

INFLUENCE OF BLOCKAID CHAIRS ON COMPRESSION & OUT-OF-PLANE BEHAVIOUR OF REINFORCED MASONRY WALLS



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Executive Summary

Recent changes in Australian Masonry Standards (AS3700-2018) and Australian National Code of Construction (NCC-2019) pertaining to the design of reinforced masonry (RM) walls under compression impress the need of a grout annulus thickness of at least twice the vertical bars diameter and the need of vertical bar confinement through the 6mm tie bars. Maintaining the verticality of reinforcement in the middle of the grouted cores and restraining them with the tie bars are challenging tasks and usually are not followed on construction sites. To deliberate this issue, BlockAid have designed masonry bar chairs or support chairs to align and restrain the reinforcing bars in the centre of the cores. This report presents an experimental investigation to ascertain the performance of BlockAid bar chairs in supporting the steel reinforcing bars embedded in the reinforced masonry (RM) walls subject to vertical compression and out-of-plane loads. Twelve (12) wall specimens were constructed and tested – 4 each under concentric compression, eccentric compression and out-of-plane bending. Five grout cylinders, four single blocks, two ungrouted and three grouted prisms were also tested for the material characterisation. All construction and testing was conducted at Queensland University of Technology (QUT) Banyo Pilot Plant Precinct, Brisbane from August 2020 to October 2020 under a research contract funded by BlockAid Pty Ltd. The construction and testing procedure for this research was consistent with a previous study conducted by QUT in 2018 for BlockAid bar chair performance for a different type of block and the QUT-CMAA (Concrete Masonry Association of Australia) test campaign where the effectiveness of vertical steel in reinforced masonry walls built without BlockAid under compression was examined.

The mean compressive strength obtained from the fully grouted RM walls with BlockAid was determined higher than the strength obtained from the QUT-CMAA research conducted on similar walls without BlockAid for a different concrete block. Under concentric compression, control specimen (with 6mm restrainer bars) using 20.42 blocks as per client request sustained maximum load of 3100kN, while maximum load for the BlockAid sample was 3030kN (only 2.2% lower). Strain in the vertical steel bars – irrespective of the presence of the BlockAid remained compressive throughout the loading history with no evidence of buckling; this behaviour is similar to the QUT-CMAA research. Whereas in eccentric compression, there was no significant difference in the maximum compressive capacity of the control and BlockAid walls, although the tensile steel strains in BlockAid walls were observed significantly lower (50% less as per this study) than in the control specimen with 6mm tie bars in lateral directions. These observations conclude that the BlockAid

bar chairs are effective in restraining the vertical bars against buckling and do not compromise the capacity under compression loads. Additionally, the comparison of experimental compression capacities with the AS3700-2018 predictions revealed that the BlockAid walls had sufficient safety factor (about 2.5 times higher) than the code predicted values.

The out-of-plane test results of BlockAid walls and the control walls (without any chairs) were similar in terms of failure modes, load-displacement behaviour and steel strain variations. The maximum out-of-plane load capacity of BlockAid walls was 383kN and the control wall was 364kN with similar level of ductility.

In conclusion, it can be stated that the use of BlockAid bar chairs makes the construction process of the RM walls more efficient, has no obvious adverse effects on the load carrying capacity and the strain in the reinforcing steel of the RM walls under concentric and eccentric compression and out-of-plane loads. The successful results in this report are expected to increase the use of BlockAid bar chairs in the construction of structural reinforced masonry walls.

1 Introduction

BlockAid bar chairs are designed to accurately position the horizontal and vertical reinforcement in reinforced masonry block walls. According to recent revisions in Australian Masonry Standards (AS3700-2018), the vertical bars should be placed in the centre of grouted cores as such an annulus grout thickness not less than twice the diameter of vertical reinforcing bars should be maintained for considering the contribution of vertical bars in the compression capacity. To achieve this compliance, it is necessary that the vertical bars remains straight and central in the block cores when the grout is poured. BlockAid bar chairs provide an effective solution to keep the bars straight in the required position under compression loads as shown in Figure 1. An experimental study was conducted at QUT in 2018, in which RM walls were constructed using BlockAid bar chairs for maintaining the annulus grout requirements around the bars and were tested under concentric and eccentric compression. It was concluded that the bar chairs maintained the grout annulus requirements without any adverse effect on the compression capacity of the walls. However, Australian National Code of Construction (NCC-2019) requires RM members in compression to be restrained by 6mm diameter round bars to laterally restrain the vertical reinforcement in addition to the annulus grout diameter requirements. Practically, this kind of lateral arrangement is not very efficient and is generally not followed on construction sites due to the large amount of time required to restrain the vertical bars laterally using 6mm tie bars. Consequently, BlockAid have revised their chair design with two restrainer fingers to snug fit the vertical bars and restrain them laterally as shown in Figure 1.

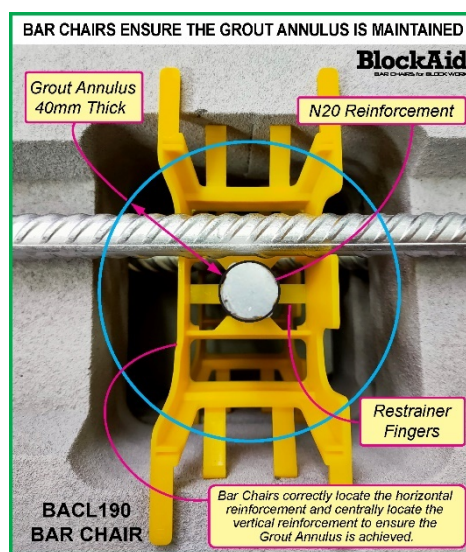


Figure 1: BlockAid bar chair to maintain the minimum grout annulus requirement

BlockAid bar chairs are designed for both “Non-Centrally Located (BANCL)” and “Centrally Located (BACL)” reinforcements, with the vertical steel location determining the correct product for the application as shown in Figure 2. Non-centrally located bar chairs are designed to support the vertical and horizontal bars to resist out-of-plane bending especially in the retaining masonry wall structures. The BlockAid bar chairs are made of plastic and come in sizes suitable to either 190mm or 290mm thick walls; this research has used 190mm thick blocks commonly available in Queensland. The aims of this research are:

- 1- To examine experimentally whether the improved version of BlockAid bar chairs for centrally located bars through the grout annulus around the vertical compression steel can restrain the bars laterally without compromising the compression capacity of the walls in concentric and eccentric compression loads.
- 2- To ascertain the out-of-plane capacity of RM walls with BlockAid bar chairs for the non-centrally located vertical and horizontal bars.

