Application of Recycled Brick on the Properties of Concrete

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Abstract: Now-a-days, huge amount of waste bricks are produced all over the world during demolition of construction. Use of recycled aggregates in Portland cement concrete (PCC) construction can offer benefits associated with both economy and sustainability. In order to ensure a sustainable waste management it is necessary to predict its properties and to specify its utilization. The paper mainly focuses to study the performance of concrete due to the replacement of crushed stone with recycled brick in various proportions. Laboratory testing programs were accomplished to determine mechanical properties (such as compressive strength, splitting tensile strength) of concrete. It has been observed that the recycled crushed brick can be blended with crushed stone chips up to a certain percentage depending on the categories of various civil engineering applications.

1. Introduction

Concrete is one of the important construction material used in the world in all engineering works including the infrastructure development at all stages. Due to wide spread usage and fast infrastructure development in all over the world, there is shortage of natural aggregates. The quality of concrete is determined by its mechanical properties as well as its ability to resist the deterioration. It’s a great opportunity for the concrete industry that they can save natural aggregate by replacing coarse aggregate with construction demolition waste and other waste materials like ceramic waste aggregates, granite waste aggregate and slab waste aggregate in the production of concrete [1]. This research presents the current state of knowledge of successful uses of alternative used materials in concrete technology, particularly the usage of recycled brick aggregates in concrete composition.

Generation of construction and demolition debris (C&D) means those materials resulting from the alteration, construction, destruction, rehabilitation, or repair of any manmade physical structure including houses, buildings, industrial or commercial facilities, and roadways [2, 9, 10]. It was reported over 20 million tons of C&D wastes were generated in Hong Kong in the year 2004 [3].

Concrete consumption in the world is estimated at two and a half tons per capita per year (equivalent to 17.5 billion tons for 7 billion population in the world) [4]. To make this huge volume of concrete 2.62 billion tons of cement, 13.12 billion tons of aggregate, 1.75 billion tons of water are necessary. A significant amount of natural resource can be saved if the used brick is recycled for new constructions. In addition to the saving of natural resources, recycling of used brick will also provide other benefits, such as creation of additional business opportunities, saving cost of disposal, saving money for local government and other purchaser, helping local government to meet the goal of reducing disposal, etc.

Due to the increasing volume of waste and by-product materials generated in our society and the associated cost of disposal of the waste materials, there is increased pressure and incentive to recover and recycle these materials for use in secondary applications such as in concrete [5]. Studies related to the recycling of demolished concrete are generally found for stone chips made concrete [6-8]. Therefore, investigations on recycling of brick made demolished concrete are necessary. With this background, this study was planned. The main
The objective of this research is to characterize and evaluate the use of recycled brick in applications of concrete. The research performed necessary laboratory testing to know the engineering and mechanical properties for the projected applications of recycled brick in blends with crushed stone. This research provides a contribution to Structural Engineering, Environmental Engineering, and Sustainability in Structural engineering particularly in the applications of concrete.

2. Methodology

All the key materials used in this research work include waste brick aggregates (coarse aggregate), natural sand (fine aggregate), crushed stone chips (coarse aggregate) and binder (Cement). The natural sand used in this research was locally known as Sylhet sand, adhering to ASTM C33 (ASTM 2011c), with a saturated surface dry (SSD) specific gravity of 2.4, water absorption 4.1% and fineness modulus (FM) of 2.97. The sieve analysis of used natural sand is shown in Figure 1. The gradation curve of used recycle brick aggregate and stone chips are shown Figure 2 and Figure 3 respectively.

![Figure 1. Sieve analysis of fine aggregate](image1)

The main ingredient of this study, waste brick, was collected from the demolition of Civil Engineering Building, KUET during its horizontal extension. Concrete was mixed according to ASTM C192 using a standard concrete mixture. 100 mm x 200 mm concrete cylinders were cast and compacted according to ASTM C31. In this research, total five batches of concrete were cast as presented in Table 1. The mixing ratio was kept 1: 1.5: 3 with a constant water cement ratio of 0.5. Compressive strength test and tensile strength test of each batches were determined though laboratory testing.

