Study Report

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Investigative pull-out testing of anchors near corners of concrete house foundations formed with masonry header blocks

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Preface

This is a report on exploratory testing undertaken on bottom plate anchor installations near corners of concrete house foundations formed using masonry header blocks. The results of the testing were expected to provide an indication of whether fuller research was required to ensure that these anchors performed satisfactorily.

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Reference

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Abstract

It is likely that the framing in light timber-framed buildings will be altered in the near future so that less framing is required. One effect of this change is that hold-down bolts for the bottom plates of these structures will be placed closer to the corner of concrete foundations than they currently are. The effect could be particularly marked when the foundation is formed with masonry header blocks as the permanent formwork.

This report describes an exploratory investigation to determine the strength of anchors located close to the corners of such foundations. The exploratory testing has indicated that the strengths of these anchors is still more than is required for wall bracing elements that may be placed at the corner of light timber-framed building foundations.

Keywords

Bottom plate anchors, anchor pull-out, masonry header block

Contents

Figures

Tables

1. Motivation for the research

There is a push by the building industry towards a reduction in the quantity of framing in the walls of a light timber-framed house. This will result in reduced construction costs, but this arrangement may cause strength issues with bottom plate anchors installed on bracing elements that end at the corner of the house. This may be particularly problematic when the foundations are constructed using masonry header blocks.

Before the details become too commonly used, this project aims to determine whether there is a need to conduct more extensive testing in order to prove or disprove the details.

2. Background

Concrete house foundations are often constructed with masonry header blocks as the permanent formwork. The options for securing wall bottom plates to the foundation are either the inclusion of cast-in M12 bolts or proprietary anchors. Testing undertaken by BRANZ for proprietary anchor manufacturers over the years has shown that expanding anchors are not suitable. They can spall the masonry block shell from the foundation when under load or even if tightened too much during installation. As a consequence, proprietary anchor manufacturers specify screw anchors. These are convenient to install and may be installed once the wall frame is standing. Cast-in anchors are hardly ever used now for securing bottom plates.

Tests that are undertaken to determine the strength of these anchors are always conducted along the edge of a representative slab with masonry header blocks as the permanent formwork. Anchors are tested in shear (in two orthogonal directions) and in tension. NZS 3604:2011 *Timber-framed buildings* has strength requirements that must be attained in the tests. These requirements are for walls that do not have a bracing function. When a bracing panel is included in the wall, the hold-downs for the end of the bracing panel can have a tension demand up to 15 kN. The tests that are undertaken for manufacturers will also determine whether the anchor can take this load.

However, all of the tests are done with anchors spaced at least 400 mm from the end of the foundation. When bracing elements are placed at the corner of a dwelling, this means the hold-down anchor is located at approximately 160 mm from the corner of the foundation (see Figure 2). There is a reasonable amount of concrete beyond the anchor for both foundation types.

The existence of a spare slab of concrete constructed with masonry header blocks at BRANZ provided the opportunity to conduct exploratory strength tests on screw anchors installed near the four corners of the slab.

3. Test specimen properties

3.1 Concrete slab

The test slab available for the tests was cast on 28 January 2014. It was 2,530 mm long by 580 mm wide by 190 mm thick. It was reinforced centrally with 665 reinforcing mesh to aid transport, but the mesh played no part in the determination of the strength of the anchors. The slab was formed using 20-45 masonry header blocks as permanent formwork. The blocks were butted together with no mortar jointing for ease of construction, and the concrete was poured inside the masonry block formwork. Details of the specimen are presented in Figure 1.

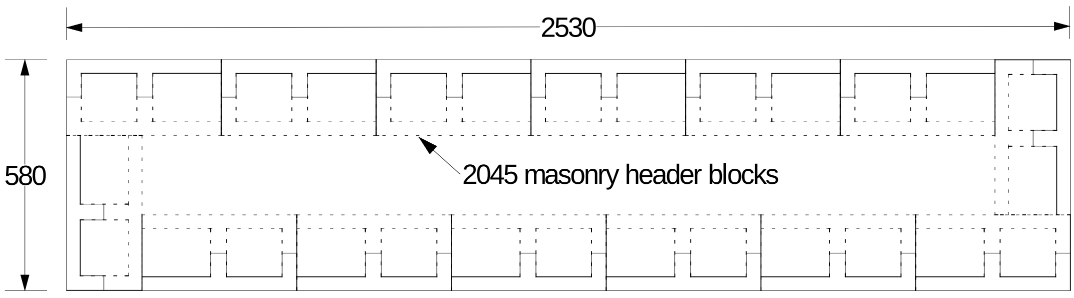

Figure 1. Details of the reinforced concrete slab (mesh omitted for clarity).

