Cement & Concrete Association of New Zealand

CCANZ
concrete answers

Submission to the

Canterbury Earthquakes Royal Commission of Inquiry into the CTV Building Collapse

Critique of

CTV Site Examination and Materials Tests Report
by Hyland Fatigue + Earthquake Engineering
16 January 2012

CTV Building Collapse Investigation Report
by Hyland Fatigue + Earthquake Engineering/StructureSmith
25 January 2012

April 2012

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30 April 2012

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Dear Sir / Madam

Please find below a submission to the Canterbury Earthquakes Royal Commission from the Cement and Concrete Association of New Zealand (CCANZ).

1. BACKGROUND TO CCANZ

CCANZ is a not-for-profit organisation that can trace its history back over 50 years, during which time it has developed a proud reputation as the leader in ensuring industry decision makers realise the full potential of concrete.

The many roles fulfilled by CCANZ include fostering industry solutions based on robust concrete technology, as well as co-ordinating education, training and research initiatives in concrete related areas. Key to achieving its objectives is a level of in-house and aligned industry technical expertise that covers a range of engineering disciplines, along with architecture and concrete technology.

CCANZ represents a membership in excess of 300 corporates and individuals who collectively account for a significant proportion of the building and construction sector in New Zealand.

The cement and concrete industry annually produces and uses about 1.5 million tonnes of cement in New Zealand, which equates to around 3.75 million cubic metres of concrete for new residential, non-residential and commercial construction. In total, the direct, indirect and induced economic impact of the cement and concrete industry resulted in close to $7.5 billion of output across the economy in the year to March 2006. This activity supported more than 24,000 jobs and created a value add of about $2.8 billion – around two percent of New Zealand's GDP in 2006.

CCANZ is a member of the New Zealand Construction Industry Council (CIC).

2. THIS SUBMISSION

This submission presents CCANZ's critique of two reports prepared for the Department of Building and Housing. These are:

- *CTV Site Examination and Materials Tests Report - 16th January 2012*, herein termed the Hyland Materials Report and
- *CTV Building Collapse Investigation Report - 25th January 2012,* herein termed the Hyland Collapse Report.

This submission refers to these reports collectively as the Hyland Reports, and critiques sections within both that pertain to the concrete columns only.

The Hyland Materials Report concludes that the concrete strength at the time of testing did not meet the specified strength level for the columns. It also states that the column concrete may not have met the 28 day strength requirement at the time of construction.

CCANZ questions this view, which is based on the compressive strength of cores taken from column remnants of the collapsed structure located at a Burwood Landfill, Christchurch. CCANZ has carried out its own interpretation of the core compressive strengths, and does not agree with the conclusions reached in the Hyland Materials Report on the column concrete strengths.

The Hyland Materials Report does not categorically state the method used to interpret the concrete core strengths. However, it does refer to a UK Concrete Society Technical Report No 11 (TR 11) which has recently been superseded by BS EN 13791:2007 *Assessment of in-situ compressive strength in structures and precast concrete components* and BS 6089:2010 *Assessment of in-situ compressive strength in structures and precast concrete components – Complementary guidance to that given in BS EN 13791*. CCANZ has used these standards in its interpretation as they represent the latest international best practice for the analysis of concrete test results to determine in-situ concrete strengths.

In summary, the reason CCANZ is compelled to submit this critique is based upon the belief that the concrete core test methodology employed by Hyland Fatigue and Earthquake Engineering for the CTV Building columns, and the interpretation of the resulting test data, was not appropriate, and in turn, not accurate.

While CCANZ has reinterpreted the test data using what it believes to be best practice, and has achieved a set of higher strength results for the concrete cores, there remain questions about the reliability of the extracted cores based on their number, and the level of damage sustained by the columns from which they were taken during the collapse, fire and transportation to landfill.

As a result of these circumstances CCANZ believes that any conclusions as to concrete strength, including that presented in the executive summary of the Hyland Collapse Report that “low concrete strengths in critical columns” was a factor that “contributed (or may have contributed) to the failure”, cannot be adequately supported.

