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A Comparison Among the Physico-Chemical-Mechanical of Three Potential Aggregates Fabricated From Fly Ash

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Abstract

This research paper mainly focuses on the utilization of Class F-fly ash (by-product of power plant) for production of aggregates by different method. In the present study three different types of methods are adopted for preparation of aggregates. Cold bonding, autoclaving and sintering techniques are the very general technique used for preparation of the aggregates. Sodium hydroxide, Bentonite and Sodium silicate are used as a binder material during the pelletization process. The binder and fly ash proportions of 15: 85, 10: 90 and 17: 83 with water to cement ratio 0.3 are mixed to get the fly ash aggregates. Various mechanical properties of the aggregates such as crushing strength, impact test, abrasion test, specific gravity, water absorption, porosity were determined. The test results shows that the 7 days crushing strength and water absorption value of cold bonded aggregates 6.30 Mpa and 12.25% followed by autoclaving is 5.46 Mpa and 13.10% and sintering are 5.80 Mpa and 5.20% respectively. Overall test results have shown that fly ash aggregate can be used as a possible construction material in concrete world.

Keywords: Autoclaving; Binder; Cold bonding; Class F fly ash; Lightweight aggregates; Sintering

Introduction

In India around 70% of electric generated through coal based thermal power plant. Approximately, annually 112 million tons of fly ash generated in India, but only small portion of fly ash is utilized in the construction and other purposes. As a result large quantities of the fly ash remain lying unutilized in most countries of the world. It's a major challenge of reducing and recycling of wastes in 21st century [1-3]. Development of new techniques for managing waste is one of the major areas of interest of researcher in recent days. Fly ash can be utilized in various engineering purpose for the production of cement, bricks, geopolymer, lightweight block, synthesis of dyes so on. The large scale production fly ash aggregate is an opportunity for the construction industry for the utilization of fly ash [4-7]. In the present state some attempts have been taken to use fly ash for the lightweight aggregate production by applying cold bonding, autoclaving or sintering technique. Now-a-days fly ash pellets are also applied as materials for road-ways application. Sintering, cold bonding or autoclaving are the three very common method generally used for the converting fly ash into pellets [8,9]. The Sintering process mainly involves hardens the pellet by using the fly ash particle together at the point of mutual contact [10,11]. In Cold bonding technique fly ash react with calcium hydroxide at ordinary temperature to form a water resistant bonding material [12]. Similarly, autoclaving uses pressurized saturated steam curing for hardening of fly ash pellet [13] Different types of lightweight aggregate for structural application are available on the market, there is a renewed interest in the production of fly ash aggregates by cold bonding pelletization [14,15]. The entire process requires very low minimum energy consumption and medium technical skill with Videla and Martinez have investigated the feasibility of production of fly ash lightweight aggregate through cold bonding pelletization technique [16]. Priyadharshini P et al. have studied the manufacturing of fly ash aggregate by cold bonded technique [17]. The mechanical properties of this fly ash aggregate has been tested in laboratory scale and compared with natural gravel. The test results show that cold bonded fly ash aggregates can be used as a possible construction material.

In this study Class F fly ashes obtained from NALCO thermal power plant in India have been used as for preparation of lightweight fly ash aggregate by various methods. In addition, the study presented herein aim at providing some basic information on the effect of fabrication process on the properties of fly ash aggregate.

Research Objective

The objective of the present study was to evaluate and compare various mechanical properties of aggregates fabricated from Class-F fly ash. The study includes the strength effect, binder ratio, manufacture method of all aggregates extensively.

Experimental Program

Materials

In this process a Class - F fly ash is being procured from a nearby power plant fused as the raw material the materials Class – F fly ash confirming ASTM C618 as source material. Raw material, Class F fly ash from NALCO, Anugul being used for production of fly ash aggregates (Figure 1).

