MINISTRY OF EDUCATION
Te Tāhuhu o te Mātauranga

Report on Structural Testing of a Standard Classroom Block in Christchurch in December 2013

‘Dominion’ Block, Hammersley Park School, Shirley, Christchurch

February 2014

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 BRANZ Ltd on behalf of the Ministry of Education on 9 and 11 December 2013 in Shirley, Christchurch.

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 'Dominion' block, at Hammersley Park School in Shirley, Christchurch. The school had been closed in January 2013. The block selected for testing had suffered minimum damage during the Christchurch earthquakes and was assessed as a suitable candidate for the test.

The Hammersley Park test has confirmed the results of previous full-scale destructive testing carried out in Carterton in June, 2013. These results support 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 has been 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 latest test outcomes support the recommendation of the Ministry's Engineering Strategy Group following the first destructive testing that a factor of two can be applied to the calculated probable strengths of single storey timber framed buildings with light roofs. 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.

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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 destructive testing be undertaken on standard classroom blocks to provide specific information to better inform structural assessments.

The first destructive test was carried out on an 'Avalon' Block at South End School, Carterton in June of 2013. It 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 decision was then made to undertake a second destructive test on another standard type of classroom block, in order to enhance the applicability of the Carterton test outcomes and to provide further evidence of the resilience of single and two storey timber buildings.

The second test involved three classrooms that formed part of a large 'Dominion' block at Hammersley Park School, Shirley, Christchurch (as shown on the front page). The school had been closed in January 2013 and the buildings deemed surplus. The block selected for testing had suffered minimal damage during the Christchurch earthquakes and was assessed as a suitable candidate for testing.

The Dominion block is a common building type that exists in a number of primary schools in many regions. These blocks feature extensively glazed facades and diagonally braced timber framed walls, elements that are present in a number of other standard classroom designs. The tested block was clad in brick veneer, which appears more common in the South Island than in the North Island, where weatherboard cladding is typical.

2. Overview of Dominion Blocks

Constructed in the early 1950s, this single storey timber framed classroom block features a front wall that is essentially fully glazed except for one part height cross braced panel per classroom. The rear wall of each classroom also has high level glazing running most of the width. Ceiling bracing is made up of single 6" x 1" diagonal timber members nailed into the top side of the bottom chord of each truss. Lightweight corrugated steel roof cladding is fixed directly to timber trusses, with no sarking present. The standard Dominion block originally featured heavy roofing tiles; however, these were replaced circa 2000 as part of the Ministry's initiative to remove heavy roofs.

The transverse walls are set out such that pairs of classrooms share a storage space as shown in Appendix 1: Layout of Dominion Block Classroom). These walls feature timber cross bracing cut on a 45 degree angle and lined on the inside with softboard ('pinex'). External cladding consists of either bevel back weatherboards or brick veneer fastened to timber framing with wire ties. Neither of these cladding types is expected to provide additional lateral bracing, however the seismic load imposed on the building will be higher for buildings with brick veneer.

The block selected for testing was constructed as a multi-classroom block. Given the capacity constraints of the test equipment, the middle part of the classrooms was removed prior to the test to allow the longitudinal and transverse tests to be performed on different parts of the block. Two adjacent classrooms at the western end were tested in the longitudinal direction, and a single classroom at the eastern end was tested in the transverse direction.

3. Assessed Structural Capacity and Demand

The capacity of the selected classrooms has been estimated based on plans of a standard block dated 1954. 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 (two-classroom block)	**25 kN**	**38 kN**	**55 – 112 kN**
Transverse Direction (single classroom)	**51 kN**	**102 kN**	**152 - 303 kN**

For comparison purposes, Table 2 gives a summary of the lateral load demand for a two-classroom, weatherboard clad Dominion 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

	Lateral Load (kN)	
% NBS	**Single Block**	**2 Classroom Block**
100	36	72
66	24	48
33	12	24

4. Scope and Format of Test

The test was undertaken by BRANZ engineers on 9 and 11 December 2013 at Hammersley Park School, Shirley, Christchurch. Details of the test configuration and arrangements are provided in BRANZ report ST1004 “Load Testing of a Dominion Block at Hammersley Park School” (2014).