In making this submission CCANZ is acutely aware of the tragic loss of life that resulted from the collapse of the CTV Building, and shares the nation’s heartfelt sympathy towards the victims and their families. CCANZ is driven by the importance of drawing correct and technically robust conclusions from the hearing process, which will provide the answers demanded as well as lay the platform from which everyone, including the construction industry, can move forward.

While this submission highlights the difficulties in determining accurate concrete strengths results in order to question the conclusion that low concrete strengths in critical columns may have been a factor in the CTV Building collapse, it in no way constitutes criticism of the Department of Building and Housing, or its advisors, as they undertake a tremendously difficult task. CCANZ remains firmly committed to assisting the Department in its on-going investigation around the CTV Building collapse.

CCANZ would like an oral hearing to present its comments to the Royal Commission.

3. EXECUTIVE SUMMARY OF CCANZ CRITIQUE OF HYLAND REPORTS

The following conclusions on the Hyland Reports can be drawn from this CCANZ critique:

- The Hyland Materials Report has not followed standard procedures in interpretation of concrete core strengths and Schmidt Hammer results.

- The number of cores taken to draw firm conclusions on the concrete strength was inadequate, 19 cores were taken from only seven columns (7% of all CTV columns). As the specified design concrete strength reduced with the height of the building, and the floor level of five of the seven columns cored was unknown, this makes comparison of core strengths against specified strength problematic.

- Core strengths have been compromised by being taken from areas of distressed concrete as a result of the building collapse and fire damage. These cores should have been rejected.

- Aspect ratio (length/diameter) of three cores was less than 1.2, as against the recommended ratio of 1.9 – 2.1.

- For five of the seven columns only two cores have been taken representing a particular column location. 16 of the 19 cores were only 70 mm diameter, for which BS EN 13791 recommends six cores be taken for each column.

- Three outlier results based on BS 6089 Pt 6.1 were not removed from the core results.

- No allowance has been made for voidage in determining characteristic strength (or nominal strength) of standard specimens.

- The correlation of the Schmidt Hammer testing against core strengths was based on only six pairs of strength vs. Hammer results. BS EN 13791 recommends a minimum of nine pairs. The correlation curve derived in the Hyland Materials Report is highly questionable, and has not taken variation in concrete strength between columns into account. This places all the concrete strength determination for 19 columns based on Schmidt Hammer readings in doubt.

- The Hyland assumption of compressive strength increase with time after 28 days is questionable in a New Zealand context. The Caltrans reference (USA) quoted is for external concrete containing a cement blend. This does not apply to cements used in New Zealand and should not apply to the CTV concrete.

- CCANZ has the utmost confidence in the third party certified New Zealand Concrete Ready Mixed Association (NZRMCA) Plant Audit Scheme, termed the Plant Classification Scheme in 1988. All concrete plants supplying the Christchurch metropolitan area at the time of the CTV construction were *Special Grade* plants under the scheme. The Scheme provides an independent audit of a ready mixed concrete plant's own quality system for compliance against NZS 3104:2003 *Concrete production* and the relevant parts of related documents. Further details on the Scheme are given in Section 7 of this submission.

4. METHODOLOGY OF SAMPLING, TESTING AND REPORTING IN THE HYLAND REPORTS

Nineteen cores were extracted from seven circular and square columns taken from the CTV site which were stored at Burwood Landfill, Christchurch. The Hyland Materials Report repeatedly implies that 26 cores were taken. Two of the columns were from Level 1 and from Level 6, however for the remaining five columns, represented by 10 cores, their location in the structure is not known. This is relevant because the specified strength of the columns reduces from 35 MPa for Level 1, to 30 MPa for Level 2 and 25 MPa for Level 3 and above. Therefore, for over half the cores, the specified strength of the concrete from which the cores came is unknown.

The Hyland Materials Report states in many places that core samples were extracted from column remnants which had been damaged in the collapse, or 'suffered distress'. Some columns had also been affected by fire. It is well known that concrete compressive strength is affected by fire, with Fletcher (2006) suggesting a 15% compressive strength reduction at 300°C, 60% at 550°C and 90% at 900°C. This reduction results from a chemical inversion of the cementitious phase of the concrete. Also, discolouration of concrete in fire takes place at around 300°C. The fire at the CTV Building lasted for several days. Discolouration can be observed for the column in Figure 1. However, loss of strength from fire still may occur even where discolouration is not evident.

