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EXPERIMENTAL RESEARCH ON BUCKLING BEHAVIOUR OF REINFORCEMENT IN MASONRY CAVITY WALL

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ABSTRACT

This study analyses the behaviour of bed joint reinforced masonry cavity wall subjected to compression action parallel to reinforcement's plane. It is evaluated the buckling behaviour of diagonal reinforcement that connect both walls. The experimental work studies four different situations: two reinforcement diameters and two distances between the parallel walls.

The analysis compares the experimental and the theoretical values and it keeps in mind two hypothesis: not considering the diagonal reinforcement curvature and considering the wire real curvature. The results obtained show that it is essential to consider the curvature of the diagonal reinforcements in the design of masonry cavity walls subjected to horizontal actions.

Key words: *buckling behaviour, masonry, bed joint reinforcement, diagonal wire eccentricity.*

1. INTRODUCTION

This study is part of a research project entitled "Physical and mechanical behaviour of the reinforced ceramic masonry by bed joint reinforcement", being the general coordinator of the investigation D. Josep Mª Adell Argilés. It is inserted in the summons of financial helps and subsidies of Interministerial Commission of Science and Technology of 11th July 1994, corresponding to Research Project of the National Program of MATERIALS.

This article analyses the behaviour of bed joint reinforced masonry cavity wall under compression actions parallel to reinforcement's plane.

It is tried to evaluate the compression maximum effort that supports the diagonal reinforcement of the lattice truss, which connect both walls.

2. OBJECTIVE

a) To analyse the buckling behaviour of the diagonal elements in the truss reinforcement joining two parallel brick walls. Eight specimens of cavity walls consisting each of them in two parallel brick walls separated 5/7 cm and two sets of steel trussed reinforcement (MURFOR) situated perpendicular to the walls plane and anchored (inserted) to them, were realised. The effect of two parameters was studied: gap between the walls (buckling length of the diagonal elements of the truss) and diameter of the reinforcement.

b) To compare the experimental results obtained in the test with the theoretical results calculated by numerical analysis.

3. TEST PROGRAM

The specimens were built being vertical the plane of the walls and they were tested in horizontal position applying the load vertically. The test was realised approximately 28 days after the construction. In order to avoid relative transversal displacements between the two walls of the specimens, two metallic profiles we-

Table 1. Types of specimens.

SPECIMENS	DIMENSIONS (m)	SEPARATION BETWEEN THE WALLS (cm)	TYPE OF REINFORCEMENT
M-1	0,50 x 0,25 x 0,28	5	3,75 RND/250 mm
M-2	0,50 x 0,25 x 0,28	5	3,75 RND/250 mm
M-3	0,50 x 0,25 x 0,28	5	5 RND/250 mm
M-4	0,50 x 0,25 x 0,28	5	5 RND/250 mm
M-5	0,50 x 0,25 x 0,30	7	3,75 RND/250 mm
M-6	0,50 x 0,25 x 0,30	7	3,75 RND /250 mm
M-7	0,50 x 0,25 x 0,30	7	5 RND/250 mm
M-8	0,50 x 0,25 x 0,30	7	5 RND /250 mm

re disposed acting as lateral guide in the compression direction, impeding the lateral instability of the group.

3.1. Design of test system and load application

In order to warrant an uniform distribution of the load over the specimen it was placed a metallic profile as distributor element. The test was realised to constant velocity of load (between 0, 7 and 0, 4 Kg /s), with an approximate duration between 5 and 10 minutes, finishing when the buckling of the reinforcements is produced.

The specimens was placed in the centre of the testing machine, securing a perfect contact with the surface of loading application by means of a fibber sheet, approximately, 8 mm thick.

3.2. Monitoring and data acquisition

In order to measure the strain in the diagonal wires they were utilised strain gages of resistant printed film, HBM of 4 mm of grid length and 120 Ohmios ± 0,35 % of resistance. The gauges were installed in two of the four diagonal elements in every specimen.

The Division of Experimental Analysis of Structures prepared the program of data acquisition specifically for these tests, and it has permitted:

- That the monitoring of the data has been practically at the same time that the realisation of the test.
- To register the values of applied load in the specimens and the strain in the diagonal wires in relation with the time.

4. DEFINITION OF MATERIALS

For the realisation of these walls Malpesa perforated brick has been utilised.

