Properties of Brick Waste as Coarse Aggregate Material in Concrete

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Abstract

Peoples around Jimma, Ethiopia use Brick waste as aggregate material traditionally. This is mainly due to the availability of Brick and shortage of coarse aggregate material in the area. However, this material property was not studied and its replacement percentage was not known. To reach on conclusion, Brick wastes were collected from three different categories, which were manufactured in the same area. The first one was Brick waste collected from eighteen years old demolished building, the second type was broken on production site and the third type was broken at sellers hand at time of transportation or poor handling. The materials collected were broken manually to maximum aggregate size of 25mm. To minimize the moisture content, the samples were exposed to sun. Batching and mixing of materials was conducted for percentage replacement of 0% to 35% in 5% range of brick waste. Due to high water absorption capacity, Brick waste replaced concrete was less workable. 7th day and 28th day compressive strength result shows, 25% of 18years old and Broken on sellers hand Brick waste type can be used as an aggregate for C25 concrete; while 20% of those broken at production site type can be used on structure.

Keywords: Artificial Aggregates, Brick Waste Aggregate, Age of Brick

1. Introduction

Sustainable construction was introduced due to the concern on the future of our planet because the construction industry is found to be a huge consumer of natural resources and producer of waste [1]. Worldwide consumption of concrete is estimated as two and half per capita per year [2]. To make this huge volume of concrete, 2.62 billion tons of cement, 13.12 billion tons of aggregate and 1.72 billion tons of water are required [3]. It is difficult to meet demand of aggregates in area like Jimma, where there is shortage of both fine and coarse aggregate. Hence, most of quality aggregates are collected from outside the city and the cost is higher. In addition, recycling and reuse of construction material wastes is an interesting option to save waste disposal sites and conservation of natural resources [4].
Not only shortage of resource and Environmental impact, production of aggregates consumes a large amount of energy. Hence, Aggregate replacement is one of the concerning area.

Aggregates can be classified based on different categories. Depending on their weight, aggregate can be classified as normal weight, lightweight and heavyweight aggregates. Normal weight aggregates can be further classified as natural aggregates and artificial aggregates [5]. Natural aggregates are mainly collected by cutting mountains or breaking river gravels or boulders, [2] or can be collected from igneous, sedimentary and metamorphic rocks [6]. Artificial aggregates sources may not be specific. The main requirement is meeting the quality specification of aggregates. The most common artificial aggregates are Broken Brick, air-cooled slag and sintered fly ash blotted clay [8]. Therefore, it is significantly important to obtain right type and quality of aggregates (fine and coarse) because aggregates occupy 60 to 75% of the concrete volume (70 to 85% by mass) and strongly influence the concrete’s freshly mixed and hardened properties, mixture proportions, and economy [6].

Brick is highly available construction material around Jimma Zone. Sometimes, it is traditionally used as aggregate. The waste materials of clay bricks are usually come in different ways [2]. It may be the mistakes made at time of production, using inappropriate materials, during transportation, [2] or most common source or large amount is from demolished material. Sometimes, removing this material may need additional cost for cart away.

2. Materials and Methods

2.1. Materials Used

Raw materials used for the study were Natural Sand available around Jimma, Crushed Aggregate from crusher site, Brick waste come in three forms, OPC type Cement from Dangote factory and tap water from JiT.

The three different forms of Brick waste around Jimma are: broken at production area due to less quality or handing, which is most of the time exposed for sun and rain for about two to four weeks before reaching on sellers hand, the second one which is broken on sellers hand and the third and not widely available in the area is demolished from old structures. The first and second type of bricks wastes are available on market with relatively less price than the normal brick. The materials were collected from each samples. They were originally produced in similar areas and labeled as “A” “B” and “C” for analysis purpose

A- Material collected from demolished 18years Building
B- Material collected from those broken on production site and exposed for sun and rain for three weeks
C- Material collected from Broken brick on hand of sellers
2.2. Experimental Procedure

Collected materials were dried on sun and crushed by hand for a maximum size of 25mm aggregate. Then sieve analysis, unit weight, water absorption, specific gravity and moisture content were determined before mix design. The sand used was first tested for silt content and it was found to be 4.8%, which is below 6% limit of Ethiopian standard and sieve analysis was done and fineness modulus is found to be 3.0, which is on the range of ASTM C33 standard 2.3 to 3.1. Coarse aggregate having maximum size of 25mm was collected from crusher site and checked for main aggregate characteristics. Brick waste collected from three sources were crushed manually. Based on ASTM C125 & D8 Brick waste aggregates were categorized under lightweight as shown on Table 1 below.

