CAN PRESTRESSED BRICKWORK BEAMS BE USED AS AN ALTERNATIVE TO PRESTRESSED CONCRETE BEAMS?

B P Sinha BSc PhD MICE FIStrutE FIE(India) CEng
Department of Civil Engineering
University of Edinburgh

R F PEDRESCHI BSC PhD MICE CEng
Department of Architecture
University of Edinburgh

ABSTRACT

The Paper endeavours to answer this question by comparing the structural behaviour observed by fullscale tests on fullscale prestressed brickwork and concrete beams. The dimensions, prestressing forces and the compressive strengths of the brickwork and concrete were similar. The flexural strength, shear strength and load/deflection response of both beam types are considered.

1. Introduction During the last 15 years there has been a considerable amount of research into the application of prestressing of brickwork flexural members. Prestressed concrete on the other hand has a history of use extending over the last 100 years. Prestressed brickwork may provide a viable alternative to prestressed concrete in a number of situations. Techniques for the analysis have been developed which allow the behaviour of prestressed brickwork to be accurately predicted. However, there has been little direct comparison between prestressed concrete and brickwork. This Paper presents the results of experiments which compare directly the structural behaviour of such beams, having the same cross sectional dimensions, % area of steel, prestress force and similar compressive strengths. Two different % areas of steel were chosen, providing over and under reinforced beams.

2. <u>Construction of beams and test arrangements</u>. In designing a suitable cross section for the brickwork beams, it was felt important to establish certain criteria which would ensure that the beams would exploit the full structural potential of the material and not be problematic in construction. The criteria were as follows:

   (i) The beams should use as much ceramic as possible and the compressive forces in flexure should be carried only by the brickwork.

   (ii) Traditional bonding patterns should be used to ensure that no undue difficulties were experienced by the bricklayers.

(iii) There should be a cavity that would allow the tendon to be installed, after construction of the beam, using similar techniques as these developed for prestressed concrete.

(iv) The tendon should be fully bonded to the beam section.

The cross section finally chosen is shown in Fig 1(a). It can be seen that it satisfies these criteria. The grouted cavity occupies only 10% of the cross sectional area. Prestress was applied to the beams using 10.9mm diameter prestressing strand using standard barrel and wedges. Further details are given elsewhere [1]. The prestressed concrete beams tested were constructed in the section shown in Fig 1(b). The beams were tested over a span of 6.2m on the rig shown in Fig 2. Load was applied in small, equal increments. At each increment the deflections were measured using dial gauges, the strains, using demec gauge for surface strains and electrical resistance gauges on the tendons.

3, **Theoretical analysis** The material properties required for theoretical analysis of the brickwork were obtained by a series of compression tests on brick prisms, Fig 3, representing the top course of a prestresssed brickwork beam. The stress/strain relationship for brickwork was idealised using a three degree polynomial expression, illustrated in Fig 4. The behaviour of brickwork in testing was assumed to be linear up to the modulus of rupture. The stress/strain relationship for the concrete given in BS8110[2] was used with the compressive strength obtained from 100mm cubes. The stress/strain relationship for the prestressing steel was obtained from uniaxial tension tests and idealised as shown in Fig 5.

A computer programme[3] was developed that allowed for the nonlinear stress/strain relationship, cracking and tension stiffening to predict the deflection and cracking from prestressing up to failure of the beams.

4. Experimental results and discussion

The test results are presented in Table 1. From this Table it is clear that the ultimate moment of beams with 0.274% steel, ie (1-6) and (11-14) brickwork and concrete respectively are similar. All beams failed in flexure and strain measurements indicated that the steel had yielded. With higher % of steel, namely 0.548% (beams 7-10 and 15-17), the failure of the brickwork was by shear and again the concrete beams failed in flexure. The full moment capacity of the brickwork was not reached and hence the difference in ultimate moments between the brickwork and concrete beams.

