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Performance Evaluation of M35 Grade Concrete Paver Blocks using Coal Bottom Ash as Partial Replacement of Fine Aggregate

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***Abstract*—Concrete is the world's heavily consumed constructional material which is being used for thousands of years. It is manufactured from four main ingredients; cement, water, fine aggregates and coarse aggregates. Concrete paver blocks are unreinforced solid small elements used for surface course of pavements. Holland was the first country introducing the paver blocks as replacement of paver bricks which had become scarce due to the post-war building construction outreach. Concrete industries are manufacturing concrete and supply aggregates and other construction materials. In spite of having many advantages, it has some deficiencies as well. For instance, high usage of natural sand, which is the main raw material used as fine aggregate in the production of concrete, its natural resources are getting depleted gradually. Thus for sustainable development, considerable improvements are required in productivity, energy efficiency and environmental performance. To achieve sustainability, in this study, coal bottom ash, which is a coarse granular material and incombustible by-product from coal burning furnaces is used as a partial replacement for fine aggregate for making concrete paver blocks.**

Keywords*—Concrete paver blocks; Coal bottom ash; Aggregates; Sustainability.

I. INTRODUCTION

Energy is the main backbone of the modern civilization of the world. The prevailing source of energy is the electric power from thermal power plants. India depends primarily on coal for the requirement of power. Over 70% of its electricity generated is by combustion of fossil fuels. Out of which almost 61% is contrived by coal-fired plants, which results in the origination of about 100 tons of ash [1]. The India's current annual production of coal ash is about 100 million tons per year. This ash is of two types; fly ash which is 80 percent and bottom ash as 20 percent [2]. Fly ash is the finer particle ash that rises up with the flue gases. It has pozzolanic properties that reacts with calcium hydroxide, and can be used as a partial replacement for cement. While bottom ash is coarse granular and incombustible by-product, which does not rise but drops in to the bottom of the furnace. Figure 1.3 shows the process in which bottom ash is produced [3]. About thousand million tons of bottom ash is produced every year in India. The disposal of bottom ash is a great challenge to the thermal plant authorities. The problem in disposing off this huge waste material has led the researchers to focus on the alternative use of this waste material. The appearance and particle size of coal bottom ash is similar to that of river sand [4], hence can be selected as a partial replacement of fine aggregate.

II. LITERATURE REVIEW

Aggarwal P. et al; [5], studied the effect of bottom ash as replacement of fine aggregates in concrete at 10%, 20%, 30%, 40% and 50% replacement level. OPC 43 grade cement was used as a binding material. It was observed that the workability decreases with increase in the percentage replacement of bottom ash in concrete.

Hamza A.F et al; [6], studied the nomograph of self-compacting mix incorporating coal bottom ash as partial replacement of fine aggregates at the range (0-30) % with w/c ratios 0.35, 0.40 and 0.45. The fine aggregate used were natural river sand and coal bottom ash collected from one of coal-fired power plant in Malaysia. The coarse aggregate used were sieved through a sieve of 16 mm size and retained on a sieve of 10mm size. Additionally, polymer based super plasticizer with a specific gravity of 1.09 was added to the mix. It was marked that the strength of bottom ash concrete with 10% replacement is higher compared to concrete without bottom ash for all w/c ratios.

Raju R. et al; [4], studied the strength performance of concrete using bottom ash as fine aggregate at 5%, 10%, 15%, 25%, and 30% replacement level and adding micro silica by 4%, 6%, 8% 10%, 12% and 15% Ordinary Portland Cement (OPC) 53 grade with consistency as 35% was used. Manufactured sand as fine aggregate, and crushed stone of 20 mm maximum nominal size as coarse aggregate was used for the study. It was observed that the strength reduced marginally on the inclusion of bottom ash in concrete. It was observed that the water absorption of bottom ash concrete at 28 days curing age increases approximately linearly with the increase in replacement level of sand and it decreased when microsilica was added to the optimum mix.

Anoni et al; [7], studied the use of bottom ash for replacing fine aggregate in concrete paving blocks. In the phase I of the study, the mixture of cement and bottom ash passing sieves of 2 and 5 mm were done with ratios of 1:3, 1:4, and 1:5. Tests conducted were for compressive strength at 7, 14 and 28 days. It was concluded that paving made with bottom ash passing a 5 mm sieve has a compressive strength better than that of the 2 mm ash, due to less surface area with larger particle size. It was concluded that at 28 days, the paving made with 5 mm bottom ash size has a lower water absorption than the one with 2 mm size. It was Further observed that for abrasion test, all mixtures performed well under the standard specification of grade A.