Cores were taken from the slab and compression strength tested by Materials Testing and Advisory Services Ltd on 9 November 2015. The age at testing was 651 days. The mean strength of the three cores was 17.5 MPa. The anchor investigation was undertaken in February 2016, and it was expected that the concrete strength would not have increased significantly since the date of the compression tests on the cores.

3.2 Masonry anchors

The masonry anchors chosen for testing were typical of what is used with proprietary hold-down systems at the ends of bracing wall elements in light timber-framed construction to NZS 3604:2011. These were 140 mm long M10 screw anchors, which are fitted in a predrilled 10 mm diameter hole. The anchors are hardened steel and are therefore capable of cutting a thread in the concrete in much the same way as a coach screw is fitted into timber.

4. Traditional and reduced framing details

Acceptable Solution E2/AS1 for New Zealand Building Code clause E2 *External moisture* requires that direct-fixed cladding is installed with a space of 6 mm between the cladding and the concrete foundation to prevent capillary action.

To simply achieve this requirement, the timber bottom plate of the framing is installed with a 6 mm overhang on the edge of the slab.

Figure 2 shows the typical location of hold-down bolts for bracing elements in each wall, installed at the corner of the foundation using typical framing details.

Figure 3 shows the potential locations of the hold-down bolts for the reduced 90 x 45 mm wall framing layout, and Figure 4 shows the potential locations of the bolts for the reduced 140 x 45 mm framing.

It can seen from Figure 3 and Figure 4 that, with the reduced framing layout and particularly for the 90 x 45 mm framing, the hold-down bolts are closer to the corner of the foundation.

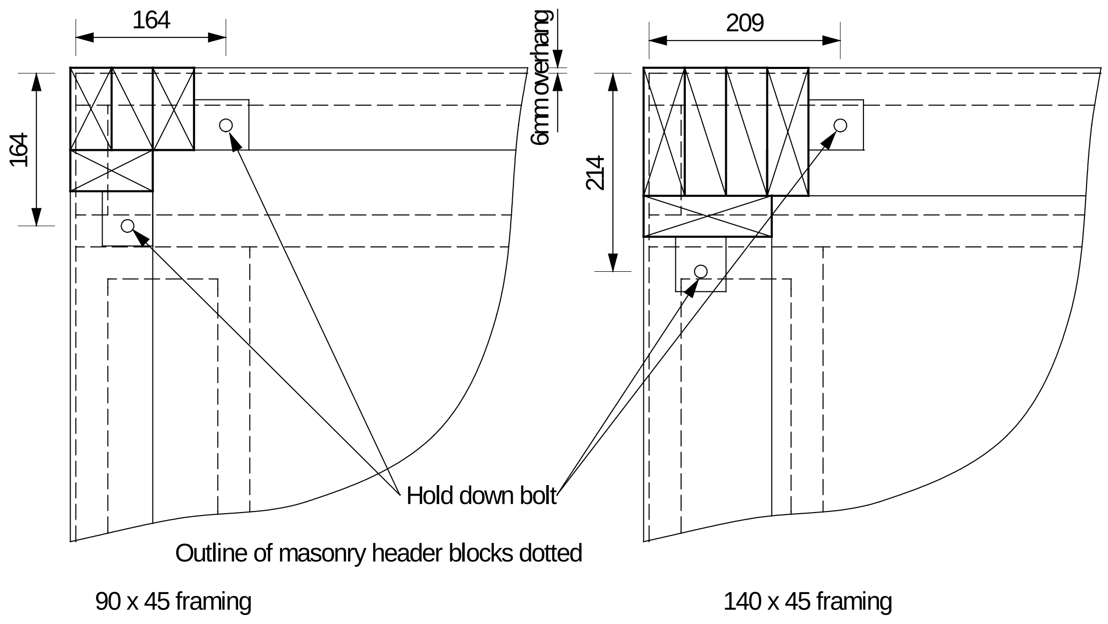

Figure 2. Layout of traditional wall framing at a foundation corner showing hold-down bolt locations.

