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ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.8, pp 110-118, 2017

An Experimental Investigation on High Volume Fly Ash Concrete by Replacing Fine Aggregate using Bottom Ash

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Abstract : The parameters like protection of natural resources, environmental consciousness are the present construction field requirements. Environmental pollution a major problem faced by mankind, mainly in the construction industry the production of portland cement causes the emission of pollutants that causes serious threat to the environment. Fly ash and bottom ash are waste products generated by coal burning power plants. It has been generally used for land filling. Fortunately several years back a discovery has been made that fly ash can be used as a partial replacement of cement in concrete. High Volume Fly Ash concrete system addresses all the major sustainability issues. It considerably saves cement and also prevents environmental pollution. The fly ash makes concrete more impermeable and denser as compared to Ordinary Portland Cement. Sand mining is also current problem faced by the construction industry in the present day. Bottom ash obtained from the coal burning industry can be replaced with bottom ash.This study reveals the strength properties of hardened concrete for M30 grade by partially replacing cement with fly ash at varying percentage (30% - 70%) and sand by bottom ash at varying percentage (10% - 30%). The mix design for M25 grade of concrete is arrived as per IS codes.

1.0 Introduction

High Volume Fly Ash Concrete is constituted by a minimum of 30% fly ash, low water content 130 kg/m^3, less than 200 kg/m^3 cement content, and a low water-cement ratio less than 0.5. When used in concrete, fly ash is a cementations material that can act as a partial substitution for Portland cement without significantly compromising the compressive strength[2,5]. The pozzolanic properties of a good-quality fly ash are governed primarily by the mineralogy, low carbon content, high glass content, and 75% or more of particles finer than 45 micron. High Volume Fly Ash Concrete has excellent workability, low heat of hydration, adequate early-age and high later-age strengths, reduced drying shrinkage, reduced micro cracking, excellent durability characteristics while being more economical and environment-friendly when compared to conventional concrete. Due to its superior performance and engineering properties the development of High Volume Fly Ash Concrete has opened new doors to sustainability of modern concrete construction. Increasing the amount of fly ash in concrete is not without shortcomings[7]. At high levels problems may be encountered with extended set times and slow strength development, leading to low early-age strengths and delays in the rate of construction.

Bottom ash is the burned coarse material, which falls into furnace bottom and is getting collected in huge quantities in modern large Thermal Power Plants[4,9]. In India, over 70% of electricity generated is by combustion of fossil fuel, out of which nearly 61% is produced by coal fired plants, this results in the roughly 110 million ton of ash. Most of the ash has to be disposed off either dry or wet to an open area available near the plant or by grounding both the fly ash and bottom ash and mixing it with water and pumping into dumping yards[1]. Fly ash is recovered by electrostatic precipitation from the gases of burning coal during the production of electricity in thermal power plants. It is available abundantly worldwide. Presently, as per the Indian Ministry of Environment & Forest Figurers, only a little percentages of fly Ash is being used in manufacturing cements, construction concrete, block & tiles and some are disposed off in landfills and embankments but a huge amount of fly ash is unutilized. The use of fly ash and bottom ash from different sources, as well as different batches from the same source resulted in bottom ash concrete with significantly differing strengths according to the available literature[5,6]. Again, the trends in early strength across a particular group of fly ashes do not match the trends in final strength for the same ashes. Therefore, producing the fly ash and bottom ash with consistent physical and mechanical material like silica fume as it is being done successfully in case of traditional cement based concrete. Properties despite the variability in the raw materials is a challenging issue. Here comes the concept of blending of some supplementary

1.1 Objective

- To find out the engineering properties of high volume fly ash concrete using bottom ash.
- To overcome the high utilisation of cement and natural sand due to the developing infrastructure.
- To determine the strength and durability properties of High Volume Fly Ash Concrete by replacing natural sand with various materials.

2.0 Materials

2.1 Cement

Cement is the most important ingredient in concrete. Ordinary Portland Cement (OPC) is now available in three grades namely 33, 43 and 53 grades. The number indicating the compressive strength of standard cement sand mortar cubes in MPa after 28days of curing. OPC 53 grade is used in this project.

2.2 Class C Fly Ash

Fly ash produced from the burning of younger lignite or sub bituminous coal generally contains more than 20 percent lime (CaO). This type of ash does not require an activator & the contents of Alkali and sulfate (SO_4) are generally higher as compare to the Class F Fly ash.

