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DURABILITY STUDIES ON BOTTOM ASH CONCRETE WITH MANUFACTURED SAND AS FINE AGGREGATE

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ABSTRACT

Quarry (Manufactured) sand is used as fine aggregate in this research. Cement was replaced by silica fume (10% by weight) and Super plasticizer (varying percentage by weight of binder) was added for good workability. Normally the disposal of bottom ash from the thermal power plant leads to land pollution. Manufactured sand (M-Sand) was partially replaced (10% - 50%) by bottom ash in concrete to solve the disposal problem. Mechanical property such as compressive strength and Durability properties, such as water absorption, sea water and acid resistance, abrasion, chloride penetration of concrete mix (M60) were evaluated. The result showed that use of bottom ash slightly affects the durability properties of concrete.

INTRODUCTION

To avoid the depletion of natural resources and to use the waste materials which are extracted from stone quarries, the river sand was completely replaced by manufactured sand (M-Sand). The use of M-Sand represents a higher strength than the corresponding natural sand concrete at all test ages (Donza *et al.*, 2002). Super plasticizer with varying percentage was used to get the medium workability. In this study, ordinary Portland cement (OPC) was replaced by pozzolana Portland cement (PPC) due its more advantages. Compressive strength was increased when cement was replaced up to 12% (40 and M50 grades) (Bhikshma *et al.*, 2009). In this research cement was partially replaced by silica fume (10 % by weight). In this study the bottom ash was used in concrete to reduce the pollution in nearby water bodies due to its disposal. The concrete strength increased with age when the fine aggregate was replaced with bottom ash (Aggarwal *et al.*, 2007). In this study the effect of Bottom ash in concrete were investigated for mass laying of concrete with pumpable property. The durability properties were studied with partial replacement of M sand with bottom ash of 10%, 20%, 30%, 40% and 50%.

EXPERIMENTAL PROGRAM

Materials

Portland pozzolana cement conforming to IS 1489

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(Part 1): 1991 was used. Silica fume of grade 920- D obtained from Elkem India private limited, Mumbai, India was used as mineral admixture. Manufactured sand (M-Sand) from locally available Quarry industry conforming to IS 383:1970 was used as fine aggregate. Crushed aggregate of 20 mm size conforming to IS 383:1970 was used as coarse aggregate. Bottom ash obtained from thermal power plant at Erode, Tamilnadu in India was used in this studies. A polycarboxylic acid based superplastizicer commercially available as cera hyper plast was used at varying percentage by weight of binder to maintain medium workability as per IS 456 -2000.

Mix proportions

The control mix (M60) was designed (Table 1) as per Indian standard specification I.S 10262-2009.

Table 1. Mix ratio

Mix ratios	BA 0
SF %	10
Silica fume (kg)	43.59
Cement (kg)	392.34
BA %	0
Bottom Ash (kg)	0
F.A. (kg)	672.34
C.A. (kg)	1238
Hyper plasticizer %	0.8
Water (litre)	139.5

METHOD

Workability and Compressive strength

The workability of concrete (slump test) was maintained as medium value by using variable percentage of super plasticizer. Compressive strength of concrete was determined at the age of 28 and 56 days as per IS: 516 – 1959.

Durability properties

Water absorption and porosity

Cube specimen of size 150mm x 150 mm x 150 mm (18 nos) at the age of 28 days was tested to determine the water absorption and porosity as per ASTM C642-81.

Acid resistance

For acid resistance test 5% dilute hydrochloric acid (pH - 2) was used .Test was carried out for the cube specimen of size 150 mm x 150 mm x 150 mm (18 nos) at the age of 60 days after the normal curing period (28 days) in portable water. Strength was measured as per IS: 516 – 1059.

Sea water (sulphate) resistance

The tests were carried out by immersing the cube specimen (18 nos) of size 150mm x 150 mm x 150 mm after 28 days curing in a solution containing five precent of sodium sulphate ($Na2SO_4$) and five percent of magnesium sulphate ($MgSO_4$) by weight of water for 60 days. Strength was measured as per IS: 516 – 1059.

Abrasion

The abrasive value was determined as per IS 1237-1980. A test specimen of size 70 mm x 70 mm x 35mm (18 nos) were casted and loss in thickness was calculated.

RCPT

Rapid chloride permeability test were conducted using a specimen of size 50 mm thick.

In this test the primary specimen of size 100mm x 200 mm cylinder (18 nos) was casted and a test specimen of thickness 50 mm was cut from the primary specimen. The test was carried out after 28 days curing as per ASTM 1202.

RESULTS AND DISCUSSION

Workability and Compression strength

The workability of concrete mixture was decreased when M sand was replaced with bottom ash. The slump value was decreased with addition of BA as fine aggregate (Kim *et al* ., 2011). The slump was maintained as constant value 80 mm to get the medium workability as per IS 456 – 2000.

