HEARING RESUMES ON MONDAY 16 JULY 2012 at 10.00 AM

ALAN REAY (SWORN)

CROSS-EXAMINATION: MR ELLIOTT

Q. Dr Reay, Mr Rennie said at the Royal Commission last week that our single aim is to put forward such matters as will, taken with other evidence, ensure that all facts and all issues are before the Royal Commission. So I take it you would agree that it is important that the Royal Commission has all documents relating to the CTV building that it can get?

A. Yes.

Q. And I think that issue is highlighted especially in relation to your position on Code Compliance where you say that you can't definitively state whether the building complied as there is no certainty about the documentation issued to the building contractor. Is that right?

A. That's correct.

Q. In the case of that documentation I assume that would have been on your firm's file?

A. No.

Q. You wouldn't have kept a copy?

A. We would not have got a copy.

Q. You're aware that Mr Tapper wrote a letter to your firm on the 27th of August 1986 requesting further information about the application for a permit aren't you?

A. Yes I'm aware of that.

Q. And your firm's response to that would be of assistance to the Commission, you would agree?

A. I beg your pardon?

Q. The response that your firm made to that letter would be of assistance to the Commission?

A. Yes.

Q. And documentation relating to that response would have been on your firm's file?

A. We don't have the documentation related to all of that response.

Q. I will just refer you to a document BUI.MAD249.0227.1. Do you agree this is a letter from your lawyers to the Royal Commission dated the 24th of February 2012?

A. Yes.

Q. I will just ask for paragraphs 2 and 3 to be enlarged please. The letter says, "Our client has already provided all file and explanatory notes that it considered to be relevant to either DBH or the Royal Commission." Do you see that?

A. Yes.

Q. And in paragraph 3, "Another search of our client's records in response to your further request for any other documentation regarding the building relevant to the Commission's inquiry has identified a handful of additional documents not previously requested by or provided to the DBH or the Commission." Do you see that?

A. Yes.

Q. And then the last sentence goes on to say that none of those documents appear to be of much significance to any technical investigation. Do you see that?

A. Yes.

Q. So I take it your intention at that time was to convey to the Royal Commission through your lawyer that you had provided all relevant documentation and carried out in fact a further search which had produced some documents, none of which were of much significance. Is that right?

A. Yes that's correct.

Q. Do you agree that the time records that Mr Rennie referred to in his opening were provided in your third brief just last month?

A. That's correct.

Q. And are you aware that last week your lawyer produced copies of papers from a seminar, apparently attended by Mr Harding in 1986 with

notes apparently made by Mr Harding relating to a wall arrangement that may have been relevant to the CTV?

A. Yes.

Q. In your evidence last week you said to me, page 129, line 29, "When in searching the records, historical records for the work on this building, I was of course going through some very old files having been in business for 40 years and came across a Press article dated 1 June 1991 and it was probably the 1st of June 2011 that I found it." Do you recall saying that?

A. Yes.

Q. I take it you would agree that the time records Mr Rennie referred to are very significant documents in terms of what happened with the design of this building?

A. Yes they are.

Q. Can you explain why you did not locate and provide them to the Royal Commission or to the department as part of your previous searches for documents?

A. Um, firstly the department never asked for documents of that type. They asked specifically for technical documents. In terms of why I hadn't found them was because they were in a box in a storeroom marked "Miscellaneous" and I had no idea that that information was in them. I was having a final clear out and came across the box and found the records in it. A lot of the records that we have found are recorded under file numbers. Those records aren't recorded under job file numbers.

Q. The process that your firm adopted back in 1986 was to keep a separate file, was it, for each of the buildings that you were designing?

A. Yes.

Q. And was that just one file or were there different files?

A. There was one file number and everything at that time would have been put in that. In those days a soft cardboard file.

Q. And that would have included copies of correspondence would it?

A. Yes, everything to do with the job at that time apart from individual's time records would be in that file.

Q. On that point of time records, we can produce this if you like, but I think it's right isn't it that the time records that Mr Rennie referred to are not timesheets relating to the CTV itself but they are time records summarising hours of work on a number of different buildings. Is that right?

A. That's correct, those ones are.

Q. So that you would have also kept separate individual time records solely relating to the CTV building?

A. No, the time records would be weekly time records that staff would fill out which would cover all the work that they did, whatever job that week.

Q. And you filled out similar records as well?

A. I would have, yes.

Q. And did those records contain a space to write down exactly what the person had done?

A. I can't remember whether that designation was on those records back then.

Q. And those records you say were held separately to the individual file records for each building, is that right?

A. That's correct.

Q. So talking firstly about the individual file for the CTV building that your firm would have held. What do you say has become of that file?

A. Well some of it was retained. What isn't retained we can't be 100 percent sure of.

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Q. So some was retained and some was not you say. Why was some retained and some not?

A. Well, the files are kept in filing cabinets I think initially. Then they, this is after they come off people's desks. If someone has a query about a job they'll go and get the file. They may have pulled stuff out of it and not put it back.

Q. So are you saying that some documents on the CTV file were retained and those documents have remained available to you since 1986?

A. I'm sorry, I've?

Q. I'm talking about those parts of the CTV file –

A. Yes?

Q. – which you say would've been retained?

A. Yeah?

Q. And is it your position that those documents have been available to you since 1986?

A. They must've been retained somewhere within the company to have ended up as part of the records that were finally kept.

Q. So that file was stored somewhere at some point after 1986?

A. Yes, yes, either within the office or at a, one of those lock-up garages which we had for quite a while where we stored files.

Q. And as part of your search for records you've located that file. Is that right?

A. Yes.

Q. And you've provided that file in its entirety to the Royal Commission. Is that right?

A. That's correct, yes.

Q. So talking about that part of the file which was not retained, can you just explain to me why part of the file was not retained? Are you saying it was inadvertence or a mistake, or was there an actual reason for removal of documents?

A. I don't, I can't be specific about that. People, everyone in the office has access to the files to go and look for whatever they choose, and if someone chose to go and get information out of that file then they would've done it and they may not have put the information back.

Q. So if there are documents which we can identify as having, as being missing as it were, from the file which you have, the reason would be that people took them off the file and left them somewhere else without ever returning them to the file, is that right?

A. That's one possibility.

Q. Would that have been consistent with the sort of systems that you had in place in your office for document retention?

A. I, because it's so long ago I can't actually say specifically what our document retention was. In general it was focused around retaining records for the Inland Revenue Department which was a legal obligation. We had no legal obligation to retain job files. The clients didn't ask us to, they didn't, didn't pay us to as you might say. It was really us just retaining what we thought was appropriate in case we might've needed it for some reason in the future.

Q. I appreciate that but you've just given evidence that you did retain the CTV file?

A. Yes.

Q. And I'm trying to identify what may have happened to documents which for some reason were not on the file that you retained. And you've said that people may have removed documents from that file and not put them back. That's your evidence, so…

A. Well, for example the files that were kept in this lock-up, after about 10 years a whole lot of them were mouldy because the roof leaked, so – whatever went mouldy and we couldn't copy or recover we wouldn't have kept. Whether that was part of that I don't know.

Q. Well these other documents that may have been extracted from the CTV file may have ended up on other files mightn't they. That's a possibility?

A. Yes, the only file that they might've ended up on was the one in 1990 when the issue of the, say the drag bar issue arose, in that at that time the CT – the original file would've been collected and opened to get the information from it for the work to be done in 1991.

Q. So the file relating to the 1991 work was a separate file?

A. Yes.

Q. Is that right?

A. That's correct.

Q. And that also is a file that you retained somewhere and could access and provide to the Royal Commission and you did. Is that right?

A. Yes, that's right.

Q. So is it not a possibility though that through inadvertence or otherwise, documents from the 1986 CTV file may have ended up on other building files at that time?

A. I would think that's quite unlikely.

Q. Have you carried out a search of other files that you've held to see whether they contain documents relevant to the CTV building?

A. Yes, I have looked in files where I thought there was a possibility of them being put by mistake but I haven't found anything else, including in the 1991 work file. There was nothing in there relative to the original work.

Q. How did you identify which files there may have been possible documents ended up on by mistake?

A. The, I looked for a few transposed job numbers which I've noticed in the past has happened sometimes. Also when we've been going through other files to, 'cos some of this material was actually archived onto computer disks at one stage. If in fact the information had been on another file it is a reasonable probability that it would've been noticed and pulled because at times we have found material from one file on another where it is quite random.

Q. Where are these other files which you have checked?

A. Well all the files that we have are held in the office.

Q. They're held in the office of Alan Reay Consultants Limited?

A. Yes.

Q. They're all there are they?

A. Well they're there to the extent that we have retained the information.

Q. You referred to a disk. Did you have computer disk based records from 1986?

A. Yes we did.

Q. For the CTV building?

A. Yes.

Q. Correct me if I'm wrong but you've not produced any disks to the Royal Commission have you?

A. No, what we've produced is the printouts that we took from the disks.

Q. Would you produce those disks please to the Royal Commission?

A. We don't have any disks anymore.

Q. Why not?

A. Well in the February earthquake everything ended up as a shambles so what we've done since is put the information onto a drive.

Q. But you said you'd printed documents off the disk, which I take it must've been after February. So are you saying that you've destroyed the disks since February 2011?

A. The disks, we don't hold, we transferred everything from the disks that we had onto the drive.

Q. When?

A. Last year, I don't remember exactly.

Q. After February 2011?

A. Aft – certainly after February 2000 [*sic*] because that was when we had the problem with the shambles.

Q. So what became of the disks?

A. The disks are, I think that that's, that has been disposed of along with all the other material that we've got rid of.

Q. Your evidence is that you disposed of a disk containing information relating to the CTV building after February 2011, is that your evidence?

A. Could you ask me that again please?

Q. Is it your evidence that after February 2011 you disposed of a disk containing documents relevant to the CTV building?

A. Well I think they were disposed of with all the disks, but I'd have to, I can have another check.

Q. Would you do that please?

A. Yes I certainly will.

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Q. The timesheet that you've referred to which we've had separately to the CTV file upon which individual employees would have recorded their time for this building were stored separately in your office to the CTV files?

A. Yes.

Q. Where in your office were they held?

A. I think they were originally held in steel filing drawers, small cabinets but those cabinets are long gone and those sort of records we don't hold.

Q. Wouldn't those records have been held in the same location as the time summaries that you've now produced?

A. No, no.

Q. How do you know that?

A. Because the actual sheets that people filled out were in a steel cabinet. The record that I found was in a, one of those cardboard storage boxes in a different – and it was – well it was in a location where some accounting records were in the office we're in now but we were in a different office when the CTV building was designed and those cabinets that the records were in then were, haven't been utilised in the newer office.

Q. So this box in which you located the time summaries is in your current office, is that right?

A. The box is yes.

Q. And that boxed is marked miscellaneous, is that right?

A. Yes.

Q. And that box has been in your office since February 2011 has it?

A. That box has been in the office since the year 2000.

Q. Did it not occur to you to search that box when looking for documents to produce to the Royal Commission as at February and earlier, February 2012 and earlier?

A. No it didn't.

Q. Why is it that it later occurred to you to look into that box?

A. Because I was having a final clear out because we've had the material come off the shelves three times and I was going through looking to get rid of anything that we didn't need to retain and I didn't just throw the box out, I opened it to have a look at what was in it before I threw the material out. I understood it would just be some sort of accounting records and I found those particular records.

Q. So by looking into this box it yielded further relevance documentation hasn't it?

A. Yes as it transpires it has yes.

Q. Are there other boxes of which you're aware that could yield further relevant information about the CTV building?

A. No after I found that I then went through all those accounting type boxes to see if there was anything else.

Q. When you say accounting type boxes, do you mean records relating to the accounts of the firm?

A. Yes.

Q. Including time records which support accounts?

A. I looked for any other time records that were you know to see if there were any available.

Q. Considering the timesheets as opposed to the time summaries, timesheets, did any of those boxes have timesheets for any other buildings?

A. There are timesheets in this area but they relate to the last two or three years of records not going back to the time of the CTV building.

Q. So you've carried out a search of these boxes in your office. Are there any other boxes in your office or anywhere else that you think might yield relevant documentation?

A. Well I haven't been able to find any and I don't think there are any.

Q. When you say you haven't been able to find any what else have you done apart from what you've already described, if anything?

A. Well I've been through all of the shelves in the various storage areas where material was put following when we moved office in 2000. At that time I think the people packaged up material. If they weren't sure of it they put it in a box, marked it and it appears it was put in a certain area and it is basically they have stayed in that area until now.

Q. Is it you personally who has conducted these searches or have you asked others to conduct them as well?

A. No some of the staff at times. The admin staff have looked for certain information. I've asked them to, but I've also looked myself particularly

when searching the historical records, for example any photos or whatever I personally searched for them because I didn't think the staff were likely to be able to find anything particular for that building.

Q. Are you saying that staff had looked at some documents that you had not looked at and which could produce documents that are relevant?

A. No because when if they've found anything that they thought was relevant they have asked me about it.

Q. Who were the staff members who did this?

A. There's a woman Alison who's done it.

Q. Is she an engineer?

A. No they are admin people.

Q. Did you give her a list of what to look for or just say go and find something that might be relevant?

A. Well I got her to do what she could because obviously it's time pressures with me but quite separate to that having got her to do as much as she could I have then gone through myself and searched through.

Q. Do you say on oath that you've done everything possible to ensure that every document your firm had about the CTV building has been provided to the Royal Commission?

A. Yes I do.

Q. And so we don't need to expect to receive any further documents from you that might be relevant?

A. Well I hope not.

Q. I refer you to your statement of evidence. Do you have a copy of that in front of you?

A. Yes.

Q. Second statement paragraphs 22 and 23.

WITNESS REFERRED TO STATEMENT

A. I'm sorry which paragraph was that.

Q. Dr Reay, second statement of evidence.

A. Yes.

Q. I'm going to refer you to some comments in paragraphs 22 and 23.

JUSTICE COOPER:

Q. So this is the combined document, Dr Reay, which you read the other day and that maintained the heading "First, second, third". So that is the one you are looking for. Do you have it?

A. Yes.

CROSS-EXAMINATION CONTINUES: MR ELLIOTT

Q. Dr Reay, I am just going to ask you some questions about what you described as shaking table reduced scale physical model experiments on a six degree of freedom shake table.

A. Yes.

Q. And I will just quote your words there. "Strictly", you say, "there should be shaking table reduced scale physical model experiments on a shake table to investigate the overall behaviour and to recreate the structural failure", and then at the end of paragraph 23 you say "only in this way and the true reasons for the CTV building collapse to be known" and you refer to that paragraph to compare in the results of this shake table process with computer modelling and so on?

A. Yes.

Q. That's what I'm asking you about. I just want to identify exactly what you are saying this would mean. Am I right that this type of physical model experiment involves constructing a reduced scale model of the CTV building, is that right?

A. Yes.

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Q. And is it right that the smaller that is the less accurate the results would be so that the reduced scale model would need to be as close as possible to actual size?

A. Yes, the results are affected by the scale effect.

Q. So do you say that this model should be the actual size of the CTV building or some reduced scale?

A. Well in the perfect world it would be actual size but the reality is that that is not possible.

Q. So would it need to be, for example, at least 50 percent of the size to be a reliable model?

A. The modelling would be done in association with full-scale testing of componentry, so the two need to go together. The model on its own isn't sufficient. In terms of how big it is, the more true to scale it is the better but you're limited really by the size of the shake tables available.

JUSTICE COOPER:

Q. I think what you're being asked really is, is there a minimum size that the model building would have to be so as to ensure adequate results?

A. I couldn't be specific about that.

CROSS-EXAMINATION CONTINUES: MR ELLIOTT

Q. Based on what you've just said though you would need in fact two things – you would need actual replicas of certain parts of the building and a reduced scale model of the building to compare?

A. Yes, yes, to undertake the work yes.

Q. In terms of the reduced scale model I take it it means that we would need to find scaled versions of the reinforcing steel that was used in the CTV building. Is that right?

A. Yes.

Q. If, for example, the original design provided for a 28mm reinforcing bar we'd need to find one of 14mm if it was a 50 percent sized model wouldn't we?

A. Yes.

Q. Do you agree though that that type of reinforcing doesn't necessarily even exist?

A. Oh that's correct.

Q. The reinforcing bars used in this model would need to have the same strain ageing characteristics as those which were actually in the CTV building wouldn't they?

A. Metallurgically they would need to be the same, yes.

Q. So we couldn't use new reinforcing steel could we?

A. Well we could if it was the same metallurgically.

Q. One would need to find a concrete with similar aggregates to that which was actually used in the CTV building construction wouldn't you?

A. In proportion, yes.

Q. And this model would require instrumentation to be placed, wouldn't it, at each of the important parts of the building to quantify how the building behaved during simulated earthquakes, wouldn't it?

A. Well you would have to establish exactly what the monitoring of the model was and deciding that would be part of that.

Q. There is no shake table in New Zealand is there?

A. No.

Q. A shake table is a device upon which you would place the model and the table can then simulate certain types of earthquakes, couldn't it?

A. That's correct.

Q. So we would need to carry out this process in Japan or the United States wouldn't we?

A. That's correct.

Q. And if, for example, it was necessary to source Canterbury aggregate for the concrete that would have to be taken from Canterbury to the US or to Japan, wouldn't it?

A. Yes. In terms of doing this sort of testing though you focus on certain elements to a degree to determine the likely effects of an earthquake on that building and so parts of it may be replicated, as you say. Other parts may not be exactly replicated if it was considered that it wasn't necessary to do so.

Q. And once this model in whatever form it is, is assembled it would then need to be subjected on the shake table to an earthquake equivalent to the 22nd of February. Is that what you're saying?

A. Well ideally subject to the ground movements that occurred at the CTV site on the 22nd of February, but because we don't have them we would

have to use what other ground records we have or factored or whatever to simulate the effect.

Q. Your position is that the building suffered diminished capacity in September and subsequent aftershocks so in fact we would need to subject our model to a Canterbury earthquake sequence equivalent wouldn't we?

A. Ideally yes.

Q. But then to really test the issue of diminished capacity wouldn't we want to build a second model and test that solely in an event equivalent to the February 22 earthquake, compare the two?

A. I haven't considered that.

Q. And to be really sure you would want to prepare a number of models wouldn't you so you could compare results?

A. It depends on the results that one gets from the testing of the model initially, the results one gets from full-scale testing and some of the structural elements as to the extent that you would go to. You're trying to predetermine or suggest that you can predetermine the testing sequence without doing any testing at all.

Q. Well let's take a cautious approach, or a conservative approach, and say well there's just one model we need. Can you give an idea of approximately how much this process would cost?

A. I've no idea.

Q. More than a million dollars? It would have to be wouldn't it?

A. Oh yes it would.

Q. Millions of dollars?

A. I'd be guessing and I'm not going to guess.

Q. Mr Rennie said in his opening the Commission's work is likely to result in the best possible understanding of the causes of the building's collapse. I take it he was contemplating that there would be no shake table tests. So do you agree with Mr Rennie's comment?

A. Well certainly in the circumstances that's true.

Q. Next I'd like to refer you to some evidence you gave last week. On Thursday you said that you've looked at the permitted drawings for the

CTV but not studied them in depth. Secondly, Mr Mills (sorry, and that's at page 108, line 14). Secondly, page 111, line 1 Mr Mills said to you in relation to the five issues that you discussed with him, "How extensive have your own investigations been into those five issues?" and your answer was, "I haven't investigated them in depth in relation to the CTV building. Some of them I can't..." and you went on to talk about strain hardening. Now one of the five issues that you've given evidence about is that of cumulative damage resulting from aftershocks and I refer you in particular to paragraphs 68 and 72 of the same statement I've just asked you to look at. So would you like to have a look at that please.

A. What page is this?

Q. So this is in your second brief. It's on page 11. If you look down the bottom right-hand corner. Your evidence begins at paragraph 68 and goes through to paragraph 72.

A. Yes.

Q. So your evidence about cumulative damage is set out in those five paragraphs there. Is that correct?

A. Yes.

Q. And in paragraph 72 you say, "In my opinion the ongoing sequence of aftershocks continues to cause cumulative damage to concrete reinforced buildings, each time reducing the capacity of the building to some extent. I believe that by the time of the 22 February earthquake the CTV building had lost part of its capacity as a result of not only the 4 September 2010 earthquake but all of these large ongoing aftershocks." Now as you've given an expert opinion on this and other issues, you've said that you've read and you've agreed to comply with the Code of Conduct for Expert Witnesses. That's right, isn't it?

