MINISTRY OF EDUCATION
Te Tāhuhu o te Mātauranga

Report on Structural Testing of a Standard Classroom Block in Carterton in June 2013

'Avalon' Block, South End School, Carterton

October 2013

Executive Summary

This report outlines the purpose, scope and observations from a destructive test of a single-storey timber framed classroom block. The test was undertaken by the Building Research Association of New Zealand (BRANZ) on behalf of the Ministry of Education on 15 and 16 June 2013 in Carterton, Wairarapa.

Timber framed school buildings account for up to 90% of the Ministry's school property portfolio. This type of construction is generally acknowledged as presenting a low risk to occupants from seismic or extreme wind loading. However, traditional engineering assessment methods invariably result in low structural assessment values.

The destructive testing was performed on a standard type of school buildings, the 'Avalon' block, at South End School in Carterton. The block was selected for testing because it was a surplus block and scheduled for demolition.

The test has confirmed the view held by many engineers that timber framed buildings have an inherent lateral resistance and ductility beyond that which can be readily calculated. The longitudinal and transverse tests support the use of higher ductility and F factors within the Initial Evaluation Procedure to take account of the inherent ductility and damping of timber framed buildings, as recommended in the Ministry's Guidelines for the Seismic Evaluation of Timber Framed School Buildings (June, 2013).

Consideration is being given to reflecting the good performance of these structures by using a lower structural performance (S_p) factor. This will generate greater calculated probable strengths when used in quantitative (detailed) assessments and better reflect actual performance. Further work on this is being carried out in conjunction with the wider national project to update the New Zealand Society for Earthquake Engineering seismic assessment guidelines. The initial indications from analysis following this test are that a factor of two can be applied to the calculated probable strengths of single storey timber framed buildings with light roofs.

The Ministry is considering whether other types of school buildings could usefully be tested, in order to enhance the applicability of the test outcomes and to provide further evidence of the resilience of single and two storey timber buildings.

Contents

1. Background

Timber framed school buildings account for up to 90% of the Ministry of Education's school property portfolio. This type of construction is generally acknowledged as presenting a low risk to occupants from seismic or extreme wind loading. However, traditional engineering assessment methods (qualitative or quantitative) invariably result in low structural assessment values, due to the few identifiable bracing elements that are typically present. The resulting low assessment scores for many classroom blocks from Canterbury and other regions led the Ministry's Engineering Strategy Group to recommend that a destructive test of a standard classroom block be undertaken in order to provide specific information to better inform structural assessments.

The test involved two classrooms that formed part of a four-classroom 'Avalon' block at the South End School, Carterton (as shown on the front page). This block was selected for testing because it was a surplus block and scheduled for demolition. The Avalon block is a common building type that occurs in a number of primary schools in many regions. These blocks feature extensively glazed facades and clerestory windows, aspects which are also present in a number of other standard classroom designs.

2. Overview of Avalon Blocks

Constructed in the late 1950s and early 1960s, this single storey timber framed classroom block features a front wall that is essentially fully glazed, with no recognisable structural bracing panels. The classroom ceiling features a high-level vertical glazed (or 'clerestory') section, again with no identifiable form of bracing to connect the upper 6" x 1" diagonal board sarked diaphragm to the lower tongue and grooved board sarked diaphragm over the rear of the classroom and the cloakroom area.

The transverse walls are lined on the inside with 4.5mm ply at the lower levels and softboard ('pinex') at the upper levels, with weatherboard and either opposing 6" x 1" let in diagonal braces or fitted 4" x 2" diagonal braces to the exterior (end) walls, both in an inverted "V" pattern. There are two external walls and one internal wall in a two-classroom block.

An indicative plan and side elevation are shown in Appendix 1. The block selected for testing was constructed as a four-classroom block, but the end classrooms were removed to produce a two-classroom block for this test, given the capacity constraints of the test equipment.

3. Assessed Structural Capacity and Demand

The capacity of a two-classroom Avalon Block has been estimated based on plans of a standard block dated 1964. It is difficult to accurately predict the strength of a building of this type due to the inherent redundancy provided by secondary elements.

