The Performance of Truss-Type Reinforcement in Masonry

by

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Abstract

Brick and block masonry containing a truss-type reinforcement has been tested to determine the load carrying capacity of lintol beams and the tying resistance of cavity walls; the bond of galvanised and plastic-coated versions of the reinforcement in the mortar joints have been compared.

1. INTRODUCTION

This paper describes experiments to determine the performance of brick and block masonry with truss-type reinforcement laid in the bed joints. The experiments had three objectives:

A. To compare the bond resistance of galvanised and plastic coated reinforcement in the bed joint of clay brickwork.

B. To determine the magnitude of the forces transmitted by the reinforcement, when both in compression and tension, from one leaf of a cavity wall to the other.

C. To determine the load-bearing capacity of brick and block masonry lintol beams containing truss-type reinforcement.

2. CONSTRUCTION OF TEST MASONRY AND METHODS OF TEST

2.1. Materials

The bricks used were semi-dry pressed single frogged, having a mean compressive strength of 25.4 N/mm^2, a water absorption of 21.7% and a suction rate of 2.7 $kg/m^2/min$, which was adjusted to approximately 1 $kg/m^2/min$ before laying. The autoclaved aerated concrete blocks had a

mean crushing strength of 4.0 N/mm^2. The mortar was 1:4½ Portland cement: sand (BS 5628 Designation ii) and it had a mean crushing strength of 12.0 N/mm^2.

The types of reinforcement used in the tests are illustrated in Figure 1. The steel was reported by the manufacturer to have a tensile strength of 550 N/mm^2. Type A was galvanised and Types B and C were plastic-coated. The cross-rods of Type C had a water-drip at their mid-point.

2.2. Bond Resistance

The test specimens constructed to meet objective A consisted of two courses of brickwork with a length of truss-type reinforcement laid in the bed joint and protruding from one end. A constant compressive load was applied to the test specimen while a tensile load was applied to the reinforcement protruding from the end of the specimen through a clamping bar. The method of test is illustrated in Figure 2.

Two levels of compressive load were applied, that equivalent to the self weight of 0.3m height of masonry and that equivalent to the self weight of 2.6m of masonry. In the case of the galvanised reinforcement the bond lengths were 200 and 250mm; for the plastic coated reinforcement the bond lengths were 300 and 400mm. For each combination three replicates were tested. In all cases the ends of the reinforcement as embedded were identical to the end as manufactured, as shown in Figure 3.

2.3. Compressive and Tensile Strength of Cavity Reinforcement

The test specimens constructed to meet objective B consisted of two-leaf clay brick cavity walls approximately 1.35m high and 1m long. The two leaves were connected by three pieces of plastic coated reinforcement set in bed joints at 450mm vertical centres; the cavity width was 105mm. Three specimens were tested with the reinforcement in compression; one leaf was uniformly restrained by an immovable plane vertical surface while a uniformly distributed load was applied to the outer face of the other leaf by air-bags. Three specimens were tested with the reinforcement in tension; they were subjected to a uniformly distributed load applied equally to the inner faces of the two leaves by means of air-bags situated in the cavity of the wall. In both cases the relative displacement of the two leaves was measured by suitably disposed linear transducers coupled to a data logger.

2.4. Lintol Beams

The test specimens constructed to meet objective C consisted of three lintol beams built of clay bricks and three built of autoclaved aerated concrete blocks laid in stretcher bond. The beams were 2.6m long by 0.6m (clay brick) and 0.675mm (AAC) high, and incorporated plastic

coated reinforcement in each bed joint. They were tested to destruction under 4 point loading over a 2m span. Vertical deflections were measured by suitably disposed transducers coupled to a data logger.

3. RESULTS

3.1. Bond Resistance

The failure loads are given in Tables 1 and 2. In only one case was the failure of the galvanised reinforcement due to bond slip, and in four cases the plastic-coated reinforcement failed by bond slip. In all other cases the longitudinal wires failed in tension with conventional necking at the point of failure.

3.2. Compressive and Tensile Strength of Cavity Reinforcement

The lateral loads applied to the cavity wall specimens are given in Table 3, and the changes in cavity width versus applied pressure are plotted in Figures 4a-f.

