The Buttressing Resistance of lightly Loaded Partition Walls

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Abstract

An apparatus is described in which the effect of wind loading on an external wall being transferred to internal buttressing walls is determined. The floor loads, direct and transferred wind loads can be varied. Results are given for masonry walls in both clay bricks and concrete blocks and the modes of failure are discussed. Preliminary conclusions are drawn about the relative strengths of the walls and the effect of providing a return.

1. INTRODUCTION

An investigation is being carried out into the buttressing resistance of partition walls as part of a programme of research which has the objective of examining the interaction between external masonry walls and buttressing walls of masonry and other materials in modern forms of low rise construction. Interaction with other elements such as floors and walls above is being simulated by applied loads.

In multi-bay cross wall construction the main cross walls, including the gable walls, are the principal load-bearing elements. These walls, by virtue of their size and of the load on them, usually provide adequate resistance to wind forces parallel to them, that is normal to the longer faces of the building. The component of any wind force perpendicular to the cross walls must be transmitted into, and resisted by, flank, corridor and partition walls. These buttressing walls may be designed according to the simple rules given in Schedule 7 of the Building Regulations[1], but with the use of modern materials which lead to lighter and less robust structures, it is necessary to verify the empirical base of these rules. The results of the current programme are intended to be suitable for the development of these rules and to provide guidance on the means of improving the performance of existing buildings.

2. EXPERIMENTAL

2.1 Programme

In order to define the range of variables to be investigated an analysis of possible shapes and sizes of external and internal buttressing walls was carried out. This was based on the plan forms referred to in a feedback study[2] of the frequency of use of different house shells for

two-storey four, five and six person houses. The analysis included a large number of separate combinations of openings, wall sizes and loading conditions but to begin with walls without openings of three different lengths, both plain and with a return on one end, built in both brickwork and blockwork have been considered. The returns simulate the load-bearing inner leaf of the external cavity wall to a building.

The walls were all of storey height, made from either fletton bricks or autoclaved aerated concrete blocks (A.A.C.) laid in 1:1:6 mortar and were generally built off a bituminous damp proof course. In the case of walls with a return on one end, the difference between using a fully bonded and a buttered-up connection between the buttressing wall and the return was investigated. The walls were subjected to compressive loads consisting of a concentrated load on any return and a uniformly distributed load along the buttressing wall. These loads were chosen to be representative of those acting in one, two and three storey buildings, since the simple rules in the Building Regulations do not extend to taller buildings.

2.2 Test Arrangement

The first tests in this programme were carried out on the shorter fletton brickwork walls by modifying the B.C.R.A. 1000 t. wall testing machine. All the later tests were carried out in a purpose built rig. Up to four walls at a time can stand on its 200 mm thick reinforced concrete floor slab. This slab is 10.5 m long and 5.5 m wide and is enclosed within a peripheral frame of rolled steel sections, the maximum length of wall that can be accommodated is 8.1 m. A braced frame erected from the peripheral steel of the floor slab carries a gantry which may be moved sideways so that it can be aligned and clamped in position over each of the tests walls in turn. This gantry carries a number of small hydraulic jacks which are used to apply the uniform precompression through rollers and short spreader beams. At one end of the slab is a multiple buttress frame which is connected to the rear of the floor frame and tied back to its longerons. The vertical members of this buttress frame are used to react the hydraulic jacks which apply the horizontal load through short spreader beams. A load, uniformly distributed up the height of the wall, simulates the effect of the wind load on the external wall of the ground floor. A concentrated load at the top of the wall simulates the effect of loads on the other storeys and on the roof which are transferred into the wall. The test arrangement is shown in Figure 1.

During the tests the deflection of the wall in its plane at various positions up its height at both ends, and the sliding along the damp proof course were measured using electrical displacement transducers. Vertical strains were measured at various positions along the base of the wall and principal strains were determined at a number of other places on the face of the wall from measurements made using demec gauges.

3. RESULTS

The results of the tests on plain walls are shown in Table 1.

The first of the 1.0 m long walls were tested when subjected to a precompression corresponding to that in a three-storey building and these failed by overturning about the base of the unloaded edge at a relatively low shear load. The average shear stress in these walls at failure was 0.08 N/mm^2 only, this is considerably lower than the value that would be predicted using the structural masonry code[3]. As a result, 1.0 m and 2.5 m long walls were tested at increased precompressions and a further series of tests was planned to include walls with returns. At the increased precompression the failure of 1.0 m long blockwork walls included an element of crushing of the units and the 2.5 m long fletton brickwork walls all failed by sliding at the damp proof course. Despite the increased precompression these failures occurred at fairly low shear stresses. After testing each fletton wall was structurally sound except for the failed damp proof course so the walls were retested, sliding being prevented by a stop at the unloaded corner. In these cases the failure was by localised crushing at the stopped end.

