



## LATERAL PERFORMANCE OF VERY WIDE CAVITY WALLS

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### ABSTRACT

The past few years have seen a growing trend towards the increased use of insulation in the walls of domestic dwellings to improve the sustainability of the housing stock. In UK masonry buildings the insulation is commonly placed in the wall cavities, and this trend has resulted in the demand for an increase in the size of the cavity. The engineering principles which are the basis of the British Code method for calculating the overall lateral resistance of cavity walls imply that cavities of any sensible width should give the same performance providing the ties behave like pin-ended struts (have adequate stiffness).

The programme of work described, was aimed at providing an empirical database to confirm the principles and extend the range of the Code which is arbitrarily restricted to 150mm wide cavities in the 1992 edition.

A total of six walls were tested and the results compared with the performance of individual single leaves and archival data for other widths of cavity. The authors took advantage of the wide cavity to carry out tests to a serviceability load with the ties in tension before a final test to failure with the ties in compression (the standard test format).

The results support the principles of the Code calculation and suggest, if anything, a slight improvement in performance as cavities are widened possibly a result of partial composite action.

**Keywords:** masonry; cavity; wide; lateral; flexural; serviceability; first-crack; ultimate;

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## **INTRODUCTION**

The past few years have seen a growing trend towards the increased use of insulation in the walls of domestic dwellings to improve the sustainability of the housing stock and to reduce energy consumption as part of UK efforts to comply with the Kyoto agreement. In UK masonry buildings the insulation is commonly placed in the wall cavities, and this trend has resulted in the demand for an increase in the size of the cavity to accommodate thicker layers of insulant and retain an air cavity to prevent rain ingress. The maximum allowable cavity width envisaged in the UK Code of Practice, BSI (1992), is 150mm and the intention of this work was to establish that walls with a cavity width of up to 300mm perform satisfactorily when subjected to lateral load.

A sustained programme of research on lateral loading has been carried out in the UK over many decades and has established a performance database which underpins the semi-empirical calculation method in the UK Code of Practice BS5628. Much of this work was reported in four papers to the Structural Engineer by Hodgkinson et al (19xx) de Vekey et al (1986) and Haseltine et al (1986). Most of the data on cavity walls is for specimens having a 50mm wide cavity which is the standard width for uninsulated walls and is designed to prevent rain leaking through the outer leaf from crossing over and entering a building. This data gives a reasonable empirical basis for the calculation in the Code which assumes that the ties act as pin-ended connections and therefore that the flexural resistance of a cavity wall can be taken as the sum of the individual resistances of the two leaves.

In previous work a limited number of wider cavities up to 150mm were tested and indicated that the principles held provided the body of the ties was stiff enough to transmit the forces without undue deformation. The current work was carried out to confirm the reasonable assumption that the principle should hold for any reasonable cavity width and to give a database to underwrite the UK housing design method which works via experience-based sizing rules.

## **MATERIALS**

All the outer leaves were built from semi-dry-pressed clay bricks laid in designation (iii) 1: 1: 6 cement: lime: sand mortar. The cement was ordinary portland type to BS12, the lime was hydrated pure lime to BS890 and the sand was a local pit sand complying with BS1200 grade S. The inner leaves were built from one of three types of concrete blocks, AAC, lightweight aggregate and dense aggregate, in the same mortar. The data on the unit materials is given in table 1 and the sand grading in table 2.

Wallettes in accordance with BS5628:Part 1: 1992 Append B2 were made with the same batches of materials as the main walls. These were tested at 28 days either in horizontal or vertical flexure and the results are summarised in Table 3.

The ties were vertical twist fishtail wall ties complying with the Prescriptive British Standard for wall ties - BS 1243 in most respects except that they were longer than normal ties. The tie dimensions were length: 425mm; thickness: 3.16mm and breadth: 18mm.

