STUDIES ON THE INTERACTION OF FLY ASH WITH LIME IN PRESENCE OF VARYING QUANTITY OF SAND

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Abstract: ***Presently, the pozzolanic character of fly ash is exploited extensively for the making of building bricks, blocks and other construction materials. When fly ash is mixed with lime and sand and the mass is compacted under pressure and subsequently treated under steam curing process, there is a noticeable improvement in properties in the compacted block. In the present work, the physico-chemical properties of the blocks like dry weight, bulk density, porosity, water absorption, dimensional shrinkage and compressive strength were studied in relation to fly ash-sand ratios at a fixed percentage of lime having 70 % CaO content. It has been observed that optimum properties in the blocks can be achieved with 30-35% sand and 10% lime (70%CaO) content.***

***Key words*: Fly Ash, Lime, Building Blocks, Steam Curing, Sand]**

1. INTRODUCTION

Fly ash when mixed with right proportion of lime in presence of water develops pozzolanic characteristics and in presence of sand when the mass is molded, it forms different hydrated phases like calcium silicate hydrate, calcium aluminate hydrate etc. during hydration reaction. These hydrates are responsible for the development of strength in the fly ash-lime system in the form of building blocks. Fly ash based building blocks are suitable for use in masonry similar to burnt clay bricks. But fly ash based building blocks enjoy certain advantages. The process for making these types of blocks eliminates the requirement of firing and consequently it saves high fuel cost as required in traditional clay brick making process. The process is environment-friendly as it is not associated with the gaseous emission level, which is prevalent in burnt clay brick making processes.

Another noteworthy advantage of the process is that it saves the consumption of precious top soil which is generally used for making building bricks.

Again, it has been observed that fly ash bricks have several superior properties compared to burnt clay bricks like better surface finish, more compressive strength, less weight, less mortar consumption for laying etc.

In fly ash based blocks although the initial strength development in the compacts is around 100kg/cm^2 after 7 days of steam curing, with the progress of time (within 7 months) the strength reaches up to 150 kg/cm^2. The rate of strength in the blocks depends on the fineness, quality and quantity of fly ash, lime and sand and other process parameters.

Several researches have been done on fly ash-lime based compacts. Some of the important works have been mentioned here, Ma and Brown[1] studied the hydrothermal reaction of fly ash with $Ca(OH)_2$ and $CaSO_4.2H_2O$. Variation in the reactivity of fly ash depended on the presence of $Ca(OH)_2$ or $CaSO_4.2H_2O$. Isothermal colorimetric method was used to determine the kinetics of the reaction between fly ash and this activity influence hydration rates as determined by the rate of heat evolution. XRD analysis determined the phases formed as a result of hydrothermal treatment. The mechanical properties developed by hydrothermal treatment demonstrated that hazardous ashes could be consolidated for handling. Alternatively, non-hazardous ashes could be reacted to form useful products. Tsunematsu et al[2] studied the hydrothermal reactivity of fly ash with lime and gypsum with respect to the mineral composition. Kumar[3] made a perspective study of fly ash-lime-gypsum bricks and hollow blocks for low cost housing development. Muntcan etal[4] studied on the properties of autoclaved limestone materials with fly ash addition. The physico-mechanical properties of the resultant siliceous limestone with 10-30% fly ash were found to be superior compared to the limestone obtained from lime and sand only. Wang etal[5] studied the reaction mechanism of fly ash-lime system and established a model of the reaction. Maitra et al[6]] studied the effect of compaction pressure on the physico-mechanical behavior of the fly ash-lime compacts under steam curing. It was observed that compaction process has a distinct influence on the physico-chemical properties, like free lime content, bulk density, water absorption capacity and compressive strength. After steam curing for an equilibrium period of 10h, the compacts showed water absorption tendency when exposed to saturated humidity, and 50% of the absorbed water was desorbed when the compacts were subjected to ambient condition of reduced humidity. Both absorption and desorption followed first order rate kinetics in terms of the concentration of the water absorbed.

Majumdar etal [7]also studied on the reaction between fly ash and lime in different conditions.

In the present investigation fly ash-lime-sand compacts have been hydrothermally cured and the effect of the variation in fly ash/sand ratio on the physico-mechanical properties of the compacts has been investigated.