The final part of this programme was the testing of eight, 4.5 m long, plain walls with a bituminous damp proof course. At one-storey precompression the blockwork wall failed by horizontal cracking at the bed joint above the first course and at two-storey precompression by sliding at the damp proof course. All the brickwork walls and the blockwork walls subjected to three-storey precompression failed by diagonal cracking.

The diagonal cracking in the brickwork walls was confined to the joints whereas it extended through both the units and the joints in the blockwork walls. In the brickwork wall with the lowest precompression the principal tensile strain near to a crack was measured as 80 microstrain at 65^o to the horizontal. In the blockwork walls principal tensile strains of 165 and 180 microstrain were recorded at 56^o and 42^o to the horizontal.

Figure 2 shows that for all the walls, except those which overturned there are, for both brickwork and blockwork, reasonable linear relationships between the average shear stress at failure and the total precompression applied to the wall. The strength of the brickwork walls is superior at precompressions typical in low rise construction.

The results of the tests on 4.5 m long walls with a return are given in Table 2. In these tests typical one-, two- and three-storey construction vertical loads were applied to the return in addition to the uniformly distributed precompressive load on the shear wall. All these walls failed by sliding at the damp proof course with some cracking at the vertical junction between the shear wall and the return. There is no clear distinction between the strength of the walls with different types of bonding to the return; certainly the vertical mortar joint, the weakest bond in general use, does not lead to walls with inferior shear resistance. Generally the brickwork walls were slightly stronger than the blockwork walls. The effect of the return was to increase the shear resistance of the walls by, on average, 20%.

4. DISCUSSION

For the plain walls clearly the length and the precompression affect the mode of failure. Chinwah[4] found that failures were due either to a horizontal tensile crack near the unloaded corner of the base of the wall or to diagonal cracks passing through both joints and units or the joints alone. At length/height ratios greater than 1.5, he found that the failure of brickwork walls was by diagonal cracking through the joints. In the present work the 4.5 m brickwork walls have a length/height ratio of 1.73 and exhibited the same mode of failure.

It is of interest to consider the orientation of the principal tensile stress to the bed joints in the walls which failed by diagonal cracking. Samarasinghe and Hendry[5] have produced data from model scale brickwork on the influence of this factor and their results are shown in Figure 3. This data was from a biaxial tension-compression test and this was shown by finite element analysis[6] to be the most important biaxial stress condition for failures initiated in the central or heel area of buttressing walls. Figure 3 shows that the failure envelope reduces in size as the angle between the bed joint and the principal tensile stresses increases. Failures at large orientation were caused by cracking through the mortar joints only. At lower orientations failures involved cracks through the units also. This seems to be confirmed by Mann and Muller[7] where greater normal stresses across a bed joint were accompanied by higher shear stresses at failure, the failure then involving cracking through the units. Failures at low normal stresses were through the joints only. From the trends in Figure 3 it seems reasonable to infer that in the 4.5 m brickwork wall with the lowest precompression, where the principal tensile strain was at 65^o to the bed joint, the brickwork may have had a comparatively low shear strength. At this orientation failure would be expected to occur through the joints only and this occurred. In the blockwork walls, cracks occurred through both units and joints although the orientation of the principal tensile strain to the bed joint was lower. It also seems likely that for the failure to be confined to these joints, the angle between the principal tensile stress and the bed joint will be greater for blockwork than for brickwork.

5. CONCLUSIONS

1. At precompressions typical of low rise construction 1.0 m long plain shear walls fail by overturning when subjected to a low average shear stress. This type of failure can be prevented by increasing the precompression, however the average shear stress at failure is still fairly low. The suitability of walls of this length should be determined when the influence of a return has been established.

2. 4.5 m long, plain walls fail by diagonal cracking, which in the case of brickwork is confined to the joints but passes through the units also in blockwork. This behaviour can be explained qualitatively by consideration of the orientation of the principal tensile stress to the bed joint and this agrees with the results of other workers.

3. For plain walls of both brickwork and blockwork there is a reasonable linear relationship between the average shear stress at failure and the total precompression.

