low.

(q) Low Cycle Fatigue

547. Professor Mander also advanced a hypothesis that low cycle fatigue could have been responsible for some "hidden" damage as a result of the September earthquakes and the after-shocks which preceded the February earthquake. Although this hypothesis may have had some theoretical basis, it was not supported by any physical evidence.

(r) Post Boxing Day

548. There is conflict between the evidence of Jo-Ann Vivian, and John Drew on the issue of what was said by Mr Drew in a telephone conversation he had with Ms Vivian on 6 or 7 January 2011, in which she discussed cracks to the column on Level 6 (C18).

549. Ms Vivian clearly gained the impression from what Mr Drew said that an engineer had inspected the Building following the Boxing Day aftershock.[368] Mr Drew denied saying this.[369] Ms Vivian had phoned the CCC to request an inspection of the Building. She says she subsequently phoned Mr Drew to let him know she had made this call and he told her an engineer had been through the Building after both September and Boxing Day.[370] She then phoned the CCC and cancelled the inspection. A CCC file note records that call.[371] It records that a structural engineer had been through the Building.

550. In an email on 1 March 2011 from Ms Vivian to her Chief Executive she recorded that Mr Drew had told her he had "*already had the building inspected by his own engineers* …".[372] When that email was put to her she accepted it did not record Mr Drew telling her the inspection had been after Boxing Day, but she nonetheless insisted this is what he had said to her.[373] Mr Drew said that post Boxing Day he had relied on the CCC green sticker, although he could not recall whether he mentioned this to her. He said

[368] TRANS.20120702.109, L18-26
[369] TRANS.20120702.64, L4-29
[370] TRANS.20120702.107, L21 - .108, L21
[371] BUI.MAD249.0310.1
[372] BUI.MAD249.0094B.5
[373] TRANS.20120702.111, L26 - .112, L17

he would have intended any reference to an engineer's inspection to be either the post-September inspection, or the CCC inspection that had been done after Boxing Day.[374]

551. The evidence does not allow any firm conclusion to be drawn about what actually happened. However, that phone call to Mr Drew from Ms Vivian did add to the number of concerns that had been expressed to him by occupants of the Building following Boxing Day.[375] It should have emphasised to him the need for him to arrange a re-inspection of the Building by Mr Coatsworth after Boxing Day and he did not.

552. The photograph produced by Peter Higgins, who provided a quotation for concrete cracking repair in February 2011, shows that there had been potentially significant additional damage to the lintel above column C18 following the Boxing Day aftershock.[376]

553. Mr Drew said in evidence that in January 2011 he tried to contact Mr Coatsworth to arrange another inspection. This confirms Mr Drew's awareness that a further inspection should occur. Mr Drew said that because it was the holiday period there was an answer message on Mr Coatsworth's phone and he did not follow this up because he thought that his "*energies were better employed getting the next phase underway*".[377] This was a reference to the concrete cracking repair.

554. Given the nature and location of the Boxing Day aftershock, the continuing concerns being expressed by the occupants, and indications of further damage, Mr Drew should have persisted in trying to contact Mr Coatsworth or another engineer to arrange a further inspection. Mr Drew accepted in cross examination that he could have done that.[378] It should have been done and it may have resulted in a different conclusion by Mr Coatsworth and a different ultimate outcome. Mr Drew treated the situation too lightly.

[374] TRANS.20120702.64, L4-29
[375] TRANS.20120702.64, L4-29
[376] BUI.MAD249.0454
[377] TRANS.20120702.40, L32 - 41, L32
[378] TRANS.20120702.67, L13-19

Construction Issues

555. The Hyland/Smith report highlighted a number of errors and omissions in the construction process.[379] One in particular may have contributed to the failure of the Building. This is the failure to roughen the faces of pre-cast beams where they connected with in-situ concrete, and in particular the ends of the beams where they met the circular columns.

556. Other errors and omissions that have been identified are:

    a. 'Bent-back' reinforcement bars in pre-cast beams where they connected to the North Shear Core.

    b. Insufficient spiral reinforcing through the beam-column joints.

    c. Insufficient attachment of the column C18 to Line D/E.

    d. Insufficient spiral reinforcing to properly contain and centre the vertical reinforcing bars.

557. These issues were explored at the hearing with the former Williams Construction employees, Messrs Brooks, Scott, Shirtcliff and Jones. Their evidence highlighted a catalogue of financial difficulties, mismanagement and inadequate supervision, all of which are likely to have contributed to the observed construction defects.

(a) Financial difficulties

558. The financial difficulties which beset the parties involved in the CTV project are likely to have had their genesis in the nature and timing of the project. It was a speculative design-build fixed price contract entered into at a time of high interest rates (26%)[380] with no principal tenant signed-up and not long before the 1987 sharemarket crash.

