CHARACTERIZATION OF THE MECHANICAL PROPERTIES OF DIFFERENT TYPES OF MASONRY INFILL WALLS

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ABSTRACT
The masonry infill walls play an important role on the seismic behaviour of reinforced concrete buildings. Due to this, it has been widely studied in terms of their strength and stiffness contribution in the in-plane direction and on their response in the out-of-plane direction. Significant improvements were achieved regarding the development of accurate numerical modelling approaches that simulate the infill panels’ behaviour and interaction with RC structure. However, both approaches require several parameters regarding the infills mechanical properties to simulate their expected seismic behaviour. With this aim an extensive experimental campaign was carried out to characterize the mechanical properties of masonry wallets made with different types of masonry units. Wallets made with different horizontal hollow clay bricks and concrete blocks were subjected to compressive strength, diagonal tensile and flexure strength tests according to international standards. The main test results and global findings will be discussed with the main objective of provide key properties to structural designers regarding some infill masonry panels representative of those existing on the Southern Europe countries.

Keywords: Masonry infill walls, experimental testing, mechanical properties, hollow clay bricks, vertical hollow concrete blocks.

INTRODUCTION
The masonry walls are widely used for partition purposes and also to provide thermic and acoustic insulation to the reinforced concrete structures. Many different types of masonry units were developed throughout the last decades with the aim of optimize those characteristics or to use innovative and green materials. The requirements from recent codes regarding the thermic and acoustic insulation of buildings also motivated the development of new materials and new construction techniques of the buildings’ façades. The use of double-leaf walls or on-leaf walls composed by thermos-acoustic blocks or usual ones combined with external thermic insulation composite system. On the one hand the codes focus and requirements regarding these functional characteristics are increasing, and it is notorious the continue increment of the demands with the aim of maximize the comfort of the buildings’ users. On the other hand the contribution of the masonry infill walls to the structural response of reinforced concrete buildings when subjected to an earthquake continues to be relativized or ignored by some structural codes. Usually, the infill walls are considered non-structural elements and no special attention is given to them during the design process of new buildings and in the safety assessment of existing ones [1]. Recently, some structural design codes
started to suggest the use of one-strut models to simulate the panel’ stiffness contribution to the structural response.

Neglecting the contribution of the masonry infill walls can result in catastrophic consequences, for example buildings with innovative architectural configurations characterized by irregular distribution of the infill panels are quite vulnerable to brittle failure due to different mechanisms such as soft-storey (vertical irregular distribution), torsional (plan irregular distribution) or combined ones [2].

It is remarkable, the recent advances observed during the last decade in terms of numerical modelling frameworks capacity developed by different authors by using strut models concepts or detailed modelling approaches [3, 4]. However, there is a lack of experimental data to calibrate mechanical properties of the numerical models with higher accuracy. Additional and further experimental data concerning different types of masonry infill walls made with different materials such as clay or concrete are needed to provide enough information to the structural designer and then result in more accurate numerical models.

The main aim of the present research work is to present an extensive experimental campaign that was carried out to achieve the mechanical properties of masonry walls made with three different types of masonry units: thermos-acoustic concrete blocks and horizontal clay hollow bricks with two different thicknesses (110mm and 150mm). Specimens with and without plaster were built under laboratory conditions. four different types of experimental tests were carried, namely: compressive strength tests according to EN1052-1 [5], diagonal tension strength tests according to ASTM E 519-02 [6] and RILEM TC 76-LUM [7] and flexural strength tests parallel and perpendicular to the horizontal bed joints according to EN 1052-2 [8].

**TESTING CAMPAIGN OVERVIEW**

The experimental campaign was carried out at the Laboratory of Earthquake and Structural Engineering (LESE) in the Faculty of Engineering of University of Porto. A total set of 80 experimental tests were carried out in order to achieve the mechanical properties of clay and concrete infill masonry walls. The masonry units selected to construct the infill panels are the most common over the buildings’ façade in the southern European countries.

A thermo-acoustic concrete block with vertical perforation (VHCB) was selected for the current study. This type of masonry unit starts to become quite common in the buildings façades due to the quite interesting thermic and acoustic characteristics. As can be observed in Figure 1a, the block consists of 11 longitudinal partitions separated by ten micro-air boxes, which together with the type of concrete used, can be obtained reduced coefficients of thermal transmission.

This type of block is, nowadays, designed for simple exterior walls or in contact with unheated areas. It can also be applied in partitions between fires-stairs, stairwells and elevators. This is nowadays an alternative solution to the double-leaf solutions with light insulation in the air box and to simple wall solutions with light insulation from the outside (ETICS). This type of block presents an interesting breathing capacity, which avoids undesirable condensations inside the dwellings.

The others masonry units selected are the hollow clay bricks with horizontal perforation with 110mm and 150mm thicknesses, here designated HCHB110 and HCHB150 respectively. This is one of the most common masonry units, and are quite used for example to the construction
of double-leaf walls where typically the external leaf is composed by HCHB110 and the internal one by the HCHB150 unit. Geometric dimensions of each masonry units can be found in Figure 1b and c respectively.

![Fig. 1 - Masonry units used in the experimental campaign: (a) VHCB315; (b) HCHB110; and (c) HCHB150.](image)

Four different types of tests were carried out, namely compressive strength tests (number minimum of specimens according to EN1052-1 [5] is 3), diagonal tension strength tests (number minimum of specimens according to ASTM E 519-02 [6] is 3), flexural strength tests parallel and perpendicular to the horizontal bed joints (number minimum of specimens according to EN 1052-2 [8] is 5 each other). Each type of test and the corresponding number of specimens tested are summarized in Table 1.

