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Strength Properties of Ternary Blended Concrete by Alccofine Bottom Ash Replacement in Cement and Blast Furnace Slag in Fine Aggregate

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Abstract

This paper presents the results of an experimental investigation carried out to evaluate the compressive strength of standard concrete. Standard concrete is made by ternary blending with partial replacement of cement by bottom ash and blast furnace slag in fine aggregate. In this study the bottom ash used in various proportions 10%, 20%, 30% in partial replacement of cement and that of alccofine 10% constant to total weight of cement and blast furnace slag used in various proportions 20%, 30% and 40% in partial replacement of fine aggregate .The mix proportions of concrete had a constant water binder ratio of 0.4 and superplasticizer was added based on the required degree of workability. The concrete specimens were cured on normal moist curing under normal atmospheric temperature. The compressive strength was determined at 7 days and 28 days. The results indicate the concrete made with these proportions generally show excellent fresh and hardened properties.

Keywords : Alccofine, Bottom Ash, Blast Furnace Slag, Compressive Strength.

INTRODUCTION

India produces approximately more than 100 million tonnes of coal ash annually. Coal-based thermal power plants all over the world facing serious problems of handling and disposal of the ash produced. The utilization of fly ash is about 30% as various engineering properties requirements that is for low technical applications such as in construction of fills and embankments, backfills, pavement base and sub base course. Bottom ash based artificial lightweight aggregate offer potential for large scale utilisation in the construction work. Apart from using it in concrete industry as cement replacement, fly ash usages by other related industries have been for cubes and bricks manufacture, cellular concrete, prefabricated items and road construction. Yet about 80% of bottom ash remains unutilised.

The management of coal fly ash produced by coal thermal power station is a major problem in many parts of the world. However, its generation tends to increase every year. Although some coal fly ash is used in a range of applications, particularly as a substitute for cement in concrete. Large amount remain unused and thus required disposal. At present, coal fly ash is used in civil engineering for production of cement, concrete, cube and artificial aggregate. Safe disposal of the ash without adversely affecting the environment and the large storage area required are major concerns.

Bottom ash is a by-product of burning coal at thermal power plants. Bottom ash particles are much coarser than the fly ash. It is a coarse, angular material of porous surface texture predominantly sand sized. This material is composed of silica, alumina, and iron with small amounts of calcium, magnesium, and sulphate. Grain size typically ranges from fine sand to gravel in size. Chemical composition of bottom ash is similar to the fly ash but typically contain greater quantity of carbon.

Bottom ash exhibits high shear strength and low compressibility. These engineering properties make bottom ash an ideal material in design construction of dam and for other civil engineering applications. Bottom ash also exhibits a relatively high permeability and grain size distribution that allows the design engineer to use it in direct contact with impervious material. Bottom ash has proved to be an economical material because it has demonstrated to have not only good engineering property but also to have constructability benefits. Bottom ash can be used as concrete aggregate for several other civil engineering applications where sand, gravel and crushed stone are used.

Government should encourage the use of bottom ash related products so that bottom ash can be used in huge quantities in many civil engineering construction purpose.

LITERATURE REVIEW

An experimental investigation of various fresh and hardened properties of concrete was reported. Tests were conducted on mixes of natural sand (known as control mix), bottom ash and mixes having equal volumes of natural sand and bottom ash. Also, mixes were developed using high range water reducing admixtures. The results indicated that the mixing water requirement increases rapidly when bottom ash is used in the concrete, also inclusion of bottom ash has no significant influence on the entrapped air content and setting times of fresh concrete. Due to the higher water requirement and yield, the compressive strength properties of the bottom ash and combined bottom ash and natural sand mixtures are lower than those of the control samples [1].

A study on the potential of using bottom ash as pozzolanic material was done. The quality was improved by grinding until the particle size retained on sieve 325 micron was less than 5% by weight. The results showed that pastes of cement with replacement by original or ground bottom ash, between 10-30% resulted in longer initial setting time, depending on the fineness of the ashes, compared to setting time of the cement paste. Original bottom ash mortar had higher water requirement than that of the cement mortar and ground bottom ash mortar had lesser water requirement than that of the cement mortar. Bottom ash could be used as a pozzolanic material if it was ground having retention on 325 micron sieve less than 5% [2].