Mixture proportions

The manufacturing process requires raw material like Class-F fly ash, organic binder and some amount of water to be mixed in a suitable proportion. In this study, totally three different types of aggregates were produced in the ratio of 15: 85, 10: 90 and 17: 83 respectively. All the mixtures are homogenously mix in the pelletizer disc and then the calculated water (0.30) is sprayed during pelletization operation. During the pelletization process, initially small balls are formed, on subsequently increase in time period, large size of aggregates are formed. Finally, the discharge of pellets has been collected in the disc. Quality of aggregates produced by this process depend on the following factors such as quality of raw materials, fineness of raw material, proportioning of raw materials, and handling and mixing of raw materials respectively. The mix proportion for the laboratory grade fly ash aggregate pprepared for the study are represented in Table 1 in the given mix design ratio.

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Aggregate type	Fly ash (in gms)	Sodium hydroxide (NaOH)	Bentonite (in gms)	Sodium silicate	Water (in gms)	Fabrication method
CFA	850	150	-	-	300	Cold bonding
AFA	900	-	100	-	300	Autoclaving
SFA	830	-	-	170	300	Sintering

Table 1: Mix proportion of light-weight production.

Figure 1: Raw class - fly ash from NALCO.

Production of lightweight fly ash aggregate

Lightweight fly ash aggregates were produced through various processes such as cold-bonding, autoclaving and sintering. The details are given below.

Cold bonding method: In laboratory scale, fly ash and binder are uniformly mixed. This proportion is thoroughly dry mixed in a mixture. After dry mixing, water is sprinkled in a pelletizer and the contents were thoroughly mixed in pelletizer until the formation of fly ash aggregate. This method of formation of aggregates is called pelletization [18-20]. A specially fabricated disc pelletizer as shown in Figure 2 was used in this study which has a disc diameter 500 mm and depth 250 mm. The angle of the disc can be adjusted between 45^0 to 50^0 and speed 55 rpm. In cold bonding process the aggregates were allowed for curing for 1, 3 and 7 days in order to achieve green strength [21-23] (Figure 2).

Autoclaving method: This method involves green pellets are then cured in pressurized saturated steam at a temperature of 140°C for 30 minutes. After that they are collected and allowed for dry in 24 hours. This process helps in reducing bonding material in pellet formation and curing time. It seems that the strength property and durability properties of AFA and CFA are very close to each other.

Sintering method: Once the aggregate is formed in disc pelletizer, it is collected in tray allowed to dry for a day. Finally the aggregates are allowed for sintering for a temperature of 1150°C for half-an-hour duration in order to gain good strength. Sintering of fly ash aggregate was done by down draft sintering method. Batch type suction grate sinter machine of 300 × 300 mm and cross section area 500 mm height hearth is used for prepare sintered fly ash aggregate from the pelletizer raw machine. The sintering experiment is being carried out by maintain 400 mm bed height of the granulated particle on a 50 mm thick hearth layer with suction pressure 400 mm WG below the grate to complete the preheating at 1150˚C and cooling in 25 to 30 mins of time. The process of laboratory produced sintered fly ash aggregates are shown in Figure 3. During the sintering process higher amount of coal is accepted as it helps for sintering. But the high energy requirement makes the process undesirable. The aggregates which are formed in sintering process show better durability and corrosion resistance property (Figures 3-5).

The laboratory prepared different types fly ash aggregates procedure in various methods is shown in Figures 4 and 5.

Tests Performed on Aggregate

Keeping on view, the utilization of fly ash aggregate in high way construction to as substitute concrete source, standard tests such as crushing strength, impact test, abrasion test, specific gravity and water absorption test were carried out

Crushing strength of fly ash aggregates

The crushing strength of pellet can be determined with the help of Carlifornia bearing ratio machine in according to IS: 2386 (Part-4)-1963 [9]. A total of 3 nos. of pellet have been collected from various fabrication methods. The individual crushing strength ('σ') of pellet can be obtained from the formula. Figure 6 shows the setup for carrying out the test

$$\sigma = 2.8*P/\pi d^2 \quad (1)$$

Where "P" = failure load "d" = diameter of pellet

Impact value of fly ash aggregates

This test is generally carried out in order to know about the strength, resistance of pellet to repeated impact loading. The impact

Figure 2: Disc pelletizer.

