IN THE MATTER OF

THE CANTERBURY EARTHQUAKES ROYAL COMMISSION

BRIEF OF EVIDENCE OF GEOFFREY NIGEL BANKS

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Duncan Cotterill
Solicitor acting: Helen Smith
PO Box 5, Christchurch

Phone +64 3 379 2430
Fax +64 3 379 7097
h.smith@duncancotterill.com

1. My name is Geoffrey Nigel Banks. I have been asked to provide evidence to the Royal Commission about my involvement with the CTV building.

2. My only involvement with the CTV building was in the early 1990s. The building was not known as the CTV building then although for simplicity I will refer to it as the CTV building. I simply knew the building as 249 Madras Street.

3. My involvement occurred in a relatively brief period 22 years ago. I have not retained an intimate knowledge of all matters relating to the CTV building and the calculations in light of the time that has elapsed since my involvement and the many building projects that I have been involved with since. It was some weeks after the collapse that I realised I had undertaken work on the CTV building, and that was around the time I was contacted by Dr Hyland who was investigating for DBH.

4. My evidence is to the best of my recollection. I am able to remember some matters and in other cases I have relied on documents produced at the time to aid my recollection. These documents have been provided to me by counsel assisting the Royal Commission and by Dr Reay. The purpose of having accurate file notes and calculation records is to ensure any engineer (including the engineer who created the original record) can come back years later and know they can rely on there being an accurate record available for examination or review. I am conscious, however, that some things may have occurred outside of that essential written record and that the record is also not complete. For example, I have asked for copies of my diaries and timesheets as these would have contained records of meetings and conversations that I had at that time. I have been advised by Dr Reay's lawyers that these no longer exist, which is understandable given the passage of time.

5. Before going into the detail of my evidence, I want to acknowledge that the CTV building is now the cause of anguish and heartbreak for a large number of people. I am deeply saddened by the terrible loss of life, and many injuries, caused by the collapse of this building. I cannot know the grief it has caused the families and friends of those who died, and to those who were injured. I do not know why the collapse occurred and, like all of those involved, I look to this inquiry to consider all the issues and to help ensure nothing like this could happen again.

Qualifications and experience

6. I graduated from the University of Canterbury in 1980 with a Bachelor Degree (1st Class Honours) in Civil Engineering. I am a Chartered Professional Engineer and a Professional Member of IPENZ (MIPENZ).

7. I studied at university under Professors Bob Park and Tom Paulay who were world experts in seismic design of concrete structures at that time, and Nigel Priestley who has given expert evidence. I can recall graduating with the latest copy of the concrete code NZS3101 which the university had a significant involvement with, and with the book "Reinforced Concrete Structures" written by Park and Paulay. My impression at that time was that the University of Canterbury was at the forefront of reinforced concrete design for earthquakes.

8. I have been practicing as a structural engineer for some 30 years. My experience covers a wide range of buildings, from houses to low-rise commercial buildings to a number of high rise projects. Most of that experience relates to the design of new buildings, although I did design some strengthening of older buildings such as parts of the Arts Centre in Christchurch.

9. I worked as a structural design engineer for Holmes Wood Poole and Johnstone (now Holmes Consulting Group) (**Holmes)** from around 1982 to 1986. I designed low rise commercial and public buildings and a number of multi-storey buildings in the Auckland CBD. Much of that work was under the direction of Russell Poole, a senior director of the firm. Those buildings were mostly constructed using reinforced concrete frames, but some would have had shear cores. I can recall one building was the Stock Exchange Tower in Queen Street, but can't recall the specifics of all the building names and types.

10. I left Holmes in 1987 to start a new practice, Cambridge Consulting Engineers (**CCE**), with another engineer. CCE undertook the design of a number of low rise commercial buildings.

11. Alan Reay Consultants Limited (**ARC**) was formed in 1988, providing a new corporate entity which continued the work of Alan M Reay Consulting Engineer, Dr Reay's former practice. I was invited by Dr Reay to join ARC late

in late 1988, after CCE had worked as sub-consultant for him on the Duty Free building in Cathedral Square. I was aware that Dr Reay had a PhD in seismic design and a strong reputation in the commercial building design sector. I was employed at the end of 1988 and became a director on 31 March 1989 and subsequently a shareholder. I remained at ARC for 13 years until late 2002 when I left and formed Structex. At the time I started in 1988, ARC was undertaking a range of work, but the dominant project type was low rise commercial and industrial buildings (that is one or two storeys high). However, I do recall doing construction monitoring on the Heatherlea apartment high-rise building in Deans Ave.

