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Study of Strength of Concrete by Partially Replacing Fine Aggregate with Bottom Ash and Marine Sand

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Abstract: The present study investigates the effect of use of bottom ash and marine sand as a replacement of fine aggregates in concrete. Concrete mixes with a combination of bottom ash, marine sand and normal sand are cast and cured in sea water. The strength properties viz., compressive strength, and splitting tensile strength are studied. The strength development for various percentages of bottom ash (30% - 50%) with a constant 20 percentage of marine sand (as replacement for fine aggregates) are equated to the strength development of normal concrete at different ages of concrete namely 3 days, 7 days and 28 days. Even though the strength development is less for bottom ash concrete, it can be equated to lower grade of normal concrete.
Key words: Bottom Ash, fine aggregate replacement, marine sand, compressive strength, sea water curing.

Introduction:

The structural performance and durability of concrete is on par excellent. When the concrete element is subjected to a marine environment, it is affected by early deterioration. Corrosion of steel reinforcement, with subsequent spalling of concrete is the most common cause of deterioration. The concrete/reinforced concrete structures which are in contact with the marine environment either directly or indirectly are exposed to both physical and chemical detrimental effects during their service life. The physical effects on concrete are the erosion, wetting-drying and freezing-thawing while the chemical effects are due to the presence of sulfate, chloride, magnesium and carbonic acids. The concentration of chemicals, the duration of exposure and the chemical resistance of concrete are responsible for the deterioration rate of hardened concrete due to the presence of harmful chemicals[1,2]. The movement of pollutants in concrete are governed by the following phenomenon viz., diffusion of substances in the pore water, adsorption and desorption of pollutants onto the pore walls and hydrodynamic dispersion and convection of substances due to flow of the pore water[3]. The essential parameters in producing a durable marine structure concrete is the selection of materials, mix design, and proper detailing of reinforcement[4]. Due to the alarming growth of construction industry, the demand for fine aggregate is escalating. Over-exploitation of river sand to meet the demand has led to various harmful consequences such as lowering of the water table, deepening of the river course etc.[5].

Review of Literature:

In recent past, a number of literatures are available concerning seawater attack on concrete and the performance of reinforced concrete. The ability of concrete to resist the effects and influences of the environment, while performing its desired function is called as the durability of concrete[6]. The environmental hazards posed by the disposal of bottom ash have reached alarming proportion such that the use of bottom ash in concrete manufacturing is a necessity than a desire. The use of coal ash in normal strength concrete is a new dimension in concrete mix design and if applied on large scale would revolutionize the construction industry, by economizing the construction cost and decreasing the ash content[7]. The effect of mixing and curing of concrete with sea water on the compressive, tensile, flexural and bond strength of concrete was investigated and the results indicated that compressive, tensile, flexural and bond strengths increases for specimens mixed and cured with sea water at early ages upto 14 days and definite decrease in various strengths for the age of concrete more than 28 days[8].

Materials and their Properties:

Cement

Portland pozzolana cement (PPC) 53 Grade was used in the investigation. The specific gravity of cement is 3.15

Fine Aggregate

(i) Bottom Ash

Bottom ash obtained from Dr. Narla Tata Rao thermal power plant, Vijayawada was used in the experimental investigation. The specific gravity and bulk density of bottom ash was found to be 1.68 and 800 kg/m^3 respectively. Table 1 and Figure 1 gives the grain size distribution of bottom ash and grading curve of bottom ash. Table 2 shows the chemical properties of bottom ash. Fineness modulus is 3.39.

Table 1 Grain Size Distribution of Bottom Ash

Size of IS Sieve (mm)	Weight Retained (kg)	% of Weight Retained	Cum. % Retained
4.75	0	0	0
2.36	0.16	16.0	16.0
1.18	0.095	9.5	25.5
0.6	0.11	11.0	36.5
0.3	0.335	33.5	70.0
0.15	0.21	21.0	91.0
Lower than 0.15	0.09	9.0	100