Figure 3: Downdraft sintering machine.

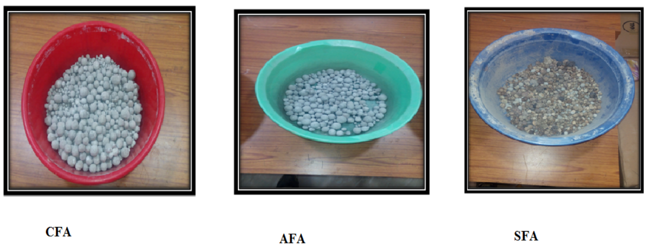

Figure 4: Various types of fly ash aggregates.

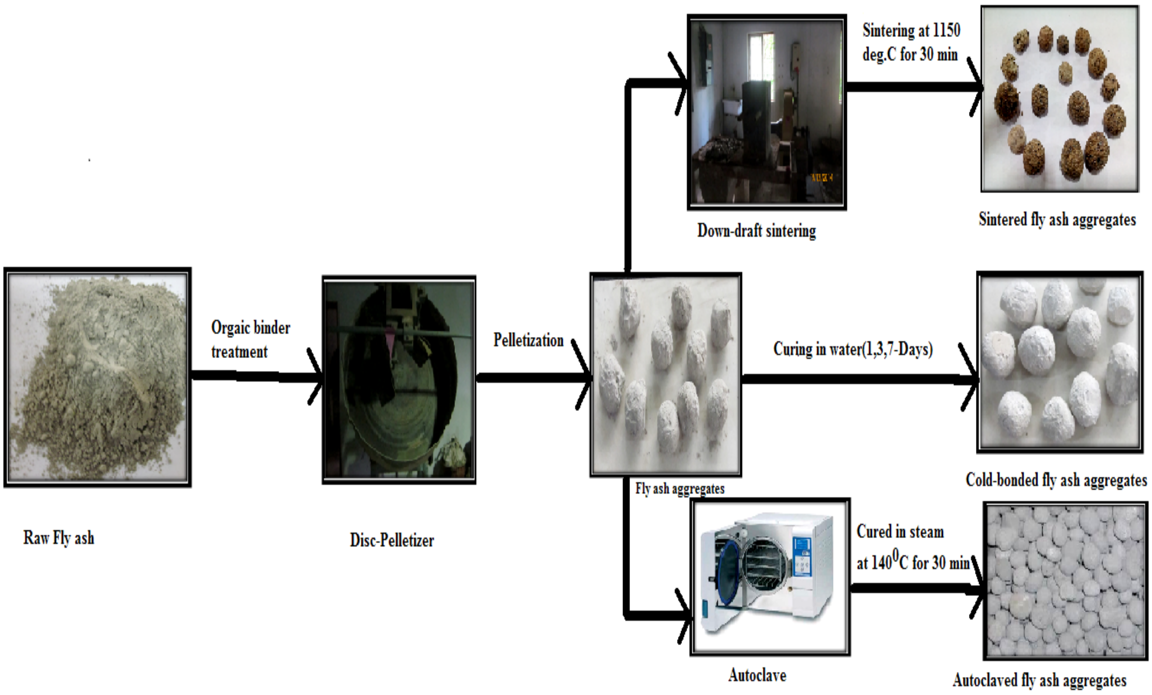

Figure 5: Laboratory methods of preparation of fly ash aggregates.

Figure 6: Testing setup for individual crushing strength of pellet.

strength of the aggregates was tested according to IS: 2386 (Part IV)-1963 [10] using an impact test machine as shown in Figure 7.

Aggregate impact value = W_2/W_1*100% (2)

Where, W_1 = Weight of the fly ash aggregate sample used for testing

W_2 = Weight of fraction passing through 2.36 mm sieve size

Abrasion value of fly ash aggregates

Abrasion value gives an idea about performance of aggregate. The test is carried out according to IS: 2386 (Part IV)-1963 using Los Angeles abrasion machine as shown in Figure 8.