Experimental investigations were carried out by replacing sand by equal weight of fly ash, with sand replacement levels of 0, 20 and 30 % and w/c ratio of 0.35, 0.40, 0.45 and 0.50, keeping cement content constant at 350 kg/m^3 in all mixes. Compressive strength gain and corrosion resistance was higher for sand replaced with fly ash mixtures. Also, the corrosion rate of reinforcing steel bars in concrete was lowest in 30% replacement level [3].

A study on the potential of using bottom ash from the Mae Moh power plant in Thailand as pozzolonic material. He found bottom ash which was used in concrete due to its pozzolanic reaction, improved its quality by grinding until the particle size retained on sieve 325 micron was less than 5% by weight. Bottom ashes before and after being ground were investigated and compared for their physical and chemical characteristics. The bottom ashes were used to replace Portland cement in mortar and concrete mixtures. They found that the particle of bottom ash was large, porous and a regular shapes. The grinding process reduced the particle size as well as porosity of bottom ash. Compressive strengths of mortar containing 20 to 30% of bottom ash as cement replacement were much less than that of cement mortar at all edges, but use of ground bottom ash produce higher compressive strength than the cement mortar after 60 days. They used bottom ash at 20% replacement of cement to make concrete, the concrete with higher cement content produce higher percentage of compressive strength. They concluded that ground bottom ash could be used bottom ash as a good pozzolanic material [4].

MATERIALS AND METHODS

Cement

Ordinary Portland cement Zuari 53 grade conforming to IS: 12269-1987 [5] was used in concrete.

The physical properties of the cement are listed in Table 1.

Table 1: Physical Properties of Zuari-53 Grade Cement

S.No	1	2	3	4	5		
Properties	**Specific Gravity**	**Normal Consistency**	**Initial Setting Time**	**Final Setting Time**	**Compressive Strength (MPa)**		
Values	3.15	32%	60 min	320 min	3 days	7 days	28 days
					29.4	44.8	56.5

Aggregates

The aggregates are the main components of the concrete which greatly varies the strength, density and other properties of the concrete. Different types of aggregates used are discussed below.

Fine Aggregate

The fine aggregate used in the project was locally supplied from the river Swarnamukhi, near Chandragiri in Chittoor district and conformed to grading zone II as per IS:383-1970 [6]. It was first sieved through 4.75mm sieve to remove any particles greater than 4.75mm. Properties of the fine aggregate are tabulated below in Table 2.

Table 2. Properties of fine aggregates

S.No	Characteristics	Values
1.	Type	Uncrushed (natural)
2.	Specific gravity	2.54
3.	Bulk Density	1668 kg/m^3
4.	Fineness modulus	2.76
5.	Grading zone	Zone II

Coarse Aggregate

Locally available coarse aggregate having the maximum size of 20mm were used in this work. Properties of the coarse aggregate are tabulated in Table 3.

Table 3. Properties of Coarse aggregates

S.No	Characteristics	Values
1.	Type	Crushed
2.	Specific gravity	2.6
3.	Bulk Density	1765 kg/m^3
4.	Fineness modulus	6.45
5.	Maximum size	20mm

Blast Furnace Slag:
The blast furnace slag was obtained from Sesa Goa Limited. Goa. The chemical composition of blast furnace slag is shown in Table 4

Table 4. Chemical composition of blast furnace slag:

Components	**Percentage (%)**
SiO_2	11
P_2O_5	10
CaO	51
MnO	08
FeO	10
Fe_2O_3	04

SUPPLEMENTARY CEMENTING MATERIAL

Bottom Ash:
Coal bottom ash is the by-product of coal combustion. The rock detritus filled in the fissures of coal become separated from the coal during pulverization. In the furnace, carbon, other combustible matter burns, and the non-combustible matter result in coal ash. Swirling air carries the ash particles out of hot zone where it cools down. The boiler flue gas carries away the finer and lighter particles of coal ash. The boiler flue gases pass-through the electrostatic precipitators before reaching the environment. In the electrostatic precipitators, coal ash particles are extracted from the boiler flue gases. The coal ash collected from the electrostatic precipitators is called fly ash. Fly ash constitutes about 80% of coal ash. During the combustion process some particles of the coal ash accumulate on the furnace walls and steam pipes in the furnace and form clinkers. These clinkers build up and fall to the bottom of furnace. In addition, the coarser particles, which are too heavy to remain in suspension with the flue gases, settle down at the base of the furnace. The ash collected at the bottom of furnace is called coal bottom ash. Coal bottom ash constitutes about 20% of coal ash and the rest is fly ash. The chemical composition of washed bottom ash and OPC is shown in Table 5