## **SPECIMENS AND METHOD**

Tests were carried out on six single storey height cavity walls constructed using a 300mm cavity. All six walls were 2.6m high by 5.5 m long, and incorporated brick outer leaf with one of three types of concrete block inner leaf. All the walls were restrained at the base and both vertical edges. Two of the inner leaf walls were additionally supported along their top edge. Wall 2 was built with an opening - 2m wide by 1.2m high - which was boarded over during the testing. All the walls were tied together using vertical twist fishtail wall ties spaced at a density of 2.5 ties/m<sup>2</sup> and embedded at least 50mm into the mortar beds. The wall construction data is given in Table 4. The wall layout and deflection transducer positions (numbered) for the two leaves are shown in Figures 1a/b for the plain walls 1,3 & 5, 2a/b for the perforated wall 2 and 3a/b for the four-sided support walls 4 and 6.

Control tests were also carried out on a number of isolated single leaf walls made from the same materials used in the cavity walls but some control values were derived from a database of previous tests. The performance of the 300mm cavity walls were then assessed by comparing the lateral strength of the 300mm cavity walls with the sum of the lateral strength of the relevant control walls or equivalent walls from the database.

Two types of loading were applied, (A) an in-cavity serviceability loading of the inner leaf putting the ties into tension and (B) an external surface load to failure via the outer face of the outer leaf putting the ties into compression. The pressure was applied by inflating airbags which reacted against a reaction board. Figure 4 illustrates the two test arrangements. Failure was taken as the maximum pressure which the walls would resist.

## **RESULTS AND DISCUSSION**

A summary of the performance of the six cavity structures is given in table 5.

At the serviceability pressure with the ties in tension (test A) there were no signs of distress and the deformations were well below the level at which damage would normally be expected. The level chosen for the serviceability pressure would cope with most design requirements for wind-loaded walls in the UK. The positions of maximum deformation are broadly as expected, ie. near the centre of the top edge for three sided support walls and near the wall centre for four-sided support walls. The worst tie deformations are often near the edges but tie action at these points (near supports) is less critical. Tie deformations for the peak wall deformation positions are quite modest usually less than 1mm.

With the ties in compression (test B) the first crack may be regarded as a peak serviceability resistance and all but wall 2 were well above normal design requirements. The failure pressure was generally even higher except for walls 3 and 5 where it was equal. The wall with the opening had a significantly lower serviceability resistance but this did not seem to reduce the ultimate resistance and thus prejudice safety. At these very extreme loads the deformations were substantial reaching as high as 30mm for both leaves even at the first crack level. The ties suffered more deformation in compression due to the higher loads and the additional mechanism of buckling in addition to elastic deformation and movement within the mortar bed. A summary of the failure test results for the type 2 test together with archival data is given in Table 6.

With one exception, the maximum lateral loading pressures for the 300mm cavity walls were at least as high as the sum of the failure pressures for two single leaf walls made from the same materials. The exception was probably due to a fortuitously high individual wall performance for a four-sided restraint blockwork wall. Despite analysing the test data for this wall in detail, it has not been possible to identify any unusual characteristics, and the result must therefore stand. Comparative data, from the database, for 150mm and 75mm cavity walls in similar materials indicates there is no reduction in performance for wider cavities provided the ties give sufficient load transfer performance in compression or tension. There is some indication that there may be partial composite action which appears, if anything, to increase the performance with cavity width, but the database is insufficient to give a statistical confirmation.

Figure 5 illustrates the deformed shape of the blockwork leaf at the serviceability load in compression of wall 5 showing the larger deflection at the unsupported top edge. Figure 6 illustrates the deformed shape of the blockwork leaf at the serviceability load in compression of wall 4 showing the larger deflection at the centre since all four edges were supported.

## **CONCLUSIONS**

With one exception, the maximum lateral loading pressures for 300mm cavity walls were at least as high as the sum of the failure pressures for two single leaf walls made from the same material and equal to or greater than equivalent walls with narrower cavities.

Again with one exception, the maximum lateral loading pressures for 300mm exceeded the values calculated using the UK code of Practice indicating that it would be safe to construct such walls using the Code design method. The one exception was marginal and only represents a slight reduction of the overall factor of safety.

These results confirm that these walls built with cavities up to 300mm wide perform as well or better under lateral loading than those built with smaller cavities, and that the performance of a cavity wall under lateral loading can be conservatively calculated as the sum of the resistances of the individual leaves making up that wall.

