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Influence of Addition of Pond Ash as Partial Replacement with Sand and Cement on the Properties of Mortar

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Abstract*— This paper presents an experimental investigation on the effect of addition of pond ash partially replaced with cement and sand in the mortar. Effect of pond ash on compressive strength, flexural strength and bulk density were observed under standard curing conditions. Pond ash of 0% to 40% (with increase of 5%) by weight to cement and sand replacement respectively were used. The specimens were casted and cured under standard curing conditions for 3, 7, 28 and 90 days. At the end of each curing period, compressive strength and flexural strength values were determined. Dry bulk densities for each replacement were recorded after 28 days curing period. The result shows that in case of cement replacement in compression as well as flexure strength gives higher values for 15% to 20% replacement of pond ash. The result of dry bulk density test also indicates that the values of density for cement replacement as well as sand replacement decreases with increase in percentage of pond ash.

Index Terms*— bulk dry density, cement replacement, compressive strength, pond ash, sand replacement.

I. INTRODUCTION

It is expected that the increase of cement production would be 1.4 billion tones in 1995 to almost 2 billion tones in the year 2010. This results in the emission of about 2 billion tones of CO_2 in the environment per year [1]. The huge amount of pond ash accumulated around the thermal power stations is still posing threat to environment. The utilization of pond ash as a building material is one of the possible way of its sustainable management. In the present study, an attempt is made to ascertain the possibility of using the pond ash as a replacement of sand in plaster mortar**.**

Cement manufacturing process consumes about $7.36x10^6$ KJ energy per one tonne of cement [2]. The amount of CO_2 is about one tonne for production of one tonne of cement [3]. The main objective of using fly ash in high strength concrete is to reduce heat generation and to obtain better durability properties [4]. Some cement manufacturing companies have started using fly ash in cement production during the last five years, but the overall percentage utilization is very small and most of the part of this thermal power plant waste is dumped at land hills or in ash pond dykes [5].

The fly ash can be utilized in cement concrete and mortar as an ingredient or partial replacement of cement and sand. The replacement of Ordinary Portland Cement (OPC) may vary from 15 to 35 % or even higher percentage in mass concrete.

According to BIS: 456 [6] the pond ash can also be utilized in manufacturing of Light Weight Aerated Concrete (LWAC) products such as blocks, panels, reinforced slab, etc, which are much lighter than conventional materials. The bulk density of product ranges from 500kg/m^3 to 1800kg/m^3, depending upon reinforcement. The use of fly ash blocks in housing construction can result nearly 40 % reduction in dead weight and about 80% saving in consumption of mortar in comparison to conventional brick work.

II. EXPERIMENTAL DETAILS

A. Material

Ordinary Portland cement conforming to BIS: 8112 [7] and ASTM C-150 [8] was used throughout the research work. Sand confirms to BIS:383(1970)[9] and IS:2116-1980 [10], free from natural resources or crushed stone sand, not contained any appreciable amount of clay balls or pallets, not contained any harmful impurities have been used. The sand was properly graded and of medium sized with a fineness modulus of 2.0 to 2.2.

Pond ash as per IS:3812:2003 [11], the generic name of the waste product due to burning of coal or lignite in the boiler of a thermal power plant is pulverized fuel ash (PFA)11,12. PFA can be fly ash, bottom ash, pond ash or mound ash. Fly ash is the pulverized fuel ash extracted from the flue gases by any suitable process like cyclone separation or electrostatic precipitation. PFA collected from the bottom of boilers by any suitable process is termed as bottom ash. The terminology pond ash is used when fly ash or bottom ash or both mixed in any proportion is conveyed in the form of water slurry is deposited in pond or lagoon. ASTM C 618-03 categorizes fly ash into two classes; class F and class C, which are equivalent to SFA and CFA, respectively of IS 3812: 2003. Bureau of Indian Standards (BIS) has published the specifications of pulverized fuel ash, IS 3812: 2003 in two parts, Part-I for use as pozzolana in cement, cement mortar and concrete and Part-II for use as admixture in cement mortar and concrete. Both the parts of the code define fly ash as a special class of PFA. This code can be adopted for characterization depending on its use as pozzolana or mineral admixture.

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B. Test Methods

All laboratory experiments were conducted in general accordance with the applicable procedures outlined by the European Norm EN 1015-10 (1999) [12], ASTM C 270, ASTM C780 [13]. To evaluate the possibility of reducing the cement content of rendering and plastering mortars with pond ash, three tests dry bulk density test, compressive strength test and flexural strength test were performed. The reference mortar was a cement and sand mortar without addition of pond ash.