The Murfor reinforcements are formed by two longitudinal parallel wires linked by other diagonal wires in zigzag in the same plane, forming a lattice truss, whose total thickness is not major than the longitudinal wires diameter. Two types of reinforcements MURFOR have been employed: 3, 75 RND/250 mm and 5 RND/250 mm, whose diagonal wires have 3,75 and 5 mm of diameter respectively and the longitudinal wires are separated 250 mm.

In the construction of the walls was used mortar M-8 (compressive strength 8 N/ mm^2) elaborated "in situ" and tested (compressive strength) in order to warrant an adequate resistance. It was used cement type P-350.

5. TEST REALIZATION

5.1. Description of the type of failure

Following, it is described the type of strain and failure originated after the tests for each one of the walls.

Wall 1: The buckling of the 4 diagonal wires is produced in the same direction. The separation between walls after the test was of 43- 50 mm.

Wall 2: In the superior reinforcement, the buckling takes place in the 2 wires in the same direction. In the inferior reinforcement, the buckling is presented nearing the 2 wires in the opposite direction. The separation between walls after the test was 34- 47 mm.

Wall 3: The buckling of the 4 wires is produced in the same direction, with longitudinal wires in an extreme. The separation between walls after the test was 30- 33 mm.

Wall 4: In the superior and inferior reinforcements, the buckling takes place in one only wire, in the same side. Both diagonal wires of the other side do not buckling, it causes practically the detachment of all superior layers of bricks.

Wall 5: In the superior reinforcement is produced the buckling of the 2 wires in the same direction and in the inferior reinforcement the buckling is produced of the 2 wires in different direction. The separation between walls after the test was 38- 43 mm.

Wall 6: In the superior reinforcement takes place the buckling of the 2 wires in the same direction, one of them with clear vertical orientation downwards. In the inferior reinforcement is originated the buckling of the 2 wires in the same direction, but contrary to the wires of the superior reinforcement. The separation between walls after the test was 65- 67 mm.

Wall 7: In the superior reinforcement as the same as in the inferior reinforcement, is produced the buckling of two wires in opposite direction. Indicate that it is firstly happened the buckling of one of the diagonal wires that was not monitored with strain gage. The separation between walls after the test was 58- 69 mm.

Wall 8: In the superior reinforcement is produced the buckling of one only wire, approximating toward the other wire that not buckling; in this side it is produced separation of mortar and brick. On the other hand, in the inferior reinforcement, the buckling of the 2 wires takes place in opposite direction, separating. The separation between walls after the test was 37- 49 mm.

5.2. Results

The following table indicates the values of load resisted by the walls and the approximate tensions in each strain gage.

Table 2. Load and stress of the reinforcements

SPECIMENS	BUCKLING LOAD (N)	STRESS REINFORCEMENTS STRAIN GAGE 1 (N/mm²)	STRESS REINFORCEMENTS STRAIN GAGE 2 (N/mm²)
M-1	13.283	378	111
M-2	14.146	419	636
M-3	25.692	460	294
M-4	21.660	457	676
M-5	10.990	>677	141
M-6	12.498	—	370
M-7	20.875	92	368
M-8	18.413	210	572

5.3. Analysis of results

The determination of the theoretic load buckling of the diagonal reinforcement was realised according to the standard NBE-EA- 95:"Estructuras de acero en edificación".

Table 3. Determination of thr buckling coefficient ω.

Specimen	Length of the diagonal wires l(mm)	β	Buckling length lk= lxβ (mm)	Radius i=R/2(mm)	Slenderness λ	Buckling coefficient ω (table 3.2.7)	Area A (mm2)
M-1	64,41	0,5	32,2	0,9375	34,35	1,07	11,04
M-2	64,41	0,5	32,2	0,9375	34,35	1,07	11,04
M-3	64,41	0,5	32,2	1,2500	25,76	1,04	19,63
M-4	64,41	0,5	32,2	1,2500	25,76	1,04	19,63
M-5	90,17	0,5	45,1	0,9375	48,11	1,18	11,04
M-6	90,17	0,5	45,1	0,9375	48,11	1,18	11,04
M-7	90,17	0,5	45,1	1,2500	36,08	1,08	19,63
M-8	90,17	0,5	45,1	1,2500	36,08	1,08	19,63

In the following table it is determined, from the buckling coefficient and the area of the wire, the maximum load of compression that supports the wire before the buckling and the maximum load that supports the wall.

The theoretical values have been calculated in two different hypothesis with the object to compare with the real values obtained in the test.

- Hypothesis 1: The theoretical buckling load (N) was calculated not taking into account the curvature of the reinforcement's diagonal wires.

