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Effect of Bottom Ash as a Mineral Admixture in Concrete

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Abstract : Solid waste management is important for the well-being of our society. Bottom ash, a by-product from coal has several issues related with its disposal. This study investigates the effect of bottom ash as a supplementary cementitious material in concrete. Bottom ash is substituted in 0, 10, 20 and 30% by weight of cement. Slump test, compressive and split tensile strength of concrete were tested. The test results indicate that the substitution of bottom ash for cement improves the strength properties of concrete. The slump value of concrete reduces as the bottom ash increased. The compressive strength of concrete increased as bottom ash increased upto 20% replacement for cement.
Keywords : Solid waste management; bottom ash; cement replacement; slump; compressive strength.

1.0 Introduction

Solid waste management is becoming a greater issue nowadays[1]. Huge amount of solid waste is produced by various industries every year. The disposal of solid wastes produces numerous environmental hazards such as air pollution, water pollution and land pollution for the surrounding living beings. These pollutions make way for many diseases to the surrounding human beings and other living organisms. The productive utilization of these solid wastes is the only way to reduce the problems associated with the disposal of solid waste. These solid wastes can be utilized in the construction industry in the production of concrete, tiles, paver blocks etc. Industrial solid wastes such as fly ash, silica fume, rice husk ash, and ground granulated blast furnace slag have been utilized as partial replacement either in the manufacture of cement or concrete based on the previous researches.

Bottom ash is a by-product from coal combustion. The impurities present in the coal are separated during the pulverization process from coal[2,3]. In the burning of coal, carbon and other combustible matter present in coal are burnt leaving the non-combustible ash behind. The finer and lighter ash particles collected through the electrostatic precipitators are called fly ash[5]. The coarser ash particles collected in the bottom of the furnace is called bottom ash. Bottom ash constitutes to about 25% of the total ash generated while fly ash constitute the remaining 75% of the ash.

At present India is the third largest consumer of coal, since 67% of the country's electricity demand is fulfilled by the coal fired thermal power plants. These coal fired thermal power plants are the main source of production of coal ash. As per CEA, report about of 57.6% of coal ash generated is utilized in the manufacturing of cement, construction of ash dykes and reclamation of low lying areas. Fly ash is already utilized in the manufacture of cement production. Some amount of bottom ash is used as partial replacement of sand but the pozzolanic property of bottom ash is not considered till now. Large volumes of bottom ash are accumulated near the coal fired thermal power plants (Mahapara Abbas et al., 2015)[4,6]. Bottom ash is generally disposed as landfills or in ash ponds. The method of disposal in landfills leads to wastage of land and land pollution. Bottom ash contains hazardous particles; therefore when bottom ash is disposed in ash ponds pose health hazards to human and the environment by spreading hazardous components and contaminating adjacent soil and underground water. Therefore it is necessary to utilize bottom ash to reduce the problems associated with the disposal of bottom ash. On the other hand, enormous amount of CO_2 is generated every year by the production of cement. Manufacture of cement is responsible for environmental problems such as emission of green house gases, extraction of natural resources for the raw materials and energy consumption. Bottomash pose chemical composition andpozzolanic properties similar to that of flyash[5]. The utilization of bottom ash as a supplementary cementitious material eliminates the disposal problems of bottom and also reduces the CO_2 emission as it replaces the cement. The utilization of bottom ash in concrete also curbs the cost of concrete construction.

The main aim of this study is to investigate the effect of bottom ash as a partial replacement of cement on the fresh and hardened properties of concrete by replacing cement in 0, 10, 20 and 30% by bottom ash.

2.0 Expermental Program

2.1 Materials

2.1.1 Cement

Ordinary Portland cement 53 grade conforming to IS 12269-1987 was used for the study. The physical properties of cement is listed in table.1.

