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| **UNDER** | **THE COMMISSIONS OF INQUIRY ACT 1908** |
| **IN THE MATTER OF** | **ROYAL COMMISSION OF INQUIRY INTO BUILDING FAILURE CAUSED BY CANTERBURY EARTHQUAKES**<br>**KOMIHANA A TE KARAUNA HEI TIROTIRO I NGA WHARE I HORO I NGA RUWHENUA O WAITAHA** |
| **AND IN THE MATTER OF** | **THE CTV BUILDING COLLAPSE** |

# JOINT REPORT OF ELASTIC RESPONSE SPECTRA ANALYSIS PANEL

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## INTRODUCTION

1. This is the joint report pursuant to clause 9 of the Order of the Royal Commission dated 18 June 2012 in relation to Elastic Response Spectra Analysis (ERSA).

2. The purposes of the experts conferring were:

   2.1 To endeavour to reach agreement on the input data to be used to conduct an ERSA of the response of the CTV building to determine whether the design of the building was consistent with the provisions of NZS 3101:1982 and NZS 4203:1984

   2.2 Where agreement cannot be reached on the inputs, to identify:

      2.2.1 The inputs which cannot be agreed.

      2.2.2 The reasons for the disagreement

   2.3 To produce ERSA results which provide the most reliable model for the purposes set out in clause 1, and which can then be analyses and interpreted.

## TOPICS

3. This report address the following topics:

   3.1. Areas of agreement.

   3.2. Areas of disagreement, including the reasons for the disagreement.

   3.3. The results of any further ERSA/s.

## AREAS OF AGREEMENT

### Use of Elastic Response Spectra Analysis (ERSA)

4. From the lack of response from the panel it appears that all members of the panel were comfortable with ERSA analyses being used to verify the degree of code compliance of the CTV building. Mr Latham did query whether an ERSA analysis was required by the design standard of the time but the panel was asked to consider the data for the ERSA analysis and not whether it was, or was not, needed.

5. Clause 3.4.7.1 of NSZ4203:1984, was not written to deal with buildings that were dominated by a torsional response. Sub-clause (b) suggests that a two dimensional ERSA could be used instead of an equivalent static analysis. This would not pick up the torsional response at all. Sub-clause (b) then did recommend that a three dimensional ERSA could be used. The ARCL designer did use the three dimensional ERSA.

6. Prof. Carr believes that the current standard NZS1170-5:2004 does not necessarily deal with torsionally dominated responses any better than the 1984 standard. The current standard requires the number of modes considered to be enough to represent 90% of the translational inertia or mass of the structure. The torsional inertia does not have units of mass. The torsional inertia has units of mass times length squared. Further consideration needs to be given to buildings whose fundamental response is in a torsional mode.

## AREAS OF DISAGREEMENT

### Weights Used in Analysis

7. There was a degree of disagreement between Mr Latham and Dr Hyland on the weights used in the Compusoft ERSA analyses that were referred to in the Hyland/Smith report and those used in the original design by Alan Reay Consultants Ltd. (ARCL). Mr Latham regards that the weights of certain elements assumed in the Compusoft analyses were greater than those used in the original design. He considered that the overall building mass was therefore overestimated by approximately 5%. Mr Smith countered that the calculated weights differ by less than 1% from those used in the original analyses. It is important to note that the original calculation of the building mass was likely to have been carried out before the building was fully designed.

**Foundation Stiffness**

8. Mr Latham requested that the original Geotech Consulting Ltd. (Geotech) soil stiffness values supplied at the time that the building was designed be used in the analyses rather than the Tonkin & Taylor Ltd. (T&T) values used in the Compusoft ERSA Analyses. The Geotech soil stiffness values are smaller than those supplied by T&T and which were used in the Hyland/Smith report. A lower foundation stiffness would give a longer natural period of free-vibration for the structure. This would imply smaller design actions and possibly smaller inter-storey drifts. It appears from the ARCL calculations that the original analyses assumed a rigid foundation, i.e. the foundation is infinitely stiffer than that used for the Hyland/Smith report.

9. The analysis program ETABS used at the time of the original design would need to use a dummy storey below the building to represent a foundation flexibility (compliance) and there is no evidence in the ARCL calculations that this was done. This however, cannot be confirmed unless the original ETABS input or output is available. Dr Hyland found similar variations in the responses when he considered analysis cases including and excluding the Group 2 gravity-only frames within the computational model. Dr Hyland commented that a stiffer structure leads to higher frequency response and a more flexible structure leads to a lower frequency response, resulting in similar demands. In the context of a subsequent capacity design process the differences do not appear to be significant. The original design model appears to have excluded the gravity-only parts of the structure, and this was also the basis of the Compusoft ERSA used for code compliance checks in the Hyland/Smith report.

**Scaling of results**.

10. The standard requires that the ERSA analysis be scaled if the actions from the ERSA analyses were less than a specified fraction of those obtained from the equivalent static analysis. Mr Latham queried whether the scaling used by Dr Hyland was in accordance with the 1984 loadings standard. Mr Smith responded by providing a revised table with corrections to two of the base shears, and acknowledged that the scaling was not exact but within a few per cent which he considered reasonably good agreement.

11. A static analysis is much simpler than the ERSA analysis and as a result is a little more conservative in the design actions used, i.e. the equivalent static design actions are sometimes greater than those obtained from the ERSA. An example where they weren't was at the South Wall. Dr Hyland commented that his understanding was that the ERSA drifts should be used if they are greater than the static analysis drifts. This is a little problematic in that theoretically the ERSA drifts (calculated as the difference between maximum floor displacements) are not necessarily the maximum drift between floors unless the point drift option is used in the ETABS analysis. This option was not available in the ETABS program used at the time of the design. However, Dr Hyland's checks indicated that the direct use of the ERSA drifts are very similar to the point drifts. Dr Hyland thought that it is also better to use the ERSA drifts and perhaps make an allowance for additional effects rather than to ignore them on a technicality. The scaling was done in accordance with the requirements of the Standard NZS 4203:1984.

**RESULTS OF ANY FURTHER ERSA/s**

12. Mr Latham requested a further ERSA analysis be undertaken using the Geotech soil stiffnesses and corrected masses. With little response from the panel to the discussions and given that different foundation stiffnesses would have compensating effects on the analyses, Dr Hyland, Mr Smith and Prof. Carr considered that a further ERSA was not warranted. The Compusoft ERSA input files were transmitted to ARCL so that ARCL could review the inputs and carry out further ERSA analyses with modified inputs if they wished.

Signed: .....

**ATHOL CARR**

Date: 16 th July 2012

Signed: .....

**CLARK HYLAND**

Date: 25/7/12

Signed: .....

**ASHLEY SMITH**

Date: 25/7/2012

Signed: .....

**JOHN MANDER**

Date: 16/7/2012

Signed: .....

**ROBIN SHEPHERD**

Date: 17/07/2012

Signed: .....

**BRENDON BRADLEY**

Date: 16/7/2012

Signed: .....

**GRAEME MCVERRY**

Date: 25 JULY 2012

Signed: .....

**DOUGLAS LATHAM**

Date: 16 July 2012