The CTV building

12. I had no involvement in the original design or construction of the CTV building, as that occurred prior to my joining the firm. It was designed by Dr Reay's previous practice, Alan M Reay Consulting Engineer, not by ARC.

13. In 1990 I undertook work to investigate a particular aspect of the building that was thought to be deficient, following a review by Holmes which I refer to in more detail later. I designed retrofit works which were undertaken in 1991 (**the retrofit works**). I designed the retrofit works to the Standards at that time.

14. My recollection is that it was principally Dr Reay and I involved in matters relating to the retrofit work. My role was focussed on the more detailed aspects while Dr Reay had an oversight role. As I was relatively new in the company, and also new to the building, I liaised with Dr Reay throughout my involvement.

15. I recall Dr Reay telling me that David Harding had done the calculations for the original design. I have recently read John Henry's evidence that this was Mr Harding's first design of this type of building. At the time of my involvement I cannot recall being briefed on Mr Harding's experience with this type of building.

16. Mr Harding had left ARC just before I started and, to my knowledge, Dr Reay was the only engineer in the firm at that time with knowledge of the CTV Building.

17. In terms of the retrofit work, sketches CD1, CD2 and CD3 (referred to in more detail later) were prepared by one of the drafting technicians. I undertook all

calculations. Although Dr Reay may not have specifically reviewed the calculations, he would have been aware of the remedial works I designed.

The Holmes' report

18. In late January 1990 I became aware that Holmes was looking at the CTV building as part of due diligence being conducted by a prospective purchaser. I am not clear exactly when my involvement began although it is likely to be around 29 January 1990 as that is the date of my initial calculations **(BUI.MAD249.0130.15)**. I may have been introduced to one of Holmes' engineers when they came to ARC to inspect the files, but I cannot specifically recall that.

19. I recall receiving a copy of a Holmes report dated January 1990 (**Holmes' Report**) **(BUI.MAD249.0130.1-10)**. It refers to me being available for comment on aspects of the design. I do not recall commenting but I do remember having discussions with Mr Wilkinson of Holmes sometime later about the concerns raised and the remedial solution required. I did not receive the version of the Holmes' Report which is included in the material before the Royal Commission; that is, the version which includes calculations and notes prepared by John Hare **(BUI.MAD249.0081.19-42)** and a memo from Grant Wilkinson dated 1 February 1990 **(BUI.MAD249.0081.17-18)**. I did not receive those documents at the time. I know that because they post-date my initial calculations and they were also not included in the Holmes' Report on the ARC file forwarded to me last year by Dr Reay. Also, if I had seen them at the time I would have likely reviewed the calculations undertaken by John Hare as opposed to undertaking my own. Other than those additional documents, the reports are identical. I was provided with the 10 typed pages, concluding with section 7.0, Condition Report.

20. I would have been asked by Dr Reay to liaise with Holmes, but I cannot recall when this happened. Dr Reay was certainly involved at this time. I refer to ARC's letter to its broker dated 1 February 1990 (**BUI.MAD249.0129.2**). The letter is written by me, and it says that if further information is required they are to contact me or Dr Reay. The content of the letter also suggests that ARC had carried out some inquiries and investigations by this date and some of these were undertaken by Dr Reay; in particular the contact with Mr Harding.

21. The Holmes' Report states that Holmes had:

21.1 Reviewed a full set of architectural drawings and some structural drawings, made available by Alun Wilkie Architect.

21.2 Viewed the full design, documentation, Soils Investigation and a complete set of drawings at the office of Alan Reay Consulting Engineer.

21.3 Spoken with Bryan Bluck at Council to discuss any concerns relating to the building permit and construction process.

21.4 Undertaken an inspection of the building (excluding levels 1 and 4).

22. Noting that its review was brief, no materials testing was carried out and inspection was limited to accessible areas only, Holmes concluded that:

1. The building is in a condition appropriate to its age and the contractor-as-developer form of construction.

2. The layout and design of the building is quite simple and straight forward and generally complies with current design loading and materials codes.

