Effect of Lignite By-products in Plastic Shrinkage Property of Concrete

P. Priyadharshini, G. Mohan Ganesh, A.S. Santhi

Abstract— The reduction in moisture of fresh concrete results in plastic shrinkage due to tensile stress induced by capillary pressure. When the tensile strength signs beyond the capacity of concrete, it cracks and this effect in early stage of concrete is termed as plastic shrinkage of concrete. This becomes a serious issue for large surface area members like slabs. The shrinkage of concrete under restrained conditions during early stages can be characterized by experiments. The present study was aimed at studying the plastic shrinkage property of fly ash aggregate concrete incorporated with bottom ash as fine aggregate. Concrete mix with combination of fly ash aggregate with 20% and 40% replacement of fine aggregate with bottom ash has been studied. The 20% replacement of bottom ash gives good results and higher percentages like 40% of bottom ash together with fly ash aggregate makes better combination to avoid plastic shrinkage of concrete. Higher percentage incorporation of bottom ash shows mild surface cracks in concrete due to plastic shrinkage.

Index Terms— Artificial aggregates, Bottom ash, Fly ash, Plastic shrinkage, Restrained shrinkage

1 INTRODUCTION

PLASTIC shrinkage cracks are due to the rapid loss of water when they are still in plastic state. The crack appears when the evaporation rate exceeds the rate of water bleeding to compensate it. The crack occurs when the high evaporation rate causes the concrete surface to dry out before it set. These cracks rarely affect the strength and durability of concrete and can be avoided by proper measures before placing the concrete.

Any factor that delays setting of concrete will increase the chances of plastic shrinkage cracking. Other factors are high cementitious materials, high fines content, reduced water content, high concrete temperature and thinner sections.

Here in this study, the fine and coarse aggregate of concrete are replaced with bottom ash and fly ash aggregates. The bottom ash and fly ash are residues of power plant, which are dumped as waste and leads to major environmental issues [1]. Government has imposed laws for compulsory usage of power plant wastes as construction materials now a day. Works has been done to use these materials as a potential replacement for concrete materials [2], [3], [4], [5]. Though many works has been done to study the strength and durability factors, the plastic shrinkage property have not been studied in detail so far [6], [7], [8], [9], [10]. The fly ash aggregates found its major use as a replacement material in pre-cast units of blocks and bricks. Hence, it needs to be studied for plastic shrinkage property of concrete. When considered for structural replacement material or as a reinforced cement concrete, the crack study is an important one to avoid corrosion in rebar.

- *P. Priyadharshini is a research scholar in structural engineering department in Vellore Institute of Technology, Vellore, Tamil Nadu, India. E-mail: mail2pridha@gmail.com*
- *Co-Authors Dr. G. Mohan Ganesh & Dr.A.S. Santhi are professors in structural engineeringdepartment in Vellore Institute of Technology, Vellore, Tamil Nadu, India.*

2 MATERIALS AND EXPERIMENTAL METHODS

2.1 Cement

Ordinary Portland 53 grade cement with specific gravity 3.15 was used as the binder. The initial and final setting was 110 minutes and 260 minutes respectively.

2.2 Fine Aggregates

River sand of specific gravity 2.6 and lignite based bottom ash of specific gravity 2.4 were introduced as fine aggregates. A stereo microscopic image of bottom ash taken at 20X zooming is shown in Fig. 1. The black particles illustrate the carbon content in bottom ash. Bottom ash with less than 4% carbon content is taken for this study.

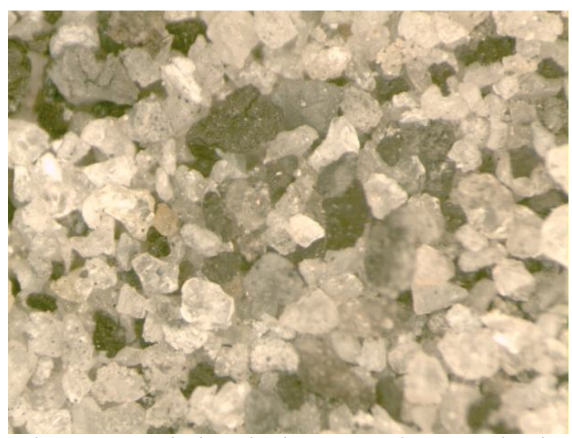

Fig1. Bottom ash viewed using stereo microscope (20X).