The mode of failure in compression was by buckling of the cross-rods as struts, about the drip points. The mode of failure in tension was by tensile failure of the cross-rods. In one instance tensile failure apparently occurred in all the rods simultaneously; in the other two instances failure occurred at one end of the wall and progressed along it. There was no evidence of bond failure in any of the specimens.

3.3. Lintol Beams

The failure loads of the lintol beams are given in Table 4, and graphs of deflection at mid-span versus applied load are given in Figure 5.

The lintols behaved as beams and the mode of failure was shear, due to failure of the bond between the mortar and the bricks or blocks. In no case did any of the reinforcement fail in tension. Plots of the crack patterns are given in Figures 6a-f.

4. DISCUSSION

4.1. Bond Resistance

All the tests were subjected to a statistical analysis, which showed that there were no significant differences within nor between groups. Eleven of the twelve tests on the galvanised reinforcement resulted in failure due to wire breakage and similarly eight of the twelve tests on the plastic coated reinforcement. The average bond resistance of the

galvanised reinforcement was 19.4 kN and that of the plastic coated reinforcement 18.9 kN. These compare with the calculated tensile strength of the reinforcement, including the component of the diagonal rod, of 19.6 kN based on the tensile strength of the wire as reported by the manufacturer.

The minimum bond length used in the tests, i.e. 200mm for the galvanised reinforcement and 300mm for the plastic coated reinforcement, is adequate with a minimum precompression of 0.005 N/mm^2 in a designation (ii) mortar. Further tests are necessary to determine the minimum bond length and minimum precompression required.

4.2. Compressive and Tensile Strength of Cavity Reinforcement

The tests for the transfer of compressive and tensile forces across the cavity showed that the truss-type reinforcement is capable of providing adequate resistance and compares well with the figure quoted for wall ties in BS 5628:Part 1[1].

The compressive resistance of the truss-type reinforcement was 4.2 kN/m. BS 5628[1] does not give compressive values for wall ties in cavities over 75mm wide, but for 75mm wide cavities, assuming the code spacing of 750mm for a nominal 100 cavity width, the characteristic compressive resistance would be 0.7 kN/m for butterfly ties, 1.7 kN/m for double triangle ties and 6.7 kN/m for vertical twist ties. With a larger cavity width, the code values would be reduced.

The tensile resistance of the truss-type reinforcement was 19.5 kN/m compared with BS 5628 characteristic tensile strengths of 4.0 kN/m for butterfly wall ties and 6.7 kN/m for double triangle and vertical twist wall ties assuming 750mm spacing as above.

4.3. Lintol Beams

The beams did not fail in bending and it was found by calculation using SP 91[2] that the moment of resistance of the beam was in excess of the applied moment at failure load; the reinforcement behaved in tension as expected.

The beams failed in shear and, at the failure load, the calculated maximum horizontal shear in the bed joints was 1.1 N/mm^2 for the brickwork beams and 0.4 N/mm^2 for the AAC beams compared with a BS 5628 characteristic value of 0.35 N/mm^2.

5. CONCLUSIONS

When a minimum precompression of 0.005 N/mm^2 is applied, a bond length of 200mm, in a designation (ii) mortar joint, is adequate for galvanised truss-type reinforcement and 300mm for the plastic coated version.

When transferring loads across a cavity the compressive and tensile strength of cavity truss-type reinforcement is adequate and compares well with code values for normal cavity wall ties.

Truss-type reinforcement laid in horizontal bed joints allows brickwork or blockwork to act as a lintol beam. In the tests neither tensile nor compression failure occurred but high values of shear were found in the bed joints.

ACKNOWLEDGEMENT

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REFERENCES

1. BRITISH STANDARDS INSTITUTION. Code of Practice for Structural Use of Masonry. BS 5628 Part 1:1978.

2. BRITISH CERAMIC RESEARCH ASSOCIATION. Design Guide for Reinforced and Prestressed Clay Brickwork. SP 91, 1977.

TABLE 1

Bond Resistance of Galvanised Reinforcement

Bond Length mm	Precompression N/mm^2	Failure Load kN	Mode of Failure
200	0.005	21.17 20.18 18.68 Mean 20.01	Wire breakage Wire breakage Wire breakage
250	0.005	14.95 19.93 20.68 Mean 18.52	Bond slip Wire breakage Wire breakage
200	0.042	16.19 21.67 20.92 Mean 19.59	Wire breakage* Wire breakage Wire breakage
250	0.042	21.17 17.44 20.18 Mean 19.60	Wire breakage Wire breakage Wire breakage*