Table 2 compares the service moments for brickwork and concrete beams ranging from class 1 - class 3[2]. In class 1 members, no tension is allowed under working loads, hence the service loads for both concrete and brickwork beams will be similar if the prestress forces are similar. For class 2 members, tension but no cracking is permitted. The service moment for the concrete beams will be greater in the concrete beams as the modulus of rupture is higher than brickwork. However, the brickwork beams have a greater factor of safety.

In class 3 members, some limited cracking is permitted up to 0.2mm. On neutralisation of the prestress force, flexural tension develops and eventually cracks form as the load increases. In brickwork beams[3], cracks are well distributed among the brick-mortar interfaces along the bottom course of the beams and hence the crack widths open comparatively slowly in relation to the load. Consequently there is a considerable difference between service moments for class 2 and class 3 brickwork beams. In contrast, in the concrete beams the differences between class 2 and class 3 service moments is much less. Once cracking develops in the concrete beams[4] the cracks are not as well distributed as the brickwork beams and hence larger cracks develop sooner.

Typical load-deflection relationships for the beams are shown in Figs 6 and 7. For beams with 0.274% steel (Fig 6), the load deflection response shows a distinct three phase form from prestressing to cracking, from cracking to steel yielding, and then an approximately horizontal portion to final failure. The behaviour of both the concrete and brickwork beams are similar. As would be expected the load at which cracking occurs, forming the transition from the first to the second phase, is greater for the concrete beams. Fig 7 shows the results for the beams with 0.548% steel. It may be observed that the three phase form of relationship is not as apparent as the low % steel beams. Also the post cracking deflections of the brickwork beams are notably greater than the concrete beams. Figs 8 and 9 present the theoretical load-deflection response for brickwork beams and concrete beams respectively. Excellent agreement is obtained in both cases.

5. Conclusions

(1) Where flexural failure occurs in under-reinforced beams, the ultimate moment capacity of prestressed brickwork and prestressed concrete beams will be similar.

(2) Prestressed concrete beams tend to have a greater shear resistance than prestressed brickwork. Hence as the % area of steel is increased, the difference between ultimate moments between concrete and brickwork beams will also increase when shear failure in the brickwork occurs.

(3) The ultimate moment and the load deflection response can be accurately predicted using the properties of materials obtained from small scale tests.

(4) The service moments are similar for class 1 and class 3 members of prestressed brickwork and concrete beams. The service moment for class 2 beams is greater for prestressed concrete than prestressed brickwork, although the safety factor may be lower.

(5) As the structural behaviour of prestressed brickwork beams, particularly when under-reinforced is very similar to comparable concrete beams, there may be many situations where prestressed brickwork could provide a suitable alternative.

REFERENCES

1. Pedreschi, R F and Sinha, B P, 'Development and Investigation of the Ultimate Load Behaviour of Post-te nsioned Brickwork Beams'. The Structural Engineer, Vol 60B, No.3, Sept 1982, pp 63-067

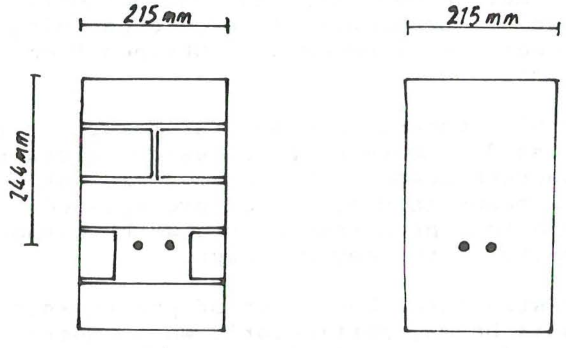
2. British Standards Institution, 'Structural use of Concrete, Code of Practice for Special Circumstances', BS8110, Part 2, 1985

3. Pedreschi, R F and Sinha, B P, 'Deformation and Cracking of Post-tensioned Brickwork Beams', The Structural Engineer, Vol 63B, No.4, Dec 1985, pp 93-99

4. Uduehi, J, 'A Comparative Study of the Structural Behaviour of Prestressed Beams of Brickwork and Concrete and the Shear Strength of Brickwork Beams'. PhD Thesis, Department of Civil Engineering, University of Edinburgh, 1989

