

OPENING: FORSYTH BARR BUILDING

Submissions of Counsel Assisting

Introduction

1. The Forsyth Barr Building is on the south-east corner of Colombo and Armagh Streets in central Christchurch, a short distance away from Cathedral Square.
2. It is an 18 storey building. The permit was issued in 1988. It relies for its lateral strength on concrete beams and columns. The stairs in the Building were pre-cast scissor stairs, fixed at the top end of each flight, but designed to slide at the bottom end during an earthquake, with that movement being accommodated by a seismic gap. The stair details are in the structural drawings **BUI.COL764.0041.85 - 88**. The seismic gap detail is shown in the drawings at **.87** and **.88**. The stair specifications are at **BUI.COL764.0040A.7**.
3. The Building itself performed well in both the September and Boxing Day earthquakes, but in February the stairs sustained an almost complete collapse. The fact that this occurred at a point well before the Building sustained any significant damage has now emerged as a cause of particular concern. Egress stairs need to be 'the last man standing'.
4. By great good fortune no one was on the stairs at the time, or fell in trying to descend non-existent stairs in the dark. However tenants were trapped in the Building for a number of hours, some escaping by abseiling down the side of the Building, others being lifted out by crane. Tenants had no means of immediate escape despite the continued aftershocks and the fear some of them had of fire. For many it was clearly a frightening experience.
5. How close this came to a much more tragic event is made frighteningly clear in an item posted on the website Stuff.co.nz, by an unidentified person who I will refer to as "Jane". Jane was on L17 when the February earthquake hit.
6. Jane's account makes for both graphic and terrifying reading. Following a lull in the rocking, rolling, shaking and crashing that seemed to last forever, Jane decided she was getting out of there! She took off for the exit stairs, only to find when she opened the stairwell door that there was no emergency lighting in the

stairwell and it was dark – not just night-time dark, but pitch black dark. Nonetheless Jane knew she had to get out.

7. She began to feel her way down in the dark. She was scared. She became even more scared when she felt loose things underfoot on the stairs. She reached the L16 landing before deciding she could not continue on like this. She went looking for someone she knew on L16. Joined by 5 others from that floor they all continued on down the stairs, propping open the doors to L16 and the L16 toilet in order to get at least some light. They reached L15 and propped open the door on that level to try to get some light. Jane and her group were about to continue when someone on L15 told them that below L15 there were no stairs. They were gone.
8. Had Jane and her party continued further it is likely they would have plunged into what was by then a dark void.

The Royal Commission's Terms of Reference

9. Because of the high level of concern engendered by the collapse of the stairs in a relatively new high rise building, where the building Standards that applied in 1984 were not significantly different to those in place today, the Royal Commission is required to inquire into the following issues:
 - (a) The design of the stairs
 - (b) Whether as originally designed and constructed the stairs complied with any earthquake risk or other legal and best practice requirements that were current when it was designed and constructed and then on or before 4 September 2010
 - (c) Why the stairs failed when those in other buildings did not
 - (d) Whether any particular features of the Building contributed to the failure of the stairs
 - (e) The nature of the land associated with the Building and whether this was a contributing factor

- (f) The nature and effectiveness of the assessments of the stairs carried out between 4 September 2010 and 22 February 2011.
10. The stairs in the Forsyth Barr Building were not the only ones that collapsed in the February earthquake. Stairs collapsed in at least 4 other multi-storey buildings and in many other cases they sustained serious damage: Bull, *Stairs and Access Ramps between Floors in Multi-Storey Buildings (Bull Report): ENG.BULL.0001.1*. This included the Hotel Grand Chancellor where many of the stairs collapsed in the upper two-thirds of the building.
11. This report, prepared at the request of the Royal Commission, concludes that the horizontal displacement of floors relative to each other that occurs during an earthquake (referred to by structural engineers as 'inter-storey drift'), had been underestimated by both the current (2011) and previous Loading Standards.
12. In addition to the collapse event that occurred in the Forsyth Barr Building, the Bull report identified two other ways in which an underestimation of inter-storey drift could implicate the stairs in building performance:
- (a) Stairs could increase the stiffness of a building. As a result of stairs transferring forces between floors the building may deform in unanticipated ways, significantly reducing seismic performance.
 - (b) The action of the stairs can damage the landings, possibly leading to collapse.

