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A STUDY ON DIFFERENT PROPERTIES OF CEMENT MORTAR BY PARTIAL REPLACEMENT OF FINE AGGREGATE WITH BOTTOM ASH

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ABSTRACT
This paper consists of the results of an experimental research on the effect of bottom ash as partial replacement of natural sand on the properties of cement mortar. The experimental works were carried out by replacement of fine aggregate with varying percentages of bottom ash i.e. 15%, 20%, 25% and 30%. As the microstructure of mortar matrix changes with varying water cement ratio, the w/c was kept constant i.e. 0.45.Mortar cubes of 70.6mm×70.6mm×70.6mm were casted and vibrated on an electrically operated vibrator. Then various tests including compressive strength, water permeable porosity (apparent porosity), percentage of water absorption, sorptivity were performed on mortar cubes replaced with bottom ash. The results were compared with the results of control mix and all the tests were performed at 3, 7, 28, 56 and 90 days. Based on the results, it is concluded that fine aggregates can be replaced up to 20% with bottom ash in cement mortar.

Keywords: bottom ash, fine aggregate, mortar, compressive strength, water permeable porosity test, percentage of water absorption test, coefficient of water absorption test, XRD

INTRODUCTION
There is scarcity of availability of natural aggregates due to rapid development in construction technology. Nowadays deforestation and withdrawal of natural aggregates from river beds, lakes & other water bodies have brought about huge ecological issues. Moreover,due to the exploitation of natural sand from water bodies, filtration of rain water attained is being lost, in this way causing defilement of water reserves utilized for consumptionby humans. To counteract contamination, the authorities are therefore, forcing more stringent limitations on the withdrawal of natural aggregates and crushing has been banned.The most ideal approach for conquering this concern is to discover substitute of conventional natural aggregates for construction,as one day these natural resources will become extinct.

LITERATURE REVIEW
In the review of the literature it was studied that Prasanna et al., concluded that the Washed Bottom Ash can be efficiently

supplemented to normal concrete in small proportions between 0% and 20% [8].Bakoshi et al., in their experiment conducted by replacing 10-40% fine aggregate with bottom ash found that as the curing period and the replacement ratio of fine aggregate increases the compressive and tensile strength of bottom ash based concrete increases[2]. Whereas study conducted by Kasemchaisiri et al., concluded that thecompressivestrength decreases with the increase in content of bottom ash. The replacement of 10% bottom ash gave the optimized result of compressive strength at 56 days by improved pore refinement [6]. Sandhya et al., concluded that the 28 days flexural strength and split tensile strength of concrete replaced with 20%, 30%, 40% and 50% bottom ash has a reducing value when compared with plain concrete specimen and also found that the workability of concrete decreases with the increase in bottom ash percentage [10]. Archana et al., studied that the increasing content of bottom ash in concrete increases the water demand which can be overcome by using superplasticizer in it. Results of the experimental work showed that bottom ash concrete requires more time to attain required strength when compared to conventional concrete [1]. Sachdevaet al., replaced coal bottom ash in varying percentages of 10%, 20%, 30% and 40% in place of fine aggregate and on the test results concluded that workability of bottom ash concrete decreases when percentage of replacement is increased as bottom ash is more porous as compared to fine aggregate. The compressive strength and flexural strength decreases with increase in replacements, the decrease in strengths is due to replacement of stronger material with weaker material [9]. More et al., concluded that 20% replacement of pond ash as sand replacement gives optimum results of compressive strength and durability they studied that pond ash concrete gain strength at faster rate beyond 28 days. It was found that the increase in curing period increases the compressive strength of pond ash concrete. In aggressive environment i.e. chloride solution and sulfate solution, there were no adverse consequences found on pond ash concrete [7].

MATERIALS USED AND ITS PROPERTIES

Cement

In this experimental work, Birla UttamOrdinary Portland Cement of 43 grade was used.The cement was fresh and without any lumps. The results of physical properties of cement are specific gravity is 3.0, normal consistency (% by weight of cement) is 27, initial setting time (minutes) is 80, Final setting time (minutes) is 215 and soundness is 1mm.

Fine Aggregate

Fine aggregate used was Badarpur sand without any organic impurities and confirming to grading zone II of Table 4 of IS: 383-2016. The results of physical properties of Fine aggregate are gradation zone is Zone-II, fineness modulus is 2.99, specific gravity is 2.66, silt and clay content (%) is 5.3, Bulk Density (kg/m^3) is 1646.