The first part of the 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 excavator at one end of the block and a truck which both acted as deadman anchors. The force was applied via two connection points at roof level, corresponding to the front (glazed) wall line, and the rear wall.

A similar test was carried out in the transverse direction on a single classroom, with loads being applied directly to the top plates of the walls.

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 plots for the longitudinal test and transverse tests are shown in Figures 1 and 2 respectively. Principal achieved strengths for both directions of testing are indicated in Table 3.

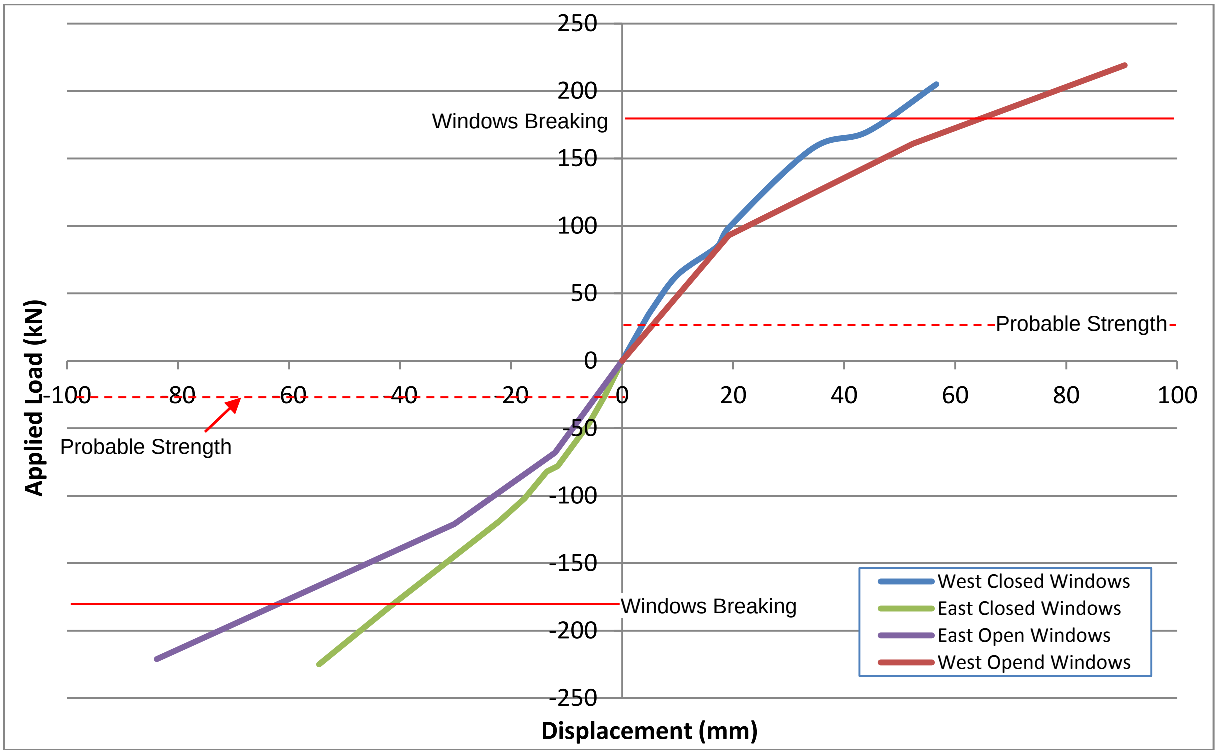