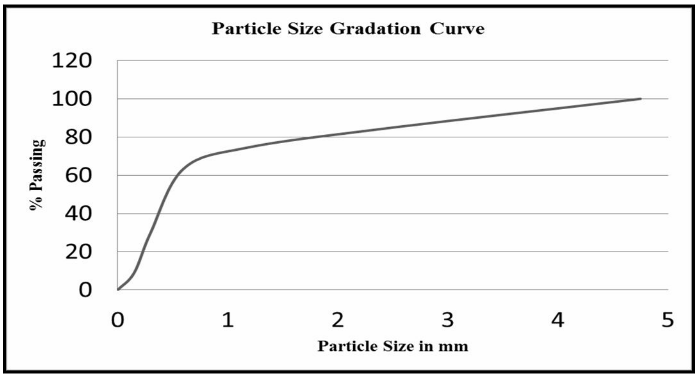

Figure 1 Grading Curve of Bottom Ash

Table 2 Chemical Composition of Bottom Ash

Constituent	Test results	IS 3812 requirement
SiO_2	72.3	35.0 min
$SiO_2 + Al_2O_3 + Fe_2O_3$	90.1	70.0 min
MgO	1.65	5.0 max
Total sulphur as SO_3	1.24	2.75 max
Alkalies as Na_2O	-	1.5 max
Loss on Ignition	0.29	12.0 max

Above figures in the table are in percentage by mass

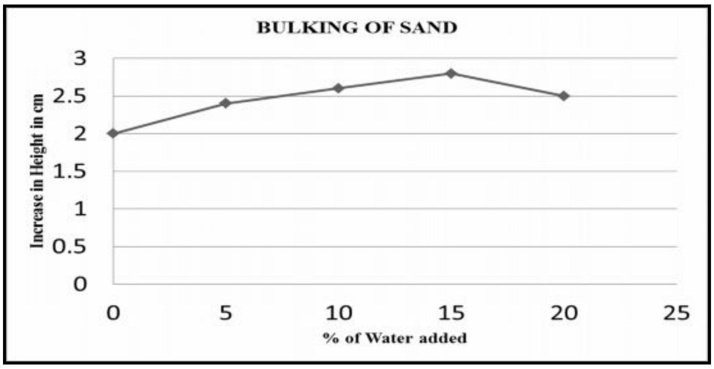

Figure 2 Bulking of Sand

(ii) **Marine Sand**

Marine sand obtained from Velankkini, Tamilnadu. India was used in the investigation. The specific gravity of the marine sand was found to be 2.59. Figure 2 shows the bulking of marine sand.

(iii) **Normal Sand**

Normal sand with specific gravity and fineness modulus of 2.6 and 2.60 respectively was used.

(iv) **Coarse Aggregate**

Coarse aggregate with specific gravity 2.6 was used. The maximum size of aggregate was 20 mm.

(v) **Sea Water**

Sea water obtained from Velankkini, Tamilnadu was used in the investigation. The total dissolved solids of sea water were found to be 36000 ppm. The various properties of sea water are shown in Table 3

Table 3 Chemical Composition of Sea Water

Ions	% By Mass
Chloride	55.6
Sodium	30
Magnesium	3.70
Sulphate	7.5
Calcium	1.0
Potassium	1.1
Others	1.1

Table 4 Detailed Ingredients of Control Mix

Cement	Fine Aggregate	Coarse Aggregate	Mixing Water	Curing Water
PPC	Normal sand	Gravel	Fresh water	Fresh water

Table 5 Mix Design Details

Design mix adopted	M 30
Maximum size of aggregate	20 mm
Slump	150 mm
Water cement ratio	0.47
Water per m^3 of concrete	210 kg/m^3
Specific gravity of CA and FA	2.65 and 2.6
Fineness modulus of FA	2.60
Bulk density of coarse aggregate	1600 kg/m^3

Table 6 Mix Proportions

Item	M 30	Item	B 30	B 40	B 50
Cement (kg/ m^3)	447	Cement (kg/ m^3)	447	447	
Fine aggregate (kg/m^3)		Fine aggregate (kg/m^3)			
Normal sand	687.5	Normal sand	343.7	275	206.3
Bottom ash	------	Bottom ash	206.3	275	343.8
Marine sand	------	Marine sand	137.5	137.5	137.5
Coarse aggregate (kg/m^3)	1034	Coarse aggregate (kg/m^3)	1034	1034	1034
Water (kg/m^3)	186	Water (kg/m^3)	186	186	186

Mix Design:

Mix design was prepared using ACI method. The various data used for mix design is shown in Table 4. The mix proportions for various mixes are shown in Table 5 and Table 6.

Table 7 Detailed Ingredients of Bottom Ash Mixes

Cube	Cement	Fine Aggregate	Coarse Aggregate	Mixing Water
B30	PPC	20% Marine sand + 30% bottom ash+ 50% normal river sand	Gravel	Sea water
B40	PPC	20% Marine sand + 40% bottom ash+ 40% normal river sand	Gravel	Sea water
B50	PPC	20% Marine sand + 50% bottom ash+ 30% normal river sand	Gravel	Sea water

Experimental Programme:

(i) Testing of Material Properties

Physical and chemical properties of bottom ash, marine sand and sea water were tested.