Bottom Ash

Bottom ash used in this work was collected from NTPC Dadri. The results of physical properties of bottom **a**sh are gradation zone is Zone-III, fineness modulus is 2.53, specific gravity is

1.83,silt and clay content (%) is 17.7 and bulk density (kg/m^3) is 812.3.

Table 1: Chemical Composition of Bottom Ash

S No.	Parameters	% by Weight Test Results
1.	Silica, SiO_2	51.25
2.	Alumina ,Al_2O_3	20.18
3.	Iron Oxide , Fe_2O_3	13.32
4.	Lime, CaO	7.04
5.	Magnesia, MgO	0.75
6.	Sodium Oxide, Na_2O	0.27
7.	Potassium Oxide, K_2O	1.27
8.	Loss on ignition, LOI	3.05
9.	Sulphuric anhydride, SO_3	0.31

Superplasticizer

The superplasticizer used in this work was Naphthalene Formaldehyde based super-plasticizer, CEMWET SP-3000 (NR) high range water reducer in the form of an aqueous solutionwithout any chlorides. The super -plasticizer is available as a dark brown colored aqueous solution with standard specifications of ASTM C 494 Type G and IS: 9103-1999 [5].

EXPERIMENTAL PROGRAM

Table 2: Quantities of material for different mixes for one cube

Mix	Cement (g / mm^3)	Fine Aggregate (g/ mm^3)	Bottom Ash(g/ mm^3)	Admixture (%)	Water (including 2% for water absorption) (ml)
M1	272	720	0	0.8%	136ml
M2	272	612	108	1%	136ml
M3	272	576	144	1.5%	136ml
M4	272	540	180	1.5%	136ml
M5	272	504	216	2%	136ml

Compressive Strength

A set of standard size of 60 cubes were made for 5 different trial mixes. Table 4.1 shows the materialquantities for different mortar mixes for one cube. The cubes specimen of size 70.6mm^3 were cast using the different designed mortar mixes and tested for compressive strength in accordance with IS: 516-1959, [4].

Fig. 1: Test specimens for compressive strength

Water Permeable Porosity Test

This test is also called as Apparent Porosity test. The cubes of size 70.6mm×70.6mm×70.6mm, after curingfor specific days is surface dried and is weighed, submerged weight of the specimenis taken and then is oven dried at 65ºC for 24 hours after which it is cooled at room temperature for 12 hours and then the dry weight is taken. The temperature of 65º c is curing temperature selected for drying the specimen as higher temperature above 105º c may cause the breaking of week microstructure of mortar specimen thereby resulting in incorrect values.

The following formula is used to calculate the apparent porosity of a mortar specimen:

$$\text{Apparent Porosity} = \frac{(W_{sat} - W_d)}{(W_{sat} - W_{sub})} \times 100\%$$

Where

W_{sat} = saturated weight of the specimen

W_d = weight of specimen after oven drying

W_{sub} = submerged weight of the specimen

Water Absorption Test

The porosity was measured in terms of water absorption by soaking the specimens in water.The porosities of the controlled specimen and specimens with bottom ash were measured according to BS 1881-122 [3], the specimen of size 70.6mm×70.6mm×70.6mm, were dried at a controlled temperature of 65ºC for 24hr. after cooling the specimen at room temperature for 12hr. the specimen is then fully immersed in a water tank for 6 hr. the specimen is then taken out, surface dried and is weighed. The following formula was used for calculating percentage water absorption.

$$\text{Percentage water absorption} = \frac{W_s - W_d}{W_d} \times 100\%$$

Where

W_s = saturated weight of specimen

W_d = Oven dry weight of specimen

Sorptivity Test

The amount of absorption rate of any homogeneous material by means of capillary rise is defined as sorptivity. Specimen size of 70.6mm×70.6mm×70.6mm were taken out after specific curing period and is kept in oven for drying at a controlled temperature of 65ºC for 24hr. then cooled for 12hr. at room temperature the specimen is then weighed. The specimen is then kept in the assembly by submerging the specimen with water level not more than 5mm above the base of the specimen and the peripheral surface flow is prohibited by applying a non-absorbent coating as shown in Fig. 4.2. The specimen is then kept for 60 minutes in the water and then the specimen is surface dried and is weighed with weighing balance accurate up to 0.1 mg. Sorptivity (S) is the tendency of a porous material to transmit and absorb water by the capillarity action.