A. Yes.

Q. Now that code will come up now, BUI.MAD249.0529. Just referring firstly to point 1 under the heading Duty to the Court. "An expert witness has an overriding duty to assist the Court impartially on relevant matters within the expert's area of expertise." This opinion I have just

referred you to do you believe that in expressing that opinion you are assisting the Commission impartially?

A. Yes.

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Q. Mr Mills pointed out that of those five issues you raised including this one, all having common the fact that none of them attribute responsibility to you or your firm for the collapse. Do you recall that?

A. Yes.

Q. And certainly in relation to this issue of diminished capacity it is true, isn't it, that any diminished capacity to the building caused by aftershocks has nothing to do with you or your firm. Agreed?

A. I don't understand the question.

Q. Well unless you or your firm was responsible for the ongoing aftershocks, it is true that any diminished capacity caused by those ongoing aftershocks is not something for which you or your firm could be held responsible. That is right, isn't it?

A. Yes.

Q. Now the code of conduct requires you to, and this is, I will refer you to the exact point, clause 3F, requires you to specify any literature or other material used in support of your opinion. Now since you've not referred to any then we can take it that you have not relied on any literature or other material in support of your opinion have you?

A. Well I have been asked to provide some and it has been provided relative to the IRD building.

Q. I see, yes. But I am talking here just about literature or I suppose you are referring to other material. So was there any literature that you have relied upon? Clearly there wasn't, is that right?

A. No I've relied on reports which you could define as literature or other material on the IRD building identifying the effects of strain hardening on the reinforcing.

Q. Clauses D and E of the code of conduct require you to state the facts and assumptions on which your opinions are based and the reasons for your opinions. I think this is what you are referring to that your reasons

as stated are firstly that you have noted cracks got bigger in some buildings that you looked at including IRD, correct?

A. Yes.

Q. And that's the supporting material that you've just referred to, relates to IRD doesn't it?

A. It does.

Q. So your first reason for your opinion as stated is that you've looked at cracks on some buildings but not the CTV building, is that right?

A. The only cracks I have looked at relative to the CTV building were in photos that were taken of elements retained at one stage, but from that I can't tell whether there was deterioration over time or...

Q. No and you didn't carry out any personal inspection of the CTV building between September and February, did you?

A. No.

Q. The second reason that you seem to give your opinion apart from saying other buildings had cracked is that there was a lot of major aftershocks and you produce a list, don't you?

A. Yes, that is correct.

Q. Point 4 of the code of conduct says, "That if an expert witness believes that his or her evidence or any part of it may be incomplete or inaccurate without some qualification that qualification must be stated in his or her evidence." Well isn't the fact that you did not physically look at the CTV building a fairly obvious qualification that should have been stated when giving an opinion about diminished capacity of the CTV building?

A. No because what I have said is, what I had the issue with is the consultants investigating the CTV building had not considered this matter. I didn't say I had specifically considered the matter for the CTV building.

Q. I see I must be mistaken. When you say, "I believe that by the time of the 22 February earthquake the CTV building had lost part of its capacity as a result of the 4 September earthquake and ongoing

aftershocks," you are not saying the CTV suffered diminished capacity as a result of the earthquake and aftershocks?

A. I said I believed it would have, but it was based on the information that I referred to in terms of the IRD building.

Q. You've expressed an opinion about the state of the CTV building, haven't you?

A. Yes based on – and I have said what that is based on.

Q. So to summarise the position as you said to Mr Mills you have not studied the drawings in depth, you have not investigated any of these five issues in depth, you didn't actually inspect the CTV building, so do you agree that it is not open to you if you are complying with the code of conduct to say the CTV building had lost part of its capacity?

A. I believe I should have said that it probably had lost part of its capacity rather than being as definitive as I was.

Q. Well no it wasn't even open to you to say that, was it? You can't even express an opinion about probability given the lack of information that you have, can you?

A. Well as an engineer I believe I can.

Q. And that is consistent is it with your stated position to get the best possible understanding of the causes of the collapse and to assist the Commission in doing so?

A. Yes it is.

Q. In fairness to you, I will put this to you, do you accept the Royal Commission should disregard the opinion that you have expressed about diminished capacity?

A. No I don't.

Q. Mr Mills addressed the other four issues that you discussed in your evidence. One of the others, apart from diminished capacity was that of vertical acceleration. That is one of the five issues that you have highlighted, isn't it?

A. Yes.

Q. You would accept that other buildings in the CBD would also have been subject to vertical accelerations, wouldn't you?

A. Yes.

Q. And you accept that the CTV building pancaked, don't you?

A. That is the expression that has been used.

Q. Well do you agree with it?

A. Beg your pardon?

Q. Do you agree with it?

A. I am not sure what the definition of pancaked is in engineering terms.

Q. Well if I was to say that all of the floor slabs ended up on top of each other leaving those on the floors with little chance of survival, would you agree with that?

A. Yes.

Q. And it is a fact that no other building in the CBD collapsed in that way on the 22nd of February, isn't it?

A. Oh, I think there were similarities with PGC building and that some of the floors were held up partly but there was, in terms of if you said exactly in that manner the probably that was the only one.

Q. I am sorry probably?

A. Was the only one that collapsed in that manner, exactly in that manner.

RE-EXAMINATION: MR RENNIE

Q. Dr Reay my friend has asked you some questions about five matters which he called issues, in your brief you called scenarios, and in your answer to Mr Mills you called elements in the matter, starting with strain hardening and going on through. Do you know the five that I mention?

A. Yes.

Q. Leaving aside the role of any of those as a cause of failure, do you perceive each of those matters to be relevant to the Commission's work and if so how?

A. Well I do consider them to be relevant and referring to the strain hardening issue, in particular the effects of strain hardening have been to substantially diminish the capacity of the structures to withstand earthquakes. The IRD building is one example we've given. There are

other buildings which, in which testing has been carried out and similar effects have been noted.

JUSTICE COOPER:

Q. Did you say other buildings in which testing has been carried out, or is being carried out?

A. Has, has now been carried out.

RE-EXAMINATION CONTINUES: MR RENNIE

Q. Now in your answer to Mr Mills in relation to strain hardening you said that this is an issue which emerged in November/December of last year. You recall that?

A. Yes.

Q. How did it emerge?

A. I recall that we learnt that the reinforcing was being tested for strain hardening in other buildings by Home Solutions, and because in particular at that time with the IRD building the insurance company had agreed to pay to re-level the building. Before the re-levelling was undertaken I arranged for the reinforcing to be checked to make sure that it was in fact worthwhile to re-level that building, and that was the first time that we had been involved with testing for strain hardening.

Q. Speaking generally of the code as it applied in 1986 for buildings in Christchurch, did it identify strain hardening as an issue to be designed for or responded to?

A. No and it's only since the earthquakes that in fact this issue has been, or we've been alerted to this potential problem with this issue.

Q. Is it now possible to know whether the CTV building suffered from strain hardening effects before 22 February 2011?

A. If you could find the reinforcing that exists, that existed, then there is the possibility of testing, but I'd have to say it is fairly remote due to the, the extent of the demolition of the material.

Q. Leaving aside the issue as to whether it is relevant to explaining that collapse, is it relevant to any assessment or review of the adequacy of the current earthquake code?

A. Well it's definitely relevant to the review of the earthquake code and in part there was a recommendation from our structural engineering society to the Royal Commission I think last December in which part of the recommendations were in effect recommendations to take account of the effect of strain hardening, and in particular it recommended that a ductility factor reduced from maybe four, three to four down to 1.25 be used for strain structures.

Q. Have you raised this issue in some way to reduce you or your firm's responsibility in respect of the CTV building as you acknowledged on Friday?

A. I'm sorry I don't understand?

Q. Have you raised this issue in any way to reduce you or your firm's responsibility for the CTV building which you acknowledged on Friday?

A. No I haven't. I've raised it because of my concern that, or two concerns. One is that it does affect the design of buildings in my view going forward, and it does potentially impact on for example time history analysis of the building. It doesn't mean that it is necessarily the cause of the collapse, but it's certainly one of the items that should be considered. I think, perhaps my, let's, our initial concern was with the major structures, the shear walls and the frames in buildings. With, we have found that this issue exists in connection, reinforcing connections between floors and walls recently and I've noted that there is an unusual separation described by Mr Frost between the south wall and the floors, and this is why I've raised this question. Strain hardening effects could've easily influenced the performance of that sort of connection.

Q. Now you indicated to my friend Mr Mills on Friday that looking at a newspaper article 20 years ago, and then looking at it more recently caused you to reflect on the fact that as you put it, you've been designing for the Alpine Fault, whereas there were fault lines under Christchurch, do you recall that?

A. Yes.

Q. What is the relevance of that to the design of buildings in Christchurch, from your perspective?

A. Well the relevance has been that the type of ground motion that has occurred from these earthquakes emanating from beneath or near the city have had quite different characteristics to the Alp – expected Alpine Fault characteristics and in particular the high vertical accelerations or high vertical displacements were not expected because the Alpine Fault earthquake wouldn't have been expected to have generated that type of motion.

Q. Through your 40 years of practising as an engineer in Christchurch has the primary focus been on Alpine Fault type movements or –

A. Yes.

Q. – have you, and in terms of the scale of the difference between the Alpine Fault type movement and those observed particularly in February, can you explain how extensive that difference is?

A. Well the difference is the significantly higher horizontal and vertical accelerations that occur with a near, when you have got a near fault earthquake.

Q. And the level of order of the significance?

A. Well it's, it's several, it has been several times in effect for the loadings on the buildings.

Q. So again in considering the scenarios, elements or issues that my friends were asking you about, what do you see as the significance of that in relation to the work of the Commission?

A. Well the significance is twofold. The first is that it's important for the design of buildings going forward, and may well be important for the review of existing buildings in other parts of New Zealand. But it is also relevant to the CTV building in terms of establishing the most probable cause of failure. I think, I perhaps would like to say something else. You've raised the question that has been raised by Mr Mills yesterday and again today as to these five items being items that would have, were items that perhaps the company couldn't be responsible for and

that hasn't been something that I've thought about but I think it's probably worth noting that the issue of the strength of the concrete was an item that our company I don't believe could have been held responsible for because that concrete was ordered, supplied et cetera to the contractor and it was the contractor's sole responsibility. I decided that it was very unlikely that that concrete was that weak and hence reinstigated the extensive testing that has been carried out and has shown that it isn't that weak. In fact it has shown that the concrete was probably of the standard it was supposed to be. That doesn't help our position because it would have been obviously useful to have been able to blame somebody else and weak concrete, and I think it's just worth noting that we did do that to illustrate the fact that we are not cherry picking issues.

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Q. Dr Reay my friend counsel assisting asked you some questions about shake table and the process involved in that and the costs involved in that. In terms of your view that an investigation of that type should be undertaken do you consider it to be explained as he's proposed as not being able to proceed because of the level of cost?

A. No I don't think the level of cost would have prevented it proceeding.

Q. Are you describing a process which is hypothetical or one which is used from time to time?

A. It is used from time to time. There are shake tables which will, on which you would be able to put I would imagine a half scale model of the building. I think probably the best one I think is in Japan at the current time where they have tested parts of buildings, parts of full scale building frames.

Q. What would you expect to come out of such a process which would otherwise have not come out of the testing and investigation which has been done?

A. If it can be modelled correctly it should produce the effects of strain hardening on reinforcing for example and the impact on that on the structure.

Q. Given my friend's proposition that a half dimensional model would require half dimensional reinforcing, is that something which to your knowledge prevents that type of testing being done?

A. No not fully because you'd focus on the particular issues, if it was a particular type of reinforcing. You may be able to manufacture it to achieve what you need in terms of modelling it correctly. It is quite common practice to test model structures.

Q. He made reference to the reinforcing and you referred to the metallurgical make up of the reinforcing, do you recall that?

A. Yes.

Q. Would the metallurgical make up of modern reinforcing necessarily match that which existed in 1986?

A. No it doesn't, it's different.

Q. In what way?

A. The stress strain characteristics of the reinforcing are different and the yield and ultimate strengths of the reinforcing are different.

Q. Does it follow that to carry out such modelling such 1986 specification reinforcing would have to recreated?

A. Ideally yes.

Q. In terms of the metallurgical effects that you described, are they an underlying assumption to the design code?

A. Well the characteristics of the reinforcing used meet certain specifications which are defined in the design code.

Q. Yes. So in that sense the reinforcing responds to the code rather than the code responding to the reinforcing?

A. Yes I think you could put it that way.

Q. I appreciate that's a bit like which came first, the chicken or the egg but – and in relation to the strain hardening which we were discussing slightly earlier, are the metallurgical characteristics relevant to that?

A. Well they would be yes.

Q. So again in terms of the learning from the CTV building is this is a scenario, an element or an issue which you seek to see addressed?

A. The issue of the strain hardening is probably in terms of learning from it the learning is available from other buildings than the CTV building. It is that learning that could possibly be applied to the CTV building in order to assess possibility of that having an effect on it.

Q. Now my friend asked you a number of questions about the record keeping practices of your firm and your personal practice prior to that over the years do you recall that?

A. Yes.

Q. And you referred ultimately to the time records that you'd produced as accounting records?

A. Yes.

Q. Is that a record keeping distinction that is observed in how you keep records?

A. Yes it would have been.

Q. Would accounting records normally be found on the building file for any design building?

A. No.

Q. Would accounting records normally be retained beyond the period required by the IRD?

A. Not normally no.

Q. Can you account for the survival of the time records in those circumstances?

A. Only that I think someone decided they didn't know what to do with them and they just put them in a box.

Q. And in relation to the earlier enquiries from my friends, the counsel assisting and the Commission for documents do you recall ever receiving a request for accounting records as opposed to building files?

A. No.

Q. Now my friend also referred to the technical paper which came from the seminar that Mr Harding had sent, do you recall that?

A. Yes.

Q. Was that located on any building file?

A. No, no it was amongst groups of old seminar papers.

Q. And were they retained for any particular purpose?

A. No specific purpose, just happened to have been retained.

Q. And in relation to that as archival or library resource or something do you have any particular practice for keeping such material?

A. No the material was just kept on a shelf.

Q. Or indexing?

A. No it wasn't indexed.

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Q. And when you recently found the seminar paper had it previously appeared to you that there would be a copy of the seminar paper from the seminar Mr Harding attended?

A. I hadn't remembered that he had attended a seminar 26 years ago.

Q. And on finding it did you promptly make it available or did you sit on it?

A. No, I made it available straight away.

Q. So in terms of my friend's questions of you as to the records held by your company and the records of your prior personal practice, leaving aside the disk that he asked you about, can you think of any other category of documents other than building files that could have any possible reference or relevance that might still be retained?

A. No I can't think of any.

Q. Now you indicated to my friend Mr Mills on Thursday that you would have taken a greater role in the job if you were looking back now. At that time you didn't see that as necessary for that particular building but "clearly now after what's happened I would". Do you recall saying that?

A. Yes.

Q. What other main reasons that have caused you to change your view on that?

A. Well the fact that the building collapsed is the major reason that has caused me to continually rethink what I might have done. I don't..., that would be the main reason I think.

Q. Now lastly you may recall that Mr Mills asked you about a list of six buildings which he put up – BUI.VER0057A002 for the record but I don't think we need to have it up. Do you recall that list?

A. Yes.

Q. Was that a list that you had prepared?

A. No.

Q. Was that a list that you had submitted for this hearing?

A. No.

Q. Do you know when that list was drawn up?

A. Going by the reference on it I think it was drawn up last year.

Q. Do you know why it was drawn up?

A. Yes, one of our engineers was involved in doing an assessment of a building just after September and he appeared before the Commission in relation to that collapse and I understand the list was related to his appearance.

Q. Is that a list which is relevant to the buildings that you have personally inspected?

A. I have subsequently looked at one or two of the buildings that are on that list but post February was when I've looked at them.

Q. And have you looked at buildings other than the buildings on that list?

A. Yes.

Q. Do you continue to do so?

A. Yes.

QUESTIONS FROM COMMISSIONER FENWICK:

Q. Dr Reay it's important we understand your background so I'd just like to make sure I've got that correct.

A. I'm sorry I couldn't hear that properly.

Q. I've said it's important we understand your background and your areas of expertise so I'd just like you to check I've got this correct. You undertook a PhD in Structural Dynamics and I understood you tested a number of buildings. One of these I believe was the Zoology Building at the University of Canterbury which has actually some features which are similar to the CTV building. Now you undertook testing of that building is that correct?

A. Yes that's correct.

Q. So this building is a six storeys high, shear wall building, mounted on pads on alluvial gravels, in some ways similar to CTV and the CTV had shear walls also mounted on pads on alluvial gravels and sand. Is that correct?

A. Yes. I think the Zoology Building was on alluvial gravels. The CTV building I think was on other material before whereas the gravels were deeper.

Q. The CTV building might have been on poorer materials?

A. Yes.

Q. When you examined the Zoology Building can you remember how much the deformations and the foundations affected the performance of the building?

A. Ah, yes. It was of the order of in terms of first mode deflection it was to the order of 20 to 30 percent as I recall.

Q. So you would expect the same sort of level of compliance perhaps in the foundation with the CTV building?

A. In comparing the two the Zoology Building itself was a stiffer structure but it was on potentially more rigid material so in balance yes I would expect them to be of a similar order.

Q. So in fact you have the ability to make quite a contribution to the study is really the point that I'm making?

A. Yes.

Q. Now you then subsequently after you set up your consulting firm you really, you know, if anyone says, "Well Alan Reay, what's he done?" immediately comes to mind the tilt-up structures that you really introduced to this country and it's caused quite a revolution in the way we build a lot of buildings in New Zealand now hasn't it?

A. I can't take credit for introducing them because Bill Lovell-Smith did that but I certainly put a lot of effort into developing them further.

Q. And you won awards for that?

A. Yes that's correct.

Q. I know that because I was Chairman of the Committee which gave you one of those awards. So in developing this tilt-up construction you've

clearly got a very good knowledge of the behaviour of reinforced concrete and concrete. You must have studied material properties and the way the different components of reinforcement and concrete work together and have quite a level of expertise in this area mustn't you?

A. Well particularly with reference to the tilt-up work, yes.

Q. Thin sections and so on?

JUSTICE COOPER:

Q. Do you agree with that?

A. Yes.

QUESTIONS FROM COMMISSIONER FENWICK CONTINUES:

Q. Now strain hardening you indicate is a major issue in connection with the CTV and other buildings round the town. You see this strain hardening characteristic as in a negative sense I guess from what you're saying. If we look at the Codes of Practice we have for material properties of reinforcement those Codes actually specify that our reinforcing steel shall have certain strain hardening characteristics. For instance, minimum strain hardening characteristic is 15% increase in stress due to strain hardening and the maximum is set at 50%. Do you agree those are characteristics in our current standard?

A. I'll accept that they are.

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Q. You're not familiar with them?

A. I haven't read it in recent times.

Q. Yes, so you're saying the strain hardening characteristics, can you just tell me exactly how these strain hardening characteristics introduced negative effects into the CTV building in your belief? Or may have introduced negative effects in the CTV building? We're talking about strain hardening?

A. Well what we're finding with the testing that's being undertaken is that the, the yielding of the steel is not occurring over the length of the reinforcing in relation to its diameter for example, as what we would've

expected relative to the laboratory tests that were carried out many years ago. The – in those original tests there usually appeared to be multiple cracks occurring in the concrete. We're finding that we tend to get very few cracks and when we've tested the reinforcing we find that the deterioration of it is more than would be expected in relation to the size of cracks that we're seeing, and the effect of it is that, well in the case of the IRD building the insurer there agreed primarily because of the issue of the strain hardening, and even with their American experts, obviously looking to repair the building as the insurers do, even with them there in the end the insurer agreed to pay out for the total building loss.

Q. Yes.

A. That's, that's sort of an example of where this strain hardening effect has led us to. Now I don't claim to be a metallurgist. What I'm talking about is the, is the effects of what we're seeing in terms of the analysis of buildings and these are relatively new buildings, and the effect on whether these buildings can be repaired or not.

Q. And this is due to strain hardening?

A. It's not strain hardening per se, I think if you took that piece of reinforcing out of the concrete and tested it and in fact I, we have produced all at Mr Mills request, a whole lot of test results for the IRD building, and some of those include where the reinforcing is simply taken out of the concrete and just tested. It complies, but it appears that the, the concrete is modifying the propagation of the yielding through the reinforcing in some way that was never envisaged.