History of the Building

13. The building permit for the Building was issued by the Christchurch City Council on 9 May 1988. It was for what was described as a retail and office development. The developer was Paynter Developments Ltd and the Building was sold on completion to Robt Jones (Canterbury) Limited. It was originally called "Robert Jones House".
14. The architectural design was done by Warren & Mahoney. The final structural drawings were done by Holmes Consulting Group (**HCG**). The contractor was

Fletcher Construction Ltd. The current owner of the Building is 764 Colombo Street Limited.

15. A Design Certificate for the Building was signed off on behalf of HCG by R.A. Poole on 7 March 1998: **WIT.MCC.0029.11**. The certification includes the following:

- I have exercised reasonable control over the design processes for the works defined above which have been designed in accordance with sound and widely accepted engineering principles to support the loads specified in NZS 4203:1984
- I believe the stresses in the various materials of construction and force resisting elements of the structure including the foundation strata under the above loads are such as to ensure the safety and stability of the structure if the works are constructed in accordance with the above described drawings and specifications.

16. The Building was founded on a reinforced raft slab at a depth of around 2.5 metres below the ground floor level. Both the Beca report and the Expert Panel have concluded that there is no evidence that liquefaction or foundation failure played any role in the collapse of the stairs.

The DBH reports: the Beca Carter report and the Expert Panel review

17. The report on the collapse of the Forsyth Barr stairs, prepared by Beca for the Department of Building and Housing (**DBH**), has reached a clear conclusion on the cause of both the stair collapse and the design changes required to minimise the risk of recurrence. Its conclusions are relevant to the design to be used when the stairs are replaced in the Forsyth Barr Building. They are also relevant to other buildings in Christchurch and elsewhere in New Zealand where urgent investigations are now required to ensure that stairs can survive a very occasional earthquake with a magnitude considerably greater than that used for the design of the building as a whole.

18. The Expert Panel appointed by DBH to review the Beca report agrees with the key findings Beca has reached. Similarly, Mr William Holmes, the United States structural engineer engaged by the Royal Commission to peer review the DBH reports, also concurs with these findings. As a result Mr Holmes will not be required to give evidence at this hearing.

19. In brief, the conclusion is that in the face of the strong lateral shaking the Building experienced in February, the seismic gap provided insufficient space for the pre-cast scissor stairs to respond to that movement. As a result the stairs compressed (crushed) when they reached the limits of the available space. This compression reduced the length of the stair section and appears to have caused the stairs to slump. This then caused one or more flights to come off the lower seating as the Building moved in the opposite direction. Once any one flight dislodged and fell it brought down those below it: **BUI.COL764 0003.46**. It seems likely that the initial collapse was at a higher level in the Building as the stairs remained in place above levels 14 and 15.
20. The scissor stair design is shown on page 10 of the Beca report in Figure 4.3: **BUI.COL 764.0003.15**. The stairs were in the south eastern corner of the Building, which is shown in Figure 4.2 on that same page.
21. In its report Beca shows the typical way in which both the top and the bottom of the stairs are supported: **BUI.COL 764.0003.16**. Mr Rob Jury and Dr Richard Sharpe will explain this in more detail when they give their evidence. The design feature that is critical to the identified collapse scenario is the connection between the bottom of each section of the pre-cast stairs and the seating channel on which that toe sits. As Figure 4.5 illustrates, that sliding arrangement involves a steel channel and a seismic gap. The seating channel allows a maximum movement of 72mm, plus the 30mm seismic gap that is shown in that drawing in front of the bottom stair.
22. The seismic gap shown in Figure 4.5 was designed to accommodate inter-storey drift by allowing the lower end to slide horizontally in response to building displacement. The seismic gap was intended to give the pre cast stair unit sufficient space to slide, without damage to the stairs. However, as can be seen from Figure 4.5, if the inter-storey drift is greater than the seismic gap can accommodate, compression of the concrete stair may result. This in turn can shorten the stairs. When the building moves in the opposite direction, the shortened lower end can fall off its seating. This is what happened here, with one set of stairs collapsing on another with a cascading effect.

23. In its investigation, Beca identified several factors that affected the actual width of the seismic gap:
- (a) Pre-casting of the stair units may have removed the option of adjusting the stair flight length on site if it was found that this was required to maintain the specified width of the seismic gap.
 - (b) Some of the collapsed stair units appeared to have had their lower landing edges ground back. However this grinding of the concrete did not extend through the steel edge on the bottom stair, which meant the stair remained at its original length and the gap remained its original size.
 - (c) The seismic gaps may have been filled with construction debris, mortar and/or polystyrene. This reduced the effective width of the seismic gap.