Figure 1: Longitudinal Test – Load vs. Displacement Plot

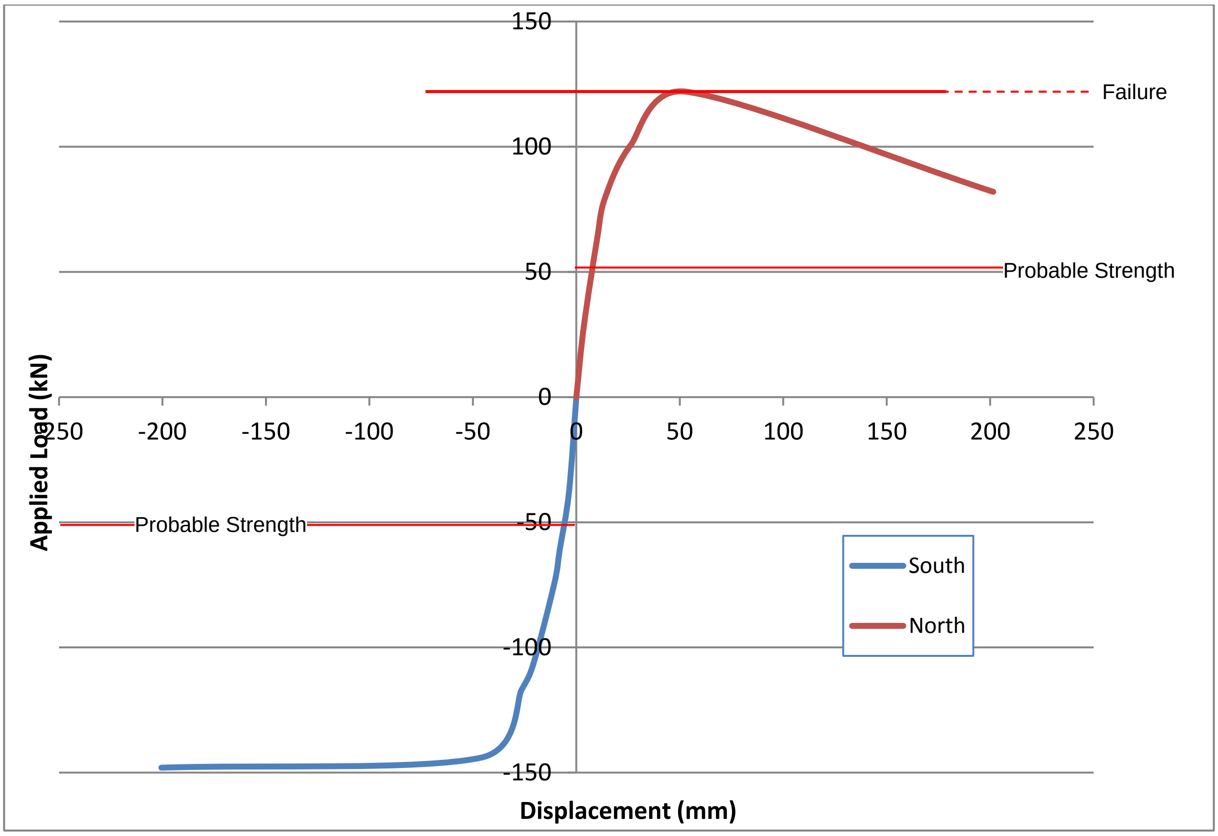


Figure 2: Transverse Test – Load vs. Displacement Plot

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)	**25 kN**	**38 kN**	**55 – 112 kN**	**200 kN**	**8.0**
Transverse Direction (single classroom)	**51 kN**	**102 kN**	**152 - 303 kN**	**125 kN**	**2.5**

For the longitudinal test, the first glazing crack occurred in the front façade at loading to 180kN. Rear high-level windows started to shatter at loads of 200kN. The building withstood a maximum loading of 262kN before a local failure occurred at the points of load application. At this maximum load level there was no sign of imminent collapse.