Q. Yes, what I'm trying to get at, why does strain hardening cause this? You're saying it's strain hardening effect. I'm saying how is strain hardening causing this?

A. Okay.

Q. If we got rid of strain hardening would be have got rid of the problem?

A. No because what, my understanding is that the –

Q. Can I suggest to you strain hardening which you put down as something you said you learnt apparently from me on the 1st of April 2011 on a

Friday. I doubt whether you learnt it from me, I think strain hardening is something you would've studied in your second year at university when you looked at metallurgy and the composition, you would've learnt it along with yielding of steel, the formation of Luder lines and all the rest of it and again you would've been subject to the importance of strain hardening on the performance of plastic hinges in your fundamental reinforced concrete, design and materials courses. Would that be correct?

A. That's correct, but the point I'm making is that the, it's not the fact that reinforcing strain hardens per se, it's the fact that the way it is. The reinforcing is behaving within the concrete structure when it's been subject to these earthquakes appears to be significantly different to what was envisaged.

Q. Thank you Dr Reay but you put this all down to strain hardening and you're saying it's cause is strain hardening. Now you're saying it's not strain hardening it's something else. It's either strain hardening or it's something else. You've made a big play about this strain hardening. Now strain hardening as far as I can see is an essential feature of design of reinforced concrete. We couldn't do it if it didn't design, it would be very brittle. Strain hardening, would you not agree, causes the yielding to extend?

A. Yes it does but the yielding isn't extending to the degree that was envisaged.

Q. Then you can't blame strain hardening for it can you? Because we've just said strain hardening is a beneficial effect. You agree it is a beneficial effect. This yielding could not spread if it didn't strain harden could it?

A. (no audible answer 11:26:07)

Q. Whatever else you're doing I cannot see, I think you support me in this, it's not strain hardening. Strain hardening is an essential feature to cause plastic deformation in reinforcement or in structural steel to extend to allow plastic hinges to form.

A. But the strain hardening is occurring and it is limited in length to the stage where it doesn't propagate, the yielding does not propagate along the bar, so it starts with strain hardening and then due to that limitation in propagation the ductile capacity of the member isn't achieved that was envisaged.

Q. So it's not due to strain hardening is it? It's due to some other cause isn't it?

A. Well it's due to the interaction between the concrete and the steel, but it's the effect of the strain hardening, it eventually means that the reinforcing bar fractures, and that's why I've been referring to strain hardening but.

Q. But the higher the strain hardening characteristic to reinforcement, the more that yielding will spread, is that correct?

A. If the reinforcing is tested in a machine, yes, but within the concrete structure it doesn't, it isn't, it isn't performing in the manner that we would expect because it isn't, the yielding is not propagating along the bar as we would expect to occur with the advent of the strain hardening. So the strain hardening is causing the bars to lose capacity because of the very limited length of the ductility that's available.

Q. So what you're saying then is the more strain hardening you've got, you said the strain hardening is reducing the length of which yielding occurs, is that your thesis?

A. No because if you actually had a great deal of strain hardening it may actually be strong enough to break the bond of the reinforcing beyond and propagate the yielding along the bar. But these are, I'm only dealing with the effect of this, and having had a large number, well it is quite a few, I don't know how many buildings, but we've had a lot of testing done with this and the result of it is that the buildings have lost capacity to quite a degree and I've identified this specifically in relation to the IRD building, and that as a result of that, building, some of these buildings have been demolished because they can't be repaired.

Q. Yes but as I think you've agreed to me, that the higher the strain hardening the greater you're going to destroy the bond along, you're

going to get a longer length and more ductile performance. So strain hardening is in fact improving the performance. It's not a problem, it's improving the performance. Do you agree? That's what you implied, what you were saying before, so now I'd like you just to confirm that's exactly your understanding?

A. Well it potentially could improve the performance, but what we're seeing and with whatever reinforcing in concrete we've got, and it occurs over quite a range of reinforcing steel in concrete. We've found this issue in buildings that were built 40 years ago. It is an issue and I am not, I can't claim to be an expert in the degree of characteristics of concrete and reinforcing to deliver the ultimate analysis of this but I can say that this is what we have found on several buildings.

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Q. Yes I am aware it has been found on several buildings. I have seen it –

A. Right.

Q. – it is just the cause that it has been put down to that strain hardening is somehow an adverse effect which comes through strongly in your submissions.

A. Mmm.

Q. Which is one that seems to be contrary to the standard theory that you were taught in your second and third years of university where strain hardening has beneficial effects. Do you agree with that or?

A. I'd agree with – certainly agree with that.

Q. So perhaps need to look for another cause of failures which is not related just due to strain hardening. Do you agree?

A. Yes happy with that.

JUSTICE COOPER:

Q. Well just perhaps before we move on to something else, you've referred to the IRD building and other buildings where this phenomenon whatever it's called has been judged to be significant. Can you tell us what the other buildings are?

A. Yes I can perhaps give you a list.

Q. Oh, you can't tell us off the top of your head?

A. Oh, I can remember some of them.

Q. Well perhaps yes, what are those?

A. The Hornby clock tower building.

Q. Yes?

A. The hospital carparking building.

Q. Christchurch Hospital?

A. Yes it is privately owned carparking building but it is called the Hospital Parking Building. It is in Tuam Street.

Q. Tuam Street?

A. Yep.

Q. And there may be others –

A. Yes.

Q. – but you can give us a list of those?

A. Yes.

MR RENNIE

Maybe I can assist in one other way in that and that is that you will recall that last week I indicated there was some confidentially issues over one of these buildings. Mr Mills at the end of last week asked whether it was possible to overcome these and I have just been advised that it has been possible to overcome those in relation to one particular building and that the relevant parties have consented to waiving whatever rights they may have in that information coming forward. Now I know this is late in the piece but it is only just been achieved Sir.

JUSTICE COOPER:

So what building is that?

MR RENNIE:

That is the IRD building.

HEARING ADJOURNS: 11.33 AM

HEARING RESUMES: 11.51 AM

QUESTIONS FROM COMMISIONER FENWICK:

Q. Dr Reay, the issue which you have referred to is as strain hardening, is one that we have looked at in some detail, seen in a number of buildings and done a little bit of work on it and I would suggest to you it is nothing to do with strain hardening, in fact strain hardening is assisting action. As far as we can see it occurs in lightly reinforced members where when you form a crack there is insufficient tensile capacity of the reinforcement to crack the concrete surrounding those reinforcing bars, so it is the function of the tensile strength of the concrete and the way the reinforcement is arranged, well that's our belief at this stage. I don't know if you would like to comment but that is what we think. If you can strain that reinforcement so you can force another crack to form, if that reinforcement was strained sufficiently, strain hardened sufficiently to cause the reinforcement the next crack would form then the yielding was spread but if the tensile strength of the concrete is too high you cannot form that second crack, that the strain hardening is inadequate you cannot force yielding to occur at that second crack. I don't know if you would like to comment on that but that's the sort of conclusion we have come to, as I say by looking at a range of buildings in Christchurch and going through their drawings carefully and spotting where they have cracked, comparing them where cracks have been reported?

A. Yes, no I understand that is what you've said is as I understand it, certainly.

Q. So perhaps when you are comparing it to the CTV building you need to look in areas where there is a light level of reinforcement or a high tensile strength of concrete rather than looking at strain hardening just concentrating on strain hardening or possibly even strain aging, characteristics of the reinforcement?

A. Yes I accept my terminology was not the best. I have actually been told at the break what is, best described in other ways. The only comment I would make is that we have found that it has occurred in lower strength concrete as well.

Q. Yes the tensile strength concrete of course is very indirectly related to the strength of, compression strength of concrete and so is a higher proportion of tensile strength with the lower strength concrete at the higher so that is not, that doesn't surprise me at all.

A. No.

Q. Just move on to a second issue. You refer to vertical acceleration quite a lot as causing a problem and you refer to it specifically in relation to the south structural wall, the coupled shear wall?

A. Yes.

Q. Could you elaborate please how vertical acceleration influences the strength of the south wall?

A. It was not the strength it was the stability of the south wall in that the wall is dependent on the gravity loading for overturning and that the – not so much the acceleration but the de-acceleration or the reverse of the acceleration diminishes the available dead load or gravity load I should say available for resisting overturning of the south wall.

Q. Can we have BUI.MAD249.0123.16 please.

WITNESS REFERRED TO BUI.MAD249.0123.16

Q. If we concentrate on the figure on the left-hand side, plan of the building. You can see the south wall on the left-hand side?

A. Yes.

Q. And the tributary area or axial load for that south wall would be midway between line 2 and line 1 and then we have columns, intermediate columns which will further restrict the tributary area to somewhere close to line E and somewhere on the lower side of line C. So the actual gravity load that's supported by that wall will be relatively small won't it compared to the mass of the building?

A. It is, yes.

Q. The seismic lateral load, lateral load you get of course will be a little bit complicated, probably a bit more than half the mass of the building, given that the centre of mass of that building is a bit closer to the south wall and just to the north wall and of course it will be confused appreciably by the high torsion or inertia of that floor slab which is 30 metres by 22 metres high. Quite a high torsional component but looking at it basically you expect half the inertia forces, lateral forces to come from somewhere around about half the mass of the building, would you agree?

A. Yes in general that –

Q. So the axial load capacity is going to be relatively small compared with the lateral forcing function, wouldn't it?

A. I am sorry I don't swallow that part.

Q. Half the mass of the building –

A. Yeah.

Q. Lateral forces due to half the mass of the building?

A. Mmm.

Q. Are coming on to the south wall approximately?

A. Yep.

Q. The gravity load set out by the south wall is a very small fraction. The weight that goes on there is a very small fraction of the total weight of the building?

A. Oh, yes, yes.

Q. One might expect this, twentieth or something, tenth or something like this?

A. Yes.

Q. So the axial load induced by that gravity load is actually quite a small proportion of the weight of the building, the point I am getting it?

A. Yes.

Q. You agree, right. What would you anticipate would be the lateral, the sort of fundamental period of this building for east-west (inaudible 11:58:38)?

A. I think the fundamental period is about 1.2 seconds.

Q. Yes, a bit less in the east-west direction but of that order, yes. Well that would be my estimate at any rate looking at the Compusoft results. Can we have WIT.BRADLEY.0003.44 please.

WITNESS REFERRED TO WIT.BRADLEY.0003.44

Q. Just concentrate on the figure please. So that is the response spectra for vertical excitation from the four different earthquake records proposing that we should use or it is being proposed that we should use for the analysis of the building or three of those happening. The fundamental period of your wall or east-west or north-south movements is of the order of, as you have stated around about a second, you accepted 1.2 seconds, around about a second. The vertical excitation here is going to be -

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Q. What would you assess the vertical stiffness of the wall? What period, fundamental period would you expect for the vertical stiffness of the wall due to that vertical excitation that you've got the stiffness, the soil. You've got the axial stiffness of the wall and then you've got a number of slabs which is not showing very much axial load as we all know on one side which of course had its own dynamic history. So what sort of period of fundamental vibration and I'm aware that you were specialised in structural dynamics and so this sort of thing you should be able to give a rough estimate of the likely vertical period of this?

A. I would imagine that it would be driven primarily by the actual vertical excitation of the floors in the first instance which we would expect to be perhaps at a point to give that sort of order of period.

Q. So if it's driven by that you're way off the peak response aren't you?

A. You are yes.

Q. So you've got a small portion of the vertical excitation coming or it would take about .2 of a second so in .1 of a second if those curve shaped midpoint .7G vertically between .5 and 1G there are different records. Vertical excitation which would occur for .1 of a second for a structure which is vibrating backwards and forwards somewhere around about

one second period. So for .1 of a second that excitation would increase your axial load and therefore increase your lateral force resistance and the next .1 of a second that force could reduce your lateral resistance. Is this, would you agree with that deduction?

A. The, based on the assumption of the period being .2 that is correct. The axial vertical displacements that I have viewed from integrating this sort of information they do show significant vertical movement which clearly can't occur in that short space of time so superimposed on these results is a general rise and fall of the ground but what the acceleration of that rise and fall is I'm not sure.

Q. If we have the response spectra we can calculate a displacement can't we? I can pull up the displacement response if you wish or you can accept that there is – it's not large for those periods of time.

A. No it may not be large. It's just in effect it has an effect on the capacity I believe of the wall.

Q. In what way do we have the capacity being increased when your acceleration is upwards to .1 of a second?

A. Yes.

Q. And decreased and you've agreed to this I think when acceleration down is that correct?

A. Yes. The, if we look at the records that I've looked at which aren't from this report indicated a more significant displacement that would occur within the .1 of a second than what you're referring to.

Q. How would this displacement affect the stability of your wall? We're talking about in the vertical direction, whole structures moving vertically and whole structures moving down. Now how does this vertical displacement affect the stability, lateral stability of your wall? Are you saying it reduces the resistance? I'm saying I don't understand how over such a short period, can you explain to me why when you have a sudden increase in lateral strength and a sudden decrease in lateral strength how this increases the overall lateral stability of the wall?

A. Well in a short period it wouldn't but if this is integrated as I have seen other results acceleration spectra done then the actual vertical

movement of the ground is more than would be indicated by looking at simply the very, very short period spectral acceleration that's shown here. I'm not sure if there does exist an integrated version of this giving displacement of this particular –

Q. What do you mean by integrated version?

A. Well if you integrate the acceleration you get velocity and if you integrate velocity you get displacement and it shows in that. Obviously you have the ground displacement.

Q. And there are displacement spectra published by the Royal Commission for all these four earthquakes. Would you like me to pull some of those up for you?

A. Yes.

1210

Q. 0001.36. There are four different records in this report. This refers to the earthquake in February. The top one is the CHHC vertical, I don't know which one you'd like to look at, if you look at the top one and you'll see the top figure?

A. Yes.

Q. They're all fairly similar. You'll see there at .5 of a second. The displacement looks like being about 20mm. At .2 of a second it looks like about 5mm vertical displacement. Would you like to look at some of the other records?

A. No, no, that's fine. I was actually referring to the actual displacement itself rather than the response spectra.

Q. Well this is the displacement corresponding to the response spectra?

A. I don't...

Q. You can't differentiate them. If you have the acceleration you have the displacement. I'm sorry, you're aware of that you specialised in structural dynamics. My apologies.

A. Yes the figures that I've looked at, not here, but have had the actual displacement against time rather than displacement against natural area and it is in those ones that the actual ground displacement itself is evident as compared to the accelerations and it was based and I'd have

to say it was a record from Christchurch airport that I was sent and it's in the integrated form and it was in that that I particularly noted the type of vertical displacement that was occurring.

Q. Yes of course you're quite correct but it's the whole ground moves isn't it. So during an earthquake, you know, the whole thing moved several hundred millimetres to the left or to the right. In this case I think the actual area went up. From memory I think it went up about 50 or 60mm as a result of the February earthquake so this is just the relative movement relative to the ground, not the whole movement of the ground. I don't think the whole movement of the ground is relevant because the whole building moved that much so I don't think affects a differential movement which we're talking about or unless you can explain to me how shifting the whole building to the sideways left or right or up can influence the actions in the building?

A. No, not the total movement from the start of the earthquake to the end of the earthquake but in between there is a vertical ground oscillation that is the effect that I was talking about.

Q. And this graph is the vertical ground, the peak value of the vertical ground oscillation –

A. But it's related to –

Q. – the response spectrum

A. What I'm referring to is the actual ground vertical displacement relative to the time of the earthquake so that the, for example, at the airport the ground in the first part of the earthquake, the first eight, 10 seconds, lifted 50mms, 50mm and then there was a vertical oscillation and then at the end the ground was back where it started from and it's that sort of effect which superimposed on that general movement of the ground is the acceleration or the effects of the short periods of the acceleration response that you're talking about.

Q. This is measured from the acceleration of the ground so it's a result of the peak ground acceleration. The peak acceleration is a result, as you say, of the uplift or decrease in height over all of the whole area plus the individual vibrations about that point. I cannot see the point you are

getting at. Can you explain it more clearly to me please. If the whole ground moves up gradually during this excitation, perhaps you can explain exactly what you're referring to?

A. What I'm referring to is the general ground movement that occurs during the earthquake and when that acceleration information is integrated it doesn't produce a rapidly varying acceleration or rapidly varying graph that looks like that acceleration graph and I suggest that what I do is get hold of an actual graph that I'm talking about and perhaps send it through because it gives a totally different impression of the effects of the ground movement and perhaps may reflect what people have actually said they've seen rather than the response spectra material where clearly, you know, the levels of acceleration of 3G I think it was in the very very short period, whilst that's a massive acceleration, it's for such a short time as you've said you would never pick it visually.

Q. I look forward to seeing that information and how that can influence the south wall.

You were asked before about the need for a model of the building to be tested on a shake table. You remember you were asked about it before?

A. Yes.

Q. And this is something you've thought about carefully?

A. Yes.

Q. But you haven't considered how practical this is in terms of the cost?

A. I haven't assessed what the cost might be, no.

Q. If you are looking at it realistically would you not assess, have some idea of the cost involved for proposing this to a Royal Commission as a step that should be taken?

A. Well I simply haven't considered the cost implications no.

Q. You do not think that's relevant?

A. Well I didn't think it was, no.

1220

Q. When you test your model, the ground as you've told me before has quite a significant influence on the way it behaves. You talked about 30% compliance, 20 or 30% compliance –

A. Mmm.

Q. – with the building, and the potential for CTV to be even a higher compliance to the ground, so on this shake table how are you going to reproduce the foundations?

A. Well in the simplistic terms it's by introducing springs, but it may be possible to modify the seismic inputs to simulate it.

Q. They would need to be nonlinear springs, but well you'd have to impose the differential displacements due to the compression and tension of the pads wouldn't you?

A. Yes you would.

Q. So it's not going to be a simple matter. You've got this building half scale, 15 metres high, weighing hundreds of tonnes you put on a shake table. These shake tables of course are enormously expensive to run and I'm sure that your experts Professor Shepherd and Professor Mander will be able to give us some idea of the cost per day of running these shake tables. You've got to, you have a whole lot of precast components in there which come from standard moulds. You'd have to make up special moulds for those precast components. Now I would like to repeat to you what do you now think the cost, roughly, would be? What order of magnitude are we talking about?

A. (no audible answer 12:22:22)

Q. Would you agree that the, sorry I haven't given you a chance to reply?

A. No, no, no, I'm happy to have your suggestion?

Q. Please go ahead?

A. It will be several million.

Q. Several million?

A. Mmm.

Q. Well I'll pursue that one a little bit further later on.

QUESTIONS FROM COMMISSIONER CARTER - NIL

QUESTIONS FROM JUSTICE COOPER:

Q. Dr Reay, you were involved I take it in the response that your firm made when given the opportunity by the Department of Building and Housing to respond to the draft consultants' report, the Hyland and Smith report?

A. Yes in an overview I was.

Q. And it seems to me that quite detailed comments were sent in, in response to the draft by your firm. Would you agree with that description?

A. Some were detailed and some were general I would've thought.

Q. But did you – Who was the author, or who were the authors of that response that was made on behalf of your firm?

A. The majority of the work was done by Mr Latham and Mr Urmson.

Q. Yes.

A. And I had an overview involvement.

Q. So did you check what they were writing before it left the firm?

A. Yes I did, I read it through.

Q. And I would've thought, but you correct me if I'm wrong, that in order to do that you must've made yourself reasonably familiar with the plans of the building, is that right?

A. In a general sense and in places and if there was some specific item that was being considered I would've looked at that perhaps more closely.

Q. Because you gave evidence when being questioned by Mr Mills last Thursday that you hadn't looked at the drawings in depth, and I, I wonder whether that was what you meant to say?

A. Yes that is, that is correct. I haven't studied them in, you know, absolute detail. I've tended to look at certain elements that were in question rather than at the overall.

Q. Well, such as?

A. I, at that time I would've looked at the columns I think. I would've looked at the specification for the concrete strengths, particularly in relation to the columns. I recall looking at the actual floor system design.

Q. And how it connected to the north core?

A. I looked at that in general but not, I didn't do any analysis of it.

Q. And what about the design of the south wall?

A. The design of the south wall I noted that it was a coupled shear wall system that based on the work of Hyland he considered it complied with the code of the day so I didn't look too much, didn't look at that really beyond that.

Q. West wall?

A. The west wall. I looked at the detailing for that, and I looked at the, some of the comments that were made in the Hyland report regarding whether it was going to impact on the response of the structure of the building.