TABLE 2

Bond Resistance of Plastic-coated Reinforcement

Bond Length mm	Precompression N/mm^2	Failure Load kN	Mode of Failure
300	0.005	20.18 19.93 19.43 Mean 19.85	Bond slip Wire breakage Bond slip
400	0.005	18.68 18.18 17.44 Mean 18.10	Wire breakage Wire breakage Bond slip
300	0.042	16.44 18.68 19.31 Mean 18.14	Bond slip Wire breakage Wire breakage
400	0.042	18.68 19.43 20.43 Mean 19.51	Wire breakage Wire breakage Wire breakage*

* In these cases both longitudinal wires broke; in all other cases only one longitudinal wire broke.

TABLE 3

Compressive and Tensile Strength of Cavity Wall Specimens

Specimen No.	Type of Loading	Failure Load kN/m^2
1	Compressive	9.0
2		9.9
3		9.2
		Mean 9.4
4	Tensile	46.0
5		43.0
6		44.0
		Mean 43.3

TABLE 4

Failure Load of Lintol Beams

Specimen No.	Type of Masonry	Failure Load kN	Load at First Crack kN
1	Brick	88.6	46.7
2		81.7	34.4
3		72.2	38.5
		Mean 80.8	
4	AAC Block	23.3	11.7
5		25.2	13.1
6		22.8	7.8
		Mean 23.8	

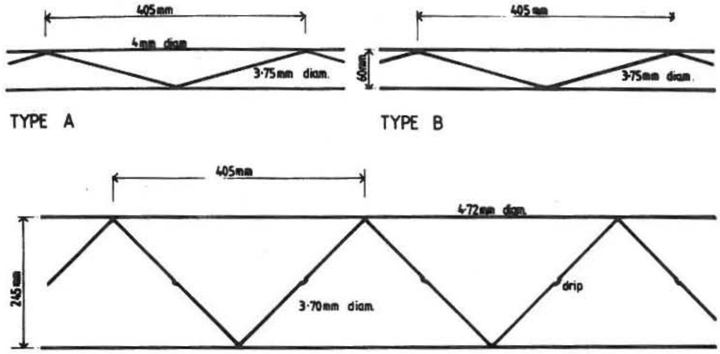

Figure 1. DIMENSIONS OF REINFORCEMENT.

