Use of Bottom Ash as Fine Aggregate in Manufacturing Concrete Paving Blocks

N.G.N. Erandi\textsuperscript{1}, W.C. Sakunthala\textsuperscript{1} and K.M.L.A. Udamulla\textsuperscript{1}
\textsuperscript{1}Department of Civil Engineering
The Open University of Sri Lanka
Nawala, Nugegoda
SRI LANKA
E-mail: lakshika0807@hotmail.com

Abstract: The 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. This paper presents the results of experimental investigations carried out to investigate the potential of using bottom ash as a partial substitute material for fine aggregate (sand) in the production of concrete paving blocks for road paving. Paving blocks were casted by replacing bottom ash with sand in percentages of 25, 50, 75, and 100 as well as one control mixed proportion. The physical and mechanical properties (compressive strength, unpolished slip resistance value, water absorption and density) of paving blocks with fine aggregate (sand) replaced by various percentages of bottom ash were evaluated. The test results show that concrete paving blocks with 25% of bottom ash replacement by weight of sand achieved the standard values of properties as prescribed by the Sri Lankan Standards 1425 part 1:2011, specification for concrete paving blocks part 1 requirements.

Keywords: Concrete Paving Blocks (CPB), Bottom Ash, Compressive Strength, Water absorption Density, Unpolished Slip Resistance

1 INTRODUCTION

Out of various types of waste materials in Sri Lanka, Bottom Ash (BA – coarse, granular material collected from the bottom of a coal furnace (American Coal Ash Association Educational Foundation 2008)) is a novel waste material disposed from Norochcholai power plant. At this power plant a large amount of bottom ash is generated and this is estimated to be 20% of the total ash production in the combustion. When the power plant runs in full load (300 MW) the total bottom ash production is approximately 2.5 tons per hour (Samira, 2012). It is estimated that 20 tons per day of bottom ash are directly dumped to the yard, without being used for any purpose. Stocking of this waste is inadvisable as it leads to environmental pollution.

In this situation, the study was aimed at finding the feasibility of using bottom ash as a partial substitute to fine aggregate in manufacturing concrete paving blocks (CPB) for Sri Lankan roads and its effects of on the physical and mechanical properties of concrete paving blocks so produced. The results are compared with standard specification of Sri Lankan Standards (SLS) specification for concrete paving blocks Part 1: Requirements. Furthermore, the demand for natural sand for construction purposes has increased significantly in Sri Lanka in recent years. Sand mining is also continuously increasing with the increasing demand for sand and this practice causes several problems such as river bank erosion, water quality deterioration as the water table lowers in some places and sea water intrusion into rivers and groundwater. On the other hand the price of a cube of sand is also increasing. Baskaran and Gopinath, (2011) reports that compressive strengths of sample blocks obtained from local concrete paving block manufacturers have met the criteria meant for Sri Lankan Standards for Concrete Paving Blocks in strength classes 2, 3, 4 roads and none of them were compatible with the compressive strength criterion meant for strength class 1 roads. Accordingly to introduce an alternative material to natural sand such as bottom ash is considered worthwhile. Therefore, this study was undertaken to find out the suitability of bottom ash from thermal power plants as a substitute for the depleting resource sand in the manufacture of concrete paving blocks and as a means of environmentally friendly disposal method besides its suitability as a partial replacement for sand in concrete paving blocks meeting the class 1 road requirement.
2 METHODOLOGY

2.1 Materials

2.1.1 Cement

Ordinary Portland cement (OPC) complying with SLS 107, which belongs to the strength class of 42.5kN was used as the binding material.

2.1.2 Aggregates

Mainly two types of aggregates were used in the production of concrete paving blocks; coarse and fine. Coarse aggregate was crushed stone in nominal size of 20mm with specific gravity of 2.78. Fine aggregates were river sand with specific gravity of 2.78 and bottom ash with 2.08. The figure 1 shows the particle size distribution curve for bottom ash.

![Figure 1 Particle Size Distribution Curve](image)

2.2 Methods

2.2.1 Mixture Composition and Fabrication of Paving Blocks

A series of mixtures which included five mixtures were prepared, with an aggregate-to-cement (A/C) ratio of 3.5 and water-to-cement (W/C) ratio of 0.5. In this series, a total of five series of concrete paving blocks were prepared with bottom ash content of 0%, 25%, 50%, 75% and 100% by replacement ratio of fine aggregate by weight. Hand mixing method was used for concrete mixing and blocks were manually casted in plastic moulds of size 220mm x 110mm x 80mm. The blocks were removed from moulds and cured in a water bath.