2. EXPERIMENT

In the present investigation fly ash sample was collected from Bandel Thermal Power Station (West Bengal, India). The chemical analysis of the ash samples was carried out gravimetrically and complexometrically following sodium carbonate fusion process. Particle size distribution of the ash sample was measured by sieve analysis following specification as laid in IS: 1528-1974, Part-XIV. Sand sample was collected from the bed of Ajoy and Damodar River flowing in West Bengal, India. Chemical analysis of the sand was carried by HF treatment method. Pulverized lime sample with high CaO content (70%) was collected from Katni and Satna (MP, India) for the present experiment. The lime sample had considerable Blain's surface area (10,800 cm^2/gm).

The chemical characteristics of fly ash, sand and lime samples are given in the Table1. The sieve analysis of the samples is given in table2. $MgCl_2$, $6H_2O$ was used as activator with 0.25% of total weight of mixture.

The test blocks were prepared with variable fly ash and sand proportions in the mixes, keeping the lime percentage of 10% of total mix in weight. All the compacts were prepared under a compaction pressure of 200 kg/cm^2. The sizes of the test blocks were kept in the dimension of 190mm×90mm×90mm. On an average 6% moisture content was maintained in all the compacts. All the test samples of different sand percentage were subjected to autoclave treatment under temperature of 130ºC and steam pressure of 2.5kg/cm^2 for a period of 6 hours. It was followed by water curing of the samples and for a period of 15 days. Properties of the different test samples after complete curing have been detailed in Table3.

3. RESULTS & DISCUSSION

The power plant from which the ash sample was collected use bituminous coal. Therefore the ash sample collected was of class-F type, characterized by low lime and high silica in the chemical composition. From the chemical analysis of the ash sample (Table1), it was observed that the sample contained more than 50% silica in the composition. The total content of silica, alumina and iron in the composition were about 85%. Therefore it satisfied the requirement of ASTM C-618 for use as mineral admixture. The loss on ignition value of the sample can be related to the presence of un-burnt carbon content in it. As the ash sample was collected in dry form, it was relatively free from absorbed moisture. From the sieve analysis of the sample (Table2) it was observed that more than 90% of the sample existed in the size range of 45-90 µm. The Blain surface area of the sample was found to be also quite high (more than 5000 cm2/gm). Generally, constituents like silica, alumina and iron oxide in the composition of fly as are responsible for its pozzolanic properties, as lime reacts with these oxides to develop different lime bearing hydrated phases which give rise to strength development in the compacts. It appears therefore, that the sample had satisfactory pozzolanic properties. Again, the reaction between fly ash and lime was observed to follow an interface-controlled mechanism. Therefore, small particle size and high surface area of the samples improved its pozzolanic properties further, making it extremely suitable for the use as building materials.

Siliceous sand is basically used as filler or aggregate in the fly ash-lime compacts. It occupies the interstitial positions in the cement hydrates formed as a result of the chemical interaction between fly ash and lime, making the cement network rigid and mechanically more stable. The surface of the sand particles also can undergo reaction with the lime with the formation of small quantity of calcium silicate, which improves the interfacial bonding between the hydrated cementitious phase and the sand filler. A certain part of the un-reacted coarser fraction of fly ash sample has also the potential to act as filler. Therefore, in the present investigation the ratio of the fly ash and sand were varied in different compositions to study its effect on the physico-mechanical properties of the compacts and to develop the limiting value of the composition.

From Table3 it was observed that the porosity and consequently the water absorption value of the compacts decreased with the increase in the proportion of the sand. It has been depicted also in figures3 and 4. It can be related to the more filling of the voids in the structure of the compacts as a result of the increase in sand content. With the increase in sand content from 10% to 40% the water absorption value can be reduced to half of its initial magnitude. The dimensional change of the samples after curing (% shrinkage) also reduced withy the increase in the sand content in the composition (Figure5) as a result of the somewhat chemically inert nature of the sand samples. The compressive strength of the compacts after curing was also found to increase with the increase in the sand content in the composition (Figure 4). It can be related to the development of more compact, void free structure after curing as a result of the enhanced sand content in the composition.

