COMPRESSION STUDY BEHAVIOUR OF PLASTIC STRIP REINFORCED BOTTOM ASH BASED MATERIAL

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ABSTRACT: In India, thermal power plant produces enormous quantity of bottom ash as a by-product. The utilization of bottom ash in geotechnical engineering applications can solve its disposal problem in environmental friendly manner. There has been a steady increase in the use of plastic bottled drinking water over the last few decades resulting in an astonishing rise of plastic waste in the municipal solid waste across many cities in India. Recycling of this plastic waste has become one of the major challenges in India. In the present study, an attempt has been made for proper utilization of bottom ash as a replacement of conventional materials and also provides an approach for the use of strips cut from used and waste plastic water bottles as reinforcement material in bottom ash. In this direction, series of compression tests carried out on bottom ash based material reinforced with plastic strips cut from used and wasted plastic bottles, EPS beads and ordinary Portland cement as a binder. The mix ratios used in the experimental study was 0.2 %, 0.6 % and 1.0 %. The plastic strips were used in two different aspect ratios 0.1 and 0.2 with different mix proportions 1 %, 2 % and 3 %. The cement to bottom ash ratio was considered as 10 %. The compressive strength was evaluated for 7, 14 and 28 days of curing period. The effect of mix ratio, aspect ratio, percentage of plastic strips and curing period on the bottom ash based material compressive strength, stress-strain behaviour, density and initial tangent modulus were studied and results are incorporated in the paper. The result indicates that, the compressive strength of the material increased with increasing aspect ratio, plastic strip percentage and curing periods. Higher compressive strength was observed when plastic strip percentage was 3 %. Nonlinear stress-strain relation was observed between compressive stress and axial strain. For each plastic strip percentage, aspect ratio 0.2 has shown higher compressive strength value when compared with aspect ratio 0.1. For a particular mix ratio value the density of developed material increased with increasing plastic strip percentage values and decreased with increasing mix ratio values. The initial tangent modulus of the material decreased with increasing mix ratio values.

KEYWORDS: bottom ash, plastic waste, mix ratio, aspect ratio, compressive strength

1 INTRODUCTION

The demand for construction materials increases exponentially due to huge rise in construction activities all over the world. Hence, for sustainable development worldwide new solutions need to be obtained regarding high consumption of conventional material, high production of industrial wastes and corresponding environmental pollution. Coal ashes are one of the alternative materials that have been given a substantial guarantee as a construction material.

In India, over 70 % of electricity generated is by combustion of fossil fuels, out of which nearly 61 % is produced by coal-fired plants [1]. Bottom ash exhibits high shear strength and low compressibility. These engineering properties make bottom ash an ideal material in civil engineering applications [2].

There has been a steady increase in the use of plastic products over the last few decades resulting in a proportionate rise in plastic waste in major cities of India. It is reported that the estimated production of plastic in India was 8 million tons in the year 2008 [3].

EPS beads are colourless and consists polystyrene and dissolved pentane. It has closed cell structure which prevents absorption of water in it. EPS beads can be used as lightweight fill material in construction of embankments, abutments and backfilling of retaining walls [4].

The current study focuses on the compressive strength behavior of plastic strips cut from the used and wasted plastic water bottles and EPS beads reinforced geomaterial using bottom ash and ordinary Portland cement as binding material. The effect of different mix ratios, plastic strip percentages and curing periods on compressive strength, stress-strain behaviour, density and initial tangent modulus of the geomaterial was studied and the results are incorporated in the paper.

2 MATERIALS

Waste plastic bottle strips obtained by manually cutting used and wasted plastic water bottles with the help of scissors in various aspect ratio of 0.1 (2*20 mm) and 0.2 (4*20 mm) as shown in Figure 1. Aspect ratio (AR)
Compressive Strength Behaviour of Plastic Strip Reinforced Bottom Ash Based Material

is the ratio between width and length of the plastic strip. The density of the EPS beads used in the present study are 22 kg/m³ and they are spherical in shape. The physical properties of bottom ash used in the present study are given in Table 1. Ordinary Portland cement of 43 grade was used as binding material.

Table 1. Physical Properties of Bottom Ash

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>1.91</td>
</tr>
<tr>
<td>Maximum dry unit weight (γ_{dmax}) (KN/m³)</td>
<td>13.7</td>
</tr>
<tr>
<td>Optimum moisture content (OMC) (%)</td>
<td>30</td>
</tr>
<tr>
<td>Coefficient of uniformity</td>
<td>3.64</td>
</tr>
<tr>
<td>Coefficient of curvature</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Fig. 1 Photograph of plastic strips cut from used and wasted plastic water bottles
(a) AR = 0.1 (2×20 mm) (b) AR = 0.2 (4×20 mm)

**3 EXPERIMENTAL PROGRAM**

**3.1 Mix Ratios and Preparation of Specimen**

The definition of mix ratio is expressed as ratio between weight of EPS beads and bottom ash. The mix ratios are expressed in terms of percentages in the present study. Previous research works carried out by [5], [6], [7] and [8] are the basis for mix ratio calculation and preparation of specimen. The mix ratios used in the present study were 0.2 %, 0.6 % and 1.0 %. W_{BA}, the dry weight of the bottom ash was determined by multiplying maximum dry unit weight of bottom ash (γ_{dmax}) by volume of dry bottom ash (V_{BA}). Volume of dry bottom ash is calculated by formula V_{BA} = V - V_b - V_{ps}, where V is total volume of specimen (197 cc), V_b is volume of EPS beads and V_{ps} is the volume of used and wasted plastic water bottles strips. The formula W_{BA} = ρ_b × V_b gives weight of beads, where ρ_b is density of EPS beads. V_b was considered as 20 cc and V_{ps} was considered as 20 cc in order to achieve the weight of EPS beads required for initial mix ratio value of 0.2 %. Plastic strips cut from used and wasted plastic water bottles were added with different percentages 1 %, 2 % and 3 % with respect to weight of bottom ash. Two different aspect ratios 0.1 and 0.2 were used in the experimental program. Weight of cement to bottom ash ratio (C/BA) was taken as constant 10 %. The quantity of water to be added for the preparation of specimen was calculated by multiplying optimum moisture content of bottom ash with weight of dry bottom ash that is V_w = W_{BA} × OMC. In the same manner, the remaining mix ratios and weight of samples were calculated. The various mix ratios used in the experimental program is given in Table 2.

