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Research Article

# Performance Evaluation of Structural Lightweight Concrete Using Jhama Brick as a Partial Replacement of Coarse Aggregate

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**Keywords**

*Lightweight Concrete,*
*Jhama Brick,*
*Coarse Aggregate,*
*Compressive Strength,*
*Slump Test.*

**Abstract**

Through the ancient time structural lightweight concrete has been used successfully all over the world due to having its pleasant property of reducing dead load of multi-storied buildings which is very much important for high rising structures. This research represents the experimental works on the structural lightweight concrete to observe the cost and the physical properties using jhama brick (also known as over burnt brick) chips as partial replacement of coarse aggregate. For producing C-35 grade concrete, jhama brick chips was used for the partial replacement of coarse aggregate by 0%, 5%, 10%, 15%, 20%, 25%, and 30% weight of coarse aggregate. For this purpose, 21 sets of cylinders (100 mm x 200 mm) were prepared. Slump tests were carried out for each mix in the fresh state and 3, 7 and 28 days of compressive strength tests were also performed in the hardened state. The 28-days compressive strength of concrete with 0%, 5%, 10%, 15%, 20%, 25%, and 30% replacement of jhama brick chips were 37.12, 36.37, 34.23, 33.01, 30.89, 30.50, and 21.98 MPa respectively. The unit weight of concrete with 0%, 5%, 10%, 15%, 20%, 25%, and 30% replacement of jhama brick chips after 28-days curing were found 2409.3, 2379.2, 2286.9, 2230.2, 2197.0, 2104.1, and 2094.9 kg/m$^3$ respectively. According to ASTM C 330, the compressive strength of concrete with jhama brick chips up to 25% of coarse aggregate fulfilled its requirements.

## 1.Introduction

For Concrete is a common and versatile engineering material consisting of a mixture of aggregates, water and binding materials that is extensively used in the construction industry from basic work to multi-story buildings as well as mega structures. Partial replacement of coarse aggregate with over burnt brick ballast aggregate in lightweight concrete. Over burnt brick aggregate was used 5%, 10%, 15%, 20% replacement of coarse aggregate [1]. It can be reported that the crushed over burnt bricks–sand concrete was medium-lightweight concrete with a density ranging between 2000 kg/m$^3$-2200 kg/m$^3$ and the compressive strength of up to 29.5 MPa [2]. Venkataramana et al. (2020) has studied the properties of concrete using crushed over burnt bricks as an aggregate in comparison with concrete using natural coarse aggregates.

The coarse aggregate was replaced with 0%, 25%, 50%, 75%, and 100% of over burnt bricks by volume of concrete [7]. The series of tests are conducted to study the effect of 0%, 25%, 50%, 75% and 100% replacement of coarse aggregate with over burnt bricks [3]. It has started to produce lightweight concrete by using lightweight aggregates to develop lightweight concrete production in 20th century [6].

In Bangladesh, it has noted that the use of C-35 concrete is used mostly in reinforced concrete structures. For this purpose, in producing of reinforced concrete used in construction, jhama brick chips are used to make the concrete lightweight and for the savings of jhama bricks which are produced in the brick field due to over burning.

## 2.Testing process

### 2.1 Test specimens and properties

The concrete mix ratio was found as 1:1.7:2.5 and the water-cement ratio (W/C) were taken as 0.49. Figure 1 shows the steps to be carried out for this research.

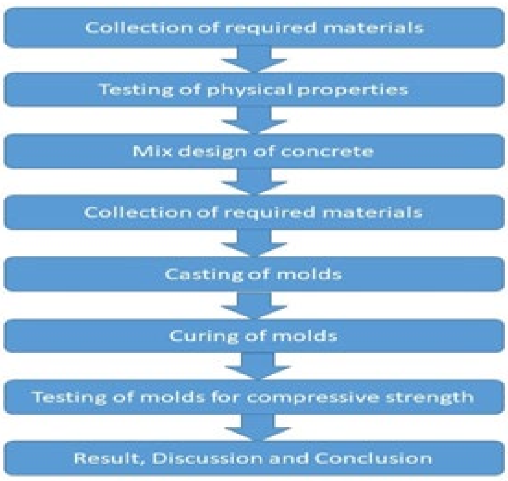


Figure 1. Steps to be carried out for this research

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#### 2.1.1 Materials used

Materials that were used for making concrete mix had been tested in laboratory for control mix C-35 concrete.

