INVESTIGATION ON USING OF MORTAR AS INFILLING MATERIAL ON CLAY BLOCKWORK

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The new Brazilian Standard ABNT NBR 15812-2 (2010) for clay block structural masonry allows the use of mortar to fill the hollow block instead of grout. This may play important role to increase the position of this type of material in the construction market. The aim of this study was to evaluate the efficiency of clay block structural masonry with mortar as infilling material on compression. Three types of industrial dry mortars (Multipli-use, 5 and 10 MPa) and hollow clay blocks with declared nominal resistances of 6, 9, 12 and 15 MPa were used. Preliminary results of compressive strength of molded prisms reveals the technical feasibility of using mortar as infilling material.

**Keywords:** Structural masonry, clay blockwork, mortar, grout, prism

1 INTRODUCTION

In structural masonry construction systems, in certain situations of project, it is necessary to increase the strength capacity of the constructed walls. Such structural demand can be achieved by grouting these walls, a process that consists in filling up the empty spaces inside the walls with a component named grout. Grout is a type of concrete with aggregates of small dimension and relative fluidity that causes the increase of the transversal section area of the blocks, uniting them with occasional steel bars that are positioned on the inside of these blocks' empty spaces (CORRÊA and RAMALHO, 2003).

Whenever required, the grouting of the walls is done right after 24 h of the laying of the unities, as it is prescribed in the ABNT NBR 15812-2 (2010) Standard – Structural masonry – Part 2: Execution and site quality. However, the same standard states that grouting can be done with laying mortar itself right after the unities are laid, provided that masonry is not reinforced.

Considering rationalization as the predominant feature of a structural masonry construction system, as Parsekian and Furlan Júnior (2003) pointed out, the use of laying mortar for infilling the unities right after they are laid would cause a diminution of the use and control of materials that are employed in producing grout, thus increasing the constructability of such processes, allied to inherent reduction of costs. Thereby, the main goal of this article is to
investigate the efficiency of prisms of structural hollow clay blocks when they are infilled with pre-casted mortar that is employed to their laying, in substitution of grout.

The results obtained so far are part of a greater study that has been developed in the Civil Engineering Doctors program of the first author in collaboration with the Federal University of Santa Catarina – UFSC, Brazil.

2 METHODS AND MATERIALS

2.1 BLOCKS
For this study we used structural clay blocks classified in Brazil as of class T29, with nominal dimensions of (14x19x29) cm and nominal compressive strength declared by the clay industry as of 6 MPa, 9 MPa, 12 MPa and 15 MPa. Each block has a different geometry as it is shown in Figure 1. To make it more comprehensible throughout the article, these four classes of blocks were adopted to identify them.

Figure 1 – Geometry and respective declared nominal compressive strength of the blocks used in the research.

In order to minimize variability in the results, the sample of clay blocks is represented by a single production batch of a clay factory installed in the region of the Itajaí High Valley, in the state of Santa Catarina, Brazil.

The determination of the dimensional variation, gross area, water absorption (WA), initial rate of suction (IRA) and the compressive strength of the blocks was done according to procedures established by ABNT NBR 15270-3 (2005). Following the prescription of this technical standard, in order to determine the compressive strength of the blocks they had their load surfaces regularized with cement paste, at least 48 h before the tests, with thickness varying between 1 mm and 3 mm. The loading speed adopted was of 0,05 ± 0,01 MPa/s using the hydraulic press AMSLER 2500 kN at the Materials and Civil Construction – LMCC of the Federal University of Santa Catarina – UFSC, Brazil.

2.2 PRE-CASTED MORTAR
Three classes of pre-casted mortar were used in the study, all of them commercialized in the region of the Greater Florianopolis, Brazil, and all of them meant to be used for laying blocks in masonry. The following classes were used: Multiple Use, for structural masonry with f_{ck} of 5 MPa and of 10 MPa.

In a preliminary study, both the consistence index and the relation water/mortar (F_{w/mort}) were
defined as a function of cohesion and workability of the mortar used for laying and infilling the prisms. The determination of consistence followed the procedures established by the ABNT NBR 13276 (2002) Standard. The apparent specific mass of the anhydrous mortars was determined according to ABNT NBR NM 23 (2000). The air entrainment and water retention capacity were also determined for each of the mortars, respectively, according to EN 1015-7:1999 and ABNT NBR 13277 (2005). These features, after they were obtained through tests, were maintained throughout the study and are presented in Table 1.