Szypula and Grossman (1990), writing in the American Concrete Institute's *Concrete International* journal, outline their mock-up of a suspended in-situ floor and supporting columns, on which early age loads were applied to simulate construction loads. A comparison was made between core strengths and standard cylinder strengths to ascertain the effect of micro-cracking on core strengths. The study indicated that field cores taken from flexural members that are supporting loads and/or are restrained by stiff supports, cannot be relied upon to determine characteristic strengths because of the presence of micro-cracks and other larger cracks.

CCANZ has commissioned a limited study to ascertain the effect of cracking on core strengths. No results are available at the time of this submission. In his definitive technical publication *The properties of concrete* Neville (1995, p. 614) states that the effect of cracking on core strengths is greater for smaller diameter cores. Most of the CTV cores were 70 mm in diameter.

In the Hyland Materials Report no consideration was given to excluding core results from damaged concrete in determining in-situ concrete strengths. The six cores taken from Level 1, shown in Figure 1 and Table 2 (CTV 1, 2 and 3) in particular, had fire damage and collapse damage, and the cores had to be trimmed to remove damaged concrete. The report says that difficulties were encountered in gaining suitable uncracked cores possibly because they were taken too close to the fractured zone. CCANZ considers that cores from these column remnants should not have been used in the analysis at all.

The OPUS core compression test reports do not give a visual description of the core prior to testing. NZS 3112.2:1986 *Methods of test for concrete - Tests relating to the determination of strength of concrete* (Section 9) on determination of compressive strength of cores, states that the ends of the cores shall be examined for cracks prior to conditioning, and any cracks found should be sawn off so that the sawn off piece extends 15 mm beyond the visible crack.

This procedure is critical for the interpretation of core strengths from a collapsed structure such as the CTV Building. Also, the voidage needs to be assessed if core strengths are being used for the estimation of concrete strength as supplied, which appears to be the intent of the Hyland Reports.

Shear failures, which typically result in premature lower-bound failure, were noted for three cores in the CTV test report TC 1 (See Table 2), but the associated test result has not been removed from the in-situ strength interpretation. The other six reports state that the type of fracture was 'not established'.

Sixteen of the 19 cores were 70 mm in diameter. EN 13791 clause A.3.1 requires six cores to be taken for each location for 70 mm diameter cores; typically most columns had two cores with only the level one column having the required six cores. However, these cores were from the column shown in Figure 1 which was damaged as outlined above.

To supplement the core testing, 'Schmidt Hammer' readings were taken on a further 19 column remnants from Burwood Landfill. The Schmidt Hammer is a non-destructive test method using a spring loaded 'Hammer' which impacts on an outside surface of the concrete.

Figure 1: Level One Column 18 at Line 4 D/E

Six paired Schmidt Hammer readings from two columns were taken to establish a relationship between the Hammer reading and corresponding core strengths. Some of these may have come from defective concrete with micro-cracking.

In general, stressed concrete with micro cracking is more likely to affect Schmidt Hammer readings reflecting the imperfections in the surface layer as opposed to the concrete interior. This relationship was then used to interpret compressive strength from 27 sets of Schmidt Hammer readings. EN 13791 clause 8.3.1 requires at least nine sets of paired results to establish the correlation of Schmidt Hammer readings with core strengths.

Also in this case, there were only two cores taken for each paired location instead of the six required for 70 mm diameter cores.

These departures from standard procedures place significant doubt on the core results and strength derived from Schmidt Hammer readings, and undermine the interpretation of the results to predict in-situ concrete strengths.

5. HYLAND MATERIALS REPORT INTERPRETATION OF CONCRETE TEST RESULTS

Thirteen 400 mm diameter circular and twelve 400 x 300 mm rectangular concrete column remnants were randomly selected from the CTV debris for either core testing or Schmidt Hammer testing. The mean core strength for a particular member was then compared with the theoretical 28 day strength of concrete conforming to NZS 3104:1983, the Standard covering supply of ready mixed concrete at the time of construction.

Many of the cores were taken from columns which were cracked and damaged in the building collapse and the Hyland Reports state that concrete test results need to be interpreted in the light of this fact. However, the Hyland Reports do not exclude or factorise any of these compromised cores (See Figure 1).

