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Study on Strength Properties of Concrete by Using Bottom Ash and Foundry Sand as a Partial Replacement of Fine Aggregate

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ABSTRACT

The management of solid industrial waste is of big global concern nowadays. The majority of industries are not interested in the treatment and safe disposal of industrial waste due to its high cost involvements, causing environmental and other ecological impacts. The disposal of waste foundry sand is of prime importance due to the big volume produced from the metal casting industries all over the world as well as the waste bottom ash produced from the thermal power plant. The possibility of substituting natural fine aggregate with industrial by-products such as bottom ash and foundry sand offers technical, economic and environmental advantages which are of greater importance in the present context of sustainability in construction sector. Concrete is the most important engineering material and the addition of some other material may change the properties of concrete. Studies have been carried out to investigate the possibility of utilizing the board range of material as partial replacement material for cement and aggregate in the production of concrete. Natural fine aggregate are becoming scarcity because of its huge utility in various constitution process the possibility of substituting natural fine aggregate with industrial by product such as waste foundry sand and bottom ash in concrete. This study investigate the effect of waste of bottom ash and foundry sand is equal quantities as partial replacement of fine aggregate in 0%, 20%, 30%, 40% on concrete properties such as compression strength and split tensile strength. This study also aims to encourage industries to start commercial production of concrete products using waste bottom ash and foundry sand.

Keywords: Bottom ash, Foundry sand, Compression strength, Split tensile strength.

1. INTRODUCTION

Our earth is heading towards huge climate and environmental change. Every field is responsible for this change and our civil field is also not an exception. The cement factories are emitting lot of carbon dioxide which affects the environment. The construction field extracts aggregates and raw materials for bricks from quarries degrade the environment and natural resources slowly and also the blasting in quarries may sometimes lead to earthquake in nearby areas. Many steps, such as Kyoto to minimize the global warning and environmental degradation around the world, but still one way or the other, the degradation is not under control. The main solution for this problem is the usage of eco-friendly products and 3R (Reduce, Reuse, Recycle) concepts.

Concrete is one of the most widely used construction materials throughout the world. The advantage of it is, it can be mould in to any shape and can be made to take required compressive strength. The ingredients for making conventional concrete are cement, fine aggregate, coarse aggregate and water. Making concrete is an art, which one has to be perfectly through otherwise that will end up with bad concrete. Sometime improvements in concrete properties can be made by altering the ingredients in proportion. Hence as a civil engineer one should be through with the entire factor of concrete from which he can produce a good concrete. Sometime improvements in concrete properties can be made by altering the ingredients in proportions.

To abate the degradation of natural resources like rocks and sand and also in order to minimize the dependence on natural resources for aggregates, one can use some other similar materials for concrete and construction. Using an alternative ingredient for concrete is an emerging trend and it also proves to be effective than conventional concrete in many ways such as improved strength, workability, durability and in preventing corrosion, environmental depletion etc. Some of the solid waste, such as coconut shell, rubber tires, and electronic wastes, steel and copper slag can be used as a replacement of aggregate in concrete. Use of solid wastes not only helps in increasing the strength but also helps in the management of solid wastes.

MATERIALS AND METHODS

Materials

The material used to develop the concrete mixtures in this study were cement, fine aggregate (sand), coarse aggregate (gravel), bottom ash, foundry sand and water. Cement is a basic requisite for any construction work and also provides a binding medium for the discrete ingredients. The cement used was Portland Pozzolana Cement. The cement is manufactured as per the code IS: 1489(part-I):1991. In the present study Portland Pozzolana Cement (Chettinad cement), which is readily available is used. The specific gravity of cement is 3.15. Natural River sand, bottom ash and foundry sand passing through 4.75mm IS sieve is used for making of concrete. The specific gravity test conducted for natural sand, bottom ash and foundry sand as per IS: 2386-1963(part-I). The fineness modulus test Conducted for sand, bottom ash and foundry sand is as per IS: 383-1973. Natural river sand was categorized under grading zone II. The size of coarse aggregate is 20mm. The specific gravity test showed that result 2.63 for coarse aggregate. Bottom ash and foundry sand used as partial replacement for fine aggregate is obtained from thermal power plant and metal casting industries. Portable water is used for mixing. All these studies were done under room temperature.

METHODOLOGY

Concrete specimens of cubical, and cylindrical were casted with IS method of mix design procedure. The casted specimens were tested for their compressive strength, splitting tensile strength after curing for 28 days in the laboratory.

RESULT AND DISCUSSIONS

Sieve analysis test carried out to find the particle size distribution of the bottom ash and foundry sand, through which find out the effect of replacing fine aggregates as bottom ash and foundry sand.

The below tables 1, 2, and 3 represents the sieve analysis test values.

