Masonry Behavior of Local Brick from East-java Indonesia

Wisnumurti, Sri Murni Dewi, Agoes Soehardjono MD

Departement of Civil Engineering, Faculty of Engineering, University of Brawijaya, Malang, Indonesia.

ABSTRACT

Local red brick masonry structure is widely used as the main structure housing. In any event a large earthquake in Indonesia, the collapse of the masonry structure is always there. Theories that explain the masonry structure in Indonesia refer to the references from other countries. This is due to research published in Indonesia is not a lot. The theory that widely used in the equations for masonry structures based on the strength of brick units higher than the mortar. Preliminary results and review of literature shows the strength of local brick unit in Indonesia is lower than the strength of mortar. The same thing happened also with its physical properties. The aim of this study is to obtain a more appropriate theoretical for the behavior of local masonry structures, especially the material from East Java. The independent variables in this study are the thickness of mortar and the strength of mortar. Mortar strength obtained from a mixture that is often used in Indonesia. The results showed the thickness and the strength of the mortar has positive influence on the strength of masonry structures. This behavior is different from the existing theoretical studies in foreign literature. The ductility of masonry wall is obtained higher in the mortar with a lower strength.

Key words: Local clay brick, masonry behavior, mortar.

Introduction

Masonry wall of local red brick is very widely used in building construction in Indonesia. In the construction world, masonry wall is considered as a secondary structure that only burden the building structure. Masonry walls are grouped in the architecture work. In fact the red masonry wall performed the function as the main structure. It can be observed in the behavior of masonry walls during the life of the building.

In any event a large earthquake in Indonesia, the ruins of the existing building always can be seen red brick masonry wall. Behavioral theories of masonry structures in Indonesia refer to the reference of other countries. The theory is based on the strength of brick units higher than the strength of mortar (El-Refai, 1984; Paulay, 1992). This is in accordance with the regulations of the country concerned (ACI 530-05, 2005; AS 3700, 2001; BS 5628-1992).

In civil engineering universities in Indonesia masonry wall structure was introduced to the extent of building materials. Strength, stiffness and ductility of the masonry wall structure has not been studied. However this structure would work effectively in the event of an earthquake. Initial observations of the 7 red brick producing areas in East Java, namely Malang, Mojokerto, Kediri and Tulungagung are obtained the highest average compressive strength of 35 kg/cm$^2$ and the lowest average compressive strength is 7 kg/cm$^2$ (Wisnumurti, 2009). Mortar mix used is (1 cement: 8 sand) to (1 cement: 4 sand) with sufficient consistency. Lowest average strength is 30 kg/cm$^2$ and higher average strength is 150 kg/cm$^2$. Thus strength of mortar is higher than the red brick units. Felix (1999) and Basoenondo (2008) obtain initial stiffening due to the influence of strong mortar. In this connection the influence of the thickness of the mortar also play a role in the behavior of masonry walls.

2. Research Methodology:

This research was conducted to find materials to study a more appropriate theoretical for behavior of local masonry structures in Indonesia. This study uses the masonry wall model of local brick from the East Java region. The independent variables are thick of mortar (horizontal and vertical) and strength of mortar.
Each test masonry model wall is made 3 replications. Mortar strength obtained from a mixture commonly used in Indonesia. Load test using a simple monotonic load. Chart test model used shown in Figure 1. Figure 2 is the masonry model in the laboratory.

![Fig. 1: Chart of model test and its components.](image)

**Fig. 2:** Masonry model in the laboratory.

### Results and discussion

The discussion is based on the influence of 2 variables studied. These variables are the thickness of mortar and mortar strength.

#### 3.1. Effect of Mortar Thickness:

Test results the materials making up the masonry wall can be seen in Table 1. Test results of mortar thickness on the masonry wall model are shown in table 2. The thickness of the mortar has significant effect on wall strength. This influence applies to both the thickness of the mortar, ie horizontal and vertical. In this study, a more dominant influence has not been analyzed properly, because of limitations of model. It appears that the strength of the resulting masonry wall is lower than the strength of the constituent materials (mortar and brick). These tests have an average efficiency of the masonry wall strength 56.4% against the brick strength. Mortar has a major influence on the value of this efficiency.

![Table 1: Materials properties.](image)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength of brick</td>
<td>34.45 (kg/cm²)</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>44.57%</td>
</tr>
<tr>
<td>Compressive strength of mortar</td>
<td>70.21 (kg/cm²)</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>5.09%</td>
</tr>
</tbody>
</table>
3.2. Effect of Mortar Strength:

Characteristic properties of materials to test the influence of mortar strength are shown in Table 3. Test results of influence of mortar strength to the masonry strength are shown in table 4. The thickness of the mortar in the horizontal and vertical direction is 1.5 cm. Strength of the masonry walls seemed influenced by the strength of mortar but are under the strength of mortar and brick. These results indicate there is other influence on the strength of the wall that is the interface between mortar and brick.

Results in Table 4 show the same thing by testing the influence of the thickness of the mortar. Strength of mortar give a positive influence on the strength of the masonry wall. Ductility of the structure can be observed by making the load deflection relationship. Ductility behavior is very interesting, because high strength mortar produces lower ductility. It can be seen in Figure 3. This means the masonry wall with mortar stronger becomes more brittle than the walls with weak mortar.

### Table 2: Effect of the mortar thickness on the masonry.

<table>
<thead>
<tr>
<th>Number</th>
<th>Vertical : Horizontal thickness</th>
<th>Compressive stress (kg/cm²)</th>
<th>Coefficient of variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 cm : 1 cm</td>
<td>14.21</td>
<td>21.90</td>
</tr>
<tr>
<td>2</td>
<td>3 cm : 1 cm</td>
<td>15.72</td>
<td>10.82</td>
</tr>
<tr>
<td>3</td>
<td>1 cm : 3 cm</td>
<td>18.90</td>
<td>15.33</td>
</tr>
<tr>
<td>4</td>
<td>3 cm : 3 cm</td>
<td>28.90</td>
<td>15.24</td>
</tr>
</tbody>
</table>

### Table 3: Test results of material characteristics.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Compressive stress (kg/cm²)</th>
<th>Coefficient of variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay brick</td>
<td>42.55</td>
<td>36.92</td>
</tr>
<tr>
<td>Mortar 1:3</td>
<td>130.04</td>
<td>8.84</td>
</tr>
<tr>
<td>Mortar 1:5</td>
<td>79.81</td>
<td>16.17</td>
</tr>
<tr>
<td>Mortar 1:7</td>
<td>48.01</td>
<td>7.90</td>
</tr>
</tbody>
</table>

### Table 4: Strength of mortar and strength of the masonry walls.

<table>
<thead>
<tr>
<th>Mortar</th>
<th>Masonry wall structures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compr. Strength (kg/cm²)</td>
</tr>
<tr>
<td>1:03</td>
<td>130.04</td>
</tr>
<tr>
<td>1:05</td>
<td>79.81</td>
</tr>
<tr>
<td>1:07</td>
<td>48.01</td>
</tr>
</tbody>
</table>

### Conclusion:

The thickness of the mortar has positive influence on the strength of masonry brick wall structure. The strength of the wall structures increases with increasing thickness of mortar. This is in contrast with results from developed countries. The strength of masonry wall is also under the strength of constituent materials. In general, local bricks in this study produce a wall structure in the category of strong mortar. Monotonic load test showed that the more low-strength of mortar produce the higher ductility of the walls.
References

ACI 530-05, 2005. Building code requirements for masonry structures. American Concrete Institute.