4. The effect of providing a return at the loaded edge of 4.5 m long walls is to increase the failure load by about 20%, failure being by sliding along the damp proof course. There is no significant difference between the resistance of walls with bonded and buttered connections to the return.

5. At the loads tested, the shear resistance of brickwork walls, both plain and with returns, is, on average, somewhat superior to that of blockwork walls.

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Table 1

Results of Tests on Plain Shear Walls of Different Lengths

Wall No	Material*	Length (m)	Length/ Height	Total Precompression (kN)	Shear Load at Failure (kN)	Failure Mode**
1163	B	1.0	0.38	33	7.2	O
1164	B	1.0	0.38	33	9.3	O
1167	C	1.0	0.38	33	7.5	O
1165	C	1.0	0.38	75	18.75	O + N
1166	C	1.0	0.38	100	20.25	V + N
1177	B	2.5	0.96	187.5	75	S
1180	B	2.5	0.96	250	114	S
1184	B	2.5	0.96	250	90	S
1191	B	2.5	0.96	312.5	114	S
1252	B	4.5	1.73	31.5	120	D
1253	B	4.5	1.73	90	120	D
1255	B	4.5	1.73	90	120	D
1257	B	4.5	1.73	148.5	105	D
1228	C	4.5	1.73	31.5	70	D + S
1226	C	4.5	1.73	90	100	D + S
1225	C	4.5	1.73	148.5	108	D
1227	C	4.5	1.73	148.5	135	D

* B = Fletton Brickwork   C = AAC Blockwork

** O = Overturning
N = Crushing
S = Sliding
D = Diagonal Cracking
V = Vertical Crack

Table 2

Results of Tests on Shear Walls 4.5m Long with Returns

Wall No	Material/ Return*	Length/ Height	Total Precompression (kN)	Shear Load at Failure (kN)
1280	BU	1.73	41.5	110
1283	BU	1.73	142	190
1285	BU	1.73	142	130
1284	BU	1.73	231.5	150
1311	BR	1.73	41.5	103
1306	BR	1.73	142	130
1324	BR	1.73	142	160
1305	BR	1.73	231.5	135
1327	CU	1.73	142	130
1321	CR	1.73	41.5	80
1322	CR	1.73	142	150
1323	CR	1.73	231.5	165