559. Although Mr Brooks initially recalled that in spite of financial problems affecting Prime West, Williams Construction was paid in full for the project, he conceded that after the takeover of Williams Construction by the Richmond Smart Group in April 1987 financial

[379] BUI.MAD249.0189.145-146
[380] TRANS.20120808.22, L19

problems began which could have affected the workmanship on the project.[381] This included problems with sub-contractors and suppliers not being paid.[382]

560. Mr Brooks went on to describe the situation that developed in early 1987 as one which had an unsettling effect on everyone and as a result could have manifested itself in poor quality workmanship. [383]

561. Mr Tony Scott also noted "*a change of culture within Williams Construction when Smart Group took over*".[384] Court proceedings that had been issued by the Smart Group against Messrs Brooks, Scott and Shirtcliff at a time when the CTV Building appears to have been half completed[385] must also have had an unsettling effect on both management and workers.

562. All of this occurred around the time of the September 1987 share market crash. The result was that ultimately the Richmond Smart Group went into statutory management, the Angus Group which held the majority shares in Union Construction Ltd, which had been formed by Messrs Brooks, Scott and Shirtcliff and which took over the CTV Building job, went into receivership. It appears that soon after completion of the CTV Building by Union Construction that company was also wound up.[386]

563. Mr Brooks was asked to return to Williams Construction in September/October 1987 because of the "*parlous state*"[387] *of the company*" and the management which had replaced him. The end result was that the CTV contract was assigned to Union Construction.[388] It appears that most of the Williams Construction staff were transferred over to Union Construction at this point.

564. It seems inevitable that the financial and management troubles throughout much of the period of the CTV construction must have caused disruption and have been unsettling to the work staff. The potential was certainly there for this to have led to errors and omissions in construction details.

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[381] TRANS.20120808.12, L13-15
[382] TRANS.20120808.16, L16-19
[383] TRANS.20120808.15, L14-21
[384] TRANS.20120808.86, L15-16
[385] TRANS.20120808.87, L2-4
[386] TRANS.20120808.87, L24-29
[387] TRANS.20120808.20, L10
[388] TRANS.20120808.21, L20-21

(b) Supervision

565. As described by Mr Brooks, Bill Jones, the foreman of Williams Construction for the CTV job, appears to have been a classic example of most foremen of that era who were fundamentally carpenters by trade, trained to a level of light timber structures up to three storeys in height and who over many years of experience pick up other skills and a wealth of knowledge in construction.[389] Mr Jones does not appear to have completed a formal apprenticeship, but rather worked his way up to leading hand and then foreman over some years.[390]

566. Mr Brooks commented that management expected more from the foremen than they were initially trained for.[391] He referred to the management system of former Ministry of Works contracts, which included a Clerk of Works who provided comprehensive oversight. He contrasted this to the CTV job which he described as a "design-build contract a package deal" with no one performing such a role.[392]

567. Mr Brooks believed that the CTV Building may have been Mr Jones' first experience with a design-build contract.[393] This was confirmed by Mr Jones who said that there had been less supervision of construction than he had been used to in the past. He was used to having a Clerk of Works on site who was invaluable to a foreman to help with technical matters.[394]

568. It was because of the expansion of Williams Construction in 1986, and the perceived need to strengthen the management by employing a structural engineer and alleviating some of the responsibility placed on the foreman, that Gerald Shirtcliff was appointed as Construction Manager.[395] Mr Shirtcliff says that this was in about September/October 1986.[396]

569. Although Mr Shirtcliff was not intended to specifically act as a Clerk of Works he was, with his engineering background, intended to provide "guidance and mentoring" to the foremen on several different Williams Construction jobs in Christchurch. However, according to Mr Brooks, "*he just wasn't up to the job*".[397]

570. Both Messrs Brooks and Scott said they expected Mr Shirtcliff would have visited the CTV site daily. However, Mr Shirtcliff's evidence was that he only visited the site about

[389] TRANS.20120808.24, L32 – 25, L3
[390] TRANS,20120808.125
[391] TRANS.20120808.25, L15-16
[392] TRANS.20120808.25, L27-32
[393] TRANS.20120808.26, L5-6
[394] TRANS.20120808.134, L4-7
[395] TRANS.20120808.3, L9-17
[396] TRANS.20120808.55, L12-13
[397] TRANS.20120808.26, L32

once a month because he believed it was a reasonably simple and straightforward job.[398]

