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INVESTIGATION OF FLY ASH POLYMER

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ABSTRACT: Industrial waste like fly-ash which is creating environmental problems, is mainly used as a building material due to its low cost and easy availability. But the main disadvantage of these bricks is its low strength. So, a lot of research is going on to increase the strength of these bricks. The present research work is carried out to develop a new systematic procedure to produce fly ash composite bricks which will have higher compressive strength. Here the fly-ash is mixed with Cold setting resin at different proportions and water treated at different temperatures to find out a solution to the brick industry. The compressive strength, Hardness, water absorption, Density and thermal conductivity of the fly ash-resin powder bricks obtained under optimum test conditions are 11.24 MPa, 47.37HV, 19.09% 1.68 g/cm3, and 0.055 W/mK respectively. The sliding wear behavior is also investigated. The structure-property correlations of these composites are studied using X-ray diffraction, FTIR analysis and scanning electron microscopy.

I. INTRODUCTION

The entire development of a country depends on the production value of power and consequently its consumption as energy. Our country, India needs huge power resources to meet the expectation of its occupant as well as its aim to be a developed nation by 2020. Fossil fuel plays an important part in meeting the demand for power generation .Coal is considered to be one of the world's richest and widely distributed fossil fuel. Around the world, India dominates the third position in the largest production of coal and has the fourth largest coal reserves approx. (197 Billion Tons).It has been estimated that 75% of India's total installed power is thermal of which the share of coal is about 90%. Nearly about 600 Million tons of coal is produced worldwide every year, with Fly ash generation is about 500 MT at (60-78 %) of whole ash produced [1, 2].In India, the current generation of FA is nearly about 180 MT/year and is probable to increase about 320 MT/year by 2017 and 1000MT/year by 2032 [3] .No doubt Indian coal has high ash content and low heat value. In order to meet the increasing challenging demands, many coal based thermal power plants have been constructed. As a result of which huge amount of combusted residue in the form of Fly ash (80 %), and Bottom ash (20%) has been produced. The finely dispersed particle from the burnt coal is discharged out through the flue gases which are detached mechanically through electrostatic precipitators and separators which are then collected together in the field of hoppers. The rate of production of FA is high and it goes on increasing year after year. The annual production of FA in China, India and US is approximated about 275 million metric tons. But less than half of this is consumed in various areas. The greatest challenge before the processing and manufacturing industries is the disposal of the residual waste products. The harmful impact on the surroundings suggests the necessity for appropriate dumping of fly ash and justifies full utilization of FA when feasible. Waste products that are generally toxic, ignitable, corrosive or reactive have detrimental environment consequences. This major issue requires an effective, economic and eco- friendly method to tackle with the disposal of the residual industrial waste products.

1.2 Fly Ash

It is characterized by its light weight, Silicate glassy appearance, spherical in shape, grey colored, polymeric, alkaline and refractory in nature. In addition, FA has a pozzolanic property [6]. The FA forms a hard and cementitious compound like calcium silicate hydrate and calcium aluminate hydrate in the presence of moisture. The hydration reactions of fly ash and Portland cement are almost similar resulting in similar properties as compared to each other. It is advantageous to use FA as a replacement of cement in the concrete, providing some distinct features. Some of the important characteristics shown by fly ash concrete are better textural consistency and detail of sharper. Fly ash shows similarity with volcanic ashes which was used to produce hydraulic cements almost 2,300 years before .The term "pozzolans" was named after a small Italian town of Pozzuoli where these cements were made. A pozzolan is a silica and alumina rich material which forms a hard and cementing compound in the presence of moisture. The features of Pozzolans and lime binding capacity of fly ash makes it possible for the production of high strength bricks, cement and aggregates [2]. One of the best pozzolans in the world is fly ash and that is why it is best known with this. Now a day's fly ash can directly be taken from coal fired power generation plants, so Fly ash coming from volcanoes is of no use. Before combustion, these power plants grind coal to powder fineness. After burning the coal huge amount of fine residue can be collected from the exhaust of power plants and these can be used further. Both Fly ash and Portland cement appears to be structurally similar but can be distinguished under optical microscope. Fly ash particles are almost spherical, and can be allowed to move and blend freely in any admixtures. Fly ash possess excellent physicochemical and mechanical properties which includes low dense structure with high strength, negligible porosity and shrinkage, excellent thermal stability and durability, high surface hardness, and better fire and chemical resistance. Owing to these characteristics feature of FA, it can be used in different civil, mining and metallurgical applications like architectural sector, transportation and aerospace industry, as road sub base material, wear resistant ceramics and tiles, Geopolymers and many others. There is an extensive variation in the physical and chemical configuration of Indian FA. These variations are mostly due to the combustion chamber or incinerator efficiency. All the thermal related plants of India are governed and accomplished by a single unit i.e. NTPCs. Unavailability of decent quality of coal, below standard maintenance and non-renewal of different parts of combustors even after the completion of its ideal life are some of the features accountable for low incinerator efficiency [7].