- Hypothesis 2: In the obtention of the theoretical buckling load (Ne) it was taken into account the curvature of diagonal wires. So for every diameter and separation of walls of brick, it was measured the eccentricity in the centre of the wires, in an aleatory sample, the following average values have been obtained:

Table 4. Determination of yheoretic value of the buckling load (axial stress whitout eccentricity).

Specimens	Area A (mm^2)	Buckling Coefficient ω (table 3.2.7)	Characteristic strength of steel σ (N/mm^2)	Compressive stress (N)	Maximum load in the specimens N (N)
M-1	11,04	1,07	677	6.985	21.690
M-2	11,04	1,07	677	6.985	21.690
M-3	19,63	1,04	677	12.778	39.679
M-4	19,63	1,04	677	12.778	39.679
M-5	11,04	1,18	677	6.333	19.668
M-6	11,04	1,18	677	6.333	19.668
M-7	19,63	1,08	677	12.305	38.209
M-8	19,63	1,08	677	12.305	38.209

DIAMETER (mm)	3,75	5
SEPARATION 5 cm	e=0,375	e=0,125
SEPARATION 7 cm	e=0,875	e=0,200

Table 5. Comparation between theoretic values and experimental results in 2nd hypothesis.

Specimens	Theoretical load N (n)	Theoretical load Ne (n)	Maximum Theoretical steel (N/mm^2)	Maximum load in the test (N)	Maximum tension of test in the steel (N/mm^2)
M-1	21.690	12.414	677	13.283	378
M-2	21.690	12.414	677	14.146	636
MEDIA	21.690	12.414	677	13.714	507
M-3	39.679	33.279	677	25.692	460
M-4	39.679	33.279	677	21.660	676
MEDIA	39.679	33.279	677	23.676	568
M-5	19.668	7.621	677	10.990	208
M-6	19.668	7.621	677	12.498	370
MEDIA	19.668	7.621	677	11.744	289
M-7	38.209	29.477	677	22.347	368
M-8	38.209	29.477	677	18.413	571
MEDIA	38.209	29.477	677	20.380	469

In the following table are compared the results obtained in the test with the theoretic values.

6. CONCLUSION

The following conclusions have been carried out:

- The values of the buckling coefficient ω (1, 04 to 1, 18) indicate that the buckling has little influence in the determination of the maximum tension of the wire.

- The theoretical values obtained not taking into account the eccentricity of the wires, are approximately a 63 % major than the experimental results, for wires of diameter 3, 75 mm; and they are 77 % major for wires of diameter 5 mm. It is due to the curvature of the wires that is originated by the process of fabrication of them.

- On the other hand, the results of the experimental tests are major than the theoretical values obtained taking into account the eccentricity from wires of diameter 3, 75 mm, even a 54 % more in the case of separation between walls of 7 mm. It means that even small eccentricities influence enormously in the results.

- In the case of reinforcements with diagonal wires of diameter 5 mm and taking into account the eccentricity, the theoretical values are approximately a 42 % major than the results of test. Then the increase of section of the element that buckling raises the stability, but not in the way measure by the numerical design.

- According to the results obtained it is necessary and essential to consider the curvature of the diagonal elements to design a cavity wall against to horizontal loads, always that the straightness of the diagonal wires is not guaranteed.

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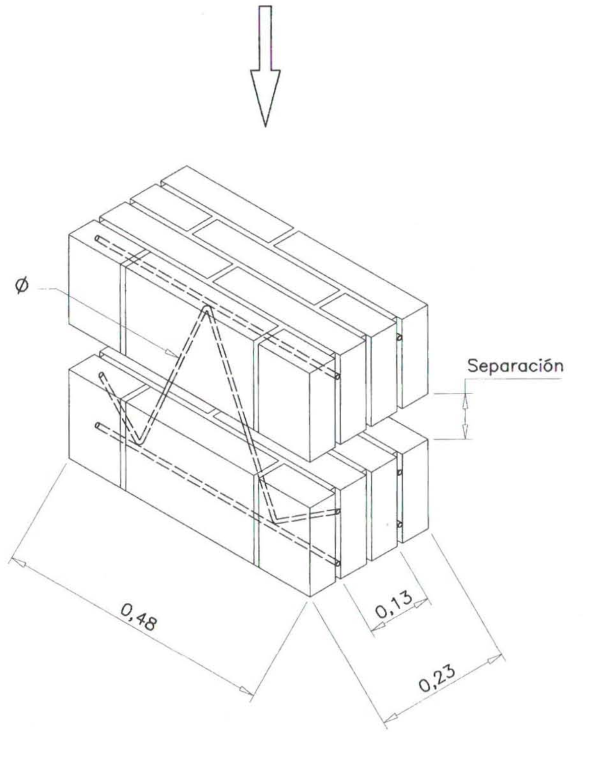
Figure 1. Test of cavity walls to compression stress in the plane of the reinforcement.