571. Although Mr Shirtcliff agreed that it was apparent once he commenced his job, that there was a need for more management and oversight of the project, he said he was unaware that he was supposed to be providing mentoring and guidance and "*left it*" to Mr Jones because he considered that he was a highly competent and capable foreman and that it was a relatively straightforward job which was being monitored by the design engineer and the Council.[399] He accepted that he essentially relied on others.[400]

572. Although there were difficulties with Mr Shirtcliff's credibility, his evidence made it clear that he spent insufficient time at the CTV site. This was confirmed by Mr Jones who said that Mr Shirtcliff did not spend much time on the site at all and that he had "*very little contact with him*". [401]

573. Mr Jones may have been a competent and experienced foreman. However he was working in circumstances he appears to have been unused to and without the "guidance and mentoring" and technical advice he might have received from a competent construction manager supervising him. This may have contributed to the errors and omissions in construction that are now known to have occurred.

574. There is also a note in the CCC inspection record in August 1987 that a new foreman had been appointed.[402] Mr Jones was unclear on this, but accepted that there may have been a period when he was not on the site. If that was the case, Mr Shirtcliff was spending very little time at the site and Mr Brooks had by then departed to Union Construction. This may also have been a contributing factor to the construction defects.

(c) Staff

575. It appears that there were some 8-14 staff on the CTV site at any given time, plus Mr Jones. According to Mr Jones, at any one time some would be working on shear walls, others working on the south wall and others on the columns. He said that it was hard at that time to get good staff and that some were hired on a daily or weekly basis. If they were good they were kept on, otherwise he would get rid of them. [403]

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[398] TRANS.20120808.60, L15-20
[399] TRANS.20120808.65-72
[400] TRANS.20120808.81, L19-21
[401] TRANS.20120808.145, L32
[402] BUI.MAD249.0117B.1
[403] TRANS.20120808.128, L1-5

576. This difficulty in employing good tradesmen and retaining them is another factor that could have contributed to the construction defects.

(d) Supervision by David Harding and CCC

577. Supervision of construction was part of the contract between Williams Construction and Alan Reay's firm. Mr Harding says he visited the site regularly and completed site inspection reports,[404] but there are also indicators that the supervision was not as thorough as it should have been

578. Bill Jones said that he would ring David Harding for every concrete pour except the columns, because there the steel was already "*sticking out of the columns for them to see at their initial inspection*". However he said that sometimes Mr Harding did not arrive at the site, but would ring and say "*if you don't see us, go ahead*". Mr Jones said this did not concern him.[405] Mr Harding denied this had occurred.[406] Unfortunately Mr Harding's site inspection records have not been able to be located.

579. Mr Brooks said pre-cast beams were delivered to the building site where they sat stacked at the site for some time. The problem with the lack of roughening to the beam faces should have been visible to an engineer carrying out regular inspections, as well the foreman and construction manager.[407] Mr Harding should certainly have been well aware of the critical significance of beam roughening. The problem with the "bent back" bars in the pre-cast beams should also have been visible.

580. The CCC inspection records show a five month gap in inspections between April and August 1987, with no apparent explanation.[408] Mr Scott thought that the gap showed a problem with the CCC inspection staff and their reliance on the design engineer carrying out supervision. Mr Jones also formed the impression that the CCC inspectors relied on the design engineer to carry out supervision.[409]

581. The evidence of Mr Leo O'Loughlin, a building inspector with the CCC during this period, commented that the number of inspections for CTV was a "*bit light*" for a building of that size in relation to both the number of inspections and their extent. He did observe that at that time inspections were occasionally carried out that were not recorded on the microfiche cards. [410]

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[404] TRANS.20120730.45, L6-16
[405] TRANS.20120808.132, L15-19
[406] TRANS.20120807.76, L9-31
[407] TRANS.20120808.42, L9-18
[408] BUI.MAD249.0117B.1
[409] TRANS.20120808.134, L1-2
[410] TRANS.20120807.43, L4-21

582. It is submitted that the important failure to roughen the faces of the pre-cast beams ought to have been identified by Mr Shirtcliff and Mr Jones and by Mr Harding, as should the bent back reinforcement bars. The other defects may be more debateable. The CCC inspections should also have performed a supervisory role.

(e) Explanations for construction issues

583. The Williams Construction witnesses, with the possible exception of Mr Brooks, did not offer any suggestions on how the identified construction defects had occurred. In particular the person who would have been closest to the day to day construction, Bill Jones, was at a loss to explain them.

(f) Failure to roughen surfaces

584. The roughening of the faces of the pre-cast beams was a design issue as well as a construction issue. There was both a lack of detail and inconsistency in the way this requirement was detailed by Mr Harding on the drawings and in the specifications.