Table 1 - Name and features of pre-casted mortars.

<table>
<thead>
<tr>
<th>Type of pre-casted Mortar</th>
<th>Name</th>
<th>Apparent Specific Mass (kg/dm³)</th>
<th>Air Entrainment (%)</th>
<th>Water Retention (%)</th>
<th>Fw/mort</th>
<th>Consistency Index (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Use</td>
<td>M</td>
<td>2,795</td>
<td>11,0</td>
<td>89,5</td>
<td>0,134</td>
<td>± 175</td>
</tr>
<tr>
<td>Structural Masonry of 5 MPa</td>
<td>5</td>
<td>2,785</td>
<td>5,8</td>
<td>85,9</td>
<td>0,153</td>
<td>± 210</td>
</tr>
<tr>
<td>Structural Masonry of 10 MPa</td>
<td>10</td>
<td>2,780</td>
<td>5,0</td>
<td>85,5</td>
<td>0,153</td>
<td>± 220</td>
</tr>
</tbody>
</table>

The preparation of the pre-casted mortars was performed on a vertical mortar mixer, in the following order:

1º) Half the water was put up in the tub of the mortar mixer;
2º) Next, all the anhydrous mortar was put up into the mortar mixer while it was working;
3º) The mixing was carried on in the mortar mixer for 3 minutes. After this step, the equipment was turned off when necessary and part of the mortar that adhered to the wall of the mortar mixer's tub was removed, for no longer than 3 minutes;
4º) Afterwards, the rest of the water was put up in the tub and the mixing was performed again for 1 minute, considering this to be the time necessary to get the mixture with consistence and workability as determined in previous tests.

The mechanical characterization – compressive strength and flexural strength of 28 days – of the pre-casted mortar was done with prismatic specimens (4x4x16) cm, in accordance to ABNT NBR 13279 (2005). At least three prismatic specimens were molded on metallic molds for each molded and grouted prism. The tests were performed using a hydraulic press of the brand SOLOTEST at the Materials and Civil Construction Laboratory – LMCC/UFSC, with maximum capacity of 196 kN for the compression test and of 19,6 kN for the flexural strength test.

2.3 PRISMS

Three course prisms with whole block area mortar were molded. One opted for making the prisms with three blocks, because this way the effects generated by the plate restrictions are softened on the blocks on the edges.

Three prisms were molded for each combination of block-mortar-grout, totalizing 54 prisms with different features. The prisms were identified in function of the pre-casted mortar (I), grouted prism (G) or hollow prism (P), block class (6, 9, 12 and 15) and pre-casted laying mortar class (M, 5 and 10). The nomenclature and the combinations used in the article are presented in Table 2.
The prisms were molded on a leveled granite table covered with a plastic blanket, which was anointed with mineral oil. All the blocks were moistened before the molding of the prisms. According to Carvalho (2003), prisms that are built with moistened blocks have a tendency to increase their compressive strength. The bed joints of the prisms were done maintaining a thickness of 10 ± 3 mm. The regularization of the prisms was done with cement paste on their load surfaces in order to correct the imperfections of the prisms, hence distributing the load evenly across the active area of the section. For the hollow prisms the blocks on the edges were capped at least two days before the molding the prisms was started. For the grouted prisms the blocks on the edges were regularized after the prisms were molded, at least 48 h before the compressive strength test, making it easier for one to prepare the prisms for the test. The grouting of the prisms was done in three layers right after they were molded, considering that the densification was done with 30 hits per layer using a hitting rod according to recommendations in the ABNT NBR 8215 (1983) Standard. Both grouted and hollow prisms were ruptured through compression after 28 days of having been molded. The loading rate used for the compressive strength tests of the prisms was 0,05 ± 0,01 MPa/s, as recommended in ABNT NBR 15270-3 (2005). The hydraulic press AMSLER 2500 kN was used for this test at the Materials and Civil Construction Laboratory – LMCC/UFSC.

Efficiency or efficiency factor is the ratio that exists between the strength of the prism or wall and the strength of the block. In practical terms, for this article efficiency represents the interaction level between the components, having that the higher the efficiency's ratio, the better this interaction will be. This ratio can be calculated as shown in Equation 1.

\[ \eta = \frac{f_p}{f_b} \]  

Where \( \eta \) is the efficiency factor; \( f_p \) is the compressive strength of the prism (MPa) and \( f_b \) is the compressive strength of the block (MPa).

