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EXPERIMENTAL STUDY OF BRICK MASONRY WALLS SUBJECTED TO ECCENTRIC AND AXIAL LOAD

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Abstract

Masonry buildings represent a huge building stock. The need for preservation of masonry structures may be due to various reasons: economic, heritage, etc. These buildings are often subjected to diagnosis processes that involve structural assessment which can be complex when the slenderness of the walls and the eccentric loading are taken into account.

Load-bearing masonry walls have a complex structural response characterized by the second-order bending effects often caused by the eccentricity of the load. This characteristic is taken into consideration in the Spanish and European regulations which contemplate decreases in the bearing capacity of the walls according to their slenderness. This contrasts with the actual behaviour of the walls, since the collapse rarely occurs due to buckling.

This paper presents the results of an experimental campaign that has been carried out in order to study the effects of slenderness and axial and eccentric load in structural masonry walls. For this purpose, masonry walls with different mortar dosages and identical type of moulded bricks have been tested under different load conditions. The results of the tests are compared to those given by the current regulations, European and Spanish, EUROCODE-6 and CTE.

Keywords: Brick masonry walls, wall testing, buckling

1. Introduction

Looking back in history, it can be ratified that many of the historic buildings in Catalonia and the rest of Spain have been built with masonry structures, especially brick masonry structures. This has been the most common solution until the first half of the XXth century when steel and concrete structures have become usual in construction.

Masonry buildings in this historical build stock are often subjected to diagnosis processes that involve structural assessment which can be complex due to the difficulties in stablishing its safety conditions.

Spanish and European regulations [1] [2] take into consideration the complex behaviour of the masonry, contemplating decreases in the load bearing capacity of the walls according to their slenderness. It is considered that when a compression load (centred or not) is applied to a slender masonry element, it will end up collapsing due to the excessive stress that concentrates in one part of the section as a result of buckling. This fact contrasts with the actual behaviour of the structural walls in such buildings, since scarce damage is observed due to buckling and actual slender walls reach tensions far above the regulation limits [3].

This paper presents the results of an experimental campaign that has been carried out in order to study the effects of slenderness and axial and eccentric load in structural masonry walls.

2. Aims and purpose

The main objective of the present paper is to obtain data of the compression stresses that reach load bearing slender walls at real scale to analyse the effect of buckling on the section of masonry when simple and eccentric compression are applied. The resulting data provide information that may help in the diagnosis of historical brick masonry buildings.

3. Methodology

3.1 Test design

The experimental campaign was based on 12 tests on 12 slender wall specimens. In order to obtain behaviour as close to the reality of such historic buildings, the wall specimens were real size: 13,5cm thick, corresponding to the actual thickness of the so-called Catalan brick, 87.5cm wide and 300cm high. With that aim, bricks, brickwork and mortar dosages were carefully chosen. Mortars used in the wall tests were portland cement CEM II / B-P 32.5 with river sand exclusively, their dosages were low: 1:6 and 1:9. In Table 1 mortar dosages used in each of the tests are specified. Bricks used in the wall test building were ceramic manual moulded bricks which reach state regulations requirements [4].

Bricks, mortars and masonry were characterized. Compressive strength tests were carried out in each of them according to regulations [5][6] and [7] respectively. Results are shown in table 2.

In order that the lower end of the wall specimens behave as similar as possible to the actual bonding conditions of walls in masonry structure buildings, each of the walls was built on a UPN160 profile which was filled with a non-retraction mortar Bettogroud 150. Consequently, the connection between the wall and the floor results not a ball joint but a support without lateral rotation possibilities.

Table 1: Wall tests references and main characteristics

Test Reference	Mortar dosages	Width of joining (cm)	Dimensions (cm)	Upper ending
2	1 : 6	1	13.5 x 87.5 x 300	C.P. 1:6
3	1 : 6	1	13.5 x 87.5 x 300	C.P. 1:6
4	1 : 6	1	13.5 x 87.5 x 300	C.P. 1:6
5	1 : 6	1	13.5 x 87.5 x 300	C.P. 1:6
6	1 : 6	1	13.5 x 87.5 x 300	C.P. 1:6
1.1	1 : 6	1	13.5 x 87.5 x 295	C.P. 1:3 (15% C.A.C.)
7	1 : 9	1	13.5 x 87.5 x 300	C.P. 1:3 (15% C.A.C.)
8	1 : 9	1	13.5 x 87.5 x 300	C.P. 1:3 (15% C.A.C.)
9	1 : 9	1	13.5 x 87.5 x 300	C.P. 1:3 (15% C.A.C.)
10	1 : 9	1	13.5 x 87.5 x 300	C.P. 1:3 (15% C.A.C.)
11	1 : 9	1	13.5 x 87.5 x 300	C.P. 1:3 (15% C.A.C.)
12	1 : 9	1	13.5 x 87.5 x 300	C.P. 1:3 (15% C.A.C.)
4R	1 : 6	1	13.5 x 87.5 x 276.5	C.P. 1:3 (15% C.A.C.)
5R	1 : 6	1	13.5 x 87.5 x 280	C.P. 1:3 (15% C.A.C.)

