Use of Bottom Ash in Replacement of River Sand in Making Cement Mortar

R.M.I.E. Piyarathne¹ and K.M.L.A. Udamulla²
¹Department of Civil and Environmental Engineering
Faculty of Science and Engineering
University of Wolverhampton
Wolverhampton
UNITED KINGDOM
²Department of Civil Engineering
Faculty of Engineering Technology
The Open University of Sri Lanka
Nawala
SRI LANKA
E-mail: ireshaerangani@gmail.com

Abstract: Disposal of bottom ash that is generated in huge quantities from thermoelectric power plants is a major problem globally in general and Sri Lanka in particular. Several approaches exist to augment its beneficial use. An attempt has been made to utilize this material in producing cement mortar. This paper presents an experimental investigation carried out on the potential for using bottom ash, i.e. the coarser material, which falls into furnace bottom in modern large thermal power plants and constitute about 20% of total ash content of the coal fed in to the boilers, as a partial substitute material for fine aggregate (sand) in the production of cement mortar for rendering and plastering mortar. The main purpose of this paper is to study the feasibility of using the Incinerator bottom ash as fine aggregate to replace natural fine aggregate in the production of cement mortar. The experiment uses Incinerator bottom ash fine aggregates, which passes through 2.36mm sieve, and natural sand which passes through 2.36mm. Sand replacement ranged between 0 and 40 % in steps of 10% by volume while water to cement ratio is kept constant at 1.4 : 1. The study revealed 30% replacement of sand in mortar has obtained the highest compressive strength. It was also observed that with increment of the bottom ash replacement, workability of fresh mortar decreases. The results revealed that with the increase of bottom ash percentage the density of fresh as well as hardened mortar decreases while water absorption of hardened mortar increases. Considering the fresh and hardened state parameters 30% of bottom ash replacement gives the best performance in designation (iii).

Keywords: Masonry Mortar, Bottom Ash, Workability, Compressive Strength, Water Absorption, Dry Density

1. INTRODUCTION

Mortar is a material used to bind blocks, bricks, and stones together while filling the gaps between them and also for bedding and plastering during building construction. Generally mortar consists of sand, water and a binder such as cement or lime. As the country Sri Lanka continues to develop and urbanize at a rapid rate, the need for cement mortar becomes an essential part of town and city development and expansion. The different types of waste materials are directly dumped to the environment and this causes environmental pollution. There is an urgent need to find ways to handle such waste owing to growing environmental concerns. Therefore there is a growing need to reuse and recycle the waste for different construction purposes so that this will reduce the pressure on natural resources as well. The use of waste material in producing cement mortar could be a viable solution for the recovery and recycling of waste materials.

Out of various types of waste materials in Sri Lanka, Bottom Ash (BA – coarse, granular material collected from the bottom of a coal furnace) is a novel waste material disposed from Norochcholai power plant. Bottom ash is lighter and more brittle and is dark grey material with a grain size similar to that of sand (Bajare et al., 2013). It is composed of silica, alumina, and iron with small amounts of
calcium, magnesium, and sulphate. Grain size typically ranges from fine sand to gravel in size (Kumar et al., 2014).

Norochcholai coal power station is the largest electricity generating power plant in Sri Lanka compared to the other power plants. As coal power plant is the most profitable way to meet the increasing demand of electricity in the country, wastage of the production “coal ash” also has been increased. In the Norochcholai power station, 2500 MT of coal is burnt per day when plant running at 300 MW and it produces 2500 MT of fly ash and bottom ash at a rate of 25 MT per day (Ranjan & Nanayakkara, 2013). Currently Sri Lanka is faced with a major problem in disposing this bottom ash as a result of an installation of coal power plant in Norachcholai area.

In this situation, the study was aimed at finding the feasibility of using bottom ash as a partial substitute to fine aggregate in producing cement mortar by considering the effects of the physical and mechanical properties of cement mortar so produced. Furthermore, rapid extraction of sand have caused many environmental issues like erosion of river beds, losing water retaining strata, deepening of river beds, loss of vegetation on the river bank and due to lowering of the water table aquatic life as well as the agriculture industry get disturbed. The Demand for natural sand for construction purposes has increased significantly in Sri Lanka in recent years. On the other hand the price of a cube of sand is also escalating. Therefore this study was aimed to identify whether bottom ash could be used as an alternative material to replace sand in masonry mortar to help reduce the usage of depleting resources by reducing the use of sand, and minimizing environmental hazards through waste disposal by making use of bottom ash.

2. METHODOLOGY

2.1 Materials

For the preparation of mortar mix cement, sand, water and bottom ash were used.

2.1.1. Cement

Ordinary Portland Cement (OPC) as specified in Sri Lankan Standard 107 (2008) & ASTM C150 was used.

2.1.2. Aggregates

Sand and Bottom ash was used as fine aggregate. The clean, sharp river sand that was free of clay, loam, dirt and any organic or chemical matter was used. Bottom ash samples are collected from Lakvijaya Power Station. Particle sizes for mortar were tested in accordance with BS EN – 933 – 1997. Particles below 2.36 mm was used for the mortar preparation. Specific gravity of sand and bottom ash is given in table 1 and the particle distribution of the material is represented in the figure 1.

![Figure 1 - Particle size distribution curve](image-url)


2.2 Methods

2.2.1. Sample Preparation

Sample preparation of mortar was done accordance with BS 5628 – 3 – 1985 which was adopted by Specification for Rendering and plastering mortar given in BS EN 998 – 1 – 2003. Material composition for the selected mortar designation is given in the table 2. After several trials it was identified that provided water content in the BS 5628 – 3 – 1985 was not sufficient to achieve the target flow given in BS EN 1051 – 2 – 1999 and a suitable water content was identified. The mortar designation, cement: sand ratio and water: cement ratio used were given in table 2.