<table>
<thead>
<tr>
<th>Type of masonry wallets</th>
<th>Compression strength tests</th>
<th>Diagonal shear tension strength tests</th>
<th>Flexural strength tests parallel to the horizontal bed joints</th>
<th>Flexural strength tests perpendicular to the horizontal bed joints</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHCB315</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>HCHB110</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>HCHB150</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>HCHB150P10 (existent)</td>
<td>N/A</td>
<td>N/A</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>HCHB150 (existent)</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>HCHB150P10 (existent)</td>
<td>4</td>
<td>N/A</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>13</td>
<td>23</td>
<td>23</td>
</tr>
</tbody>
</table>

VHCB315 - wallets made with VHCB with 315mm thickness without plaster  
HCHB110 - wallets made with HCHB with 110mm thickness without plaster  
HCHB150 - wallets made with HCHB with 110mm thickness without plaster  
HCHB150P10 - wallets made with HCHB with 150mm thickness with 10mm plaster  
HCHB150 (existent) - wallets made with HCHB with 110mm thickness without plaster that were removed from existing walls  
HCHB150P10 (existent) - wallets made with HCHB with 110mm thickness with 10mm plaster that were removed from existing walls
Fig. 2 - Mechanical characterization tests. (a) compressive strength tests according to EN1052-1 [5]; (b) diagonal shear tension strength tests according to ASTM E 519-02 [6]; (c) flexure strength tests perpendicular to the horizontal bed joints; (d) parallel to the horizontal bed joints according to EN 1052-2 [8].

TESTS AND RESULTS

From the compression strength tests it was found that the wallets made with VHCB315 (Figure 3a) achieved the highest mean compressive strength of 1.82MPa with lower coefficient of variation (COV) equal to 5.11%. The lowest one was reached by the HCHB110 group with 0.66MPa. From the results, it can be noted again that the higher value was again achieved by the VHCB315 group with 3251MPa and the lowest by the HCHB110 equal to 1837MPa. For other instance, slight differences were obtained between the HCHB150 (existence) group and the as-built one, which obtained 5% lower elasticity modulus compared with the HCHB150.

Regarding the diagonal tension strength tests, the HCHB 150 group (Figure 3b) achieved the higher stress with mean value of 0.645MPa and the lower one was reached by the VHCB315 group with 0.204 MPa. For other instance, the larger variability among the specimens’ results was gathered by the HCHB110 group with COV equal to 35.2% and the lower one again by the VHCB315 group with COV equal to 5.7%.

From the flexural strength tests parallel to the horizontal bed joints it was found that the highest flexural strength was achieved by the HCHB150P10 group (Figure 3c) with a mean value of 0.218MPa. The plaster increased the flexural strength of 57% comparing with the result obtained by the HCHB150 (note that only 2 tests satisfied the criteria defined by the standard which reduce the amount of data). The lowest flexural strength was obtained by the HCHB110 group with a mean value of 0.117MPa, which is 15% lower than the one obtained by the HCHB150 group.

Finally, from the flexural strength tests perpendicular to the horizontal bed joints it was observed that HCHB150 specimens (Figure 3d) achieved the highest flexural strength with a mean value of 0.322MPa, which is 6% higher than the results obtained by the HCHB150P10
group. The reason behind this difference can be attributed to the results variability. Lower difference is observed when it is compared the HCHB110 and the HCHB150 results, with the first ones reached a mean value of 0.271MPa, 11% less than the last one.

Fig. 3 - Experimental results. (a) compressive strength vs vertical strain VHCB315; (b) shear stress vs vertical shortening HCHB150; (c) flexural strength parallel to the horizontal bed joints curves HCHB150P10; and (d) flexural strength parallel to the horizontal bed joints curves HCHB150.

CONCLUSIONS

The main objective of this research work was to present an experimental campaign carried out at the Laboratory of Earthquake and Structural Engineering (LESE) with the aim of characterize the mechanical properties of three types of infill masonry walls made with different types of masonry units: VHCB315, HCHB150 and HCHB110. Additionally, it was performed a comparison between results of as-built specimens and results from specimens that were collected from existing walls to assess and discuss possible differences between them. 

Table 2 - Summary of mechanical properties obtained from the experimental campaign.

<table>
<thead>
<tr>
<th>Mech. Properties</th>
<th>VHCB315</th>
<th>HCHB110</th>
<th>HCHB150</th>
<th>HCHB150P10</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_c$,mean (MPa)</td>
<td>1.82</td>
<td>0.66</td>
<td>0.806</td>
<td>N/A</td>
</tr>
<tr>
<td>$E_{\text{mean}}$ (MPa)</td>
<td>3251</td>
<td>1837</td>
<td>1975</td>
<td>N/A</td>
</tr>
<tr>
<td>$S_s$ (MPa)</td>
<td>0.204</td>
<td>0.565</td>
<td>0.645</td>
<td>N/A</td>
</tr>
<tr>
<td>G (MPa)</td>
<td>1389</td>
<td>1141</td>
<td>996</td>
<td>N/A</td>
</tr>
<tr>
<td>$f_b$,parallel,mean (MPa)</td>
<td>0.083</td>
<td>0.117</td>
<td>0.139</td>
<td>0.218</td>
</tr>
<tr>
<td>$f_b$,perpendicular,mean (MPa)</td>
<td>0.166</td>
<td>0.271</td>
<td>0.322</td>
<td>0.303</td>
</tr>
</tbody>
</table>
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REFERENCES