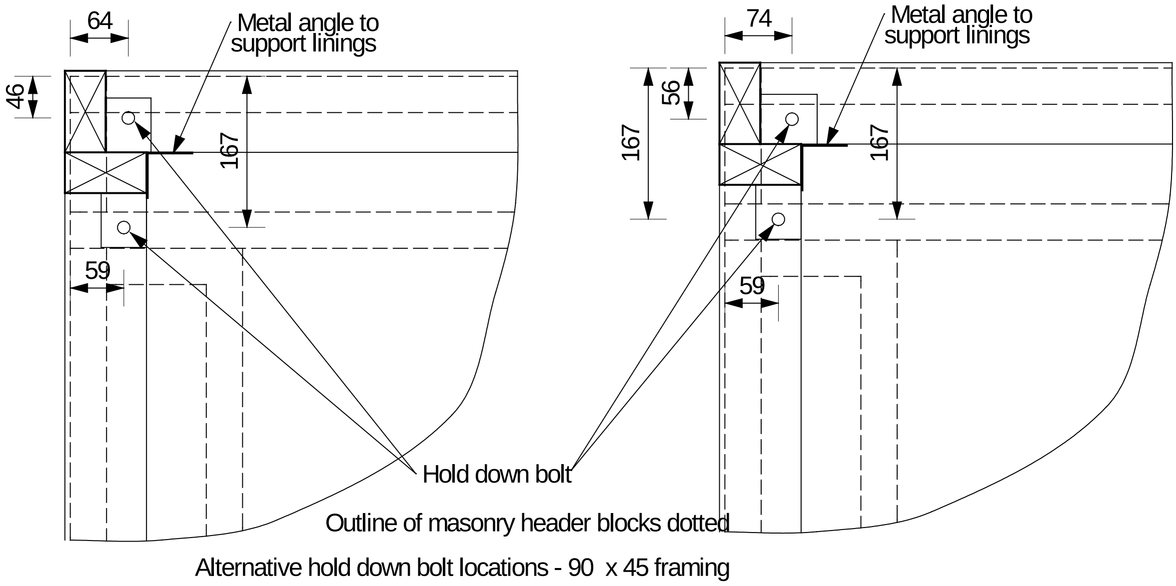

Figure 3. Layout of reduced wall framing at a foundation corner showing hold-down bolt locations – note that the upper hold-down bracket is either fixed to the stud in the lower wall (left diagram) or the stud in the upper wall (right diagram).

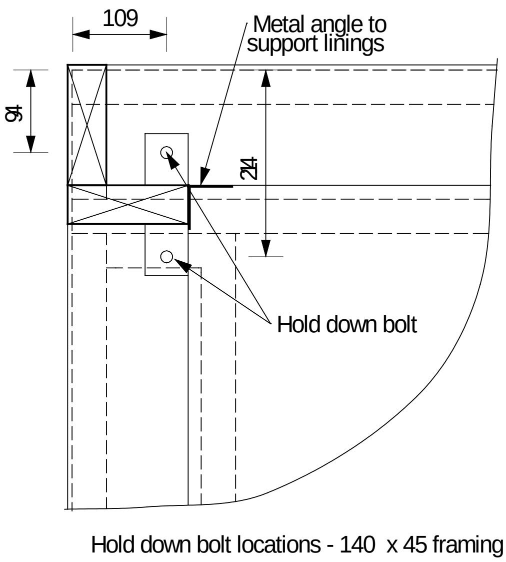

Figure 4. Layout of reduced 140 x 45 mm wall framing at a foundation corner showing hold-down bolt locations.

5. Experimental testing

5.1 Anchor locations

Four locations were available on the concrete slab for testing the performance of the screw anchor hold-down bolts. These are shown in Figure 5.