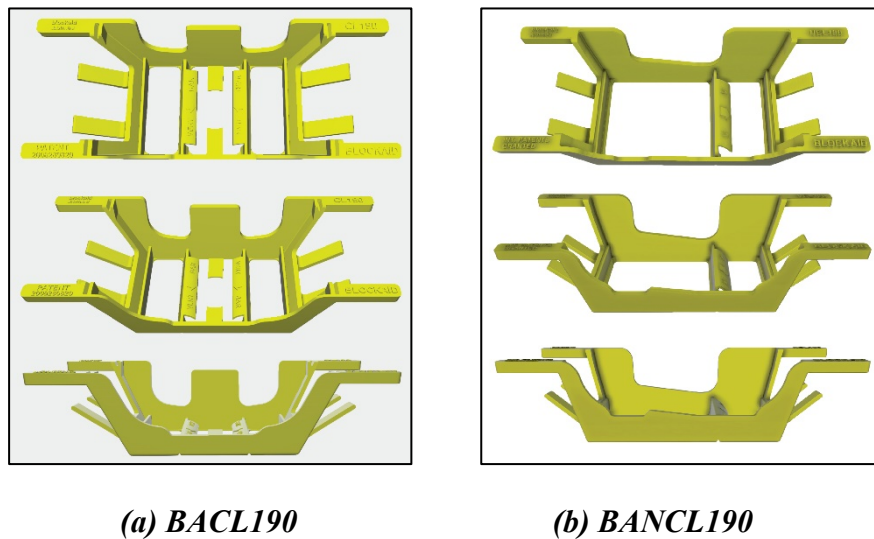


Figure 2: Types of BlockAid bar chairs

To achieve these aims, a test scheme was designed to test the RM walls under compression and out-of-plane loads to ascertain the benefits of the novel BlockAid bar chairs. Twelve medium high walls with a limited effect of slenderness were constructed – of which four each were tested under concentric compression, eccentric compression and out-of-plane bending. One undergrad student under the supervision of a research assistant carried out all laboratory experimental activities. To prove the hypothesis that the intrusion of the BlockAid bar chairs are expected to exhibit beneficial effect on the response of masonry walls to axial compression (concentric and eccentric) and out-of-plane bending behaviours, wall samples without bar chairs having 6mm diameter restrainer bars

under compression while tie wires were used to tie the horizontal and vertical bars to test under bending for comparison. In addition, the strains in the reinforcing bars were also measured to examine any premature buckling and effect of restraining provided by the BlockAid bar chairs. The results of these tests are presented in this report.

2 Experimental Program

In total, twelve block walls were constructed by a professional mason, of which nine (9) walls were built with BlockAid bar chairs in every alternative bed joints. The remaining specimens were built without bars chairs as control specimens with standard 6mm diameter restraining bars in compression, while tie wires were used to tie the horizontal and vertical bars to test under out-of-plane bending. More details are presented in the following sub-sections.

2.1 Construction materials and properties

For the construction of the walls, grout, blocks, mortar, reinforcement bars were required. All individual materials were tested for their properties.

2.1.1 Grout

Grout was ordered from Excel Concrete Pty Ltd. The ordered mix was a 25MPa Grout with 220mm slump and 7mm aggregate. A slump test was conducted to ensure the slump was as prescribed – the slump tested on site was 230mm. Five Grout Cylinders (100mm diameter × 200mm high) were also filled in three layers, with 25 tamps at each layer. These cylinders were then tested after 28 days of curing as shown in Figure 3(a). A 2000kN INSTRON machine was used to apply a uniform compression displacement at the rate of 1mm/min. Grout strength is presented in Table 1.

Table 1: Grout cylinder test results

Sample #	Compressive strength (MPa)
1	36.53
2	41.11
3	36.15
4	33.73
5	33.09
Mean	36.12
COV	9%

2.1.2 Blocks

175 full (20.42) and 175 half (20.43) Adbri Blocks were sourced. Four full blocks were randomly selected and tested to determine the compressive strength consistent with AS/NZS 4456 (2003). These blocks were tested under face-shell loading by placing 40mm wide × 6mm thick plywoods

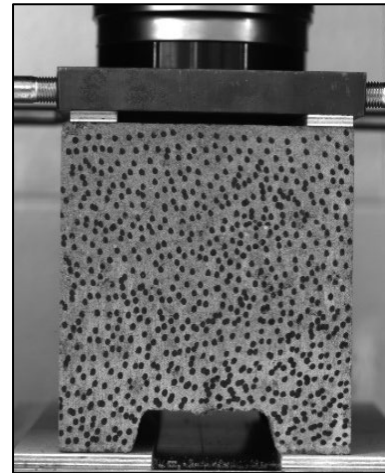
along the full length of the block (390mm) as shown in Figure 3(b). The test results are listed in Table 2.