2.3 Bottom ASH

Bottom ash refers to part of the non-combustible residues of combustion[2]. In an industrial context, it usually refers to coal combustion and comprises traces of combustibles embedded in forming clinkers and sticking to hot side walls of a coal burning furnace during its operation. The portion of the ash that escapes up the chimney or stack is, however, referred to as fly ash. The clinkers fall by themselves into the water or sometimes by poking manually, and get cooled. The clinker lumps get crushed to small sizes by clinker grinders mounted under water and fall down into a trough from where a water ejector takes them out to a sump. From there it is pumped out by suitable rotary pumps to dumping yard far away.

2.4 Fine Aggregate

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size being finer than gravel and coarse than silt. Sand can also refer to a textural class of soil or soil type. Clean and dry river sand available locally was used. Sand passing through IS 4.75 mm sieve was used for casting all the specimens. Fine aggregate used are confirming to IS 383-1970.

2.5 Coarse Aggregate

Crushed angular aggregate with maximum grain size of 20mm is used. The specific gravity and fineness modulus was found to be 2.74 and 2.75 respectively. Coarse aggregate is the strongest and the least porous component in concrete. It is also chemically stable material. Ordinary blue granite crushed stone aggregate confirming to IS: 383-1970 was used as a coarse aggregate in concrete.

2.6 Replacement

Table 3.1 Replacement for cement

% Replacement	Cement (kg)	Fly Ash (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)
30	315	135	766.90	962.28
40	270	180	766.90	962.28
50	225	225	766.90	962.28
60	180	270	766.90	962.28
70	135	315	766.90	962.28

Amount of water required = 197 litres

Table 3.2 Replacement for fine aggregate

% Replacement	Cement (kg)	Bottom Ash (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)
10	450	76.69	690.21	962.28
20	450	153.38	613.52	962.28
30	450	230.07	536.83	962.28

Amount of water required = 197 litres

2.7 Properties of Cement

Table 4.1: Chemical Constituents of Cement

S. No.	Constituents	Symbol	Percentage
1	Tricalcium aluminate (CaO)3 · Al2O3	C3A	0 – 13%
2	Tricalcium silicate (CaO)3 · SiO2	C3S	45 – 75%
3	Dicalcium silicate (CaO)2 · SiO2	C2S	7 – 32%
4	Tetracalciumaluminoferrite (CaO)4 · Al2O3 · Fe2O3	C4AF	0 – 18%

Table 4.2: Physical Properties of Cement

S.No	Properties	Values
1	Specific Gravity	3.15
2	Bulk Density	1440 Kg/m^3
3	Surface area	225 m^2/Kg
4	Initial setting time	30 min
5	Final setting time	600 min

Table 4.3: Physical Properties of Class C Fly Ash

S. No.	CHARACTERISTICS	RANGE
1	Colour	Whitish grey to grey with slight black tinge
2	Bulk density	1.0 – 1.4 g/cc
3	Specific gravity	2.146-2.429
4	Fineness	280-325 Sq.cm/g
5	Lime reactivity	56.25 – 70.34 Kg/sq.cm

Table 4.4: Chemical Properties of Class C Fly Ash

S. No.	Characteristics	Range
1	Loss on ignition	0.5-2.0 %
2	Silica as SiO_2	40-60 %
3	Alumina	15-32 %
4	$Fe_2 O_3$	9-24 %
5	Lime CaO	5-24 %
6	Magnesia	1.5-5 %
7	Sulphur as SO_3	0-2.6 %
8	Others (Na_2, TiO_2, K_2O)	0 - 1.5 %

Table 4.5: Setting Time and Compressive Strength of Cement Fly Ash Sand Mortar

CaO%	Specific surface sq.cm/g	Setting time of cement fly ash mix in minutes		Compressive strength in Kg/cm2 of cement fly ash sand mortar	
		Initial	Final	At 7 days	At 28 days
16.13	2785	44	76	112.8	186.6
7.93	2749	49	94	117.8	281.0
5.56	3079	45	102	141.25	284

Cement fly ash mixed in the preparation of 80:20 by weight cement fly ash mixed in the mortar in the proportion of 80:20 by weight. Overall mix proportion cement + (plus) fly - ash sand: 1:3 (80 + 20)

2.8 Properties of Bottom Ash

Table 4.6: Mechanical Properties of Bottom Ash.