Table 1 Sieve analysis test for Bottom Ash IS Sieve Size

IS Sieve Size	Weigh Retained (gms)	Cumulative Weight Retained (gms)	Cumulative Percentage Weight Retained (gms)	Cumulative Percentage Passing (gms)
4.75 mm	14	14	1.4	98.6
2.36 mm	10	24	2.4	97.6
1.18 mm	29	53	5.3	94.7
600µ	123	176	17.6	82.4
300µ	621	744	74.4	25.6
150µ	22	964	96.4	3.6
Pan	28	992	99.2	0.8

Finess modulus for bottom ash 2.97

Table 2 Sieve analysis test for Foundry Sand IS Sieve Size

IS Sieve Size	Weight Retained (gms)	Cumulative Weight Retained (gms)	Cumulative Percentage Weight Retained (gms)	Cumulative Percentage Passing (gms)
4.75 mm	7	7	0.7	99.30
2.36 mm	10	17	1.71	98.29
1.18 mm	10	27	2.72	97.28
600µ	80	107	10.77	89.23
300µ	493	600	60.42	39.58
150µ	293	893	89.92	10.08
Pan	100	993	100	0

Finess modulus for foundry sand 2.8

Table 3 Sieve analysis test for Fine Aggregate (sand) IS Sieve Size

IS Sieve Size	Weight Retained (gms)	Cumulative Weight Retained (gms)	Cumulative Percentage Weight Retained (gms)	Cumulative Percentage Passing (gms)
4.75 mm	50	50	5	95

2.36 mm	55	105	10.5	89.5
1.18 mm	265	370	37	63
600µ	345	715	71.5	28.5
300µ	260	975	97.5	2.5
150µ	15	990	99	1
Pan	10	1000	100	0

Finess modulus for fine aggregate (sand) 3.2

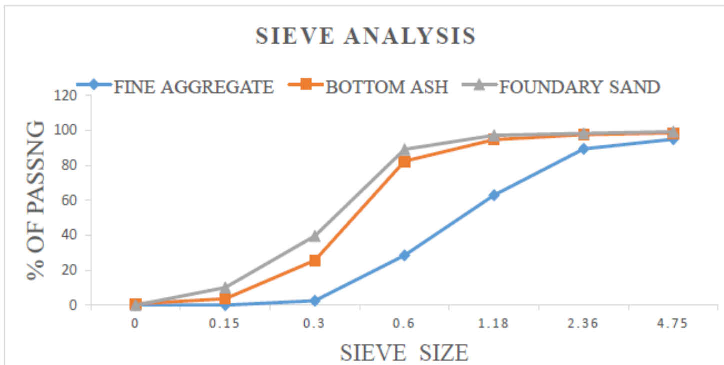

Figure 1. Sieve Analysis

From the above Figure 1 it is evident the sieve analysis curve of bottom ash and foundry sand is similar to that of fine aggregate. Hence it is clear the bottom ash and foundry sand can be replacement for sand in concrete. There fineness modulus of bottom ash and foundry sand is also nearly equal to the fine aggregate.

Table 4. Specific Gravity of different Concrete Ingredients

Sl. No	Material	Specific Gravity
1	Cement	3.15
2	Fine aggregate	2.66
3	Bottom ash	2.20
4	Foundry sand	2.63

SPECIFIC GRAVITY TEST

Specific gravity test is defined as the ratio between the weight of a given volume of the material and weight of an equal volume of standard material. The value is dimensionless. The specific gravity test is carried out to find out the density and strength or quality of material.

The test results of cement, Fine aggregate, Bottom ash, Foundry sand and Coarse aggregate are furnished in below table 4

Slump Test

Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction.

Table 5 Workability of Concrete

Percentage of Replacement of Foundry Sand And Bottom Ash	Value of Slump (mm)
0	73
10	66
20	60
30	54
40	45

From the above table 5, it is evident that the slump value of the fresh concrete decreases when the replacement percentage of the foundry sand and bottom ash is increased. Lesser the value of water lesser will be the workability of concrete. The workability of concrete decrease when the replacement percentage of bottom ash and foundry sand is increased, because, bottom ash is an water absorption material so it will absorb more water content in the fresh concrete mixture. This reduced water content corresponds to the reduced workability of concrete, and as the percentage of replacement of the bottom ash and foundry sand increases the amount of water is decreased. This is the reason for the continuous decreases in the value of slump of fresh concrete. Very poor slump value is not good for concrete, it will leads to segregation and separation of aggregates which in turn leads to poor strength of concrete. So optimum replacement value of foundry sand and bottom ash has to be founded.

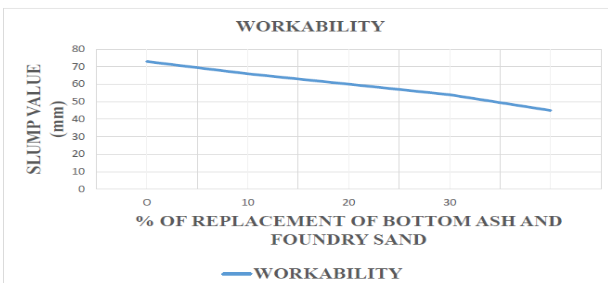

Figure 2. Workability of Concrete.