An ageing factor of 1.25 has been applied to the concrete core strengths based of a California Department of Transportation (Caltrans) publication. This showed that for 20-25 MPa specified strength concrete there was a 25% strength increase over 20-30 years. Priestley, Seibel, and Calvi (1996) use a divisor of 1.5 on strength-aged specimen core test results to approximate the specified 28 day compressive strength. This takes account of the ageing and the margin of the target strength over the specified strength.

The Hyland Materials Report page 72 has used an ageing factor of 25% which has a significant effect on the predicted strength, however its application for the CTV concrete is inappropriate. Concrete used in Californian highways utilises Supplementary Cementitious Materials (SCMs), such as flyash or slag, and is subject to on-going hydration being exposed to the atmosphere. New Zealand concretes typically use General Purpose Cement (type GP) to NZS 3122:2009 *Specification for Portland and blended cements (General and special purpose)* which exhibits different strength gain characteristics to those featured in the Caltrans document. Strength gain for type GP Cement beyond 28 days is not considered significant, particularly for concrete not exposed to the weather as in the internal faces of columns for instance.

Neville (1995, p. 614) states that in the absence of definitive moist curing, no increase of strength should be expected with age, and no age correction should be used in the interpretation of the strength of cores.

For the CTV concrete, a blended cement was not used and most of the columns were sheltered from the weather, and therefore received no curing beyond the period following casting. As such, CCANZ does not consider it appropriate that a curing or maturity factor should be applied to the core strengths in deriving the characteristic strength of standard specimens.

Table 3 on page 63 in the Hyland Materials Report also assumes the concrete supplied to construct the CTV Building was from a *High Grade* ready mixed concrete plant. In fact, on the advice of the New Zealand Ready Mixed Concrete Association (NZRMCA), all the urban concrete plants supplying Christchurch at the time were *Special Grade* plants (D.P. Barnard, personal communication, April 3, 2012). A *Special Grade* plant has a lower target mean strength of 3 MPa to reflect the higher level of quality control. Thus the data in Table 3 are 3 MPa too high and the associated statistical data is in error. This also introduces an error into the distribution curves in Figures 51 and 52 (pp. 71 & 72) of the report.

Based on Table 3, the Hyland Materials Report concludes that the mean strength of the columns tested was equivalent to that for a concrete with a 28 day specified strength of 20 MPa. As the floor level from which 10 of the 19 columns tested is unknown, CCANZ considers that one cannot come to any conclusions on the compliance of individual results. However, because the mean strength was incorrectly established as being equivalent to a 20 MPa concrete, the Hyland Materials Report concludes that the columns on levels one, two and three to six may not have achieved the 28 day specified strength of 25 MPa for levels three – six, 30 MPa for level two or 35 MPa for level one. CCANZ believes that no such conclusion can logically be made, and for the ten columns where the floor level is unknown, no conclusion can be drawn on the adequacy of the concrete in meeting the specified strength.

Table 1 and Figure 2 below show the revised target mean strengths for 25 MPa, 30 and 35 MPa specified strength by removing the ageing and target strength errors, and demonstrates the significance of the reduction.

Table 1: Target Concrete Strength verses Specified Strength to NZS 3104:1983

Specified Strength	**20 MPa**	**25 MPa**	**30 MPa**	**35 MPa**
Target Mean Strength (TMS) based on:				
NZS 3104 High Grade and Ageing applied in Hyland Materials Report	34.4 MPa	41.9 MPa	50.0 MPa	56.9 MPa
NZS 3104 Special Grade TMS as should have been applied	24.5 MPa	30.5 MPa	36.5 MPa	42.5 MPa