23. It was clear from the Holmes' Report, the investigations undertaken, and in particular the statement that the building "generally complies with the current design loading and materials code" that Holmes did not consider there were areas of non-compliance, other than the tying of the floors to some of the shear walls. The issue was expanded on in section 6.3 of the Report. After noting that the shear walls appeared to have been generally well designed to the requirements of the correct design loading and materials codes, Holmes states:

> An area of concern however has been discovered in the connections of the structural floor diaphragm to the shear walls. While this is not a concern on the coupled shear wall to the south of the building, connections to the walls at the North face of the building are tenuous due to penetrations for services, lift shafts and the stairs, as detailed on the drawings.
>
> The result of this would be that 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.

24. As a result of Holmes' conclusions I was not asked to carry out a general review of the design nor would I have done so of my own accord. I am aware now that there are many aspects of the building that are being examined and questioned, such as the flexibility of the building, detailing of columns and adjacent structure, and non-ductile mesh, and with hindsight those are the issues I would investigate now, with the benefit of the latest 2012 codes and experience. However, at the time, it was very specifically only the ties to two of the shear walls that caused any concern to both the Holmes engineers, and to Dr Reay and me. I relied on the Holmes' Report and the issue identified in that report. Holmes had an excellent reputation and had particular expertise with multi-level building design. Having worked at Holmes for 5 years until 1986 I held Holmes in high regard and there was nothing in the Holmes' Report which caused me to question the conclusion it had reached. It was also clear in my later discussions with Mr Wilkinson that Holmes' concern was limited only to the tying of the floors to some of the shear walls.

25. Based on my observations of the drawings I had seen detailing that area of the building, I agreed with the concerns that had been expressed by Holmes. I discussed and agreed with Dr Reay that this matter had to be investigated.

26. I can summarise the area of concern as follows:

    26.1 On the north side of the building were four concrete shear walls oriented north/south, which appeared to provide the lateral resistance of the building in the north/south direction earthquake.

    26.2 Whilst the two larger western walls were adjoined by the floor, providing a floor to wall tie for north/south loads, there appeared to be very little connection between the two smaller walls to the east due to the voids formed in the floor for the lift well and stairwell.

    26.3 From the drawings, it appeared that there were only a limited number of light 12mm diameter reinforcing bars in these areas, although their location was not clear, and there were no larger ties to the floor.

    26.4 It appeared therefore that the effectiveness of the wall system to carry north/south seismic loads may have been reduced without

better tying of the two eastern walls to the floors. These walls are on gridlines D and D/E.

Initial calculations

27. I had access to project documents in the ARC archives. I recall that included the drawings and calculations and some correspondence, but did not include any direct computer output from the ETABS analysis. I do not recall seeing any structural specifications, and neither could I see any record of this matter having been addressed during the construction.

28. There were no calculations I could find in the file relating to the connection between the floor diaphragms and the two walls in question. I have reviewed the calculations again and they confirm my recollection. There is an index of calculations relating to seismic load analysis (**BUI.MAD249.0273.1**) but it appears incomplete as S48 relating to walls 7 & 9 is the last entry. In fact, the calculations extend in this section to S56 and S57 (**BUI.MAD249.0272.65-66**). However, these deal with the seismic load for lines 1 and 4 of the building only. There are no calculations that deal with the seismic load in the north/south direction.

29. I do not know why the calculations were missing, but because they were I undertook my own calculations. My initial calculations were headed "Diaphragm Check", and were done in order to understand the magnitude of load transfer which was of concern **(BUI.MAD249.0130.15)**. In preparing those calculations I noted the loads set out on S56 of those original calculations **(BUI.MAD249.0272.65).** However, I did not use these further as they did not address the walls in question. The calculations also referred to computer output, but I cannot recall finding any such output. I therefore undertook my own calculations with regard to these specific connections.

30. In respect of my initial calculations, I have noted in section 2.1 entitled "previous Calcs", that my interpretation was that on page S56 of the original design, where the engineer had *"checked line 1 & 5 walls only (level 5). 60% load to each. Used factored static design shear of 501kN (storey), no overstrength"* **(BUI.MAD249.0130.15)**. This refers to the south wall and the far north wall running in the east/west direction which had not been identified as being of concern.