Table 2: Wall materials characteristics

	w/c	Compressive strength (28 days) N/mm2
Mortar 1:6	0.99	7.4 ± 0.5
Mortar 1:9	1.37	5.6 ± 0.3
Bricks		27.4 ± 1.2
Brick masonry 1:6		12.2 ± 0.7
Brick masonry 1:9		11.3 ± 0.8

During the execution, the verticality of the wall specimens was taken thoroughly; also, the masonry joint measure was fixed in 1 cm, controlling the consistency of the mortar according to the current regulations [8]. Two UPN100 profiles were fixed in each face of each wall to ease the placing of the wall specimens under the press machine.

The upper end of the walls was made by two different mortars. The first round of tests had an upper ending made of portland cement mortar 1:6 while the second round had a portland cement mortar ending 1:3 with 15 % of aluminous cement (calcium aluminate cement). The second ending solution was held because the mortar setting was faster.

3.2 Compressive test

The compressive test consisted on the application of an increasing load on the wall test specimens described in the preceding paragraphs. Load application has been carried out with a dynamic MTS press of 15MN to a constant displacement speed of the piston of the pressing machine of 0.5mm/min. Each test had two phases:

- Phase 1: load application in stepwise increments of 0.1MN. Deformation measurements take place with a deformometer. During the whole sequence the instrumentation performs a continuous recording of the displacements. The sensor of the pressing machine also provides deformational data during the test.
- Phase 2: once a certain load is reached, the instrumentation is removed and then a continuous load is applied until the wall specimen collapses.

The instrumentation of deformation of each sample has been threefold:

- Measurement of transversal deformation with LVDT displacement sensors (Figure 1) allowing real time displacement measurements. Sensor sensitivity is 0.01mm and the accuracy is above 0.5%.
- Placement of measuring points for deformometer readings on the front face of the wall specimen for measuring horizontal and vertical displacements (Figure 1). Accuracy sensitivity of the deformometer is 0.002mm.
- Height displacement measurement performed by the own pressing machine sensor.

In a first group of tests, the load transmission to the wall specimens is performed by the placement of a neoprene band between the ending mortar layer in contact with the pressing machine and the wall (Figure 2). This procedure was rejected, since once the load is applied; the failure appears in an unexpected way. In this first group, a vertical crack appears on the top of the wall as a result of the tensile stresses induced at this spot by the neoprene band. Afterwards, contact with the press was modified by applying the load through a UPN profile in contact with the press over a regularization mortar layer (Figure 2). This change is made to achieve a more realistic behaviour. The results provided in this paper correspond to those obtained with the second solution of transmission load.