Table 2: Masonry blocks test results

Sample #	Compressive strength (MPa)
1	15.79
2	15.34
3	14.46
4	15.99
Mean	15.39
COV	4%



(a) Grout test



(b) Block test

Figure 3: Testing of grout and blocks

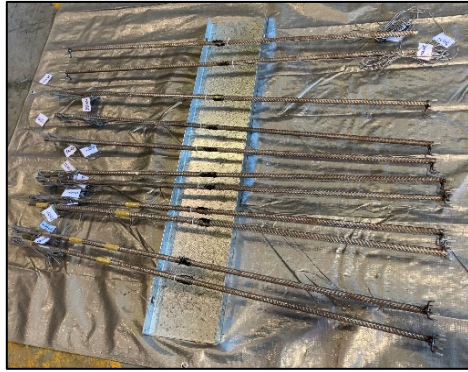
2.1.3 Mortar

M3 Mortar in the mix ratio of cement (1): lime (1): sand (6) was used for the construction of the stack bonded prisms and the RM walls. The mortar was supplied and applied by the masons from ‘Templeton Brick Laying’.

2.1.4 Reinforcing Bars

Reinforcing bars (16mm diameter – N16 and 12mm diameter – N12 normal ductility deformed bars) were sourced from Mesh & Bar Pty Ltd. The reinforcement bars were visually inspected upon delivery to ensure the straightness and quality of these bars. The bars are shown in Figure 4(a). To avoid direct contact between the steel loading platen and the reinforcement bars, the vertical reinforcement bars were welded to a four-legged steel chair which was 25mm high. At the top, the steel bar finished 25mm lower than the top surface of the masonry wall specimen. This was to

ensure direct contact between the loading platens and the bars was avoided to prevent bowing as shown in Figure 4(b).



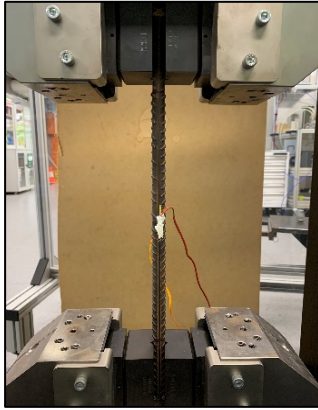
(a) Prepared bars



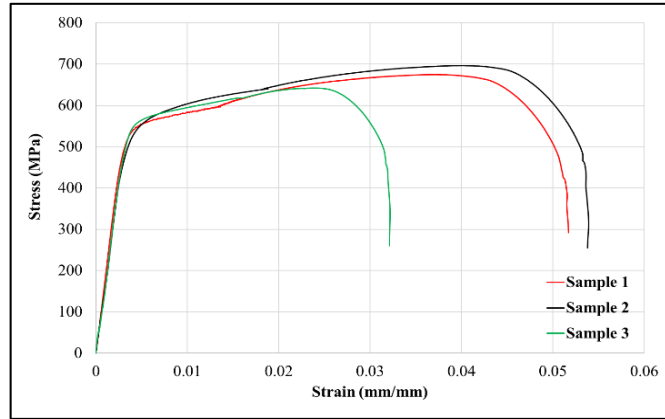
(b) Bars welding



(c) Strain gauging



(d) Bars testing



(e) Tensile stress-strain curves of bars

Figure 4: Reinforcing bar preparation and testing

The preparation of the reinforcement is vital to the success of the project's testing. Each wall had three 1340mm long vertical reinforcement bars at 190mm c/c spacing. All loaded walls had strain gauges. Four walls had two strain gauges on only the middle vertical reinforcement, whilst the other walls had two strain gauges on all three vertical reinforcement bars. The strain gauges were installed at around mid-height (670mm) at front and far face of the bars as shown in Figure 4(c).

Prior to installing the strain gauges, the steel bar was milled to an adequate depth where the surface was flat enough. Cyanoacrylate was applied onto the sticky tape with the strain gauge and pressure was applied for 60 seconds to keep the gauge attached onto the bar. Polymer resin coating was then applied on top of the gauges as a protective layer. Additionally, a hot glue gun was used to seal the strain gauges at a cool temperature. Finally, the strain gauges were sealed by black silicone for waterproofing, mechanical protection and insulation. The tensile testing of bar samples is shown

in Figure 4(d) and the stress-strain curves of three tested N16 bars are shown in Figure 4(e). The yield stress of bars was determined as 550 MPa on an average.

2.1.5 Masonry Prisms

Four courses high stack bonded ungrouted and grouted masonry prisms of size 390mm (long) × 790mm (high) × 190mm (th.) were constructed using the chosen blocks and mortar; three of them were grouted. Testing of prisms was consistent with Appendix C of AS3700 (2018). Results are shown in Table 3.

Table 3: Masonry prisms test results

Sample #	UngROUTED prism strength (MPa)	Grouted prism strength (MPa)
1	8.65	26.99
2	9.40	23.35
3	-	25.64
Mean	9.02	25.33
COV	6%	7%

2.2 Construction of walls

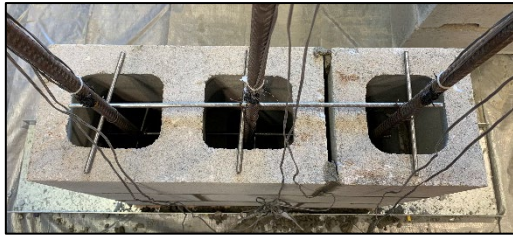
For compression tests, eight (8) RM walls were developed in the QUT lab for compression loads without any eccentricity (i.e. concentric compression) and with eccentricity. Three (3) walls each for concentric and eccentric compression testings were built with BlockAid bar chairs while two control specimens with 6mm restrainer bars were developed for comparison. For out-of-plane testing, four (4) RM walls were developed with one wall as 'control' without BlockAid bar chairs and 3 walls with BlockAid bar chairs in every alternative bed joint. Testing scheme for all the tests is presented in Table 4. Individual blocks, grout cylinders and grouted prisms were also tested to characterise the materials under compression.