31. I checked the Parts & Portions section of NZS4203:1984. This was a method of considering the seismic loads applying to parts of a building. As I did not have access to the ETABS analysis, I understood that this approach would have produced higher loads requiring far less stringent detailing requirements, which would likely better suit retrofit work if needed. This approach was consistent with the commentary to NZS4203:1984 which states that "Ductility for the purpose of this clause was considered to be capable of being achieved with far less stringent detailing requirements than for the principal members of a structure required to dissipate significant amounts of seismic energy". This analysis gave a design seismic load for the entire floor at level 5 of 1241kN, which was greater than the 501kN referred to on S56 of the original calculations, and I would have considered therefore that the higher load I calculated was appropriately conservative for details with lesser ductility.

32. I wish to comment on this aspect of determining the design loads between the floor diaphragm and shear walls. First, even as late as December 2011 in the NZ Structural Engineering Society (Sesoc) Practice Notice *Design of Conventional Systems Following the Canterbury Earthquakes* it is acknowledged in section 9 that "Little guidance is available for either the assessment of design actions or the design of diaphragms or collectors". The authors then refer to a research paper dated 2010. I believe that this is an area that appears to have been overlooked for many years, and therefore subject to the individual judgements of engineers without much guidance, and suggests that more research is long overdue. Secondly, the Hyland January 2012 report at p119 states:

> The Parts and Portions in the NZS 4203:1984 design provisions for connection of diaphragms to seismic lateral resisting walls seem inadequate. They did not ensure that diaphragm ties were not a weak link limiting the overall strength of the structure under severe seismic demands. The provisions did not appear to account for full displacement and strength demands, or higher mode response characteristics of the structural system.

33. I agree with Dr Hyland's comments now but at the time I applied NZS4203:1984 as it was the relevant Standard of the day.

34. The two walls themselves only carry a part of the total load in the north/south direction, in proportion to their stiffness. The majority of the load would be carried by the stiffer western walls which had been indicated by Holmes were

not a concern. In a scenario where an earthquake forced the floor towards the south, I determined that at the highest floor level in the building, a 231kN tie was required for wall 3 (on gridline D/E) and 279kN for wall 9 (on grid D) **(BUI.MAD249.0130.17-18)**.

35. I concluded that the lack of connections shown on the drawings for these two of the four walls did not appear to comply with the Standards in place in 1990; in particular loadings standard NZS4203:1984 (including any amendments) which was the applicable standard when the building was designed and when I was reviewing the connections.

36. I discussed the matter with Dr Reay who thought the potential point of weakness identified might have been addressed during construction. I had not found any record of such remedial work in the archived files. Dr Reay also contacted Mr Harding but he was unable to recall any site instructions dealing with the issue **(BUI.MAD249.0041.RED.2)**. For that reason, Dr Reay and I agreed that we should proceed on the basis that it had not been addressed during construction, and develop a remedial solution.

37. On 1 February 1990 Dr Reay and I met with Mr Young of KPMG Peat Marwick (**KPMG**), the receiver for Prime West Corporation which was the owner of the building. I cannot recall that meeting or its purpose but I have seen a letter sent following that meeting which suggests that I was there (**BUI.MAD249.0129.27).** The letter records that Dr Reay and I:

    37.1 Advised that investigations were continuing as to whether or not steel ties were placed between the structural floor and some shear walls as a metal detector had indicated the presence of some steel;

    37.2 Advised that the cost of the remedial work would be approximately $5,000 and should take only one week's work to complete;

    37.3 In view of the relatively modest cost for the remedial work, advised that it would be more cost effective to assume that the steel is not in place, as the cost of further investigating the matter would in all probability exceed this amount.

    37.4 Advised that there was reasonable agreement with Holmes as to the level of remedial work required, and that once carried out, there is no suggestion that their building is not at proper standard.

38. KPMG went on to state that:

> To ensure that Holmes Consulting Group can promptly report to the Canterbury Regional Council that current design codes have been fully complied with, no doubt you will ensure that full agreement is obtained with them as to the level of work required.