S.No	Elements Present In Bottom Ash	Percentage (%)
1	Silica as SiO_2	± 78%
2	Iron as Fe_2O_3	± 8%
3	Alumina as Al_2O_3	Traces
4	Calcium as CaO	± 5%
5	Magnesium as MgO	± 2%
6	Sulphate as SO_3	± 3%
7	Loss on ignition	± 4%

3.0 Results and Discussions

3.1 Fresh Concrete Properties

Slump Cone Test

Addition of Fly Ash in %	Slump Value in Cm	Slump Nature
30	8	True
40	13	True
50	17	True
60	28	Shear
70	34	Shear

3.2 Hardened Properties

Compressive Strength Test

Table 4.2 Compressive strength test results for fly ash replacement

% Replacement	Compressive Strength			
	7 Days		28 Days	
	Load (Kn)	Strength (N/Mm^2)	Load (KN)	Strength (N/Mm^2)
0	640	28.44	800	35.55
30	700	31.11	730	32.44
40	650	28.88	750	33.33
50	630	28	690	30.66
60	610	27.11	570	25.33
70	500	22.22	550	24.44

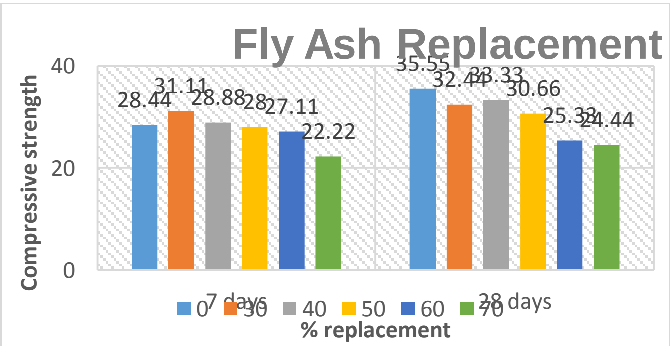

Fig4.1 Graph Showing Compressive Test Results

Table 4.3 Compressive test results for bottom ash replacement

% Replacement	Compressive strength			
	7 Days		28 Days	
	Load (Kn)	Strength (N/Mm^2)	Load (Kn)	Strength (N/Mm^2)
0	640	28.44	800	35.55
10	680	32.88	1150	51.11
20	740	30.22	930	41.33
30	690	30.66	880	39.11

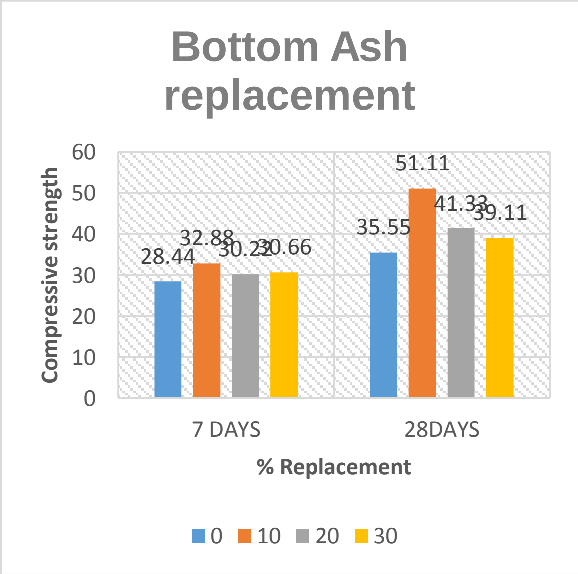

Fig4.2 Graph Showing Compressive Test Results

Split Tensile Strength Test

Table 4.5 Split tensile test results for fly ash replacement

% Replacement	Split Tensile Strength			
	7 Days		28 Days	
	Load (kN)	Strength (N/mm^2)	Load (kN)	Strength (N/mm^2)
0	240	3.39	280	3.96
30	210	2.97	250	3.53
40	190	2.68	220	3.11
50	120	1.69	160	2.26

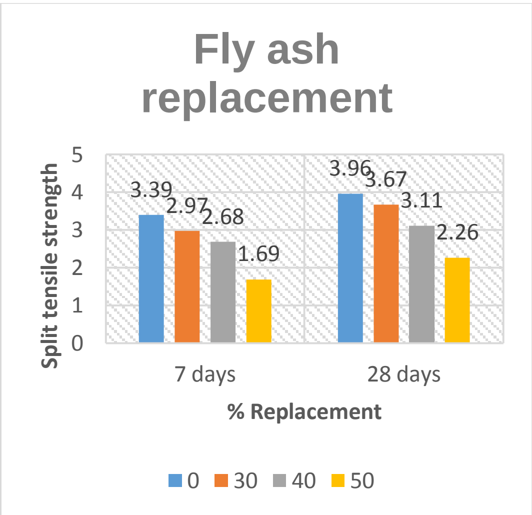

Fig4.3 Graph Showing Split Tensile Test Results

Table 4.6 Split tensile test results for bottom ash replacement

% Replacement	Split Tensile Strength			
	7 Days		28 Days	
	Load (kN)	Strength (N/mm^2)	Load (kN)	Strength (N/mm^2)
0	240	3.39	280	3.96
10	230	3.25	270	3.81
20	220	3.11	250	3.53
30	180	2.54	210	2.97

