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EXPERIMENTAL ANALYSIS OF SMALL CLAY BRICK CYLINDERS CONFINED BY BFRP GRID UNDER AXIAL COMPRESSION

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Abstract

Many investigations have shown that fibre reinforced polymer (FRP) composites can be effectively used to induce a passive confinement action on masonry columns and improve their axial capacity and ductility. This paper presents the results of an experimental study on the compressive behaviour of clay brick masonry cylinders externally wrapped with basalt fiber reinforced polymer (BFRP) grids. The circular section shape was chosen to assess the pure confinement effect on the masonry material. Fourteen clay brick masonry cylinders, cored from two different masonry assembly types, were confined with one or two layers of BFRP grids. The two assemblies were used to investigate the effect of vertical joints on the response of the cylinders. The cylinders were tested under uniaxial compression load. The test results showed a strength increase between 30% and 38% for cylinders wrapped with one layer and between 69% and 71% for those wrapped with two layers of BFRP grids.

Keywords: Basalt Fibre Reinforced Polymers; BFRP; Masonry columns; Strengthening and Repair.

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Introduction

Many studies have shown that the use of BFRP grid composite materials can improve the axial capacity and ductility of masonry columns through a confinement action. Although research on this topic is still limited compared to the work carried out for FRP-confined concrete columns ([1], [2]), the effective contribution of FRP wrap and the evaluation of the ultimate strength of columns have been investigated in several experimental studies (e.g. [3], [4], [5], [6], [7]). CNR-DT200 Guidelines [8] were adopted for some of these studies. In particular the reliability of available confinement models ([9], [10]) for small scale masonry cylinders was investigated in [11] by comparing predictions with uniaxial and triaxial test results.

This paper presents some results of a project on masonry cylinders confined by both basalt reinforced cementitious mortar (BFRCM) and basalt reinforced polymer (BFRP) composites. As the first step, cylinders cored from preassembled masonry were tested to assess the confinement effect on masonry without the influence of the section corners. The cylinders, manufactured using pressed bricks, were tested under monotonic axial compression. The number of layers of BFRP grid and the different assembly geometry were considered in the study. Only results from the BFRP grid wrapped cylinders are reported in this paper.

Experimental Programme

Fourteen clay brick cylinders were tested under axial compressive loading in this study. Two assembly schemes were used for preparing the cylinders: wall (Scheme I) and column (Scheme II). These were both prepared using three rows of 50x100x210 mm pressed bricks and 8 mm thick mortar joints.

The cylinders, with a diameter of 94 mm and height of about 190 mm, were obtained by coring the assembly with a laboratory-coring machine after 30 days of curing time. Scheme I cylinders had only one vertical joint in the middle third while Scheme II cylinders had three staggered vertical joints, one at each level. The specimens were wrapped with either one or two BFRP layers and their response compared to the unconfined control specimens, see Table 2. Two specimens per type were tested.

A cement/sand weight ratio of 1/5 was used for the mortar. Water was added until a minimum workability was achieved. Three-point bending tests were carried out on six standard 40x40x160 mm mortar prisms and uniaxial compressive tests on twelve standard 40 mm cubes according to EN 1015-11 [13]. The average tensile and compressive strength were 5.33 MPa and 20.93 MPa respectively. Compressive test according to EN 772-1 [12] were carried out on six 50mm cubes cut from bricks. The average compressive strength was 42.53 MPa.

A bidirectional primed alkali-resistant basalt fibre grid with a cell size of 6x6 mm was used. The mechanical properties of the basalt grid and the two parts epoxy resin are reported in Table 1. A 600 kN Dartec test machine was used to carry out the monotonic compressive tests on the cylinders. Three loading/unloading cycles under load control up to 40-50 kN were conducted first to condition the test setup. A monotonic axial compressive loading was then applied at a displacement loading rate of 0.005 mm/s up to failure. The displacement of the upper and lower loading platens were monitored using respectively four and two LVDTs.

Table 1: Properties of basalt grid and epoxy resin (manufacturer data)

Material	Unit weight	Mesh size	Density	Unit tensile strength	Elastic modulus	Equivalent thickness	Elongation at failure
BFRP grid	250 g/m3	6 x 6 mm	2.75 g/cm^3	60 kN/m	89 GPa	0.039 mm	1.8%
Epoxy resin				30 MPa	4GPa		

Test Results and Discussion

All the cylinders tested showed large and almost vertical cracks at failure (Figure 1). Unconfined specimens also showed horizontal cracks and spalling. The unconfined masonry specimens exhibited, as expected, a brittle behaviour. Failure of confined cylinders was due to the rupture of the BFRP grid wraps.