Q. And in preparing the evidence that you've given to the Royal Commission did you go back to the plans and study them in any more depth?

A. I can't recall specifically.

Q. Well you've come up with five scenarios for collapse that you say have not been adequately considered in relation to why the building collapsed. Are you saying that before coming up with those scenarios you didn't think it was necessary to consider or study in reasonable depth the plans of the building?

A. Well what I was putting forward were scenarios that I considered hadn't been considered. I wasn't analysing those in coming up with a definitive answer. It could be that some of them aren't significant in relation to the collapse of the building, but if the, in preparing a report such as the DBH had prepared I would've expected some investigation and analysis of those.

1230

Q. You were concerned and you complain about the length of time or you would say the lack of time that you were given by the Department of Building and Housing to respond to the draft report. That is the case isn't it?

A. Yes it is.

Q. Now nevertheless a detailed response was sent in by the draft report in which you were involved with your employees, Mr Latham and Mr Urmson. That is correct isn't it?

A. Yes.

Q. And in the – I think is more than six months that have elapsed since that process occurred, you have been able to consider at greater leisure as it were, other possible explanations for the collapse of the building for the purposes of giving evidence to the Royal Commission, that is the position is it?

A. Yes.

Q. And that has resulted in the five scenarios that you have identified as matters which might assist in explaining the collapse of the building?

A. Yes I think I referred to them as five possible scenarios.

Q. Yes. But they don't reflect any particular study of the plans of the building, that is right isn't it?

A. Well they reflect the sort of general form and type of the building.

Q. Yes.

A. So when I've talked about southern shear wall and the stability of it, it is in specific reference to that southern wall.

Q. You have done, so far as I can see no calculations in relation to any of these possible collapse scenarios, have you?

A. No I haven't.

Q. Why is that?

A. Because simply I did not have time to investigate it.

Q. Well one of the matters that you put forward for the Commission, for serious consideration is the internal staircase that was installed between levels 1 and 2, in the CTV tenancy?

A. Yes.

Q. And how long would it take to calculate the effect of that?

A. In terms of replacing the lost strength from the effect on the building or potential effect it would probably take two or three hours and I did actually have another member of the staff just check that, that particular

part but I haven't, it was only a preliminary check, it isn't something that I would put forward.

Q. Well why is that?

A. Well because it wasn't done in sufficient depth to provide it.

Q. Well I suppose my question was, how long would it take to do the calculations in sufficient depth to ascertain what the effect of the installation of that internal stair was. Now, you said a few moments ago, two or three hours. Was that to do a superficial examination of that question?

A. Oh, it is a preliminary assessment of the loss of strength of the cut reinforcing in relation to transfer of shear to say the southern face.

Q. Well you will understand I am not an engineer so you tell me when I'm asking you a question which isn't a sensible one but is it not the case that you could calculate the likely effect on any impairment of the earthquake performance of the building of the installation of that internal staircase by reference to the plans of the building and well known methodologies that structural engineers would have at their disposal?

A. To analyse it in full you would need to assess the effect on the whole building not just the immediate element and it was the effect on the whole building that was, well if you do it you might involve a time history analysis or something like that to see what effect it might have.

Q. So is there nothing that can be done short of a time history analysis to work out in broad terms the possible impact of the installation of that staircase?

A. Well the effect is also dependent in part on the construction of the remainder of the connections that weren't cut and so one of the points I think I was making is that you need to consider the effect of cutting a hole like that in addition to any other potential defect that there may be in the building but my main point was that this was a relatively significant opening in a floor of a building and I considered that in putting that opening in the building some investigation would have been expected to have been done as to the impact of it.

Q. Well my question was whether you can carry out calculations or whether you need a non-linear time history analysis?

A. Well there may be something in between Your Honour, I am uncertain.

Q. You are uncertain?

A. As to exactly how you would go about analysing for the effect of it until you assess how that would be done.

Q. You instructed a staff member to do it though?

A. I beg your pardon?

Q. Didn't you tell us you instructed a staff member to do it?

A. Only to look at a preliminary assessment of the strength loss through cutting the reinforcing.

Q. Mmm and but that exercise is not one that you want to share with the Royal Commission, the results of that preliminary exercise?

A. I am happy to provide it, if it is of benefit. I have no problem with that. It wasn't an exercise that I considered was exhaustive in terms of analysing what the potential issue would be.

Q. I see. Thank you very much.

QUESTIONS ARISING: ALL COUNSEL – NIL

WITNESS EXCUSED

MR RENNIE ADDRESSES THE COURT

MR PALMER ADDRESSES THE COURT – READING BRIEFS

1240

MR PALMER CALLS

ROBIN SHEPHERD (SWORN)

Q. Is your full name Robin Shepherd?

A. It is.

Q. Do you reside both in Tauranga and at Big Bear Lake, California, United States of America?

A. One or the other yes.

Q. And are you a consulting engineer?

A. Yes.

Q. Professor, do you have a copy of your written brief with you?

A. Yes.

Q. Could you please read your evidence starting at paragraph 2 and where appropriate can you please refer to your Powerpoint presentation as you think it helpful to illustrate or emphasise a point?

A. Does it start with Mr Palmer in accordance with?

Q. Yes it is.

WITNESS READS BRIEF OF EVIDENCE

A. "In accordance to the requirements of Rule 9.43 of the High Court Rules I confirm that I have read the Code of Conduct for Expert Witnesses and that my evidence complies with the code requirements. Matters on which I express an opinion are within my field of expertise. I have no interest or relationships with any parties to these proceedings. I have known Dr Reay professionally and personally for many years but our contact is intermittent and I do not believe this affects my impartiality in this matter." Do you wish me to go through the qualifications?

Q. Yes. If you go through don't read the headings just continue on.

WITNESS READS BRIEF OF EVIDENCE

A. I hold a Bachelor of Science Honours in Civil Engineering from the University of Leeds, UK in 1955, a Master of Science in Civil Engineering same university in 1966. I completed a doctorate in civil

engineering at the University of Canterbury in 1971 and was awarded a doctorate of science in civil engineering by the University of Leeds, UK in 1973. My thesis for my PhD in civil engineering included computer based non linear time history structural analyses. I am an Emeritus professor of civil university at the University of California, Irvine, United States of America and now run a private consultancy business. I have previously held a number of directorships including with the Earthquake Damage Analysis Corporation, a California corporation which I established to provide expert specialised consultancy services, earthquake damage analysis mitigation. My employment history includes employment and assistant structural engineer with the Ministry of Works, Readership at the University of Canterbury and departmental chairman at the University of California Irvine. I hold a variety of professional memberships including the American Society of Civil Engineers, fellow and life member; the Institution of Civil Engineers London, fellow; and the New Zealand National Society of Earthquake Engineering, fellow and life member. I was registered with the New Zealand Engineers registration board in 1959 and with the board of registration for professional engineers in California in 1981. My involvement in post earthquake structural damage assessments extends from the 1968 Inangahua earthquake to California earthquakes including the 1971 San Fernando, the 1989 Loma Prieta and the 1994 Northridge earthquakes. My full resumé is attached and marked as item A. I have been instructed by Buddle Findlay on behalf of Alan Reay Consultants Limited (ARCL) to provide independent expert advice on issues relevant to the collapse of the CTV building on the 22nd of February, 2011 following an earthquake of magnitude 6.3. In particular I have been asked to comment on the following issues:"

Q. Do you wish to refer to your Powerpoint at this –

A. I'm trying to bring up –

Q. Slide two.

A. Slide two and I'm not having much luck. I'd like slide two please. This is an overview of my – it's divided into sections. I'm going to talk about

forensic engineering practice. I'm going to talk about the evolution of seismic design standards. I'm going to refer to cumulative earthquake damage. I'm going to mention seismic excitation of the building site, the CTV site, and I'm going to talk about dynamic analyses including non linear time history analyses although Sir as you'll be aware we're still working on the non linear time history analyses and I believe we will be reporting to you later on that issue.

JUSTICE COOPER:

Q. Later this week I think isn't it?

A. I hope so Sir yes.

EXAMINATION CONTINUES: MR PALMER

A. "In preparing this evidence I referred to and relied upon the principal sources of information set out in an appendix to this statement."

Q. That's the appendix at pages 14 and 15 of your brief?

JUSTICE COOPER:

Q. Is there anything in particular Professor Shepherd?

A. Well I can express Sir that I have no firsthand experience of seeing this building in its immediate collapsed state so I'm relying entirely on other people's observations.

EXAMINATION CONTINUES: MR PALMER

WITNESS READS BRIEF OF EVIDENCE

A. "As far as forensic engineering practice is concerned various efforts have been made most notably in the United States." next slide please. "To standardise best practice structural failure investigations. The National Academy of Professional Engineers referred to as NAFE was formed in 1982 to advance the art and skill of engineers who served as consultants to members of the legal profession and as expert witnesses in Courts of law. Objects included the provision of continuing education and the promotion of high standard of professional ethics and of

excellence in practice. The American Society of Civil Engineers authorised the Technical Council of Forensic Engineering (TCFE) in 1985 with the purpose of developing practices and procedures to reduce the number of failures, to disseminate information on failures and their causes, to provide guidelines for conducting failure investigations and to provide guidelines for ethical conduct of forensic engineering. One of the products of the TCFE was the 2003 publication "Guidelines for Forensic Engineering Practice." The objectives of each of the above referenced organisations include the fostering of competent, independent and unbiased applications of engineering principles within the jurisprudence system. Additionally it was anticipated that the practice of engineering would benefit from the learning from failure investigations," and I refer to a paper I published in 2010. "Clearly the terms of reference of the Royal Commission of inquiry into the building failure caused by the Canterbury earthquake requires that the engineering reports into the collapse of the CTV building shall be of the highest possible standard, which I interpret at the very least in compliance or conformance with the NAFE and TCFE recommendations referred to above."

1250

Q. Professor Shepherd if I just stop you there. That paper that you've referred to, is that listed in your CV?

A. Yes.

Q. Carry on please, paragraph 7?

WITNESS CONTINUES READING STATEMENT FROM PARAGRAPH 7

A. "In simplistic terms the report should attempt to answer the questions how did the CTV building fail? And why did the CTV building fail? And in this context "failure" refers to a state or condition of not meeting desirable or intended objectives. The following comments result from my review of the reports made available to me of the various investigations undertaken since the February 2011 CTV building collapse.

Dealing first with the "how" question. An excellent effort was made, CTV building collapse investigations for the DBH prepared by Dr Clark Hyland and Ashley Smith dated 27th of January 2012, referred to generally as the Hyland Smith report, chapter 8, to interview the many eye witnesses to the collapse and to integrate their memories to produce a most likely actual scenario. With the exception of the observations made by chartered engineer Graham Frost, a much less impressive effort was made to record and critically evaluate those portions of the structure remaining after the collapse. Apparently the opportunity was missed to undertake a comprehensive examination of the remains of the south tower or of the north tower before they were demolished. Also many of the columns' remains were transported to the dump, absent a rigorous attempt to identify their positions in the building. The impression remains that after the recovery of survivors and bodies the work to clear the site took precedence over the opportunity to maximise the information available from that part of the structure that had not collapsed.

The "why" aspect first led to the suspicion that the concrete strength of the columns was seriously deficient and this was supposedly substantiated by a few somewhat less than state of the art concrete material tests on column remnants as covered in the Hyland Smith report. Recent investigations by James Mackechnie, Douglas Haavik, The Cement and Concrete Association of New Zealand and Brendon Bradley have very largely discredited the presumptions of concrete column material deficiency. However the Hyland Smith investigation appears to have been locked into pursuing the hypothesis that the columns provided the critical failure initiator to the extent that in undertaking the nonlinear computer based time history analyses (NTHA) the focus of the modelling was placed on the columns at the exclusion of a possible alternative weakness. The Hyland Smith report suggests a reluctance to accept the results of the NTHA where these did not agree with the consultants' view of a collapse sequence. It appears probable

that the September 2010 earthquake resulted in more deterioration of the CTV building structure than was assessed immediately following that event. In a somewhat arbitrary decision, those undertaking the NTHA analyses chose to neglect the possibility that the CTV building might not have been in an essentially undamaged state at the commencement of the February 2011 shaking.

The Department of Building's effort to provide a credible answer to the "why" question as represented by the Hyland Smith report cannot be considered conclusive. By failure to abide by the generally accepted open-minded approach to a failure analysis investigation, too many avenues of possible inquiry were neglected.

Efforts to ensure quality assurance of constructed facilities have been made from time immemorial. It is recorded that in ancient Babylon the Code of Hammurabi held contractors liable for their work, stating that if a man built a house which collapsed and killed a householder, the builder 'shall be slain'. In the English speaking world building codes can be traced back to those formulated following the rebuilding of London in the 17th century after the Great Fire. A common purpose of earlier codes was to provide minimum standard of construction to safeguard personal safety and public welfare. Early seismic resistance standards following earthquake such as the 1931 Napier and the 1933 Long Beach California events were very basic, typically requiring the provision of resistance to static lateral loads of a tenth of the weight of the structure. The overall objectives is to such codes were essentially ill defined and in the absence of reliable quantitative records of seismic ground motion records of seismic ground motion, the choice of the tenth of gravity factor was decidedly arbitrary. The development of strong ground motion measuring instruments initially of mechanical configuration but subsequently rendered obsolete by electronic devices in the last half century, prompted improved understanding of the dynamic characteristics of both ground motion and superstructure response. As

a result awareness grew of the importance of matching structures' dynamic properties with ground vibrations. The first significant strong ground motion time history response record was obtained in 1940 at El Centro, near the California/Mexico border. The north/south component of this trace, with a peak acceleration of about .3g was used in early digital computer based analyses of seismic structural response. Simplistic inverted pendulum scratch plate ground motion recorders were developed in New Zealand some 50 years ago and one such instrument indicated a peak ground acceleration of about .2g near to Gisborne in 1960."

Q. Sorry did you say .2g or .28?

A. I am sorry .2g, .28g.

Q. .28, so .28 is correct?

A. Yes I stand corrected, sorry, about .3g.

WITNESS CONTINUES READING STATEMENT FROM PARAGRAPH 26

A. "Such measurements prompted review of adequacy of the .1g static load provision in vogue at that time. In 1968 the Structural Engineers Association of California Lateral Force Code specified the intent that structures designed in conformance should be able to resist minor earthquakes without damage, resist moderate earthquakes without structural damage but with some non-structural damage and resist major earthquakes without collapse but with some structural as well as non-structural damage. Subsequently the term, "earthquake," was replaced by ground motion and attempts were made to define the ground motion and attempts were made to define the ground motion in terms of a maximum considered event (MCE) with a primary goal of no collapse in the MCE. In the 1978 the California Applied Technology Council introduced explicit considerations of risk in seismic design. Recognition was stressed that, 'It is not possible by means of a building code to provide a guarantee that buildings will not fail in some way that will endanger people as a result of an earthquake. While a code cannot ensure the absolute safety of buildings, it may be desirable that it should not do so as the resources to construct buildings are limited.

Society must decide how it will allocate the available resources amongst the various ways in which it desires to protect life safety. One way or another the anticipated benefits of various life protecting programmes must be weighed against the cost of implementing such programmes'."

HEARING ADJOURNS: 1.00 PM

HEARING RESUMES: 2.15 PM

EXAMINATION CONTINUES: MR PALMER

Q. Professor Shepherd, before lunch you finished at the end of paragraph 28 of your evidence. Could you please now continue reading your evidence at paragraph 29?

WITNESS CONTINUES READING BRIEF OF EVIDENCE

A. "Prompted by much basic research in seismology and on structural component behaviour more sophisticated design codes in New Zealand and Japan have developed in parallel with those in California. Necessarily the codes became more complex as attempts were made to better represent both the demand, ie the structural response to ground motion and the capacity, ie the ultimate strength characteristics of the structure's components and their interaction. A general pattern emerged. As a result of post earthquake studies and damage structures and the availability of many more strong motion records, refinement to existing codes tended to be enacted most effectively soon after each significant event whilst communities are still receptive to more stringent requirements. Community memories being short resistance to such changes tends to increase with time. Nevertheless a notable achievement in the developed world has been made by progressively improving seismic design standards thereby reducing dramatically the loss of life due to earthquakes." Next slide please.

"An inevitable result of the stepwise development in code requirements has been the production of a stock of buildings in any given location with variable seismic resistant capabilities. In general the newer structures respond more closely to their intended behaviour than the older ones. The current trend is to focus in the future on the performance aspects of a proposed structure and to provide a reasonable assurance that serious injury and loss of life will be avoided, that critical facilities will continue to function and that wherever practicable repair costs will be minimised." Next slide please.

"On the subject of cumulative earthquake damage, the vulnerability of building structures to damage in successive earthquakes was referred to by Charles Richter better known to the general public for the magnitude scale that bears his name in his seminal work 'Elementary Seismology' published more than 50 years ago. He referred and I quote, 'The weakening effects of repeated shaking on common place construction' and he wrote 'some spectacular failures in all buildings are attributable to progressive weakening in successive minor shaking.' Since then the technical literature contains reports of failure of structures in earthquake aftershocks after weakened by earlier ground shaking. Much of this is a colloquial nature without reliable reference to specific buildings. However it is clear that as a result of the complex pattern of energy release in successive earthquakes and aftershocks cumulative damage does occur." Next slide please.

"Through the learning from earthquake programme of the California based earthquake engineering research institute multi-disciplinary reconnaissance teams have been dispatched to damaging earthquakes around the world. Their reports including the observation that buildings that experienced successive earthquakes may suffer progressive weakening or eventual collapse have influenced many aspects of structural design in recent years. Current seismic design anticipate that some non-elastic deformations will occur in selected structural members during strong motion events. When members are subjected to successive excursions each causing plastic deformations but within insufficient deterioration to cause structural collapse, the structure as a whole is clearly weakened. Such sequences can occur either in the course of one earthquake together with its aftershocks or over a longer time as a result of successive earthquakes. The damage may be in the form of material deterioration consequent upon repeated cycles of alternating stresses or in the form of residual displacement that can prompt potential instability of the structure. The lateral dynamic response of a multi-storey building to seismic ground movements is

critically sensitive to the natural period of vibration. Progressive weakening may lead to greater damage in multiple events as the more flexible structure better matches the input excitation. It is not necessary for the later events to be as energy intense as the earlier one but where this is the case the structure is most likely to suffer more damage even to the point of complete collapse. The ongoing practice of, "Repairing", cracked reinforced concrete structures by injecting epoxy into earthquake generated cracks and walls and other elements is undertaken in an attempt to reinstate the strength and stiffness of the degraded member and thereby to restore the structure as near as possible to its original condition. By inference the cumulative nature of earthquake damage is recognised and attempts are made to compensate for it." Next slide please.

"The CTV building may well have been damaged more seriously in the September 10 earthquake than was appreciated immediately following the event. More serious damage could have been consistent with the Compusoft NTHA analyses. For example, see the draft CTV building collapse investigation for the DBH prepared by Dr Clark Hyland and Ashley Smith dated 7th of December, 2011. 'First impressions are that the maximum strains suggest the level of damage somewhat higher than the minor 0.3mm wide cracks that were reported… after the 4 December Darfield earthquake.' However the authors elected to assume that these column cracks did not deteriorate the columns to the extent that they were less able to resist failure in the February 2012 event. It is noted that whereas item 4 of the conclusions, section of appendix D in the Hyland/Smith draft report read, 'It has been difficult to reconcile the damage predicted by the analysis with reports of damage by others after the Darfield earthquake. The analysis generally indicated a higher level of damage than was reported'. The equivalent paragraph of the Hyland/Smith final report reads, 'Overall the output of the NTHA analyses was not inconsistent with the reported condition of the building after 4 September 2010. The limited available evidence of

the building condition after 4 September 2010 leaves room for a range of interpretations of the likely maximum displacements in the 4th of September 2010 event. However the conclusions drawn from the analyses are not particularly sensitive to the level of demand assumed by the NTHA with indications that collapse could have occurred at lower levels of demand'. The modifications of the Hyland/Smith draft report wording to the final Hyland/Smith report could be interpreted as recognition by the authors of the problem of forming consistent conclusions based on the generally imprecise nature of the quantitative results of NTHA analyses."

I wrote, Sir, I'm awaiting the results of the tests of the concrete column remnants tested in Colorado before commenting further on the validity of the view that the September 2010 earthquake did not significantly affect the strength of the CTV columns. Since then, of course, Sir, we have had the results of those tests from Colorado.

