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Analysis on Shear-Walls Reinforced with Fibres

Analyse des voiles de contreventement renforcés de fibres

Analyse von faserbewehrten Schubwänden

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SUMMARY

Aim of this paper is a description of the use of polypropylene fibres in reinforcing masonry shearwalls. The advantages of synthetic fibres allow durability, laying and mechanical behaviour; this last aspect is due not only to the high strength, but also to the possibility that the low elastic modulus allows having a complete distribution of microcracks resulting in a good ductility of the reinforced masonry shear-wall, although the fibre behaviour is fragile.

RÉSUMÉ

Ce rapport décrit l'emploi des fibres en polypropylène afin de renforcer les voiles de contreventement en maçonnerie. L'emploi des fibres synthétiques comporte des avantages en ce qui concerne la durabilité, la pose et le comportement mécanique; ce dernier aspect n'est pas dû seulement à la résistance élevée, mais aussi au fait que le faible module d'élasticité entraîne une répartition complète des microfissures donnant une meilleure ductilité, bien que le comportement des fibres soit fragile.

ZUSAMMENFASSUNG

Dieser Beitrag beschreibt die Anwendung von Polypropylenfasern zur Bewehrung von Schubwänden. Die Anwendung der synthetischen Faser hat die Vorteile der Dauerhaftigkeit, des einfaches Einbaus und des hervorragenden mechanisches Verhaltens. Vom letzten Aspekt hängt nicht nur die Hochfestigkeit sondern auch die Möglichkeit der Verteilung von Mikrorissen ab. Dadurch wird eine gute Dehnfähigkeit der einbetonierten Schubwände erreicht, auch wenn das Faserverhalten spröde ist.

1. INTRODUCTION

Interest in consolidation of ancient masonry building and historical monuments is going to increase the importance of research of new technologies and new materials. Several kinds of tests have been done to define the coupling of the braid with other materials:

- tensile tests on braid samples
- tensile tests on braid and mortar or emako samples
- tests of sandstone masonry reinforced with braids
- tests of tuff masonry reinforced with braids

2. LABORATORY ANALYSIS ON THE BRAID SAMPLES

The material employed for the experiment was made of a polymeric mixture based on propylene, which is specially treated so that the binding between the polymer and the water in cement paste are optimized. The material, initially in the form of a polymeric strand with a single orientation, was then woven into braids by twisting several of the strands. The individual fibre shows a tenfinal stress equal to 500 MPa and an elastic modulus of 14 GPa.

2.1 Tests of tensile-stress, relaxation and confinement on braids

Two sets of tensile tests were carried out, one on two-rope braids and the other one on three-rope braids. In the two cases, the apparent diameter and the equivalent weight diameter was respectively:

-D_2 12 - 12 mm - D_{e2} 8.0 mm
-D_3 22 - 24 mm - D_{e3} 14.3 mm

The samples of the first set were prepared by dipping the braid ropes into a cement paste, that constitutes the cylindric hold for the press, with a diameter of 60 mm and a length of 150 mm. The sample length is .52 m. The tensile tests revealed a σ_m 162.4 Mpa with a mean scattering of values, and a medium elastic modulus E_m of 1275 MPa. Synthetic fibre braids are always subject to release fracture.The second set of tests was carried out on three-rope braids, the ends of which were accurately tied. The overall sample length is .52 m and the length between the ties is .30 m. The σ_m is 197.6 Mpa with E_m = 1373.5 Mpa.

Some cyclic tests were also made on samples similar to the ones employed above, based on 30 cycles between 6.13 and 44.2 MPa and then brought to the collapse. The diagrams show a gradual increase of the modulus during the test, whereas the break-point values are lower than the ones derived from the tensile tests.

The braid behavior under static application of a constant 30% of the ultimate load was then analyzed, under hygrothermic controlled conditions. The viscous extension reached 50% of the initial elastic one, almost within the first 2 hrs.