A professional mason from Templeton Bricklaying was hired to construct all the walls. The construction of the walls began with a galvanised steel channel as the base. This channel simplifies the process of moving the walls from the fabrication mat to the loading frame. A 6mm thick plywood was placed centrally onto the steel channel and the first layer of blocks were positioned on the plywood. The desired location of the steel bars was marked on the plywood with a marker aligning through the plastic bar chairs, then the N16 steel vertical bars welded onto a steel chair were positioned at the marked location. Wall ties and plastic bar chairs were used according to the wall specification, with wall ties being applied on every block layer as shown in Figure 5(a) and

plastic bar chairs were placed on every second course as can be seen in Figure 5(b). For out-of-plane bending samples, the same procedure was adopted for construction, except the BANCL190 bar chairs were used with 3 N16 vertical bars and 3 N12 horizontal bars in the tension side as shown in Figure 5(c) and 5(d) for the control and BlockAid samples. Strain gauge wires were carefully extracted all towards one end of the wall and escorted through a hole before sealing the hole up with grouting. Prior to grouting, water was poured in the wall specimen to ensure the grout smoothly filled up the cores. The constructed samples are shown in Figure 5(e).

Table 4: Testing Scheme of RM walls

#	Specimen type	Test description	# of samples
1	RM wall: 590mm (long) × 1390mm (high) × 190mm (th.) [control sample with 6mm tie bars]	Concentric compression test with strain gauges in all 3 N16 vertical bars	1
2	RM wall: 590mm (long) × 1390mm (high) × 190mm (th.) [control sample with 6mm tie bars]	Eccentric compression test with strain gauges in all 3 N16 vertical bars ($e = t/3$)	1
3	RM wall: 590mm (long) × 1390mm (high) × 190mm (th.) [with bar chairs for centrally located bars]	Concentric compression test with strain gauges in all 3 N16 vertical bars	3
4	RM wall: 590mm (long) × 1390mm (high) × 190mm (th.) [with bar chairs for centrally located bars]	Eccentric compression test with strain gauges in all 3 N16 vertical bars ($e = t/3$)	3
5	RM wall: 590mm (long) × 1390mm (high) × 190mm (th.) [with bar chairs for non-centrally located bars]	4-point bending test with strain gauges in all 3 N16 vertical and 3 N12 horizontal bars	3
6	RM wall: 590mm (long) × 1390mm (high) × 190mm (th.) [control with tying wires]	4-point bending test with strain gauges in all 3 N16 vertical and 3 N12 horizontal bars	1



(a) Control specimen for compression with 6mm tie



(b) Specimen for compression with BACL190 chairs



(c) Control specimen for bending with tie wires



(d) Specimen for bending with BANCL190 chairs



(e) Constructed walls and prisms

Figure 5: RM walls construction details

2.3 Testing of walls

The samples were cured for 28 days after pouring of grout. The tests were carried out as per the scheme provided in Table 4. Instrumentation was implemented to measure the deformations and strains when the specimens were subjected to loads to determine if unrestrained bars and/or restrained bars had any dislodgement or otherwise affecting the walls behaviour. Strain gauges were attached to the vertical and horizontal steel bars for measuring the steel strains. Individual test details for compression and out-of-plane bending are in the following sub-sections.

2.3.1 Compression Tests

All RM wall samples were tested in a 4000kN capacity compression testing frame under uniform compression at the rate of 1mm/min. The test set-up for concentric and eccentric compression are shown in Figure 6. The steel strains in the proximity of chairs were measured and the capacity of walls was compared with similar walls previously tested in QUT with 6mm diameter restraining bars in both lateral directions without any chairs. Deflection and failure mode were also measured through digital image correlation (DIC) technique. DIC is a unique technique in which the surface of samples is speckled with black dots and monochrome images of samples are captured at a regular interval (5 frames per second for this project) during the test. The images are then correlated using a DIC software to calculate the strain and deformation field with respect to the first image of sample without any load.

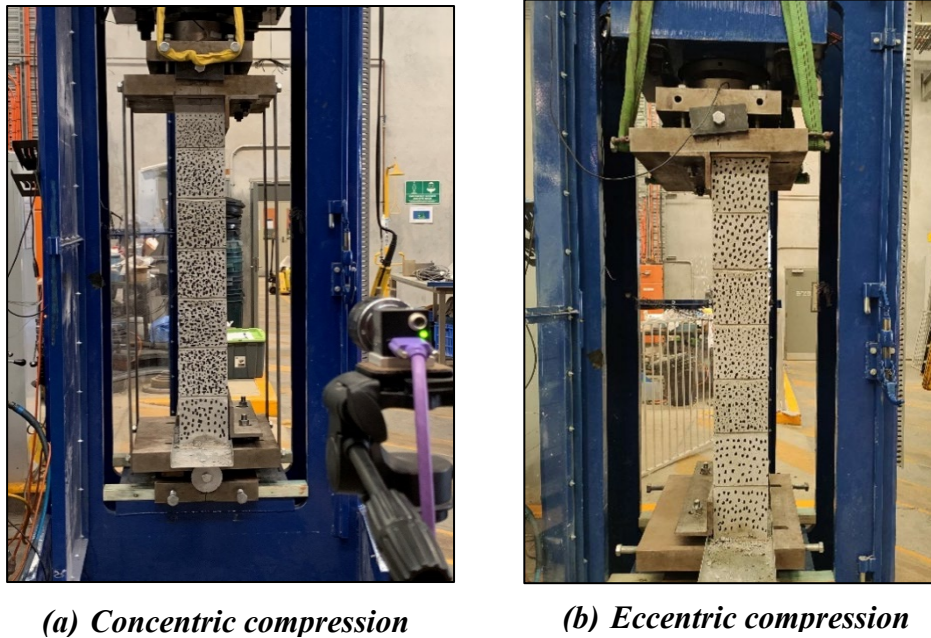
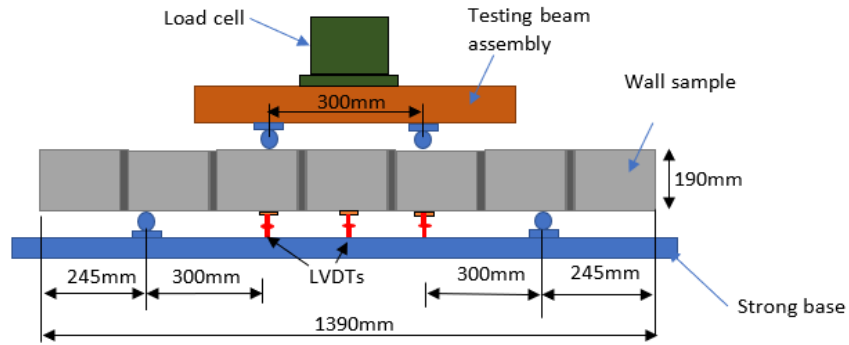