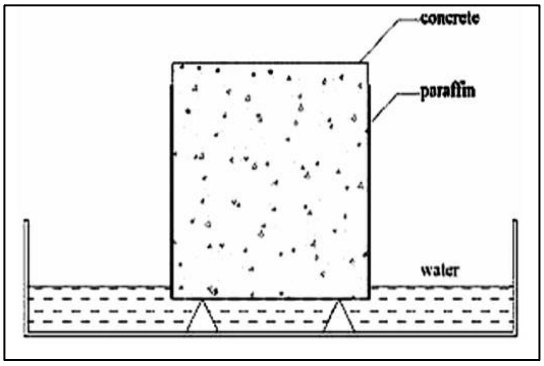

Fig.2: Schematic Diagram for Sorptivity Test

The formula to calculate sorptivity is as follows

$$S = \frac{I}{\sqrt{t}}$$

Where;

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S= sorptivity in mm,

t= elapsed time in minute.

I=Δw/Ad

Δw= change in weight = W_2-W_1

W_1 = Oven dry weight of specimen in grams

W_2 = Weight of specimen after 60 minutes capillary suction of water in grams.

A= surface area of the specimen through which water penetrated.

d= density of water

X-Ray diffractometer test

X-ray diffraction is employed on the crystalline powders for the identification and quantification of crystalline phases. This can be useful in finding the purity of any crystalline powder. Each crystalline solid has its unique characteristic pattern, depending upon the packing and inter atomic distance when the X-rays intersect the atoms at different indices the crystallography of the element is determined. For preparing the sample the cubes are finely crushed and then passed through the 100 micron sieve and the passed material is taken in amount of 25 to 30 grams and then should be placed in the discs which are then placed in the XRD equipment for finding the results.

RESULTS AND DISCUSSIONS

Compressive strength

Table 3: Compressive Strength and Unit Weight of Specimen

Mix	Compressive Strength (MPa)				
	3 Days	7 Days	28 Days	56 Days	90 Days
M1	27.73	30.8	45.06	55.39	60.05
M2	14.38	18.9	27.04	38.15	44.66
M3	18.91	31.17	39.62	57.24	63.08
M4	15.53	19.86	36.10	52.12	59.46
M5	0	8.6	13.60	17.68	23.93

The graphical representations of compressive strengths (3, 7, 28, 56 & 90 days) for different mixes are given in Fig. 5.1.

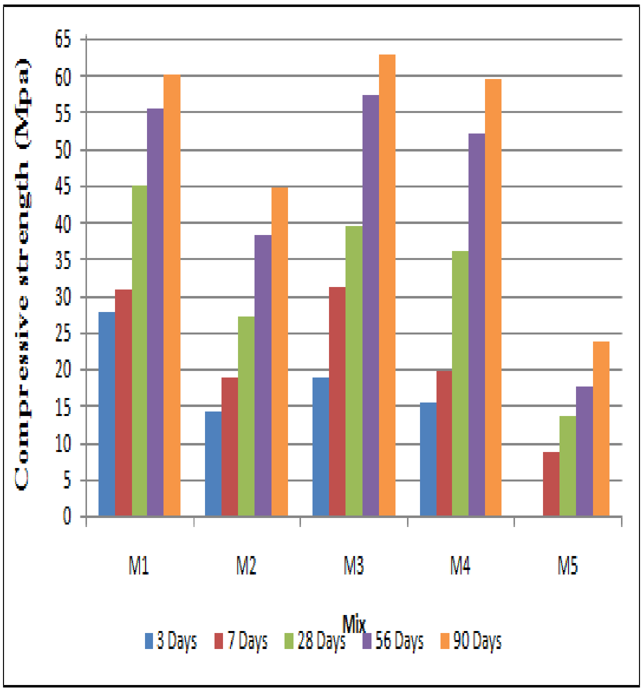

Fig. 3: Compressive Strengths of Different Mixes

From Fig. 5.1, it is observed that when the values of compressive strength are compared with mix M1 which is a controlled mix, With the increase in bottom ash content the compressive strength do not show any significant increase in the mixes M2, M4 and M5. However, the mix M3 in which the fine aggregate was replaced by 20% bottom ash shows a significant increase in compressive strength at 90 days. After further increase in the percentage of bottom ash in mix M5 the result shows that the compressive strength decreases drastically. The graph shows a drastic decrease in the strength of mortar cubes in mixes M2, M4 and M5 due to the weak microstructure of bottom ash, which do not form proper bonding with other

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ingredients. Mix M5 shows zero reading at 3 days because the ingredients get dispersed during demolding. In case of all the mixes, the strength gain starts after 28 days till 25% replacement was done.