1.3 Fly Ash Bricks

Bricks has been used as a major construction and building material. Since long Aluminous –silicate and silica bricks are chosen as refractory materials in many industrial applications, due to their high wear resistance, long lasting, sturdy and load bearing capacity at high temperatures [8]. Due to the limitation of clay resources, china has partially restricted the use of conventional fired bricks produced from clay [9]. Therefore the ultimate aim is to find raw materials for brick production alternative to clay. These days energy savings has become a very important environmental and economic issue. The consumption of energy from buildings comprises about one third of the total consumption, with nearly half of its energy lost through the walls [10].One of the effective approaches to reduce energy consumption is to decrease the thermal conductivity of wall material, such as brick. Organic residues such as saw dust, polystyrene, paper sludge, coal, coke and inorganic products are commonly used to decrease the thermal conductivity of the brick. These residues used as a pore forming additives to obtain highly porous bricks. Numerous studies have been conducted on fired brick made of Fly ash [11, 12]. FA bricks show better mechanical and physicochemical properties which includes low dense structure with high strength, negligible porosity and shrinkage, excellent thermal stability and durability, high surface hardness, fire and chemical resistance than conventional earthen bricks [13].These bricks are an environment friendly cost saving building product. Fly ash bricks are durable, have low water absorption (8-18%), less consumption of mortar, economically stable and no emission of greenhouse gases. These bricks remain static and are not affected by environmental conditions, thus ensuring longer life of the structure. The bricks made of FA are three times resilient and stronger than conventional bricks with constant strength. Due to the presence of free lime the strength of compacts is accelerated at high rate. Hence these bricks are perfectly fit for internal and external load bearing and non-load bearing walls. To determine the compressive strength and microstructure of the cracked samples, compacts of Fly ash and cold setting resin along with hardener with various percentages are prepared and treated in water at 1100 C - 180oC for 24 hours.

1.4 Cold setting resin: - An Overview

Cold mounting compound resin is used as a binder material to provide inter particle bond between the FA particles and to increase their strengthening effect. They are good resistance to atmospheric and chemical degradation. Resin powder cannot shows its effect alone until it is mixed with hardener (or accelerator) to provide the mounting compound, and then the polymerization process takes place to form the desired block. This process sometimes generates heat but this generation can be minimized by the use of cool air or cooling water. These compounds can be ideally chosen for those materials which show sensitivity towards heat or pressure. This cold setting resin offers better properties for Fly ash compacts. Improved mechanical strength and hardness, resistance to atmospheric and chemical degradation, reduced thermal conductivity, eliminates porosities and cavities, fast curing of compacts are some of the common properties. The setting compound and the hardener were supplied by Geosynpvt. Ltd. Kolkata.

II. LITERATURE REVIEW

ObadaKayali studied the properties of Fly ash and clay made bricks and concluded that the mechanical properties of fly ash bricks have exceeded to those of standard load bearing clay bricks. Compressive strength was 24% better than good quality clay bricks and tensile strength was nearly three times the value for standard clay bricks. The bond strength of the fly ash bricks is 44% higher than the normal clay bricks. The density of fly ash bricks is 28% less than that of standard clay brick. The reduction in a weight of bricks results in a great deal of savings in terms of raw materials and transportation costs. Fly ash brick can easily soak up mercury from normal air which is in contact with it and thus makes it cleaner for berating. There is also a process named carbonation in which fly ash absorbs carbon dioxide from normal atmosphere due to which carbon sequestration occurs and the amount of carbon gets reduced in atmospheric air which helps in minimizing global warming.