Several cylindric samples with a length of .30 m and diameter of 40 mm were prepared with braid and mortar and braid and emaku. Such samples simulate, with the exception of the restraint caused on the mortar by masonry, the conditions of braids injected. The results obtained were a substantial increase of the elastic modulus (about 4000 MPa) and an ultimate load increase (σ_m = 290

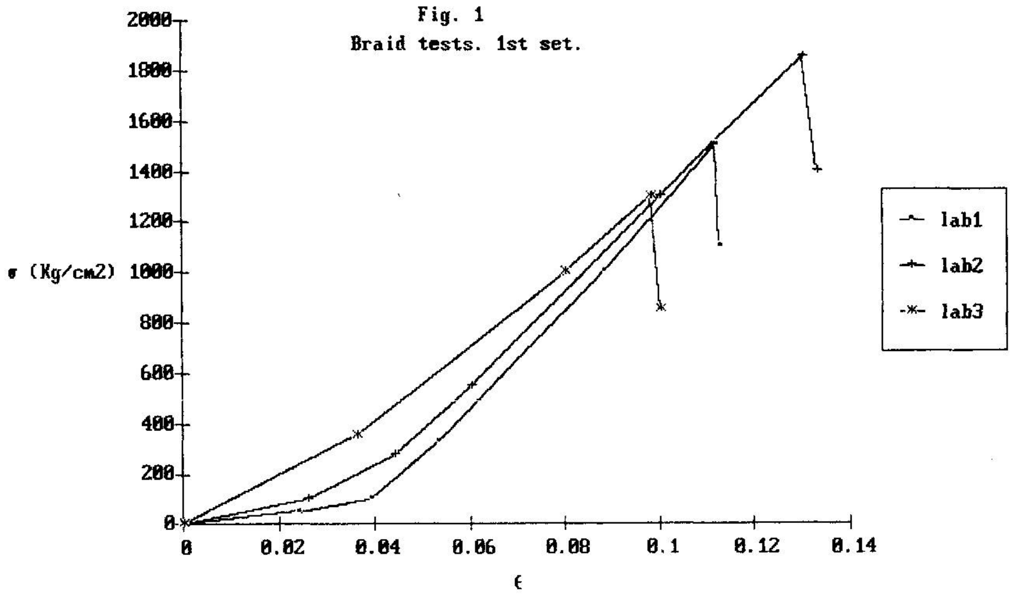


Fig. 1
Braid tests. 1st set.
σ (Kg/cm2)
ε
lab1
lab2
lab3
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14

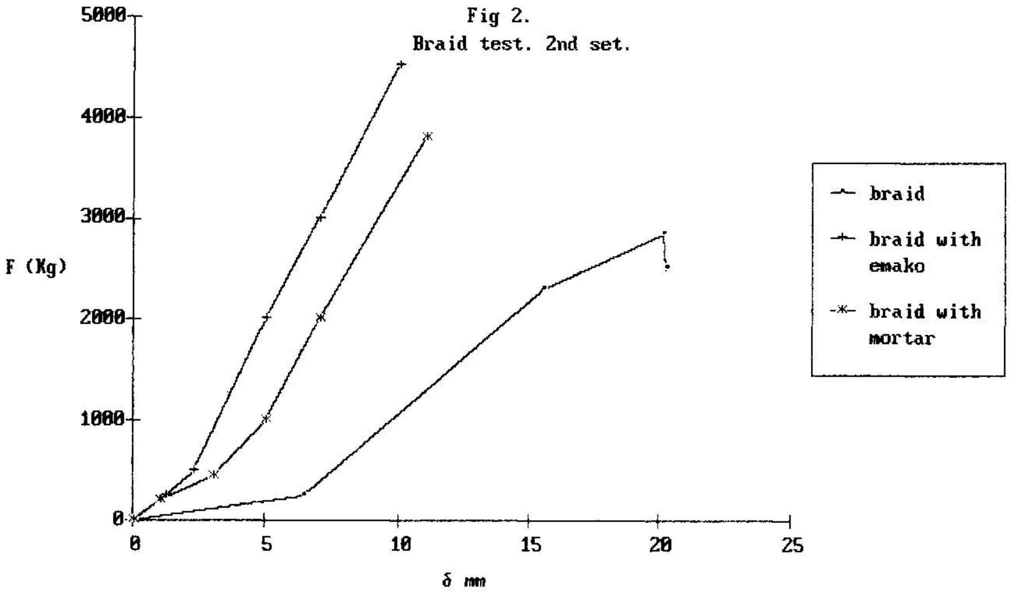


Fig 2.
Braid test. 2nd set.
F (Kg)
δ mm
braid
braid with emako
braid with mortar
0
1000
2000
3000
4000
5000
0
5
10
15
20
25