585. The specifications provided that "*all surfaces against which concrete is later to be cast shall be left roughened by brooming the poured face while the concrete is still plastic*" and that the surface of pre-cast shell beams inside the stirrups "*shall be roughened to ensure good bond to the infill concrete*".[411]

586. However, while the structural drawings detailed roughening on most inside surfaces of shell beams, they did not detail any roughening on the ends of beams where they would meet the in-situ concrete of a column.[412]

587. For this potentially very serious failing in the structural drawings the responsibility must lie with Mr Harding and Dr Reay. However, it is also a matter of concern that Mr Jones, who said he understood the concept of roughening, never gave it any thought at the time.[413]

588. It also became apparent at the hearing that the method of roughening specified in the specifications would have been difficult, if not impossible to achieve, in relation to the beam ends.[414]

[411] BUI.MAD249.0199.8-9
[412] BUI.MAD249.0284.19-25
[413] TRANS.20120808.135, L18 – 136, L24
[414] TRANS.20120808.40, L22 - 41, L1

(g) Bent-back bars

589. The Hyland-Smith report shows a photograph of the steel connecting bars in one of the shell beams connected in an east-west direction to the North Shear Core, completely bent back.[415] The structural drawings show these H24 bars going directly into the North Shear Core.[416] According to the Hyland-Smith report this defect was repeated on all but Level 2.[417] The effect of this is that none of those beams were adequately anchored into the critically important North Shear Core.

590. Mr Brooks said that the bars could not have physically been bent back on site and were more likely to have been the result of an error regarding what was received from the supplier.[418] This might suggest that the problem originated with the steel fabricators, but this should have been picked up by Messrs Harding, Jones and Shirtcliff and possibly the CCC inspector. The fact that the bent-back bars were not providing a connection to the North Shear Core should have been obvious to those working on the site, particularly as the L2 connection was different.

591. Mr Brooks commented that this was a serious problem and one that clearly contributed to the failure of the building.[419]

592. Whether this construction defect did contribute to the way the Building separated from the North Shear Core has not been established. However, the connections in this area were certainly important. This is another issue that raises concerns over the level of supervision and quality control at the site.

(h) Spiral Reinforcing

593. The inadequacy of the spiral reinforcing in the columns is principally a design issue, but it also involves an issue "buildability". Mr Jones said that it was difficult to get it through the beam-column joints – one circle of the steel would be "*the max*".[420] The post collapse evidence found virtually no evidence of the spiral confinement being carried through the beam-column joint and Mr Harding's drawings were also inconsistent on whether this was required. In the end, given the weakness of the beam-column joint the failure to carry through the widely spaced spiral is unlikely to have contributed to the collapse, but it again illustrates both design and construction failings.

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[415] BUI.MAD249.0189.210
[416] BUI.MAD249.0284.20
[417] TRANS.20120808.139, L11-33; BUI.MAD249.0189.209
[418] TRANS.20120808.31-34
[419] TRANS.20120808.32, L25-26
[420] TRANS.20120808.142, L3-4

594. There was also at least one example of very poorly aligned vertical steel reinforcing in a column. Mr Jones could not offer an explanation for the vertical reinforcement steel being so close to the outside of the columns in the photo taken by Mr Heywood.[421] Although this should have been picked up on site it is also a design issue, with the spiral being inadequate to properly contain the vertical reinforcement steel.

595. Mr Jones said he remembered thinking the reinforcement and the size of the columns made the Building "*light*" having regard to its height. He also noted that the spiral reinforcing was "*quite light*" because it was able to be stretched out on site.[422]

596. He also confirmed that the spiral reinforcing was not anchored into the centre of the column. [423] He also said that he "*worried*" about the bottom bars because they did not do anything. [424]. There is no evidence that Mr Jones voiced his concerns to anyone.

597. Essentially Mr Jones said that he did not raise any of these concerns, as he had learned to keep quiet, he not having an engineering degree.[425]

598. It is of concern that the issues referred to by Mr Jones, some of which were Code compliance issues, were not raised with Mr Harding or the CCC. Had they been it may have at least caused a reconsideration of some of the design details, although given Mr Harding's continued unwillingness to accept any shortcomings with the design 26 years later it is unlikely he would have been any more receptive then.

(i) Conclusion

599. The lack of roughening on the pre-cast beams and the bent-back bars were both serious construction errors which may have contributed to the collapse.

600. The picture that emerged from the evidence is of a speculative design-build project, built fast under the pressure of very high interest rates and with an inadequate regard for quality. Despite supposed built-in profit margins it struck financial and management problems. The foreman and workers needed more technical assistance and supervision than they were given. This was a troubled site and troubled sites are often associated with troubled buildings.