Urgent remedial action already recommended

24. Because of the very high level of concern about the performance of escape stairs during the Christchurch earthquakes, including those in the Forsyth Barr building, and the urgency of addressing this issue, the Royal Commission made recommendations in its Interim Report issued in October 2011. The Commission strongly recommended the amendment of the design criteria in NZS1170.5 to require stairs and other critical means of egress to be designed to meet the service actions of an earthquake that is expected to occur only once in every 2500 years (the Maximum Credible Earthquake Event) so that egress would remain available up to the point of complete building collapse.
25. In addition DBH has issued a Practice Advisory to the industry (*Egress Stairs Practice Advisory 13, 30 September 2011*): **ENG.DBH.0024** It applies to all multi-storey buildings to which members of the public have access, particularly those with scissor stairs where the stairs are designed to slide under the effects of seismic action. The Practice Advisory notes a particular concern with stairs designed to slide using a “gap-and-ledge” detail: **ENG.DBH.0024.5**. This is the design the Forsyth Barr stairs relied on.
26. DBH has recommended that clearances and seatings for stairs should be sufficient to accommodate at least twice the Ultimate Limit State (**ULS**) inter-

storey drift displacement and has urged structural engineers who are undertaking building assessments to “*strongly recommend*” to clients that this include checking stairs and carrying out any required retrofit measures as soon as possible. The Advisory also urges that the seismic gap be checked for any obstructions and they be removed.

27. The DBH Expert Panel has made a very similar recommendation. It has urged that a provision be included in the Building Code that requires clearances and seatings for stairs to be capable of sustaining at least twice the Ultimate Limit State inter-storey displacements, after allowing for construction tolerances: **BUI.VAR.0056 at 74-83; 87; 94-95.**

The treatment of stairs in the previous and current Standards

28. The performance of the Forsyth Barr stairs appears, at least in part, to be a consequence of the way in which stairs are treated in both the previous and current (2004) Standards. Stairs and buildings are both required to meet what is referred to as the Ultimate Limit State. This, in turn, implies a high level of confidence that there will be no collapse in a 500 year return period earthquake. What this has not sufficiently factored in, however, is that the critical deformation for stairs and building structures is not the same.
29. Unlike a modern, ductile building, which is designed to be capable of sustaining a number of cycles of ground shaking, the performance of stairs is a function of the maximum inter-storey drift. A single cycle may be sufficient to knock stairs off their seating, causing collapse.
30. Neither the previous nor the current Standards adequately address this, a problem that has now been recognised following the Canterbury earthquakes.

The issues

31. As a result of this high level of agreement amongst the various experts on both the cause of the collapse and what is required to address the identified cause, the issues that need to be more closely examined in this hearing relate principally to issues other than the immediate cause of the collapse. They are:

- (a) Why this particular stair design was chosen. The design is now described by Beca as a design with a worrying lack of resilience.
- (b) Whether other more resilient designs were known at the time and, if they were, why an alternative design was not selected. This appears to be a point of disagreement between Beca and Holmes Consulting Group (**HCG**), with Beca stating that there were known alternatives and HCG insistent that there were not: Letter dated 16 September 2011 (HCG/Hopkins) with annotated Beca responses: **BUI.VAR0018.1** and **.19**; see also Beca report: **BUI.COL764.0003.50-51**.
- (c) The level of attention (or more accurately inattention) given to the critically important seismic gap, both during construction and at final completion. This issue requires attention because of the finding in the Beca report that there may have been a significant compromise of the seismic gap as a result of mortar, construction rubble, and polystyrene being left in the gap. This concern is also identified by Hyland Consultants Ltd, who carried out the site examination and materials tests: **BUI.COL.764.0008.1** at **5-8**. It seems clear that at least some of these obstructions were placed during the construction phase.
- (d) The extent to which this design, or designs with similar vulnerabilities, have been used in other buildings in New Zealand and the steps that are now needed to address the resulting critical structural weaknesses.
- (e) The inspection process followed after the September earthquake. Although the L2 assessments identified concerns with damage to the stairs and the fact that the seismic gap had apparently been compromised, no steps were taken to address these concerns prior to 22 February.
- (f) The correctness of Beca's conclusion in its L2 assessment that the "*stairs still contain sufficient capacity for normal use*": L2 assessment dated 6 September 2010: **BUI.COL764.0003A.16**, and that the damage observed after 4 September did not alter the stairs sufficiently to make them vulnerable in the 22 February earthquake: Beca report at 43, 48, **BUI.COL764.0003.43 & 48**, when:

- i. Photographs show cracking in the stairs
 - ii. Cracking appears to have been the result of compression
 - iii. The effect of compression is to shorten the stairs
 - iv. A further effect of compression appears to be to bend the stair flight downwards: Beca report at 40: **BUI.COL764.0003.45**
 - v. There was evidence of vertical slumping of the stair unit: Hyland report at 4, 6, 7: **BUI.COL764.0008 .10-11.**
- (g) The Expert Panel's concern about the use of scissor stairs generally, on the ground that they are less reliable than other stair systems because the loss of any one stair can result in the loss of the entire egress route.