COMPRESSION STRENGTH TEST ON CUBES

The Compressive strength test of concrete mix is carried out to find out the effect of replacing fine aggregates as bottom ash and foundry sand. Properties of concrete can be obtained by identifying the test results of compression strength have been studied and the results are as follows.

Table 6. Compression strength of cube on 28th day

SI.No	Material			Area (mm^2)	Load (kN)	Compressive Strength (N/mm^2)
	FA	BA	FS			
1	100	0	0	22500	650	28.88
2	90	5	5	22500	663	29.5
3	80	10	10	22500	684	30.4
4	70	15	15	22500	585	26
5	60	20	20	22500	562	25

Figure 3 Shows the optimum compressive strength is obtained at the 10% replacement of foundry sand and 10% replacement of bottom ash for fine aggregate (80-10-10).

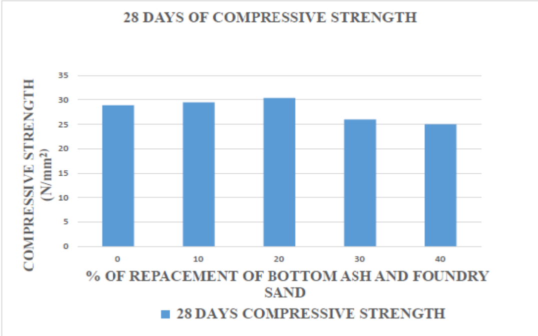

Figure 3. Compression strength of cube on 28th day

The compressive strength for 10% replacement of foundry sand and 10% replacement of bottom ash for fine aggregate is 30.4 N/mm2, which is nearly 10.52% higher than that of the conventional concrete specimen, which is 28.88 N/mm^2.

SPLIT TENSILE STRENGTH TEST ON CYLINDERS

Concrete is strong in compression but weak in tension. There is no direct method, available to determine the tensile strength of concrete. One of the indirect method available is split tensile test.

The values of splitting tensile strength for different replacement levels of bottom ash and foundry sand contents (0%, 10%, 20% 30%, and 40%) at the end of curing period (28 days) are shown in Table 7.

Table 7 Split tensile strength of cylinder on 28th day

SI.No	Material			Dimension (mm)		Load (kN)	Tensile Strength (N/mm^2)
	FA	BA	FS	DIA	LEN		
1	100	0	0	150	300	200	2.82
2	90	5	5	150	300	210	2.97
3	80	10	10	150	300	218	3.18
4	70	15	15	150	300	185	2.61
5	60	20	20	150	300	175	2.47

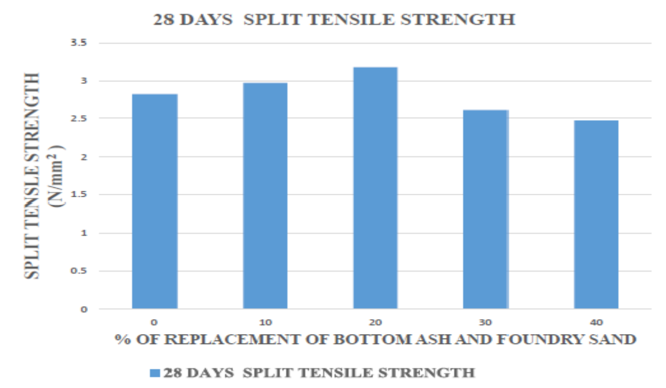

Figure 4. Split tensile strength of cylinder on 28th day

Figure 4 Shows the optimum Split tensile strength is obtained at the 10% replacement of foundry sand and 10% replacement of bottom ash for fine aggregate (80-10-10). The Split tensile strength for 10% replacement of foundry sand and 10% replacement of bottom ash for fine aggregate is 3.18 N/mm^2, which is nearly 11.27% higher than that of the conventional concrete specimen, which is 2.82 N/mm^2.

CONCLUSIONS

1. The sieve analysis results prove that the Foundry sand, Bottom ash can be replaced for the fine aggregate in concrete.
2. The compressive strength of concrete replaced with the foundry sand, bottom ash has shown better results than conventional concrete.
3. The 28 days compressive strength of the specimen replaced with 10% of foundry sand and 10% of bottom ash has proved the optimum compressive strength.
4. The optimum compressive strength of specimen, 30.04 MPa, is nearly 10.52% more than the compressive strength of conventional concrete.
5. The optimum split tensile strength of specimen, 3.18 MPa, is nearly 11.27% more than that the split tensile strength of conventional concrete.

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Conflict of Interest

None of the authors have any conflicts of interest to declare.

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