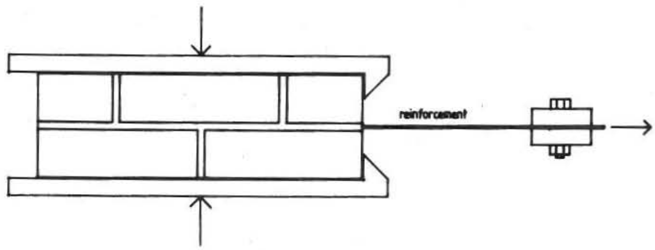

Figure 2. METHOD OF TEST OF BOND RESISTANCE

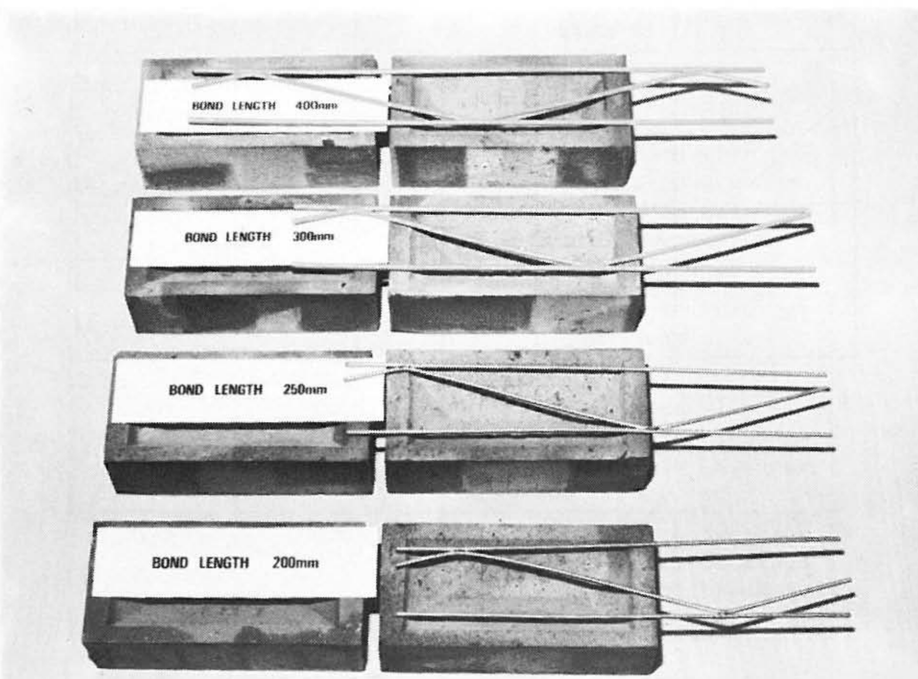

