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Experimental Investigation on Replacement of Fine Aggregate with Bottom Ash in Concrete

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Abstract: Present study investigates the effect of coal bottom ash as partial replacement to sand in concrete. The bottom ash was procured from Neyveli Lignite Corporation, and partially replaced with sand. Compressive strength characteristics of concrete were studied with various percentages of bottom ash replacement and at different curing periods. Analysis of results showed some improvement in the strength.
Key words: *Bottom Ash, sand, compressive strength, curing.*

Introduction:

Concrete is an extensively used material for most of the civil engineering projects. It is produced with cost effective material. Concrete is used to support, to enclose, to surface and to fill. Thus from the consideration of energy and resource conservation and sustainability of the environment, concrete is the most preferred material. Concrete industry is drawing upon enormous natural resources. One day these natural resources will become extinct which compels for replacement of these materials with alternate materials. The search for a compatible material to replace sand in concrete become very vital in the light of the world facing serious problem due to the decreased availability of river sand.

Bottom ash is the residue or non-combustible substance formed after the combustion of lignite or coal in the furnace at a temperature of 1300 degree Celsius. It is removed as slag from the bottom of the furnace. The total amount of fly ash and bottom ash produced in Neyveli lignite corporation is 3.75 lakh tons per annum (approx.). The fly ash produced is used as pozzolonic material in cement, fly ash bricks etc. nevertheless the bottom ash is being merely deposited in piles which is becoming hazardous to the environment. Sand is one of the major constituent of concrete is diminishing in its quantity around the world, which creates a need for finding an alternative. Bottom ash has particle size similar to sand. Hence this can be used as a replacement for fine aggregate in concrete.

Review of Literature:

Experiments carried out[1] reveal that up to 50% bottom ash can be replaced in lieu of river sand for several applications in structural engineering. In another study carried out[2] by replacing coal bottom ash as partial replacement to sand, the compressive strength was increased up to 20% replacement and beyond that it was found to be decreasing.

An investigation also had been carried out to study the effect of use of coal bottom ash as a replacement of fine aggregates. The various strength properties such as compressive strength, flexural strength and splitting tensile strength were studied. The strength development for various percentages (0-50%) replacement of fine aggregates with bottom ash had been found. The time required to attain the required strength is more for bottom ash concrete.

Experimental Program:

Characteristics of Bottom ash:

Bottom ash is a byproduct of coal and lignite combustion. The largest producers of bottom ash are power plants, which burn a very high volume of coal and lignite annually to generate electricity. Bottom ash is a coarse material having grains similar to or slightly bigger than that of sand. Bottom ash obtained after burning of Lignite with calorific value of 2600 kcal/kg.

Table-1 illustrates the constituents of bottom ash used in this work. The results of sieve analysis carried out on bottom ash are tabulated in Table-2. Fig-1 shows the particle size distribution curve of bottom ash. The curve is a smooth curve revealing that particle size distribution of bottom ash is almost similar to that of fine aggregate. It has a Co-efficient of curvature of 2 and Co-efficient of uniformity 1.125. Fineness modulus of bottom ash is found to be 2.967.

Table-1 Constituents of Bottom Ash

S.No.	Name of Constituents	In %(mass/vol.)
1.	Silica (SiO_2)	48.71
2.	Aluminium Oxide (Al_2O_3)	29.23
3.	Titanium Oxide (TiO_2)	1.88
4.	Iron Oxide(Fe_2O_3)	4.29
5.	Calcium Oxide (Cao)	7.44
6.	Magnesium Oxide (MgO)	1.70
7.	Sodium Oxide (Na_2O)	1.16
8.	Potassium Oxide (K_2O)	0.55
9.	Sulphur Trioxide (SO_3)	3.96
10.	Phosphorous Oxide (P_2O_5)	0.22

Table-2 Results of Sieve Analysis for Bottom ash

IS Sieve Size	Cumulative percentage passing
4.75 mm	98.6
2.36 mm	97.6
1.18 mm	94.7
600 micron	82.4
300 micron	25.6
150 micron	3.6
75 micron	0.8
< 75 micron	0

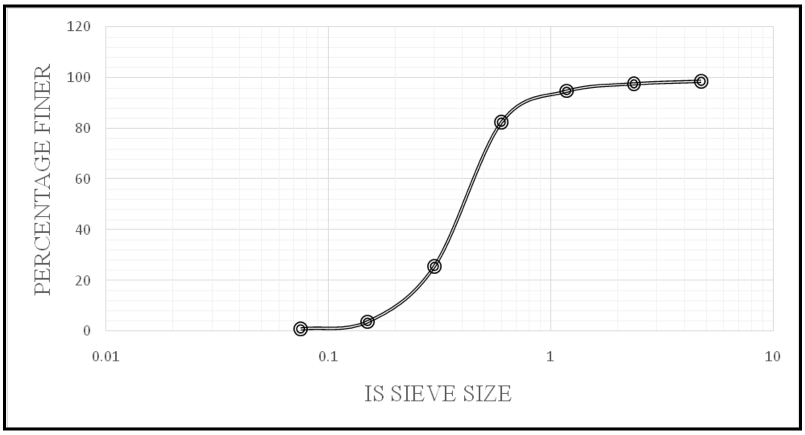

Fig -1 Particle size distribution curve for Bottom Ash

Cement:

Portland pozzolana cement (fly ash based) is used throughout the experiment. We preferred Portland pozzolona cement- flyash based instead of ordinary Portland cement because now-a-days practically PPC is used in concrete.Table-3 illustrates the properties of the cement used.