Table 1 shows the capacity values that have been calculated under two commonly used engineering criteria. *Probable Strength* (or *Unfactored Capacity*) is the value which correlates to the approach used for assessing existing buildings in accordance with the New Zealand Society for Earthquake Engineering (NZSEE) 2006 Guidelines "Assessment and Improvement of the Structural Performance of Buildings in Earthquakes". *Overstrength Capacity* makes allowance for material overstrengths, including factors such as 1.25 for timber studs in bending and 2.0 for shear walls.

Estimated Actual Capacity was also identified in order to provide an estimate of the likely pull-over capacity of the building, taking into account material overstrength, the capacity provided by secondary members and redundancies in the building.

Table 1: Assessed Structural Capacity

	Calculated Capacities		Estimated Actual Capacity
	Probable Strength Capacity	Overstrength Capacity	
Longitudinal Direction (2 classroom block)	**27 kN**	**43 kN**	**65 – 130 kN**
Transverse Direction (individual internal wall)	**9 kN**	**11 kN**	**17 kN - 34 kN**

For comparison purposes, Table 2 gives a summary of the lateral load requirements for a two-classroom Avalon Block on a Wellington site, corresponding to different levels of '%New Building Standard' ('%NBS'). These demands are based on a site subsoil class of C, an Importance Level of 2, a ductility of 2.5 and an assumed period of 0.4 seconds in accordance with the Ministry's "Guidelines for the Seismic Evaluation of Timber Framed School Buildings" (2013). This is a global demand calculation and does not take into account the tributary areas or specific loading of individual elements.

Table 2: Structural Demand

% NBS	Lateral Load (kN)
100	40
66	26
33	13

4. Scope and Format of Test

The test was undertaken by BRANZ engineers on 15 and 16 June at South End School in Carterton. Details of the test configuration and arrangements are provided in BRANZ report ST0961 "Load Testing of a Two Classroom Avalon Block at Carterton South End School" (2013).

The first test involved simulated lateral loading in the longitudinal direction of the classroom (parallel with the main glazed façade) of the whole block. Lateral force was applied in increasing increments in alternating cycles from each end of the building using a hydraulically movable 'fifth wheel' capable of traversing approximately 1.4m on a house removal truck, which in turn was anchored by a small excavator. The force was applied via three connection points at roof level, corresponding to the front (glazed) wall line, the clerestory window line and the rear (lower) wall.

A second similar test was undertaken to one of the internal transverse walls, with only single direction forces being applied due to site constraints.

A sample of images taken during the test is shown in Appendix 2.

5. Test Outcomes

Detailed test results are presented in the BRANZ report. The Load vs. Displacement plot for the longitudinal test from the BRANZ report is reproduced as Figure 1 following, and principal achieved strengths for both directions of testing are indicated in Table 3.