## **ACKNOWLEDGEMENT**

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Table 1. Characteristics of unit materials

Unit block or brick material	Mean Water absorption	Mean compressive strength	Nominal density	Actual density
	%	N/mm <sup>2</sup>	kg/m <sup>3</sup>	kg/m <sup>3</sup>
Semi-dry pressed clay brick (Fletton)	22.5	31.1	1750	-
Autoclaved aerated concrete (AAC)	45.5	4.1	650	832
Dense aggregate concrete (DAC)	6.36	7	1975	2116
Lightweight aggregate concrete(LWAC)	12.24	6	1100	1538

Table 2. Sand grading curve (cumulative)

seive aperture	5	2.36	1.18	600	300	150	75
Size / units	mm	mm	mm	µm	µm	µm	µm
% passing	100	98.5	97.3	95	61	8.1	2.2

Table 3. Flexural strength from wallette tests using the same batches of materials

Datum	Units	Fletton brick	AAC block	DAC block	LWAC block
		parallel	parallel	parallel	parallel
Replicates	No.	5	5	3	5
Mean	N/mm <sup>2</sup>	0.66	0.309	0.536	0.405
Std. Devn.	N/mm <sup>2</sup>	0.023	0.083	0.038	0.045
Characteristic strength	N/mm <sup>2</sup>	0.61	0.156	0.454	0.309
Coeff. of Var.	%	3.48	26.86	7.09	11.11
Mortar strength	N/mm <sup>2</sup>	5.9	6.15	5.05	4.95
		normal	normal	normal	normal
Replicates	No.	5	5	3	5
Mean	N/mm <sup>2</sup>	1.353	0.291	0.935	0.79
Std. Devn.	N/mm <sup>2</sup>	0.115	0.034	0.039	0.07
Characteristic strength	N/mm <sup>2</sup>	1.1	0.218	0.849	0.645
Coeff. of Var.	%	8.5	11.68	4.17	8.86
Mortar strength	N/mm <sup>2</sup>	6.2	5.85	6.15	5.65

Table 4. General characteristics of the six walls

Wall no.	Inner leaf ‡		Size (length x height) metres	Feature ?	Mortar strength N/mm <sup>2</sup> †
	material	support			
1	AAC block	3-sided simple	5.5 x 2.6	plain	5.25
2	AAC block	3-sided simple	5.5 x 2.6	central opening	4.85
3	LWAC block	3-sided simple	5.5 x 2.6	plain	4.55
4	LWAC block	4-sided simple	5.5 x 2.6	plain	5.65
5	DAC block	3-sided simple	5.5 x 2.6	plain	4.75
6	DAC block	4-sided simple	5.5 x 2.6	plain	4.95

Notes: ‡ All outer leaves were 5.5m long x 2.6m high brickwork with 3-sided support. Wall 2 outer had a matching window opening. † The mortar cubes were tested on the day of test of the wall.

Table 5. Resistance and maximum deflection performance data for walls 1-6

Maximum deflection level and transducer position at which it occurred							
Wall No.	Pressure kN/m <sup>2</sup>	Brick leaf mm	Posn.	Block leaf mm	Posn.	Tie deformation mm	Posn.
Test (A) - Serviceability pressure applied to inner leaf - ties in tension							
1	1.6	4.9	3	4.85	3	1.92	9
2	1.2	2.82	4	3.66	9	2.46	11
3	1.6	3.89	3	3.6	3	0.69	6
4	1.6	0.54	9 / 1	0.44	9	0.36	8
5	1.6	2.07	3	2.13	3	1.25	9
6	1.6	0.45	1 / 8	0.35	8 / 9	0.62	7
Test (B) - Pressure at first crack when applied to outer leaf - ties in compression							
1	2.6	9.27	3	7.05	3	2.4	4
2	0.8	1.89	4	1.67	9	1.49	1
3	5.2	30	8	10.79	3	6.99	2
4	3.6	8.82	8	3.36	9	9.23	8
5	5.5	31.66	4	11.23	3	13.92	1
6	3.8	3.84	15	1.74	1	3.24	15
Test (B) - Pressure at failure when applied to outer leaf - ties in compression							
1	3.8	18	4	15.44	11	7.54	9
2	4.05	7.63	2	14	9	2.96	10
3	5.2	30	8	24.81	4	6.99	2
4	5.2	29	5	15.11	4	5.46	14
5	5.5	31.66	4	32.86	3	13.92	1
6	5.1	16	1	18.58	7	16	9