Water Permeable Porosity Test (Apparent Porosity Test)

Table 4: Percent apparent porosity of specimens

Mix	% Apparent Porosity				
	3 Days	7 Days	28 Days	56 Days	90 Days
M1	3.68	3.89	2.69	1.82	0.8
M2	9.29	7.04	4.56	2.82	1.08
M3	8.04	8.23	6.70	4.49	2.28
M4	14.18	10.24	8.65	5.27	3.56
M5	0	18.57	10.82	5.18	4.28

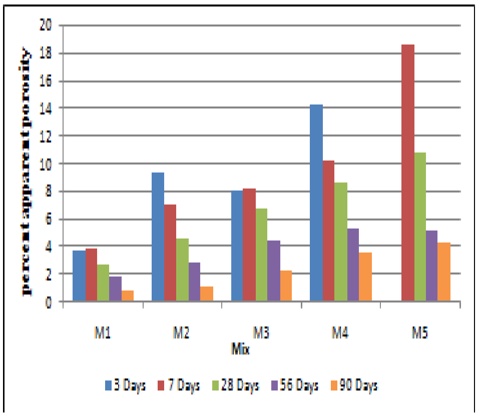

Fig. 4: Graphical representation of Percent apparent porosity of specimens

The graphical representation of apparent porosity test shows that by comparing results obtained with the mix M1 which is a controlled mix, it was found that none of the mix proportion showed better results on different curing periods. The values of different mixes i.e. mix M2, M3, M4 and M5 are comparatively higher than values of mix M1. But if we compare mixes M2, M3, M4 and M5, mix M2 shows better results i.e. it shows a low value of apparent porosity at 90 days. Furthermore the apparent porosity of mix M5 which contains 30% bottom ash in it has a very high porosity value by which we can conclude that lower the quantity of bottom ash in mix the lower will be the apparent porosity of the specimen. Zeroreading at 3 days is because the ingredients get dispersed during demolding.

Water Absorption Test

Table 5: Percent Water Absorption of Specimen

Mix	% Water Absorption				
	3 Days	7 Days	28 Days	56 Days	90 Days
M1	1.37	0.73	0.37	0.10	0.07
M2	1.46	1.14	0.41	0.08	0.06
M3	1.66	1.04	0.61	0.06	0.03
M4	2.82	1.37	0.64	0.12	0.09
M5	0	5.81	1.17	0.19	0.11

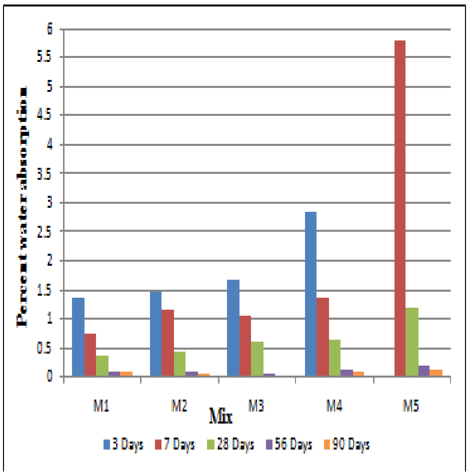

Fig. 5: Graphical representation of Percent Water Absorption

From the graph plotted for the values of water absorption it is observed that the capillary suction of mix M3 when compared to the controlled mix i.e. mix M1 shows lower value of water absorption at 90 days, also when compared to other mixes having different proportion of bottom ash mix M3 is the most optimal mix. Further if we study the behavior of mix M5 which contains 30% bottom ash in it has a very high value of water absorption at 7 days and 28 days curing period. Mix M5 shows zero reading at 3 days because the ingredients get dispersed during demolding. The graph shows such a drastic increase in the value in mix M5 because bottom ash has a property of water retention which results in such deviation.Based on the test results, it is observed that mix M3 having 20% bottom ash showsthe lowestvalue of water absorption.

Sorptivity Test

Table 6: Sorptivity of specimen

Mix	Sorptivity (mm)				
	3 Days	7 Days	28 Days	56 Days	90 Days
M1	0.30	0.11	0.05	0.02	0.01
M2	0.22	0.14	0.04	0.02	0.01
M3	0.21	0.12	0.06	0.02	0.01
M4	0.31	0.14	0.06	0.02	0.01
M5	0	0.53	0.10	0.02	0.01