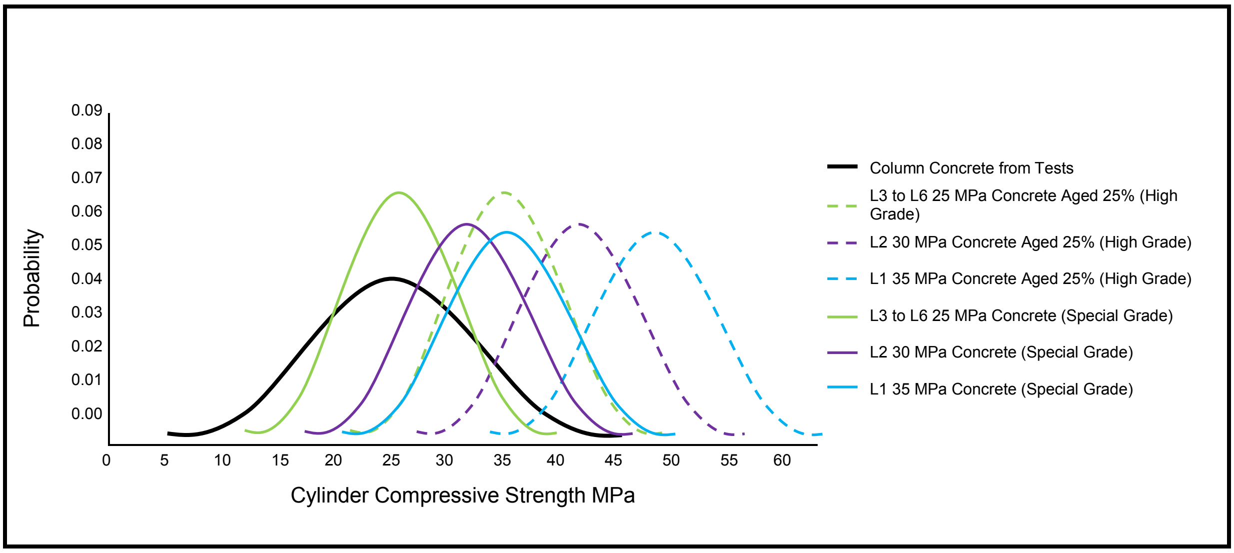

Figure 2: Column test strength distribution. Special Grade Concrete versus High Grade Concrete aged 25%

6. CCANZ INTERPRETATION OF HYLAND TEST RESULTS

The following CCANZ interpretation is based on BS EN 13791:2007 and BS 6089:2010. The method used by Hyland has been superseded by these two standard methods. However, the CCANZ core interpretation is still compromised by the low number of core samples.

6.1 Core Interpretation

BS EN 13791 recommends that cores are tested at close to an aspect ratio (L/D) of 2. It also states that the number of cores from one location should be at least 3. Where the core diameter is less than 100 mm, BS EN 13791 states that the number of cores shall be increased. For the Hyland cores:

- Three of the 19 cores had an aspect ratio of 1.2 and one core had an aspect ratio of 0.65. The remainder were close to 2. Squat cylinders with a low aspect ratio give test results with more variation between tests.

- Five of the columns had two cores, one had six cores and one had three cores.

- The core diameter was 70 mm for 16 of the 19 cores. BS EN 13791 requires that six cores be taken from each location for 70 mm cores.

These departures from BS EN 13791 place significant doubt on the core interpretation.

BS 6089 Clause 6.1 gives a method from determining if ‘outlier’ test results should be excluded in determining the mean core strength in a set. Analysis of the core results requires the exclusion of 3 of the 19 core results, two of which are from the same set of six results. These are shown in Table 2.

The calculation of characteristic in-situ compressive strength from the mean core strengths uses the t-statistic application of the standard deviation to BS 6089. In deriving the characteristic strength of standard specimens from the in-situ characteristic strength the following factors are to be applied:

- The ratio of characteristic in-situ compressive strength (95 percentile) to the characteristic strength of standard specimens in EN 13791 is 0.85.

- The core compression tests were conducted with dry specimens. The ratio of dry to wet specimens, applicable to standard cured cylinders, is 1.13.

- BS 6089 Table A.3 provides correction factors for voidage. Voidage of 0.5% and above would have the effect of increasing the derived characteristic strength of cylinders. No voidage measurement was given in the core test reports so the Hyland Materials Report has not accounted for excess voidage in the cores. Typically some voidage would be present in in-situ concrete owing to the vagaries of site compaction.

A summary of the characteristic strengths of standard specimens derived from the core strengths is given in Table 2.

