IV-25. The Lateral Resistance of Cavity Walls with Different Types of Wall Ties

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ABSTRACT

The resistance to lateral loading of cavity walls of different lengths is examined in relation to the type of wall ties used. Vertical twist steel ties and butterfly wire ties are the most common forms in U.K., but polypropylene ties and a truss type reinforcement between the two leaves have also been tested.

La résistance aux charges latérales des murs à cavité interne de murs de longueurs différentes est examinée en rapport avec le type d'agrafes d'ancrage utilisées. Les agrafes à vrillage vertical et les agrafes en huit sont celles des formes les plus communes au Royaume Uni mais les agrafes en polypropylène et un renfort du type console entre les deux pans de mur ont aussi été essayés.

Der Widerstand von Hohlwänden mit verschiedenen Längen gegen Seitenbelastung wird für verschiedene Mauerbinder untersucht. Die gewöhnlich in Großbritannien angewendeten Formen sind vertikal verdrehte Stahlbinder und Flügeldrahtbinder, jedoch wurden Polypropylenbinder und eine gerüstartige Verstärkung zwischen den beiden Schichten geprüft.

La resistenza a sollecitazioni laterali di muri a intercapedine di varie lunghezze viene esaminata con riferimento al tipo di collegamento murario usato. Le forme più comuni in Gran Bretagna sono i collegamenti d'acciaio a torsione verticali ed i collegamenti a filo metallico a farfalla, ma sono anche stati provati i collegamenti a polipropilene ed un tipo di rinforzo reticolare nell'intercapedine tra i due muri.

INTRODUCTION

A British cavity wall consists of two leaves of masonry, usually either brick and brick or brick and lightweight concrete block, held together by ties. There are several different types of ties used, most of them galvanised mild steel but a few either stainless steel, bronze or polypropylene. In the design of masonry walls to withstand lateral loading—that is uniformly distributed loading at right angles to the plane of the wall—it is necessary first of all to compute the resistances of the two separate leaves and then make an allowance for the interaction between the two leaves. If the tie is so weak as to be incapable of acting as a stud, then a positive pressure acting on the outer leaf will not be transmitted to the inner leaf and the effective resistance of the two leaves will be little more than that of the outer leaf on its own. If the tie is capable of transmitting thrust, then there will be load distribution between the two leaves. If, in addition to transmitting thrust, the tie is also capable of transmitting some shear, then there will be a degree of interaction between the two leaves and an enhanced lateral resistance would be expected. This paper describes the results of lateral tests on cavity walls with, variously, vertical twist and butterfly ties (both in galvanised mild steel) polypropylene ties and a mild steel truss type reinforcement between the two leaves.

EXPERIMENTAL

The test walls are built into steel frames representing one bay of a multi-bay framed structure. A uniformly distributed pressure is applied to the face of the wall by a system of inflatable air-bags. The construction of the walls and the method of test are more fully described elsewhere.[1] In the case of single leaf walls linear transducers are arranged to be in contact with the back of the wall to measure the lateral deflection of the walls. For cavity walls transducers may be arranged to be in contact with the room side of the inner leaf; to measure the deflection of the outer leaf it is necessary to insert rigid ptfe tubes into small holes drilled in the inner leaf, and to pass through these tubes metal rods which contact the back of the outer leaf and which bear on the transducers at their other ends. It is thus possible to measure the deflections of the two leaves at adjacent points, and derive the closing of the cavity (if any).

The performance of the ties was determined in two types of cavity wall, one with both leaves of brick (wirecut facing and pressed common) and one with an outer leaf of common brick and an inner leaf of aerated concrete block. Most of the walls were built with a cavity width of approximately 70 mm, giving an overall wall width of 275 mm, but a small number were built with a cavity width of

150 mm (which is the widest cavity permitted in BS 5628[2]) giving an overall wall width of 355 mm. The 70 mm wide cavity walls had the ties set at the standard spacing of 900 mm horizontally and 450 mm vertically. The walls with truss type reinforcement had the reinforcement placed at 450 mm vertically. Where the reinforcement was shorter than the length of the wall there was an overlap of 300 mm.

RESULTS AND DISCUSSION

The physical properties of the bricks and blocks used are given in Table 1. The dimensions of the ties are shown in Figure 1 and the results for storey-height walls and lengths varying from 2.74 to 5.5 m are given in Table 2.

When this programme began it was considered that the lateral strength of cavity walls should be taken as 0.9 times the sum of the moments of resistance of the two leaves. However, subsequent tests with various combinations of brick and block with 1:1:6 mortar showed that the mean ratio of 24 walls built with vertical twist, butterfly or polypropylene ties was 1.08.