2.2.2 Test Methods

The compressive strength, unpolished slip resistance value (USRV) and water absorption were determined according to Sri Lanka Standard Institution (2011), Specification for concrete paving blocks part 02: Test methods. The densities of paving blocks were determined using a water displacement method as per BS 1881 part 114 for hardened concrete (BS, 1881-114, 1983). The compressive strength
of specimens was tested on specimens’ aged 7, 14 and 28 days. The water absorption, dry density and unpolished slip resistance values were determined on the produced blocks aged 28 days. All the final results were presented as an average value of three specimens.

2.2.3 SLS Specifications of Local Concrete Paving Blocks for Road Paving

The specifications pertaining to Sri Lankan standard (SLS) 1425 Part 1: 2011 for concrete paving blocks are as follows:

- Compressive strength: refer Table 1
- Slip/ Skid resistance (USRV) ≥ 55
- Water absorption (%): ≤ 6

Table 1 Minimum strength requirement and block thickness

<table>
<thead>
<tr>
<th>Strength class</th>
<th>Average compressive strength (N/mm$^2$)</th>
<th>Individual compressive strength (N/mm$^2$)</th>
<th>Block thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>40</td>
<td>80,100</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>32</td>
<td>80,100</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>25</td>
<td>80,100</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>12</td>
<td>60</td>
</tr>
</tbody>
</table>

3 RESULTS AND DISCUSSION

3.1 Compressive Strength

The compressive strength values of the concrete paving blocks are presented in Figure 1. The compressive strength of concrete paving blocks is found to decrease with increment of bottom ash replacement on aged 7, 14 and 28 days of samples. Bottom ash has a significant influence on the strength properties of concrete paving blocks. This effect could be due to weaker bonding of bottom ash compared to that of river sand. Although bottom ash is a coarser granular material (American Coal Ash Association Educational Foundation, 2008) as river sand this has a porous structure (U.S. Environmental protection Agency, 2013). Therefore, this textural difference of bottom ash attributes to the weaker bonding of paving blocks made of partial substitution of bottom ash.
3.2 Dry Density

The dry density values of paving blocks are presented in Figure 2. The dry density of specimens was found to decrease with increment of bottom ash replacement. This could be due to the fact that bottom ash has lower density when compared to the other aggregates used in the mixture. In general, the paving blocks produced with bottom ash replacement shows an average 5% decrease in density.

3.3 Water Absorption

The results of water absorption of blocks are presented in Figure 3 with Sri Lankan standard requirement. The highest water absorption value belongs to the specimens with 100% of bottom ash replacement. The blocks made with bottom ash replacement of 25% satisfies the SLS requirement of water absorption.
The water absorption of concrete is naturally related to the nature of pore system within the hardened concrete (Uygunoglu, 2011). Bottom ash consists of porous structure (ACCA Educational foundation, 2008). Hence Water absorption of CPBs gradually increases with increment of bottom ash replacement.

3.4 Unpolished Slip Resistance Value

The results of unpolished slip resistance values of blocks are presented in Figure 4 with Sri Lankan standard requirement. As seen from Figure 4 the unpolished slip resistance values of all the specimens are greater than the SLS requirement.
4 CONCLUSION

According to the Sri Lankan standard 1425 Part 1: 2011 “Specification for concrete paving blocks Part 1: Requirements”, the minimum average compressive strength for strength class 1, 2 and 3 should be 50MPa, 40MPa and 30MPa respectively. By considering the compressive strength results of the series, 75% and 50% of bottom ash replacement mixtures fulfilled the SLS requirement for strength class 2 roads. Further, 100% and 25% of bottom ash mixtures had satisfactory average strength values for strength class 3 and 1 roads respectively. The Unpolished Slip Resistance values of all specimens exceeded value of 55 and satisfied the Sri Lankan standard. The value of water absorption of the specimen which was casted by using 25% of bottom ash was found to be less than 6% and this satisfies the SLS requirement. Hence the mixture which is 25% of bottom ash replacement has accomplished all the required specifications described in the SLS 1425:2011. Therefore the results from this research suggest that bottom ash can be applied as a partial substitute to fine aggregate in the concrete paving block production.

5 ACKNOWLEDGMENTS

Authors wish to express their sincere gratitude, to all academic and non-academic staff of the department of Civil Engineering, the Open University of Sri Lanka for their guidance and support. Thanks and gratitude is also extended to the Director, Research and Development division of Road Development Authority (RDA) for granting permission to carryout laboratory tests as well as providing the relevant details about concrete paving blocks.

6 REFERENCES