Table.1 physical properties of cement

Property	Values obtained	IS requirements
Specific gravity	3.21	-
Fineness (% retained on 90µ sieve)	2%	< 10%
Consistency	28%	-
Initial Setting Time	40min	> 30 min
Final setting time	490 min	< 600 mins

2.1.2. Bottom Ash

Bottom ash obtained from Mettur thermal power plant, Tamilnadu was used for the study. SEM image of bottom ash is shown in fig.1. Bottom ash has spherical and irregular particles with varying particle sizes. Bottom ash was grinded in laboratory ball mill before using in concrete to get uniform particle size. The specific gravity of bottom ash was found to be 1.98. The chemical composition of bottom ash in comparison with that of cement is shown in table.2

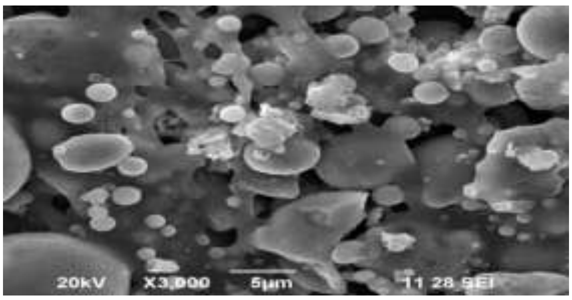

Fig.1 SEM image of bottom ash

Table.2 Chemical composition of bottom ash and cement

Chemical Composition (Wt %)	Cement	Bottom ash
SiO_2	21.0	55.47
Al_2O_3	5.4	29.76
Fe_2O_3	3.3	7.32
CaO	65.6	1.15
MgO	1.1	0.38
SO_3	2.7	-
K_2O	-	0.36
TiO_2	-	2.80
LOI	1.2	2.73

2.1.3. Coarse Aggregates

Crushed stone aggregates passing through 20mm IS sieve and retained on 4.75mm IS sieve obtained locally was used throughout the study. The physical properties of coarse aggregate used is listed in table.3

Table.3. Physical properties of coarse aggregates

Properties	Values obtained
Dry Density	1453kg/m^3
Specific gravity	2.797
Water absorption	0.52%
Fineness Modulus	3.08

2.1.4. Fine Aggregate

Clean and dry river sand passing through IS 4.75mm sieve obtained locally conforming to zone II of IS 383-1970 was used as fine aggregates. The physical properties of fine aggregates used is shown in table.4

Table.4. Physical properties of fine aggregates

Properties	Values obtained
Dry Rodded Density	1507kg/m^3
Specific gravity	2.59
Fineness Modulus	4.57
Zone	2

2.1.5. Superplasticizer

Commercially available new generation modifiedpolycarboxylated ether based super plasticizer conforming to IS 9103-1999 was used throughout the study. The specific gravity and pH value of super plasticizer was found to be 1.08 and 6 respectively.

2.2. Mix Proportions and Preparation of Specimens

Four mixes were designed including one reference mix without bottom ash and other mixes containing bottom ash (10, 20 and 30 wt %). Reference mix was designed according to IS 10262-2009[5]to obtain a target strength of 48.25 N/mm^2 at the age of 28 days. The mix proportion of reference mix is 1:1.71:1.95 by the ratio of cement: fine aggregate: coarse aggregate. The water-cement ratio is kept as 0.37 and super-plasticizer was used at 0.8% by mass of cement. Table.5 shows the mix proportions of all mixes. Bottom ash was used to replace cement and hence it was grinded in ball mill to reduce the particle size of bottom ash. Concrete mixes were mixed in laboratory drum mixer for 5 minutes and placed in appropriate moulds. The specimens were demoulded after 24±2 hours and placed in the curing tanks until testing.

Table.5 Mix Proportions

Sl.No	Mix Designation	Cement		Bottom Ash		FA	CA	W/C	Water	Super plasticizer	
		%	kg	%	Kg	kg	kg		Kg	%	kg
1	BA0	100	400	0	0	786	1201	0.37	148	0.8	3.2
2	BA10	90	360	10	40.0	786	1201	0.37	148	0.8	3.2
3	BA20	80	320	20	80	786	1201	0.37	148	0.8	3.2
4	BA30	70	280	30	120	786	1201	0.37	148	0.8	3.2

2.6. Fresh Concrete Tests

Fresh concrete properties are important for the workability and hardened strength properties of concrete. Slump cone test was used to determine the workability of the concrete in the fresh state as per IS 1199-1959[9].

2.7. Hardened Concrete Tests

Compressive strength of concrete was determined in the concrete mixes at the age of 7 and 28 days of curing. Concrete cubes of 150mm size were used for the determination of compressive strength. Three specimens for were tested in each mix and the average of the three is taken as the compressive strength of the mix. Compressive strength was done in accordance with IS 516-1959. Rate of loading for compressive strength was kept as 140kg/cm^2/min.