The stress-strain curves of Scheme I and II specimens are shown in Figure 2. The axial stress was calculated using the measured cross-sectional area. The axial strain was obtained from the readings of the transducers supported by the steel rings up to the peak load, over a gauge length of 100 mm. After the peak, the strains were evaluated considering the difference between the LVDTs readings at top and bottom platens divided by the total cylinder height.

The average peak stress of unconfined cylinders was 25.0 MPa for Scheme I and 19.8 MPa for Scheme II. The increase of the peak stress due to the confinement effect was 30% (one layer) and 69% (two layers) for Scheme I and 38% and 71% (two layers) for Scheme II. The increase of the strain at peak load, was 7% (one layer) and 10% (two layers) respectively for Scheme I and 19% (one layer) and 16% (two layers) for Scheme II. Please note that cylinder C1_Wun was not considered as its initial slope was considerably different from that of all other specimens. Overall unconfined Scheme I cylinders showed a higher strength (25 vs 19.8 MPa) which is probably due to the greater number of vertical joints of the assembly. However, the confinement effect for the stronger masonry was less pronounced: the load increase due to confinement was lower. The strain at the peak load was also higher for the confined Scheme I cylinders (0.69% and 0.76%) compared to the other set (0.58% and 0.62%). The ultimate strain, the axial strain at 15% strength degradation, was similar for cylinders of both schemes confined with 1 layer (83% and 81%), but it was higher for Scheme II specimens (98%) compared to Scheme I (89%). Scheme II cylinders also showed a more ductile behaviour as evidenced by the less steep softening branch compared to Scheme I cylinders.

Table 2: Test results of confined and unconfined masonry cylinders.

Specimen designation	Brick layup scheme	Number of BFRP grid layers	Average peak stress [MPa]	Average axial strain at peak stress, %	Increase of peak stress, %	Increase of strain at peak stress, %	Ultimate strain, %
WUn	I	NA	25.0	0.52*	-	-	-
W1L	I	1	32.6	0.69	30	7	0.83
W2L	I	2	42.4	0.76	69	18	0.89
CUn	II	NA	19.8	0.53	-	-	-
C1L	II	1	27.3	0.58	38	9	0.81
C2L	II	2	34.0	0.62	71	16	0.98

*C2_WUn specimen only. Nomenclature: W: Scheme I; C: Scheme II; Un: unconfined; 1L: one FRP layer; 2L: two FRP layers.

a) b) c) d)

Figure 1: Cylinders at failure: a) unconfined Scheme I; b) unconfined Scheme II; c) One BFRP layer Scheme I; d) One BFRP layer Scheme II.

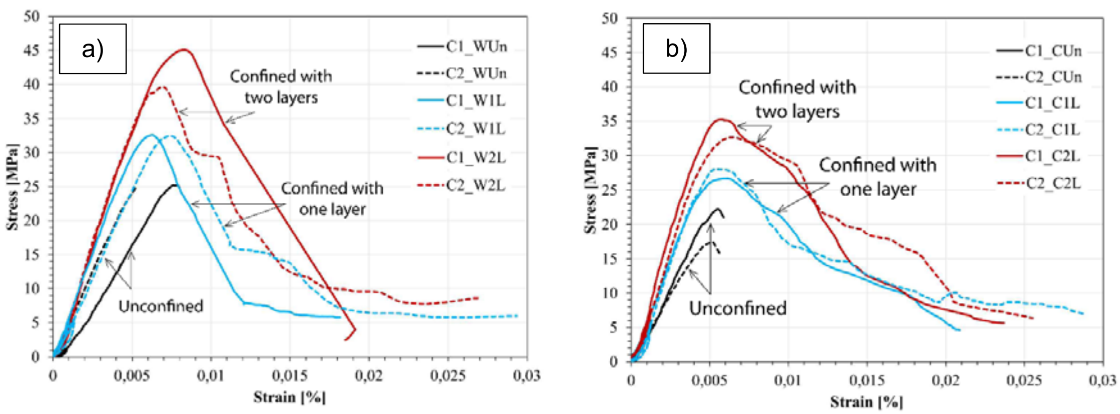

Figure 2: Axial stress-strain curves: a) Scheme I; b) Scheme II.

Conclusions

The following conclusions can be drawn from the results:

- The strength of unconfined cylinders with three vertical joints (Scheme II) was in average 20% lower than those with one vertical joint only (Scheme I);
- One layer of FRP grid wrap increased the strength by 30% and 38% respectively for Scheme I and Scheme II specimens. These values were doubled for cylinders confined by two layers (a strength increase of about 70% for both schemes).

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