1425

JUSTICE COOPER:

Q. And –

A. Well, insofar as I understand Mr Haavik's evidence which he will be giving here, within the qualification that he had a limited number of samples to test, he does not see that there was any diminution of concrete quality in the columns as he understands the intent of the design and the specifications.

Q. So where do you come to rest then on the issue raised in your paragraph 41 that you've just read to us?

A. Well I think, Sir, that the impression first given that the concrete quality in the columns was much lower than it should have been led to everybody focusing on the columns as the most likely failure initiator of the structure. I don't think that is any longer a valid assumption.

Q. But your comment in paragraph 41 which was made pending the receipt of the further tests is a comment about whether the September 2010 earthquake significantly affected the strength of the CTV columns. With

that new information to hand, are you now saying that the September 2010 earthquake did not significantly affect the strength of the CTV column?

A. I don't think it effectively in any way affected the concrete strength.

Q. And therefore the strength of the column?

A. That's right Sir.

WITNESS CONTINUES READING BRIEF OF EVIDENCE

A. Next slide please, number 14.

"Referring to the seismic excitation of the CTV building site, it is noted that specifically for the CTV building no records of the site or of the building motions were obtained in any of the Canterbury earthquakes sequence (September 2010 through February 2011). The response of a structure to an earthquake is critically dependent on the ground motion at foundation level. Both the period and amplitude of this motion can be affected by the characteristics of the near-surface layer. It has been generally accepted that the damage resulting from a major earthquake may vary considerably within a relatively small area in situations where the near-surface geology is inconsistent. The Hyland/Smith Report records that the Non-linear Time History Analyses were carried out using an input based on records obtained from three of the four sites surrounding the Central Business District where strong motion has been recorded, this choice being based on the recommendation of geotechnical specialists understood to be Tonkin & Taylor. Some confirmation of the appropriateness of this choice, with the possibility of modifying it to better represent the earthquake-induced ground motions at the CTV building site, could have been undertaken if the site had been instrumented promptly after the earthquake on 22 February 2011. It is probable that the records obtained from the several subsequent significant aftershocks that occurred would have provided available evidence regarding the unique properties of this site."

I should intercept, Sir, that of course Alan Reay Consultants Limited have in fact installed equipment on the site after having obtained permission to do so from CERA and they have now got records of some

relatively minor shaking and can in fact do some interpretation along the lines I was anticipating.

"On the basis of the study of past strong motion earthquake records, a rule of thumb evolved in which the expected peak vertical acceleration would be of the order of one-half to two-thirds of the peak expected horizontal acceleration."

Slide 15 please.

"Where the expected worst case horizontal acceleration might be taken as say .9g, this led to a corresponding worst case .6g vertical acceleration. Since buildings are designed to resist with a significant safety margin, normal static gravity loading, it was inferred that expected earthquake generated vertical forces were more than allowed for in gravity resistant design without additional vertical strength provisions. Actual records from the 22nd of February 2011 earthquake showed that at several sites in the Central Business District the maximum vertical peak ground accelerations were of the order of 1.0g. In the absence of any records from the CTV building site, the actual vertical acceleration experienced by the CTV structure can only be a matter of conjecture. However, it is clear that it was great enough to apply loads significantly in excess of those typically anticipated in code compliance seismic design. The Hyland/Smith report does not specifically address the possible effect of the exceptional vertical accelerations on the CTV columns. It is noted that in March 2012 ARCL installed instrumentation on the CTV building site. I wrote the results of the analysis of ground motion so recorded. I waited with considerable interest. My understanding is that Dr Bradley and others are going to bring that material to you in due course Sir.

Next slide please.

"Dynamic Analyses – The availability of digital computers over the last half century has prompted their use to predict the response of structures

to various dynamic excitations, including earthquakes. Initial applications were restricted to the assumptions that buildings behaved essentially elastically. In tandem with increased computational power, techniques have been developed to permit the input of forcing functions representative of seismic ground motion and to model non-linear response properties of selected structural components. Early computer programs tended to be research tools of little practical application. However, more recently, products from UC Berkeley and several derivative companies have been marketed as commercially applicable tools. These include ETABS, Drain 2-D, SAP 2000 from UC Berkeley and its offshoots. A notable contribution is the program RUAUMOKO developed by Professor Athol Carr here at the University of Canterbury. Arguably the most sophisticated, this is designed to produce a piece-wise time history response of non-linear general two-dimensional and three-dimensional structures to ground accelerations or time varying force excitations. It may also be used for static or pushover analyses of structures. A common feature of the later programmes is that as the models become more representative of a physical structure, the size of the computation and its consequent cost, increases to the extent that for practical considerations typically attention is focused on selected elements of the structure, ideally those judged to be the most critical. For similar cost saving reasons, in the case of a time history excitation input the length of the applied input record is frequently limited.

Earthquake ground motion is unpredictable. Consequently it is not possible to use forcing functions fully representative of future events appropriate to a given site. Even in post earthquake studies only rarely is a record available of the motion at the place of interest. As was done in the Compusoft analyses forming part of the Hyland Smith report, recourse is frequently made to the use of records made at nearby locations with the consequent uncertainty of their applicability. In an effort to overcome the lack of naturally occurring time history site records, researchers have generated artificial records having energy content and frequency characteristics equivalent to those observed in

typical natural events for use on computer simulations. All of these approaches are necessarily a compromise. The inherent complexity of the time history computer simulation earthquake response process with a necessity to make many judgment calls regarding the selection of the computer model and the input functions, leads to the view that there are no absolute conclusions possible from such analyses. Rather their products can be considered to be very useful in a qualitative sense whilst leaving open their success in mirroring, with quantitative accuracy, actual events.

The limitations on the size of the model used for the computer analyses prevented a comprehensive global investigation that would've involved all components of the CTV structure being simulated to the maximum degree of sophistication. This restriction required a judgemental choice to be made of the most probable, vulnerable components which were then modelled in detail whilst much of the rest of the structure was not subject to such refinement. The result is that in my opinion the computer analyses appear to have been made to prove a certain hypothesis, rather than to investigate all collapse possibilities without prejudice. An excellent comprehensive summary of the process of computer-based earthquake response simulation is available in a report to the Canterbury Earthquake Royal Commission on, '*Inelastic Response Spectra for the Christchurch Earthquake Records*,' authored by Emeritus Professor Athol Carr dated 8 August 2011. As pointed out by structural engineer Williams Holmes in his review of the report of the Hyland Smith report, the emphasis was placed on drift controlled column failures as defined primarily by concrete strain limits at the exclusion of a wider ranging investigation of other possible critical factors. It is appreciated that time and resource constraints prompted this choice, but the restriction required a judgemental choice to be made of the most probable vulnerable components, which were then modelled in detail whilst the rest of the structure was not subject to such refinement. This leaves the investigation open to the charge that the

computer analyses appear to have been made to prove a certain hypothesis, rather than to investigate the collapse possibilities without prejudice.

There are numerous disclaimers and qualifiers throughout the Hyland Smith report, for example, 'Variability and uncertainty in physical properties and analysis procedures do not allow a particular collapse scenario to be determined with confidence.' Next one, 'It has been difficult to identify a specific collapse scenario with confidence.' Next one, 'Estimating the effect on the structure of the very significant ground accelerations is subject to considerable uncertainty.'

Despite these clearly expressed reservations the authors chose to focus on a particular scenario at the exclusion of an in-depth investigation of alternatives. In doing so, in my opinion, they call into question the value of their conclusions.

A general comment, the term "redundancy" is used in structural engineering, it is possibly open to misunderstanding. Its general definition of the state of being no longer needed or useful could mislead if applied to buildings. Aeronautical engineers have typically preferred failsafe design rather than structural redundancy. It is submitted that encouragement should be given to the use of the wording used in the final report of the Department of Building and Housing 'Technical Investigation into the Structural Performance of Buildings in Christchurch' which defines alternative load paths as backup mechanisms as the preferred manner of preventing disproportionate collapse in the case of the failure of a single load bearing element."

As you're aware Sir I am participating in the NTHA expert panel being facilitated by Professor Carr. I reserve my right to modify or add to my evidence following the completion of this process which hopefully will be

this week. I do have a few more statements which I'd rather like to make now or later Sir.

1435

JUSTICE COOPER:

Do it now thank you?

EXAMINATION CONTINUES: MR PALMER:

Q. Make them now. If you, you've been sitting through the hearing haven't you Professor Shepherd, and listening to the evidence that has gone on over the past few days?

A. Yes.

Q. And arising out of that you've, you wish to provide some further evidence to the Commission of some of those observations, is that correct?

A. Yes please.

Q. Have you in front of you a page with those thoughts reduced to writing?

A. I have.

Q. Could you please read that?

A. "I note that this Royal Commission is to give consideration to the legal and best practice requirements for the assessment of buildings after an earthquake, having regard to lessons from the Canterbury earthquakes. With regard to this I respectfully suggest that the Commission recommends a more formal process for organising earthquake induced structural collapse inquiries in the future, most particularly where loss of life occurs. I am very aware of the casualties in the CTV building collapse and the hope held by those relatives of the victims and by the public at large that something extremely positive results from this inquiry. Whereas in the case of a road traffic fatality or deaths in an aircraft accident there is a clearly defined process for investigating the events starting if I understood correctly as a police controlled crime scene. No such procedures are mandated for a building collapse resulting in death. Undoubtedly a better organised handling of the

physical evidence resulting from the CTV building collapse would've greatly facilitated the subsequent inquiry. Rescue and recovery activities clearly must have priority, but need not be followed by the wholesale destruction of evidence as appears to have occurred in the clearance of the CTV site and dumping of the debris in the Burwood Landfill. If competent observers had had the opportunities to identify and record elements of interest as the site was cleared, and if a rigorous chain of custody record had been instigated and maintained, it is very probable that many of the questions aired before this Commission could've been answered with greater confidence. In summary, I hope that the Commission is able to encourage a much more competent forensic investigation of the structural collapse fatalities that unfortunately are inevitable in the future than was carried out in the case of the CTV building.

Q. Professor Shepherd, just while it occurs to me, in that you haven't mentioned there the work that Mr Frost and Mr Heywood did, it is Dr Heywood isn't it? Are you aware of their evidence?

A. I am and I'm very impressed, in view of the fact that neither of them appeared to have actually been commissioned to do a forensic investigation. Mr Frost in particular I think did an excellent job as an aside to what he was doing with the search and rescue, and if other people had done anything like as well as he did we would've been much better informed.

Q. Thank you and do you have any other comments that you wish to make before others ask questions of you?

A. I don't think so Mr Palmer.

CROSS-EXAMINATION: MR ALLAN – NIL

CROSS-EXAMINATION: MR REID – NIL

CROSS-EXAMINATION: MR MILLS – NIL

CROSS-EXAMINATION: MR ZARIFEH

Q. You say in your brief that you have known Dr Reay professionally and personally for many years?

A. That's correct.

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Q. Can you just tell us a bit about that? How do you know him professionally?

A. When I was teaching at the University of Canterbury in the 1960s he was in several of my classes. Towards the end of the 1960s he was enrolled as a PhD student under my supervision. He completed his PhD – he was the second PhD student I supervised as I recall it. I left Christchurch in 1971. Subsequently I had very sparse contact with him for many years and I was aware of his activities and his success as a practising structural engineer but I think we barely had any communication for many years in the interim until the end of last year when I was aware of the fact that the CTV building was subject to an inquiry and he asked me if I would be interested in providing any information on forensic investigations and the other things that I reported on.

Q. So Dr Reay contacted you?

A. Yes.

Q. And you mentioned the forensic engineering. Is that your speciality?

A. It has been in the last 20 years, yes.

Q. Are you a designer of buildings or not?

A. I wouldn't count as a designer of buildings in the last 20 or 30 years but I did do my share of it once upon a time.

Q. But not in the last 20 or so –

A. Right.

Q. And is that why you have limited your evidence to the areas that you can properly comment on?

A. I have tried to do that Sir.

Q. You mention the – in this, since your forensic engineering, you mention the guidelines that exist in the USA?

A. Yes.

Q. And you said a moment ago in the additional thoughts that you have had, you spoke of better organisation in terms of forensic investigation, better organisation at the outset. I want to come and ask you a bit about what happened in this case but just to help the Commission are you able to give any more detail and what kind of things are contained in those guideline that exist in the States and I presume from what you have said that there are no such similar guidelines in New Zealand?

A. I am not aware of them if there are.

Q. Would you be aware of them if they were?

A. I would have tried to have been aware of them, yes.

Q. So what are they in the –

A. Well essentially the reason why both the National Academy of Forensic Engineers and the American Society of Civil Engineers attempted to write down a set of recommendations or rules as the case may be for forensic investigation was to try to make the process extremely objective, to try to improve the ethics of some of the people involved in such investigations and to in other words make the process more respectable and more likely to be accepted by the world at large.

Q. And is that what you are suggesting is required here?

A. Yes.

Q. In New Zealand?

A. Yes.

Q. Because it is something that you say is missing?

A. Well it appears to be missing. I do not know exactly who was responsible for the decisions that were made after February 2011. I have no problem whatsoever in the first objective should have been rescue of, I have no problem in my own mind that the next most important thing is recovery, but after that I do not understand at all why anybody had the authority to go in and clean the site out without somebody else having the opportunity to record such evidence that would be useful to an inquiry such as this.

Q. And have you made inquiries in preparing your brief of evidence to establish what happened or not?

A. Well I know that the debris was taken to a landfill and shall I say dumped there without very much attempt to identify anything. I don't know who was responsible for doing that and I have not tried to find that out.

Q. So you haven't made any inquiries?

A. No.

Q. Have you been to the landfill where the remnants are?

A. No.

Q. So is it fair to say then that your observations obviously come firstly in a general sense from your experience but in terms of what happened in relation to the CTV you are aware of the remnant – building remnants being dumped at a site at some stage post 22 February?

A. Yes and there was a photograph shown the other day here, either Dr Heywood or Mr Frost, most recent visit to Burwood when I guess they still didn't manage to find anything of very great use.

Q. Why do you say that?

A. Because I am sure that had they been able to identify components of interest they would have done so. I think they are both very competent people.

Q. Have you read their briefs?

A. I saw Mr Frost's earlier ones, yes and I've –

Q. Have you read the briefs they have prepared since going to the Burwood landsite after giving evidence?

A. No.

Q. So you are not aware of what they did se there and of what use it potentially is?

A. I haven't seen a second brief.

Q. Okay, well can I just get these passed up to you please. This might be quicker than putting them on the screen Sir. Just have a look at those, a quick look yourself please.

WITNESS REFERRED TO DOCUMENTS

A. Well I have scanned both of these obviously I haven't had a chance to read them with any depth.

Q. Right, well I was interested in your comment that they obviously didn't find anything of use, do you accept that that is perhaps not accurate?

A. It may not be accurate, it may be – there is something in here which is marginally of value, certainly I am sure they tried.

Q. You can't help us with whether it is of value or not -

A. Well if –

Q. – not at the moment?

A. – I had half an hour to read it and study it, yes but in two minutes here no.

Q. Now, just going back to what happened at CTV on 22nd of February. You said that you accept that the priority was to try and rescue survivors and then to recover the bodies?

A. I did and I do.

Q. Do you also accept that that process took considerable time?

A. There are points I have read there were a matter of days I think that, shall we say the rescue operation was ongoing and eventually I guess they realised nothing was going to succeed and I think that might have been a matter of days.

Q. How many days was it?

A. I don't know whether it was two or three. I know there was a fire for some time and that was presumably one of the reasons why the recovery was delayed.

Q. Well what makes you say that?

A. Well I read somewhere and I can't remember where that in fact there was a fire and you know, there was a question of access if the place is on fire, you don't want to risk the rescuers.

Q. Right and how many days approximately did the fire rage?

A. I can't recall except I think it was a matter of a few days.

Q. And what about the recovery of bodies, how long did that phase go for?

A. I don't know exactly but I suspect it was considerably longer than the attempt of rescue.

Q. Into weeks?

A. I believe so but as I sit here I can't be sure.

1455

Q. And do you accept that given that that was the priority and given that there had been this almost total collapse of the building to try and rescue survivors to try and recovery bodies, essentially the whole of the building remnants had to be turned over didn't they?

A. Certainly had to be moved, they didn't have to be destroyed.

Q. Well they had to be moved, set aside, a search or searches made through them, correct?

A. Yes.

Q. And would that not have an effect on things that might be able to be learnt from building remnants at a later stage when that phase occurred?

A. Well I maintain it was not necessary to destroy the evidence as part of the recovery process.

Q. And this destroying you are talking about is later when they are removed from the site?

A. Well I think even while they were moving them it sounds as though from what I have read and this is hearsay I realise that that it was not a particularly scientific process.

Q. Where did you read that?

A. Oh, I can't recall now. I was following the activities as best I could. I was –

Q. Was it in the newspaper?

A. I was living in California and I was reading the newspapers and I could see various other reports that were coming out of Christchurch.

Q. Right, so in giving your expert opinion on the forensic examination you in part have based your knowledge of the facts on newspaper reports?

A. Partly yes and also I might add –

Q. Is that something you normally do –

A. – I have seen some photographs of the landfill when the stuff was moved there which showed that some of the material was virtually pulverised as far as could tell.

Q. Right and you have made no inquiries about that, when it was taken, how it was taken?

A. No I do not have the dates.

Q. Sorry I interrupted your answer before but I asked the question: is it normal for an expert witness to use newspaper reports to base their understanding of facts from your experience?

A. It is one possible source but I think the conclusion I have arrived at is largely due to the absence of information that people, I mean a person like Mr Frost for instance I think did an absolutely excellent job and if somebody like Mr Frost or Dr Heywood or somebody like that had been involved when the material was being removed I think it is possible that there would have been a much better control of the evidence.

Q. Okay, well just talking about Mr Frost and Dr Heywood, you commented about Mr Frost in your brief of evidence. Had you been aware of Dr Heywood when you prepared your brief or not?

A. Yes.

Q. But you didn't mention his efforts?

A. No because I was not, I was under the impression that Mr Frost is more detailed in his observations than Dr Heywood was.

Q. And how did – why did you get that impression, what gave you that?

A. Well I must have seen some material that Mr Frost had prepared at some stage, I don't recall when which gave me, to understand that he was attempting to do an extremely thorough job under adverse circumstances.

Q. And had you seen material from Dr Heywood?

A. No I was aware of the fact that he had taken a great many photographs but I have not seen more than – some of those that have appeared I guess in the public arena.

Q. Right, were you aware that he took over 500 photographs?

A. I was told that but I have no firsthand information of that.

Q. Have you ever sought to look at them?

A. I would love to see them but I haven't been given that opportunity.

Q. Have you asked?

A. No.

Q. And you are aware that Mr Frost and Dr Heywood have prepared drawings of things they saw of interest, structural items, are you aware of that?

A. I was aware that Mr Frost had because last we can hear references made to that and some of the sketches were produced I believe that either he made or sketches of what people interpreting that were said or done.

Q. And were you aware of the work of another structural engineer a John Trowsdale who was also at the site?

A. Not in detail.

Q. Of the scene?

A. Not in detail.

Q. But you've seen it?

A. No I do not recall seeing it but I am aware of the fact. I have heard his name before and I do not know very much about what he did.

Q. Right, so you haven't read his brief?

A. No.

Q. He was a structural engineer who as I say was at the CTV site and took a large number of photographs in a similar way to Mr Frost and Dr Heywood and made a large number of observations, similar observations about the building and potentially about the collapse. You haven't seen that as yet?

A. No I think my issue would be if that is the case why was it not appearing in the Hyland, Ashley Smith report.

Q. Why would none of what sorry?

A. Well if in fact some of these other people had done a – what I would describe as a systematic forensic investigation I don't understand why none of that material to my knowledge appeared in the Hyland, Smith report?

Q. Okay, well Mr Frost in particular was called upon wasn't he by Dr Hyland?

A. I believe he had some communication with him, yes.

Q. Right, are you aware of the extent of it?

A. No.

Q. So you are not aware that the draft report was, or parts of the draft reports were given by Dr Hyland to Mr Frost for his comment, he having been at the scene at the outset?

A. I didn't know who Dr Hyland showed his draft report for, before he concluded it.

Q. So does that affect your views at all now that you have learnt that?

A. Well as I said before I don't understand why if Dr Hyland was dependent on Mr Frost's observations and what have you, that material wasn't identified clearly in the Hyland Smith report.