It had earlier been suggested that the less rigid ties (butterfly and polypropylene) might transmit load less effectively from one leaf to the other. Some evidence for this is given by the fact that shorter, and thus stiffer, sections generally give lower values for the ratio of the failure load of the cavity wall to the sum of the leaves. However, in view of the fact that the ratio uses a mean value for the single leaves, since it is not possible to determine the actual value of those in the cavity wall, this effect may not be serious.

On the other hand the use of truss type reinforcing as a tie between the leaves gave enhanced cavity wall strengths. If sufficient reinforcement were to be provided, it would be possible for the cavity wall to behave as a solid 275 mm wall which would be an enhancement over the sums of two equal leaves of 3.6. In the present series of tests the ratio of the wall strength to the sum of the strengths of the two leaves ranged from 1.26 to 1.57, compared to about 1 when wall ties were used. This shows that the diagonal tieing effect produced by the reinforcement does lead to some composite action.

If a wall is to be reinforced to have a greater bending resistance, the reinforcement should ideally be near to the surfaces of the wall. With the type of reinforcement used in these tests, the longitudinal bars were towards the centre of each leaf, so the increase in strength of each leaf would not be very great. It is likely that almost all of the increase noted in the tests is due to the composite action achieved by the bars. The reinforcement was laid at approximately 450 mm vertical centres to replace the conventional wall ties, used at those centres. It is likely that there would have been a markedly greater benefit if the reinforcement had been used at 225 mm vertical centres, i.e. in every block joint or every third brick joint.

One wall with vertical twist steel ties set at half normal spacing both vertically and horizontally, that is quadruple the normal number of ties, also gave an enhanced strength. Three walls loaded on the inner leaf gave results similar to those loaded on the facing leaf.

Table 3 compares the result of a wall with reduced ties (0.9 m spacing vertically as well as horizontally, thus 15 ties in 3 rows instead of 25 ties in 5 rows) with a standard wall. A single leaf wall was built by the same bricklayer from the same batch of bricks. In the wall with reduced ties (No. 1236) the two leaves deflected together up to about 4 kN/m^2 and then the loaded leaf began to deflect more, indicating buckling, until at 5.9 kN/m^2 there was a sudden increase in the deflection of the loaded leaf and a decrease in the deflection of the unloaded leaf i.e. a partial recovery. (Figure 2) This was indicative of the total collapse of the ties. The failure load of the single leaf wall was considerably higher than that previously obtained with this brick and mortar and in consequence the lateral resistances of the cavity walls are less than the sum of the leaves. It should be noted that in earlier calculations e.g. Table 2 the mean value of all single leaf walls of the particular length has been taken and using this (2.21 kN/m^2) gives a ratio of 1.33 even for the reduced ties. This suggests that this particular set of brick walls was above average in strength possibly because of better workmanship but certainly not because of higher mortar strength since these are close to the minimum acceptable 28 day value given in SP 56.[3]

The results of testing walls with 150 mm wide cavities in Table 3 show that, although the standard spacing of ties was used instead of reducing the horizontal spacing to 450 mm as required by BS 5628, there was no weakening of the wall. Indeed some advantage has been gained though not fully proportional to the ratio of the moduli of the 150 mm cavity wall to the 70 mm cavity wall (2.1).

CONCLUSIONS

1. The mean ratio of the lateral load resistance of the cavity wall to the sum of the moments of resistance of the two individual leaves for 24 walls using 3 types of ties is 1.08.
2. There is some evidence that butterfly wire ties and polypropylene ties tend to give lower ratios at high lateral resistance, that is with the shorter walls.
3. The use of truss type reinforcement as a tie gives enhanced strength as does quadrupling the number of twisted steel ties.
4. In the experiments so far on reducing the number of ties, the results are inconclusive though no serious diminution in strength is suggested.
5. There is no significant difference in the results whether the cavity walls are loaded from the outer or inner leaves.
6. When walls with cavities of 150 mm width were tested using the standard tie spacing appropriate to narrower cavities, there was no weakening of the wall. Some advantage was gained, though not fully proportional to the ratio of the moduli of the two types of cavity wall.

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REFERENCES

1. WEST, H.W.H., HODGKINSON, H.R., HASELTINE, B.A. and TUTT, J.N. The Resistance of Brickwork to Lateral Loading. J.I.Struct.E., Vol. 55 No. 10, Oct. 1977.
2. BRITISH STANDARDS INSTITUTION. CODE of PRACTICE for STRUCTURAL USE of MASONRY. BS 5628:Part 1: 1978, Unreinforced Masonry.
3. BRITISH CERAMIC RESEARCH ASSOCIATION. Model Specification for Load Bearing Clay Brickwork. BCRA Special Publication, No. 56, 1975.

