EXPERIMENTAL STUDY ON COMPRESSION STRENGTH OF RECYCLED CONCRETE HOLLOW BLOCK MASONRY

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Abstract

Compressive property is the main mechanical property of recycled concrete hollow block masonry. From the compression test of masonry, the compressive strength, elastic modulus and the stress-strain curve has been researched. At the same time the rules and test results are compared and analyzed in this paper, concluding the design value of compressive strength. The test results show that recycled concrete block masonry has better compressive strength and deformability, so it can be used for load-bearing wall materials.

Keywords: Recycled concrete block masonry; Compressive strength; Elastic modulus

1. INTRODUCTION

With the rapid development of Chinese urban construction, construction waste generated has become too much. If no measures are effectively adopted to deal with the construction waste, it would not only pollute the environment, but also takes up a lot of landfill area. In recent years, the world’s earthquakes have occurred frequently, in China there were two earthquakes recently, the 2008 earthquake in WenChuan and the 2010 earthquake in YuShu. In these natural disasters, buildings collapsed and removal of dangerous houses will produce a lot of construction waste, they need to be effectively dealt with [1,2]. Construction waste can be made into different sizes of recycled fine aggregates and coarse aggregates by crushing and screening. According to different performance of the recycled aggregates, they can be used for manufacturing different recycled concrete and recycled concrete hollow block [3,4]. In this paper, recycled coarse aggregates with the particle size of 5-10mm and recycled fine aggregates with the particle size of less than 5mm were used for producing recycled concrete.
load-bearing hollow blocks, and the performances of recycled concrete hollow block masonry has been researched, including its compressive strength, elastic modulus and stress - strain rule. Through the research, it’s demonstrated that recycled concrete block masonry has good compressive strength and deformability, and can be used as a bearing wall material.

2. EXPERIMENT AND RESULTS

2.1 Specimen design

Recycled Concrete block masonry is built with three rows holes block, which specifications shown in Fig.1, its strength grade is MU10.0. Recycled concrete blocks were made from recycled aggregates, which come from the waste concrete of old removal plant by crushing and screening. At first the waste concrete is crushed by jaw crusher, then screened, and the recycled aggregates can be obtained, with size range respectively: smaller than 10mm, between 5mm and 10mm, bigger than 5mm. In this test, recycled fine aggregates with size range of smaller than 5mm and the recycled coarse aggregates with size range of between 5mm and 10mm are used for producing recycled concrete block.

![Fig. 1: Recycled concrete hollow block](image)

Recycled concrete masonry compression test is divided into three groups, and each group has three specimens, and there are 9 specimens totally. The specific plan is shown in Table 1.

![Fig. 2: Recycled concrete block masonry](image)
Table 1: Compressive strength of recycled concrete block masonry test plan

<table>
<thead>
<tr>
<th>Group</th>
<th>Grade of Recycled concrete hollow block</th>
<th>Grade of mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>KY1</td>
<td>MU10.0</td>
<td>M7.5</td>
</tr>
<tr>
<td>KY2</td>
<td>MU10.0</td>
<td>M10</td>
</tr>
<tr>
<td>KY3</td>
<td>MU10.0</td>
<td>M15</td>
</tr>
</tbody>
</table>

Masonry specimen is bricked by a medium technical level bricklayer, and the mortar of each plate should be evenly used for each specimen. In bricking process of the masonry specimen, should always check fullness of the mortar joint. The Masonry specimens and mortar specimens are all tested at same time after 28d natural maintenance. Their top should be leveled by the cement mortar (mixing proportion 1:3) of 10mm thickness and use level bar to check the levelness.

On the two narrower sides of the specimen, dial gauges are installed to measure axial deformation of specimens through adhering measurement to the surface. The distance between the two points equals to the thickness of one block plus thickness of a mortar joint. Instrument in the middle of the wider surface is installed to measure the lateral deformation, and the distance between every point and the edge of specimen should be not less than 50 mm.

The test is carried out at YE -200A compression testing machine and its maximum pressure is 2000kN (see Fig. 3). Before the test, 5% of the failure load first should be applied in order to check the sensitivity and security of the measurement, and then specimen should be preloaded repeatedly for 3-5 times to the value between 5% and 20% estimated failure load. The relative error of the two sides axial deformation should not exceed 10%, if it does not meet the requirement, the location of the specimen should be re-adjusted or leveled up. After preloading the specimen should be unload, and the pointer of the dial gauges should be moved to zero. Each value of load level should be 10% of estimated failure load, and each loading should be completed within 1-1.5min, at the same time loading should sustain for 1-2min before applying the next level load. When Loading should not impact on the specimen, and should record deformation at the same time. As loading to 80% of estimated value, the instrument should be removed, and then continuously loading to damage the specimen.

Fig. 3: Compressive test of recycled concrete masonry

2.2 Test results
The test results of recycled concrete block masonry are shown in table 2. Test parameters
are also listed in the table, including ultimate load, compressive strength and elastic modulus.

