STUDY OF CONCRETE MADE USING FLY ASH AGGREGATES

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ABSRACT: ***Many researchers have been executed within the vicinity of fly ash usage in the past. It in particularly concentrated on alternative of cement with fly ash but production of artificial aggregates with fly ash helps in using massive volume of ash in concrete. The sector is lots interested in this part currently due to this massive scale utilization which additionally reduces environmental pollution and dwindling of natural assets. This paper particularly makes a specialty of manufacturing system of light weight aggregates the usage of pelletizer and curing has been carried out in cold bonded technique. The properties of these fly ash aggregates have been tested and in comparison with natural gravel and the study shows at suggest that cold bonded fly ash aggregates may be used as an aggregate replacement material in concrete. The strength property and density of concrete made with artificial fly ash aggregates and natural gravel have been additionally studied which confirms that creation of fly ash aggregates in concrete reduces the compressive strength however meets the desired strength for use as a structural material.***

INTRODUCTION

In growing need for electricity in India, 70% of power is generated through thermal power plants. The environmental dreads from these plants include air pollution due to particulate emission, water pollution and shortage of land for dumping the fly ash. Further, the poor quality of Indian coal has high ash content, which worsens the disposal problem. Fly ash generation is estimated to be around 200 million tons in 2013 -2014. Instead of dumping the fly ash as landfills, fly ash is widely used as cement replacement material, pavement base, blocks etc., in these days. To use fly ash in large volume the applications like embankment fill or aggregate replacement material should be considered. Construction industry is growing very fast manner. The availability of raw materials for the construction is facing many problems in most of the world. The continuous usage of natural resources for the production of the concrete in some locations creates many threatens to the environmental conditions. Researchers have carried out extensive work on this area are trying for new alternative materials for this deficiency in the construction industry.

The durability properties of concrete made with fly ash aggregate cured by different methods and found that sintered aggregates produce better strength compared to cold bonded aggregates. But found that the fly ash aggregates produced by normal curing showed comparable results with the aggregates produced with other methods of curing, when the number of days of curing is increased. the properties of fly ash aggregates produced by normal cold bonding technique is discussed and compared with natural gravel. Concrete made out of these aggregates were also studied for the strength criteria to get an idea of their behavior as a replacement material.

LITERATURE REVIEW

Chi et al. (2003) used three types of cold bonded cement based fly ash aggregates for the production of concrete. The study indicates that type of light weight aggregate and water to binder ratio are the significant factors influencing strength of concrete.

Google et al. prepared concrete using cold bonded fly ash aggregate containing Portland Type 1 cement as binder. The variables of this study are water cement ratio cement content and coarse aggregate ratio. The artificial aggregates are used after soaking for a period of 30 minutes in water. The compressive strength of concrete is found to be between 20 and 47 Map. Test results indicate that compressive strength decreases with coarse aggregate to total aggregate ratio.

Jo et al. produced geo-polymer concrete of strength grade of 33 MPa using cement based fly ash artificial aggregates.

Joseph and Ramamurthy determined the fresh and hardened properties of concrete made using cold bonded fly ash aggregate. The cement content of 250 and 450 kg/m3 is used for the preparation of concrete. The variables considered are cement content, water cement ratio and aggregate ratio. It is found that the compacted density of concrete reduces with increase of in volume fraction of cold bonded fly ash aggregate. The workability of concrete is found to be controlled by content of cold bonded aggregate. The test results indicate that the strength of the concrete increases with increase cement content. The failure of concrete is found to be controlled by aggregate fracture.

Joseph and Ramamurthy studied the influence of high volume of fly ash in concrete containing cold bonded fly ash aggregate. The replacement ratio of cement with fly ash is 10, 30 and 50 percent is used. The coarse aggregate ratio of 50 and 65 percent is used. The fresh density of concrete reduces with increase in replacement of cement with fly ash and cold bonded aggregate ratio. The workability of concrete is increases with increase in fly ash content.

Joseph and Ramamurthy studied the workability and strength properties of concrete made using cold bonded fly ash aggregate. It is reported that workability of concrete is influenced by volume fraction of cold bonded fly ash aggregate. The failure of concrete is explained by the failure of mortar phase or aggregate phase. The test results indicated that cement content in concrete influences the failure of mortar phase. The strength of concrete decreases with increase in volume fraction of cold bonded aggregate.

Joseph and Ramamurthy (2011) studied the influence three different types of curing methods, namely, mist, sealed, air curing on strength of artificial aggregate concrete. The moisture movement from aggregate to the paste in the matrix is evaluated at different ages. The test results indicate that the strength and hydration of matrix are insensitive to the type of curing. This indicates that the cold bonded fly ash aggregates act as internal curing agents in concrete.