FIGURE 3: Embedment of Reinforcement

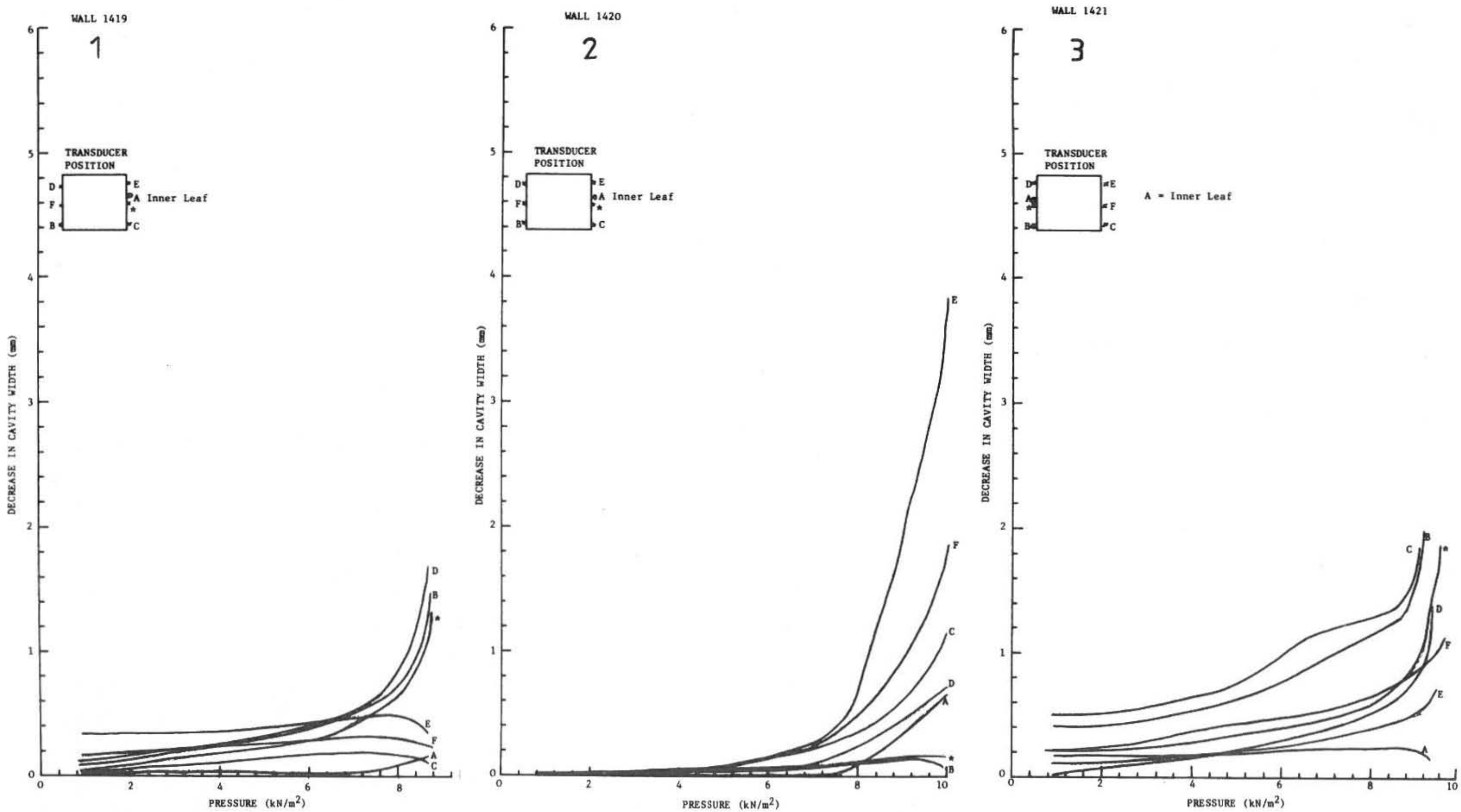

FIGURE 4: Change in Cavity Widths