Table 6. Summary of performance of cavity walls in relation to single leaves, archive data and calculation

Wall	Outer Brick leaf	Inner leaf blockwork	Sum of single leaves	Failure pressure of cavity wall specimen (‡width of cavity)	Failure pressure of cavity wall specimen (‡width of cavity)	Failure pressure of cavity wall specimen (‡width of cavity)	Failure pressure of cavity wall specimen (‡width of cavity)	Calculated to BS5628
No.	Failure pressure kN/m <sup>2</sup>	Material	Failure pressure kN/m <sup>2</sup>	Failure pressure kN/m <sup>2</sup>	‡300 mm kN/m <sup>2</sup>	‡150 mm kN/m <sup>2</sup>	‡75 mm kN/m <sup>2</sup>	Cavity wall kN/m <sup>2</sup>
1	2.2	AAC	0.9	3.1	3.8	3.8	3.4	1.62
2	2	AAC	1.1	3	4	-	-	-
3	2.2	LWAC	1.6	3.8	5.2	-	3.7	5.64
4	2.2	LWAC	4.4	6.6	5.2	-	-	3.7
5	2.2	DAC	2.3	4.5	5.5	-	4.9	1.9
6	2.2	DAC	0.8	3	5.1	-	-	2.5



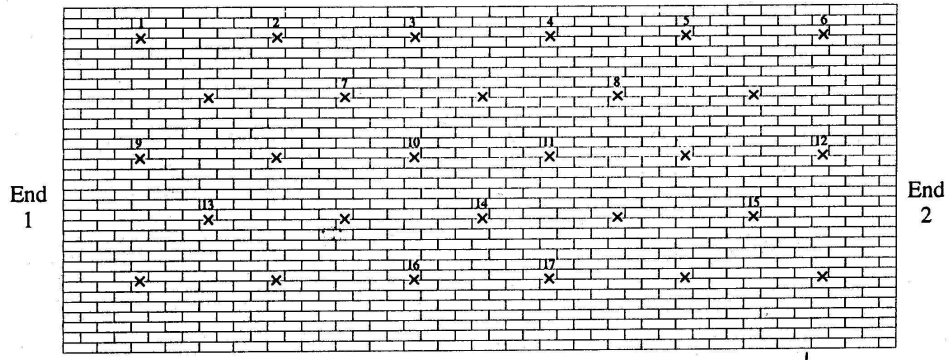


Figure.1a Wall layout and deflection transducer positions (numbered) for the brick leaf of plain walls 1,3 & 5

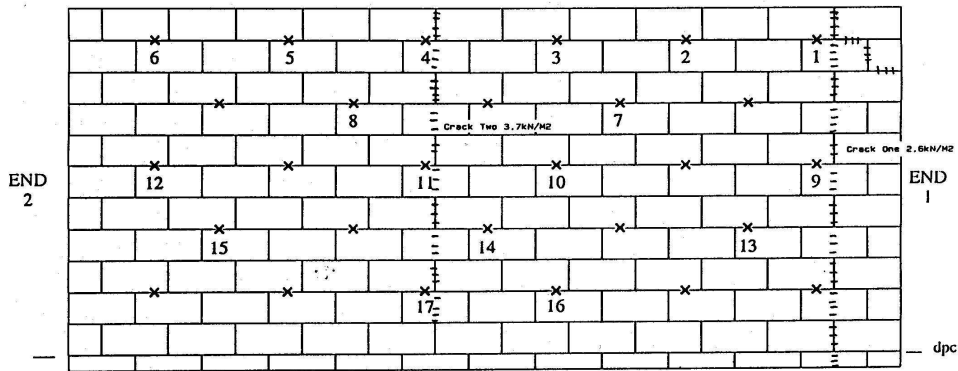


Figure.1b Wall layout and deflection transducer positions (numbered) for the block leaf of plain walls 1,3 & 5