##### 2.1.1.1 Cement

In this research, the cement was collected from the construction site of HSTU, Dinajpur. The cement was tested in the laboratory and the value obtained are given in the following table.

Table 1. Properties of the Cement (ASTM C150)

| Sl. No. | Property | Value |
|---|---|---|
| 1 | Specific gravity | 3.15 |
| 2 | Initial setting time | 57 mins |
| 3 | Final setting time | 310 mins |

##### 2.1.1.2 Sand

In this research, coarse type river sand having the following properties was used. The sand was collected from the construction site of HSTU, Dinajpur. The sand was tested in the laboratory and the value obtained are given in the following table.

Table 2. Properties of Sand

| Sl. No. | Property | Value |
|---|---|---|
| 1 | Fineness modulus | 2.90 |
| 2 | Specific gravity | 2.65 |
| 3 | Water absorption capacity | 1.63% |
| 4 | Unit weight (kg/m3) | 1562.8 |

##### 2.1.1.3 Stone chips

Stone chips are one of the most common types of coarse aggregate used for several constructional purposes. According to ASTM C33, the stone chips were sieved. Stone chips were collected from the construction site of HSTU, Dinajpur. The stone chips were tested in the laboratory and the value obtained are given in the following table.

Table 3. Properties of the stone chips

| Sl. No. | Property | value |
|---|---|---|
| 1 | Type | Crushed |
| 2 | Maximum size | 19 mm |
| 3 | Fineness modulus | 7.35 |
| 4 | Specific gravity | 2.50 |
| 5 | Water absorption capacity | 0.903 % |
| 6 | Unit weight (kg/m$^3$) | 1694.15 |

##### 2.1.1.4 Jhama brick chips

For this research, jhama brick chips aggregates were collected from brick field of Dinajpur. According to ASTM C33, the jhama brick chips are sieved and following properties are observed. The jhama brick chips were tested in the laboratory and the value obtained are given in the following table. Figure 2 shows the sample of jhama brick chips used for this research.

Figure 2. Sample of jhama brick chips

Table 4. Properties of jhama brick

| Sl. No. | Property | Value |
|---|---|---|
| 1 | Fineness modulus | 7.80 |
| 2 | Specific gravity | 1.52 |
| 3 | Water absorption capacity | 6.325 % |
| 4 | Unit weight (kg/m3) | 804.5 |

### 2.2 Testing system and manufactured specimen

#### 2.2.1 Mix ratio

In this research, for preparing C-35 concrete the mix design was done by using the ACI 211 Mix Design Method. The various materials required per m$^3$ of concrete has been shown in the following table.

Table 5. Material required per m$^3$ of C-35 grade concrete

| Sl. No. | Material | Proportion by Weight | Weight(Kg) kg/m$^3$ |
|---|---|---|---|
| **1** | Cement | 1 | 418 |
| **2** | Fine aggregate | 1.7 | 713 |
| **3** | Coarse aggregate | 2.5 | 1033 |
| **4** | Water/Cement | 0.49 | 201 |

#### 2.2.2 Preparation and casting of concrete specimen

Cylinders of size 100 mm × 200 mm were prepared for this research. The compressive strength of concrete was determined at the age of 3, 7 and 28 days respectively and unit weight for the same concrete at 28 days. In this research, 63 numbers of 100 mm x 200 mm cylindrical molds were prepared.