Table 2: 28 day Cylinder Strengths derived from Core Strengths

Lab Ref.	Client Ref	Location	Specified Strength[3]	Core Strength[1,2]	Mean Core Compressive Strength[2]	Characteristic Strength of Standard Specimens[7] to EN 13791
5833/131/1	CTV 1	Level 1 400 Square Column C18 at Line 4 D/E	35	16.5		
5833/131/2	CTV 2		35	17.0		
5833/131/3	CTV 3		35	~~11.0~~	18.1	18.7
5825/124/1	C18		35	25.1[3]		
5825/124/2	C18		35	~~12.8~~[3]		
5825/124/3	C18		35	13.7[3]		
5673/055	TC1/1	400 diameter Column E25 Level 6	25	26.5[4]		
5673/055	TC1/2		25	~~16.0~~[4]		
5673/055	TC1/3		25	27.5[4]	27.0	28.1
5907/160/1	C4/1	400 diameter Columns Level Unknown	27.1	47.8		
5907/160/2	C4/2		27.1	45.3	46.5	
5907/160/3	C12/1		27.1	27.1		
5907/160/4	C12/2		27.1	26.2	26.6	38.1
5907/160/6	R3.1	400 x 300 Rectangular Columns Level Unknown.	27.1	20.5		
5907/160/7	R3.2		27.1	20.1	20.3	
5907/160/8	R6.1		27.1	24.5		
5907/160/9	R6.2		27.1	26.4	25.5	
5907/160/10	R7.1		27.1	39.5		
5907/160/11	R7.2		27.1	42.2	40.8	30.1
		Average	**19 less 3**	**27.9**	**27.9**	**31.0**

[1] Laboratory core results adjusted for aspect ratio only
[2] Tests for determining mean strength should be based on at least 3 cores
[3] Aspect ratio (L/D) < 1.2
[4] Shear failure
[5] 27.1 is the average specified strength across 6 floors
[6] Strikethrough results refer to outliers based on BS 6089 Clause 6.1
[7] No allowance for voidage has been made

6.2 Schmidt Hammer Interpretation

BS EN 13791 gives two alternative methods of correlating Schmidt Hammer readings with concrete core results. The first requires at least 18 paired core/Hammer results and the second requires 9 paired results. The Hyland Materials Report is based on only 6 paired results which places significant doubt on the use of the Schmidt Hammer results to predict concrete strengths.

However, the CCANZ analysis, whilst it has insufficient reference data, is based on the second procedure which plots the 'basic' Schmidt Hammer correlation curve against the curve derived from the paired results to establish the extent to which the basic Schmidt Hammer curve should be shifted. The shift is calculated from a k factor, in this case 1.67 times s, the standard deviation. The k factor used is conservatively based on 9 results, not 6.

The Hyland Materials Report has not taken into account the variation in the strengths and the standard deviation of the 6 paired results which effectively shifts the correlation curve further from the basic curve, resulting in lower derived concrete strengths.

The mean of the 19 Schmidt Hammer derived compressive strengths from the Hyland Materials Report is 27.0 MPa. Following the procedure of BS EN 13791, CCANZ calculates the mean derived strength as 35.4 MPa. However, for 10 of the 19 columns the level of the columns from which the cores came is unknown.

Table 3: 28 day Cylinder Strengths derived from Schmidt Hammer Readings

Level	**Core Compressive Strength**		**Characteristic Strength of Standard Specimens to EN 13791**	**Specified Strength**
	Hyland	**EN 13791**		**f'c**
L6	26.2	34	35.4	25
L6	20.8	29.5	30.7	25
L6	23.2	32.5	33.8	25
L5	18.5	27	28.1	25
L1	18.4	24.5	25.5	35
L1	31.3	39	40.6	35
Level Unknown	29	39	40.6	27.1
Level Unknown	29.5	39	40.6	27.1
Level Unknown	19.4	27	28.1	27.1
Level Unknown	22.4	31	32.3	27.1
L6	28.1	37	38.5	25
L6	23.9	32.5	33.8	25
L5	37	45	46.8	25
Level Unknown	23.4	32.5	33.8	27.1
Level Unknown	32.4	42	43.7	27.1
Level Unknown	28.1	37	38.5	27.1
Level Unknown	23.4	32.5	33.8	27.1
Level Unknown	46.3	51	53.1	27.1
Level Unknown	31.1	40.5	42.2	27.1
Mean All	**27.0**	**35.4**	**36.8**	
Mean Unknown	**28.5**	**37.2**	**38.7**	

7. PLANT AUDIT SCHEME

The Plant Audit Scheme operates to audit NZRMCA members' ready mixed concrete plants as defined in NZS 3104:2003 *Concrete production*, including amendments 1 and 2.