TABLE 1—Physical Properties of Bricks and Blocks

Unit	Mean Crushing Strength N/mm^2	Mean Water Absorption %	Mean Suction Rate $Kg/m^2/min$	Density Kg/m^3
Brick A	63.1	6.4	0.35	N.A,
Brick B	27.9	22.2	2.35	N.A.
Block A.A.C.	4.1	N.A.	N.A.	700

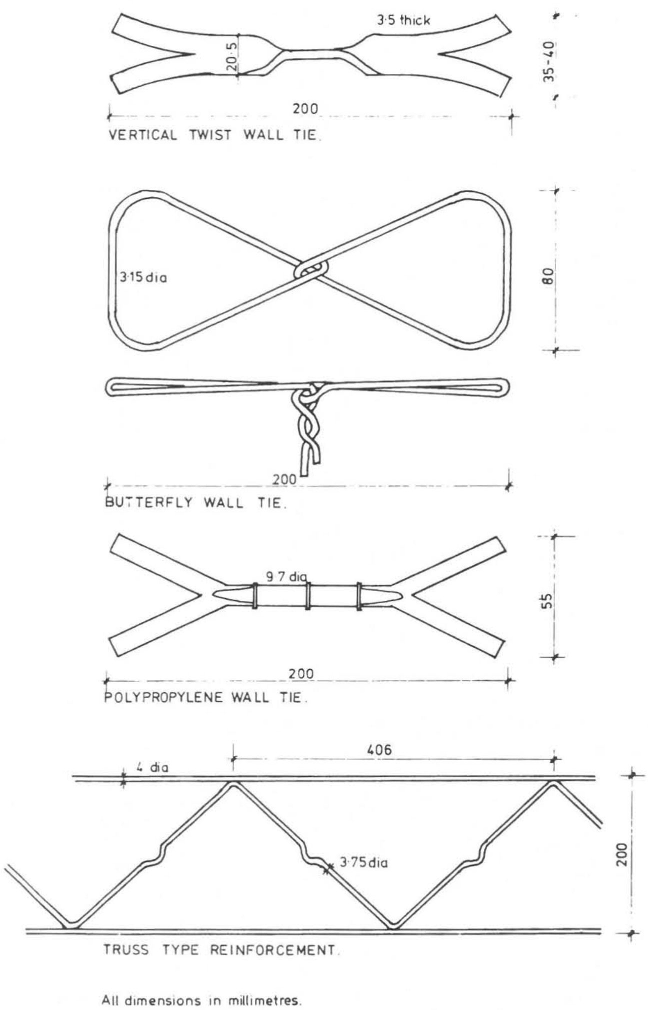

Figure 1. Form and dimensions of ties

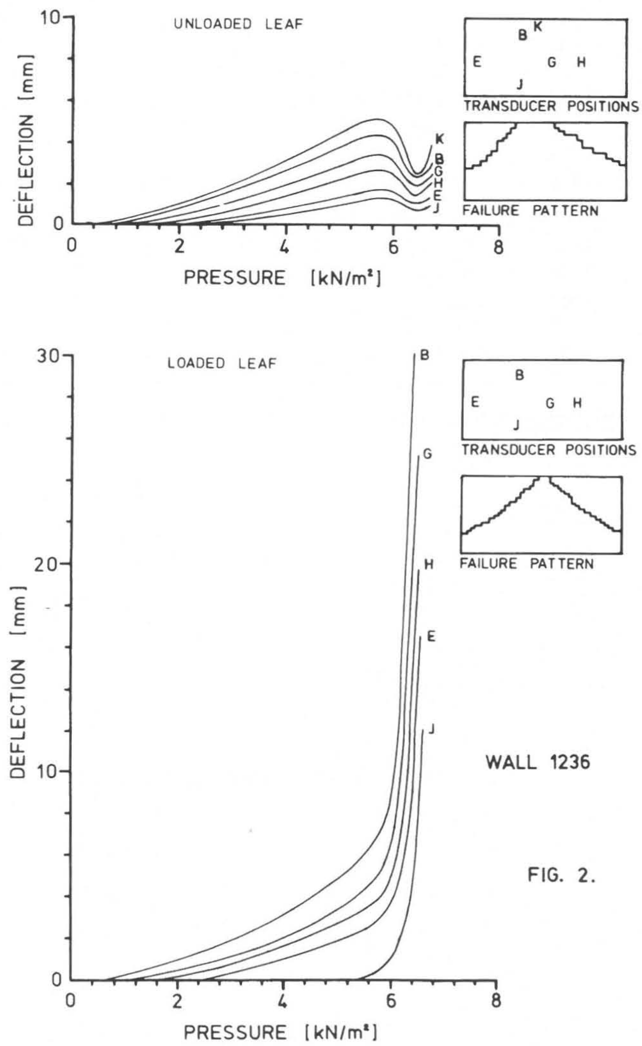

Figure 2. Deflections under load of the two leaves of the cavity wall no. 1236 with reduced ties.