Table 5. Chemical properties of washed bottom ash and OPC

Chemical Composition	**Bottom ash Weight percent (%)**	**Cement (OPC) Weight percent (%)**
Silica,SiO_2	54.8	20.6
Alumina,Al_2O_3	28.5	5.7
Iron Oxide,Fe_2O_3	8.49	2.9
Titania,TiO_2	2.71	-
Magnesia, MgO	0.35	1.8
Calcium Oxide, CaO	4.2	63.6
Na_2O	0.08	0.12
K_2O	0.45	0.75
P_2O_5	0.28	-
SO_3	-	3.2
Cl	-	0.01
Loss Of Ignition(LOI) at 1000^oC	2.46	1.5

Alccofine 1203

Alccofine 1203 is proprietary low calcium silicate based mineral additive. Controlled granulation process results in unique particle size distribution. Its latent hydraulic property and pozzolanic reactivity results in enhanced hydration process. Addition of alccofine 1203 improves the packing density of paste component. This results in lowering water demand, admixture dosage and hence improving strength and durability parameters of concrete at all age. The typical properties of alccofine is shown in Table 6.

Table 6. Typical Properties of Alccofine 1203

Property	**Value**
Average particle size (Microns)	4-6
Fineness(cm^2/gm)	12000
Specific gravity	2.86
Bulk density(Kg/m^3)	600to700

Water

Potable water was used for mixing and curing of concrete cubes.

MIX PROPORTION

In the present work, a proportion for concrete mix design of M40 was carried out according to IS: 10262-2009 recommendations [7]. The mix proportions are presented in Table 7.

Table 7. Mix Proportions for M40 Concrete.

Normal Mix	Control Mix Concrete
Cement(kg/m^3)	350
Water (kg/m^3)	140
Fine aggregate (kg/m^3)	896
Coarse aggregate (kg/m^3)	1140

RESULTS AND DISCUSSIONS

Workability Test (Slump Cone Test):

The shape and texture of aggregate affects the fresh property of the concrete. Fly ash aggregate is rounded in shape. Rounded aggregates promotes workability of concrete while the angular nature of natural gravel gives a better bonding property but requires more cement mortar for better workability. The workability results are presented in Table 8 and Fig 1.

Table 8: Workability Test (Slump Cone Test)

Trail Mix	Workability (slump in cm)
Control Mix	27.20
Mix 1	28.00
Mix 2	28.70
Mix 3	24.50

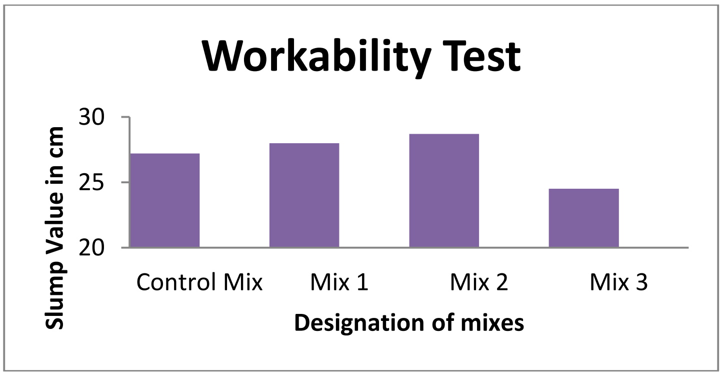

Fig.1: Variation of Slump Value for different trail mixes

Compressive Strength

The tests were carried out as per IS: 516-1959 [8]. The 150mm size cubes of various concrete mixtures were cast to test compressive strength. The cubes specimens after de-moulding were stored in curing tanks and on removal of cubes from water the compressive strength were conducted at 7days, 28days. The test results were compared with controlled concrete. The compressive strength results are presented in Table 9 and Fig 2.