3.0 Result and Discussions

3.1 Slump Test

Table.3 shows the slump values of all mixes. Concrete mixes were designed for a target slump of 100mm. Slump values of all mixes ranges from 107mm to 78mm. From the slump results, it can be seen that the addition of bottom ash reduces the slump of concrete thereby increasing the water requirement of concrete. The increase bottom ash results in decrease in slump of concrete. The slump values indicate that the workability of concrete decreases as the bottom ash increases. The reduction in slump value is due to the friction between the particles. As the slump values reduce with increase in bottom ash content the water requirement for the required slump increases.

Table.3 Slump test

Sl. No	Mix	Slump Values (mm)
1	BA0	107
2	BA10	96
3	BA20	87
4	BA30	78

3.2 Compressive Strength

Compressive strength of all bottom ash mixes increases with the age of concrete. Table.6 shows the compressive strength of concrete at 7 days and 28 days of curing. From the results it can be seen that the early strength of concrete with bottom ash was low compared to the reference mix which is due to the slow reactivity of bottom ash at early ages. Fig.2 shows the variation of compressive strength with different replacement levels of bottom ash at 7 and 28 days. From fig.2 and table.4 it can be seen that at the age of 28 days the compressive strength of all mixes were found to be greater than the compressive strength of reference mix except the mix with 30% replacement. This increase in strength is due the pozzolanic action of bottom ash with calcium hydroxide formed by the hydration process which results in formation of secondary CSH gel (Olubajo O. O. et al., 2013)[11]. The formation of secondary CSH gel reduces the voids in concrete and makes the concrete denser. From fig.2 it can be seen hat compressive strength of all bottom ash mixes were time dependent. The lower strength in the mix containing 30% bottom ash is due to the higher content of bottom ash leading to slower pozzolanic reaction.

Table.6 Compressive strength

Mix	Compressive Strength in N/mm^2	
	7 Days	28 Days
BA0	35.56	48.89
BA10	34.67	50.67
BA20	31.11	52.15
BA30	29.33	47.25

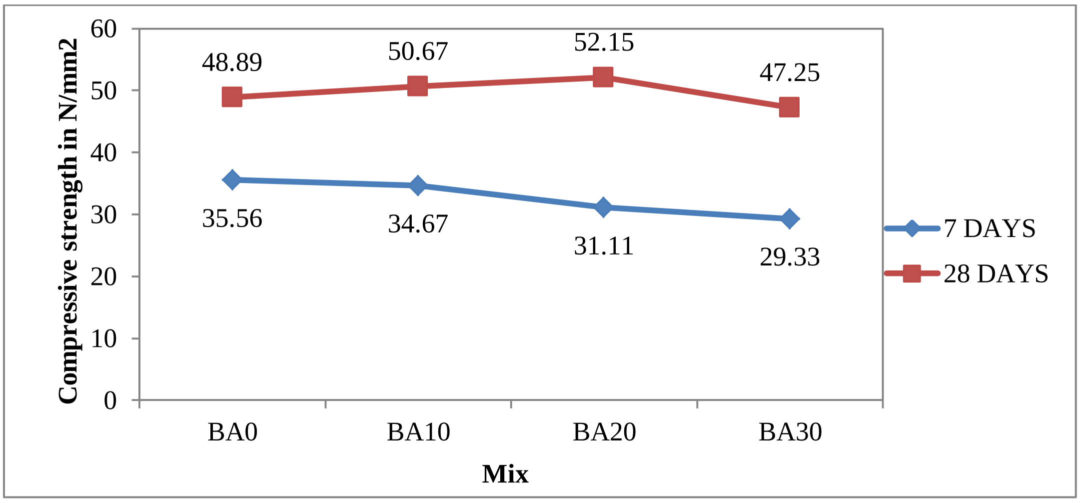

Fig.2. Compressive strength variation with bottom ash replacement

4.0 Conclusion

Based on the experimental results the following conclusions can be drawn:

1. Replacement of cement with bottom ash affects the fresh and strength properties of concrete.
2. Replacement of cement by bottom ash reduces the slump values of concrete and thereby affecting the workability of concrete.
3. Early age strength of concrete was found to be low when compared with the reference mix due to the slower pozzolanic reaction of bottom ash.
4. Compressive strength of bottom ash concrete mixes increase with an increase in age of concrete and hence the compressive strength of bottom ash concrete mixes is time-dependent.
5. Compressive strength of concrete mixes at the age of 28 days curing increase upto 20% replacement and beyond that the strength decreases.
6. Mix BA20 with 20% bottom ash replacement showed higher compressive strength at the age of 28 days.

5.0 References

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