ACKNOWLEDGEMENTS

The authors would like to acknowledge the contribution to the work made by Dr June Udueli and the financial support of the Science and Engineering Research Council, Structural Clay Products Limited and The Armitage Brick Company



(a) brickwork (b) concrete

fig 1 Test beams

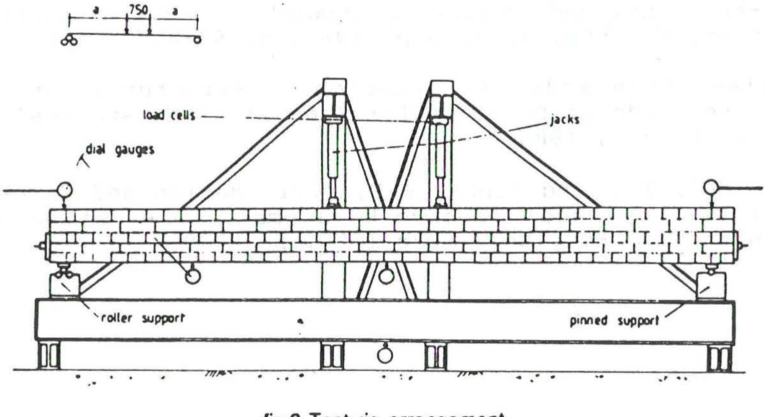


fig.2 Test rig arrangement

TABLE 2

Comparison of Service Moments

			Service Moments					
			Class 1		Class 2		Class 3	
% area of steel	Eff Prestress force (KN)	Ave ult Moment (Mu)	MC1	$\frac{Mu}{MC1}$	MC2	$\frac{Mu}{MC2}$	MC3	$\frac{Mu}{MC3}$
BRICKWORK								
0.274	135	58.5	16	3.66	24	2.44	29	2.0
0.548	275	87.2	34	2.56	41	2.13	58	1.5
CONCRETE								
0.274	130	58.5	16	3.66	32	1.80	32	1.80
0.548	283	103.0	34	3.00	51	2.00	56	1.84

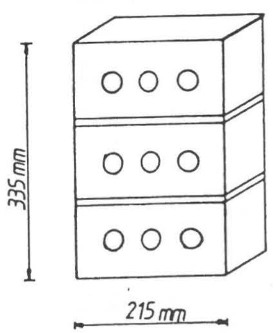


fig 3 Prism test specimen

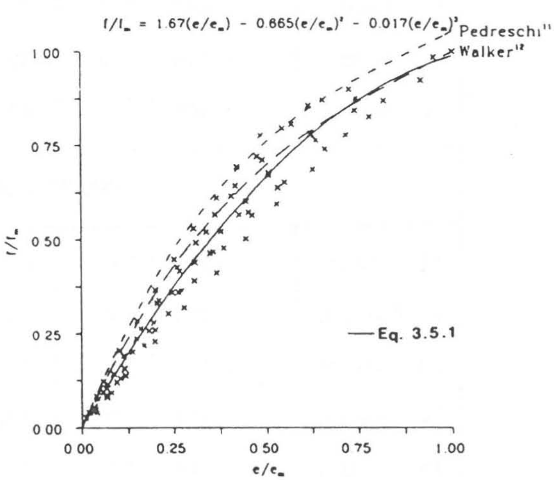


fig.4 Stress/strain relationship for brickwork

TABLE 1

Comparison of ultimate Flexural Moments of Prestressed Brickwork and Concrete Beams