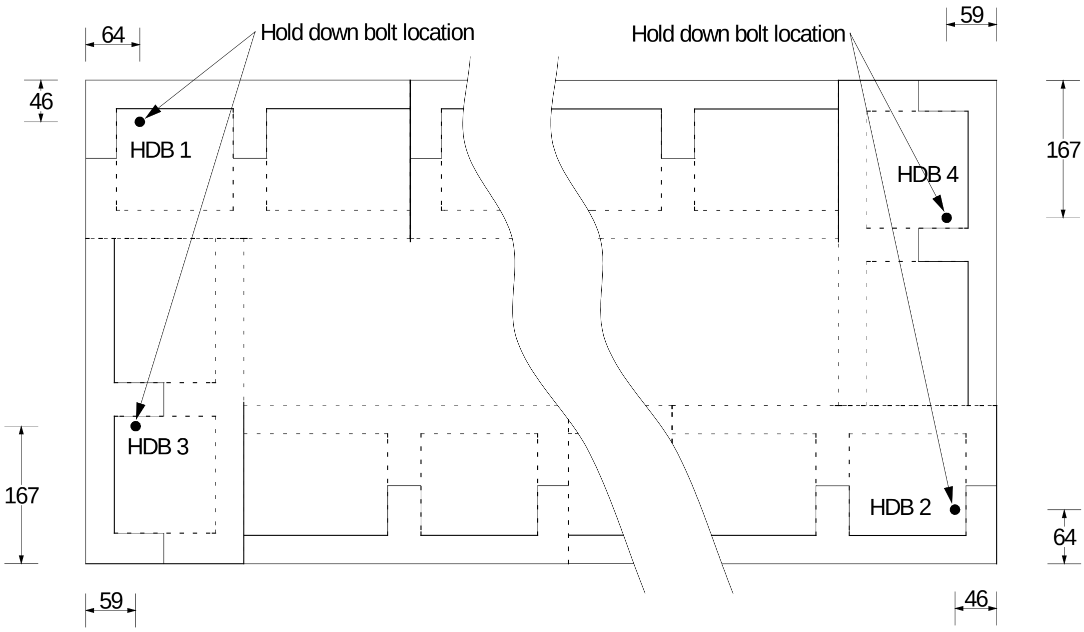

Figure 5. Plan of the test slab showing the location of the tests.

5.2 Test set-up

The 140 mm long M10 screw anchors were screwed into a 10 mm diameter predrilled hole in the concrete in much the same way as a coach screw is fitted into timber. Each anchor was installed to a depth of 90 mm to replicate the installation depth in practice.

Details of the tension test set-up are presented in Figure 6, and a view of the set-up is shown in Figure 7.

The slab was rigidly fixed against reaction frames, and the load was applied to the anchors with a 100 kN capacity closed loop hydraulic actuator and measured with a 50 kN load cell. The load cell used was within Grade 1 accuracy of international standard EN ISO 7500-1:2015 *Metallic materials – Calibration and verification of static uniaxial testing machines – Part 1: Tension/compression testing machines – Calibration and verification of the force-measuring system* .

The test load was recorded using an MTS control and datalogging system.

The load was applied to the anchor using a steel ‘shoe’ as shown in Figure 6.