Sunil Kumar has presented an extensive review in reported work on fly ash bricks. He investigated the flexural strength, water absorption test, density, porosity and stability of these solid bricks and hollow blocks. He witnessed that these bricks and blocks have enough strength for their usage in low rate housing growth. Tests were conducted to determine the compressive strength and hardening effects and to analyze the effects of curing with time. The compacts treated in hot water shows better strength and hardening effects as compared to normal water cured compacts. Initially the strength of these blocks and bricks increases with higher rate and then at a comparatively lower rate. There is a direct relationship between FA and water absorption. As the content of FA increases water absorption also increases .And on the other hand water absorption decreases with increase in density of the FA compacts. These FA bricks and blocks with proper phosphogypsum extent have improved resistance to robust sulfate environment.

Ball MC & Carroll RA has studied the various bricks manufacturing methods and understands the reason behind the strengthening effects of these autoclaved FA bricks. The FA brick becomes hard mainly due to the formation of calcium silicate hydrate and calcium aluminate silicate hydrate.The hydrothermal reaction takes place between silica, alumina and water when the compacts are allowed to cure under the steam bath normally at 1100C -1800 C. The presence of Tobermorite phase also helps in enhancing the harden ability of the Fly ash bricks.

Cultrone G, Sebastian E, and Elert K, studied the permeability of FA bricks and co-relates its effects on various chemical and mineralogical configuration of Fly ash particles. FA bricks also depend on the temperature of firing resulting in to more vitrified dense structure and phenomenal change in shape and size DimitriosPanias and Ioanna P. stated that in order to develop the better mechanical strength, water content has displayed as a critical parameter in the synthesis of FA built geopolymers .Water displays its importance during suspension, poly condensation and the different hardening junctures of geo polymerization. The presence of NaOH badly affects the compressive strengths during formation of geopolymers. The Geopolymers which are synthesized either in higher or lower NaOH content (aqueous phase), results in reduced compressive strength. The concentration of Sodium silicate (Na_2SiO_3) solution in the formation of geopolymers showed a significant effect on the acquired compressive strength. Na_2SiO_3 solution controls the solvable silicate gathering and the major silicate classes in a geopolymeric system, thus increases the strength of the formed materials.

MridulGarg, Manjit Singh and Rakesh Kumar have studied the durability of the FA, phaspho gypsum and lime based binder and its execution in water along with accelerated ageing. The cementing binder that are cured at 50°C displays little porosity with improved water resistance as compared to that of 27°C cured binder. The 50°C cured binder displays little reduction in strength and mass with rise in temperature and in alternate moist and dried cycles. 50°C treated binder displays no drop in strength and mass from the pristine standards, with rise in temperature from 27°C to 50°C and with different heating and freezing sets. Hence these are ideally suited for making structural blocks, slates, panels etc.

III. EXPERIMENTAL WORK AND METHODOLOGY

3.1 Introduction

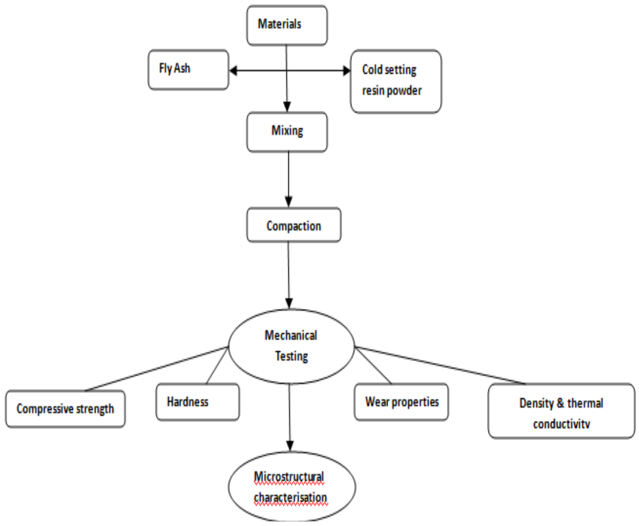
Fly ash has been used in various architectural and industrial applications on large scale. Hence Consumption of this huge amount of fly ash greatly reduces the difficulties met by coal based TPPs for its dumping. Analysis on the performance of FA at various states is essentially required before its usage. So to understand the characteristics features of FA, experiments cannot be performed on field domain. There is no any alternate option except research laboratory test to assess its importance. The research conducted in laboratory provides a calculative approach to govern several parameters that come across during practice. Brief description of the types of material used, sample preparation and its characterization through SEM, XRD, and FTIR, Mechanical and surface properties like Compressive strength, Hardness and wear resistance, Thermal conductivity measurement and others are outlined in this section.