[421] WIT.HEYWOOD.0002.9
[422] TRANS.20120808.130, L6-10
[423] TRANS.20120808.156, L2-8
[424] TRANS.20120808.142, L11-13
[425] TRANS.20120808.146, L25-29

Drag Bar Retrofit: the 1990 HCG report

601. In January 1990 HCG was instructed to carry out a pre-purchase review of the Building as part of due diligence by a prospective purchaser, the Canterbury Regional Council.

602. On 25 January 1990, after obtaining architectural drawings and some structural drawings from Alun Wilkie & Associates, John Hare of HCG carried out an "*approximate seismic analysis*" and identified an area of non-compliance in the connections between the North Shear Core and floor slabs. His evidence was that this was picked up "*fairly quickly*"[426] as there appeared to be no connection detailed for the floor on either side of the lifts. This issue was later described by him in his report as "*a vital area of non-compliance with current design Codes*".[427]

603. Mr Hare visited the offices of Dr Reay's firm the next day. His evidence was that he recalled speaking to both Dr Reay and Mr Geoff Banks. Although Dr Reay and Mr Banks were not clear on whether they both attended that meeting, it seems likely that Mr Hare's recollection is correct as he recalled it being indicated to him that there may have been some provision to address the issue during construction.[428] This must have come from Dr Reay as Mr Banks was not with Dr Reay's firm at the time of the CTV construction.

604. The issue highlighted by Mr Hare was, on any view, a serious one. Grant Wilkinson, Mr Hare's supervisor at the time, described it as a "*critical structural weakness*"[429] and that the problem was *"absolutely fundamental problem*".[430] Both Dr Reay and Mr Banks agreed that, in today's terms, it would be described as a critical structural weakness. [431] Dr Reay also described the issue as "*fundamental engineering*" [432] and "*a straight blunder*".[433]

605. There was some attempt by Dr Reay to suggest that because HCG may not have told Dr Reay's firm that HCG had been told to cease work on the matter, HCG had not been absolved of all responsibility.[434] However, ultimately both Dr Reay and Mr Banks

[426] TRANS.20120816.52, L13-15
[427] TRANS.20120816.51, L28; 52, L14; 57, L10
[428] TRANS.20120816.54, L1-9
[429] TRANS.20120816.115, L19
[430] TRANS.20120816.119, L4-5
[431] TRANS.20120817.45, L32; .120, L12-13
[432] TRANS.20120817.123, L3
[433] TRANS.20120817.125, L3-4
[434] TRANS.20120817.134, L4-7

accepted they had a responsibility to address the issue on the basis that Dr Reay's firm had designed the Building.

606. Mr Banks was clear that Dr Reay had an oversight role throughout.[435] Dr Reay, despite being the principal of the firm at the time, attempted to minimise his involvement by asserting that he was not providing oversight, but that it was Mr Banks liaising with him and a "*joint situation*"[436] This is surprising given the seriousness of the issue and the fact that Mr Banks had no previous involvement with the CTV Building. This aspect of the evidence shows some similarity to the way in which Dr Reay has sought to put primary responsibility on Mr Harding for the original errors in the Building design.

607. Dr Reay also attempted to minimise any responsibility in this matter by contending that "Holmes otherwise considered that the building generally complies with current design loading and material codes."[437] As a result both he and Mr Banks had concluded it was unnecessary to carry out any wider enquiry into the structural soundness of the building.[438]

608. Dr Reay had to take that stance because it must have been apparent to him that once this serious and fundamental error came to light, a wider review of the design should have been carried out, particularly as he knew Mr Harding had been inexperienced in multi-level design.

609. Dr Reay did not tell Mr Banks of David Harding's inexperience. When asked about this Mr Banks said this would have been relevant information which he should have been given and which, had he been given it, might have affected his inquiries. [439] Dr Reay's failure to tell Mr Bank's this is puzzling.

610. The attempt to suggest that the HCG report could be relied on by Dr Reay and Mr Banks for concluding that no general review of the design was necessary was disingenuous and can be rejected on a number of grounds:

[435] TRANS.20120817.58, L3-24
[436] TRANS.20120817.126, L16
[437] TRANS 20120817.106, L24-25
[438] TRANS 20120817.2, L4-23; TRANS 20120817.122, L15-20
[439] TRANS.20120817.52, L16 - .53, L4

a. The HCG report was not a full peer review, but a pre-purchase review directed to the prospective purchaser and not Dr Reay's firm. Dr Reay's firm was legally not entitled to rely on it.

b. More substantively, despite efforts in cross examination to present it otherwise, the report was clearly limited:

i The terms of the report made it clear that there had been limited time available, that the review was limited to a brief inspection of the Building and documents and approximate calculations.[440]

ii The conclusions reached were stated to be qualified by those facts.

iii Further, the report's conclusion as to Code compliance other than the North Shear Core connection was qualified ("*generally complies with current design loading and materials Codes*").

c. There is nothing in the evidence to suggest that either Dr Reay or Mr Banks made any inquiry of Mr Hare to ascertain the extent of the review of the rest of the Building. The responsible course by Dr Reay, given the background, of which he was aware, would have been to do so. Again, it is surprising that he did not do this, given the extent to which he said he was relying on it providing an assurance that the Building was Code compliant.