Q. Do you accept that it is good practice for someone in Dr Hyland's position to speak to someone like Mr Frost who has been there from early on and made those observations?

A. Yes I have no problem with that.

Q. So that would be a positive in your mind?

A. Yes.

Q. And I talked to you about Dr Heywood's very many photographs, his photographs from Mr Trowsdale and also from Mr Frost and you no doubt have seen some of those and I suggest to you that they were able to, let's leave aside how they became involved but just talk about what comes from their involvement. They were able to develop all of their observations, photographs, drawings into very comprehensive briefs of evidence particularly Mr Frost and Dr Heywood. Would you agree with that?

A. I think they made a very good job with the limited opportunities they had.

Q. Right, limited in what sense?

A. Well as far as I know they were not commissioned to be lead forensic investigators, it was almost as if they were doing this out of the goodness of their heart peripheral to the Hyland investigation.

Q. Well Hyland and Smith had not been instructed at that point, had they?

A. I am not sure exactly when they were instructed.

Q. Well were you thinking that they were instructed very early on after 22 February?

A. If my memory serves me correctly somebody told me at some stage and I don't know who, that maybe they were commissioned in April.

Q. Right, so that was well after any of these initial investigations by Messrs Frost and Co, wasn't it?

A. Yes and I don't know who was in charge of the process before Dr Hyland was commissioned.

1505

Q. So coming back then to Messrs Frost, Heywood and Trowsdale, you accept don't you that together with all of these materials that they have been able to provide to the Royal Commission leaving aside the Hyland/Smith investigation, with all of that material – the photographs, the diagrams, the briefs, the reports, conclusions that they felt able to come to, opinions that they felt able to express, it's a fairly formidable body of forensic work whether it was fortuitous or not that the Royal Commission has now before it, isn't it?

A. You use the word "formidable". I would say that while they did a good job we're lucky greatly with information which would be very useful to the Commission.

Q. Right. I'll come back to that in a minute. You've also said or commented on Dr Hyland in his interview of the many eyewitnesses to the collapse, that is your paragraph 20 and integration of their memories to produce the most likely actual scenario would that be fair?

A. Yes I think Dr Hyland, he or his group did an excellent job in attempting to put together the scenario. We all know if you ask people what they were doing two days you'll get a different answer from everybody who happened to be at the same place at the same time and so to be able to do that the way that Dr Hyland did I think is tremendous.

Q. Right. And are you aware that in its own investigations the Royal Commission has spoken to other eyewitnesses and occupants of the building. Were you aware of that or not?

A. I'm not aware that where I would go to find that information if I heard of it in the past.

Q. Have you had access to the secure site of the Royal Commission?

A. Yes I have.

Q. Have you looked through all that material?

A. Not all of it, some of it.

Q. So sorry you're not aware that the Royal Commission has spoken to other eyewitnesses and occupants?

A. Well now you remind me I believe I have seen such evidence on the secure site. I don't claim to have read all what's on the secure site.

Q. Well do you accept from me that that is the case?

A. Yes I'll accept that.

Q. And is all that part of this forensic information from which conclusions may or may not be able to be drawn?

A. It's all contributory but my concern is that there didn't appear to be any cohesive efforts to direct all this and put it all together in a timely manner.

Q. So your criticism is that it wasn't a formal process and a chain of command if you like or didn't appear to be a chain of command in relation to the forensic examination?

A. That's a fair summary yes.

Q. What I'm suggesting to you is that leaving that to one side for a moment accepting the fact that the criticism can be made, looking at what we ended up with. Certainly the Royal Commission rather than the Hyland/Smith report and that's why I've gone through these three in particular: Dr Heywood, Mr Frost, Mr Trowsdale, the interviews of the eyewitnesses by Hyland and Smith or Hyland and by the Royal Commission, all of that material has to be brought together to determine whether conclusions can or can't be drawn. Do you agree with that?

A. Yes.

Q. That's what I'm asking you about. Were you aware that Dr Hyland went to the site after the remnants had been removed I think he said but before the north core had been removed?

A. Yes I believe I read that somewhere.

Q. Do you recall his evidence that he arranged for a Christchurch engineer to examine the north core once it was removed?

A. I do recall reading something to that effect, yes.

Q. Right. I think that's before the north core was detached from the foundations.

A. Yes somewhere I read that it was jack hammered out. I don't know whether that's correct or not.

Q. You're talking about reading the evidence or in the paper?

A. I think that was in some evidence. As you pointed out to me I've had the opportunity to read a great deal of material which is on the secure site and I can't remember which one of those items I picked it up from.

Q. Dr Hyland's evidence as I recall it was that he got a Christchurch engineer to look at the north core just before it was or when it was being removed to check on the attachments and he had observed no cracking. That was the relevance of Dr Hyland giving that evidence when he was in at the hearing. That too though is part of the picture do you accept that?

A. I've no reason to doubt the veracity of that statement.

Q. So we've got all of this material however it came to be there and in particular a huge number of photographs and the importantly I suggest the observations that we've got from the engineers, Dr Hyland included.

JUSTICE COOPER:

Q. Can I just clarify, were you here when Dr Heywood gave evidence to the Royal Commission?

A. No Sir.

Q. Have you read his brief of evidence to the Royal Commission?

A. I really can't recall. I seen some parts of the material but I don't know whether I've read his submission in its entirety Sir.

Q. Well you don't recall you've read it at all?

A. No I don't, for sure, that's true.

CROSS-EXAMINATION CONTINUES: MR ZARIFEH

Q. You've read Mr Frost's?

A. The first one of Mr Frost's but I haven't had a chance to look at this one.

Q. Right. You've read Mr Trowsdale. His evidence was read or accepted rather than him having to give evidence but it's there.

A. I think on the, part of the material that I have read on the secure documents that's you know not in the last little while so I can't recall when.

Q. But these are the facts or the factual basis upon which you're coming along to give an expert opinion on aren't they?

A. I don't know what you mean by facts. I have an opinion that despite the good intentions and hard work of several people this forensic investigation was not conducted in a timely manner or in a particularly well organised manner. That's my opinion.

Q. Okay. And I understand that as a general criticism. What I want to get from you though is your, firstly your understanding of what actually happened in terms of what forensic material was ultimately or is ultimately available to the Royal Commission and it seems that you don't have a full appreciation or understanding of that.

A. I have I think an appreciation of the omissions and it's the omissions that are causing us the difficulties, not the very good work that some of those people do.

Q. How can you have an understanding of the omissions if you don't know what material was actually gathered?

A. Well I'm sure that if in fact we had a proper chain of custody of the material which was taken off the site a lot of it would have been examined in detail by now and we would have that evidence in front of

this Commission. We don't have it and therefore by omission I assume it was never done.

JUSTICE COOPER:

Q. Professor Shepherd, I thought you told us a few moments ago that you don't know what evidence is before the Commission.

A. I know some of the evidence that's before the Commission Sir. I can't claim to know all of it. On the other hand I do believe I see omissions which I can only assume are because the evidence was not collected.

CROSS-EXAMINATION CONTINUES: MR ZARIFEH

Q. Sorry to labour the point but I'm not sure I understand what you mean. My point is if you don't have an understanding of what material has been put before the Royal Commission, how can you made a comment on omissions that, omissions that are presumably of some relevance in terms of the Royal Commission's job.

A. Well because I'm sure that had we had a chain of command, sorry a chain of custody that we could have traced back which column came from where we would have that evidence in front of us. We don't have it in front of us so that's the kind of thing that I'm referring to when I say I can't be expected to know every piece of evidence that was found but I know that an awful lot that should have been found wasn't.

1515

Q. So again it's a criticism that the rules that should've been there if you'd applied these American guidelines weren't, therefore there's going to be omissions?

A. Yes, as I understand it there are other investigations that could be carried out in this country such as if there was an aircraft accident which would have a set of rules and certain people would be in charge of taking the role of investigation on from word go. This, that did not appear to have been in this case.

Q. I understand what you're saying as a general criticism, but what I'm more interested in doing, I accept that criticisms can be made and that

you've made them. What I'm more interested in doing though is looking at what in fact the Royal Commission does have in terms of observations, photographs, drawings, the expert opinion from engineers who were there at the scene, Dr Hyland for example who saw the north core, who's made various observations, been out to the site et cetera, the eye witnesses, all of that material, that is material that the Royal Commission has before it, right?

A. Yes.

Q. And from which it can draw, could draw conclusions, correct?

A. I hope so, but right now it's not clear to me that they have sufficient evidence to be able to draw a definitive conclusion.

Q. What do you say that the Royal Commission cannot do as a result of all this material that it has?

A. I don't think it's for me to say that.

Q. Well you've said that, you've given that opinion, what's the basis of it?

A. Would you like to repeat the question, I don't think I gave that opinion to criticise the Royal Commission.

Q. No, no, you have said that you don't believe that the Royal Commission can come to conclusions because of omissions. What I want to know is what do you say the Royal Commission cannot deal with because of the omissions that you say have been made, or may have been made?

A. I think I prefer to say the Royal Commission's task is made much, much more difficult that it needed be because there is insufficient evidence in certain areas which would've been extremely helpful.

Q. My question though is, given all the material that we've got, and I'm not going to go over that again, all of those things, what is it that you say the Royal Commission cannot look at?

A. Well I gave an example a few minutes ago. It cannot look definitively at which columns came from where so that when we take cores out of columns we're not exactly sure which core came out of which, well, we know which core came out of which column but we don't know which column sample came from where, that's one example.

Q. So then the testing of the concrete strength in that column might only be able to go a certain way because you don't know where it was in the building?

A. Well, no, you can test the strength but you still don't know exactly where the column came from.

Q. Well that's right. So what else, that's one thing?

A. Well if you want me to go through a list we'd be here all afternoon sir, but you keep coming back to the same question to me. I'm not criticising the Royal Commission, I'm just saying that –

JUSTICE COOPER:

Q. There's been no suggestion that you're criticising the Royal Commission.

A. No but the job Sir is much, much harder because we don't have some vital piece of evidence.

Q. Yes and Mr Zarifeh's asking you what they are?

A. Well –

Q. So the first one's the location of the columns, what's the next one?

A. As far as I know we didn't, we don't have absolute certainty about rebar or mesh. If when –

Q. Absolute certainty in what respect?

A. Well that when the, after recovery and the start of the clearance of the site, if somebody had been on site and was able to say, "Well this is clearly from such and such a floor slab. This is clearly from the south wall. This sample is clearly from the north wall," and so on and had it been labelled, had photographs been taken at the time as it was being removed, I think we would be being in a lot better situation than we are today to form some conclusions.

CROSS-EXAMINATION CONTINUES: MR ZARIFEH

Q. What else, is that it?

A. Well I don't know what you mean by "what else"? I mean…

Q. Well what else is missing?

A. What else is missing?

Q. Yes?

A. A definitive set of evidence on which we can base the collapse scenario.

Q. What do you mean by "a definitive set of evidence"?

A. Well one that everybody can agree on.

Q. But when you say "a definitive set of evidence" are you talking about forensic evidence?

A. Yes.

Q. What, because going back to this point of things not being labelled and a chain of custody?

A. That's right.

Q. What, I've accepted that may be a criticism. What I'm wanting to know is, look at all the things that we have got, you're saying we still can't be conclusive and you've mentioned the columns, you've mentioned the mesh and reinforcing, you say you can't be sure where that came from. Anything else?

A. Well I would hope that as a result of this inquiry the Commission can come up with a firm conclusion, but what I'm saying is it's extremely difficult for me at this stage to agree with any of the scenarios that have been suggested because I don't see that that evidence exists. Now I'm only one person with limited access. I hope the Commission can do what it would like to do clearly and come up with a very firm decision as to what happened.

Q. Well, just so we're clear, you're not saying that the Commission could not come to a conclusion as to the adequacy of the beam column joints for example? You're not saying that are you?

A. I'm not saying they could or they couldn't at this stage 'cos I don't know.

Q. Well you've got no opinion on it?

A. That's right.

Q. You're not saying that the Commission couldn't come to a conclusion about the adequacy of the confinement in the columns?

A. If the as-built situation can be resolved so that they're sure of the way the place was – the way the confinement was in there, then I think they

can come to a conclusion on that one. My concern would be I'm not sure that we have any as-built drawings and I'm not sure that we have the evidence of what's exactly there yet. Maybe that will come out.

Q. And what's your, the basis of your information about the as-built drawing?

A. I don't know whether they exist.

Q. Have you made inquiries?

A. I've heard some evidence here. It sounds as though they don't.

Q. Was that yesterday or Thursday?

A. Yes, Thursday was it?

Q. What about construction issues such as the lack of roughened surfaces at the beam end, do you remember that?

A. Yes.

Q. You're not saying that conclusions can't necessarily be drawn about that issue from what we've got?

A. No, I'm not at all sure though that we have the sort of evidence you'd expect from forensic investigations.

Q. What, because the beam end's not numbered?

A. Yeah, and 'cos I'm not sure that they took the trouble to locate a beam end and to keep it in a place where we could go and look at it today. I'm not sure that they, I don't think so.

Q. And yet you haven't been out to the Burwood site and seen any of the beam ends?

A. No.

Q. And you'll see, you might've seen in those second briefs there's a photo of one. There's other photos taken earlier but there's even a photo of one from some weeks ago when Mr Frost and Dr Heywood went out there. You say we've got to know where that particular beam comes from, or beams?

A. Well it would be nice to be absolutely certain that it did actually come from this building.

Q. Oh, okay, so are you now throwing doubt on that material that was put at that site being from CTV?

A. I don't know whether to doubt it or not, but absence a rigorous chain of command, a chain of custody sorry – a misquote, chain of custody, yeah one would be much happier if you knew for certain.

Q. But you've made no inquiries yourself have you?

A. No, you keep asking me that questions and I keep saying no.

Q. About that I'm talking about?

A. No.

Q. No. So you're just throwing that out as perhaps another doubt?

A. Well you keep asking me for examples and I try to give you them.

Q. Do you say that some of the beam ends then could've been smooth and some could've been roughened in your experience?

A. I didn't say, those are your words counsel.

1525

Q. I'm asking you. Do you say that?

A. No I didn't say that.

Q. Did you accept that they were to be roughened?

A. Did I accept that they should have been roughened?

Q. Should have been roughened?

A. My understanding is they should have been.

Q. Right so the fact that a number of beam ends are found or seen that are smooth do you not accept that conclusions may be drawn about the result of that?

A. If we draw a conclusion about that and yet we can't be a hundred percent certain where that beam end came from we are jumping one jump ahead of what would be considered, in my opinion, first-class forensic work.

Q. And you say because it's not in your opinion first-class forensic work it's unsafe to draw any conclusions?

A. No I didn't say that.

Q. Right, what conclusions do you think can be drawn then?

A. Well that somebody found some beam ends which weren't roughened. That conclusion can be drawn.

Q. I mean what conclusions can be drawn about the CTV collapse then from what we've got?

A. Well I don't want to sound trite but clearly the building collapsed, it collapsed in a certain style which is referred to "pancaking" by some people. I think there are some, you know, evidence both of people who saw it and people who have photographed it and what have you. I mean those conclusions I think inviolate.

Q. Are what, sorry.

A. They are perfectly acceptable.

Q. Right, what else?

A. Sorry, what else what Sir?

Q. What other conclusions can be drawn?

A. Well it was an absolute tragedy. The engineering profession as a whole has to learn from this and hope to avoid such events in the future.

Q. Right, anything else?

A. I'm sorry I find difficulty with this "anything else" question, how to answer it for you Sir. It's not specific enough.

Q. But you're not saying that's really the limit of forensically of what can be concluded?

A. No.

Q. So you're not taking issue with some of the criticisms or the issues that have been raised in relation to, for example, column confinement, beam column joints being inadequate, put it in those terms...

A. No, there are other people in this enquiry who are more expert structural concrete people than I am.

Q. All right just so we're clear, conclusions can be drawn, you're simply saying first-class forensic examination wasn't carried out so there may have been other things that could have added to it?

A. Certainly the second part of the question I'd say yes to.

Q. Right but it doesn't mean we can't draw conclusions from what we have got?

A. I hope the Royal Commission can come to some conclusions.

Q. I'm asking you if you think that?

A. At this stage no I can't.

Q. You can't draw any conclusions?

A. Not a definitive conclusion as to the collapse scenario of this building, no.

Q. Right what if you had read all of the evidence or were aware of it all. You might be able to draw more then mightn't you?

A. Possibly.

HEARING ADJOURNS: 3.29 PM

HEARING RESUMES: 3.45 PM

CROSS-EXAMINATION CONTINUES: MR ZARIFEH

Q. Professor Shepherd, I just want to ask you about paragraph 21 of your brief?

A. I have it.

Q. Where you talk about the Y aspect.

A. Yes.

Q. And you say that the non-linear time history done by the Hyland Smith investigation, that the focus was on the columns at the exclusion of a possible alternative weakness?

A. Yes.

Q. What was that?

A. You mean what the alternative weakness?

Q. Yes, what are you referring to?

A. Well the beam column joints for one, the connections of the floor slab to the walls is another.

Q. Any others?

A. Those are the two that come immediately to mind.

Q. And from what you can see they were possibilities as well?

A. I think they are possibilities that either have to be eliminated or pursued further.

Q. Right. You go on a couple of sentences later to say, "It appears probable that the September 2010 earthquake resulted in more deterioration of the CTV building structure than was assessed immediately following the event." You see that?

A. Yes.

Q. What's your basis for saying that? Is it the non-linear time history analysis that was run or something else?

A. It was my understanding of the Compusoft time history analysis.

Q. Okay. And then paragraph 22, you say the last sentence "by failure to abide by the general accepted open minded approach to a failure analysis investigation too many avenues of possible inquiry were neglected". Now is that a reference to what we covered above in relation to alternative weaknesses?

A. I believe so yes.

Q. Right. Do you accept though that the Hyland Smith report covered a number of potential weaknesses, perhaps not emphasising as much the beam column joints but certainly covered others?

A. My impression was that they almost had blinkers on and that they were going down the route of the weak columns right from the word go and stuck to that throughout.

Q. And when you say weak columns, in what sense?

A. Well that the failure was initiated at the columns. By weak I mean vulnerable columns.

Q. Vulnerable for a number of reasons potentially?

A. Possibly yes.

Q. So it is a matter of emphasis rather than totally excluding consideration of other matters, that is your criticism?

A. Well it wasn't much emphasis, it was almost blindsided approach.

Q. Did you read the four scenarios that, possible scenarios that the report concluded?

A. I am sure I did but I don't recall them.

Q. So you can't recall for example that I think the fourth scenario involved potential failure of the connections between the floor slabs and the north core wall?

A. Now you have mentioned it I do recall that was one of them yes.

Q. So that had been taken into account?

A. I don't know what you mean by taken into account. I don't think they pursued that avenue of potential investigation very far.

Q. So I just want to ask you about paragraph 40 and 41, you said that, in 40 that the modification of the Hyland Smith draft report wording could be interpreted as recognition by the authors of the problem of forming consistent conclusions based on the generally imprecise nature of the time history analysis?

A. Yes.

Q. And you said that you were awaiting the results and you commented that those results are to hand, paragraph 41?

A. Yes.

Q. So I just wanted to be clear about that. As a result of those concrete results I understood you to say that there is no suggestion that concrete strength had been diminished by pre 22 February. Is that what you said?

A. Well when I wrote this I wasn't sure what result was going to be of the concrete testing.

Q. No but now that the results are there –

A. Right.

Q. – that is what you seem to be saying?

A. Well I felt then and I still feel now that there is no conclusive proof that the September 2010 earthquake column deterioration if there was any was linked to the weakness of the concrete.

Q. And do you accept that the Hyland Smith report referred to other perceived weaknesses with the columns other than concrete?

A. Yes.

Q. And if I can just refer you to, I won't get it brought up to the report under critical vulnerabilities I relation to columns, that listed non-ductile

reinforcement details, less than required minimum spiral reinforcing and a relatively large proportion of concrete cover. Those were the first three items and then the possibility of significantly lower than specified concrete strength, so that was the fourth factor listed. Do you recall that?

A. I am aware of those factors, yeah.

Q. You talked about cumulative damage from the September earthquake and aftershocks that followed it?

A. Yes.

Q. Just so that we are clear, are you giving a general opinion as to the fact of cumulative damage or are you saying that you have done enough study and research of the CTV building to give evidence that is specific to that building?