The concrete samples having 20% sand replaced with pond-ash showed improved compressive strength over the control sample at all the curing ages (Arumugam *et al*., 2011; Malkit Singh *et al* ., 2013).

The bottom ash concrete gain strength at a slower rate in initial curing period and attains strength at later ages (Table 2).

DURABILITY PROPERTIES

Water absorption and porosity

The water absorption and porosity of bottom ash concrete increases with increase in bottom ash percentage replacement due to presence of more voids in

Bottom ash shown in Table 3.

The mortar with FBA aggregates showed higher capillary absorption than the mortar with NF aggregates because of the higher porous structure of FBA aggregates (Kim *et al.*, 2012).

Table 2. Compressive strength in N/mm²

MIX	Compressive strength	
	28 Days	56 Days
BA 0	69.89	73.24
BA 10	57.56	67.54
BA 20	56.68	61.04
BA 30	54.06	59.29
BA 40	53.62	57.12
BA 50	47.96	51.45

Table 3. Water absorption and porosity

MIX Ratio	Water absorption %	Porosity
BA 0	1.15	1.84
BA 10	1.19	1.86
BA 20	1.24	1.94
BA 30	1.47	2.09
BA 40	1.56	2.16
BA 50	1.74	2.3

Acid resistance

The compressive strength of BA concrete (Table 4) was reduced continuously when immersed in Acid solution with increase in Bottom ash content due more porosity in matrix and concrete.

Table 4. Compressive strength in N/mm²

MIX Ratio	Compressive strength	
	Immersed in Normal water	Immersed in Acid solution
BA 0	78.45	70.45
BA 10	69.74	61.73
BA 20	64.41	58.87
BA 30	63.02	55.11
BA 40	62.34	51.49
BA 50	62.01	48.88

Sea water (sulphate) resistance

Due to more expansion of bottom ash matrix, the compressive strength of BA concrete was reduced while compare with BA 0 (Table 5). Ghafoori and Bucholc (1997) observed that expansion of bottom ash concrete when subjected to sulfate attack was higher than that of control concrete.

Table 5. Compressive strength in N/mm²

MIX Ratio	Compressive strength	
	Immersed in Normal water	Immersed in sea water
BA 0	75.01	80.20
BA 10	66.10	60.12
BA 20	61.21	58.34
BA 30	59.89	55.20
BA 40	59.03	54.00
BA 50	58.94	53.45

Abrasion

The loss in thickness of concrete was increased with increase in BA replacement due its porous nature and less stiffness (Table 6). Ghafoori and Bucholc (1996) found that with the use of water reducing admixtures, a superior abrasion resistant bottom ash concrete was produced. In this study also the increase in loss of thickness for BA 10 is 0.17mm when compared to BA 0.

Table 6. Abrasion value (loss in thickness)

MIX Ratio	Average loss in thickness in mm
BA 0	0.42
BA 10	0.59
BA 20	0.64
BA 30	0.78
BA 40	0.91
BA 50	1.10

RCPT

The chloride permeability of bottom ash concrete is higher than that of control concrete (Table 7). The permeation of chloride ions into the bottom ash concrete decreases drastically when a low dosage of super plasticizer is used (Ghafoori *et al.*, 1996). In this research also, chloride ion penetration increases with increase in super plasticizer dosage. Kou Shi-Cong *et al.*, 2009 demonstrated that at the same W/C, the resistance to chloride-ion penetration of the concrete mixes decreased with increasing percentages FBA replacement of river sand (in this research it is M-sand). In this study also resistance to chloride-ion penetration of the concrete mixes decreased when the replacement of M- sand by Bottom ash increases.

Table 7. Rapid chloride penetration value.

MIX Ratio	HP %	Electric charge (Coulomb)
BA 0	0.8	1640
BA 10	1	1855
BA 20	1.2	2493
BA 30	1.6	3393
BA 40	2	4590
BA 50	2.4	5427

CONCLUSION

Based on the results and discussion the following conclusion may be drawn to use coal ash waste (Bottom ash) as partial replacement for manufactured sand:

- The flow property of concrete (slump value) was maintained as 80 mm to pump the concrete by adding super plasticizer in varying percentage.
- The compressive strength was increased at later age.
- Water absorption and porosity increased with increase in BA and also the values are within the limit.
- Due to porous BA concrete, the compressive strength of concrete after immersion in acid solution was decreased.
- The expansion of bottom ash concrete when subjected to sulphate attack was more than that control concrete at all replacements.
- The abrasion value (loss in thickness) of BA 10 was minimum when compared to control mix.
- The chloride ion penetration was almost under moderate condition up to BA 30 concrete.

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