<table>
<thead>
<tr>
<th>Table 2. Unit Weight of Course Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Aggregate</td>
</tr>
<tr>
<td>Crushed Rock Gravel</td>
</tr>
<tr>
<td>Brick waste Category A</td>
</tr>
<tr>
<td>Brick waste Category B</td>
</tr>
<tr>
<td>Brick waste Category C</td>
</tr>
</tbody>
</table>

pH value for aggregate was not specifically set on standards. Rather the focus of standards is on mineral content rather than pH value. However, both low and high pH creates problem in concrete in terms of corrosion and spalling. Aggregates that reduce high alkalinity in concrete are preferable. In order to determine pH value of aggregate, 50g of fine aggregates that pass 2.36mm were collected and diluted in 100ml distilled water. The sample PH value was measured using digital PH meter and average of result was taken.

Aggregate gradation was based on ASTM C 33 standard. 10 Kg sample was taken by quartering method and shacked on mechanical shaver from 10min to 15min. The result of analysis shows Gravel from crusher site has fineness modulus of 7.49, Brick Waste an Aggregate has 7.29, Brick waste B Aggregate has 7.28 and Brick waste C aggregate has fineness modulus of 7.30.
Other parameters like Aggregate crushing value, Aggregate Impact Resistance were determined to study the resistance of aggregate from Brick waste. Aggregate Impact values were done on a sample passing 12.5 mm and remain on 10mm sieve. After filling the sample on mold, it is subjected to 15bowl of a metal hammer of weight 14kg [8]. The sample which passes 2.36mm sieve was measured and taken for analysis purpose.

In order to analyze the aggregate crushing value, the sample passing sieve size 12.5mm and remain on 10mm was filled on steel cylinder having internal diameter of 15.2cm and square base plate. The sample was closed by plunger having a piston diameter of 15cm. Then the sample was tasted using universal testing machine and samples passing 2.36mm sieve size was measured.

Specific gravity and water absorption was determined using a balance with suitable apparatus to suspend the sample. The coarse aggregate was sampled using sample splitter and quartering method. Finally, 2Kg sample was taken from each type and soaked in water for 24hr. After 24hr, measurement was taken and sample was again measured in saturated surface dry (SSD) condition. The sample was then inserted in to 105°C oven for 24 hr. After 24 hr., the sample was removed and weight measured after cooling for an hour.

**Table 3 Properties of Coarse Aggregate**

<table>
<thead>
<tr>
<th>No.</th>
<th>Test Description</th>
<th>Crush ed Rock</th>
<th>Brick Waste A</th>
<th>Brick Waste B</th>
<th>Brick Waste C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Moisture Content (%)</td>
<td>0.76</td>
<td>1.68</td>
<td>2.41</td>
<td>4.87</td>
</tr>
<tr>
<td>2</td>
<td>Unit weight Compacted (in Kg/m$^3$)</td>
<td>1,726.7</td>
<td>747.7</td>
<td>794.9</td>
<td>857.6</td>
</tr>
<tr>
<td>3</td>
<td>Absorption capacity (%)</td>
<td>1.26</td>
<td>11.84</td>
<td>10.85</td>
<td>11.70</td>
</tr>
<tr>
<td>4</td>
<td>Specific gravity</td>
<td>Bulk</td>
<td>2.66</td>
<td>2.16</td>
<td>2.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bulk(SSD)</td>
<td>2.70</td>
<td>2.42</td>
<td>2.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apparent</td>
<td>2.75</td>
<td>2.91</td>
<td>2.78</td>
</tr>
</tbody>
</table>

Based on collected data, mix design was done and cubic specimens were prepared for replacement of 0%, 5%, 10%, 15%, 20%, 25%, 30% and 35% of brick waste aggregate. This replacement was done for all three types of Brick wastes each percentage having three samples. The mix design was done based on ACI-211.1 1991, corrections on the amount of material was done based on each trial percentage. The design was done for maximum aggregate size of 25mm, for C-25 concrete and slump from 25mm-50mm. After preparing specimens, samples were cured in temperature controlled curing tank for 7 and 28 days according to ASTM C39-03.
The fresh property of concrete was determined using slump test. All result of tests show True Slump. The control (0%) having slump of 31mm.