#### 2.2.3 Curing of concrete specimen

About after twenty-four hours, the cylindrical molds were casted, demolded and transferred into the water container for curing. In this research, normal tap water in fresh condition was used. Curing was done for 3, 7 and 28 days in compliance with ASTM C 31.

#### 2.2.4 Crushing test of concrete specimen

According to ASTM C 39, the compressive strength for concrete molds were tested after 3-, 7- and 28-days curing using compression testing machine (CTM).

## 3. Results and discussions

### 3.1. Workability test

In this research, according to ASTM C-143, the workability of concrete was determined by performing the concrete slump test. The slump test results obtained from different concrete mix with different percentages of jhama brick chips is given in the following table.

Table 6. The slump value of concrete with different % of coarse aggregate.

| Sl. No. | Percentage of Coarse Aggregate (%) | Slump value (mm) |
|---|---|---|
| **1** | 0 | 93 |
| **2** | 5 | 86 |
| **3** | 10 | 79 |
| **4** | 15 | 73 |
| **5** | 20 | 69 |
| **6** | 25 | 65 |
| **7** | 30 | 57 |

Figure 3. shows the comparison of slump value with different percentages of jhama brick chips.

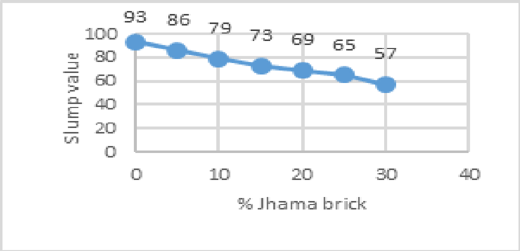


Figure 3. Variation of slump value vs percentage of jhama brick

### 3.2. Compressive strength and unit weight

For each proportion of jhama brick, 3 sets of cylindrical molds were cast, and the molds were tested for compressive strength in Compression Testing Machine (CTM) after 3-, 7- and 28-days curing. In this section, the compression test result is shown in the table-7 below.

Table 7. C-35 Concrete compressive strength for various percentage of jhama bricks.

| Sl. No. | Jhama brick (%) | Compressive strength (3 days) (MPa) | Compressive strength (7 days) (MPa) | Compressive strength (28 days) (MPa) | Unit weight (28 days) (kg/m³) |
|---|---|---|---|---|---|
| 1 | 0 | 27.53 | 34.95 | 37.12 | 2409.3 |
| 2 | 5 | 27.37 | 31.99 | 36.37 | 2379.2 |
| 3 | 10 | 27.33 | 30.29 | 34.23 | 2286.9 |
| 4 | 15 | 25.54 | 27.52 | 33.01 | 2230.2 |
| 5 | 20 | 24.05 | 27.16 | 30.89 | 2197.0 |
| 6 | 25 | 19.26 | 26.17 | 30.50 | 2104.1 |
| 7 | 30 | 17.14 | 20.56 | 21.98 | 2094.9 |

Figure 4 shows the comparison of compressive strength of concrete with different percentages of jhama brick chips.

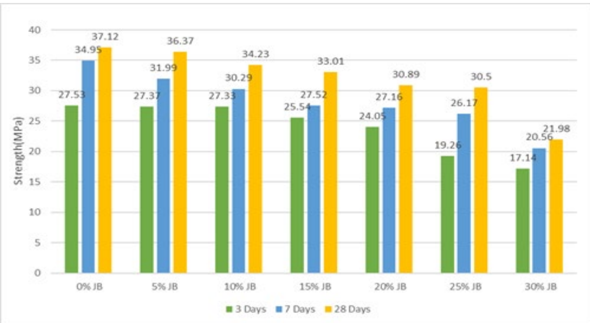


Figure 4. The comparison of compressive strength of concrete at 3, 7, and 28-days with different percentages of jhama brick chips.