C. Mix Proportions

In the present study, total of 2 mixes in 1:4 fractions is prepared. In the first series of mixes one part of cement and 4 parts of sand & pond ash is taken with pond ash replacement in sand varying from 0 to 40%. In the second series of mixes one part of cement & pond ash (PA) and 4 parts of sand is taken with pond ash replacement in cement varying from 0 to 40%. All mixes are prepared at room temperature. The details of the mix proportions are given in the Table1.

III. EXPERIMENTAL RESULTS AND DISCUSSION

A. Dry Bulk Density

All the test were performed in accordance with European Norms EN 1015-10 (1999). For each type of mortar, a sample of three prismatic specimens of 70.7 mm x 70.7 mm x 70.7 mm was used. Dry bulk densities for series I and II is presented in Figure.1 against the different replacement percentages. The dry density of mortar incorporating pond ash for series-I (sand replacement) is observed to be decrease by 2.24 % for 10% pond ash replacement.

Replacement %	M_{dry}	M_{sat}	M_i	$M_{sat} - M_i$	V_s $(M_{sat} - M_i)/\rho_w$	B.D.D M_{dry}/V_s
	Kg	Kg	Kg	Kg	m^3	Kg/m^3
0	0.768	0.786	0.456	0.33	0.00033	2327.27
5	0.77	0.77	0.424	0.346	0.000346	2225.43
10	0.76	0.761	0.419	0.342	0.000342	2222.22
15	0.75	0.752	0.414	0.338	0.000338	2218.93
20	0.746	0.748	0.41	0.338	0.000338	2207.1
25	0.742	0.744	0.406	0.338	0.000338	2195.27
30	0.713	0.715	0.389	0.326	0.000326	2187.12
35	0.684	0.686	0.372	0.314	0.000314	2178.34
40	0.77	0.77	0.424	0.346	0.000346	2225.43

Table 01: Details of mix proportions

Mortar Mix with replacement %	Series–I sand replacement with PA (1:4)		Series–II cement replacement with PA (1:4)		Water/ binder ratio
	Cement	Sand + PA	Cement + PA	Sand	
0 %	1	4.0 + 0	1.0 + 0	4	0.35
5 %	1	3.8+ 0.2	0.95 + 0.5	4	0.353
10 %	1	3.6+ 0.4	0.90 + 0.10	4	0.355
15 %	1	3.4+ 0.6	0.85 + 0.15	4	0.359
20 %	1	3.2+ 0.8	0.80 + 0.20	4	0.363
25 %	1	3.0+ 1.0	0.75 + 0.25	4	0.360
30 %	1	2.8+ 1.2	0.70 + 0.30	4	0.357
35 %	1	2.6+ 1.4	0.65 + 0.35	4	0.357
40 %	1	2.4+ 1.6	0.60 + 0.40	4	0.358

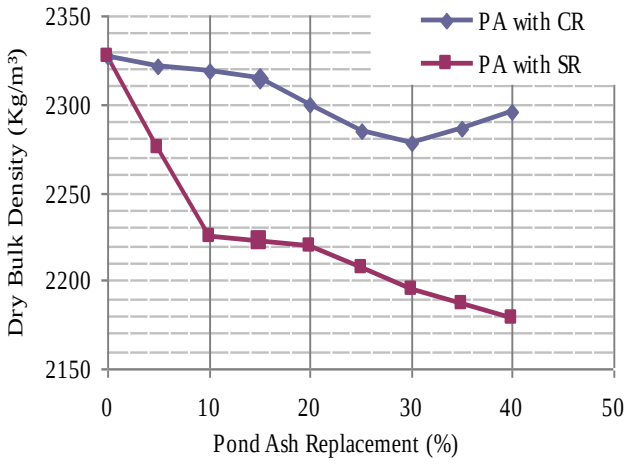

Fig.1. Dry bulk density of pond ash mortar specimen: cement and sand replacement.

Table 02: Dry bulk Density of Mortar Specimen [Series-II] Cement Replacement

Replacement %	M_{dry}	M_{sat}	M_i	$M_{sat} - M_i$	V_s $(M_{sat} - M_i)/\rho_w$	B.D.D M_{dry}/V_s
	Kg	Kg	Kg	Kg	m^3	Kg/m^3
0	0.768	0.786	0.456	0.330	0.000330	2327.27
5	0.768	0.783	0.453	0.335	0.000335	2321.21
10	0.770	0.780	0.450	0.330	0.000330	2319.27
15	0.761	0.775	0.436	0.342	0.000342	2315.15
20	0.752	0.770	0.420	0.350	0.000350	2299.69
25	0.745	0.762	0.422	0.337	0.000337	2285.28
30	0.738	0.754	0.430	0.324	0.000324	2277.78
35	0.750	0.763	0.435	0.328	0.000328	2286.63
40	0.762	0.772	0.440	0.332	0.000332	2295.18

Table 03: Dry bulk Density of Mortar Specimen [Series-I] Sand Replacement

M_{dry} = Dry weight *M_{sat} = Saturated weight*
M_i = Immersed weight *V_s = Saturated volume*
B.D.D = Bulk dry density

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In further replacement up to 40% it is observed that the dry density decreases with increase in pond ash content in mortar. For series-II (cement replacement) the bulk densities for all replacement is gradually decreases with increased percentage of pond ash content.