But with the increase in the sand content both the bulk density and dry weight of the samples increased significantly (Figures 1 and 2). The dry weight of the sample increased approximately from 1.97 kg to 2.33 kg with the increase in sand content from 10% to 40%. From the constructional application point of view these properties made the compacts less attractive.

Therefore, an optimum balance has to be made for constructional application with a trade off between weight and density requirement on one hand and water absorption and strength requirement on another hand. From the present work it appeared 30% sand content in the composition of fly ash-lime–sand compacts generated acceptable properties for constructional applications.

4. CONCLUSION

Fly ash-lime-sand compacts prepared by hydrothermal curing using class F fly ash are suitable

for building construction having all qualities as per BIS Standard. It has been observed that with the increase in sand content up to a certain extent the water absorption, porosity and compressive strength of the compacts improved significantly whereas the density and dry weight of the samples became progressively unsatisfactory. On an average 30% sand content in the composition gave optimum properties in the compacts making them suitable as building materials,

Table1: Chemical Analysis of fly ash, lime and sand sample

Chemical Constituent (Wt%)	Fly ash	Lime	Sand
SiO_2	53.10	7.5	93.0
Al_2O_3	24.40	2.2	2.5
Fe_2O_3	6.50	80.0	1.5
CaO	1.80	1.5	-
MgO	1.30	-	-
Na_2O	0.35	-	0.5
K_2O	2.21	7.5	-
LOI	8.20	-	2.0
SO_3	0.20	-	-
TiO_2	1.03	-	-
P_2O_5	0.92	-	-
Cl	0.01	-	-

Table 2: Sieve Analysis of fly ash, lime and sand.

Sieve Size (in micron)	Fly ash	Lime	Sand
>1000	-	2.08	5.30
>500	-	19.44	-
>250	0.03	-	85.00
>212	0.40	64.58	-
>150	2.95	-	-
>125	2.45	11.11	-
>90	4.40	1.38	-
>63	27.60	1.41	-
>45	60.00	-	-
<45	1.90	-	-
Specific surface area, Blain’s (cm^2/gm)	5500	10,800	60

Table3: Properties of the fly ash-lime sand compacts after curing

Fly Ash (wt%)	Sand (wt%)	Lime (as CaO, wt%)	Dry Wt. (gm)	Dry B.D (gm/cm^3)	Water Absorptio n(%)	CCS after 15 days of steam curing (Kg/Cm^2)	Porosity (approx) (%)	Shrinkage (%)
80-75	10 - 15	10 (7)	1977.0	1.270	33.0	86.0	46.0	0.110
74-70	16 - 20	10 (7)	1993.5	1.290	30.5	95.0	43.5	0.085
69-65	21 - 25	10 (7)	2046.5	1.330	26.0	110.0	41.5	0.075
64-60	26 - 30	10 (7)	2100.0	1.365	24.0	120.0	39.5	0.065
59-55	31 - 35	10 (7)	2154.5	1.400	20.0	125.5	38.5	0.055
54-50	36 - 40	10 (7)	2264.5	1.475	17.0	130.0	37.5	0.045
49-45	41 - 45	10 (7)	2332.0	1.515	15.0	140.0	33.5	0.040