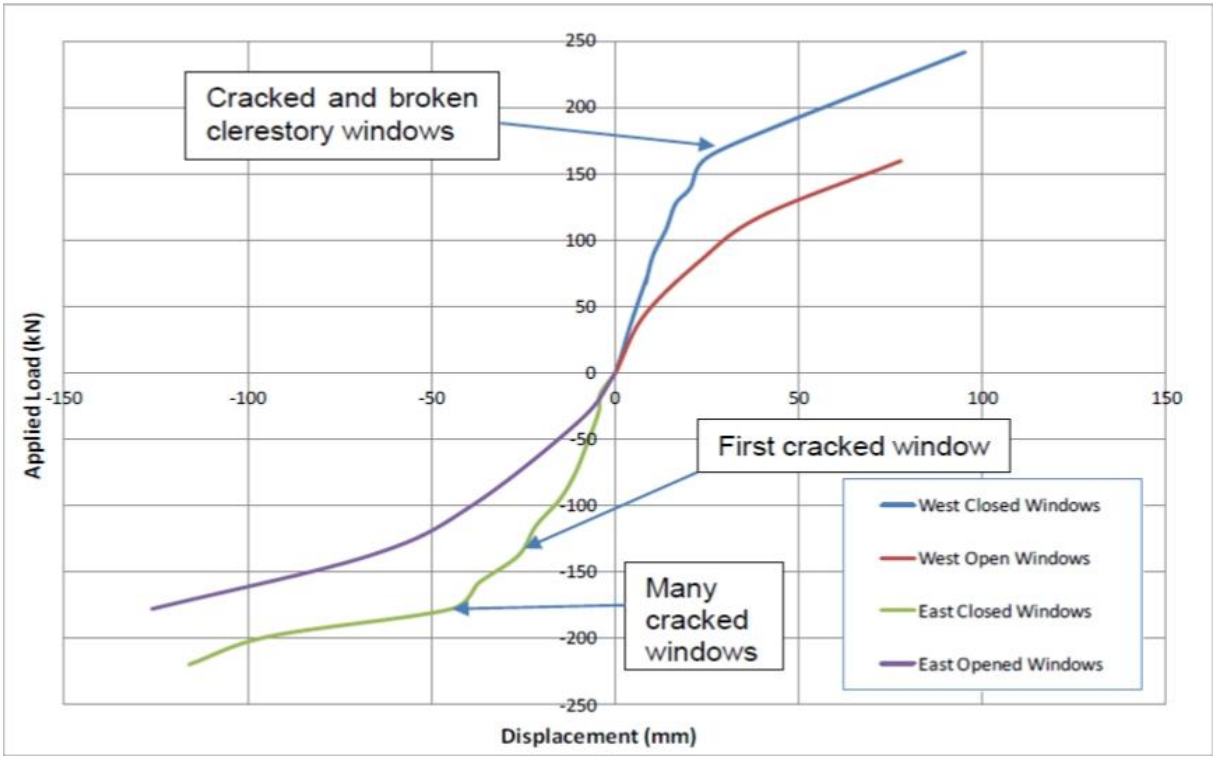


Figure 1: Longitudinal Test – Load vs. Displacement Plot

Table 3: Assessed Structural Capacity and Test Results

	Calculated Capacities		Estimated Actual Capacity	Actual Strength Achieved	Indicative Factor (Ratio of Actual/ Probable)
	Probable Strength Capacity	Overstrength Capacity			
Longitudinal Direction (two-classroom block)	**27 kN**	**43 kN**	**65 – 130 kN**	**185 kN**	**6.8**
Transverse Direction (individual internal wall)	**9 kN**	**11 kN**	**17 kN - 34 kN**	**35 kN**	**3.9**

For the longitudinal test, the first glazing crack occurred in the front façade at loading to 158kN. The rear clerestory windows shattered at 185kN. The building withstood a maximum loading of 242kN (the maximum capacity of the test equipment) without showing any signs of imminent collapse.

In Table 3, the *actual strength achieved* is shown as 185kN, reflecting the point at which a life safety condition was reached by the failure of the rear clerestory windows. It is important to note that this level of strength achieved does not represent structural failure, a condition that was not actually reached in the longitudinal test. This form of glazing vulnerability could be readily remediated by the application of a safety film.

Key observations and results are summarised as follows:

Test 1 – Longitudinal (whole building)

- Failure of some panes in the front façade occurred at about five times the calculated probable capacity. The ridge level displacement at this point was 35 mm.
- Failure of the rear high level (clerestory) windows occurred at between six and seven times the calculated probable capacity of the structure. The ridge level displacement at this point was approximately 45mm.
- During the earlier cycles of loading, the windows to the front wall, the rear clerestory section and the rear cloakroom wall were opened in order to generate greater lateral deformation or drift.
- With the windows closed, a peak drift of the front wall of approximately 70 mm (or 2.4%) was achieved at a load of 242 kN (significantly in excess of 100% New Building Standard), with little impact on vertical load carrying capacity evident. With the windows open, a front wall drift of approximately 65 mm (or 2.2%) was achieved at a load of 160 kN (also significantly in excess of 100% New Building Standard).

Test 2 – Transverse (single wall)

- The transverse (classroom dividing) wall did not include the 6” x 1” diagonal bracing members as anticipated. Plywood lining of 4.5mm thickness extending 2.1m on both sides above floor level was however present.
- Despite the thinness of the plywood lining, it appeared that the combination of skirting boards, dado rails at the door head, nogs between studs and other miscellaneous fixtures on the wall (such as blackboards) resulted in a stiff and strong lower section of the wall. As a consequence, the failure mode of this wall was minor axis bending of the timber studs, and occurred at a lateral load of 35kN. This load level is approximately four times the calculated probable strength of the wall as constructed.
- This test therefore showed that this element also significantly exceeded its calculated probable capacity.
- The calculated transverse strength of the block is 53kN, which is approximately 130% NBS. Although the whole block was not tested in the transverse direction, information from the test suggests that the actual transverse strength is likely to be significantly in excess of 100% New Building Standard.