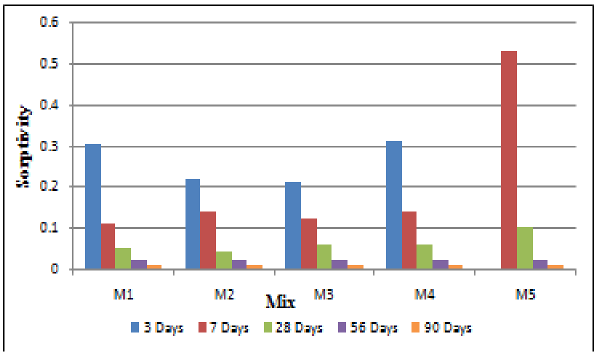

Fig. 6: Graphical representation of Sorptivity values

Figure 5.4 show that the values obtained by sorptivity test, when compared with the controlled mix, mix M3 which contains 20% bottom ash in it shows a very good result. Therefore it is inferred that the values obtained at different days i.e. at 3 days, 7 days and 28 days are comparatively lower than that of the controlled mix which is a good indication that if 20% bottom ash used in any composite material will not be affected by the environmental conditions. In other words if it is kept in the vicinity of water capillary action will not affect the composite material. But if we notice the 90 days readings of all the mixes the values comes out to be same which means that after 28 days the pore refinement begin, therefore gives a constant value in all mixes.

X-Ray diffractometer test

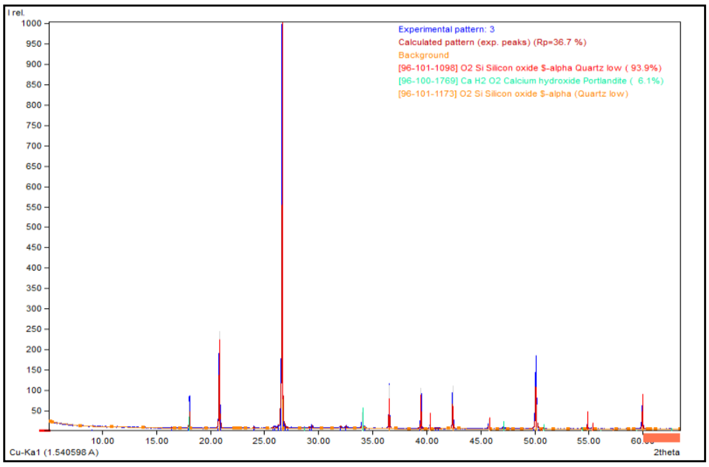

Fig. 7: XRD graph of Bottom ash only

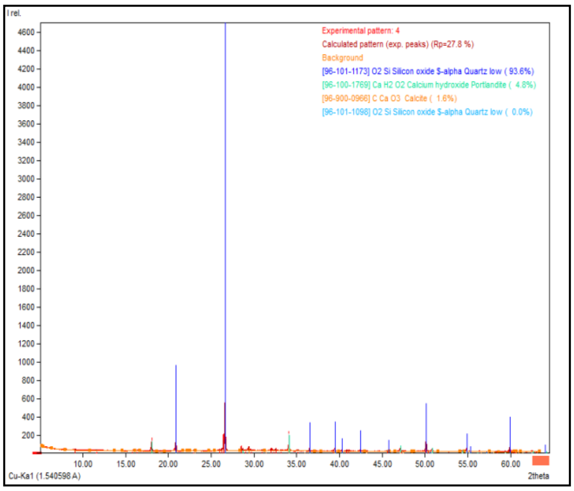

Fig. 8: XRD graph of 20% replacement with bottom ash

CONCLUSIONS

- From the results, bottom ash has a property of water retention so usage of higher percentage of bottom ash decreases the workability of mortar mix.
- The compressive strength of bottom ash based mortar mix is inversely proportional to the percentage of bottom ash replaced in the mortar mix.
- Mortar mix in which fine aggregate is replaced with 20% bottom ash shows a significant increase in compressive strength at 90 days.
- By the results obtained it is found that bottom ash cannot be used where early strength and structural stability is required.
- The average density of bottom ash based mortar mix is lower than that of normal cement mortar as bottom ash is very light in weight as compared to fine aggregate.
- The results of apparent porosity test indicate that the increase in replacement of fine aggregate with bottom ash will increase the value of apparent porosity.
- It has been observed that when the fine aggregate is replaced by 20% bottom ash the capillary suction is very low as compared to normal mortar at 90 days which means that the percentage of water absorption is very low.
- The results of sorptivity shows that by replacing fine aggregate with 20% bottom ash, the capillary rise at 28 days is lower than that of normal mortar.
- By summing up all the above conclusions we can say that by replacing fine aggregate with 20% bottom ash in mortar mix we get an optimized mix.

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