2.3 Coarse Aggregates

Crushed natural rock stone aggregate of nominal size in the range of 4.75 mm to 25 mm was used as coarse aggregate. Lignite based fly ash was used to make artificial coarse aggregates. Fly ash aggregate was made using cold bonded technique. Class C fly ash with 8% cement and 2% lime as binders, was used to prepare FAA in pelletizer machine as described in [11]. The physical properties of natural coarse aggregate and fly ash aggregate is shown in Table 1.

TABLE 1
PHYSICAL PROPERTIES OF COARSE AGGREGATES

Properties	Natural gravel	Fly ash Aggregate
Specific Gravity	2.63	2.12
Water Absorption (%)	1.5	13.23
Bulk Density (Kg/ltrs)	1.496	1.247
Fineness Modulus	7.5	7.96

2.4 Mix Proportioning

Trial castings were made to obtain target strength of 40 MPa at 28 days. In order to make the mix workable for various combinations, the super plasticizer (SP) dosage was varied. The detailed mix proportions are shown in Table 2.

TABLE 2
CONCRETE MIX PROPORTIONS (KG)

Mix	400	401	420	421	440	441
Cement	360	360	360	360	360	360
Sand	698	698	558	558	419	419
Bottom ash (%)	0	0	20	20	40	40
Bottom ash	0	0	124	124	247	247
Natural gravel	1290	0	1290	0	1290	0
Fly ash aggregate (%)	0	100	0	100	0	100
Fly ash aggregate	0	740	0	740	0	740
W/C ratio	0.39	0.39	0.39	0.39	0.39	0.39
SP (%)	0.52	0.2	0.55	0.25	0.6	0.3

2.5 Mixing and Placing

The concrete is well mixed in a rotary pan mixer of capacity 1 m^3. The aggregates and cement was mixed well initially, and then water with SP was added to achieve uniform mix. True slump was observed for all the six mixtures.

2.6 Specimen Used

Slab mould of dimension 500 x 250 x 75 mm was used with stress riser of 55 mm height at the centre and two base restraints of 35 mm height at 35 mm from both the ends, along the transverse direction as shown in Fig. 2. Additionally, bolt and nut arrangements were provided at the ends to restrict the longitudinal movement of the concrete, increasing the possibility of cracking at the notch. Concrete has to be filled in this mould and kept in oven at a degree of 40^0c for 24 hrs. After 24 hrs, the mould has to be removed and observed for any cracks in the surface using stereo microscope.

3 RESULTS

3.1 Crack Observation

When observed after 24 hrs, there was no crack found for any of the mixtures other than mix 440.

Fig2. Plastic shrinkage mould.

Plastic shrinkage was not observed in mixtures containing fly ash aggregates for the mentioned testing scenario. As of bottom ash is concerned, up to 20% replacement has no effect in plastic shrinkage of concrete, but 40% replacement shows minute cracks in the surface. This looks contrary to the available literatures saying bottom ash as a better material to reduce plastic shrinkage [12]. This may be due to the excess bleeding and constant evaporation of water, leaving the surface dry for crack formation. However, when combined with fly ash aggregates, this percentage replacement of bottom ash does not show any crack. Fig. 3 shows the crack observed in mix 440.