Table-3 Properties of cement[7]

Consistency of Cement	33%
Specific gravity	2.75
Initial Setting Time	34 min 30 sec
Final Setting Time	580 min
Fineness of Cement	98%
Compressive Strength I. 3 days II. 7 days	 16 N/mm^2 25.84 $N//mm^2$

Fine aggregate:

Table-4 shows the results of sieve analysis of sand. Fig-2 illustrates the particle size distribution curve of fine aggregate.

Table-4 results of sieve analysis for sand[8]

IS Sieve Size	**Wt. Retained on Sieve (g)**	**% passing**
4.75 mm	16	98.4
2.36 mm	42	94.2
1.18 mm	198	74.4
600 micron	348.5	39.55
300 micron	290.5	10.5
150 micron	94.5	1.05
75 micron	9.5	0.1

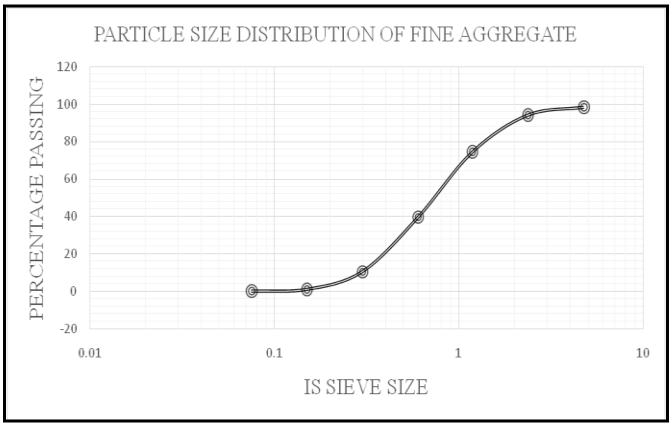

Fig 2.Particle size distribution curve of Fine Aggregate

Mix Proportions:

Mix design was carried out in the laboratory following the guidelines and standards of Indian codes[3, 4.] .The mix ratio was found to be 1:2.8:1.5 with a water-cement ratio of 0.45.

Casting and testing of Cubes:

Standard cubes of size 150x150x150 mm were casted[5] and cured for different time periods as required[6] for the testing program. Sand was replaced with bottom ash from 0 to 100 percent. The cubes are tested after 7, 14 and 28 days of curing.

Table-5 shows the proportion of materials in various mixtures. The quantity of cement, coarse aggregate water and mix ratio is kept similar in all the mixes.

Table-5 Proportion of materials in various mixes

Materials	Sand (%)	Bottom ash (%)
M1	100	0
M2	90	10
M3	80	20
M4	70	30
M5	60	40
M6	50	50
M7	40	60
M8	30	70
M9	20	80
M10	10	90
M11	0	100

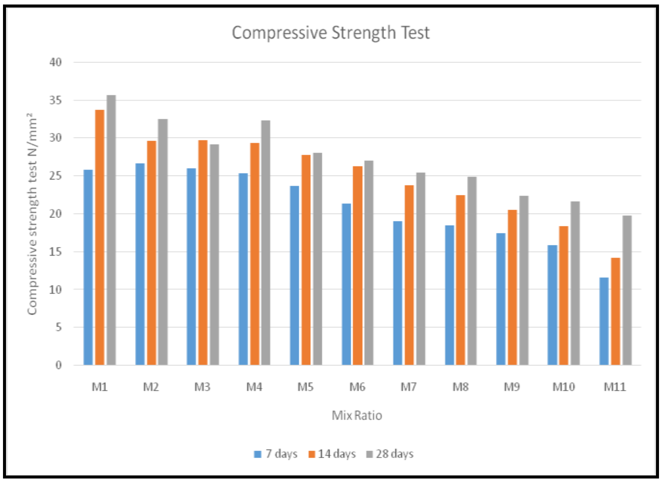

Fig-3 Cube compressive strength variation chart

The characteristics compressive strength of various mixes is tabulated in Table-6.

Results and discussions:

Bottom ash absorbs more water. This can be overcome by using super plasticizers. Even though the strength development is less for bottom ash concrete, it can be equated to lower grade of normal concrete and making utilization of waste material justifies the concrete mix-development.Bottom ash used as fine aggregates replacement enables the large utilization of waste product. Even a small quantity of bottom ash used in mass concreting work results in reduction in cost and efficient as well as eco-friendly disposal of bottom ash.Bottom ash has been a resource that has been wasted. This material has worthy property to make it suitable for construction. Though its replacement for sand in concrete in high percentage does not show improvement in strength significantly, its replacement in lesser quantities for a big construction marks it significance. Large quantities of bottom ash has been dumped into land. Such a material can be used in replacement of sand in concrete to make it useful in a better way. This decreases land pollution and makes it eco-friendly. This type of replacement in heavy budget makes it economical.Bottom ash can be effectively used along with plasticizers in considerable amount to improve the strength of concrete. Bottom ash has a property of absorbing moisture even after construction. So there is chance of dampness in the structure. This makes the need to use a waterproofing coat over the structure. The cause of respiratory related diseases is prominent in such an environment.

Conclusion:

Sand quarrying is done to extract sand for construction purposes. It affects the environment to a great extent. Bottom ash disposal in the environment disturbs the eco-system. Hence, this bottom ash concrete can be used in construction of pavement and buildings. Thus bottom ash is disposed in an eco-friendly way and sand quarrying can be reduced. Thus a greener environment can be build.

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