In Table 3, the *actual strength achieved* is shown as 200kN, reflecting the point at which a life safety condition was reached by the failure of the high level 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 (two-classroom block)

- Failure of some panes in the front façade occurred at about seven times the calculated probable capacity. The ridge level displacement at this point was about 49 mm.
- During the earlier cycles of loading, the windows to the front and rear walls as well as in the cloakroom were opened in order to generate greater lateral deformation or drift.
- With the windows closed, a peak drift of the front wall of approximately 55 mm (or 1.5%) was achieved at a load of 220 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 90 mm (or 2.5%) was achieved at a load of 220 kN (also significantly in excess of 100% New Building Standard).

Test 2 – Transverse (single classroom)

- Once wall linings became loose due to transverse displacements it became clear that the classroom being tested had been subjected to a fire, resulting in some charring of wall framing members. This is not expected to have had a significant effect on the results of the test.

- Plumbing work that had been carried out in the classrooms in the past had removed the continuity of the angle braces in one of the walls (as shown in Figure 2.10, Appendix 1). Alterations of this type have a detrimental effect on a buildings capacity, are difficult to identify without removing wall linings, and are likely to be fairly common in school buildings.
- This test showed that the classroom also exceeded its calculated probable capacity in this direction.
- The calculated transverse strength of the block is 51kN, which is approximately 130% NBS. Information from the test suggests that the actual transverse strength is likely to be significantly in excess of 100% New Building Standard.
- The single classroom was tested to destruction. Drifts well in excess of 5.6% (200mm) were achieved with the building still able to support itself under gravity loads (see Figure 2.11).

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 Hammersley Park test, in conjunction with previous testing carried out on an Avalon Block in June 2013 and similar testing carried out by Housing New Zealand in November 2013, has confirmed observations from the Canterbury earthquakes about the resilience of timber framed buildings.

Both the longitudinal and transverse tests on the Dominion block at Hammersley Park School have 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.

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 has been given to reflecting the good performance of these structures by using a lower structural performance (S_p) factor. Currently an Sp factor of 0.35 is being promoted as satisfactory for timber classroom structures with light roofs. This will generate greater calculated probable strengths when used in quantitative (detailed) assessments and better reflect actual performance. The latest test outcomes support the recommendation of the Ministry’s Engineering Strategy Group following the first test in Carterton that a factor of two can be applied to the calculated probable strengths of single storey timber framed buildings with light roofs. 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.

An overall report which draws together Canterbury earthquake observations and subsequent analysis of standard classroom blocks, in addition to the outcomes of the Ministry's two destructive tests, is separately being prepared.

7. References

BRANZ, *Load Testing of a Dominion Block at Hammersley Park School*, BRANZ report ST1004, 2014.

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

Ministry of Education, *Report on Structural Testing of a Standard Classroom Block in Carterton in June 2013*, 2013.