B. Compressive Strength

The compressive strength of OPC; and pond ash mortar of series-I and series-II are plotted in Fig.2 and Fig.3 respectively. In case of pond ash mortar, the compressive strength containing 30 % replacement is higher than standards and mortar for 28 days curing period. The strength development is quit slowly in case of all replacement after 3 and 7 days.

Incorporating the 40 % pond ash decreases compressive strength after 28 and 90 days. Compressive strength for series-II (Cement Replacement), which is also increasing with time, but it is observed that the rate of strength gaining decreases with increased rate of replacement incorporating pond ash percentage.

C. Flexural Strength

The flexural strength of mortar mixes replaced with pond ash, were determined at the stage of 28 days curing period. The flexural strength of specimens tested is plotted for all replacement levels of pond ash with sand and cement as shown in Fig.4. Series-I is for sand replacement while series-II is for cement replacement.

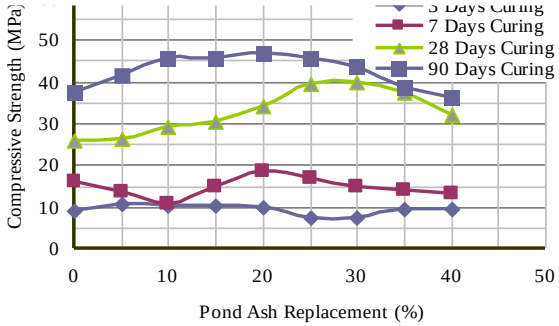

Fig. 2. Compressive strengths of pond ash mortar for 3, 7, 28 and 90 days: (Series-I).

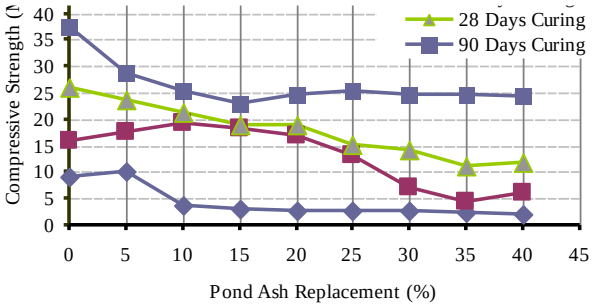

Fig. 3. Compressive strengths of pond ash mortar for 3, 7, 28 and 90: (Series-II).

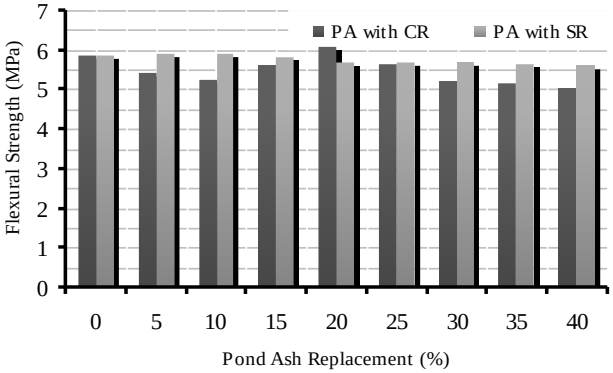

Fig. 4. Flexural strength of pond ash mortar (Series-I and II).

Flexural strength values for pond ash replacement mortar in comparison with standard cement mortar strength are observed to be increase in 5% and 10% replacement. In the further increased percentage replacement the flexural strength decreases. This is related with decrease in cement content and increase in water/binder ratio in the comparison of standard cement mortar.

IV. CONCLUSION

Based on the experimental results, the following conclusions can be drawn-

1. Pond ash mortar exhibited higher compressive strength as compared to ordinary Portland cement (OPC) mortar for series-I (sand replacement).
2. For series-I, the bulk dry density reduces with increase in percentage replacement of pond ash when compared with OPC mortar. The rate of decrease in bulk dry density of mortar is observed to be more for series-II (cement replacement) as compared to series-I (sand replacement).
3. For series-I, pond ash mortar gives maximum compressive strength for 30 % replacement for 28 days curing period. Also gives maximum compressive strength for 20 % replacement for 90 days curing period.
4. For series-I, flexural strength increases for 5% and 10% replacement but for other replacement percentages, it decreases. While replaced with cement (series-II), the compressive strength for all the replacement percentage decreases. For series-II, the flexural strength value is more for 20% replacement as compared to all other replacements.
5. The optimum pond ash content is observed to be 30% of sand replacement shows around 54 % higher compressive strength after 28 days curing.

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