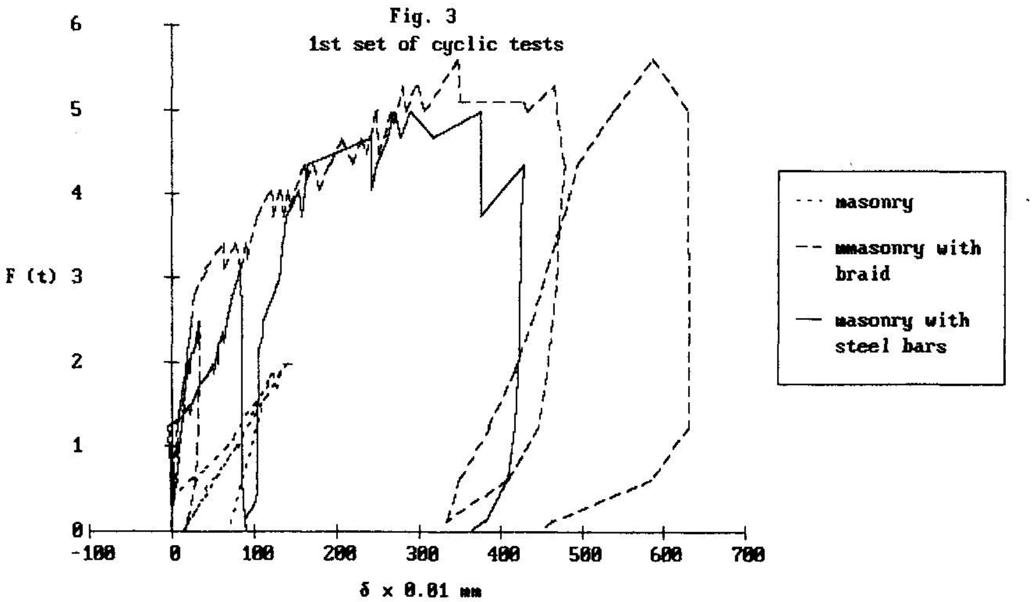


Fig. 3
1st set of cyclic tests
F (t)
δ x 0.01 mm
masonry
masonry with braid
masonry with steel bars
0
1
2
3
4
5
6
-100
0
100
200
300
400
500
600
700

MPa). The samples with emaku show a further improvement in terms of strength, as the bond between the two materials is improved.

3. TESTS ON MASONRY SHEAR-WALLS PREPARED AT YARD

3.1 Test Proceedures

The aim of the tests was to simulate the in situ behavior of the synthetic material as a structural element in stengthening masonry shear-walls which had been damaged by seismic events, in order to prove the competitiveness with respect to the steel elements presently adopted for consolidations. Thus, the first set of samples were prepared in the yard so as to reproduce exactly the characteristics of masonry elements in situ. The samples are .40 x 1.00 x 2.00 m, built with bricks of sandstone and cement mortar and reinforced in several different ways. The seismic action was statically simulated by an horizontal hydraulic jack held in place by an appropriate steel frame; the deformations were measured by means of centesimal comparators. Cycle of loading and unloading without inversion of the force direction were made.