Santos C.R. et al; [8], investigated the mineral processing and characterization of coal waste to be used as fine aggregate.

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Fine aggregate was replaced at 25%, 50%, 75% and 100% by bottom ash. For each level of substitution, the water cement ratio was reestablished to provide the same consistency of concrete. The blocks were molded in the shape of "unipaver" with the following dimensions: 22.5cm length, 12.0 cm width, and 8cm height. It was observed that 25% and 50% replacement presents satisfactory results in terms of compression resistance. It was further concluded that concrete blocks produced with substitution levels of 25% and 50% at 28 days, statistically present behavior similar to the reference blocks (0% replacements) in terms of water absorption and abrasion resistance test.

III. RESULTS AND DISCUSSIONS

The results of precast cement concrete interlocking paver blocks using coal bottom ash as 0%, 15%, 30%, 45% and 60% replacement of fine aggregate are reported in this chapter. The results include the workability test such as compaction factor, strength properties tests like compressive strength and flexural strength, and durability properties like water absorption and abrasion resistance. Note that 3500, 3515, 3530, 3545 and 3560 show 0%, 15%, 30%, 45% and 60% replacement of fine aggregate respectively.

The compaction factor test as per IS 5515:1983 at fresh state was observed as the concrete paver blocks are made up of zero slump concrete. The results of compaction factor test with and without bottom ash has been reported in Figure 1.

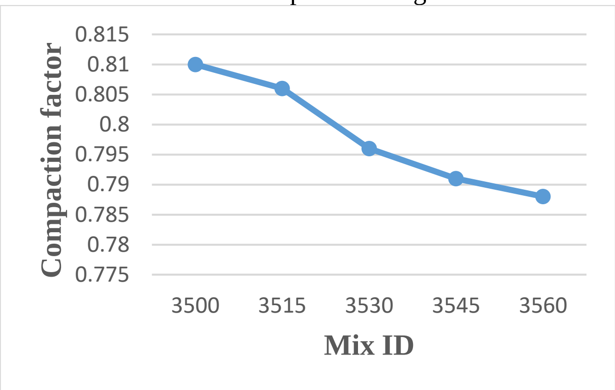

Figure 1: Results of compaction factor test

The results of compressive strength of paver blocks with and without CBA has been discussed as under with varying ages of 7 days, 28 days and 56 days. From the above results it is seen that the compressive strength of paver blocks with age increases for all CBA replacement level. The compressive strength at 7 days is found to be (80-90) % of compressive strength at 28 days. And the compressive strength at 28 days is found to be (94-99) % of compressive strength at 56 days. As the substitution of CBA by weight of sand increases the compressive strength decreases. But up to 30% replacement, it complies with the requirements of IS code. Hence 30% substitution level of CBA is the optimum. However, it fulfills the minimum requirement of the 35 MPa at 45% replacement level at 28 days also.

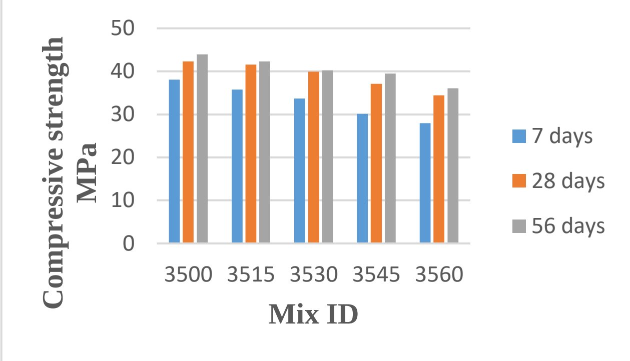

Figure 2: Variation of compressive strength with age for various mixes

The results of flexural strength of paver blocks with and without CBA has been discussed as under with varying ages of 7 days, 28 days and 56 days. From the above results it is seen that the flexural strength of paver blocks with age increases for all CBA replacement. The flexural strength at 7 days is found to be (85-95) % of flexural strength at 28 days. And the flexural strength at 28 days is found to be (92-98) % of flexural strength at 56 days. As the substitution of CBA by weight of sand increases the flexural strength decreases. But up to 45% replacement, it complies with the requirements of IS code. Hence 45% substitution level of CBA is the optimum.