39. My recollection is, as noted by KPMG, that I contacted Holmes to identify the specific issue they had and the level of load for which the floor to wall tie should be designed. That that was the approach is also supported in my letter to ARC's broker dated 1 February 1990 (**BUI.MAD249.0129.13**).

40. On 2 February 1990 I phoned Grant Wilkinson of Holmes to clarify the extent of the concerns that had been referred to in the Holmes' Report. One aspect discussed was my calculation of a maximum tie load at the top floor of 231kN to one wall and 279kN to the other. This figure corresponded closely to a figure of 300kN advised by Mr Wilkinson, which gave me confidence that my approach to determining the tie loads was appropriate. I proposed a conservative approach of using the higher figure of 300kN for both walls at the top floor. Mr Wilkinson advised that Holmes had no concern with the other walls.

41. When reviewing matters for the Royal Commission I have seen a statement from counsel assisting the Royal Commission that ARC made a "deliberate decision not to follow the suggested approach in the HCG report, which involved strengthening the shear core-diaphragm connection on all floors except L1" (**BUI.MAD249.0217.3**) and that the form of connection from the steel ties to the underside of the floor differed from that proposed by Holmes (**BUI.MAD249.0207.5**). I respond to this as follows:

41.1 First, the Holmes' Report that I received did not recommend strengthening on all floors except level 1; it simply identified an area of non-compliance with current design codes and noted that that item was under review with ARC (**BUI.MAD249.0130.5**). It also did not refer to a form of connection from the steel ties to the underside of the floor. I can only presume that the suggested approach referred to is the "Plan" referred to on calculations prepared by Holmes marked SK-01 dated 31 January 1990 (**BUI.MAD249.0005.19**). It refers to strip flanges with "detail typical to levels 1 to 5". As I have

noted, I did not receive those details, and therefore did not make any deliberate decision not to follow them.

41.2 Secondly, the Holmes' Report was not specific as to the walls which were a concern or to the levels, so I sought to clarify those matters with Holmes and the extent of their concern. I specifically discussed with Mr Wilkinson his concerns as identified in the Holmes' Report, and agreed how to address those concerns. Mr Wilkinson and I discussed how the loads could be reduced at the lower levels in accordance with the Standard. That was on the basis that reduced loads on the lower floors may mean that additional restraint may not be needed on those floors.

42. To explain this issue of loads reducing as you go down the building, NZS 4203:1984 required the highest design load at upper levels of the building, reflected in the value Kx in clause 3.4.9.2(b). This value of Kx was calculated as 1.63 in my calculations, and the corresponding tie load was 231kN to the wall on grid D/E and 279kN to the wall on grid D (rounded up a further 30% and 7% respectively to 300kN) at the top of the building. As outlined on page 6A of my calculations (**BUI.MAD249.0130.21**), the value of Kx reduced to 1.0 at levels 1, 2, and 3, resulting in a lower design load of 184kN at those levels (including the additional 30% or 7% conservatism applied in the rounding of the top floor loads to 300kN). The practical effect of this was that less remedial work, if any, would be required on the lower levels of the building.

43. I note that Mr Charles Clifton, in Table 2 on page 7 of his report of November 2011 (**BUI.MAD249.0223.7**), shows that the diaphragm demand based on the actual ground accelerations was 2,859 kN at all levels of the building. This differs from the Standard I used in 1990 (NZS4203:1984) which reduced the loads going down the building. I also note that the load determined by Mr Clifton compares with a diaphragm demand of 1241 kN at the top of the building, and reducing to 761 kN at the lower levels, calculated using the Standard NZS4203:1984. On that basis, the actual demand imposed by the February 22 earthquake was 2.30 times the load derived from the Standard at the top floor, and 3.76 times the Standard at the lower levels.

44. The outcome of my discussion with Mr Wilkinson was recorded in ARC's letter to Holmes of 2 February 1990 (**BUI.MAD249.0130.12**); that is:

44.1 The scope of possible non-compliance referred to in the Holmes' Report is the connections between the walls on gridlines D and D/E from levels 2-6 inclusive. (I used the word "possible" because at that time, whilst it was clear to me that the ties were needed at upper levels, I had not yet looked at the reduction of loads at lower levels).