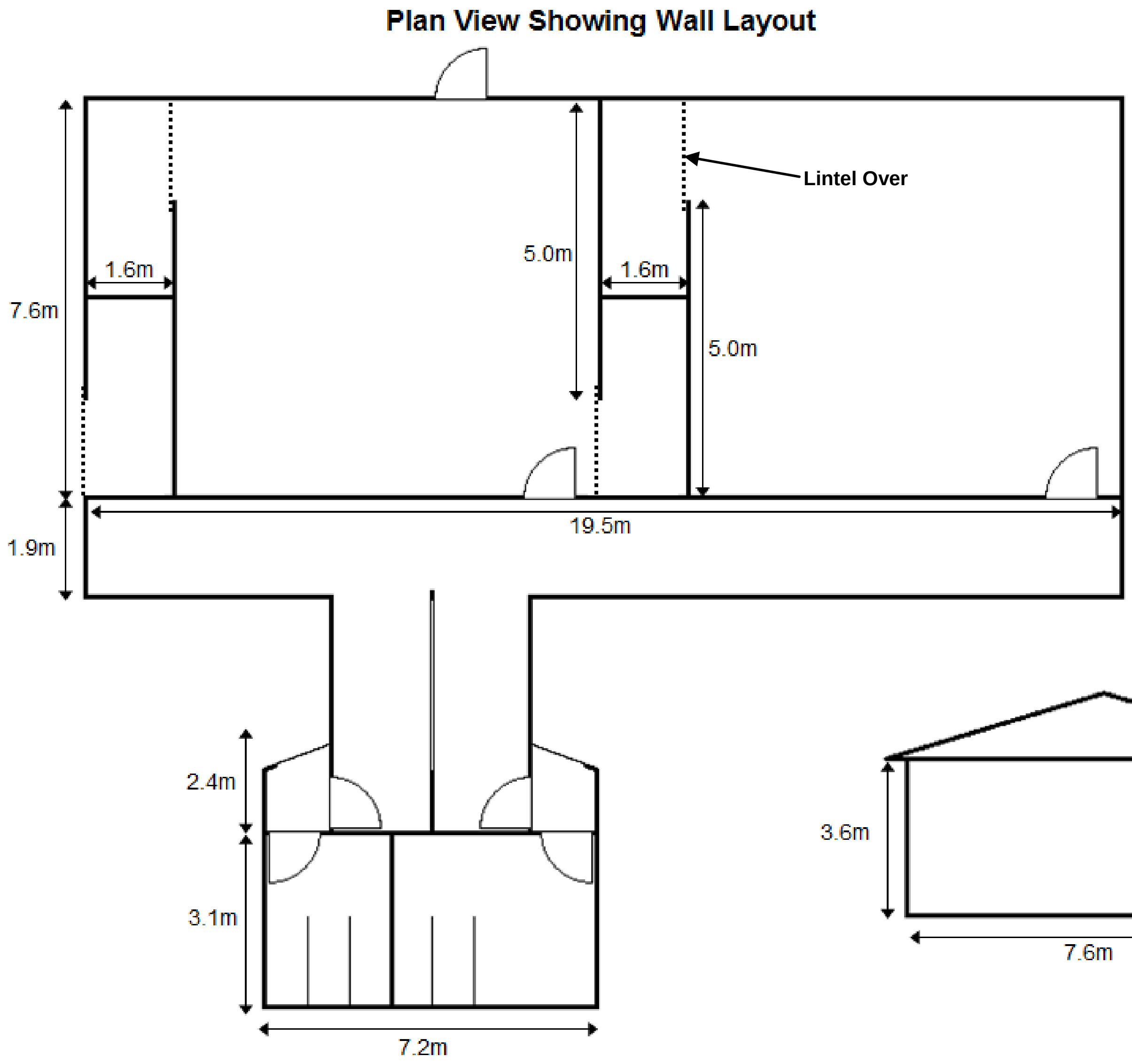
NZSEE, *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes*, New Zealand Society for Earthquake Engineering, 2006 (including Corrigenda 1 and 2).

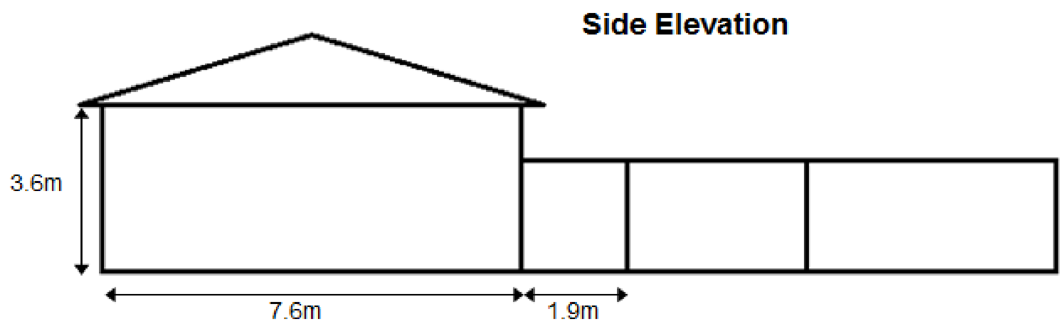
8. Acknowledgements

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 Ltd** 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;
- **Galletly Builders** for test preparation and building demolition work; and
- **King House Removals** for supply and operation of heavy haulage equipment.