![Figure 2. Gradation curve for coarse aggregate (waste brick aggregate)](image2)

![Figure 3. Gradation curve for coarse aggregate (stone chips)](image3)

<table>
<thead>
<tr>
<th>Sample Designation</th>
<th>% of Coarse Aggregate</th>
<th>% Fine Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Waste</td>
<td>Stone</td>
</tr>
<tr>
<td>F1</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>F2</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>F3</td>
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<td>50</td>
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<td>F4</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>F5</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

2.1. Mechanical Properties

Strength of concrete is commonly considered its most valuable property. Strength usually gives the other all pictures of quality of concrete because strength is directly related to structure of the hardened cement paste.

2.1.1. Compressive Strength. Three samples (100 mm x 200 mm cylinders) were tested for each mixture at 7 days and 28 days in accordance with ASTM C39-11a (ASTM 2011a). Compressive force was applied to the specimen (see Figure 4) by using...
compression strength machine and failure load was measured.

![Figure 4: Compressive strength test set up of cylindrical specimen](image)

2.1.2 Tensile Strength. The splitting tensile strength was measured at 28 days for each of the mixture. Similar to those used for compressive strength test, the test (shown in Figure 5) was also performed using 100×200 mm cylinder per mixture. Specimen was positioned into the compression strength machine according to ASTM C39-11a (ASTM 2011a). Load was applied to the specimen and failure load was measured.

![Figure 5: Test set up of splitting tensile strength](image)

3. Results and Discussions

The following mechanical properties are determined:

3.1. Compressive Strength

The compressive strength of concrete is one of the most important and useful property of concrete. Strength and performance of aggregates will influence the character of concrete. Compressive strength of the recycled brick aggregate concrete is being influenced by the properties of recycled brick aggregate and bonding between the cement paste and aggregate. The result of compressive strength of concrete determined for various mix proportion in this study is shown in Table 2. Possibly recycled brick aggregate had a lower fracture toughness of aggregate particles or weaker bonding between aggregates and cement paste. That's why compressive strengths of recycled brick concrete mix is lower than natural aggregate concrete mix.

![Table 2. Result of compressive strength for various mix proportion](image)

From Table 2 it has been observed that the compressive strength of concrete for 100% recycled brick is approximately 25% of concrete using 100% replacement by stone chips. Compressive strength is increasing with increasing the % replacement of recycled brick aggregate by stone chips for both 7 days and 28 days as presented in Figure 6.

![Figure 6. Variation of compressive strength with respect to % replacement of recycled brick aggregate by stone chips](image)
3.2. Tensile Strength

Tensile strength is an important property of concrete because concrete structures are highly vulnerable to tensile cracking due to various kinds of effects and applied loading itself. However, tensile strength of concrete is very low in comparison to its compressive strength. The splitting tensile strength of concrete determined in this study is given in Table 3. The splitting tensile strength is increasing with decreasing the recycled brick aggregate with the mixture as shown in Figure 7. This may occur due to lower fracture toughness of aggregate particles or weaker bonding between aggregates and cement paste.

Table 3. Result of tensile strength for various mix proportion

<table>
<thead>
<tr>
<th>Sample Designation</th>
<th>Load (kN)</th>
<th>Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>57.9</td>
<td>1.8</td>
</tr>
<tr>
<td>F2</td>
<td>62.4</td>
<td>1.9</td>
</tr>
<tr>
<td>F3</td>
<td>64.4</td>
<td>2.1</td>
</tr>
<tr>
<td>F4</td>
<td>71.0</td>
<td>2.3</td>
</tr>
<tr>
<td>F5</td>
<td>75.8</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Figure 7: Splitting tensile strength of tested sample at 28 days

4. Conclusions

This study compared the performance of conventional natural aggregate concretes with concretes containing recycled brick aggregate as 100% replacement of coarse aggregates. This research also studied the effect of partial replacement of conventional natural aggregates (coarse) by recycled brick aggregates. It has been observed that at a similar water cement ratio 100% recycled brick mixtures have a lower compressive strength and tensile strength compared to conventional concrete mixtures, possibly as a result of a lower fracture toughness of aggregate particles or weaker bonding between aggregates and cement paste. Use of crushed bricks as coarse aggregate in concrete increases the water to cement ratio as it increases the absorption of concrete to the water. It can be concluded that that recycled crushed bricks can be used satisfactorily up to a certain percentage as coarse aggregates for making concrete of acceptable strength characteristics.

5. References