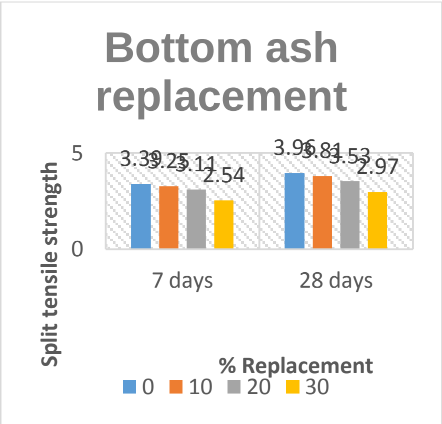

Fig4.4 Graph Showing Split Tensile Test Results

Flexural Strength Test

Table 4.7 Flexural strength test results for fly ash replacement

% Replacement	Flexural Strength			
	7 Days		28 Days	
	Load (kN)	Strength (N/mm^2)	Load (kN)	Strength (N/mm^2)
0	43.3	2.80	53.5	3.96
30	38.5	2.23	49.3	3.67
40	41.6	2.72	52.7	3.84
50	30.2	1.74	39.6	2.34

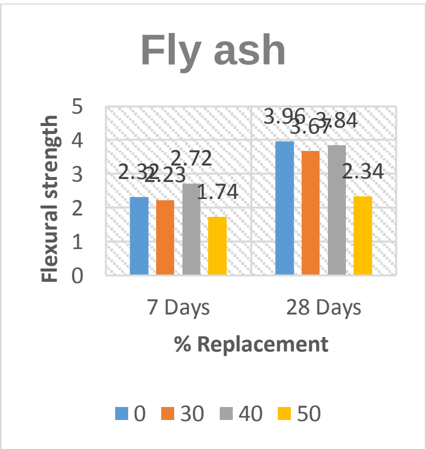

Fig4.5 Graph Showing Flexural Strength Test Results

Table 4.8 Flexural strength test results for bottom ash replacement

% Replacement	Flexural Strength			
	7 Days		28 Days	
	Load (kN)	Strength (N/mm^2)	Load (kN)	Strength (N/mm^2)
0	43.3	2.80	53.5	3.96
10	44.6	2.89	65.2	4.97
20	40.30	2.68	53.8	3.95
30	39.5	2.33	51.7	3.72

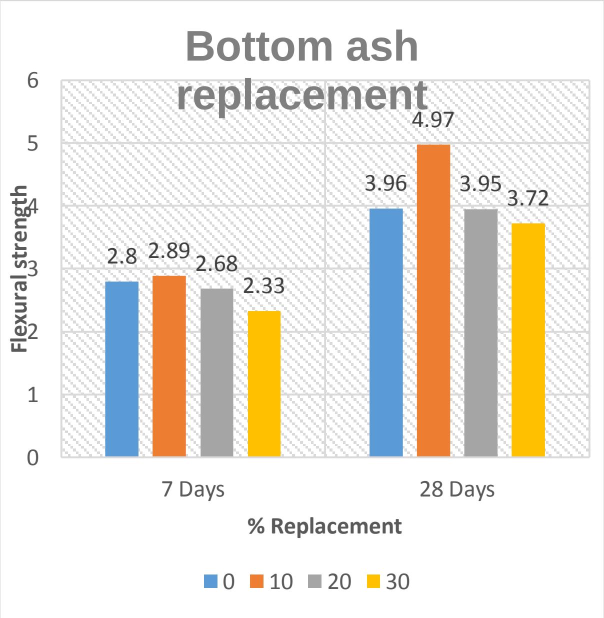

Fig4.6 Graph Showing Flexural Strength Test Results

4.0 Conclusion

- High volume fly ash concrete with bottom ash for fine aggregate replacement is found to be economical and environment friendly.
- From the study, it is evident that fly ash can be replaced partially for cement up to 50% and bottom ash can be replaced for fine aggregate up to 20% without the use of any super plasticizer.
- The use of bottom ash as a replacement for sand is environment friendly.
- Fly ash and bottom ash instead of disposal into open lands can be used for partial replacement of cement.
- Due to the reuse of materials considered as waste the economy is being stabilised.
- Replacing the cement using fly ash at higher percentages reduces the Green House Gas emission and also found to be economical.
- The main aspect followed in this project is to reduce the waste disposal and save the earth from environmental hazards.
- Work to be continued in the future.

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