### 3 RESULTS AND DISCUSSION

#### 3.1 BLOCKS AND MORTARS

It was initially found that the characteristic compressive strength (\( f_{bk} \)) of the received samples of the four classes of clay blocks ended up being lower than the nominal rate declared by the supplier clay factory, except for the block class of 6 MPa, whose results obtained in the compression tests are presented in Table 3. The blocks of classes 9, 12, and 15 presented rates of characteristic compressive strength of, respectively, 4.4%, 15% and 14% below the
declared rate. It was also found that the characteristic compressive strength \( f_{b(k)} \) of the block class 9 is inferior to the one of block class 6. This inversion of strength rates suggests, at first, that there is some failure in controlling the production process and in the raw material of such blocks. Comparing the average compressive strength \( f_b \) no significant difference between these rates was observed, for a significance level of 5%.

Regarding the physical features, the real dimensions of the blocks (width, height and length) are found to be in accordance with the ABNT NBR 15270-2 (2005), i.e., within the range of ±3,0 for the average nominal dimensions. The IRA ratio found for the blocks, in accordance to ABNT NBR 15270-3 (2005), is below the ratio 30 g/193,55cm² x min as well, which indicates that the blocks do not have high water suction.

Table 3 – Physical mechanical features of the classes of the blocks used.

<table>
<thead>
<tr>
<th>CLASSES OF BLOCKS</th>
<th>Samples</th>
<th>Dimensions (mm) e (Sd - %)</th>
<th>Gross area (cm²) e (Sd - %)</th>
<th>WA (%) e (Sd - %)</th>
<th>IRA e (Sd - %)</th>
<th>Compressive Strength (Gross Area)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Width</td>
<td>Height</td>
<td>Length</td>
<td>Fγ arg</td>
<td>Sd (MPa)</td>
<td>12.2</td>
</tr>
<tr>
<td>6</td>
<td>137.3 (0.2)</td>
<td>188.8 (0.3)</td>
<td>288.1 (0.2)</td>
<td>395.4 (0.4)</td>
<td>15.9 (1.0)</td>
<td>12.2 (18.0)</td>
</tr>
<tr>
<td>9</td>
<td>139.7 (0.3)</td>
<td>189.5 (0.6)</td>
<td>289.8 (0.5)</td>
<td>404.7 (0.7)</td>
<td>13.0 (2.9)</td>
<td>12.4 (14.7)</td>
</tr>
<tr>
<td>12</td>
<td>141.0 (0.3)</td>
<td>191.3 (0.3)</td>
<td>290.4 (0.2)</td>
<td>409.5 (0.5)</td>
<td>13.5 (4.1)</td>
<td>16.1 (10.6)</td>
</tr>
<tr>
<td>15</td>
<td>140.8 (0.6)</td>
<td>191.1 (0.6)</td>
<td>288.3 (0.6)</td>
<td>406.1 (1.1)</td>
<td>14.7 (5.2)</td>
<td>16.6 (13.6)</td>
</tr>
</tbody>
</table>

\( Sd = \) standard deviation; \( * \) IRA in g/193,55cm²/min.

It is observed in Table 4 that the average compressive strength \( f_{\text{arg}} \) of the pre-casted mortar of class 10 presented the higher rate, while the mortar of class 5 presented the lower rates. It is also observed that the rates of average compressive strength of the three classes of mortar are 70 to 100% below the strength of the blocks, which is indicated by researchers such as Mohamad (1998) and Corrêa and Ramalho (2003). However, this range of use indicated by the researchers refers to mixed laying mortars, i.e., mortars of cement, lime and sand.

In all the mortars, in order to achieve the adequate consistency and workability for this task, a water percentage lower than the one specified by the manufacturer was used in the mixture. Even using a reaction water/anhydrous mortar \( F_{\text{arg}} \) below the specified, the rates of average compressive strength that were found for the mortars were lower than the expected for structural laying mortars of 5 and 10 MPa.

Table 4 – Consistency of laying mortar in its fresh state, average compressive strength \( f_{\text{arg}} \) and average flexural strength \( f_{\text{mort-traction}} \) hardened.