The test has confirmed the general expectation that timber framed buildings with the traditional older glazed facades have a strength and resilience significantly in excess of their nominal calculated capacity.

6. Implications and Next Steps

The whole of building test has confirmed observations from the Canterbury earthquakes about the resilience of timber framed buildings. Both the longitudinal and transverse tests have also confirmed the view held by many engineers that timber framed buildings constructed prior to modern seismic codes have an inherent lateral resistance and ductility beyond that which can be readily calculated. Timber framed buildings constructed under modern seismic code requirements are expected to have earthquake resilience that meets or exceeds current building code requirements.

Although only a single test was undertaken in each direction, the tests confirm that single storey timber framed structures with light roofs are highly unlikely to be earthquake prone as defined by the current legislation. Timber framed buildings with heavy roofs are also unlikely to be earthquake prone. However, the potential dynamic effects associated with elevated masses such as from a heavy roof need further consideration. Replacing heavy tile roofs with lighter materials is an important risk mitigation measure. Most early school buildings with heavy roofs were identified as part of the 1998 national structural survey of schools, with either replacement or specific structural strengthening having been undertaken since.

Both the longitudinal and transverse tests support the use of higher ductility and F factors within the Initial Evaluation Procedure (IEP) to take account of the inherent ductility and damping of timber framed buildings, as recommended in the “Guidelines for the Seismic Evaluation of Timber Framed School Buildings” (2013).

Consideration is being given to reflecting the good performance of these structures by using a lower structural performance (S_p) factor. This will generate greater calculated probable strengths when used in quantitative (detailed) assessments and better reflect actual performance. The initial indications from analysis following this test are that a factor of two can be applied to the calculated probable strengths of single storey timber framed buildings with light roofs.

The Ministry is considering what other buildings within the Ministry’s portfolio could usefully be tested, in order to enhance the applicability of the test outcomes and to provide further evidence of the resilience of single and two storey timber buildings.

An overall report which draws together Canterbury earthquake observations and subsequent analysis of standard classroom blocks, in addition to this test, is separately being prepared.

7. References

BRANZ, *Load Testing of a Two Classroom Avalon Block at Carterton South End School*, BRANZ report ST0961, 2013.

Ministry of Education, *Guidelines for the Seismic Evaluation of Timber Framed School Buildings*, 2013.