611. It seems inexplicable that Dr Reay, on learning that Mr Harding had made such a fundament design error, did not direct Mr Banks to conduct a full review of the design and involve himself closely in this.

612. The potential for a major loss claim against Dr Reay's firm and the associated insurance implications, might explain this otherwise puzzling conduct. Dr Reay's firm was warned by the receiver of a possible claim if the defect caused the sale to CRC to collapse.[441] If further defects had been identified this would have been likely to have had exactly this effect. The Nelsonian "blind eye" might have been appealing. Subsequent conduct by both Dr Reay and Mr Banks was very clearly influenced by liability concerns, a fact that was acknowledged in cross examination.[442]

[440] BUI.MAD249.0081.11
[441] BUI.MAD249.0129.27-28
[442] TRANS.20120817.66, L25-27 (Banks)

613. Dr Reay said this was the first time he had looked at the structural drawings. Had he done so at the time of the design it is apparent that he would have seen this fundamental error and, presumably, then reviewed all of the design. Had this happened the ultimate tragedy might have been averted.

614. Within a few days of being alerted to the issue, and after perusal of the file and structural drawings held by Dr Reay's firm, inquiries of Mr Harding, and investigation with a "bar finder" at the Building, Dr Reay says a pragmatic decision had been made to proceed with the remedial work on the basis that there was no reinforcing and this serious issue should be dealt with.[443] However, Mr Banks did not accept the term "*pragmatic".* He accepted that he knew that it was very likely the identified problem did exist and nothing had been found to indicate it did not.[444]

615. Despite knowing to a high level of likelihood that the critical structural weaknesses existed, Dr Reay and Mr Banks persisted in an attempt to minimise the reality of the situation in their dealings with both KPMG and, much later, Mr Ibbotson of Madras Equities Limited. It was clear that this was motivated at least in part by the need to avoid any acceptance of liability.[445]

616. The posturing that there could be sufficient reinforcement when both Dr Reay and Mr Banks knew otherwise continued for about 21 months, up until the point that the remedial work was finally carried out.

617. This charade was extended by Mr Banks in claiming that when the holes were drilled in October 1991, prior to the installation of the drag bars, some H12 bars were located which could have provided some "minor" connection.[446] However there was no suggestion in any of the inquiries made that the Building was not built to the plans and those plans showed the H12 bars. That fact was known from the outset. They were not unexpectedly located in October 1991.

618. Despite accepting responsibility to address the issue in February 1990, and initially treating it with some urgency, nothing was done by either Dr Reay or Mr Banks after CRC decided not to proceed in early 1990, until early 1991 and the remedial work was not done under September 1991. This was 21 months after the critical structural

[443] TRANS.20120817.107, L25-29
[444] TRANS.20120817.64, L30; 65, L6
[445] TRANS.20120817.66, L25-27 (Banks)
[446] TRANS.20120817.26, L23-25

weakness was first identified by HCG. Neither Dr Reay nor Mr Banks could satisfactorily explain that delay.

619. They effectively appear to have been "laying low", perhaps hoping the problem might disappear. There certainly appears to have been no attempt to contact the receiver in that period or to adopt a pro-active approach.

620. Dr Reay explained in cross examination that during that period he had been "keeping an eye" on the Building whenever he drove along Madras Street, looking for signs of occupation. Although he claimed that he had not been concerned over what might happen if there was an earthquake, he accepted that if the Building was occupied there was a risk.[447] It is submitted that Dr Reay's suggestion that he was somehow monitoring the situation because of a potential risk, a risk which Mr Banks accepted was present whether the building was occupied or not,[448] is farcical.

621. It was apparently by chance in February 1991 that Dr Reay and Mr Banks saw an article in *The* Press newspaper advising of the sale of the Building. Dr Reay claimed that if he had not seen that article he would have discussed it with Mr Banks at some point and would not have "*let it run on indefinitely*".[449] When that might have happened is unknown and in any event this was not an appropriate stance for a responsible structural engineer with the knowledge he had of a fundamental design defect in a building his firm had designed.