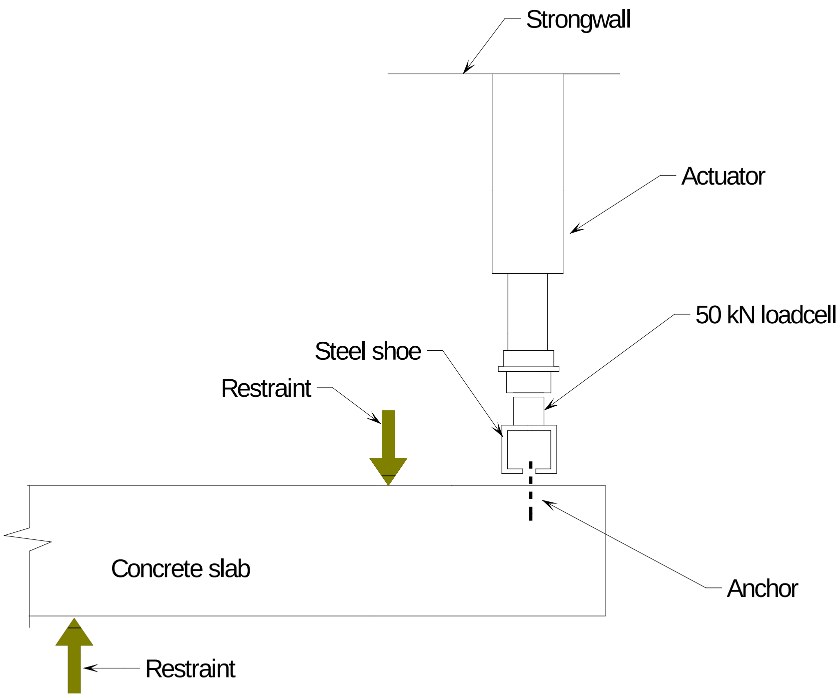

Figure 6. Plan view of the test set-up.

Figure 7. View of the test set-up for the anchor testing.

5.3 Test procedure

The required tensile capacity for proprietary bottom plate hold-downs is approximately 15 kN when used with bracing systems having a bracing rating of 150 bracing units per metre (the maximum allowed for concrete floor installations by NZS 3604:2011).

The loading regime was cyclic generally in accordance with BRANZ Evaluation Method No. 1 (BRANZ, 1999), as required by NZS 3604:2011. It involved cycling three times from zero load to each of +5 kN, +6 kN, +7 kN and so on, in +1 kN tension increments until failure occurred.

5.4 Test results

The results were assessed in two sets. Set 1 comprised specimens HDB1 and HDB2, and set 2 comprised HDB3 and HDB4.

The maximum load at which the anchor achieved three complete cycles to that load without failure was recorded for each anchor test. An analysis of the two sets of results was undertaken to determine the characteristic strength of the hold-down bolt for the location. The variability coefficient, k_t, was determined for each set using Table B1 of AS/NZS 1170.0:2002 *Structural design actions – Part 0: General principles*. However, this variability is the expected variability of a population of results. It is believed that the determined variability for the two specimens in each set is lower than what would be expected in practice and that a variability coefficient of 10% would be more representative. The results are presented in Table 1.

Table 1. Results of the anchor pull-out tests.

Hold-down bolt (HDB) number	Peak load achieved without failure
Set 1: Edge/end distance 46 mm/64 mm	
HDB 1	23 kN
HDB 2	24 kN
Mean	23.5 kN
Standard deviation	0.707 kN
Coefficient of variation (from test results)	0.03
Assumed population coefficient of variation	0.10
k_t (from assumed coefficient of variation)	1.38
Characteristic strength	**16.7 kN**
Set 2: Edge/end distance 167 mm/59 mm	
HDB 3	27 kN
HDB 4	30 kN
Mean	28.5 kN
Standard deviation	2.12 kN
Coefficient of variation (from test results)	0.074
Assumed population coefficient of variation	0.10
k_t (from assumed coefficient of variation)	1.38
Characteristic strength	**19.6 kN**

6. Summary and conclusions

The investigation was undertaken to take advantage of an available concrete slab formed with masonry header blocks. It is expected that, in the near future, the layout of timber framing in light timber-framed structures will be altered to reduce the amount of framing required. Such a change has the potential to require bottom plate anchors to be placed closer to the corners of foundations. This exploratory study was conducted to determine whether this would be a problem requiring further investigation, particularly for foundations formed using masonry header blocks as permanent formwork.

The required characteristic strength (tension demand) of anchors at the end of a wall bracing element on a concrete foundation is expected to be as much as 15 kN when the bracing element has a rating of 150 bracing units per metre. The results of this investigation indicate that these commonly used screw anchors can still achieve the required characteristic strength when installed near the corner of a concrete foundation constructed with masonry header blocks. This finding suggests that it is not necessary to conduct a more extensive study of this issue.

References

BRANZ. (1999). *Structural joints – strength and stiffness evaluation*. BRANZ Evaluation Method No. 1. BRANZ Ltd, Judgeford, New Zealand.