44.2 The proposed remedial work, if required, would consist of two ties per floor, tying the walls to the floor diaphragm.

44.3 The agreed maximum tie load is 300 kN per tie and that this load would be reduced on the lower floors in accordance with the "Parts and Portions" section of NZS 4203:1984.

45. This was what was done to determine the details and extent of the design required for the retrofit work (rather than the retrofit work itself), in accordance with the requirements of both Holmes and the Standards relevant at the time. I asked Mr Wilkinson to contact me that day if his understanding of the position was not as I had outlined. My reference to Mr Wilkinson contacting me "that day" suggests some urgency. I do not know why there was any urgency but ARC was aware that receivers were dealing with the building and a potential sale. We did not have significant safety concerns as the building was vacant and not considered earthquake prone. To clarify, at that time I recall "earthquake prone" referred to buildings with less than 10% of the new building standard, and clearly that would not have been the case with this building. There was however certainly a view that any remedial work required should be done before the building was occupied.

46. I did not hear further from Mr Wilkinson. On 14 February 1990 I telephoned John Hare (**BUI.MAD249.0130.14**). I am not sure why I called Mr Hare but I think it likely that it was a follow up call to Holmes because I had not heard back from Mr Wilkinson. We discussed the agreed design loads at each level, that a tie only system was acceptable, and that a reduced connection at level 1 may be acceptable if compensation was made at level 2. At that stage, I had not undertaken any more calculations looking at the lower levels of the building. I recall no further discussion with anyone from Holmes after this date.

47. I had no further involvement until early 1991. In the meantime I understand the property remained vacant. The owners of the building and the receivers,

KPMG, were aware of the issue that had been identified by Holmes and with which ARC agreed needed investigation and retrofit work. I also understood at that time that Council were also aware. I am not sure whether I knew that because of the reference to discussions Holmes had with Council referred to in the Holmes' Report or as something that arose in my discussions with Mr Wilkinson and/or Mr Hare.

The retrofit works

48. In February 1991 ARC became aware that the building had been sold but I do not remember whether it was Dr Reay or I that found out, or how we found out. As we did not know whether the new owners knew about the issue and because we assumed the intention was to occupy the building, we considered that it was our obligation to ensure the new owners were aware of the issue identified in the Holmes' Report. I have since seen a file note of a conversation I had with Peter Smith, ARC's insurer's representative, (**BUI.MAD249.0227.6**) which says "What are our obligations (if any) to notify anyone re status of review to date". That appears to suggest that I was asking whether we had to notify the new owners. That is not my recollection of matters. My recollection is that we considered it was our ethical obligation to advise the new owners but that we needed to obtain insurer approval before doing so. When we had become aware of the issue which Holmes had identified we had notified ARC's insurers of a potential claim. In such circumstances, we were required to seek the insurer's approval before making contact. Confirmation that we inform the new owner of the issue identified was provided on 9 April 1991 (**BUI.MAD249.0129.38**). I do not recall when that was done.

49. There is a gap in the documentation between April 1991 and September 1991. I cannot remember what occurred during that period.

50. I understand that Mr Ibbotson of Pedofsky, Ibbotson & Cooney (the new owners' agent) says that the owners first became aware of the issue when it received a letter from ARC dated 11 September 1991 or through a telephone call from me shortly before that. I cannot remember either whether I made a telephone call or if so, when that was. I have not been provided with a copy of the letter of 11 September 1991 and understand a copy is not available.

51. On 30 September 1991 a letter was sent to ARC from Mr Ibbotson (**BUI.MAD249.0129.50-51**) regarding the issue. The letter noted that

alteration and fit out of the building was taking place and a full tenancy of the building by the ANZ Bank would apply from 1 November 1991.

52. I cannot remember precisely how ARC proceeded or what, if any, instructions were given but it seems from the documentation that we were liaising with Mr Ibbotson.

53. To progress the retrofit work, we arranged for small holes to be drilled around the lift area and, in Mr Ibbotson's terms, a locating bar was used to try and ascertain whether there was any steel present. I cannot specifically remember arranging drilling to locate reinforcing, but there is reference to the H12 reinforcing bars found in my calculations, and also in the correspondence with Mr Ibbotson and CBD Construction.