Figure 6: Compression test details

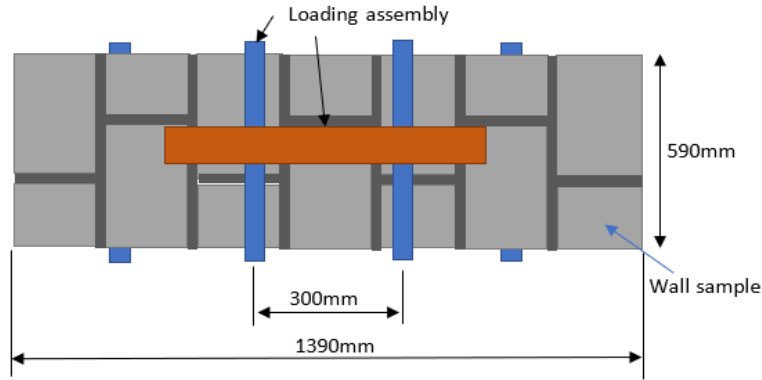
For eccentric compression tests, the eccentricity of one-third of thickness ($t/3$) which corresponds to 63mm was adopted for two samples with BlockAid bar chairs, while one of the samples was tested for the eccentricity of $t/6 = 32\text{mm}$.

2.3.2 Out-of-plane Bending Tests

Out-of-plane bending tests were also conducted in the same machine with a different loading set-up. Four-point loading assembly was developed as shown in Figure 7 to apply the out-of-plane bending loads on the RM wall specimens.



(a) Schematic Elevation



(b) Schematic Plan



(c) Side view of test wall

Figure 7: Out-of-plane bending test details

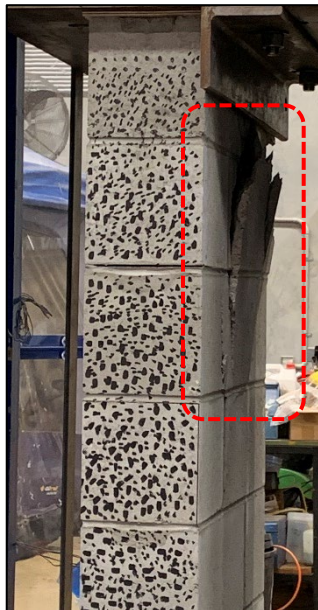
The deflections under out-of-plane bending tests were measured using three linear variable displacement transducers (LVDTs) as shown in Figure 7. Similar to compression tests, the steel strains were also measured through the installed strain gauges in the horizontal and vertical bars.

3 Results and Discussion

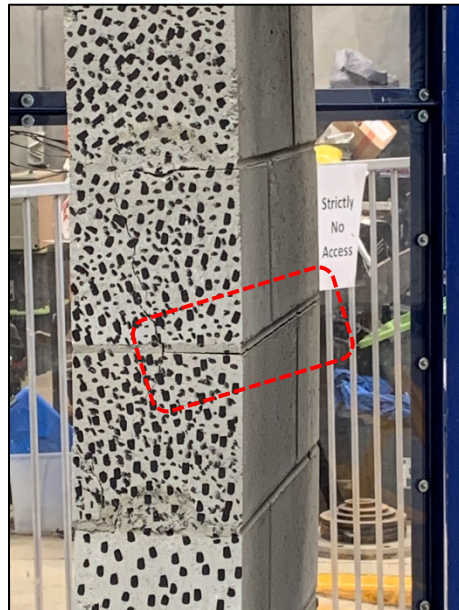
The behaviour of tested walls was examined in terms of failure modes, failure strengths, load-displacement curves and steel strain variations. The results are discussed in detail in this section.

3.1 Compression test results

The general failure mode observed in the concentrically loaded walls was vertical splitting of the face and web shells. These cracks became evident once the loading reached close to 80% of the peak load. As the load reached ultimate capacity, these cracks became larger until the walls failed by crushing of concrete near mortar joints and web splitting as shown in Figure 8(a). Under eccentric loads, the failure of walls occurred due to opening of mortar joints at tension side and crushing of concrete on the compression face (see Figure 8(b)). The failure mode is consistent with the previous tests conducted in 2018 and in QUT-CMAA test campaign for the revisions in AS3700-2018 version.



(a) Crushing failure in concentric compression



(b) Joint opening in eccentric compression

Figure 8: Failure modes under compression

The maximum (peak) loads for the tested walls under concentric and eccentric compression tests are summarised in Table 5.