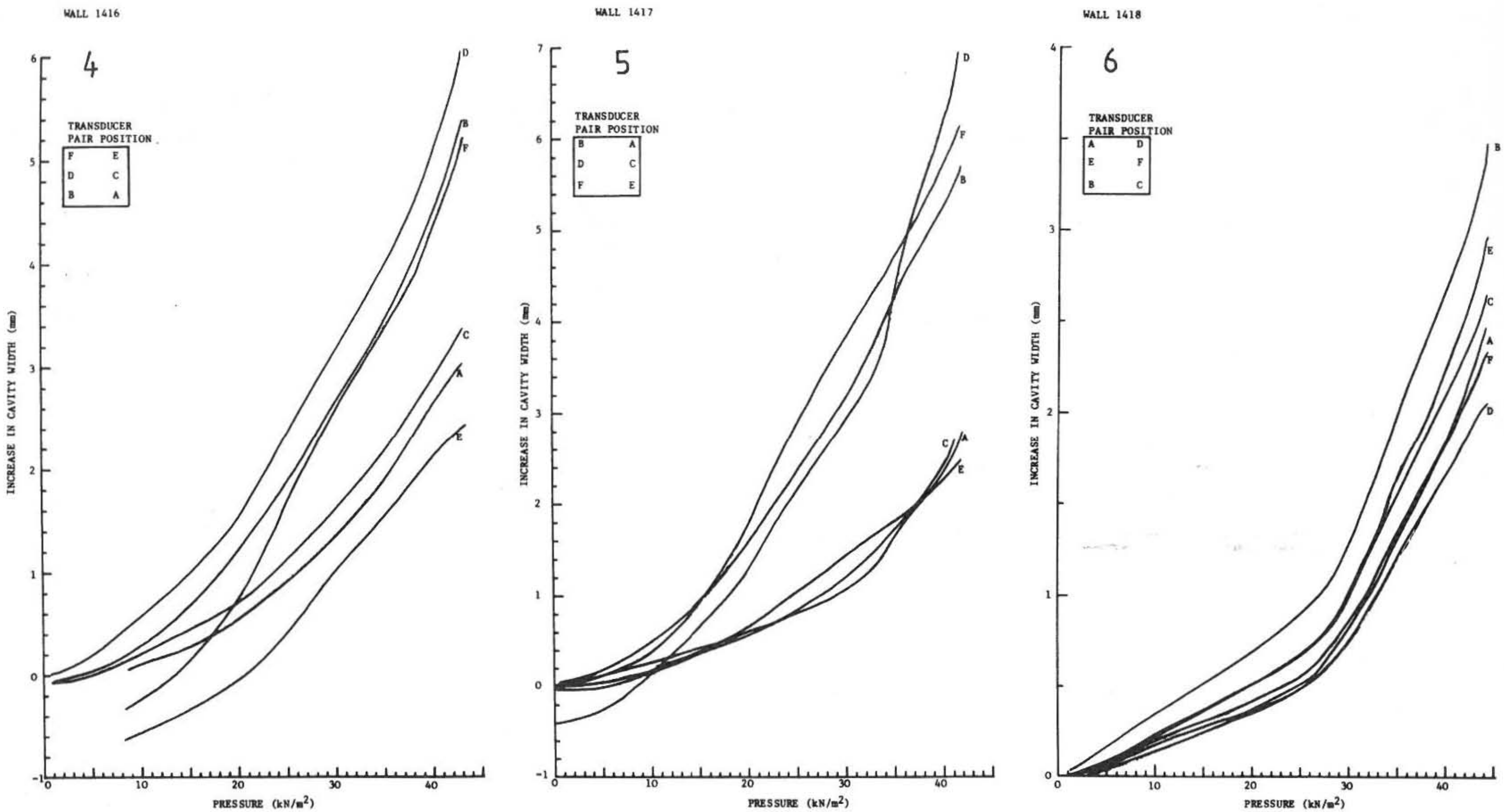

FIGURE 4: Change in Cavity Widths

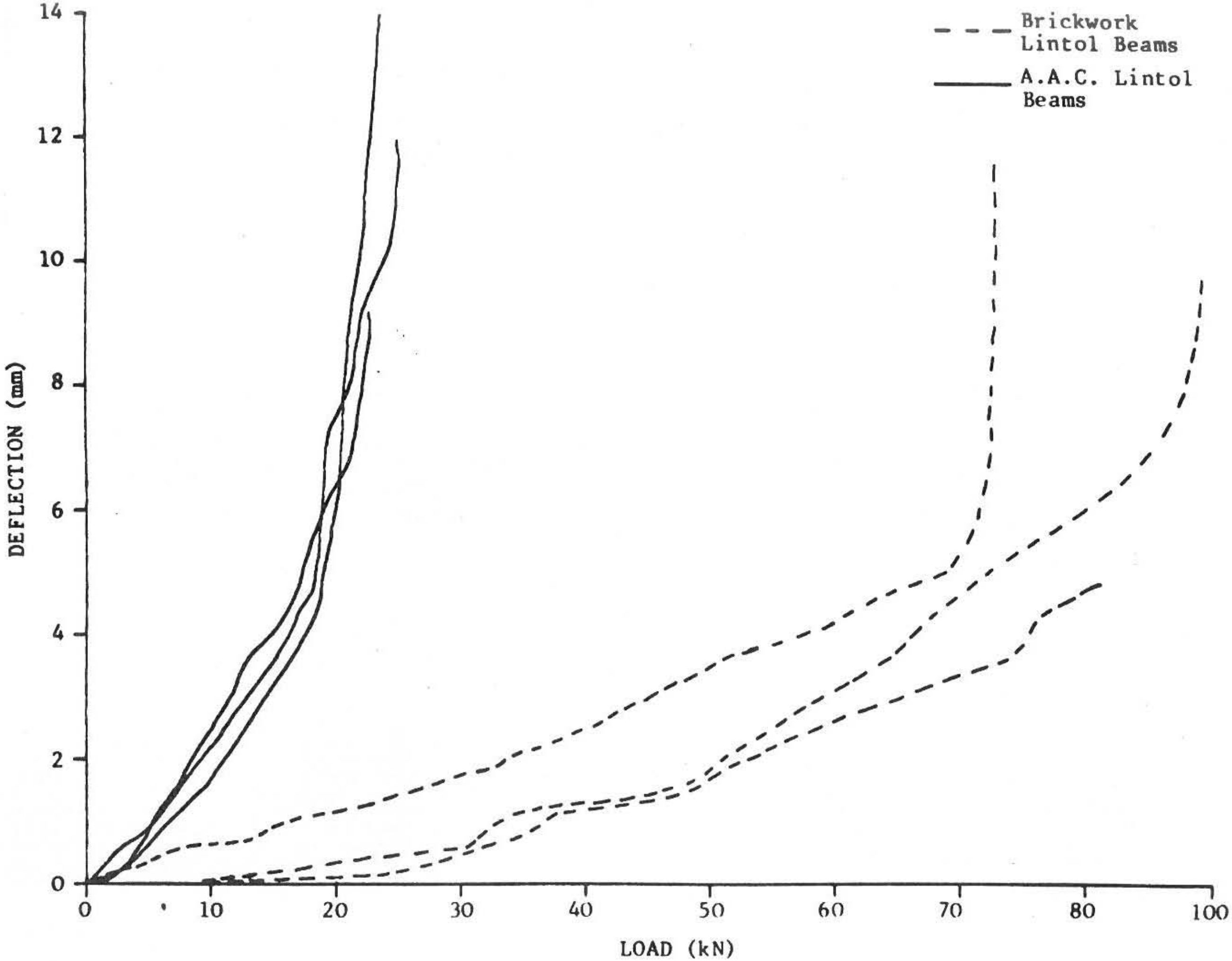