54. We wanted to know for sure whether the issue of concern had been rectified during construction as Dr Reay had suggested may have been the case. The results were not conclusive although we did determine that there was some reinforcing steel present. I do not recall now whether that was at all levels or whether it was only on level 2 but in the calculations had assumed it to be present through all levels. This is referred to in my calculations on page 7A as 2-H12 bars to wall 9 (on grid D) and on page 9A as 1-H12 bar to wall 3 (on grid D/E). These are the size of the reinforcing bars that were indicated on the floor plans as being present, but their location is somewhat imprecise on the plans. The bars were calculated to provide a small amount of tie load to each wall, but much less than the calculated requirement of 300kN. As a result I concluded they had a minor benefit only and retrofit design was required.

55. The calculations for the retrofit work were completed around 10 October 1991 (**BUI.MAD249.0130.21-27**). The calculations page 6A to 9A design the tension tie for wall 9 (on grid D) at levels 3, 4, and 5 (**BUI.MAD249.0130.22-23**), and for wall 3 (on grid D/E) at levels 3, 4, and 5 (**BUI.MAD249.0130.24**). The ties at each level and for each wall were different, in accordance with the different load requirements at each level. They also accounted for the one or two (as appropriate) H12 bars, although this had a minor benefit only. The results of these calculations are the retrofit angles shown on sketches CD2 (**BUI.MAD249.0130.34**) and CD3 (**BUI.MAD249.0130.35**).

56. In my calculations (pages 12A to 14A) (**BUI.MAD249.0130.25-27**) I also checked that at levels 1 and 2, where the loads were lower, the loads could be redistributed to the other walls. This was similar to the concept that had

been discussed with John Hare previously. By way of explanation, the concept of redistribution is that loads can be re-allocated to other parts of a building to some extent, provided that re-allocation is accounted-for. My calculations checked the effect of redistributing the load at the lower levels away from the walls on grids D and D/E to the other two walls (i.e. the two larger walls on grids C and C/D) in terms of the flexure and shear design of those walls, and concluded that both were "OK". As the other walls were capable of taking the load at these lower levels, the calculations concluded that no additional ties were required at the two lower levels. This is the point that had been discussed with Holmes in 1990.

57. I wish to summarise why my calculations indicated that additional ties were not required at levels 1 and 2, as this has been the subject of a number of queries by counsel acting for the Commission. There were several considerations identified in the calculations:

57.1 The connection loads were less at the lower levels according to the NZS4203:1984 and as agreed with Holmes.

57.2 The design also took into account that there was in fact some reinforcement tying the slab to these walls, albeit a small amount. Page 7A states that 2-H12 ties were located to wall 9 (on grid D) and page 9A states that 1-H12 was located to wall 3 (on grid D/E). The reinforcement provided only a minimal tie however. As such, this was not a major feature.

57.3 The calculations checked a redistribution of connection loads to the other two larger walls at these levels, in accordance with C1.2.5.1 of NZS 4203:1984 which states that *"Some redistribution of seismic horizontal forces between elements is therefore acceptable"*. I note also that there had been some acknowledgement of the ability to redistribute loads in discussion with Mr Hare in 1990 as recorded by my file note, and it was concluded by calculation that flexure and shear in the walls was "OK" to accommodate that redistribution. In particular, redistributing the load at a low level had only a minor effect on the wall flexure, whereas that would not be the case if the loads were redistributed at a high level.

58. After I completed the calculations, ARC prepared sketches of the retrofit work. As noted previously, these were prepared by a draughtsman at ARC. I

would have checked them before they were issued. They provided for drag bars fixed into the slab and into the two north shear walls (at line D and D/E) at levels 4, 5 and 6 with epoxy grouted threaded anchors.

59. On 10 October 1991 I faxed the construction details ARC had prepared in February 1990 (CD1 and CD2) (**BUI.MAD249.0130.28-30**) and 10 October 1991 (CD3) (**BUI.MAD249.0130.31**) to CBD Construction.