Table 5: Peak load capacity for compression tests

Sample #	Concentric compression capacity (kN)	Eccentric compression capacity (kN)
Control	3100	920 (e = 63mm)
BlockAid 1	2814	926 (e = 63mm)
BlockAid 2	2504	866 (e = 63mm)
BlockAid 3	3031	2041 (e = 32mm)

The mean strength of BlockAid wall samples under concentric compression was determined as 2785 kN with a COV of 10% while under eccentricity of $e = 63\text{mm}$ as 896 kN (COV – 5%). It can be observed that the difference of maximum concentric compression strength between the control wall with standard 6mm restrainer bars (3100 kN) and BlockAid wall (3031 kN) is only 2.2% which would be lesser if more control wall specimens would have been tested for an average strength. Whereas under eccentric compression the maximum capacities are almost same for the control and BlockAid samples.

It is important to mention that these results are much higher than the similar walls tested in 2017 for QUT-CMAA research where the average concentric compression capacity of 1237 kN and eccentric compression capacity of 610 kN was obtained. The reason for such a large difference (2 folds) can be attributed to the difference in materials strength including block strength (12% higher) and grout strength (44% higher) for the current tests.

Additionally, the experimental compression capacities were also compared with the predictions of AS3700 (2018) for compression strength using the design capacity Equation (1).

$$F_d \leq k_{es} \left[f'_m A_b + k_c \left(\frac{f'_{cg}}{1.3} \right)^{(0.55+0.005f'_{cg})} A_g + \alpha_r f_{sy} A_s \right] \quad (1)$$

The mean strength of masonry ($f_m = 9\text{MPa}$), mean strength of grout ($f_{cg} = 36\text{MPa}$), yield stress of steel ($f_{sy} = 550\text{MPa}$), steel bar area ($A_s = 600\text{mm}^2$), bedding area ($A_b = 600 \times 30 \times 2 = 36000\text{mm}^2$), grout area ($A_g = 58500\text{mm}^2$), grout strength factor ($k_c = 1.2$) and $\alpha_r = 0.4$ for RM walls were input in Equation (1). The reduction coefficient k_{es} was calculated using Equation (2) separately for concentric and eccentric compression capacities.

$$k_{es} = (1.0 - 0.025S_r)(1.0 - 2.0 \frac{e}{t}) \quad (2)$$

The slenderness and eccentricity ratios in the above equation were set as $S_r = \frac{190}{1390} = 7.32$ and $\frac{e}{t} = 0$ and $\frac{63}{190} = 0.33$ for concentric and eccentric compression, respectively. The results are tabulated in Table 6.

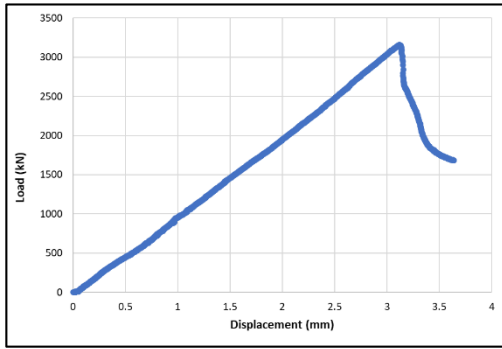
Table 6: Compressive capacity comparison with AS3700-2018

Case	Concentric compression capacity (kN)	Eccentric compression capacity (kN)
Experimental mean strength	2783	896 (e = 63mm)
AS3700 (2018) prediction	1020	340 (e = 63mm)
Ratio = Exp/AS3700	2.73	2.63

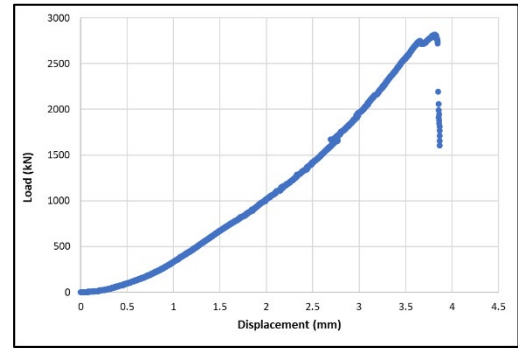
The experimental results have yielded a higher strength in comparison to the latest code predictions which shows the effectiveness of BlockAid bar chairs in restraining the vertical bars. These results show that with the use of BlockAid bar chairs, the walls can exhibit adequate margin for the safety factor to account for uncertainties in construction and materials quality.

Load displacement curves and steel strain variations were also measured to verify any buckling or dislodgement of the bars. Typical results of the control specimens and BlockAid specimens under concentric compression are presented in Figure 9. It can be observed from the load displacement curves that the behaviour of control walls and BlockAid walls is quite similar with similar peak and post peak trends. The steel strain variations with increasing displacement are also very similar for both kind of samples with maximum compressive strain of around 1200 microstrain (lesser than the yield strain of 2500 microstrain) in vertical bars which is in agreement to QUT-CMAA test results for similar walls.

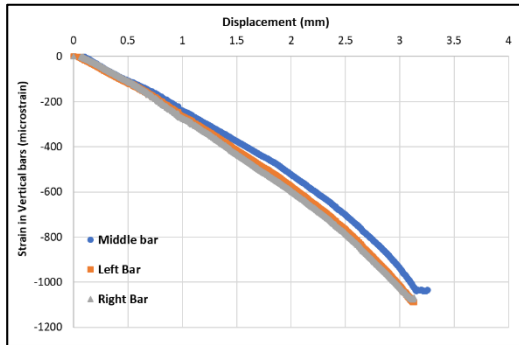
Figure 10 shows the load deflection and steel strain variations of the eccentric wall samples. Again, the similarities in the load-displacement trends can be observed. However, the steel strains under eccentric compression in the BlockAid walls were found much lower than the control walls, perhaps due to restraint provided by the chairs against tension in bars under eccentricity.