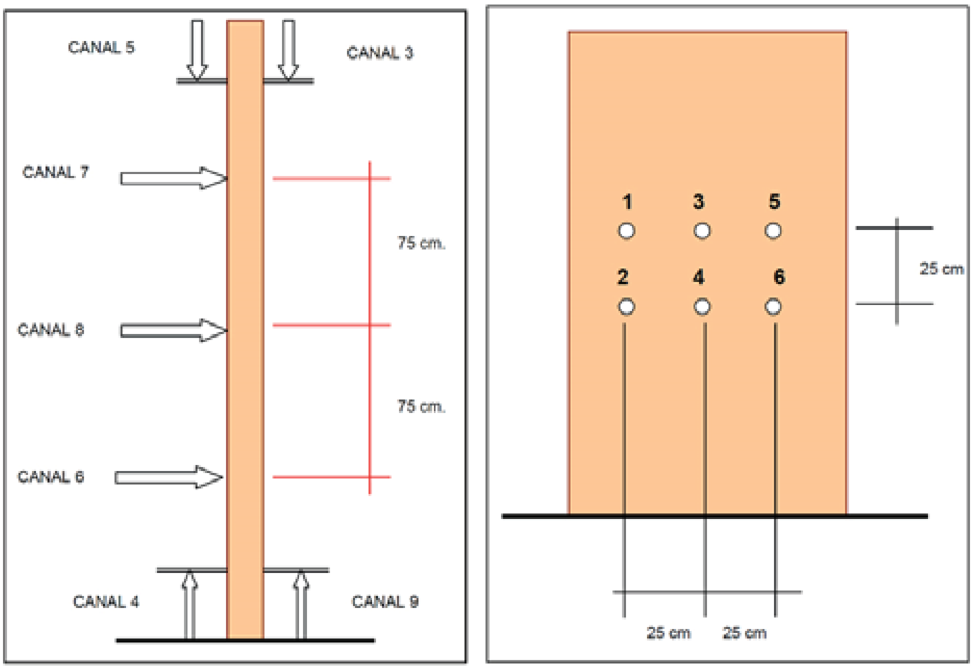

Figure 1. Location of the LVDT sensors (left) and deformometer measuring points (right)

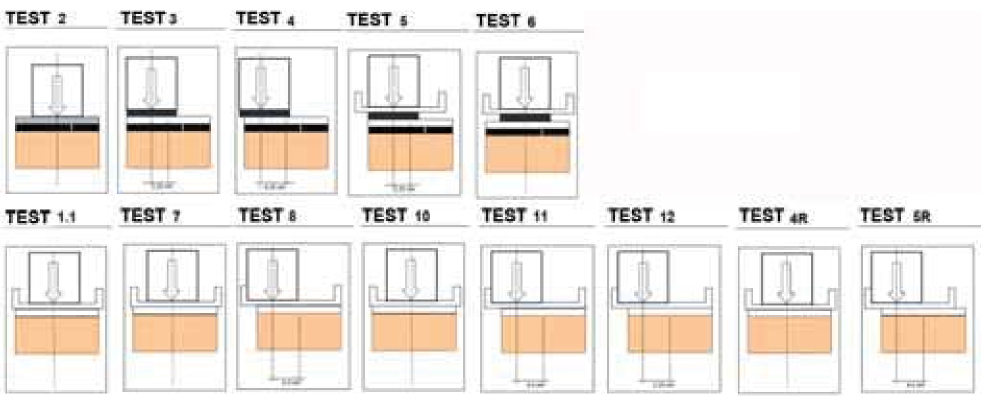

Figure 2. Load conditions on the different tests

4. Results

The results of the compressive tests are provided here below (table 3).
It can be observed that the stresses reached are slightly higher in the walls where the load is centred. However, when considering the most common type of failure of the wall tests (Figure 3, Table 3), the cracking corresponds to a flexo-compression stress whether the load is centred or not. This fact is corroborated when the transversal deformation data provided by the LVDT sensors placed along the wall test specimens is observed (Figure 4).

Table 3: breaking stresses and deformation modules of the compressive tests.

Wall	Breaking stress N/mm2	Deformation module N/mm2	Eccentricity (m)	Type of failure
1.1	11.36	3070	0	Whole height length cracking and collapse
7	7.00	2450	0	Vertical cracking
8	8.94	2500	0.045	Vertical cracking and collapse
10	9.45	2834	0	Vertical cracking and collapse
11	8.33	2503	0.045	Vertical cracking and collapse
12	6.76	2470	0,042	Vertical cracking and collapse
4R	10.39	3124	0	Vertical cracking and collapse
5R	8.45	2618	0,045	Vertical cracking and collapse

Hereafter, the data obtained from the compressive tests is compared with the masonry compressive strength (table 1) considering the reduction of bearing capacity caused by slenderness in EUROCODE-6 [2]. Table 4 shows the reduction factor for slenderness and eccentricity ϕ for each wall considering its characteristics and the eccentricity of the load application.

In the cases where the load is centred, the reduction in the load bearing capacity for slender walls given by the EUROCODE-6 [2] is smaller, so the theoretical compressive strength values are comparable to those obtained in the compression tests. However, in the cases where the load is eccentric such load bearing capacity reduction is significantly reduced. In this last case the results of the tests are above those theoretical values, this fact is discussed in the conclusion section.