3. Results and Discussion
3.1. Properties of Brick Waste as Aggregate
When aggregates are used for general construction, aggregate chemical property is mainly determined based on the minerals within the aggregate and pH is determined after mixing or when concrete is made. However, when aggregate is used for pavement purpose, it is necessary to know aggregate physical property and pH of aggregate. Clay brick aggregate (specially found in Jimma) is different

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1 BWAA- Brick Waste Aggregate A, BWAB- Brick Waste Aggregate B, BWAC-Brick Waste Aggregate C
from other aggregates in that its minerals easily react with water. Moreover, around Jimma, peoples prefer brick waste for pavement work. According to (Local Government Roads to Zero Waste 2011) it is recommended to use aggregate having pH between 6 & 10 for light duty pavements. The pH value of aggregates available around Jimma was found to be 9.21 for old Brick, 7.38 for broken on site and 8.05 for broken at sellers' hand. Hence, the aggregate is even appropriate for light duty pavement. Aggregate crushing value and impact values were not good. Eighteen years Brick shows relatively good result, while the others result was larger. The reason may be old brick was plastered and absorbed cement. Based on Indian Standard IS283-1970, impact value shall not exceed 45% by weight for aggregate used for concrete other than wearing surface and 30% of maximum for wearing surface, hence only Brick waste aggregate (BWA) from 18years structure is appropriate for wearing surface as shown in figure below. While the others can be used for other than wearing surface [8].

![Aggregate Impact and Crushing Value](image)

**Figure 4**: Aggregate Impact Value and Crushing Value

Aggregate Crushing value of 45% maximum is permitted for aggregates used for structures [8]. While all brick waste aggregates does not meet the requirement. Hence blending is required for using this brick waste as coarse aggregate material. Though using brick waste makes the structure light weight as shown in table 3 and ASTM C330 specification of light weight aggregate [9], the water absorption of brick waste was very high, which causes increase in water cement ratio and decrease in strength. Hence, its usage as coarse aggregate material is limited in some percentage.

3.2. Properties of Fresh Concrete with and without Brick Waste

Fresh concrete property is mainly determined by workability that refers to the consistency, mobility, and compatibility of concrete. Workability is commonly determined using slump test since it is simple to conduct on site. The slump value recommended depends on the purpose or application of concrete on structure. The correction on water content and other materials was made when mixing. However, Brick waste specially BWAA (18years old brick) water to cement ratio was very high due to the
absorption capacity of brick. As shown on Figure 4, the slump value was decreasing while increasing the amount of brick aggregate on concrete. This makes the brick as less workable. In addition, the increase in water to cement ratio will decrease the durability and strength of concrete on actual work.

3.3. Compressive Strength of Concrete with and without Brick Waste

One of Brick waste type available around the city is from demolished structure. However, this type of Brick was not highly damaged and brick from plastered wall is rarely available in the area. The property of this aggregate was better in aggregate crushing value and moisture content. Nevertheless, the water absorption was very large, making water cement ratio larger and concrete less workable when water cement ratio is fixed. The compressive strength was decreasing when the percentage of Brick waste was increased and the optimum level is 25% replacement. However, less workability of the aggregate may limit the percentage even below the specified amount on reinforced structures.

![Figure 5: Compressive strength of concrete with Brick waste an aggregate](image)

The second type of brick waste, which is highly available on market, is broken on site. This type of bricks is highly exposed for continuous sun and rain in rainy season due to lack of access roads to transport the material. The crushing value and impact value of this brick was found to be very large as shown in Figure 5 making it not suitable for pavement works [8]. The moisture content was very high due to continuous exposure, while water absorption is less than BWAA (18years old). The workability of this aggregate was better compared to the 18years one. However, this Brick type compressive strength is less than both type A and C, making the optimum replacement of 20% based on hardened property.
Bricks may be broken at hand of sellers due to poor handling, less quality or transportation. This type of Bricks are available on market in the city. Most of sellers mix this type of Brick with type B (broken on site). Moisture content and absorption capacity of this Brick was higher than type B. However, the hardened property (Compressive Strength) was better than type B aggregates and less than eighteen years old Brick. The reason may be, old bricks were plastered and absorbed cement from plastering activity.

4. Conclusion
The characteristics of Brick around Jimma (Ethiopia) are different from others in so many contexts. The first is high water absorption and moisture content different from Bricks in other cities or countries, which make it less preferable for structural use. The other characteristics is less workability due to high water absorption capacity and larger crushing and impact value, which may limit its usage
from pavement works and highly reinforced structure. The hardened property shows, this brick waste can be used as an aggregate 20% -25% for C-25 normal concrete. However, if the grade of concrete is lesser than C-25, its usage may increase and make it preferable due to low cost and lightweight characteristics.

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References