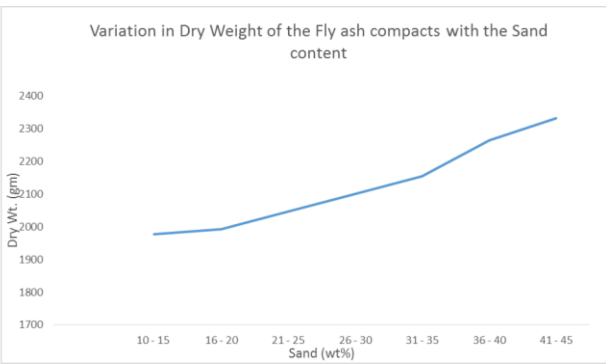

Figure 1: Variation in Dry Weight of the Fly ash compacts with the Sand content

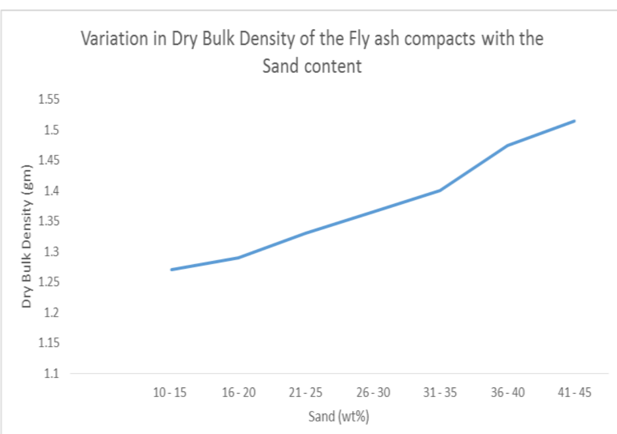

Figure 2: Variation in Dry Bulk Density of the Fly ash compacts with the Sand content

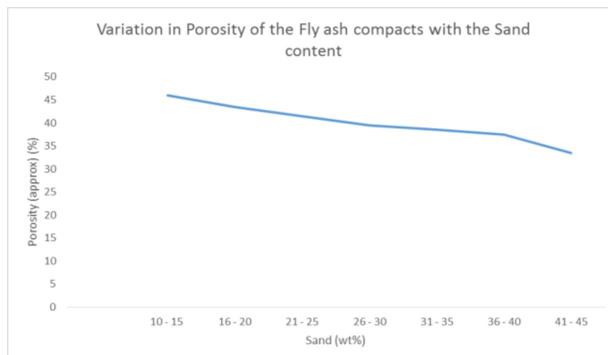

Figure 3: Variation in Porosity of the Fly ash compacts with the Sand content

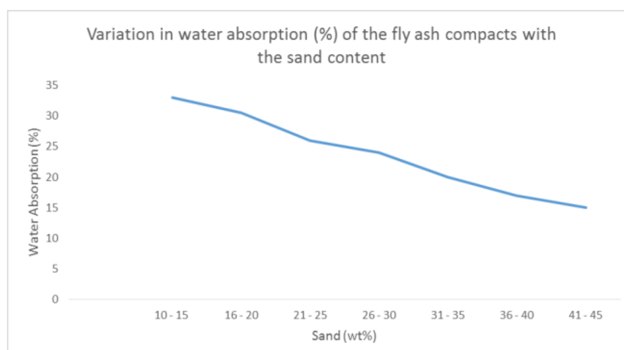

Figure 4: Variation in Water Absorption (%) of the Fly ash compacts with the Sand content

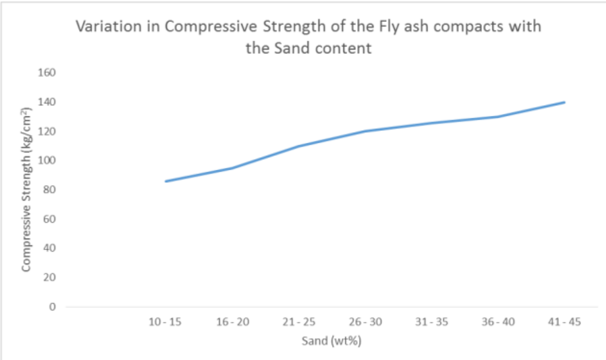

Figure 5: Variation in Compressive Strength of the Fly ash compacts with the Sand content

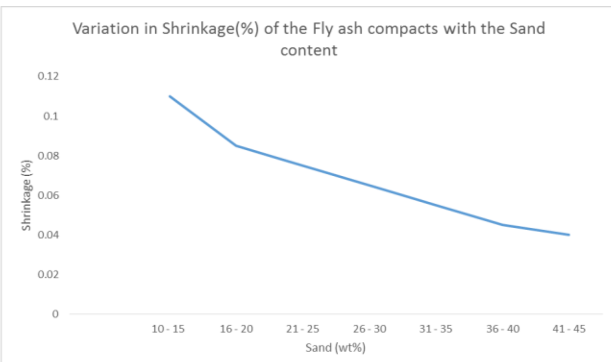

Figure 6: Variation in Shrinkage (%) of the Fly ash compacts with the Sand content

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