3.2 Results and Comments

The first sample is a non-reinforced masonry element used to determine normal conditions. It has been put trough two loading-unloading cycles; the maximum load reached is about 2 tons.(see fig.3). The second sample (fig. 3) has been reinforced with rectilinear synthetic fibre braids laid along the longer side of the shear wall, wich is under tension. We can obvserve a great increase in the bearing capacity (5 - 6 tons) and high ductility. This ductility, obtained despite the presence of a material with fragile behaviour, is due to the great capacity of the braid to be deformed and its capacity to exploit micro-cracks and anelastic deformations of masonry without losing the mutual exchange of stresses, as happens in the case of steel. The third sample is reinforced with inclined ropes (see fig. 3) so as to provide a better shear-resistance. In this case the ultimate load is 5 tons, slightly inferior to the previous one, but, above all, with much lower ductility. It seems that the shear-wall, subject to this kind of test, has at first a bending behaviour, as it can be observed in the crack frame. At the end of the load history only the inclined masonry rool appears. Effectively it requires substantial rotations of the bearings and hence the ropes along the diagonals support the load only in the final phase of tests, when the masonry shows important disconnections. This was also confirmed by the laboratory set of tests.

4. WORKSHOP TESTS ON MASONRY SHEAR-WALLS

4.1 Modalities of test

A second set of tests have been carried out in a mechanical workshop, so to have a better control on the test itself. This time the masonry shearwalls were built with regular tuff bricks and cement mortar of better quality. The two material were separetly tested and they have shown the following features:

- tuff R_{bk} = 4.00 MPa
- masonry R_{bk} = 2.75 MPa
- mortar R_{bk} = 1.20 MPa.