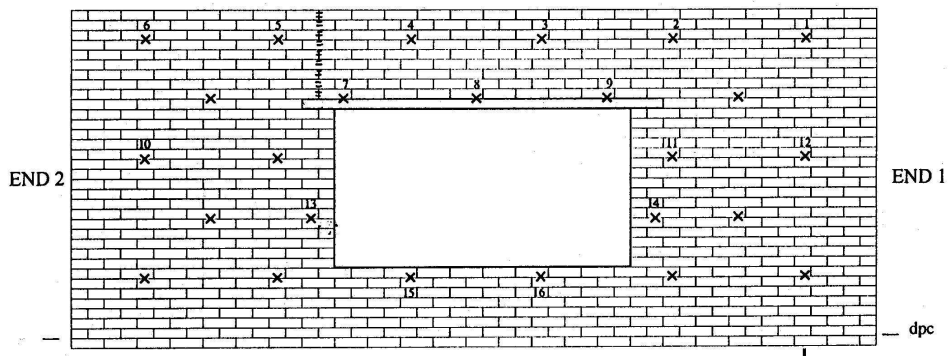


Figure.2a Wall layout and deflection transducer positions (numbered) for the brick leaf of perforated wall 2.

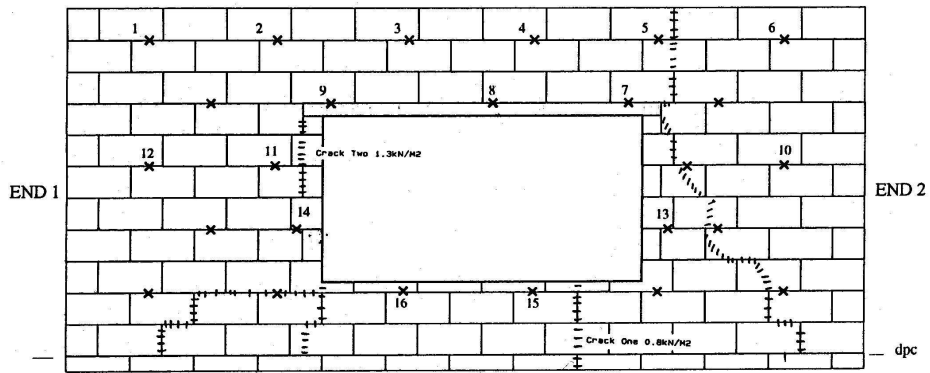


Figure.2b Wall layout and deflection transducer positions (numbered) for the block leaf of perforated wall 2.

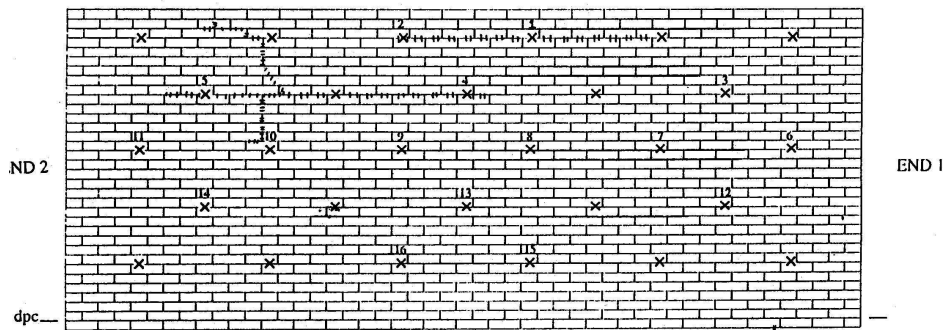


Figure.3a Wall layout and deflection transducer positions (numbered) for the brick leaf of the four-sided support walls 4 and 6

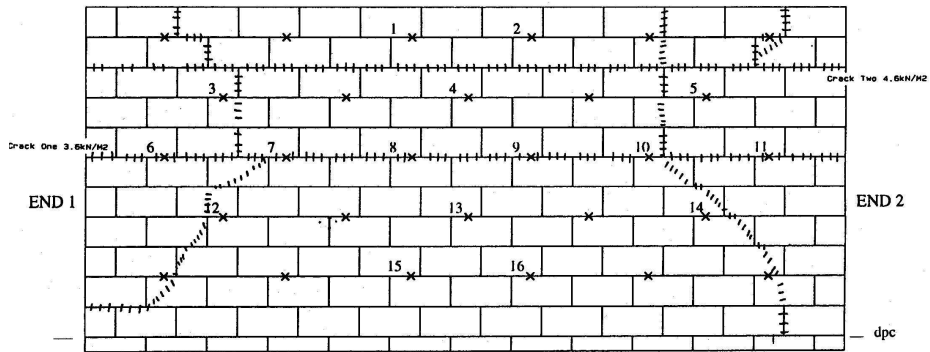


Figure.3b Wall layout and deflection transducer positions (numbered) for the for the block leaf of the four-sided support walls 4 and 6