3.2 MATERIALS USED

3.2.1 Fly ash

The Fly ash used in this project was collected from electrostatic precipitators of the captive power plant (CPP-II) in dry condition. The fine powders were oven dried at 110oC-160oC and kept in air tight bottle for later use.

Flow Chart of Experimental Procedure



3.3 Experimental Methods

3.3.1 Preparation of Samples: The samples were prepared by Powder metallurgy route.

3.3.1.1 Mixing

Three different weight percentages of Fly ash and resin powder with (75%, 80% and 85%) and (25%, 20% and 15%) were taken respectively. These compositions were mixed thoroughly by a mechanical vibrator (Abrasion Tester Model PEI-300), to get a homogenous mixture. Different compositions of Fly ash along with resin powder were kept in three different small size bottles. Around 6-10 small steels balls are kept inside for proper mixing. Mixing was done till the vibrator shows 1000 revolutions which almost took five hours.

3.3.1.2 Compaction

The compaction experiments were executed to make cylindrical FA compacts. Cylindrical die and punch having 15 mm diameter made of stainless steel was used to make cylindrical Fly ash compacts .Mixture of approximately 5 gm. was taken for each composition. Then the punch & die was cleaned with cotton followed by acetone so that all the dust is removed from the inside surface of the die and outside surface of the punch. Then greasing was done to avoid sticking. The mixture prepared earlier was poured inside carefully. Maximum load was achieved, the apparatus was powered off. The whole system was relaxed for 5 minutes which then followed by unloading. Compact was ejected from the Die in the same direction as the compression and was kept in normal atmosphere for 1 day The amount of Hardener used was 1/6th or 1/4th of the mixture. Hence in this way twelve samples for each composition were made. All the samples were dried in open atmosphere for 2 days.

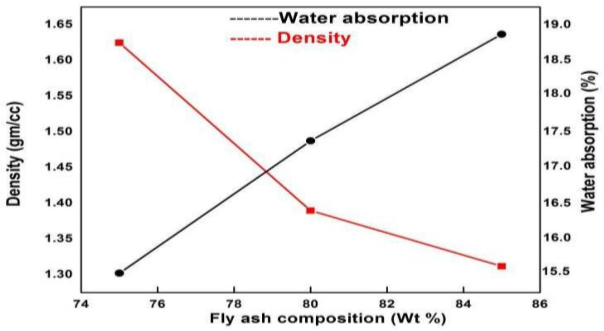
IV. RESULTS AND DISCUSSION

4.1 Composition of Fly ash

FA mainly consists Silica (Sio2), Alumina (Al2o3), Calcium Oxide (CaO), and Iron Oxide. (Fe2O3).The chemical c omposition of Fly ash is tabulated in table 4.1.

Compounds	SiO2	Al2O3	CaO	Mgo	P2O5	Fe2o3	SO3	K2O	LOI
Composition (%)	54.5	26.5	2.1	0.57	0.6	-	-	-	14.18

Fig.4.1 shows a relation between the amount of water absorbed and density of dry composite with respect to FA composition. It is evident from the graph that the water absorption increases with increase in FA content. 85wt. % FA absorbs water to a maximum of 19.09%. This indicates that that most of the openings of the compacts are open to outside.



4.2 Water Absorption Test

Table 4.2 shows the amount of water absorbed corresponding to different FA composition. The water absorption values of FA composites lies in the range of 15.55 % to 19.09%. It can be seen that all the composition met the absorption criteria set by several developing countries. India permits the maximum of 20 % water absorption when compacts are immersed for 24 hours.

Table 4.2 Percentage (%) water absorbed by various FA polymer compacts

Mix Composition (Wt. %)	Water (gm) Dry	Water (gm) Wet	Water Absorption (%)	Average Water Absorption Value (%)
(FA)75%+ (RP)25%	4.579	5.302	15.78	15.55
	4.630	5.340	15.33	
(FA)80%+ (RP)20%	4.452	5.151	15.70	16.61
	4.642	5.456	17.53	
(FA)85%+ (RP)15%	4.502	5.356	18.96	19.09
	4.329	5.162	19.23	

Figure.4.1 Water absorption and density as a function of FA Composition

4.3 Density Measurement

Density of the samples was calculated before and after treatment. From Fig. 4.2 we can say that density of dry compacts decreases with increase in weight percentage of FA. As the dry compacts are immersed in water at 110^{0}C - 180^{0}C, then through capillary action voids are filled and it becomes hard and the porosity is eliminated.