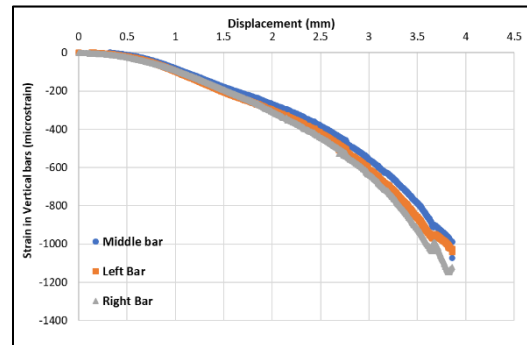
(a) Load-displacement curve of control wall



(b) Load-displacement curve of BlockAid wall

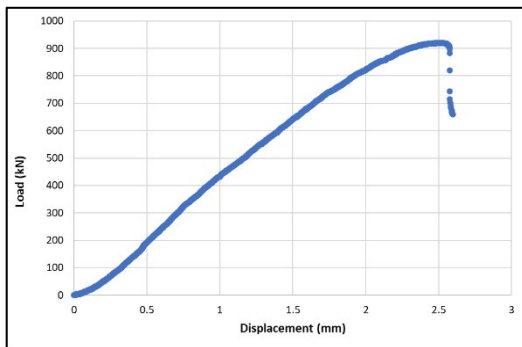


(c) Strain variation in control wall

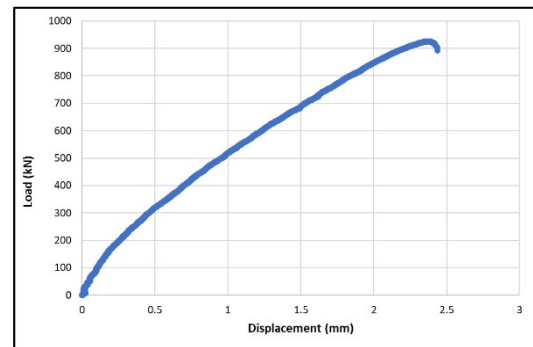


(d) Strain variation in BlockAid wall

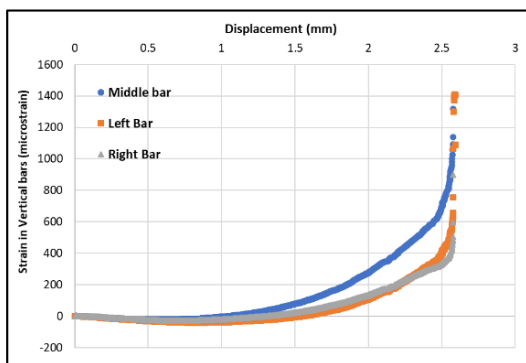
Figure 9: Load displacement and steel strains under concentric compression



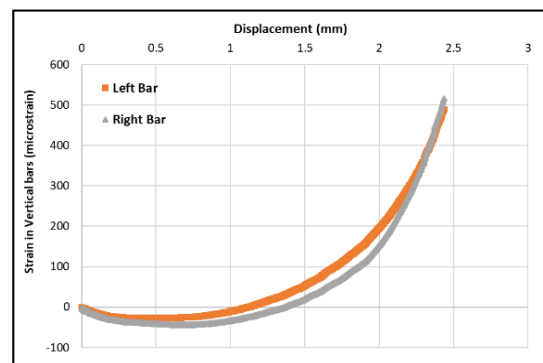
(a) Load-displacement curve of control wall



(b) Load-displacement curve of BlockAid wall



(c) Strain variation in control wall



(d) Strain variation in BlockAid wall

Figure 10: Load displacement and steel strains under eccentric compression

3.2 Out-of-plane bending test results

For all tested walls under out-of-plane bending, similar failure mode was observed with cracking at the points of load application as marked in Figure 11. The cracking was symmetric about the centreline of the wall specimen. The inclined cracking protruded from the point of load applications to the bottom side of the specimen. Vertical cracks in tension side of the tested walls were also observed.