(ii) Casting and Curing

Cubes for control mix with cement, normal sand as fine aggregate and coarse aggregate as gravel are cast using fresh water and cured in fresh water. Bottom ash mixes B30, B40, and B50 with varying proportions of bottom ash as 30%, 40% and 50% at a constant percentage of 20% marine sand and the remaining percentage of normal sand as fine aggregate and gravel as coarse aggregate are cast with sea water and cured in sea water.

Results and Discussion:

(i) Compressive Strength

The compressive strength of the control mix and bottom ash mixes were cured accordingly and tested at the age of 3, 7, and 28 days. The cubes of size 100 mm x 100 mm x 100 mm were tested in Compression Testing Machine (CTM). The obtained failure load in kN is noted and the mean compressive strength is taken into consideration for analysis.

The results of compressive strength are tabulated in Table 8 and Figure 3.

Table 8 Compressive Strength of Concrete at 3, 7 and 28 Days

Mix type	Strength at 3 days in N/mm^2	Strength at 7 days in N/mm^2	Strength at 28 days in N/mm^2
M30	13.8	16.31	32.16
B30	19.82	23.70	29.60
B40	17.60	21.45	28.86
B50	16.21	20.10	26.10

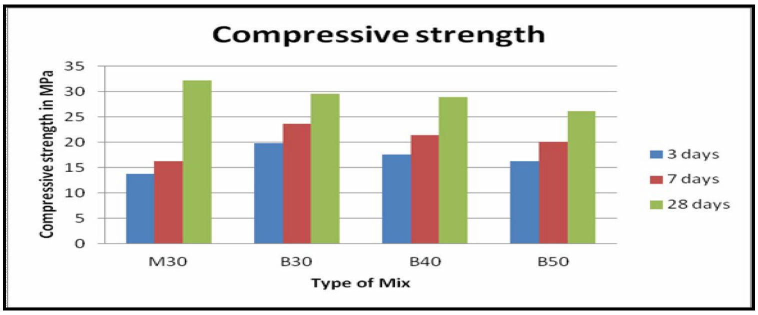

Figure: 3 Compressive Strength of Concrete with Age

Table 9 Tensile Strength of Concrete at 3, 7 and 28 Days

Mix type	Strength at 3 days in N/mm^2	Strength at 7 days in N/mm^2	Strength at 28 days in N/mm^2
M30	1.92	2.36	3.01
B30	2.54	2.79	2.84
B40	2.02	2.26	2.65
B50	1.82	1.98	2.33

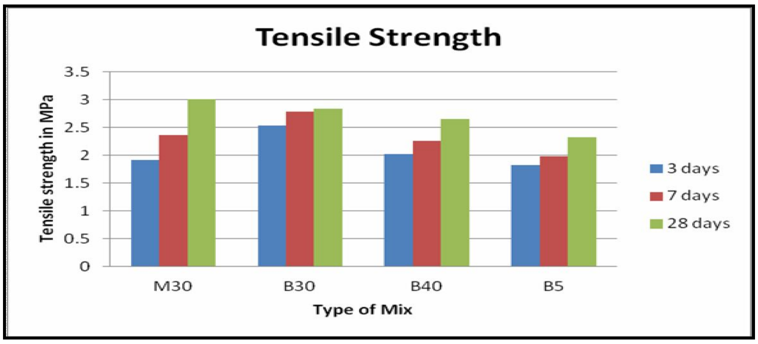

Figure: 4 Tensile Strength of Concrete with Age

(ii) **Split Tensile Strength**

Tensile strength was indirectly measured by split tensile strength test using CTM. The size of cylinders is of 100 mm diameter and 200 mm height. Their ultimate load is noted and the mean tensile strength is taken into account.

The results of tensile strength are tabulated in Table 9 and Figure 4.

Inference and Conclusion:

Replacing fine aggregate with bottom ash enables the following advantages:

1. Reduction in the demand for fine aggregate.

2. Utilization of waste product, reducing the problems of disposal.

The compressive strength of bottom ash concrete containing 50% bottom ash is less when compared to M3O grade concrete. But it is more than the strength of M20 grade concrete, which is the minimum strength of concrete to be used as per IS 456-2000.

Even though the strength development is less for bottom ash concrete, it can be equated to lower grade of normal concrete and also making utilization of waste material justifies the concrete mix-development.

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