Table 9: Compressive Strength for Different Trail Mixes

Trail Mix	Compressive Strength N/mm^2	
	7 Days	28 Days
Control Mix	23.27	44.72
Mix 1	28.75	46.24
Mix 2	29.17	51.32
Mix 3	24.01	45.25

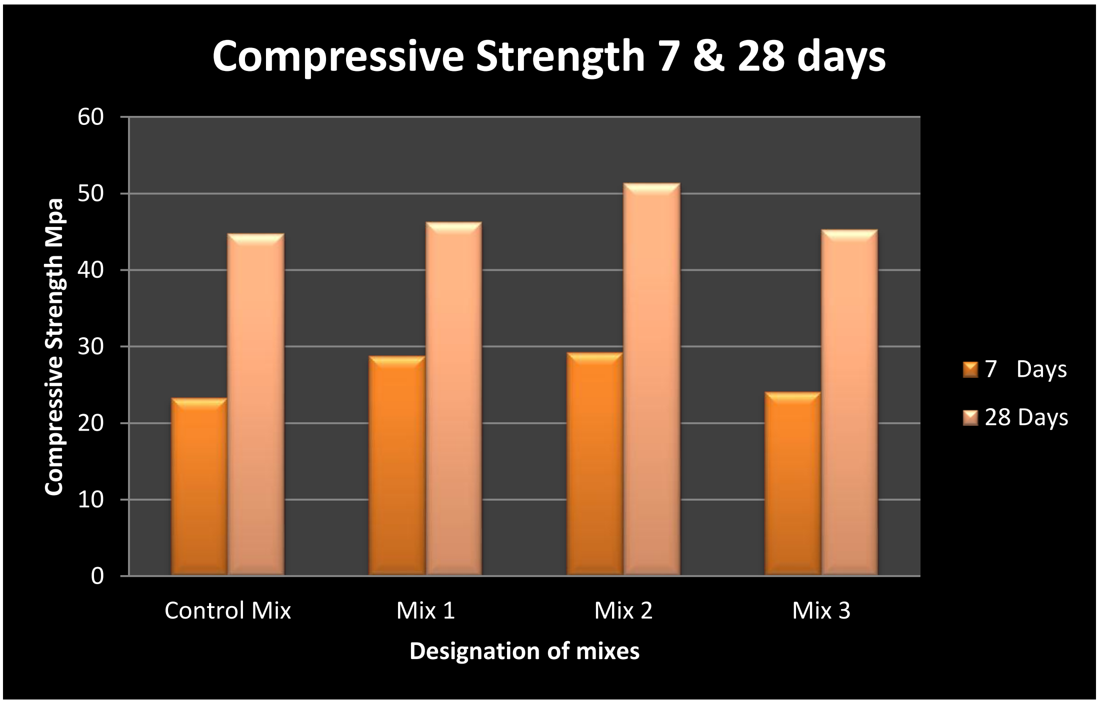

Fig. 2: Variation of Compressive Strength for different trail mixes

CONCLUSIONS:

On the basis of results produced in this study it is concluded that:

- The ternary blended concrete produced by adding different mineral admixtures may increase the strength of concrete which are partially replaced in cement concrete like bottom ash and alccofine.
- The slump results indicates that the maximum slump was attained for 20% of bottom ash and 10% of alccofine replaced in cement and 30% of blast furnace slag in fine aggregate.
- The experimental results reveals that the maximum compressive strength achieved for 7 and 28 days are 29.17 and 51.32 N/mm^2 by 20% of bottom ash and 10% of alccofine replaced in cement and 30% of blast furnace slag in fine aggregate.
- Compressive strength of standard concrete with various trail mixes is comparatively increasing more than that of conventional concrete.
- Besides achieving economy in construction, by increasing the strength of the structure, using ecofriendly material to develop the standard concrete which may greatly increase the durability and strength of structures and provides a massive structures which does not effect by natural disaster and damages less to the structures.

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