60. I note at this point that sketch CD2 is dated February 1990, but shows the variation in fixings at each level which was not determined until October 1991 according to the calculations. I think it is likely that an earlier version of this sketch was prepared in February 1990 showing only the results of the initial calculations for the top floor, and when the detailed calculations were undertaken in October 1991, the variation showing the final design at all levels was added. I have not been provided with any earlier copies of the sketch which might clarify this issue.

61. On 11 October 1991 I wrote to the Ministry of Transport (Marine and Industrial Section) to confirm an earlier discussion on 10 October 1991 that ARC wanted to install a structural steel angle in the lift shaft at levels 4, 5 and 6 as shown on CD 1, 2 and 3 (**BUI.MAD249.0130.32-35**). As work was required within a lift shaft, Ministry of Transport approval was required. I noted that this angle was a structural tie only and was not supporting any additional services. Mr Rogers replied to me on 18 October 1991 confirming that the details shown on CD1, 2 and 3 were acceptable (**BUI.MAD249.0130.36**).

62. On 15 October 1991 ARC received a quotation from CBD Construction for $4,633.50 plus GST "to supply and fix angle brackets as per details including remedial to floors broken out for investigation" (**BUI.MAD249.0130.38**).

63. I wrote to Mr Ibbotson on 15 October 1991 (**BUI.MAD249.0129.49**). I explained that ARC had removed a small area of concrete at the end of the walls adjoining the lift shaft and we had identified several reinforcing bars. I noted that while those bars provide a structural tie, a limited amount of additional remedial work was required in order to provide the seismic strength to meet the current New Zealand Standards. I advised that remedial work was required on levels 4, 5 and 6 only. I enclosed a copy of details 3608/CD1, 2 and 3 for Madras Equities' information (**BUI.MAD249.0130.33-35**). I advised that the work was estimated to take approximately 4 days to

complete and a price of $4,633.50 plus GST had been quoted by the contractor. I asked that they provide confirmation of acceptance of the quotation if they wished to proceed with the work.

64. That confirmation was provided by letter dated 16 October 1991 (**BUI.MAD249.0129.53**). They asked that the work be completed before the end of October 1991. They also stated that they assumed that the work proposed by ARC would ensure that the structural content of the building complied with all structural and earthquake loadings in every respect.

65. I replied by letter dated 17 October 1991 (**BUI.MAD249.0129.54**). I advised that we had instructed CBD Construction to proceed with the remedial work and that the work on site was planned to take place during the next week. I advised that the proposed remedial work would give the floor to wall connection the seismic strength required by NZS4203:1984, but noted that a number of other Codes to which the Building was designed, including materials Codes, had since been amended and the original design might not comply with all aspects of those Codes. I can't specifically recall what those changes if any might have been, but can't recall anything major that would have changed between Codes current in 1986 and those current in 1991.

66. ARC did not apply for a separate building permit for the retrofit work, and I am not aware whether the owner or builder did. My recollection of the early 1990s, prior to the adoption of the Building Act, is that the building permit process was much less structured than it is now. Recent attempts to obtain building permit records of older buildings, such as this one, from Christchurch City Council archives for post-earthquake strength assessments have indicated that many such records do not show all changes actually made to the buildings. This indicates to me that it was not common practice to apply for permits for all changes at that time. However, the requirements of the Building Act are now quite explicit, and I would expect this type of retrofit work to be subject to building consent approval if it were done now.

67. I recall that I went to the building and inspected the strengthening work on at least one occasion. The purpose of the inspection would have been to determine whether the intent of the design was being complied with. I cannot recall any concerns regarding the standard of workmanship of the remedial work.

68. I have had no further involvement with this building, other than advice to an architect regarding infilling a precast façade panel near the entry door some time later.

Conclusion

69. From my involvement in this inquiry, I do know this was a massive earthquake far in excess of what the 1984 Codes assumed, and I do know that the retrofit work I designed 22 years ago to the standards of the day, and many other aspects of the building, would fall short of today's Code requirements.

70. I do not know why the collapse occurred and I look to the Royal Commission and its experts to determine that, and to provide recommendations that continue to shape how we as engineers work in order to prevent this ever happening again.

This statement is true to the best of my knowledge and belief and was made by me knowing that it may be used as evidence for the purposes of the Royal Commission of Inquiry into the Canterbury Earthquakes.

Dated 31 May 2012

Geoff Banks