Appendix 1: Layout of Dominion Block Classroom





Appendix 2: Images from Testing

Figure 2.1: Classroom block in early stages of test

Figure 2.2: Rear wall configuration

Figure 2.3: Connection points for longitudinal testing

Figure 2.4: Loading rig applying lateral load

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

Figure 2.6: Local failure at the connection point at end of longitudinal test

Figure 2.7: Transverse test setup including loading rig

Figure 2.8: Transverse test showing high levels of drift

Figure 2.9: Cracking of veneer attached to the braced timber wall frame (longitudinal test)

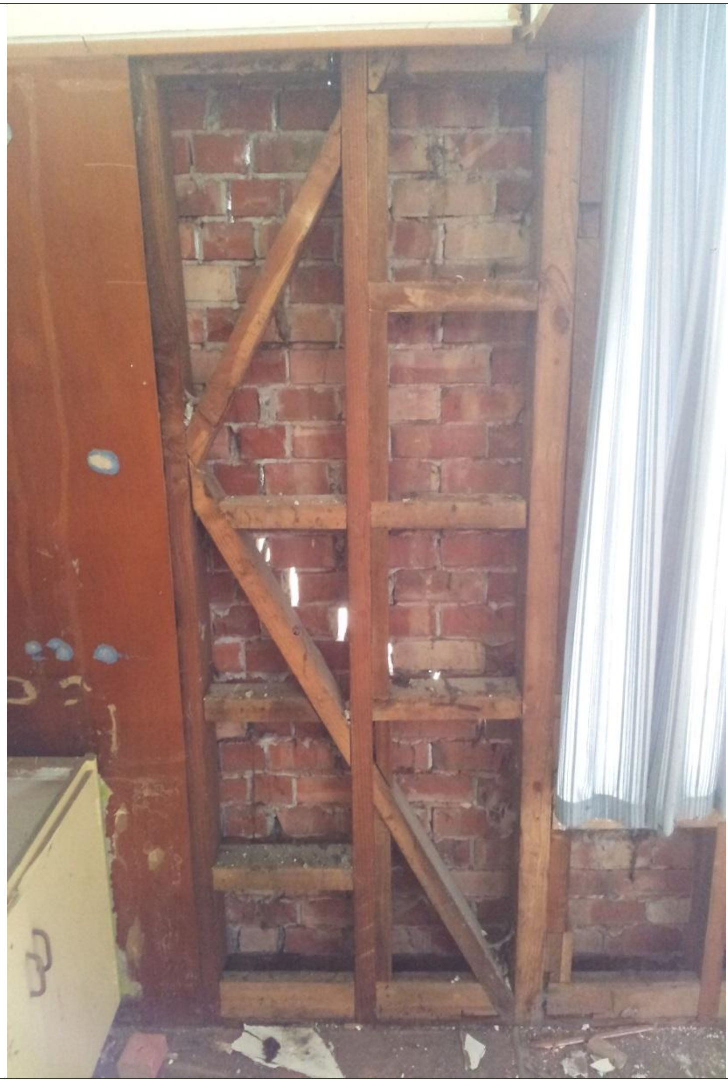


Figure 2.10: Wall bracing in panels on the north wall (longitudinal test)

Figure 2.11: Western transverse wall showing failure of cross bracing member (previous plumbing work interrupted the continuity of the angle bracing)

Figure 2.12: Eastern transverse wall showing failure of cross bracing member

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