B = Fletton Brickwork
U = Buttered Return
R = Bonded Return

C = Autoclaved Aerated Concrete Blockwork

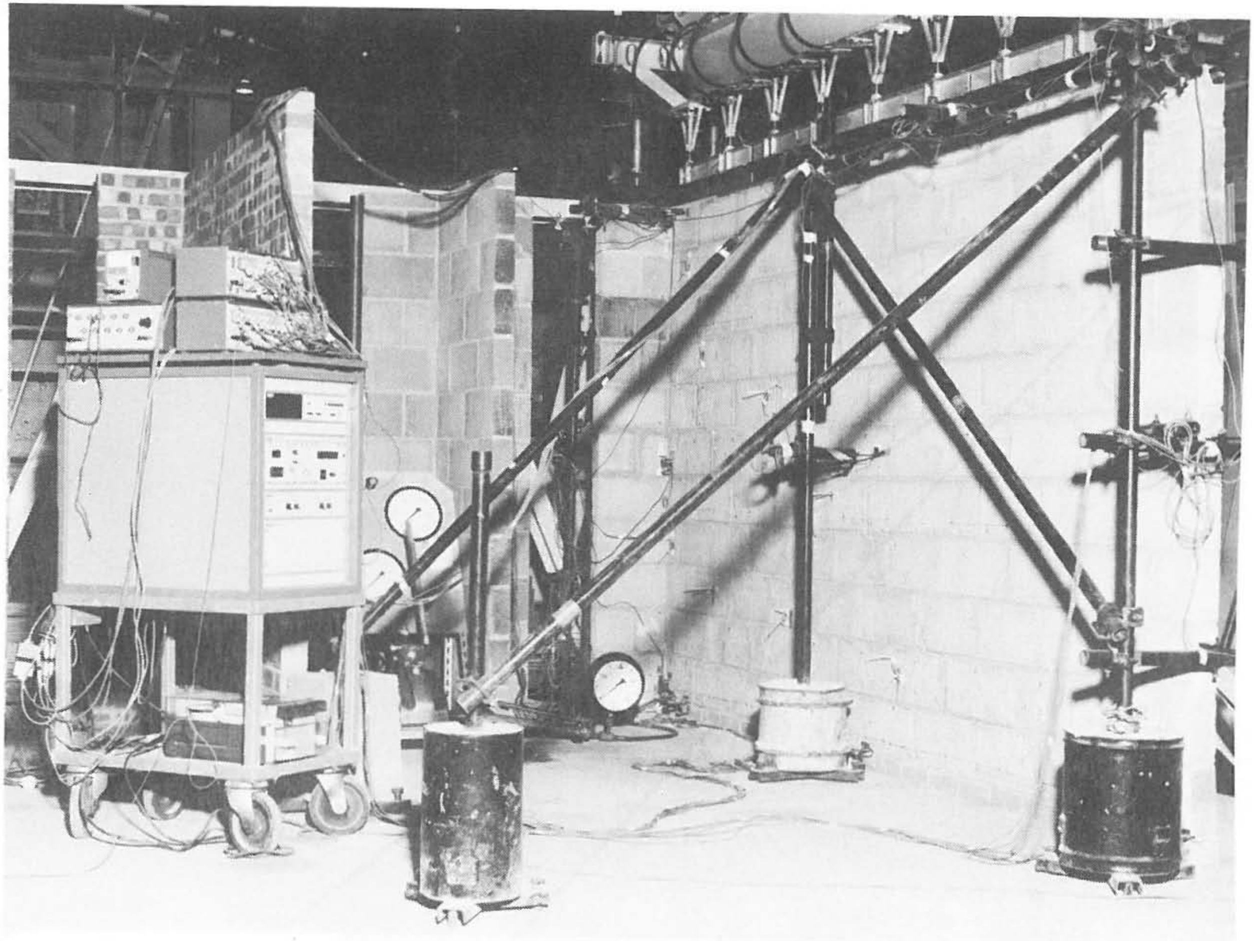

FIGURE 1. General Arrangement of Test on 4.5 m Concrete Blockwork Wall with Return