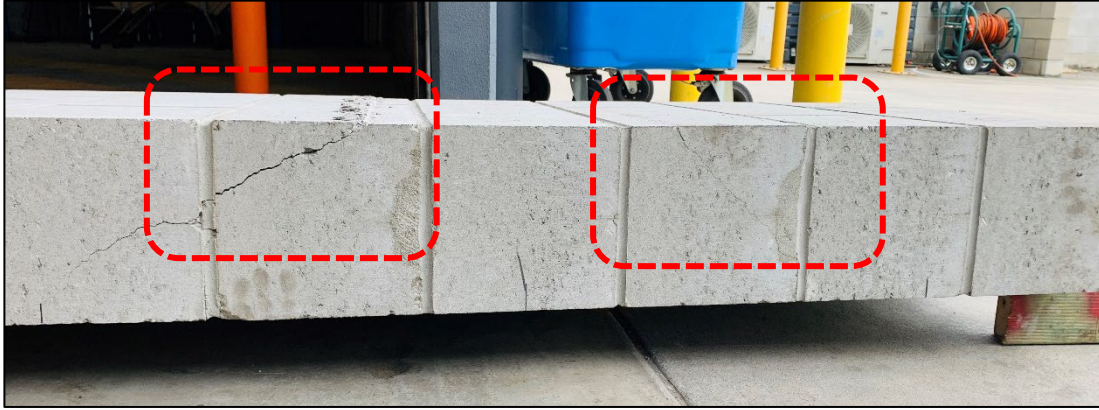


Figure 11: Failure mode of walls under out-of-plane bending

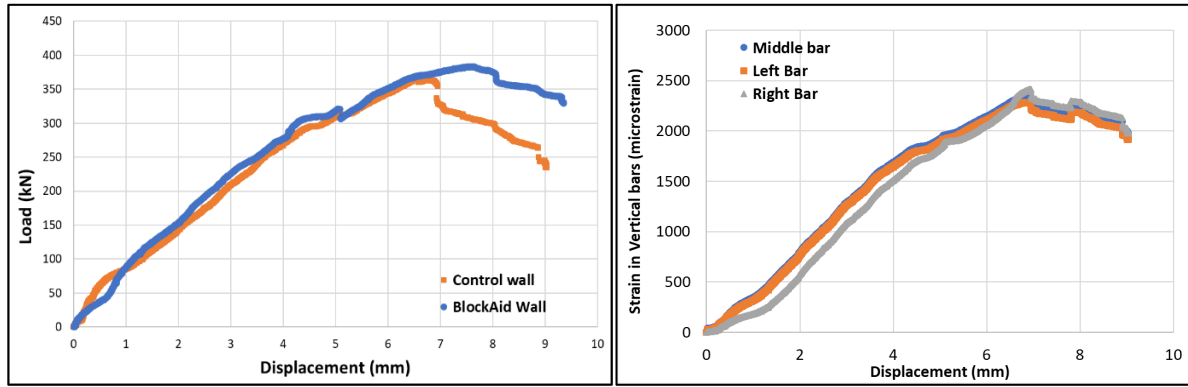
The ultimate strength or load capacity of walls under bending is listed in Table 7. The ultimate load of the control specimen was measured only 2.5% higher than the mean strength of the BlockAid wall specimens which is consistently same as in compression tests. The ultimate deflections for both kind specimens were around 9mm.

Table 7: Ultimate load capacity for bending tests

Sample #	Ultimate load (kN)	Failure deflection (mm)
Control	364	9.1
BlockAid 1	383	9.4
BlockAid 2	337	10.2
BlockAid 3	344	8.1
Mean	355	9.2
COV	7%	11%

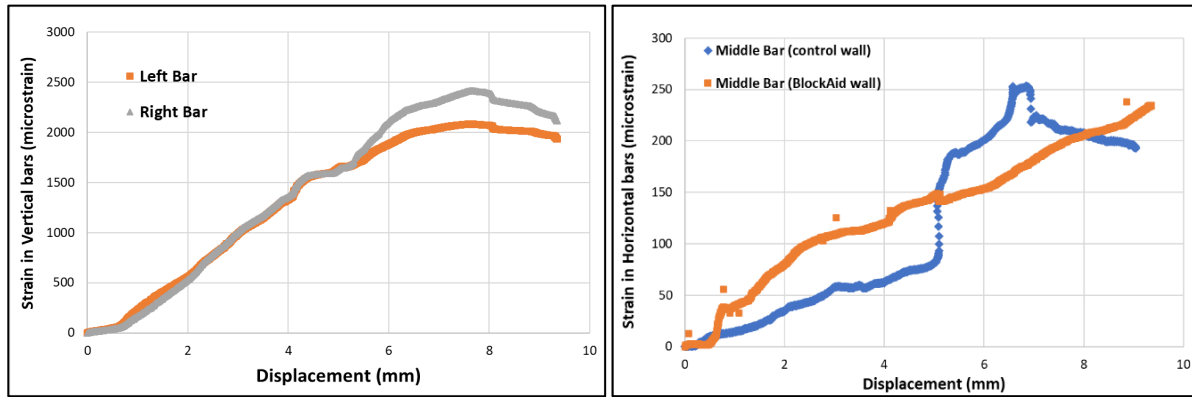
Figure 12 shows the load deflection and steel strain variations in the horizontal and vertical bars. The load-deflection behaviour of the control wall and BlockAid walls was found similar. The measured steel strains in the vertical bars under bending were observed closer to the yield strains for all bars in all tested walls, while strains in the horizontal bars were much lower at around 250 microstrain due to not directly bending under loads. The vertical steel bars which were

predominantly experiencing tension almost reached the yielding strain but did not undergo higher than yielding strains due to cracking progression in the masonry.



(a) Load displacement curves

(b) Vertical steel strains in control walls



(c) Vertical steel strains in BlockAid walls

(d) Horizontal steel strains

Figure 12: Load displacement and steel strain variations for bending tests

4 Conclusions

This research report presents an investigation on the behaviour of RM walls with novel BlockAid bar chairs installed to support and restrain the reinforcing bars to achieve compliance with AS3700 (2018) and NCC (2019). In total, 12 samples were tested under concentric compression, eccentric compression and out-of-plane bending loads. Based on the construction and testing of these RM walls, the following conclusions have been made:

1. The use of BlockAid bar chairs ensures the straightness and correct positioning of the vertical reinforcement as desired in the compression design provisions of AS3700-2018.
2. Under the test regime, no adverse effect on the load carrying capacity of the RM walls under compression and out-of-plane loading was obvious.

3. The variation of steel strain under concentric compression loads show no difference between the control walls with 6mm restrainer bars and the walls with BlockAid bar chairs. However, under eccentric compression, the tensile strains in bars with bar chairs were much lower than the control wall showing the effectiveness of bar chairs in restraining the vertical bars against excessive bending.

4. The compression capacity of tested walls was determined around 2.6 folds higher than the AS3700 (2018) predictions which can be considered as a factor of safety which demonstrates that the BlockAid bar chairs can provide adequate safety against uncertainties in construction and material quality.

5. Out-of-plane bending behaviour of RM walls with and without bar chairs were similar in terms of steel strains and load displacement responses. This also proves that the BlockAid bar chairs can be effectively used to restrain/support the vertical and horizontal bars in the retaining structures without the need of wire tying the horizontal and vertical bars.

The results in this report show that the use of BlockAid bar chairs can expediate the construction of RM walls with adequate restraint and correct positioning of reinforcing bars within the grouted cores to efficiently achieve compliance to AS3700 (2018) and NCC (2019).

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