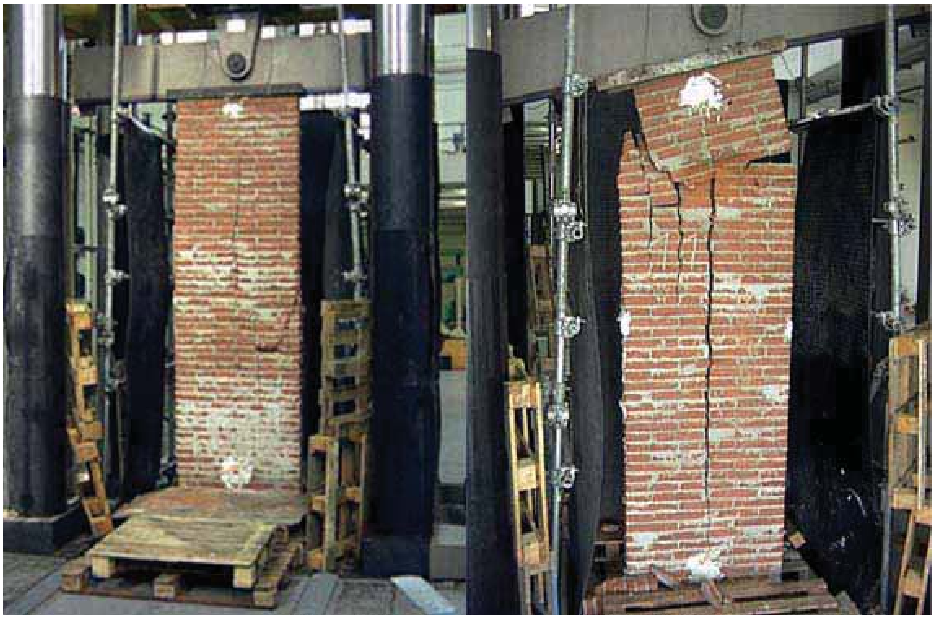

Figure 3. Break of the test number 7, with centred load (left), and 1, with eccentric load (right).

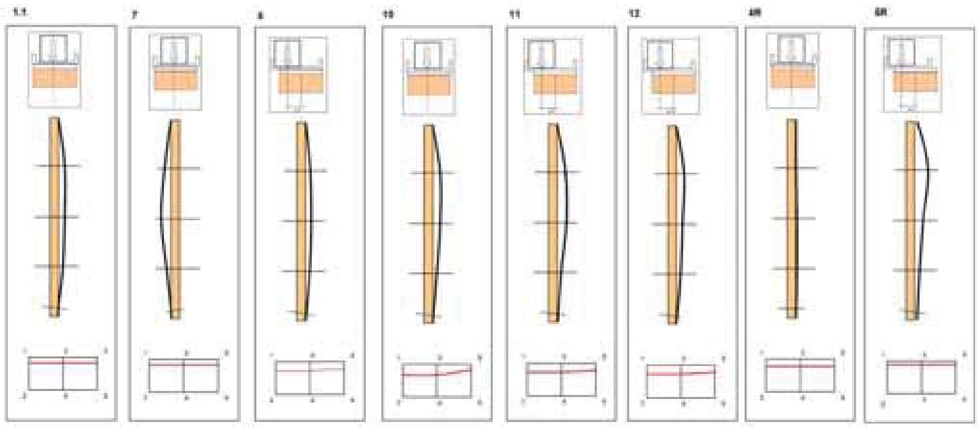

Figure 4. Deformation results

Table 4: compressive strength according to slenderness and eccentricity

wall	height (m)	with (m)	eccentricity (m)	ϕ	compressive strength	compressive strength considering slenderness
1.1	3	0.138	0	0.90406	12.2	11.03
7	3	0.138	0	0.90406	11.3	10.22
8	3	0.138	0.045	0.34587	11.3	3.91
10	3	0.138	0	0.90406	11.3	10.22
11	3	0.138	0.045	0.34587	11.3	3.91
12	3	0.138	0.042	0.38221	11.3	4.32
4R	2.765	0.138	0	0.91077	12.2	11.11
5R	2.8	0.138	0.045	0.34600	12.2	4.22

5. Conclusions

Regarding the cracking of the tests, it has to be noted that although these have been carried out in slender walls no cracks have been observed due to buckling. However, in most cases (7 of 8), readings show small movements of destabilization in the central zone of the specimen. Leaving aside the cracks by local effects, mainly induced at the top of the wall by the charging system, it can be concluded that the maximum compressive load at the time of the main cracking reaches between 40 and 60% of the maximum load at the time of collapse.

The effect of the load eccentricity shows in practice a relatively small decrease in the load bearing capacity. This fact contrasts with the load bearing capacity reductions established by the current legislation which seems to be clearly designed for construction.

In existing building assessment multiple different inputs have to be taken into account in order to provide an accurate diagnosis.

6. References

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