Abrasion value of aggregate = W_1-W_2/W_1*100% (3)

Where, W_1 = Weight of the fly ash aggregate

W_2 = Weight of the sample after 500 round revolution and sieved in 1.70 mm sieve

Water absorption and specific gravity of fly ash aggregates

The water absorption of aggregate calculated by placing 500 gm of 12.5 mm - 10 mm size of oven dried aggregates was immersed in water for 24 hours. The increased mass of saturated, surface dry aggregate was measured. The water absorption is expressed as increase in mass as a percentage of ovens dried mass. Aggregate. The specific gravity of fly ash aggregates can be carried out according to IS: 2386 (Part 3) 1963 [11] which is shown in Figure 9.

Test Results and Discussion

Test results of engineering properties of fly ash aggregate

The engineering properties such as crushing strength, impact test and abrasion test, water absorption and specific gravity of various types of lightweight aggregates are given in table. Strength improvement was noticed 6.30 Mpa in hydroxide based aggregate followed by sintered aggregate 5.80 Mpa and in autoclaved is 5.46 Mpa respectively as shown in the figure. In case of CFA as the increase in the duration of normal water increases from 1 day to 7 days, there is a reduction in water absorption value. Similarly, in this case of SFA as the sintering temperature increases from 750°C to 1150°C. The reason is formation of excessive glassy phase at higher temperature. AFA shows higher specific gravity 1.74 and in CFA, SFA are 1.64, 1.66 respectively (Table 2).

Pelletization efficiency and fly ash aggregate formation

Efficiency of aggregate production depends on the amount of raw fly ash converted to fly ash ball during the agglomeration of moist fly ash particle in a pelletization process. The pelletization efficiency represented in Figure 10 shows that it is depends on the type of binder. The maximum pelletization efficiency was obtained with the addition of 15% of sodium hydroxide binder followed by 17% of sodium silicate binder and 10% of Bentonite binder. The maximum time required for

Figure 7: Impact testing machine.

Figure 8: Los Angeles abrasion machine.

(a)Buoyancy balance use for specific gravity

(b)Picnometer used for detrmination of water absorption

Figure 9: (a and b) Water absorption and specific gravity test.

the formation of a stable ball was up to 10 min pelletization duration and for the remaining 5 min the pellet were compacted due to the compaction force. So it is realized that the efficiency of fly ash aggregate production depends on the binder content.

Effect of organic binder and crushing strength of aggregate

It is found from the experimental result sodium hydroxide binder shows highest crushing strength of 6.30 Mpa followed by silicate binder 5.80 Mpa among all the binder. So binder is used for preparation of fly ash aggregate as a possible construction material. The effect of organic binder on crushing strength of aggregate is shown in Figure 11.

Role of curing period on cold bonded aggregate

During cold bonding it has been observed that when the water curing is carried out for a long period of time, there significance decrease in the porosity along with reduction in water absorption capacity. These parametric variations are attributed to the significant reduction in open porosity of the aggregate. The study revealed that when the normal water curing period has been increased upto 7 days, phases like anhydride and dicalcium silicate get transformed to hydration leading the formation of ettringite, gypsum and calcium silicate hydrate which leads to the refinement of pores.

Effect of sintering temperature on aggregate

There was a linear reduction in total porosity in SFA when the sintering temperature increases from 750°C to 1150°C. The reason may be due to the formation of excessive glassy phase at higher temperature. Addition of more binder results decrease in porosity.

Cost analysis of fabrication process

The cost analysis of fly ash aggregates fabricated by various methods is shown in Table 3. The analysis was done in 1 kg of fly ash aggregates. From the above data, it is very clear that cold bonded fly ash aggregate is very cheaper and economical viable. So we can recommend clod bonded fly ash aggregate as a possible construction material. (Table 3).

Summary and Conclusion

A laboratory experiment was conducted to investigate the Physico-Chemical parameter, engineering properties of three types of potential aggregates fabricated from fly ash.