TABLE 2—The Effect of Different Ties on the Lateral Resistance of Storey-Height Cavity Walls Compared with That of the Two Leaves. (1:1:6 Mortar. Direction of Loading Shown)

Wall No	Unit Types Loaded + Unloaded	Wall Length m	Mortar Strength N/mm²	Failure Pressure kN/m²	Failure Pressure of Walls of Same Units kN/m²	kN/m²	Sum of Resistance of Two Leaves kN/m²	Ratio of Wall / Sum of Leaves
Vertical Twist Steel Ties								
1053	A + AAC	5.5	6.8	3.9	2.4	0.8	3.2	1.22
1087	AAC + A	5.5	4.8	3.9	0.8	2.4	3.2	1.22
1057	A + B	5.5	7.1	6.4	2.4	2.0	4.4	1.45*
1022	A + B	5.5	3.6	4.0	2.4	2.0	4.4	0.91
1242	A + B	3.66	4.6	6.9	3.5	3.4	6.9	1.00
1049	B + AAC	5.5	5.2	3.4	2.0	0.8	2.8	1.21
1241	B + AAC	4.57	4.6	5.1	2.3	1.1	3.4	1.50
1240	B + AAC	3.66	4.3	5.6	3.4	1.3	4.7	1.56
1084	AAC + B	5.5	5.3	3.2	0.8	2.0	2.8	1.14
1058	B + LWA	5.5	7.7	3.7	2.0	1.3	3.3	1.12
1068	B + HA	5.5	7.6	4.9	2.0	2.1	4.1	1.20
1093	HA + B	5.5	4.9	5.4	2.1	2.0	4.1	1.32
*Quadruple Ties								
Butterfly Wire Ties								
1118	A + B	5.5	4.6	5.0	2.4	2.0	4.4	1.14
1130	A + B	4.57	3.7	4.8	2.8	2.3	5.1	0.94
1122	A + B	3.66	4.5	5.8	3.5	3.4	6.9	0.84
1112	B + AAC	5.5	4.2	3.2	2.0	0.8	2.8	1.14
1113	B + AAC	4.57	4.3	3.5	2.3	1.1	3.4	1.03
1115	B + AAC	3.66	3.6	3.8	3.4	1.3	4.7	0.81
1146	B + AAC	2.72	4.0	5.2	3.9	1.4	5.3	0.98
Polypropylene Ties								
1161	A + B	5.5	4.2	4.4	2.4	2.0	4.4	1.00
1193	A + B	4.57	4.5	4.8	2.8	2.3	5.1	0.94
1194	A + B	3.66	4.7	7.0	3.5	3.4	6.9	1.01
1147	B + AAC	5.5	4.0	3.0	2.0	0.8	2.9	1.03
1202	B + AAC	4.57	3.4	3.2	2.3	1.1	3.4	0.94
1195	B + AAC	3.66	4.4	4.0	3.4	1.3	4.7	0.85
Truss Type Reinforcement								
1181	A + B	5.5	4.2	5.8	2.4	2.0	4.4	1.32
1217	A + B	4.57	4.1	8.0	2.8	2.3	5.1	1.57
1205	A + B	3.66	4.1	8.7	3.5	3.4	6.9	1.26
1182	B + AAC	5.5	3.8	4.1	2.0	0.8	2.9	1.41
1218	B + AAC	4.57	4.3	5.1	2.3	1.1	3.4	1.50
1206	B + AAC	3.66	4.0	6.1	3.4	1.3	4.7	1.30

HA = Heavy Aggregate
LWA = Lightweight Aggregate
AAC = Aerated Concrete

TABLE 3—Effect of Reduced Ties on the Lateral Strength of Storey-height Walls

Wall No	Brick Type	Mortar Strength N/mm²	Failure Pressure kN/m²	Sum of Resistance of two leaves kN/m²	Ratio: Wall / Sum of Leaves
1234	B	3.7	3.3		
1235	B + B	3.8	6.0	6.6	0.91
1236*	B + B	3.9	5.9	6.6	1.08

*Reduced Ties