<table>
<thead>
<tr>
<th>Sample Name</th>
<th>Sand ( % )</th>
<th>Bottom ash ( % )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>D</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>E</td>
<td>60</td>
<td>40</td>
</tr>
</tbody>
</table>

Volumetrically sand was partially replaced with bottom ash and control mix was made in accordance with exact cement: sand ratio of mortar designation. Partial replacement of bottom ash to that of fine aggregate (sand) was according to the proportions listed in Table 3.

2.2.2. Test Methods

Workability, Compressive strength, Water absorption, Fresh and Dry bulk density parameters of mortar were tested according to following specifications given in the table 4.
<table>
<thead>
<tr>
<th>Properties Mortar</th>
<th>Testing specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh state</td>
<td></td>
</tr>
<tr>
<td>Bulk sampling</td>
<td>BS EN 1051 – 2 – 1999 [Bulk sampling of mortars and preparation of test mortar]</td>
</tr>
<tr>
<td>Fluidity</td>
<td>BS EN 1051 – 3 – 1999 [Determination of consistence of fresh mortar (by flow table test)]</td>
</tr>
<tr>
<td>Bulk density</td>
<td>BS EN 1051 – 6 – 1999 [Determination of bulk density of fresh mortar]</td>
</tr>
<tr>
<td>Harden state</td>
<td></td>
</tr>
<tr>
<td>Dry bulk density</td>
<td>BS EN 1051 – 10 – 1999 [Determination of dry bulk of density of hardened mortar]</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>BS EN 1051 – 11 – 1999 [Determination of Compressive and flexural strength mortar]</td>
</tr>
<tr>
<td>Water absorption</td>
<td>BS EN 1051 – 18 – 1999 [Determination of water absorption coefficient due to capillary action of hardened mortar]</td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSION

3.1 Workability of Fresh Mortar

Consistency of fresh mortar was measured by flow table test and the results of flow values according to percentages of partial replacement of bottom ash are given in fig 2. The results of designation (iii) show that with increment of the bottom ash percentage the workability decreases. The control mix sample where the content of bottom ash particles were 0 % satisfied the target flow value in accordance with BS EN 1015 – 02 – 1999. In all other compositions samples could not achieve the target flow.

3.2 Compressive Strength

Test results of compressive strength test are given in figure 3. According to the results obtained, highest compressive strength was achieved at 30% of bottom ash replacement. Control sample where bottom ash replacement 0% gives a comparatively low compressive strength than bottom ash replaced samples. With the increment of bottom ash replacement, compressive strength gradually increases and then suddenly drops at 40% replacement. 30% bottom ash replaced samples which attained the optimum strength have achieved 150% of strength in comparison to the control sample. This may be due to the rough texture and irregular shape of particles of bottom ash which play significant role in increasing the inter particle friction, due the presence of cavities. It can be due to the extra fineness of bottom ash as the replacement level of fine aggregates is increased. Thus, increase in the specific surface due to increased fineness and a greater amount of water needed for the mix.
ingredients to get closer packing, results in decrease in workability of mix while increasing the compressive strength.

### 3.3 Density of Fresh and Hardened Mortar

Figure 4 shows the density variation of fresh and hardened mortar. Bulk density of fresh mortar is an important parameter as it represents the ease of use. If a mortar is ‘harsh’, that is of poor workability and high density and will result in a low craftsmanship. Picking up and spreading will be slower and difficulty will be experienced in plastering. The obtained result for the designations indicates that with the increase in replacement of bottom ash in mortar reduces the bulk density. That is mainly due to the low specific gravity. Due to the low specific gravity all the bottom ash replaced compositions are comparatively light weight than the control composition. This variation of the parameter makes easy to work with mortar. According to the results obtained dry bulk density and the fresh bulk density have considerable reduction. This may be due to the volumetric changes of mortar as the weight of the sample is constant at both stages.

![Figure 3 Compressive strength of hardened mortar](image)

![Figure 4 Density variation of fresh and hardened mortar](image)
3.4 Water Absorption

Water absorption of mortar is shown in figure 5. Water absorption of mortar was checked after 28 days of casting. It is evident from the figure 5 that the increment of the bottom ash content gradually increases the water absorption of mortar increases. It can also be seen that there is only a slight difference in water absorption between the control sample and the bottom ash replacements of 10%, 20% and 30%.

4. CONCLUSIONS

Bottom ash is a fine graded aggregate which has a low specific gravity. The workability of Bottom ash replaced mortar reduces with the increase in bottom ash content due to the irregular shape of bottom ash which cause high water absorption in the material. The density of Bottom ash replaced mortar decreases with the increase in bottom ash content due to the low specific gravity of bottom ash as compared to fine aggregates. Compressive strength of sand replaced bottom ash mortar is higher than control specimens at all the ages. Water absorption is more in bottom ash replaced mortar compared to conventional mortar. Results of dry bulk density shows that, this type of light weight mortar is useful for high rise building structure due to low weight of mortar in dry condition. Considering all the fresh and hardened state parameters 30% of bottom ash replacement gives the best performance in designation (iii).

ACKNOWLEDGMENTS

Authors wish to express their sincere gratitude to Director. Mrs. S. Muthurathne and Officers. Mrs. Savitha Ranjan and Mr. Yohan Dissanayaka of National Building Research Organization for their guidance and support in carrying out the laboratory experiments for this study. Thanks and gratitude is also extended to Mr. Bamunusinghe for providing the material bottom ash from Norochcholai power plant.

REFERENCES