Aggregate type	Crushing strength (Mpa)	Impact test (%)	Abrasion test (%)	Specific gravity	Water absorption (%)
CFA	6.30	9.56	28.35	1.64	12.25
AFA	5.46	11.46	30.45	1.74	13.10
SFA	5.80	10.20	29.87	1.66	5.20

Table 2: Engineering properties of cold bonded, autoclaved and sintered fly ash aggregate.

Cold bonding fly ash aggregate	Autoclaved fly ash aggregate	Sintered fly ash aggregate
1-Raw Fly ash 2-Organic binder (NaOH) 3-Normal water curing	1-Raw Fly ash 2-Organic binder (Bentonite) 3-Steam (Steam curing for 30 mins at 140^{0}C)	1-Raw Fly ash 2-Organic binder (Sodium silicate) 3-Coal 4-Sintering temperature (1150^0 C for 30mins)
For manufacturing of 100 kg of CFA=Rs.1400/- For manufacturing of 100 kg of AFA=Rs.2200/- For manufacturing of 100 kg of SFA=Rs.2800/-		

Table 3: Minimum requirements for fabrication of fly ash aggregates.

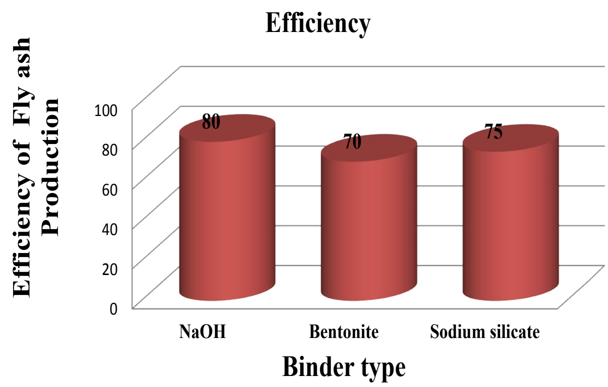

Figure 10: Relationship between efficiency of fly ash aggregate production and binder type.

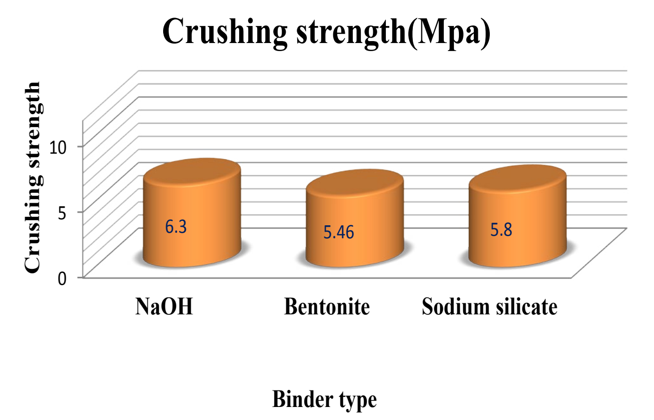

Figure 11: Effect of organic binder on crushing strength of aggregate.

1. The aggregate prepared using fly ash and alkali binder could exhibit very high crushing strength 6.30 Mpa whereas fly ash –bentonite and fly ash-sodium silicate aggregate shows 5.46 Mpa, 5.80 Mpa respectively.
2. The water absorption value of SFA was found very low as 5.20% as compared to cold bonded and autoclaved aggregates.
3. During the study, the physic-chemical characterization were carried out and specific properties such as compaction strength, toughness, durability etc. are found to be high in case of the aggregates prepared using fly ash along with alkali NaOH solution.
4. The study also reveals that with a curing period of 7 days it is possible to produce high strength green pellet from fly ash.
5. From the above test results it is concluded that the properties CFA is well as compared to AFA and SFA. So CFA can be used as possible construction materials. Now-a-days fly ash aggregates can be used as the replacement of stone aggregates.
6. The study concluded that depending on the application feasibility and requirement, various grade of fly ash aggregate can be generated for building material.

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