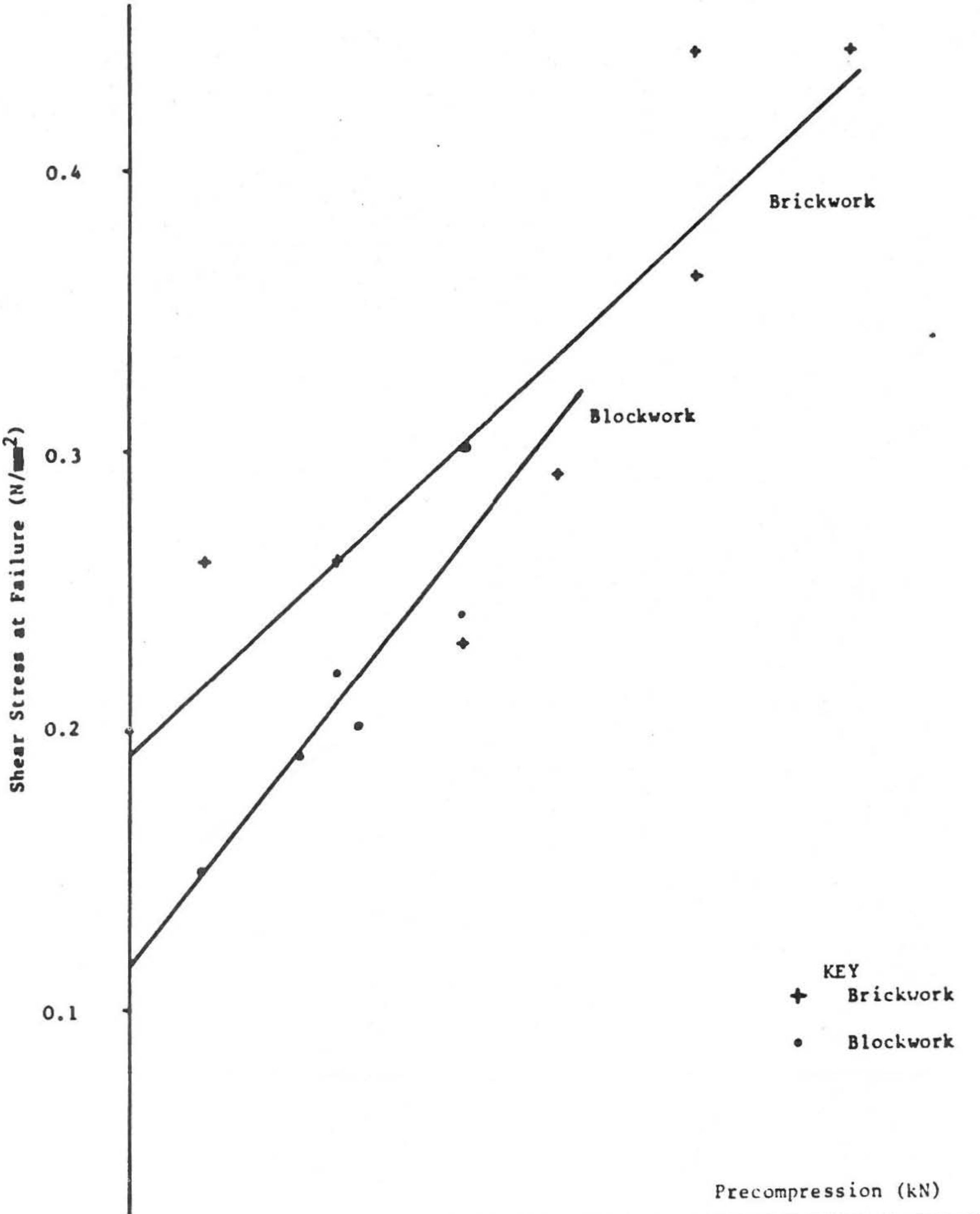

Figure 2. Relationship Between Shear Stress at Failure and Total Precompression for Plain Walls

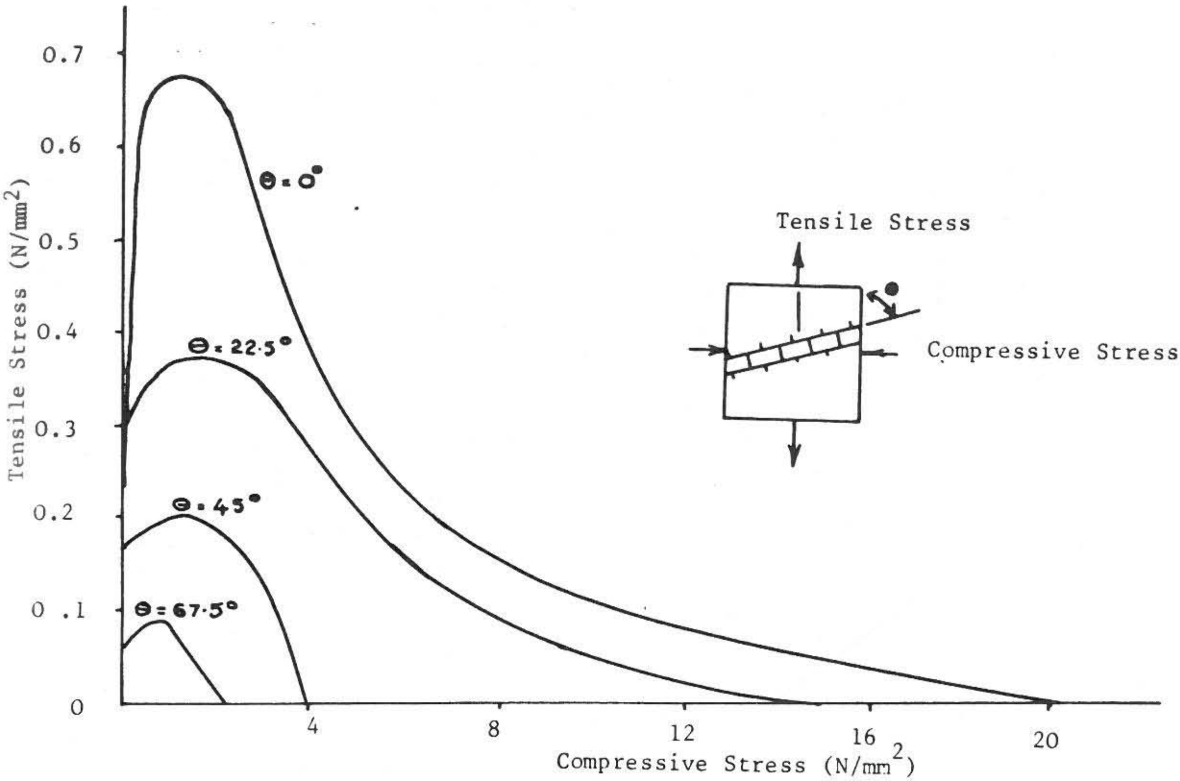

Figure 3. Biaxial Strength Envelopes for Different Bed Joint Orientations