A. I am definitely trying to give a general overview of cumulative damage. I also think now having heard of the evidence of people who were in the building subsequent to September 2010 that the building was, can we say loosened up by the 2010 earthquake.

Q. Right and that might be an indicator of damage of some sort?

A. Well deterioration yes, it is difficult to talk about damage or deterioration you know in the same breath because I understand nobody really found any severe damage after that earthquake.

Q. And have you read the evidence of Mr Coatsworth the engineer who inspected the building?

A. Yes.

Q. And I presume you would accept that he was carrying out the kind of test that would be generally accepted in the USA or in New Zealand?

A. Yes.

Q. The visually based, that a visual damage based test if I can put it that way?

A. Yes.

Q. Did you hear the evidence or read the evidence of Mr Kehoe?

A. Yes I saw it on the television.

Q. And I presume you might know him or know of him?

A. I knew of him.

Q. And he is someone that has got some expertise in post-earthquake assessments, would you accept that?

A. Yes.

1555

Q. You quoted from a publication by Charles Richter from 50 years ago in relation to buildings, the weakening effects of repeated shaking and the quote that, "Some spectacular failures of old buildings were attributed to progressive weakening."?

A. Yeah.

Q. What kind of buildings were they?

A. Some of them would be masonry buildings, some would be stone buildings, some would be essentially timber frame buildings.

Q. You then went on in paragraph 33 to say that since then, since his day, the technical literature contains reports of failure of structures and earthquake shocks after being weakened, but much of this is of a colloquial nature?

A. That's correct.

Q. Without reliable reference to a specific building, is what you said?

A. That's right.

Q. Do you accept Mr Kehoe's evidence that he gave about it being counter-intuitive but that research or current research has found that it's not necessarily the case that buildings weaken in progressive aftershocks?

A. I was surprised that, at that evidence. I intend following it up some time to find out where he got the information from.

Q. Had you not heard that before?

A. No.

Q. Are you aware of any current research?

A. I wasn't aware of that particular research until Mr Kehoe mentioned it.

Q. So apart from it being news to you, you can't really take issue with it at the moment?

A. No.

Q. What about FEMA 306, you're aware of that?

A. Not in detail.

Q. And to be fair to you is that because it's not really your area?

A. Not really that reason. I tried to follow Mr Kehoe's evidence. I thought Mr Kehoe's evidence was exceptionally good. If there's one exception I disagree with him entirely over cumulative damage.

Q. And what, because you think that it can cause, subsequent earthquakes or aftershocks can cause cumulative damage?

A. Yes, I'm sure it can.

Q. And you base that on the information perhaps colloquial but information that you're aware of?

A. My experience of many earthquake damaged structures in my time in California.

Q. And what assessments that you've made of particular buildings or not?

A. Yes.

Q. In subsequent aftershocks?

A. Yes.

Q. And what have you found?

A. Well further deterioration.

JUSTICE COOPER:

Q. Is this, are these in a published report, these observations?

A. I'm drawing on, the, my memory Sir of the reports that I've produced for attorneys or insurance companies over the years, and when you say are they published or not, some of them would've been used in Court, others wouldn't have been.

Q. No, I wasn't, I was wondering whether they were published in peer reviewed journals in the way that such research is normally promulgated?

A. I think there was, I think there was a lot of publication following the $50 million inquiry into the steel structure joint failures after the Northridge earthquake.

Q. By you? Did you publish something then?

A. I had my name on some general papers yes Sir.

Q. And were they addressing the issue that you're now addressing?

A. Cumulative damage not as much as the actual damage but.

Q. Well I'm talking, but we're talking about cumulative damage?

A. I'm not sure that it would be referred to as cumulative damage in those papers so much as the failure of beam column joints.

Q. As a result of being subject to such successive events?

A. Yes.

CROSS-EXAMINATION CONTINUES: MR ZARIFEH

Q. Just following on from that, Mr Shepherd, you can't say whether it was a result of cumulative damage or from one earthquake?

A. I don't think we have proof either for or against the cumulative damage scenario in the case of the CTV building, but on the other hand my opinion is that it's very, it's much more likely that there was cumulative damage than that there wasn't.

Q. Well, and you told us that you based that on not so much, or not the inspection that was carried out by Mr Coatsworth but more the reports that you've read of occupants?

A. Yes.

Q. I presume you accept the qualification that has to be put on such reports that people become sensitised to shaking, to, that they're not necessarily quantitative, rather subjective?

A. I certainly do. I did two cases in California of claims about excessive floor flexibility following an earthquake. One of the claims I think was justified, one wasn't, and I did some testing of floors and what have you so I think I know something about this subject.

Q. What, of subjective views?

A. Yes.

Q. And you mentioned a moment ago that it wasn't papers that you, published papers that you were referring to in relation to cumulative damage but more evidence that you've given, was that in Court?

A. I'm sorry I didn't hear the sentence?

Q. You said a moment ago in a question and answer to a question from His Honour that it wasn't so much published papers that you were referring to in relation to the cumulative damage, but evidence that you have given I think to attorneys you said? Is that evidence you've given in cases in the States?

A. Yes, it was a result of my having done post-earthquake investigations or, and writing reports or giving evidence in Court.

Q. And giving evidence presumably for what, and engineer or a building owner?

A. The client was usually either an attorney acting for the owner of the insurance company, or for the insurance company itself.

Q. I asked you before about FEMA 306. I just want to get, we've got it on the system, it's ENG.FEMA003.18. I'll just get a page of that brought up?

WITNESS REFERRED TO DOCUMENT

Q. And I think this is what Mr Kehoe was referring to. I referred it to you a moment ago. See under the heading bottom left, "Damage may not significantly affect displacement demand in future larger earthquake."?

A. Yes.

Q. It says, "One of the findings of the ATC-43 project is that prior earthquake damage does not affect maximum displacement response in future, larger earthquakes in many instances. At first, this may seem illogical. Observing a building with cracks in its walls after an earthquake and visualizing its future performance in an even larger event, it is natural to assume that it is worse off than had the damage not occurred. It seems likely that maximum displacement in the future, larger earthquake would be greater than if it had not been damaged. Extensive nonlinear time history analyses performed for the project indicated otherwise for many structures." See that paragraph?

A. Yes.

Q. Have you seen that before or not?

A. I don't recall seeing it before.

Q. Well this is part of the, what I suggested to Mr Kehoe seemed counter-intuitive in relation to accumulated damage. Have you, you haven't heard of any experiments done with nonlinear time history analyses?

A. No.

Q. Do you accept his evidence, Mr Kehoe's I'm talking about, and Mr Coatsworth I think for that matter, that you would see, in their view you would see evidence of accumulated damage in the form of cracks? Or they would expect that?

A. Well you might or you might not, that's the trouble.

Q. Perhaps I should've phrased that a bit tighter. Would you not expect to see evidence of cracks, visible cracks, if there was significant structural damage?

A. If you looked in the right place yes, but bearing in mind the form of somewhat perfunctory first stage examination you might not have the opportunity of looking in the right place.

Q. And what are you referring to when you say that?

A. Well if you don't remove ceiling tiles to be able to see the underside of a beam column joint for instance.

1605

Q. Were you aware whether Mr Kehoe removed ceiling tiles in any places, Mr Coatsworth, thank you?

A. I do remember reading Mr Coatsworth's evidence. I don't recall the answer to your question.

Q. His evidence was that he did remove some tiles and that he examined I think, I don't want to misquote it, but he certainly examined beam column joints in the lower so in the first level because they were exposed on the ground floor or first level so level 2 and then I think he removed them on level 2 so they'd be under level 3 but didn't go higher but he inspected beam column joints for cracking. You weren't aware of that?

A. Yes I was aware of that. I'm sure that he did his best and I mean I weren't criticising him. On the other hand he couldn't be expected to examine every beam column joint.

Q. Right and do you say that every beam column joint would have to be examined?

A. No.

Q. Would there not be sufficient stress on the beam column joints in the lower two floors such that if there was going to be significant damage you'd expect it to be there?

A. I don't know the answer to your question because, you know, when you do this kind of examin..., inspection you can only do so much given the opportunity that you have and I'm sure Mr Coatsworth did as good a job as he possibly could under the circumstances. On the other hand he may not have found some cracked beam column joints because he didn't look at them all and I really wouldn't have expected him to have to look at them all.

Q. Right so you're just raising the possibility that there might still be damage there that he didn't observe?

A. Sure.

Q. And I talked to you a moment ago about the collapse scenarios that Hyland/Smith Report put out. You recall those four?

A. I recall it, yes.

Q. Do you have a position on whether one can draw any conclusions on collapse scenarios or not? I had a feeling you said before the break that one can't and that's one of the problems with the forensic examination as you criticise it?

A. I don't think I can come up with a third one at this stage.

Q. Right but you don't have any comment about the ones that have been put forward?

A. Well I think they're all viable possibilities but some would probably be a better bet than others if you pursued them.

Q. And have you studied Dr Mander's?

A. Have I studied what Sir?

Q. Have you studied Dr Mander's collapse scenario that he puts forward?

A. Not the most recent one which I believe he's presenting here in the next day or so.

Q. I'm talking about the one in his brief, the first brief. Have you read his brief or not?

A. I've read it but I don't recall most of it.

Q. He puts forward an alternative collapse scenario. You can't help us on that?

A. No.

Q. Just quickly, you were in Court this morning you would have heard some questioning of Dr Reay about this shaking table experiment?

A. Yes.

Q. Do you know anything about that procedure?

A. I'm aware that there are two major facilities for such large-scale shaking tables – one in California and one in Japan. I've actually seen the one in Japan. I haven't seen the San Diego facilities recently.

Q. Right well can you help us with some of the comments that were put to Dr Reay. For example, the exercise in producing what would have to be perhaps the half-scale model and what would be involved in that?

A. Well it's certainly a marathon effort. In particular in Japan they have tested full-scale multi-storey structures on their shake table. I can't remember how many storeys. It might not be six but they're still very substantial. In San Diego they certainly tested I think it was a three storey wooden frame building one I read about most recently. These places have the facility to do this sort of thing. It's a rare facility because it's expensive and there aren't many of them.

Q. And can you give us an estimate of the expense that might be involved?

A. Well it depends if one was looking at it from a purely commercial point of view. I think it would be in the many millions but what tended to happen as far as I know in places like the facility in Japan and in San Diego a lot of the overheads would be absorbed by the institution which would have the interest in doing such testing for long-term research and in that case, if you like they're kinda subsidising it.

Q. Leaving that aside just in terms of the cost it would be many millions?

A. I would estimate yes.

Q. And presumably you wouldn't agree that without doing that, that kind of experiment, we can never know the reasons for the CTV building collapse, failure?

A. I don't know about never. I think if we did do it, it would be extremely informative. If we don't do it, I hope we can still come up with some believable conclusion.

Q. Just finally do you have a view on this issue of the south wall lateral load resistance that Dr Reay has raised. Is that an area that is inside your area of expertise to comment on?

A. Well I don't know that I necessarily followed his analysis this morning but when I was first provided with information on the CTV collapse, I think it was the draft Hyland Report my initial reaction was two-fold. One I jumped straight at the cumulative damage thing and the second thing I looked at was what happened to the connection of the south wall on the south wall itself. That was just an initial reaction that I had. I've no reason to go back on those initial reactions.

Q. And why did you have those thoughts about the south wall?

A. I don't know. It's just the feeling I had for the building, bearing in mind it was relatively unusual in my experience. I did do some dynamic analyses of torsion in balance buildings for New Zealand consulting engineers years ago and I don't recall one where the main tower was kind of outside the main floor plan of the building, or where there was a secondary little shear wall as this one was provided on the south side and so my memory took me back to those other buildings that I remembered analysing years ago and that's why I guess I focused on these aspects.

Q. So did you see a potential problem simply in the layout of the building?

A. Well not problem so much as challenges.

Q. All right so your initial view or thoughts about the south wall were not related to this issue of the vertical accelerations being somehow amplified by the horizontal accelerations?

A. Not specifically. Neither did I realise that there had been a hole cut in the floor slab at that stage.

Q. I understand that but I'm talking about this scenario or item that Dr Reay's put forward. So you said, to be fair, you said you can't, you're not sure you understood it or followed it. So does it follow that you can't say that you agree with it?

A. I don't agree or disagree with it but I am aware and I was aware right from the start of the very high vertical accelerations experienced by the CTV building in the February earthquake.

CROSS-EXAMINATION: MR ELLIOTT – NIL

RE-EXAMINATION: MR PALMER

Q. One of the last points while it's fresh in our minds Mr Zarifeh asked you Professor about the inspection that Mr Coatsworth undertook with reference to what he may have observed or might not have observed. My recollection of his evidence was that in answer to questioning from me was that he mostly looked at the internal sorry the external beam column joints and I think he said that around 50 joints he didn't look at primarily internal joints. Given that this was over six floors, 12 columns, around 120 beam column joints in the building and he didn't look at around 50 mostly internal. Could that have any bearing on the issue that you were discussing with Mr Zarifeh about his ability to observe damage caused by the 4 September earthquake?

A. Yes now you reminding me I do remember the details of Mr Coatsworth's evidence when I guess he was, sorry I believe he was unable to get at the internal column, column joints. You know no fault of his they just weren't accessible to him under the circumstances which he was doing his inspection.

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Q. Well just coming back to Mr Zarifeh's point I think was is it possible that he missed some damage by not looking in those joints?

A. It's possible. I don't accuse him of doing that but it is possible.

Q. Mr Zarifeh asked you about what might have been missing had let's just say a fuller forensic collection of the elements of the building been possible and I think you said well the columns, drag bars and mesh. We are aware that the north tower remained standing when Dr Hyland was appointed by the Department of Building and Housing and he in fact inspected it. If the north tower had remained would there have been any elements or issues that you might have focused had you had access to the north core tower for forensic examination?

A. Yes certainly I'd have made a particular issue of going to look into to see what was left of the connections between the tower and the floor slab.

Q. Is that the only issue?

A. Well I would have started there and then there was some reference about vertical cracks I think in the north tower which I would have perhaps followed up on to see what I could make of those.

Q. In a perfect world taking a forensic approach to the investigation ignoring everything else how long would you have retained the north core tower until it was brought down?

A. Well until I and some other people had conducted what they considered an exhausted examination of it. I wouldn't have relied on my own eyes only. I would have certainly had some other person involved. I don't know how long that might have taken. It depends on the access to the site. It depends on the weather and all sorts of things but certainly lack of many days.

Q. I think Dr Reay's unchallenged evidence at page 6 of his summary evidence that he gave stated that there were samples taken by the DBH for concrete testing and they hadn't been retained. What is the, what is your view of the normal practice regarding retention of samples being one element of the building that we know did exist but has subsequently been discarded?

A. Well every effort should be made to retain any such evidence until everybody has finished with it and in the event that such evidence is thrown away in my experience it's prejudicial to the person, for the

people who did that in the sense that the suspicion is the reason why they got rid of it.

Q. Now Dr Reay also again being unchallenged in his evidence at paragraphs 37 and 38 on page 7 of his evidence talked about the destruction or the demolition of parts of the building, the remaining sheer wall, floor elements that were intact. They were saw cut and transferred to Burwood, or they might have been saw cut and transported to Burwood is what he says. He says instead the sheer wall and floor were demolished in small pieces for transportation off site and now most of the building is not specifically identifiable. Were you in this hearing room when he gave that evidence/

A. Yes.

Q. Do you recall it?

A. I recall hearing it yes.

Q. You haven't been out to the Burwood site yourself have you?

A. No.

Q. Would you be prepared to go out to Burwood and inspect and if required by the Commission give any further views?

A. I'd be happy to go if I'm required to yes.

Q. Mr Zarifeh put some questions to you about the beams and the fact that they weren't roughened. They were smooth and you, I think you mentioned that you didn't know where the beams came from. I think you mentioned that you didn't know where many of the elements of the building came from which diminished their usefulness in the forensic work. Just with focus on the beams. Why for example would it make a difference as to where the beams might or might not have been taken from in terms of the smooth edges –

A. Well if they were supposed to be roughened then they weren't and they were in some critical part of the building which might then have been the trigger to the collapse it would be very important. If in fact they were in some part of the building which was not likely to have been the most vulnerable then it would have been less important.

Q. You've been asked a lot about what you might have done and what you might have retained. If you'd have had control of this site from the outset and had been asked to conduct a forensic examination noting that you have at one point been chairman of the American Society of Civil Engineers Technical Council on Forensic Engineers, what would you have done differently?

A. Well I don't know about differently because I'm not quite sure what Dr Hyland did but I would certainly probably put in a proposal to do a forensic, if I was invited to be interested put in a written proposal to do a forensic investigation and in that I would attempt to stipulate what I expected to do. In turn I would expect the contract back in due course from my client telling me what his expect, his or her expectations would be with regard to you know what I was going to produce for them, and in many cases I would also expect a fairly substantial retainer to make sure I got paid in the long run and also to lock on the contract so that I would then be in a privileged position with that particular client.

Q. Yes and then but what would you do as part of that work?

A. What would I do?

Q. Just summarise it, just in a summary form. What process would you follow?

A. Well first of all I would having got some sort of contract so that I was definitely locked in I would do I suppose it was some sort of collapse I would expect to do a site investigation as quickly as possible and I'd also try to make sure that somebody was in charge of the site presumably maybe my client or the opposition and that things remain there until we had the opportunity to do a thorough investigation.

Q. And take it to the next stage, what would you do then?

A. Well you'd probably do a quick site investigation to get a general hang of the things. You'd certainly have several cameras with you and take an awful lot of photographs. You'd probably have some spray paint with you so that you could label a lot of things you saw subject to your client or the owner of the site approving to all those kind of things, which they probably would do in any case ahead of time, and that way you'd really

try to lock in what was there and everything else before things started disappearing.

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Q. And where would you put all this material that you have labelled?

A. Well first of all you would leave it on the site. Secondly in due course it would probably have to be moved and that's, then you would have to have some secure location agreed to by the people involved. You know if there is a state or a city or some sort of authority they probably have some secure location where it would go to and stay there until such time as the whole thing was settled.

Q. Well all of that works but in a complicated situation like this where lives were at stake and immediate action had to be taken to do the best that people could to save lives. How does the forensic examination or the forensic work that you have described change or need to change?

A. Well I am in no doubt in my mind that the rescue operation takes precedence over everything. When you get to the recovery operation I think at that stage hopefully there is a little bit more opportunity to be, shall we say a little more careful with the evidence and I would hope that you can talk through that with your client and the people involved in owning the site and owning whatever it is that has happened.

Q. So you do the best you can is that what you are saying?

A. Yes.

QUESTIONS FROM COMMISSIONER FENWICK:

Q. Professor Shepherd, there was a minute sent out some time ago, about two weeks ago requesting people to give us further information on certain aspects and one of those was the performance of the south wall and the connection between the floors and the wall. You have seen and studied this minute?

A. Yes I do recall seeing it.

Q. Have you replied to it?

A. Not in writing Sir, I tried to think about it.

Q. Now you've thought about it can you think about it out loud if we can't have it in writing?

A. Well I am not an expert in structural concrete as you well know but I did wonder first of all whether it was strictly speaking a coupled shear wall. The proportions to me didn't look like the coupled shear walls I have read about in my engineering experience. Since then I've seen discussions here and from you as well Sir which I realise now there was some questions on that issue, whether it really was either designed as or able to perform as a couple shear wall. So I have some queries about that in my mind but I don't think I am qualified to make a judgment on that compared with those other people who are strictly speaking expert structural concrete people.

Q. But you didn't discuss your thoughts with Dr Mander or Dr Reay or like this to perhaps look at this in some detail and come back and help the Royal Commission?

A. No because I was relying on Dr Mander who is much more expert in this area than I am to do that.

Q. And you didn't chase out the connection between the floor slab and the walls as we sort of then hoped that one would in that minute?

A. I was concerned about that connection. I haven't done any effort, made any effort to assess its viability but certainly if I had the chance to go back and look at that, remains of that structure that is one of the places I would be looking pretty hard.

Q. I am surprised if you spotted that as a potential problem you didn't put a few calculations. Wouldn't you normally expect if someone to spot this as a problem to at least a few approximate calculations on it to see if it is credible or not?

A. Well as I said Sir I didn't and I left it to people better qualified than I am to do that, yep.

Q. Just following on from another issue that was raised when Dr Reay indicated that to work out whether the stairs were cut in there would have an influence you would need to carry out a time history analysis.

Would you recommend a time history analysis should have been made before those holes were cut to the stairway?