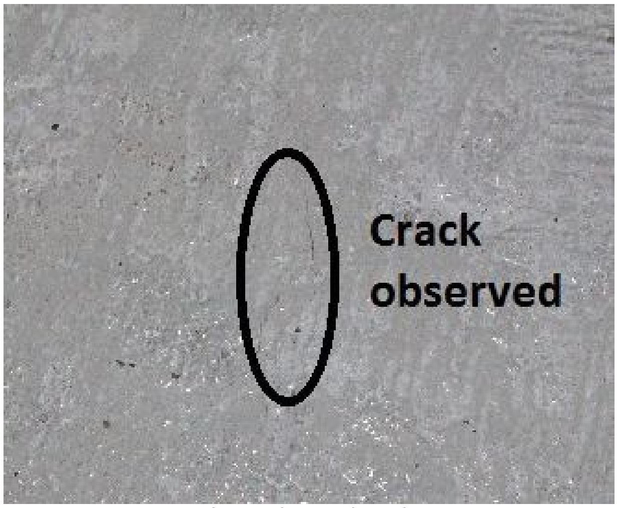

Fig. 3. Observed crack.

3.2 Crack Measurement

The crack measurement is done using stereo microscope as shown in Fig. 4.

The crack region has been first divided in to small units of 1 cm each along the crack line. In mix 440, the crack has observed in the middle portion and the crack profile is shown in Fig. 5. The length of crack can be measured from crack profile. Profile is drawn by merging microscopic images in a graph sheet. This gives an overall picture of the crack pattern and helps in measuring the length of the crack.

Fig. 4. Shrinkage crack measured in stereo microscope.

The width of the crack is measured using pixel-fox software attached with stereo microscope. Crack along unit 4 and passing unit 5 is shown in the Fig. 6.The crack width is measured as in Fig. 7, for all the small units taken along the crack line.

4 Results Discussion

The length and width of crack was measured using the techniques discussed. The graph imposed on the crack profile helps us determine the length of the crack. Maximum crack length was found to be 62 mm that extends from cell 15 to 21. The crack width ranges between 0.022 to 0.088 mm in this region. Many hair line cracks were found in the region from cell 6 to 15 with crack width less than 0.02 mm. Maximum crack width was observed in the region of cell 4 to 5. This region is magnified in the Fig. 6 with stereo microscope for 20X zooming. From Fig 7, it is identified that maximum crack width was 0.1 mm. The length of this crack was found to be 21 mm. The maximum crack was found at the mouth of the crack in region 4. The crack found in the 440 mix may be due to the property of bottom ash that absorbs much of water initially. When kept in the simulated environment, the high temperature captivates the water absorbed by bottom ash and the bond between the aggregates and the matrix might not developed sufficiently which results in crack formation at the surface in this stage.
Considering other mixtures, the water absorption will not be that high compared to 40% replacement of bottom ash with fine aggregates. This may be the reason for non-appearance of crack pattern in mixtures 400, 401, 420 and 421.

The introduction of fly ash aggregates makes the bond between aggregate and matrix stronger, as the surface of the fly ash aggregates are reactive to the matrix. Thus the mix 441 does not show any crack pattern, though 440 shows crack. A possible remedy for reduction of plastic shrinkage crack is addition of fibres in concrete [13].

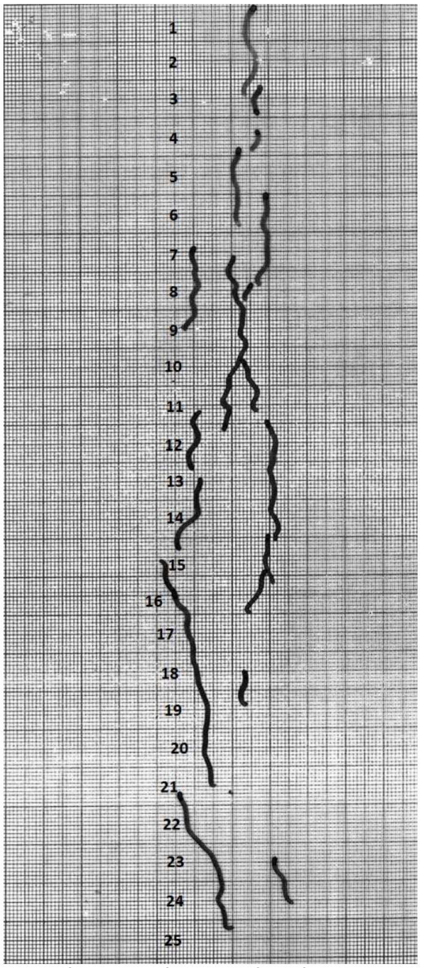

Fig. 5. Crack pattern for mix 440.