Beam	Mode of failure	% area of steel	pre-stress force KN	Compressive strength N/mm^{2}	Ultimate moment KNm Experimental	Ultimate moment KNm Theoretical
BRICKWORK BEAMS						
1	flexure	0.274	133	32.6	56.9	54.3
2	flexure	0.274	115	32.6	56.4	54.3
3	flexure	0.274	133	32.6	61.5 (58.5)	54.3
4	flexure	0.274	144	32.6	58.4 ave	54.4
5	flexure	0.274	133	32.6	59.2	54.4
6	flexure	0.274	152	32.6	58.8	54.4
7	shear	0.548	275	32.6	87.2	94.3
8	shear	0.548	213	32.6	75.5 (77.4)	97.1
9	shear	0.548	212	32.6	71.5 ave	92.9
10	shear	0.548	199	32.6	75.2	92.8
CONCRETE BEAMS						
11	flexure	0.274	137	42.8	58.8	54.1
12	flexure	0.274	132	45.0	58.1 (58.4)	54.1
13	flexure	0.274	115	38.7	59.1 ave	54.1
14	flexure	0.274	136	39.9	57.6	54.1
15	flexure	0.548	283	41.6	103.0	97.4
16	flexure	0.548	219	43.2	103.4	96.6
17	flexure	0.548	183	44.1	100.1	96.6

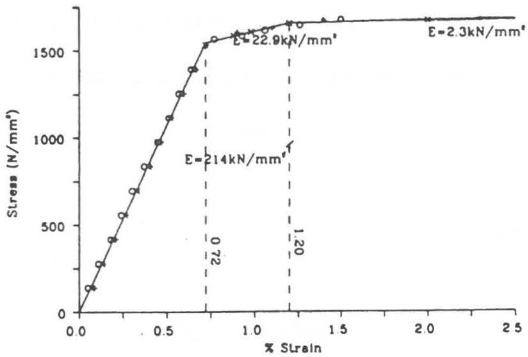


fig 5 stress/strain relationship for steel

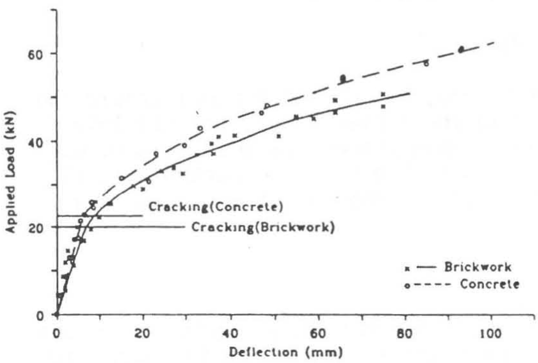


fig 6 Load/deflection for beams with 0.274% steel

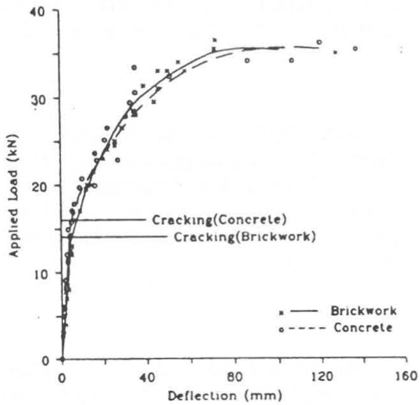


fig.7 Load/deflection for beams with 0.548% steel

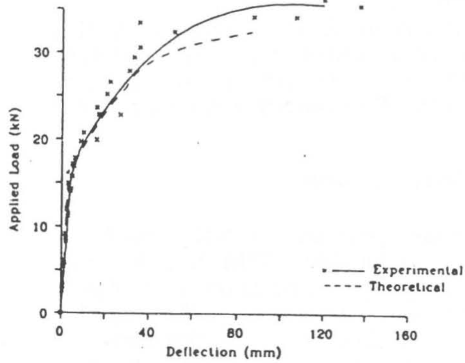


fig.8 Theoretical load/deflection curve for brick work beams

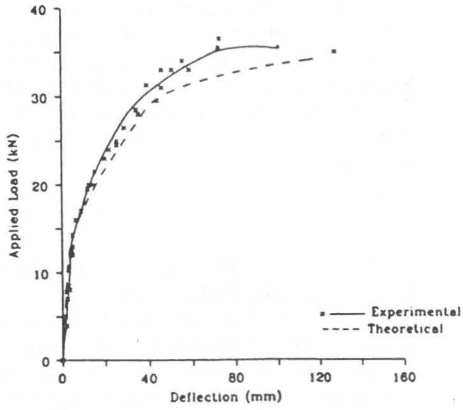


fig.9 Theoretical load/deflection curve for concrete beams