Table 2. Different Mix Ratios Used to Prepare Geomatral

<table>
<thead>
<tr>
<th>Mix Ratios (%)</th>
<th>Plastic Strips (PS/BA) (%)</th>
<th>Cement (C/BA) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>1, 2, 3</td>
<td>10</td>
</tr>
<tr>
<td>0.6</td>
<td>1, 2, 3</td>
<td>10</td>
</tr>
<tr>
<td>1.0</td>
<td>1, 2, 3</td>
<td>10</td>
</tr>
</tbody>
</table>

For accurate measurement of all ingredients an electronic weighing balance was used. Cement and bottom ash were blended thoroughly and made into uniform mass. A compound mixture was formed by adding water slowly and bottom ash cement mixture was mixed into the mixture. Then the plastic strips and EPS beads were added and mixed till they were evenly distributed. After that, with the help of trowel the mixture was cast into steel cylindrical moulds for setting at ambient conditions. The specimens were then kept in steel cylindrical mould for initial setting time of 24 hours. After setting, all the specimens were removed from the mould and then kept in water tank for curing. The experimental program had curing periods 7, 14, 28 days.

**3.2 Test Procedure**

After curing and air drying the weight of each specimen was measured by using an electronic weighing balance. These measurements were used to calculate the density of the specimen by dividing weight by volume. A compression test was done on the specimens to measure their compressive strength. The test involved a compressive testing machine accommodating the specimen having diameter 50 mm and height 100 mm at a constant strain rate of 0.12 mm/min. A load cell was used to measure the compressive load while the subsequent deformation was measured by Linear Variable Differential Transducer (LVDT). Both of these were connected to data logger and calibrated before testing. For each mix ratio with each aspect ratio and for particular plastic strip percentage two specimens were prepared and tested.

**4 RESULTS AND DISCUSSION**

**4.1 Compressive Strength**

Compressive strength of the prepared geomaterial was significantly influenced by the plastic strip percentages, mix ratio values and aspect ratio. Compressive strength was considered as peak compressive stress value. The variation of compressive strength with respect to mix ratio values for aspect ratio 0.2 is shown in Fig. 2. Linear relationship was obtained between compressive strength and mix ratio. The compressive strength values from mix ratio of 0.2 % starts converging towards mix
ratio of 1.0 %. The compressive strength values of prepared geomaterial were in the range of 38 to 294 kPa for both aspect ratios. Similar trend was observed even for aspect ratio of 0.1.

4.3 Density
The density was calculated for the geomaterial prepared with different mix ratios. Fig. 4 shows the effect of mix ratios on density of geomaterial for aspect ratio 0.1 when PS/BA was 3%. The density of the newly developed geomaterial decreased with increasing mix ratio values. Similar trend was even observed for all the PS/BA values and for aspect ratio of 0.2. Fig. 5 shows the variation in the density values with respect to PS/BA percentages. The density of geomaterial found to be increased with increasing values of PS/BA percentages. For each mix ratio value, aspect ratio was 0.2 and PS/BA of 3 % was shown higher density values of geomaterial. The density values for all mix ratios, aspect ratios and PS/BA values are in range of 500 to 800 kg/m³. The density values achieved in the present study is lower than that of conventional fill material which lies between 1700 and 1900 kg/m³ as reported by [5].

4.4 Initial Tangent Modulus
The initial tangent modulus was determined as the slope of the tangent line to the origin of the compressive stress and axial strain curve. Fig. 6 shows the correlation between compressive strength and initial tangent modulus of geomaterial for all PS/BA ratios and aspect ratios. The $E_i$ values ranges from 5 to 42 MPa.
The correlation between initial tangent modulus \(E_i\) and compressive strength \(\sigma\) can be expressed as

\[
E_i = 1.3429 \sigma^{0.8659}
\]

(1)

Where, \(E_i\) is in MPa and \(\sigma\) is in kPa.

Fig. 6 Correlation between secant modulus and compressive strength of the geomaterial specimens

4.5 Failure patterns

Under the action of axial compressive load the failure patterns of bottom ash reinforced with EPS beads and plastic strips were observed. All the specimens were failed in axial strain range of 0.65 to 1.8 %. Before failure a combination of both vertical and diagonal cracks were occurred in the specimens. The failure pattern of EPS beads and plastic strips reinforced geomaterial is shown in Fig. 7.

Fig. 7 Failure patterns of EPS beads and plastic strips reinforced geomaterial

5 CONCLUSIONS

A laboratory experimental study was performed on reinforced bottom ash based geomaterial. From the study following conclusions were drawn.

The density values for all mix ratios, aspect ratios and PS/BA values are in range of 500 to 800 kg/m³. The compressive strength values of prepared geomaterial were in the range of 38 to 294 kPa for both aspect ratios. The stiffness of geomaterial was increased with increasing PS/BA values for particular mix ratio and curing period. The initial tangent modulus \(E_i\) values ranges from 5 to 42 MPa. The prepared geomaterial using bottom ash is light weight and having relatively good compressive strength can be used in various geotechnical engineering applications in a way to minimize the waste disposed in open lands and in the direction of sustainable development.

References