The post September earthquake inspections

32. There was some damage to the stairs in the September earthquake. The extent to which the seismic gap had been compromised in September was not able to be finally determined in the Beca report, but the view of both Beca and the Expert Panel is that the stairs would probably have collapsed in February regardless of any obstruction of the seismic gap because of the very large lateral movement the building experienced.
33. Photographs showing both cracking of the stairs, and what appears to be a sag in the stairs, were taken by a tenant of the Building soon after the September earthquake: **WIT.CAM.0004.9 .10 .11.** These will be explained in evidence by Mr Grant Cameron of GCA Lawyers, who was a tenant in the Building.
34. Five assessments were done post September: a Level 1 USAR assessment, three Level 2 assessments done by Beca and a more detailed report done by HCG in late November. The Level 1 assessment resulted in the Building receiving a red placard. Beca then changed the red sticker to yellow after carrying out a Level 2 assessment and then, after a further Level 2 assessment, this was changed to green.
35. The change to green took place on 5 September after an inspection of the stairs and a recommendation to prop a beam under the ramp to the parking area under the Building. The 5 September assessment recorded that the "*stairs had generally settled and may be unstable*" and the stair landing

bulkhead needed to be removed to allow an investigation. It also recorded that there was stair settlement of 40mm under the supports at Level 7 and the stair supports needed to be investigated prior to any upgrading to green: **BUI.COL764.0003A.14.**

36. This was followed by two further Level 2 assessments. These are recorded in two ways. First, a site record dated 6 September 2010: **BUI.COL.704.0003A.16.** This reports the removal of the stair bulkhead on Level 7 and concludes that *“although the deformations in the stairs are significant, we believe that the stairs still contain sufficient capacity for normal use”*. It again referred to residual deformation of the stair and settlement of about 40mm, caused by flexural cracking in the base of the lower knee of the scissor flight.
37. A handwritten note to this typed report also identifies an issue with loose debris in the seismic gap and directs that it be cleared at the end of each stair flight in order to allow movement as originally intended **BUI.COL764.0003A.16.**
38. That inspection, and a further inspection on 13 September, is also recorded in a handwritten note on the 5 September 2010 Level 2 assessment. This further inspection is given the date of Monday 13 September at **BUI.COL764.0003A.20** and 15 September at **BUI.COL764.0003A.18**, but nothing appears to turn on which date is accurate. Table 4.1 of the Beca report also gives the date as 15 September: **BUI.COL764.0003.17.** The handwritten reference to 15 September at **.18** records: *“...to investigate Level 7 infill floor sag.”*
39. Two handwritten entries are made on this report and Mr Rob Jury of Beca has confirmed that the second of these is his, in his role as the person with overall responsibility within Beca for the assessment.
40. Beca had been engaged by the Building manager to carry out these Level 2 assessments. It had apparently anticipated that it would be retained to carry out the further inspections and then to deal with any structural problems that were identified. However, in early October the Building owner decided that HCG would be engaged to deal with these further issues. Mr Michael Connolly of

Colliers International Property Management Limited (**Colliers**) managed this on behalf of the owner.

41. It is not entirely clear what HCG knew about the Level 2 assessments that had been done by Beca. It seems clear HCG was aware that Beca had carried out some inspections and this included some work in relation to the stairs. However, it appears that HCG did not at any stage see the reports themselves. This has some significance in relation to what happened subsequently.
42. Copies of Beca's Level 2 assessments were provided to the Christchurch City Council, but they do not appear to have been brought to the attention of HCG by the Council, or sought from the Council by HCG. In any event, the follow up of the stair damage, including the inspection of the seismic gaps that Beca had recommended in its L2 assessments, was never done.
43. The HCG terms of engagement are recorded in a Proposal from HCG dated 8 October 2010: **BUI:COL764.0022A.1**. This records that the contract is to carry out post earthquake review of the Forsyth Barr Tower. Four stages are identified. Stage 1 was to include a preliminary structural survey of the Building to identify the general form and location of earthquake damage. It was also to include a review of the available documentation to identify potential 'hot-spots' for more detailed investigation. It does not appear to be a matter of dispute that this Proposal records the terms on which HCG was subsequently engaged.
44. HCG prepared a post-earthquake assessment and repair report dated 29 November 2010: **BUI.COL764.0003A.22**. In section 1.1 the report sets out in fairly broad terms the purpose of the study. This included identifying any significant life safety concerns, mapping typical damage and identifying any items requiring repair or replacement **BUI.COL764.0003A.26**.
45. Section 1.3 of that report records that the Christchurch City Council was entitled to use the findings of the report in its own evaluation of the subject property.
46. The report notes in Appendix A (Typical Building Forms) that: **BUI.COL764.0003A.45**.