Table 2: The test results of recycled concrete block masonry

<table>
<thead>
<tr>
<th>Group</th>
<th>Strength of Recycled Block (MPa)</th>
<th>Motar (MPa)</th>
<th>Ultimate Load (kN)</th>
<th>Compressive strength (MPa)</th>
<th>Calculating compressive strength (MPa)</th>
<th>Elastic modulus (MP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KY1</td>
<td>10.5</td>
<td>8.0</td>
<td>712.3</td>
<td>7.61</td>
<td>5.96</td>
<td>5562</td>
</tr>
<tr>
<td>KY2</td>
<td>10.5</td>
<td>12.0</td>
<td>771.3</td>
<td>8.24</td>
<td>7.02</td>
<td>5917</td>
</tr>
<tr>
<td>KY3</td>
<td>10.5</td>
<td>14.8</td>
<td>802.3</td>
<td>8.57</td>
<td>7.77</td>
<td>6790</td>
</tr>
</tbody>
</table>

3. ANALYSIS OF TESTS RESULTS

3.1 The phenomenon of recycled concrete masonry test

There is no sign before the failure of the specimens. Generally the first vertical crack occurs in the narrow side of the specimen, once cracks appear bearing force no longer to increase. With continued loading, the vertical or diagonal cracks also appeared in the wide side. Then the vertical cracks of the narrow side gradually expanded, and even formed into a vertical slit, at last the specimen collapsed (see Fig. 4). Fracture surface of the specimen shows that the recycled concrete blocks are easy to be destroyed by vertical cracks in the top surface. The test process shows that the initial cracking load of the specimen appeared rather later, and there is a little difference between initial crack load and ultimate load, which should be paid attention to in practice.

![Fig. 4: Damage characteristics of recycled aggregate concrete masonry](image)

3.2 Analysis of compressive strength

Chinese axial compressive strength formula of masonry:

\[
f_m = k_1 f_1^a (1 + 0.07 f_2) k_2
\]

in the formula:  
- \( f_m \) —— Average compressive strength of masonry,  MPa;  
- \( f_1 \) —— Average compressive strength of block,  MPa;  
- \( f_2 \) —— Average compressive strength of mortar,  MPa;  
- \( a \), \( k_1 \) —— Influence coefficient of Masonry type and block type, to concrete block, \( k_1=0.46 \),  \( a =0.9 \);  
- \( k_2 \) —— The parameters of mortar strength, in the concrete block, when \( f_2=0 \), then
Formula (1) is used to calculate the compressive strength and the results are listed in Table 2. Comparing the measured value and calculated value, the measured values are greater than the calculated values which shows that the formula of the average axial compressive strength is suitable for recycled concrete block masonry. The damage mechanism of recycled concrete block masonry is similar to the plain concrete block masonry. As the experimental data is less, compressive strength formula of recycled concrete block masonry also requires a lot of valid test data, which should be paid attention to in practical application.

3.3 Analysis of stress-strain curve and elastic modulus

The stress-strain curves of 9 recycled concrete block masonry are shown in Fig. 4, Fig. 5 and Fig. 6 respectively. The correlation of stress-strain curve is from the experimental results in general pressure machine. When the stress reached the ultimate strength of masonry, because of lack of rigidity of test machine, the stress of masonry reduce, strain energy saved in the testing machine rapidly release, at the same time the masonry is destroyed, it is difficult to measure the stress-strain descending curve. Therefore, this paper only discusses the stress-strain curves of the ascending part. From Fig. 4 to Fig. 6, it can be seen that the mortar strength affect the deformation of the recycled concrete block masonry. With the increasing strength of mortar, masonry deformation decreases. Recycled concrete block masonry destroyed with M7.5 mortar has the largest deformation, the maximum deformation is up to 2000με, the maximum deformation of masonry using M15 mortar is less than 1500με.

According to the stress-strain curve of recycled concrete block masonry, the elastic modulus can be calculated. As the masonry is a plastic material, the curve points of stress-strain relations is constantly changing. Usually expressed the elastic modulus of masonry in the following three ways: (1) The tangent Modulus of masonry, the tangent value of the angle between any point tangent and the horizontal coordinate at the Masonry stress-strain curves. (2) The initial elastic modulus, the slope of tangent at the origin of stress-strain curve. (3) The secant modulus of masonry, the slope of secant between a point and the origin at the stress-strain curve. In accordance with the provisions of relevant regulations in China to take secant modulus \( E \) at \( \sigma = 0.43f_{\text{m}} \), the results are shown in Table 2. According to Chinese code for design of masonry structures, for concrete block masonry with M7.5 mortar, \( E = 1600f \), when using more than M10 mortar, \( E = 1700f \). Table 2 shows that measured elastic modulus of recycled concrete block masonry is greater than the value from calculation formula, and recycled concrete block masonry elastic modulus increase with the mortar strength increasing.

![Fig. 5: The stress-strain curves of KY1](image1)

![Fig. 6: The stress-strain curves of KY2](image2)
4. CONCLUSIONS

(1) Test results show that the recycled concrete hollow block can be used for load-bearing masonry. Bearing capacity of recycled concrete block masonry can be calculated with the formulas in the current national design codes.

(2) The measured elastic modulus of concrete block is greater than the calculated value, and recycled concrete block masonry has good resistance to deformation.

(3) As the same as the normal concrete block masonry, the deformation of the recycled concrete block masonry decreases with the in the strength of mortar increasing.

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