622. That stance displayed further dilatoriness once they had become aware of the sale. Both Dr Reay and Mr Banks said in evidence that they were of the view that it was their obligation to advise the new owner of the connection issues. However, when Mr Banks contacted the insurer his own file note records that he had asked "what are our obligations (if any) to notify anyone re status of review to date?"[450]

623. Mr Banks took issue with the terms of his own file note, but could not explain why he had recorded it in that way. Dr Reay explained the file note by saying that Mr Banks would have been "*thinking about to what degree we should be notifying that, not, whether we should notify the people per se*".[451] However this explanation was

[447] TRANS.20120817.135, L33
[448] TRANS.20120817.73, L21-27
[449] TRANS.20120817.137, L1-6
[450] BUI.MAD249.0227.6
[451] TRANS.20120817.23, L28-33; TRANS.20120817.142, L7-8

inconsistent with a notation on the same file note which recorded "*preliminary advice from insurance point of view is no further action*". Dr Reay could not explain what that meant either.

624. Dr Reay said he accepted that there was an urgent need to notify once they had learnt there was a new owner.[452] Yet despite obtaining legal advice in March 1991 there followed a period of over five months during which, nothing was done. Dr Reay could not explain that delay either.[453]

625. The final insult in this sorry saga of minimisation and avoidance was to leave it to the new owner, Madras Equities Ltd, to pay for the remedial work. Mr Banks in all his correspondence with Madras Equities over this issue made no offer to pay. Throughout he made it clear that the firm was not accepting any obligation. Although Dr Reay claimed that he had to "follow insurance" rules, he must have known that he could make a "without prejudice" offer for the cost of the remedial work. It was well under his firm's insurance excess and the correspondence shows he was familiar with the term "without prejudice". [454]

626. When it came to finally attempting to remedy the problem in October 1991, instead of taking the conservative approach of installing drag bars on all Levels, Levels 2 and 3 were omitted. Mr Hare said he would not have agreed to that course and took the view that it would have been much easier to simply install drag bars on all levels.[455] The HCG preliminary analysis had all proceeded on the basis of drag bars on all floors.

627. Mr Banks said that it was not simply a matter of taking the easy approach, but rather a matter of properly calculating the loads.[456] However, when one considers the minimal additional costs involved, and the fact that the defect highlighted was a potential life safety issue, it is difficult to understand why the 'easy' course was not taken. It may have been part of the culture developed under Dr Reay which Mr Harding described, detailing only what was absolutely necessary.[457]

628. Even after the drag bars were installed they would not have been as effective as a Code compliant connection in the original design and construction:

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[452] TRANS.20120817.143, L4-5
[453] TRANS.20120817.144, L12; TRANS.20120817.145, L8
[454] TRANS.20120817.145, L9-26
[455] TRANS.20120816.74, L27-29
[456] TRANS.20120817.28, L16-22
[457] TRANS.20120730.131, L24-28

a. A retrofit was inherently incapable of putting the Building into the same state as would have been required to achieve compliance with the Code originally.

i. Professor Priestley gave evidence that:

> In my view drag bars as designed for the CTV connection retrofit were a poor alternative to a properly designed connection involving a greater contact area between the floor and the webs of the North Shear Core.[458]

ii. The drag bars were inherently brittle. Their capacity was limited to the capacity of the connections of the bolts to the wall.

iii. If adequate connections had been included in the original design, they would have included reinforcing steel which would have extended between the diaphragm and the wall within the concrete. This would have provided much more ductility than the drag bars could ever have provided.

b. The drag bars should have extended back to line 3.

i. Dr Jacobs gave evidence that:

> Retrofitting effective drag bars under the slab would have been a difficult task to achieve practically once the Building had been completed. The drag bars would have needed to connect to the slab back to line 3 to be effective, in my opinion.[459]

ii. The drag bars detailed by John Hare were longer than those which Mr Banks eventually designed.

(a) Building permit

629. When the drag bars were installed in October 1991 no building permit was obtained from the CCC. Stephen McCarthy of the CCC said that a permit was required for that work and this appears to be correct.

[458] TRANS.20120711.55, L9-14
[459] WIT.JACOBS.0002.7, para 22

630. Mr Banks said that Dr Reay's firm did not apply for a building permit for this retrofit work and he was not aware whether the owner of the building had done so. His recollection of the early 1990s prior to the adoption of the Building Act 1991 was that the building permit process was much less structured than it is now,[460] implying that a building permit would not have been required then.

631. However as pointed out to Mr Banks at the hearing, the CCC Bylaws made it clear that a permit was required for that retrofit work.[461]

632. Dr Reay said that although he did not believe a permit was sought for these works, based on his experience in dealing with Mr Bluck over many years he believed that Mr Bluck's view would have been that the works were part of the original job and that no permit was required, although Mr Bluck might have asked to receive details about what was undertaken.[462] This is contrary to the CCC Bylaws at the time and there was no other evidence to support this.