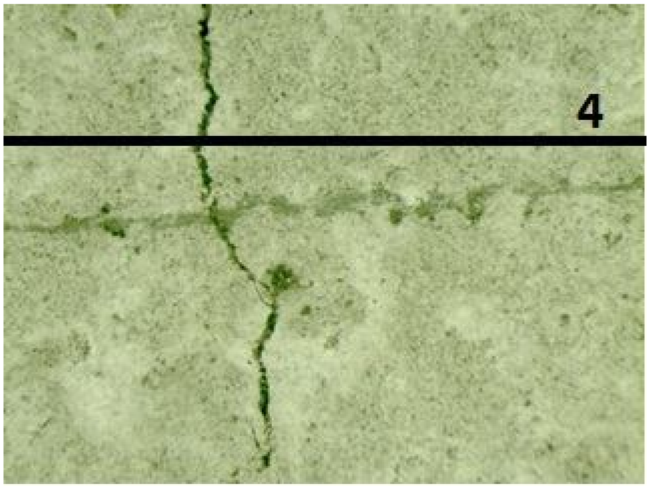

Fig. 6. Microscopic view of crack in zone 4-5.

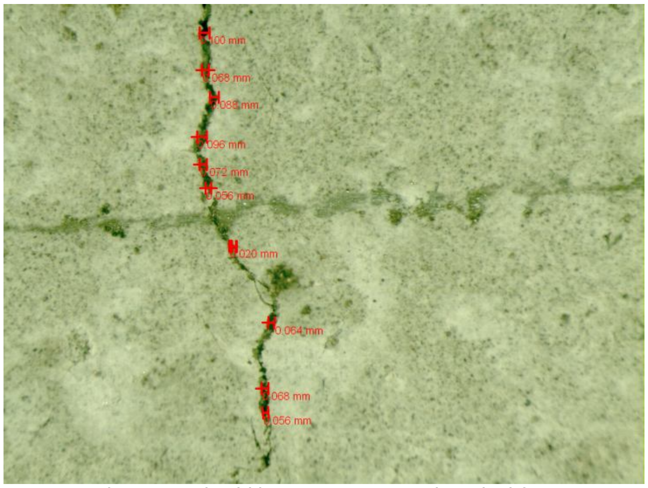

Fig. 7. Crack width measurement using pixel-fox.

5 CONCLUSION

This paper stated experimental results plastic shrinkage studies conducted on concrete incorporating bottom ash as fine aggregate and fly ash aggregate as coarse aggregate in different proportions. The following conclusions can be drawn from the results obtained from the experimental study,

- ✓ Plastic shrinkage is reduced by addition of fly ash aggregates as a coarse aggregate replacement material in concrete.
- ✓ The addition of bottom ash to the concrete as fine aggregate up to 20% performs better plastic shrinkage property beyond which it develops crack in the surface.
- ✓ The 40% replacement of bottom ash as fine aggregate in concrete results in plastic shrinkage crack in minor level with maximum of 0.088 mm width of crack and maximum lenth of 62 mm.
- ✓ When fly ash aggregate coarse aggregate and 40% replacement of bottom ash as fine aggregate were used, no crack was observed. This proves that fly ash aggregate helps arresting plastic shrinkage crack to some extent.

Even though, the experimental results shows some specific behavior of fly ash aggregates anf bottom ash, it needs further study for long time observation of cracks beyond 24 hrs.

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