FIGURE 5: Deflection at Centre of Span of Lintol Beams

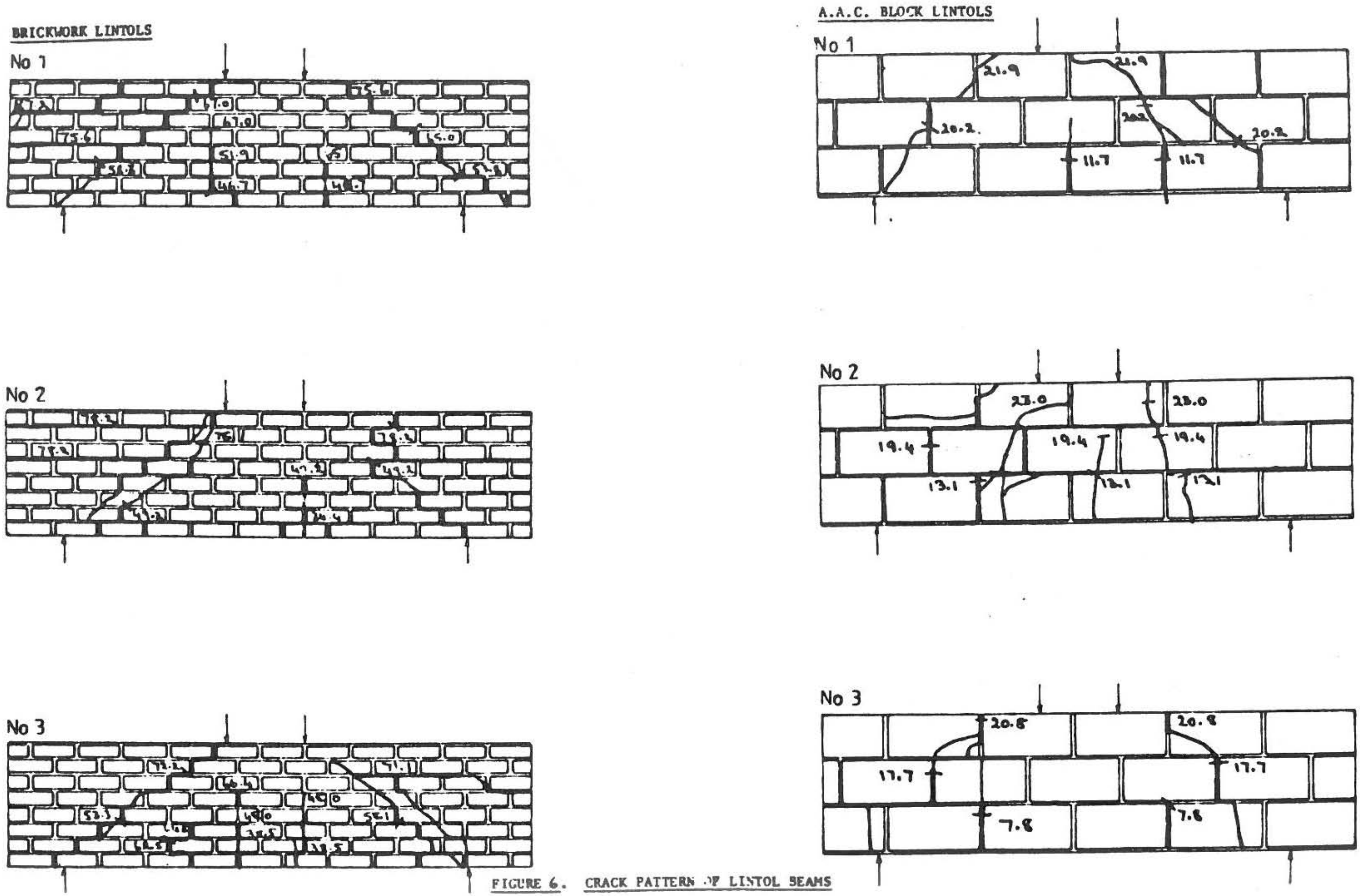

FIGURE 6. CRACK PATTERN OF LINTOL BEAMS