633. It is submitted that these explanations are simply attempts, post the event, to try to explain what was at best a clear omission and at worst a further attempt to minimise the potential issues with the Building and avoid making the CCC aware of them and enlarging the liability risk that was already a source of concern.

(b) IPENZ – Ethical obligations

634. Trevor Robertson, the structural engineer who gave expert evidence for HCG on IPENZ ethical obligations, expressed the view that because HCG had advised Dr Reay's firm of the issue and it had been accepted, and an indication given by Mr Banks that the issue would be addressed, there had been a "passing of the baton".[463] There was no longer any obligation on HCG but only on Dr Reay's firm.

635. Mr Robertson also believed that such a critical structural weakness should have been dealt with more expeditiously. In his view three to six months would have been appropriate. This differed from the more expansive time frame given by Mr Wilkinson

[460] TRANS.20120817.31, L9-11
[461] TRANS.20120817.104, L6-24
[462] TRANS.20120817.112, L25; TRANS.20120817.113, L2
[463] TRANS.20120816.145, L18-23

who thought that the 21 months still met the IPENZ Standard. He drew an analogy to the time the CCC allowed for earthquake-prone buildings to be upgraded.[464]

636. Mr Robertson made a number of comments which will be of interest to the Commission and which can be more closely scrutinised in the hearing on Training and Education on 10 September 2012.

637. Although the current IPENZ Code is more comprehensive than the Code that existed in 1990, Mr Roberston said the disclosure obligation clauses are not substantially different. Mr Robertson's view was that something more definite in terms of obligations of disclosure was necessary. He agreed that the IPENZ ethical rules appear to have a significant number of unresolved conflicts and contradictory obligations.[465]

638. In his view engineers would welcome a "*tightening up of the rules*", especially in terms of their obligations if the advice to the reviewing engineer is neglected or rejected.[466]

639. It is submitted that what has occurred with the CTV Building highlights the need for the reappraisal of these rules. If the design engineer is notified of a critical structural weakness but either does not take it seriously or does not act in a timely manner, it then becomes an issue of public safety. The rules are unclear regarding the obligations of the reviewing engineer in those circumstances. [467]

640. These events have also highlighted the difficulty where the owner is a receiver whose first obligation is to the debenture holder and, absent any misrepresentation, the receiver may for this reason feel obligated to avoid disclosure of a critical structural weakness. This raises an issue over the adequacy of the design engineer reporting the issue to the owner in these circumstances.[468]

641. The other issue which requires review is the question of disclosure of a critical structural weakness, particularly one which affects public safety, to a territorial authority. There appeared to be a favourable reaction to this being a requirement, from both Mr Robertson and Mr Wilkinson.

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[464] TRANS.20120816.134, L25-32
[465] TRANS.20120816.140, L24-27
[466] TRANS.20120816.143, L7; .144, L9
[467] TRANS.20120816.138, L20; .139, L19
[468] TRANS.20120816.140, L11-22

642. If an independent statutory body such as a territorial authority is advised, only then can there be an assurance that the issue will be dealt with expeditiously and take into account the issue of public safety.

643. The need for such an obligation is emphasised when one considers the large number of people or entities who became aware of this critical structural weakness in the CTV Building prior to 22 February 2011. No less than 10 individuals and entities were made aware of it: John Hare, Grant Wilkinson, Dr Alan Reay, Mr Geoff Banks, KPMG Peat Marwick, CRC, Michael Brooks and a number of other real estate agents, Mr Ibbotson, Madras Equities, Murray Mitchell and Opus Consultants Ltd. The CCC was never made aware of it.

(c) The failure to install drag bars on Level 1 and 2

644. Whether the absence of drag bars on Level 1 and 2 contributed to the collapse of the Building is not clear. The most recent NLTHA identified Level 1 and 2 as the most likely location of collapse initiation. All that can be said at this stage is that it might have and the approach to structural design advocated by Dr Murray Jacobs, which was almost the complete opposite of the "minimisation" approach ascribed to Dr Reay's firm by Mr Harding and others has much to recommend itself. Drag bars on all floors would have only cost an additional $2,000 or so.

Conclusion

645. The CTV hearing has been the most arduous of the hearings the Royal Commission has had to deal with. This has been both because of its duration and the emotional toll it will have taken on many people.

646. At the same time, it has also uncovered issues of great importance that have much wider implications than the collapse of the CTV Building. This includes the issues that the Royal Commission will now be required to consider and report on.

Stephen Mills QC
Counsel Assisting
Dated 27 August 2012