The NZRMCA Plant Audit Scheme provides specifiers with an overall assurance on the conformity of ready mixed concrete supply to NZS 3104, and avoids auditing of ready mixed concrete supply on a project by project basis. It provides an independent and rigorous audit of the quality systems in place at a ready mixed concrete plant.

All Christchurch ready mixed concrete plants were operating under the NZRMCA Plant Audit Scheme at the time the CTV Building was under construction, and had a current *Special Grade* certificate to NZS 3104:1983.

8. CONCLUSIONS

This CCANZ critique of the Hyland Materials Report and the Hyland Collapse Report has shown that the sampling method used for cores, the core testing itself and the associated Schmidt Hammer testing do not follow accepted practice for the testing of in-situ concrete. The following factors undermine the statistical basis upon which the conclusions were reached in the Hyland Reports.

CCANZ considers therefore that the Hyland Reports cannot satisfactorily conclude that (a) CTV Building column concrete was below the specified strength, and (b) that low concrete strengths in critical columns may have been a factor in the CTV Building collapse.

1. The Hyland Materials Report does not appear to have followed standard procedures in the interpretation of concrete core strengths and Schmidt Hammer results.

2. The number of cores taken to draw firm conclusions on the concrete strength was inadequate. As the specified design concrete strength reduced with the height of the building, and the location of five of the seven columns cored was unknown, this makes comparison of core strengths against specified strength problematic.

3. Core strengths have been compromised by being taken from areas of distressed concrete as a result of the building collapse and fire damage. These cores should have been rejected.

4. Aspect ratio (length/diameter) of three cores was less than 1.2, as against the recommended ratio of 1.9 – 2.1.

5. For five of the seven columns only two cores have been taken representing a particular column location. 16 of the 19 cores were only

70 mm diameter, for which BS EN 13791 recommends six cores be taken for each column.

6. Three outlier results were not removed from the core results.

7. No allowance has been made for voidage in determining characteristic strength of standard specimens.

8. The correlation of the Schmidt Hammer testing against core strengths was based on only six pairs of strength vs. Hammer results. BS EN 13791 recommends a minimum of nine pairs. The correlation curve derived in the Hyland Reports is in error and has not taken variation in concrete strength between columns into account. Also tests were taken on concrete which contained micro-cracks from the collapse which would effect the core and Schmidt hammer correlation. This places all the concrete strength determination from Schmidt Hammer readings in doubt.

9. The Hyland assumption of compressive strength increase with time after 28 days is questionable in a New Zealand context. The Caltrans reference (USA) quoted is for external concrete containing a cement blend. This does not apply to cements used in New Zealand and should not apply to the CTV concrete.

10. CCANZ has carried out its own interpretation of the core results and Schmidt Hammer results reported by Hyland. For both methodologies CCANZ reports average strengths significantly higher than the Hyland Reports. However, there are a number of issues on the adequacy of both the number and accuracy of the test results. CCANZ therefore does not consider that any conclusion can be reached on the adequacy of the in-situ concrete strength at the time of the collapse, and contends that the conclusions reached by Hyland in this regard are flawed.

11. CCANZ has not specifically carried out an evaluation of the concrete in the suspended slab. However, for the same reasons as listed above, CCANZ considers that the Hyland conclusion that the concrete may not have achieved the specified strength at the time of construction to be flawed.

12. The CCANZ interpretation gave compressive strengths of standard specimens significantly higher than the Hyland Reports. However, CCANZ considers that further testing is required to make any definitive conclusions regarding the concrete strengths of the columns.

Should clarification or further information be required in relation to any points raised in this submission please feel free to contact CCANZ. The concrete industry's technical resources remain available to assist the Royal Commission at any time.

Yours faithfully

Rob Gaimster
CHIEF EXECUTIVE OFFICER

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