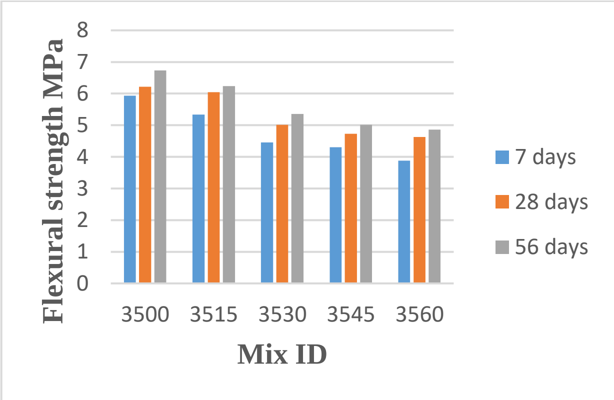

Figure 3: Variation of flexural strength with age for various mixes

At all the levels of replacement of sand by CBA, water absorption increases with respect to reference mix. The individual water absorption of the specimens is within the code limit of more than 7%. And average water absorption at 30% replacement level is 5.81% which is less than 6%, hence is optimum from water absorption point of view.

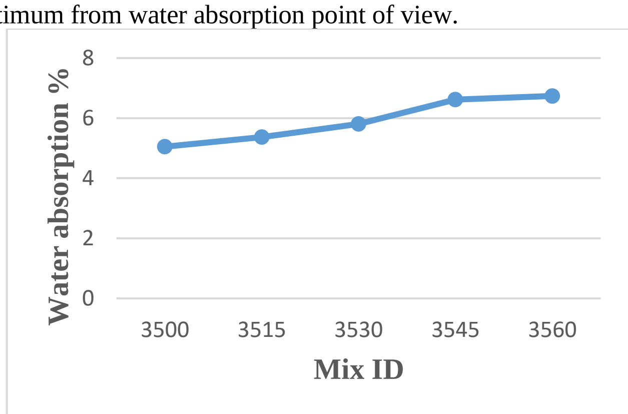

Figure 4: Results of water absorption test

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The 28 days' results show that as the percentage of bottom ash replacement increases, the abrasion value also increases as compared to reference mix. At 45% replacement level the result is 12.6 cm3, which is less than maximum value of 15 cm3 as prescribed by US code C 936 – 01. Thus 45% replacement level is optimum from abrasion resistance point of view.

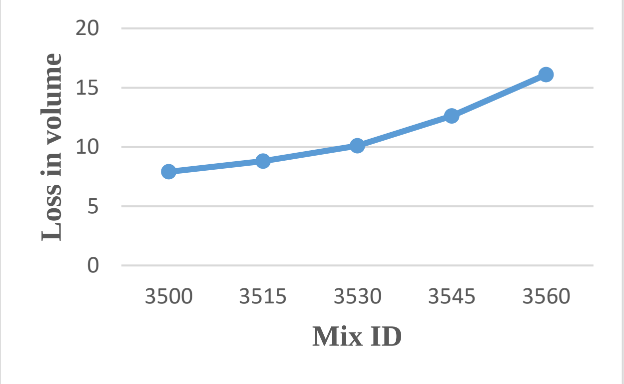

Figure 5: Loss in volume after 16 cycles of abrasion resistance test

IV. CONCLUSION

Taking all properties in to account, it is possible to utilize up to 30% replacement of fine aggregate by bottom ash in manufacturing of concrete paver blocks. In which, almost 4% in cost of manufactured paver blocks are saved. Since, CBA is an industrial waste which is produced in large quantity and at the same time is difficult to dispose it off, so utilizing it further solves this issue, and conserves the natural resources of fine aggregate.

ACKNOWLEDGMENT

Some of the suggestions for further studies regarding the performance of concrete paver blocks by utilizing industrial by-products to be used for road surfacing are given below.

- ✓ The effect of different water cement ratios on bottom ash based paver blocks.
- ✓ Use of other industrial by-products like foundry sand.
- ✓ Study of higher grades of concrete for manufacturing paver blocks.
- ✓ Evaluation of other properties of paver blocks like freeze-thaw resistance test.
- ✓ Study of other fields of applications.
- ✓ Study of other thickness of bottom ash based paver blocks.

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