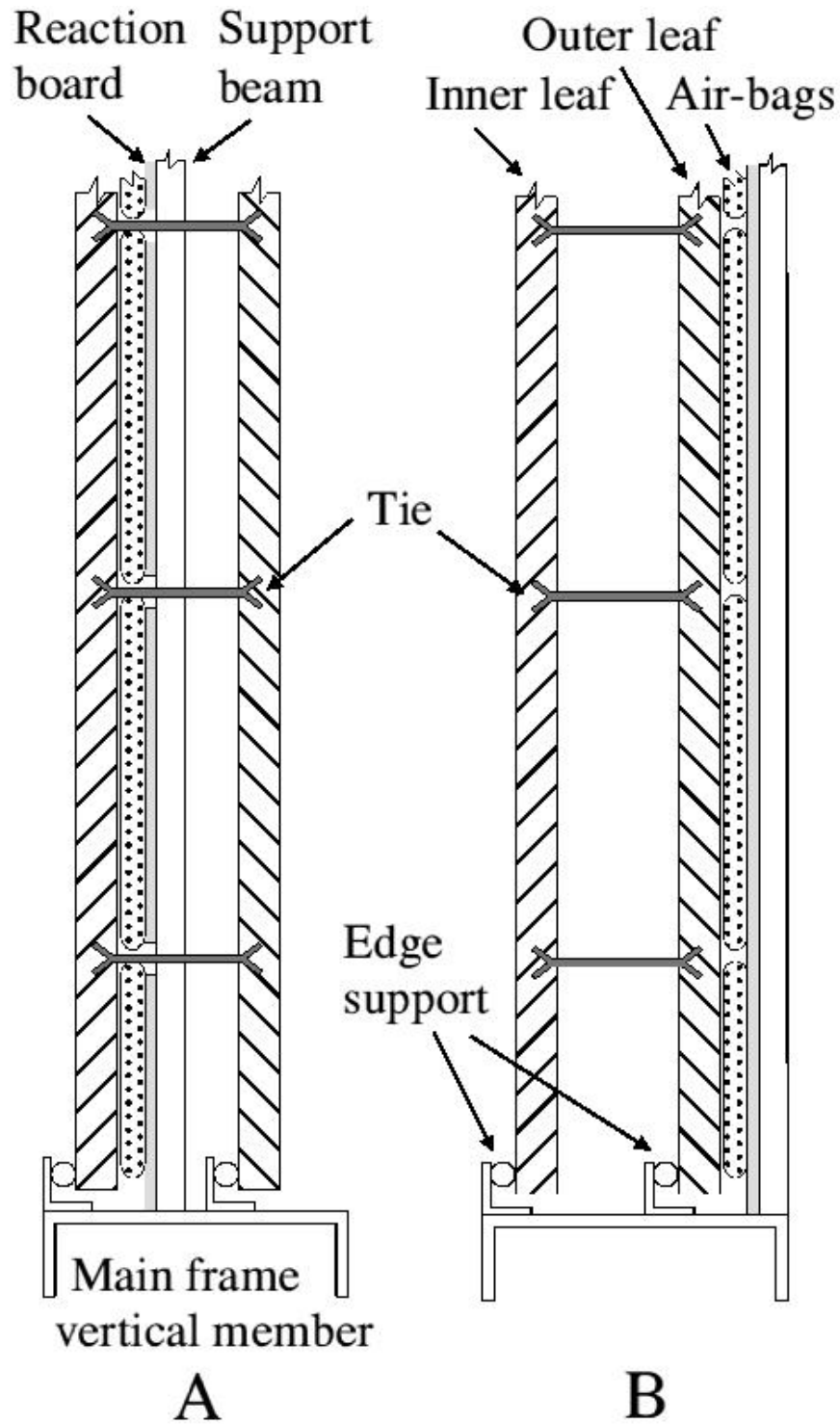


Figure 4. Test arrangement for the tension test A and the compression test B

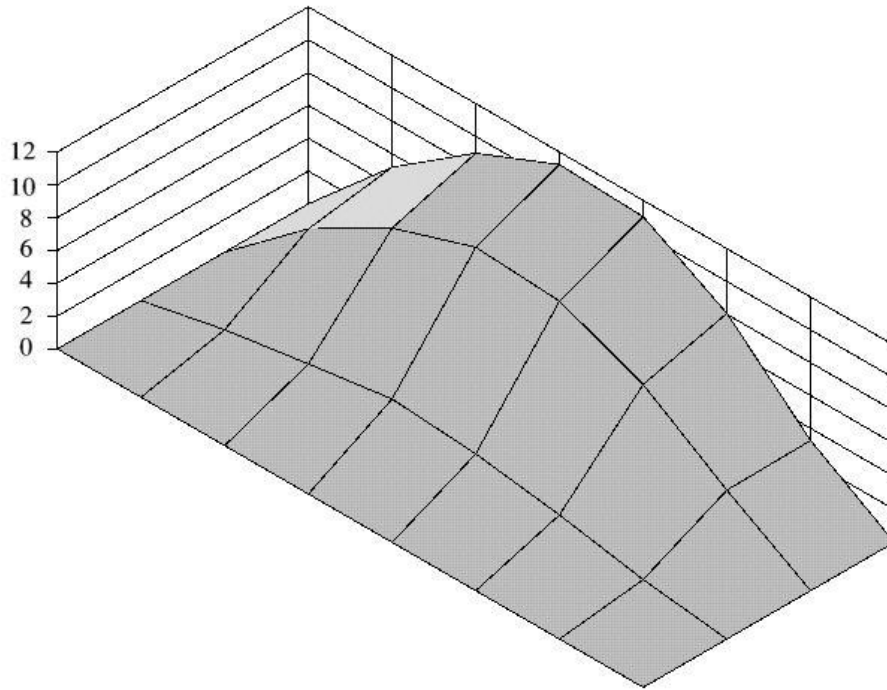