Up until the late 1990's the stairs are prone to collapse due to the jamming between floors; subsequently, detailing of the stairs (sliding at one end) became the accepted feature.

47. The report also records in a Table on page A4.5 that stairs may play a role in affecting torsional behaviour of a building and this may require cutting one end of the stairs: **BUI.COL764.0003A.48.**
48. Despite these references to potential concerns with stair performance, the report did not specifically refer to or address the condition of the stairs. No reference is made to any of the issues identified in the Beca assessments.
49. There has been some uncertainty about why the stairs were not addressed. Two emails that specifically record the Building owner's concern about the condition of the stairs were subsequently brought to Mr Hare's attention. The first is dated 12 October 2010 and is from Colliers on behalf of the owner. It follows the owner's receipt of the Proposal from HCG and seeks a specific assurance that the stairs are okay: **BUI.COL764.0035.5.** The second is dated 4 November 2010 and again seeks an assurance the stairs will be addressed, with Colliers expressing a concern about an apparent "drop" in the stairs: **same reference.**
50. After being made aware of these emails Counsel Assisting was advised in a letter dated 14 November 2011 from Mr Hare's lawyers, that Mr Hare's recollection still was that HCG had not been required to include the stairs in its 29 November report. This letter advised that Mr Hare now recalled he had met with Mr Andy Christian of Pace Project Management (**Pace**) on site and had walked through the Building to review the scope of work. A conclusion was reached that there was no need to give any priority to a structural review of the stairs. Following the receipt of the email of 4 November from Mr Connolly there was another discussion, with either Mr Connolly or Mr Christian, during which the "drop" in the stairs was discussed. Once again the stairs were not regarded as a matter of immediate concern.
51. Mr Hare's recollection has now been largely confirmed by Mr Christian, who has provided a signed statement which says that he told one of the HCG engineers (he does not think it was Mr Hare) that the vinyl from the stairs would

be lifted and HCG would be advised when this was done so they could inspect. The vinyl was eventually lifted in about late February 2011.

52. It has not been thought necessary to call Mr Christian to give evidence. His signed statement has been made available on the website for this hearing.
53. In the end the relevance of this sequence of events to the issues the Royal Commission is required to address, may principally be the systems problem in the way information was transferred from one firm of structural engineers to another and the failure of the Council, as the regulator in possession of the Beca L2 assessment reports, to take steps to ensure the identified issues were followed up. Aspects of this issue will need to be explored in the hearing.

Witnesses

54. The Commission will hear from the following witnesses:
 - (a) Mr Grant Cameron will describe his experience as a tenant of the building on 22 February. He will also give evidence about damage to the stairs that he observed following the 4 September earthquake.
 - (b) Mr Rob Jury and Dr Richard Sharpe will present the report prepared for DBH by Beca and the L2 assessments carried out by Beca in September 2010.
 - (c) The Expert Panel Report will be presented by Professor Nigel Priestley.
 - (d) Mr Paul Tonkin, who was the Site Manager for Fletcher Construction Ltd, will give evidence about the construction of the seismic gap and his knowledge of the checking that was done during construction to ensure compliance with the specified gap.
 - (e) Mr John Hare of HCG will give evidence about the structural design of the Forsyth Barr stairs and the structural report HCG prepared for the Building owner dated 29 November 2010.

- (f) Mr Stephen McCarthy will give evidence on behalf of the Christchurch City Council. He will address the regulatory issues, including how Council saw its role for inspecting compliance with the specified seismic gap.

- (g) Finally, Professor Des Bull of the University of Canterbury Engineering School will address the question of egress stair performance more generally and discuss the steps that can be taken in existing buildings to address the identified problems.

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23 February 2012**