<table>
<thead>
<tr>
<th>TYPE OF MORTAR</th>
<th>Samples</th>
<th>Consistence (mm)</th>
<th>( f_{\text{arg}} ) (MPa)</th>
<th>Sd (%)</th>
<th>( f_{\text{mort-traction}} ) (MPa)</th>
<th>Sd (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>12</td>
<td>± 210</td>
<td>2.9</td>
<td>13.5</td>
<td>1.2</td>
<td>13.5</td>
</tr>
<tr>
<td>M</td>
<td>12</td>
<td>± 175</td>
<td>6.8</td>
<td>5.9</td>
<td>2.9</td>
<td>11.3</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>± 220</td>
<td>7.7</td>
<td>10.8</td>
<td>2.8</td>
<td>10.5</td>
</tr>
</tbody>
</table>
3.2 PRISMS

According to the results obtained in the rupture of the prisms, as shown in Table 5, the hollow prisms that presented the higher efficiency factors were the prisms P15-5, P9-10, P12-10 and P15-10. These efficiency rates and the rates found for the prisms in other series are in accordance with those rates indicated by Corrêa and Ramalho (2003), which are between 0.3 and 0.6 for prisms of clay blocks.

When the strength between the hollow prisms was compared, the prisms P15-5 and P15-10, laid with mortars of 5MPa and 10MPa, respectively, presented the higher rates of compressive strength. According to Leão (2008), hollow prisms with blocks of same strength and with more resistant mortars present an increase in their rates of compressive strength. However, such behavior was not observed when comparing the prisms P15-5 and P15-10, and even less in the other series of prisms with same block and different types of mortar.

The results presented in Table 5 reveal that the prisms laid with Multiple Use mortar, of intermediate compressive strength rate, presented the lowest rates of compressive strength for the prisms. Such behavior may be related to the amount of air entrainment that was observed for these mortars due to the air-entraining additives that exist in such mortars' composition and, hence, due to the elasticity module. The tests to clarify these phenomena will eventually be performed, therefore, they will not be discussed in depth in this article.

Table 5 – Efficiency factor and average compressive strength of the grouted prisms (G) and hollow (P), laid and infilled with mortars of the type Multiple Use (M), of 5 MPa (5) and of 10 MPa (10).

<table>
<thead>
<tr>
<th>MORTAR</th>
<th>HOLLOW PRISMS</th>
<th>GROUTED PRISMS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nomenclature</td>
<td>fp (MPa)</td>
</tr>
<tr>
<td>5</td>
<td>P9-5</td>
<td>4,4</td>
</tr>
<tr>
<td></td>
<td>P6-5</td>
<td>3,7</td>
</tr>
<tr>
<td></td>
<td>P12-5</td>
<td>6,5</td>
</tr>
<tr>
<td></td>
<td>P15-5</td>
<td>8,7</td>
</tr>
<tr>
<td></td>
<td>P9-M</td>
<td>3,3</td>
</tr>
<tr>
<td></td>
<td>P6-M</td>
<td>3,1</td>
</tr>
<tr>
<td></td>
<td>P12-M</td>
<td>6,1</td>
</tr>
<tr>
<td></td>
<td>P15-M</td>
<td>7,8</td>
</tr>
<tr>
<td></td>
<td>P9-10</td>
<td>6,5</td>
</tr>
<tr>
<td></td>
<td>P6-10</td>
<td>4,8</td>
</tr>
<tr>
<td></td>
<td>P12-10</td>
<td>8,0</td>
</tr>
<tr>
<td></td>
<td>P15-10</td>
<td>8,6</td>
</tr>
</tbody>
</table>

The using of Multiple Use mortar for laying hollow prisms, technically, did not reveal itself as the most adequate when compared to the using of mortars of 5 MPa and 10 MPa, which presented the best results of average compressive strength and of efficiency.

In the graphs shown in Figure 2, one observes the tendency of the prisms to increase their strength along with the increase of strength of the blocks. However, such behavior was not verified for the blocks with nominal strength of 6 MPa (fb = 12,2 MPa). This reduction of the
prisms’ strength for the three classes of mortars can be related to the form of the blocks of class 6. Although the rates of average compressive strength of the blocks of classes 6 and 9 do not present any significant statistical difference, the geometry of block 9 can be the factor that changes this behavior. The interaction between the blocks of class 9 and the mortars must provide a better structural combination than the using of blocks of class 6, as it was observed with the efficiency rates, which follow the same tendency of the rates of compressive strength, i. e., these rates are greater for those prisms produced with blocks of class 9.