Figure 5 shows the comparison of unit weight with different percentages of jhama brick chips

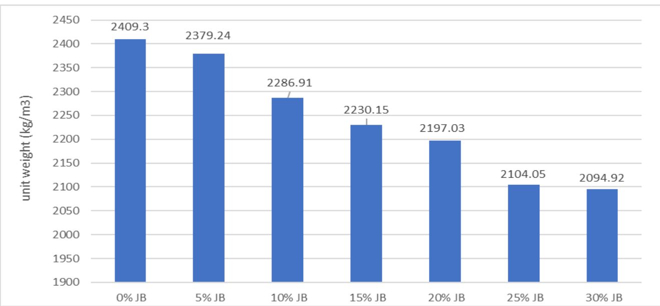


Figure 5. The comparison of unit weight with different percentage of jhama brick chips

### 3.3. Cost comparison

The cost required for per cubic meter of concrete with different percentages of jhama brick chips and the variation of cost with percent JB is given in table 08 below.

Table 8. Cost comparison between coarse aggregate (stone chips) and jhama brick chips

| Percent jhama brick (%) | Amount of CA for 1 m3 concrete (kg) | Amount of JB for 1 m3 Concrete(kg) | Cost of coarse aggregate(BDT) | Cost of jhama brick chips(BDT) | Total cost(BDT) |
|---|---|---|---|---|---|
| 0 | 1033 | 0 | 6198 | 0 | 6198 |
| 5 | 981.35 | 51.65 | 5888 | 115 | 6003 |
| 10 | 929.70 | 103.3 | 5578 | 230 | 5808 |
| 15 | 878.05 | 154.95 | 5268 | 344 | 5612 |
| 20 | 826.40 | 206.6 | 4958 | 459 | 5417 |
| 25 | 774.75 | 258.25 | 4649 | 574 | 5223 |
| 30 | 723.10 | 309.9 | 4339 | 688 | 5027 |

Figure 6. shows the comparison of total cost with different percentages of jhama brick chips.

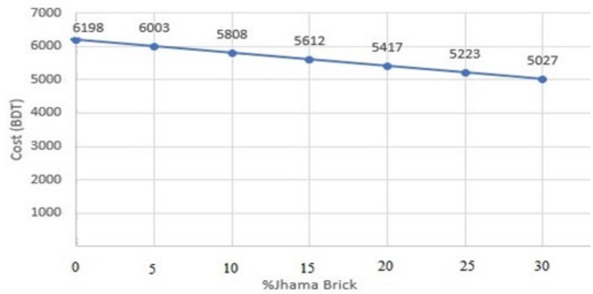


Figure 6. Variation of total cost with percent jhama brick.

### 4. Conclusion

Based on the laboratory test results obtained during the experimental investigation, it can be concluded that an SLWC of 35 MPa can be produced by using lightweight aggregate. The conclusions were made after conducting this research are given below:

- The compressive strength of concrete at 28-days with 0%, 5%, 10%, 15%, 20%, 25%, and 30% were 37.12 MPa, 36.37 MPa, 34.23 MPa, 33.01 MPa, 30.89 MPa, 30.50 MPa, and 21.98 MPa respectively. So, it can be concluded that up to 25% CA can be effectively replaced with jhama brick chips that provide sufficient strength.
- From this research, it can be said that the unit weight of jhama brick chips (804.5 Kg/m³) was much lower than the unit weight of stone chips (1694.2 Kg/m³).
- According to the ASTM C330, the density of structural lightweight concrete should not exceed 1840 kg/m3. The density of the concrete with 0%, 5%, 10%, 15%, 20%, 25%, and 30% jhama brick chips was found 2409.3 kg/m3, 2379.2 kg/m3, 2286.9 kg/m3, 2230.2 kg/m3, 2197.0 kg/m3, 2104.1 kg/m3, and 2094.9 kg/m3 respectively. So, it can be concluded that 25-30% jhama brick chips will be fulfilled its requirement.

## Nomenclature

C-35 : It means the compressive strength of concrete is 35 MPa
CTM : Compression Testing Machine
BDT : Bangladesh Taka

## Declaration of Conflict of Interests

All authors of this article declare that they have no conflicts of interest.

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