Figure 5. Deformed shape of wall 5 (no support to top edge) at serviceability level (mm)

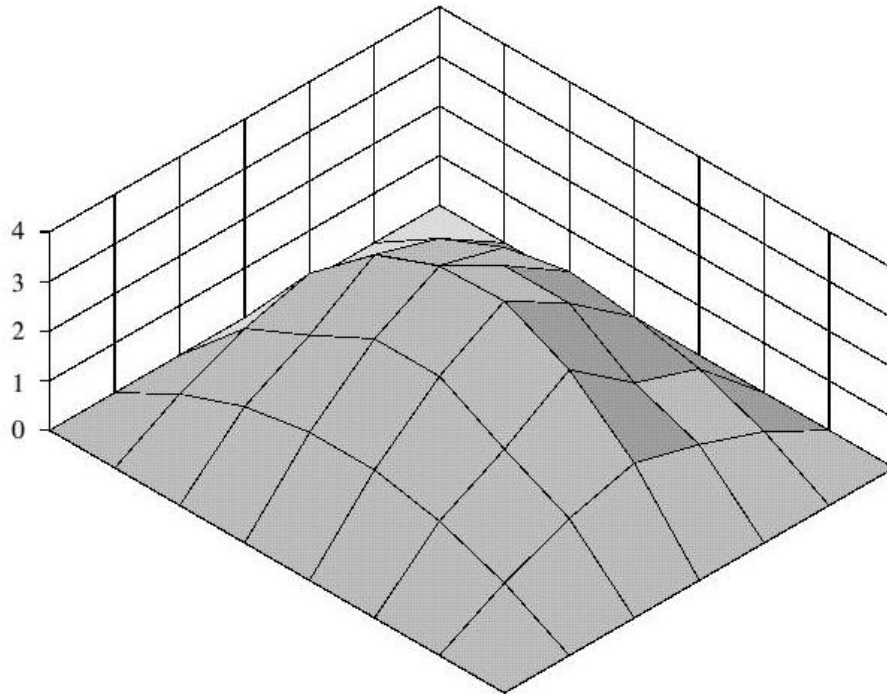


Figure 6. Deformed shape of wall 4 (4-sided support) at serviceability level (mm)