![Figure 2](image2.png)

**Figure 2** – Average compressive strength and efficiency factor prism/block of hollow prisms, with Multiple Use pre-casted mortars of structural masonry of 5 MPa and 10 MPa.

Regarding the type of rupture of the hollow prisms, it occurred without any fragile characteristic, i. e., with prior notice through crushing the mortar and formatting vertical cracks on the blocks, until the point where they collapsed as a whole, as shown in Figure 3.

![Figure 3](image3.png)

**Figure 3** – Characteristic rupture of the hollow prisms.

As for the grouted prisms, according to the results presented in Table 5, comparing the rates of
average compressive strength of the prisms, it was observed that grouting the prisms with mortar of 5 MPa caused an increase in strength between 18.9% and 46.2%, which is an evidence of the technical feasibility of using laying mortar instead of grout. However, for the prisms of the G15-5 series there occurred a reduction of compressive strength of the prisms, with rate of 9.2% when the prisms are grouted. This behavior can be explained through the fact that the average compressive strength of the mortar of class 5 was equivalent to 31.7% of the average strength of the blocks of type 15, which is extremely below the indicated compressive strength of grouts (CORRÊA and RAMALHO, 2003). In this case, as the compressive strength of the mortar that was used as grout presented a low strength rate in comparison to the one of the block, the strength of the prism decreased significantly when it was grouted. This behavior is due to the fact that, once the compressive strength of the grout was reached before the one of the set block-mortar, the walls of the blocks were submitted to traction stress caused by the grout's expansion, which led the prism to rupture, in this case in a faster way than in the hollow prisms of the P15-5 series.

In the graphs in Figure 4, one observes the tendency of the grouted prisms' strength to increase along with the increase of the blocks' strength. However, this behavior was not verified for the blocks with nominal strength of 6 MPa (fb = 12.2 MPa), as it was observed with hollow prisms produced with the same block (Figure 3). This reduction of strength of the prisms for the three classes of mortar may be related to the shape of the blocks of such class. Although the rates of average compressive strength of the blocks of classes 6 and 9 do not present any significant statistical difference, the shape of block 9 can be the factor that differs their behavior, i.e., the interaction of the block 9 and the mortars must lead to a better structural combination than the using of blocks of class 6. Such assertion is demonstrated when one observes the efficiency rates, which follow the same tendency of the compressive strength rates, i.e., they are greater for the prisms produced with blocks of class 9. It was also observed an acute decrease of strength in the prisms produced with blocks of class 15 when these are grouted with mortar of 5 MPa, showing that, when using blocks with a high strength rate, it is necessary to increase the grout’s strength as well in order to make it viable for technical use.

![Figure 4](image)

**Figure 4** – Average compressive strength and efficiency factor of grouted prisms, with pre-casted mortars of Multiple Use of structural laying of 5 MPa and 10 MPa.
To what concerns the rupture of the grouted prisms, it began with the appearance of vertical cracks on the blocks, followed by the lateral cracking of their walls, indicating that there occurred lateral traction on the walls of the blocks (Figure 5). This resulted from the confinement of the grout, i.e., once exceeded the compressive strength of the grout, the internal tension generated against the walls of the blocks causes them to be ruptured by traction (HAMID and DRYSDALE, 1979; CHEEMA and KLINGER, 1986). However, on prisms with blocks and mortar with greater rates of compressive strength, in this case the prisms of the G15-10 series, the rupture occurred in a fragile way, without prior notice, through the appearance of cracks on the blocks or through the crushing of mortar.

![Figure 5 – Characteristic rupture of the grouted prisms.](image)

### 4 CONCLUSION
The results obtained in this preliminary study demonstrate the technical feasibility of grouting the prisms with laying mortar itself, with the intention of increase the prisms' strength. However, the mortars with low compressive strength in relation to the one of the blocks revealed themselves technically inappropriate for being used instead of grout, as it has been observed by other researchers that used grout in their researches. Thus, for a good performance of masonry and a better use of its components' properties, researches are necessary in order to improve the compatibility among the constituent materials of masonry.

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