A. I don't think it would have been realistic to do so. I would have thought there were other ways of satisfying the integrity of the building without doing a time history analysis.

Q. Somewhat less numerically expensive?

A. Yes.

Q. The north tower, of course the north tower they do have a record of where the floors have torn away and remaining floors were attached and they can see the drag bars there. What conclusions can you draw from the fact the north tower was standing with no significant damage apart from a few cracks between 0.4 and 0.8 millimetres wide? What conclusions can you draw from that?

A. That the north tower didn't have to work very hard because the connections failed fairly early in the piece. I, that's the conclusion I come to.

Q. So would a very detailed examination of the reinforcement in the north tower and the strength of the concrete in the north tower have told us anything more than we already know?

A. I'm not sure that we're convinced of what the rebar or mesh connection was, exactly was between.

Q. I'm asking about the north tower now?

A. Oh the tower itself?

Q. We know the tower itself was standing there. I mean there's been some suggestion it should've been left standing and given a thorough research and I'm just wanting to know what one could learn from that that we don't already know?

A. Oh, from the tower itself?

Q. Yes?

A. Well only, there were, appears to have been some questions some vertical cracks which were observable as I understand it inside the tower but weren't observable from the outside.

Q. That's right, yes, the outside was –

A. That may be a kind of unknown now forever. If we'd had the chance to have another look at that perhaps we could resolve that one.

Q. We know where those cracks are, we know the width of them and we know they went the whole height of the tower. What additional information would you have sought?

A. Well if we could accept what you've just said as absolutely correct, probably little else but I would like to have been able to satisfy myself with my own observations of that then.

Q. So you wouldn't accept the observation unless you'd made it yourself?

A. No, no, but you asked what I would do if I had the opportunity to and I'm saying is what I would do is go back and at least confirm what other people have said about those cracks being observable from the inside and not the outside.

JUSTICE COOPER:

Q. No, the question was, given what we know, what more would you gain from looking at it?

A. I don't know that I would've gained anything but I'd like to have done so.

QUESTIONS FROM COMMISSIONER FENWICK CONTINUES:

Q. Yes, there was evidence before of this accumulated damage, and one of the issues that Dr Reay mentioned was that they were designing for an Alpine Fault earthquake rather than an earthquake which might occur such as the Port Hills Fault earthquake in '11 and this was a major difference. Now in terms of accumulated damage the February earthquake strong motion lasted eight to 10 seconds. The predicted Alpine Fault earthquake was predicted to have strong motion for about a minute. So in terms of accumulated damage, which would be the more severe, in your experience?

A. Well it's a question of the intensity as well as the duration of the shaking and I would suggest that if you have a six point something earthquake more or less underneath you the intensity's probably greater in a short timescale than the intensity might be from the Alpine Fault moving.

Q. So is it the intensity rather than the accumulation?

A. Well I think the damage would be a sum of both the intensity of the shaking and the length of the shaking and it's not clear to me, or I don't know of anybody else which takes ponderence into the given situation.

Q. You are aware of course there are expressions allowing for duration?

A. Oh yes.

Q. Incorporated in design codes. The vertical acceleration seems to have played a major issue as I think you've raised and Dr Reay has raised and we normally treat the vertical accelerate, taken as the anticipate at about, peak ground acceleration being about two thirds, that's 0.7 in the latest standard?

A. Yes.

1635

Q. It tells you in fact in the standard you'd take .7 of your horizontal spectra and you're going to look at the vertical acceleration that's what you'd include. Would you agree?

A. I believe that's right although it's a long time I've tried to do anything like that.

Q. Can we have ENG.CAR.0001.38 please. If I've got my reference correct this will bring up vertical acceleration spectra. There are four of these. You can see two there. I suggest we just concentrate on the top one. Now do you agree that that in the low period range up to .2 of a second it's well above what we'd expect from elastic spectrum for horizontal spectra?'

A. Yes.

Q. I can bring up the horizontal spectra if you wish?

A. No, I think I can accept that.

Q. If we get to .5 of a second or one second or anything above that how would you classify that now as being a proportion of the horizontal spectra. Is it two-thirds?

A. Maybe that order.

Q. I beg your pardon.

A. Perhaps that order of two-thirds. I haven't got the other one in front of me.

Q. Can you please then bring up ENG.CAR.0001.29 please and we'll have the equivalent horizontal spectra in front of you and you can look at it. And again if we can concentrate on the top one. I hope it's the same point.

A. It's the same site, yeah.

Q. Same site, yes. So there you are. You see the horizontal spectra, the black one's the elastic?

A. Yes.

Q. The other one's are ductility ones and you can see that at .5 seconds it's round about, what, close to 1.8 (inaudible 16:37:34) it's a bit hard to say because it's varying so rapidly. Now if we went back to the previous one and have a look at that. That's number 38. It's the top one. So it was .1 before and there it is looks like about .25 to me, about a quarter. So this vertical acceleration spectra actually is quite low isn't it once you move away from the very short period range?

A. It looks like that, yes.

Q. Now can you explain to me, Dr Reay as a dynamics expert, Dr Reay's comment that vertical acceleration will have reduced the strength, the resistance of the south wall because it will have decreased the axial load acting on the wall. Now I don't know if you recall but remember we looked at the picture of the floor to see how much axial load would be attracted to that wall and it's somewhere round about my guess about a fifteenth of the total mass, the structure would go to that wall in terms of axial load while somewhat more than half of the weight of that structure will go to the wall in terms of lateral resistance?

A. Yes I followed that this morning.

Q. Now as we say his estimate of the vertical ground motion, vertical period, was .2 of a second but you might well have a different estimate you'd like to make?

A. I don't have a different estimate and I must admit I had a little difficulty following Dr Reay's argument this morning.

Q. Would you agree that's a relevant argument?

A. I have no opinion because I really don't feel confident to agree with it or disagree with it.

Q. On what basis do you not feel confident? You are an expert in dynamic analysis we know that. We respect your work, and what we're saying is that increased axial load will increase the lateral resistance one tenth of a second if it's .2 and it would reduce the resistance the next one tenth of a second. Now on what basis can you not give an opinion on that please?

A. Because I'm unsure and I'd rather not give an opinion if I'm unsure in these circumstances.

Q. Well I have to accept that you can't give an assurance on that.
In your statement, number 51/52, you talked about the non-linear time history analysis and what you would do and I probably don't need to bring it up you'll probably recall the general process but as I understand it you would look before you were setting out to do this you would look at the structure, presumably look at the drawings. Would that be the first step?

A. If they were available yes of course.

Q. Could you carry the time history analysis if the drawings were not available?

A. It would be hard but one could presumably create some feeling for the structure if you had to. I've had to do that before now when drawings are not available.

Q. It would be extremely difficult wouldn't it? So you'd look at the drawings and you would look at the areas that you thought were critical?

A. Yes.

Q. And then you would design your non-linear time history analysis to concentrate on those areas because you could not do detailed members covering the whole structure could you. It just would not be practical?

A. That is correct.

Q. It would take too many weeks to run the analysis amongst other things. So, having selected the areas, are you not in fact already prejudicing

your thought that these areas are likely to fail. Isn't that a necessary step?

A. Yes.

Q. And so isn't this what Dr Hyland and his advisors did. I mean they don't all agree on what was the critical failure mode?

A. Yes but I don't think that you'd limit yourself then to just one investigation.

Q. How do you mean just one investigation?

A. Well you said correctly that you would identify what you might describe as a more vulnerable positions or joints or whatever but then I would say by all means do that but then you would examine several of those in parallel.

Q. Did they not do that?

A. I don't think so.

Q. You've studied the report?

A. Yes.

Q. And you've studied the report of the expert panel?

A. Yes.

Q. And they've come out with different failure mechanisms?

A. Yes.

Q. So they must have studied that non-linear time history analysis to assess which elements might have failed. I don't quite see, how do you get they only studied one?

A. I don't follow you. I didn't think that's what they did. I thought that they focused essentially on one most likely failure scenario and the time history analysis was directed at that.

Q. They had four scenarios. Not all members of the expert panel agreed with what they believe was the most critical scenario but they looked at four different scenarios, four different collapse mechanisms. I can't see how you can say they just did one?

A. Well I was under the impression we were still trying to do non-linear time history analyses looking at different scenarios.

QUESTIONS FROM JUSTICE COOPER:

Q. So your understanding of the history analyses that were done for the purposes of the Hyland Reports and the expert panel reports only looked at one collapse scenario. That's as you understand it?

A. I believe they focused on one scenario, yes.

Q. Well that's all they ran in the NTH –

A. That's my understanding Sir.

1645

QUESTIONS FROM COMMISSIONER FENWICK CONTINUES:

Q. In your (inaudible 16:45:20) you talked about the problems of the lack of information on the exact records which were applied to the CTV site.

A. Yes.

Q. And you suggested, I don't know quite how you intended this but are you suggesting that artificial records were often used? Are you suggesting that the CTV analysis would have been better to use an artificial record there rather than the four earthquake records which are now currently being used?

A. No my objective of mentioning that was to explain that in the absence of any records these synthetic records were generated to be used. I didn't intend these to be used in this scenario.

Q. Well I was probably reading too much into it. I just wanted to check that. If we can just return to the model again. Half scale model weighing around 400 tonnes would any of the either of the two six dimensional shake tables that Dr Reay mentions be able to handle 400 tonnes?

A. I don't know for certain but I certainly start with the Japanese one which I believe is by far the bigger and see what – they have done quite recently a full scale building on that I'm not sure of the details of the building. You and I both know reinforced concrete building is likely to be heavier than some of the others.

Q. Yes.

A. So I can't answer your question specifically.

Q. The cost of running these big shake tables is horrendous isn't it?

A. The power alone would kill most of it.

Q. That's right. So your estimate of cost by the time you included something for the foundations, the instrumentation, building it, the time it would have to be on the shake table unless you could lift the whole thing in by crane but lifting the whole thing in 400 tonnes, you just made up a pre-cast element so you would have to reform your pre-cast boxing from start and cast it. Do you think your estimate of cost allowing for all those is anywhere realistic?

A. I don't know if it was realistic. It was the best estimate I could make at the time and it could be that I'm way out but it could be more.

Q. Yes. What do you feel about the proposal to build such a model and the necessity to build such a model and the cost involved of that model?

A. Well if we look at the cost relative to the total cost of this earthquake and the benefit that might accrue in general to seismic engineering in the long run bearing in mind that there other buildings around the world which were designed in the 80s vintage, this could be a great advantage to do it within the thought that it's a small drop in the ocean compared with the total cost of this earthquake. On the other hand if you're looking at the point of view who's going to fund it locally I understand you have problems and I've got problems.

Q. I'm sure they're planning to build just a shake table at Canterbury now. But when you look at the building there are a number of vulnerabilities that one can spot: the columns, the beam column joints, the south wall, the north wall, the connection to the north wall, the slabs. Do we need a shake table test to illustrate that those, how those different elements are going to work or connections are going to work? Do you think we really need to go to the extent of the shake table test? What's it going to tell us?

A. It could be very conclusive as to the sequence of the failure.

Q. How would you if it's important to predict the sequence know if one element doesn't fail perhaps the other one will does it matter then, the order in which they have failed? It is important to establish the actual sequence when we have a number of areas that we can look at.

A. Well I think it would be beneficial. Most of the advances in earthquake engineering in the last hundred years has been as a result of examining very carefully failures and learning from the failures and I think this would be an opportunity to advance that knowledge at a great expense admittedly.

Q. You don't think that one can take out those individual elements and test them and see how they perform to draw some pretty robust conclusions at a somewhat cheaper rate than the few hundred million?

A. I think that would be very helpful to do what you're suggesting yes and it may be the only practical alternative.

Q. Then one perhaps might run time history analyses to see how those different elements would interact?

A. Yes but I'd prefer to do the testing first before we did the mathematical modelling.

Q. I couldn't agree with you more. So coming back to this model proposal, what's it worth? Would you put any value on the type of analysis, that type of model construction that Dr Reay is suggesting?

A. Well it would be wonderful to do it but if you're asking do I consider it realistic at this stage, I think I would prefer to recommend the component testing and see how we got on with that first.

Q. And then do time history analyses, get the interaction of those components?

A. Yes if one was sure that the mathematical model was truly representative of what gets discovered in your testing.

Q. Now there's been comment often asked round here that strain hardening was neglected. Now my understanding and I'm not involved obviously in the non linear time history analysis. My understanding the different elements in that were modelled by the (inaudible 16:52:11) model is that correct?

A. I believe that's right.

Q. That would include or not include strain hardening effects?

A. I'm not sure.

Q. Would it be usual for this (inaudible 16:52:27) model to include strain hardening effects?

A. I believe so.

QUESTIONS FROM COMMISSIONER CARTER:

Q. I'm interested in a couple of aspects of your evidence. One you dealt with quite thoroughly and that is the standards that have now been set up in the United States for forensic examination in the National Academy of Professional Engineers and the American Society of Civil Engineers. There will be in later aspects of this hearing careful examination of procedures that were followed and maybe that would have been better so we've now got a record of your views on that and we appreciate it. Thank you for that.

A. Thank you.

Q. I looked at your list of publications and you have been publishing for nearly 50 years, 49 years and the dates on the publications you've got and you listed on page 4 of your CV 10 papers that have resulted from earthquake damage assessments. In this particular case what we're looking at is a building in which people, many people were killed and so my question of you is when we look at those 10 papers and I can take you through them as their titles but many of them are not really relevant to this particular building in my reading of the titles, but you made comment on that. And of the four that you mentioned and that is the earthquake in Inangahua, San Fernando, Loma Prieta and the Northridge earthquakes and you were involved in damage assessment of those of collapse resulting from those earthquakes?

A. Yes.

Q. And were they, were the buildings that you looked at particular to look at of building and how it collapsed, or were you looking at a more general purpose in making the studies and reporting on them?

A. I would say a more general purpose yes.

1655

Q. So in fact the trauma that resulted here when we had a building in which we've got five layers of concrete collapsed on top of each other in which people were trapped and killed is somewhat different in emotional sense to what might be let's say the ideal world for forensic testing?

A. I agree.

Q. Thank you. Just one other thing that I wanted to have your view on and that was at the very end of your paper you talk about the term "redundancy" and perhaps "fail-safe design" is suggested by you as perhaps a more appropriate terminology. When this building was designed in 1986 was the concept of having redundancy available, alternative load paths understood by engineers or was it just sufficient to make sure the buildings withstood?

A. I think there's always been confusion as what was meant by redundancy and some engineers would argue that redundancy in its genuine terminology is not desirable if you don't know where your loads are going whereas, I would suggest that some engineers 30 years ago would be very well aware of alternative load paths but that the term redundancy was bandied about with all sorts of connotations and it wasn't clearly understood what people were talking about.

Q. You would like to see that particular point brought forward and clarified in the future?

A. I would like to because I really do believe that say the aeronautical industry with its fail-safe concept is one ahead of us at the moment, yes.

Q. And so your professional opinion is that alternative load paths which give you a second line of defence is a prudent concept to build into (inaudible 16:57:12) structures?

A. In most cases, yes.

QUESTIONS FROM JUSTICE COOPER:

Q. Professor Shepherd just referring to paragraph 20 of your statement, and I'm looking at the second sentence about five lines down where you're talking about the observations made by Mr Frost. Do you see that?

A. Yes.

Q. Now my question is whether your understanding of Mr Frost's observations is that based on how they are reported in the Hyland and Smith Report?

A. I thought I'd either seen or heard something more direct from Mr Frost than that.

Q. Right, and when was that?

A. I can't recall but I'm pretty sure it was more directly from Mr Frost than through some secondary reporting system.

Q. Well was it before or after you drafted this statement of evidence?

A. Before.

Q. Were you aware that Mr Frost came and gave evidence to the Royal Commission?

A. Yes.

Q. You weren't here when he gave that evidence?

A. No I was not.

Q. And it's a statement of some 71 paragraphs. You haven't read that?

A. No.

Q. And you didn't hear him give it?

A. No.

Q. And you haven't seen him give it on the video record of our hearings?

A. I don't believe so.

Q. Now I think we've already covered it but perhaps you'd just confirm neither have you read Dr Heywood's statement of evidence to this Commission?

A. That's correct.

Q. Which is of some 144 paragraphs in which he details and illustrates with photographs the various observations that he made at the site shortly after the earthquake?

A. I've heard of it but I haven't had the opportunity to study it.

Q. Now both statements would have been available on the Royal Commission's secure website to which you had access?

A. I can believe that Sir.

Q. So why haven't you read them?

A. I may have read part of Mr Frost's I can't recall but somewhere along the line I remember a lot of the details of what Mr Frost had reported and was very impressed with it. I can't recall when or how.

Q. So why haven't you read these two statements of evidence to the Commission?

A. I guess I ran out of time Sir. I was travelling here and I didn't have as much time as I would have liked.

Q. Do you say you were aware of them but didn't have time to read them?

A. I think that's fair Sir, yes.

Q. Whether or not it's fair is it the truth?

A. Well it's the truth.

Q. So you were aware of them and didn't have time to read them?

A. As I say I may have read part of Mr Frost's. I'm sure I didn't read any of Dr Heywood's.

Q. Despite being aware of them?

A. Yes.

QUESTIONS ARISING MR PALMER – NIL

JUSTICE COOPER ADDRESSES MR PALMER

It's a matter for you I suppose but the conclusions that were reached by Dr Bradley, at least as described in your learned leader's opening don't seem to be very controversial. Is there any reason why we need to listen to the whole statement being read?

MR PALMER:

There may be scope for it to be truncated but certainly Professor Priestley didn't accept Dr Bradley's evidence on this. He preferred the Tonkin & Taylor material and I think –

JUSTICE COOPER:

In what respect was that?

MR PALMER:

In relation to the REHS site.

JUSTICE COOPER:

But the NTHA analysis that's been ongoing has incorporated all four sites hasn't it?

MR PALMER:

Yes I understand it is doing that Sir. However, we have all this evidence before the Commission regarding the three sites and if it's not accepted by one of the experts that is giving evidence in that respect then it seems to me that his evidence remains relevant on this point.

JUSTICE COOPER:

Yes I hadn't appreciated or didn't recall that Professor Priestley –

MR MILLS:

I don't think that it is accurate to say that he didn't accept it. He wasn't aware of the later work that had been done and the evidence that he gave was related to the position as he understood it before all this subsequent work was being done and nothing was put to him to say, "Well Dr Priestley there been this further work done, what's your reaction to that?" So I think in a sense it's a sort of a false premise that might be operating here.

JUSTICE COOPER:

Well yes that's as I recall it Mr Palmer.

MR PALMER:

I'm not sure about that Sir. I think if you check the record.

JUSTICE COOPER:

Well would you mind getting in a position to be sure about it in the morning because at the moment it seems to me that if, and I'm just trying to find what was said about it.

MR PALMER:

Sir, Dr Bradley's expertise does also cover other issues that have been discussed in evidence while he's been sitting in the back of the hearing room for the past few days.

JUSTICE COOPER:

Well that's a different matter. I'm asking about –

MR PALMER:

I think that by referring to his evidence I think that there will be some, there is possibility to call upon his expertise to assist the Commission with those matters. For example, and only by way of example, I refer to the Alpine Fault issue which he can make some observations on. I believe his evidence in general will be of assistance. I'm very happy to go through that and cut as much out of it as we can.

JUSTICE COOPER:

I'm not suggesting that we don't receive the evidence or be able to refer to it but I'm suggesting that it may not be necessary to read it all out. That's all I'm saying.

MR PALMER:

Well that would be good Sir if that was possible.

1705

JUSTICE COOPER:

I have in mind Mr Rennie's statement in his opening Dr Bradley concludes, "That the general response at the CTV site is consistent with those at the other four CBD stations", and as the it seems to mean doesn't it that the basis upon which earthquakes effect at sites have been assessed and are being assessed in the ongoing non linear time history analysis will be appropriate.

MR PALMER:

Well yes on that aspect Sir that's correct. His evidence though is very important to Professor Mander's evidence in relation to particularly his cumulative effects evidence and I was thinking that there is scope for at least some of his evidence to be given and for him to comment on issues.

JUSTICE COOPER:

I'm only saying that given that one of the main areas of potential controversy to use the word has gone away presumably can have a lesser amount of the evidence read out. All of it would be taken in and considered by us but I'm just asking you to direct attention to that possibility.

MR PALMER:

I'll attend to that Sir.

HEARING ADJOURNS: 5.06 PM

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