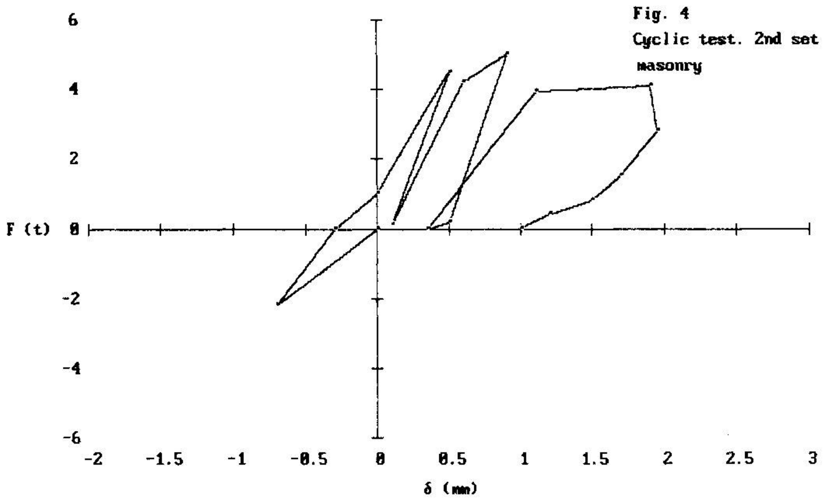


FIG. N° 5 - Cyclic tests 2nd set: masonry with steel bars

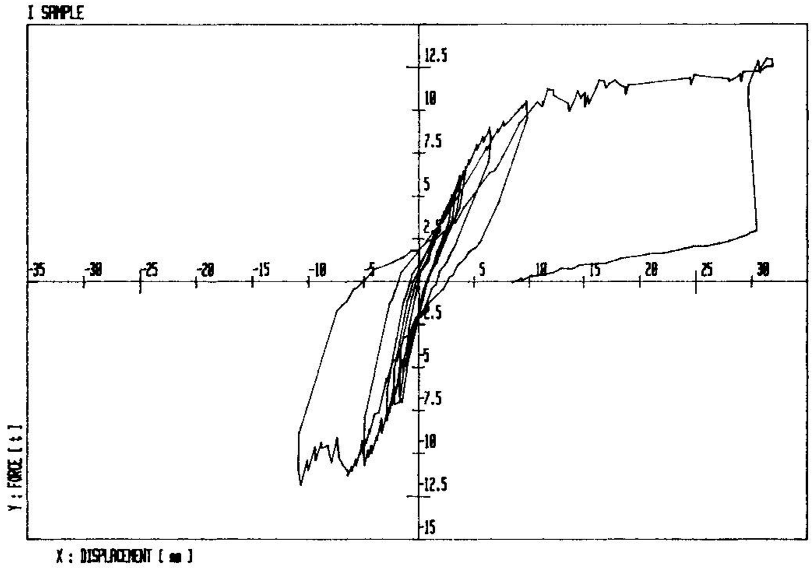
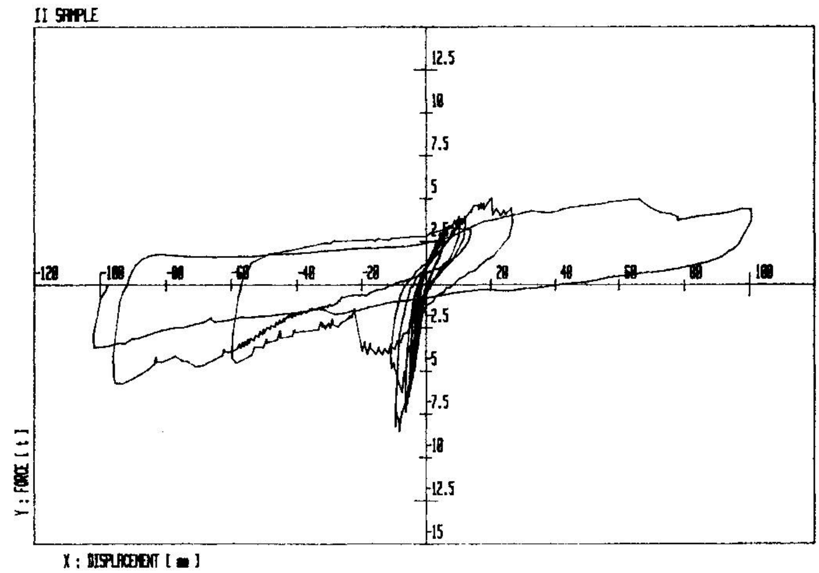


FIG. N° 6 - Cyclic tests 2nd set: masonry with braid



The dimension of the samples are 0.30 x 1.00 x 2.20 m. and they have been tested rotating them of 90½ respect to the building position. Tests equipment was realized with the aim of confer to the shear-wall overall cycles in both directions. The impact of the dead load on the mortar layers, nullified by the test alignments, was restored with a spring system, on the two sides of the shear-wall, so as to provide an orthogonal tension to the layers, which was constant during the tests, equal to the one produced by the dead load. The number of laid braids was equal to the first tests set, and were injected with cement mortar 425. The test, instrumentation, has been placed to measure strain on the principal diagonals of the shear-wall and along the longer sides of the wall. Further on, other inductance transducers have been located to determine the maximum mean camber, and any relative mouvements between the masonry and the ropes. Centesimal collimators are used on the vertical sides of the shearwall to detect horizontal displacements and rotations at the bond devices.

4.2 Results and comments

The tests are in progress and so far three different cases have been analyzed. The first one is a plain shear-wall. It has shown, after three cycles, higher resistance (3.5 tons) than the masonry of the first set, as obviously would be, due to the better characteristics of materials.The second test is the same shear-wall reinforced with steel bars along the two 2.20 m. sides. The bars are two O 16 for side, iniected with cement mortar, so that the total area of steel is equal to thatone of the ropes placed in the third sample. The different resistance of the two material is not important because they don't reach the failure stress.during the test. The elastic strength after six cycles is about 8 ton, without degradation. The hysteretic phenomenon is observed increasing the load until 12 tonn, the level which the shear-wall is able to support with a ductility ratio of about 4.5. The third test realized on a shear-wall with braids showed during the elastic phase a maximum strength of 9 tonn. with a substantial hysteretic behavior, with a max ductility of about 12.50. The maximum displacement at the breaking point is about 100 mm.

5. CONCLUSIONS

These studies, altough, at the moment they don't supply exhaustive answers, they show new perspectives for the use of synthetic fibres in strenghtening existing masonry, and in protecting them from seismic damages, tanks to the high ductility shown by the all different tests.

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