ENSAYO DE MUROS DE DOS HOJAS SOMETIDO A COMPRESIÓN EN EL PLANO DEL ARMADO

Figure 2. Wall 6 before the test.

Figure 3. Wall 2 during the test, testing system, necessary attachment and strain gages maybe seen in the photography.

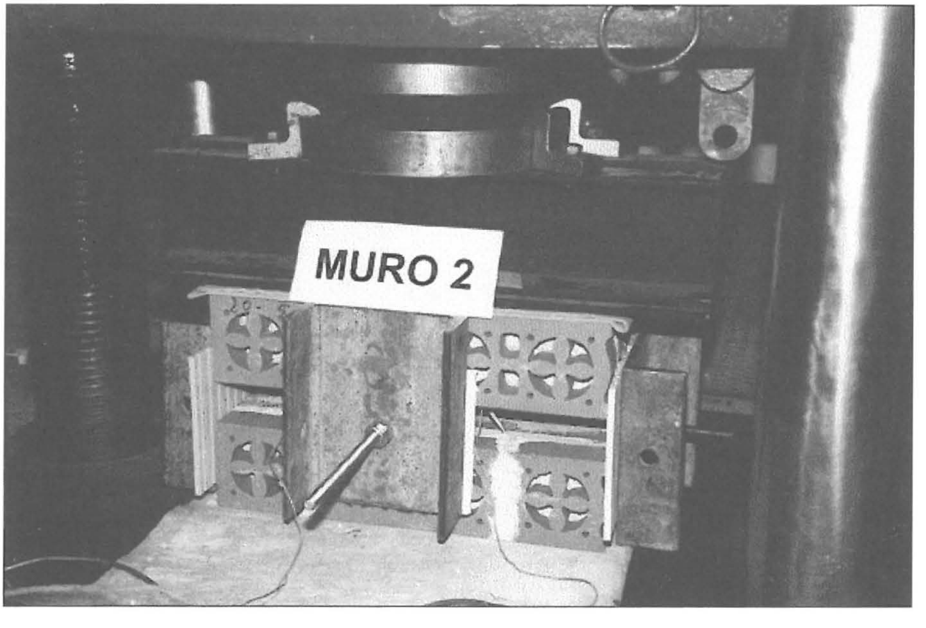


Figure 4. Wall 7. Graph time - load.

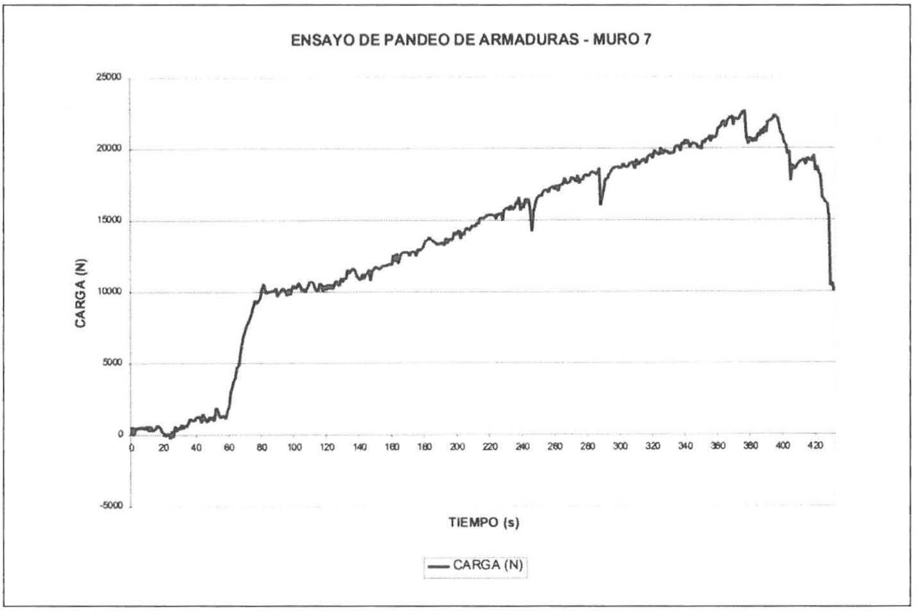


Figure 5. Wall 7. Graph time – reinforcement tension.