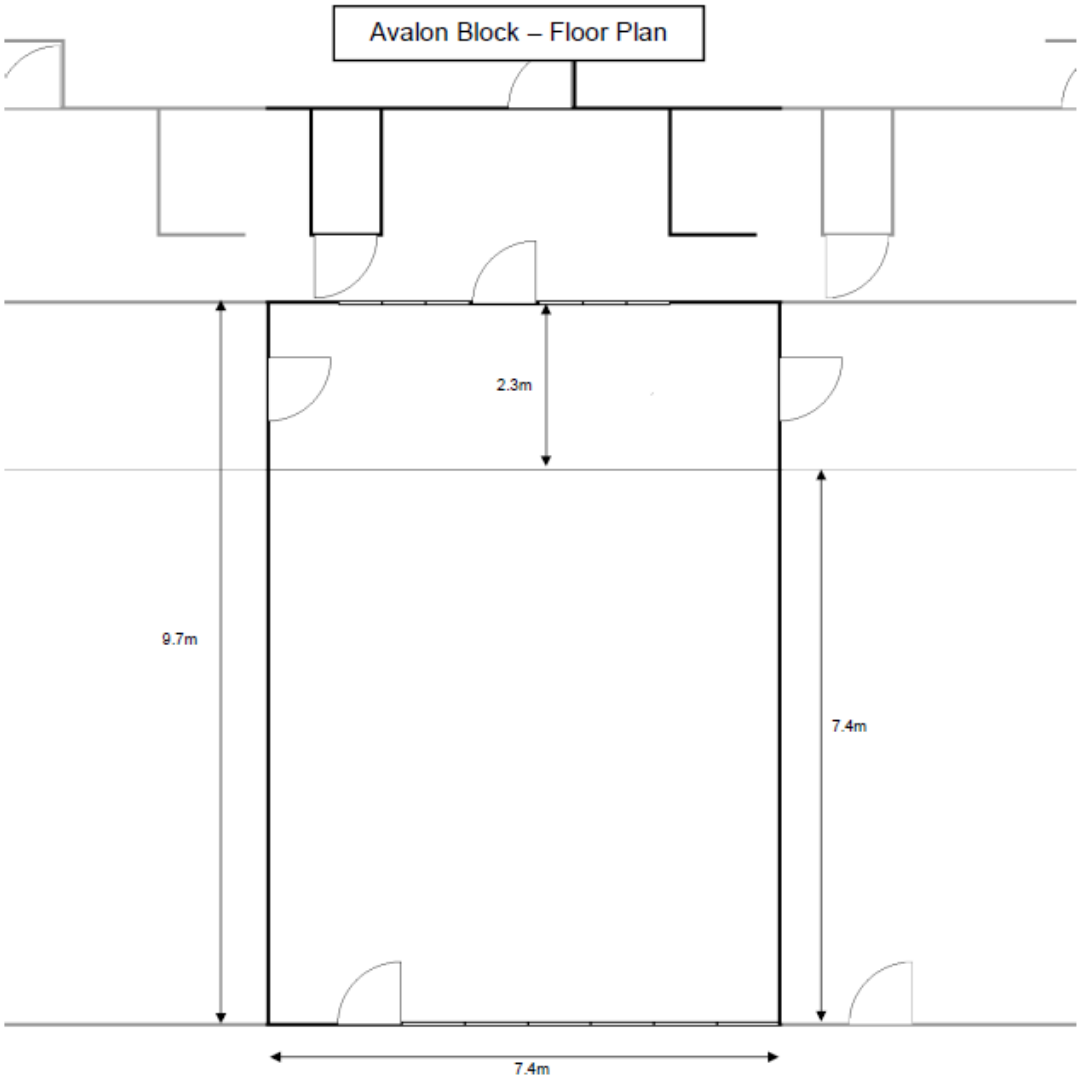
NZSEE, *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes*, New Zealand Society for Earthquake Engineering, 2006 (including Corrigenda 1 and 2).

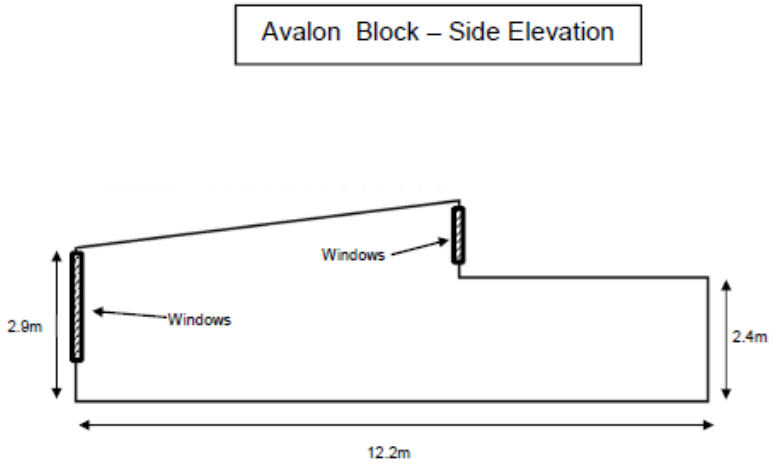
8. Acknowledgements

The Ministry of Education acknowledges the contributions of the following parties:

- The Ministry's **Engineering Strategy Group** for providing technical leadership and overseeing the testing;
- **BRANZ** for designing and undertaking the testing programme, and providing a technical report;
- **Aurecon** for surveying, and pre and post test analysis;
- **IR Build** for preparing the building for testing and project managing all site works; and
- **South End School** for supporting the testing and enabling the testing to occur on their school site.

Appendix 1: Layout of Avalon Block Classroom





Appendix 2: Images from Testing

Figure 2.1: Classroom block in early stages of test

Figure 2.2: Clerestory configuration

Figure 2.3: Connection point near front wall line

Figure 2.4: Cable junction and load cells

Figure 2.5: Building at peak drift to the east (windows open)

Figure 2.6: Building at end of longitudinal test

Figure 2.7: Building at peak longitudinal drift (windows open)

Figure 2.8: Building at peak longitudinal drift (windows open)

Figure 2.9: Transverse wall at peak drift

Figure 2.10: Softboard panels separating from the wall

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