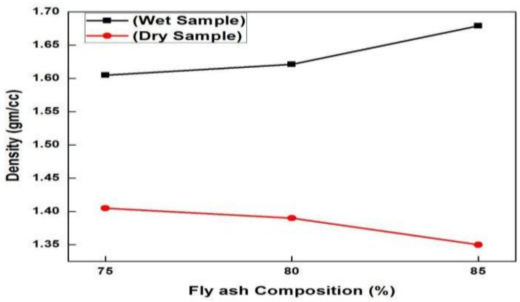


Fig.4.2 Variation in dry and wet density composition

4.4 Hardness Measurement

Hardness values of all the Fly ash polymer composite of different compositions, both in dry and wet state, were measured by the help of LECO, LM 248AT Vickers hardness tester. The Hardness values as obtained are shown in Table 4.4. The values of hardness are in the range of 32.93 HV – 44.08 HV for dry composites and 39.78 HV – 47.37 HV for wet FA composites respectively.

Table 4.4 Hardness values of various FA resin mix compacts

S.NO	Mix Composition (Wt. %)	Micro hardness value (HV) Dry	Micro hardness value (HV) Wet
1	(FA)75%+ (RP)25%	32.93	39.78
2	(FA)80%+ (RP)20%	38.26	43.04
3	(FA)85%+ (RP)15%	44.08	47.37

4.7 Determination of Compressive Strength

The compressive strength measurement of the cylindrical samples was done as per standard practiced. Test was conducted on the three samples of each composition and the average value of all is evaluated. Table 4.5 shows the strength values of different compositions of FA, both in dry and wet state. For dry composites, the Compressive strength value lies in the range of 6.5 to 11.28 MPa. 85 wt. % FA compositions have got the highest strength value while the lowest strength value of 6.5 MPa was gained by 75 wt. % FA composition.

Table 4.5 Compressive strength values of different FA resin mix compacts

S.NO	Mix Composition (Wt. %)	Compressive Strength (MPa)	
		Dry	Wet
1	$(FA)_{75\%}+(RP)_{25\%}$	6.5	5.52
2	$(FA)_{80\%}+(RP)_{20\%}$	8.73	7.98
3	$(FA)_{85\%}+(RP)_{15\%}$	11.28	9.43

It can be seen from Figure.4.6 that the composition of (FA) 85%+ (RP) 15% has higher compressive strength than other two compositions. It is found that with decrease in the resin percent with fly ash mix has increased the compressive strength. As it is evident from SEM micrographs that 75 wt. % FA mix composite possesses cracks which leads to decrement in compressive strength. As the percentage of FA is increased there is a good bonding between the interfaces which leads to improvement in strength of the compacts.

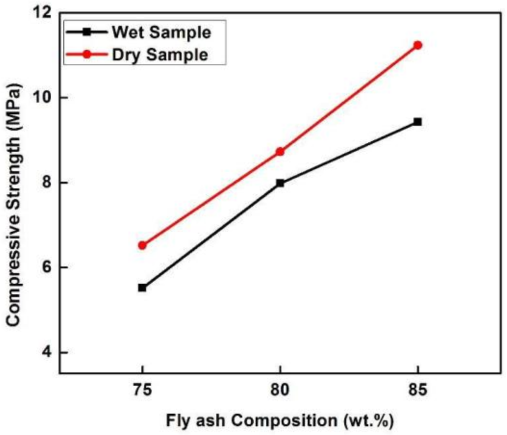


Fig.4.6 Compressive Strength of Compacts at different FAcompositions

V. CONCLUSIONS

On the basis of present study following conclusion can be drawn:

- Water treated compacts shows positive effects on the hardness values. Out of all dry compacts, FA with 85 wt. % possesses a higher hardness value of 44.08 HV. Much improvement in the hardness value is achieved when the composites are treated in water at
- 1100- 1800C. This increment in hardness value is due to the presence of CSH and CASH in the presence of moisture as obtained from XRD analysis.
- With an increase in polymer addition (resin powder), the compressive strength of dry compacts decreases to a lower value of 6.5 MPa. Composition of 75 wt. % FA shows lower value. No significant reduction in Compressive strength is achieved in the case of wet compact.
- Wear study of different composites can easily be correlated with the hardness value. In both the dry and wet state, FA with 85 wt. % composition shows better resistance to wear than other two compositions. Wear resistance increases with increase in FA content. The co-efficient of friction decreases with increase in FA percentage and follows a linear trend throughout the time of testing.

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