Bui et al. studied the strength of concrete produced using artificial aggregates made from ground granulated blast furnace slag (GGBS), rice husk ash and class F fly ash. The binder used in preparation of artificial aggregate is alkaline activator solution containing sodium silicate and sodium hydroxide. The concrete of compressive strength between 14.8 and 38.1 MPa is prepared using the geo-polymer artificial aggregates.

Gesoglu et al. prepared concrete of strength grade 51 MPa using artificial aggregate. The cold bonded aggregates containing ground granulated blast furnace slag and fly ash are used. Two types of Fly ash, namely, class F and class C are used. The ordinary Portland cement is used as the binder. The test results indicated that aggregates prepared using class F fly ash without Portland cement is not suitable for concrete production.

MATERIALS AND METHOD

- **CEMENT:**

Portland cement gets its strength from chemical reactions between the cement and water. The process is known as hydration. This is a complex process that is best understood by first understanding the chemical composition of cement.

Manufacture of cement

Portland cement is manufactured by crushing, milling and proportioning the following materials:

i. Lime or calcium oxide, CaO: from limestone, chalk, shells, shale or calcareous rock

ii. Silica, SiO_2: from sand, old bottles, clay or argillaceous rock
iii. Alumina, Al_2O_3: from bauxite, recycled aluminum, clay
iv. Iron, Fe_2O_3: from clay, iron ore, scrap iron and fly ash Gypsum, $CaSO_4.2H_20$: found together with limestone

The materials without the gypsum are proportioned to produce a mixture with the desired chemical composition and then ground and blended by one of two processes - dry process or wet process. The materials are then fed through a kiln at 2,600º F to produce grayish black pellets known as clinker. The alumina and iron act as fluxing agents which lower the melting point of silica from 3000 to 2600º F. After this stage, the clinker is cooled, pulverized and gypsum added to regulate setting time. It is then ground extremely fine to produce cement.

- **FLY ASH:**

Fly ash is a finely divided residue resulting from the combustion of pulverized coal and transported by the flue gases of boilers fired by pulverized coal.

Fly ash

According to ASTM-C 618[3] categorizes natural pozzolanas and fly ashes into the following three categories.

i. Class N Fly ash
ii. Class F Fly ash
iii. Class C Fly ash

- **Clay:**

Clay is a soft, loose, earthy material containing particles with a grain size of less than 4 micrometers; it forms as a result of the weathering and erosion of rocks containing the mineral group feldspar (known as the mother of clay) over vast spans of time.

Clay

During weathering, the feldspar content is altered by hydrolysis (reaction with water) to clay minerals such as kaolinite (the principal minerals in kaolin clays) and smectites (the principal minerals in bentonite. Clay is an important material in preparation of cold bonded fly ash aggregate because it acts as binding material.

Classes of Clays

The clays are generally divided into three classes:

i. Porcelain clay, which is approximately pure kaolin. This burns to white or light-cream color.
ii. Plastic clay, which contains more impurities than to porcelain clay. It burns to a yellow-red color and is used for ordinary earthenware.
iii. Fire clays, these clays approach very close to the porcelain clays in composition; however they contain a larger quantity of iron, also more silica as quartz. Some of the highest fire clays are very rich in quartz.

- **Lime:**

Lime

Calcium oxide (CaO), commonly known as quick lime or burnt lime is a widely used chemical compound. It is a white, caustic, alkaline, crystalline solid at room temperature. The broadly used term "lime" connotes calcium –containing inorganic materials, in which carbonates, oxides and hydroxides of calcium, silicon, magnesium, aluminum, and iron predominate. By contrast, "quick lime" specifically applies to the single chemical compound calcium oxide. Calcium oxide which survives processing without reacting in building products such as cement is called as free lime. Quick lime is relatively inexpensive. Both it and a chemical derivative (calcium hydroxide, of which quick lime is the base anhydride) are important commodity chemicals. Lime is an important material in preparation of cold bonded fly ash aggregates because it acts as binding material.

- **METHODS OF PREPARING OF FLY ASH AGGREGATES**

There are different post processing techniques for fly ash aggregates which includes, sintering, autoclaving and cold bonding. Sintering causes many drawbacks like higher manufacturing cost, as it involves the usage of expensive energy (Gokhan Baykal and Ata Gurhan Doven, 2000). As a result, cold bonded fly ash aggregates are manufactured, to avoid the sintering process and it gave comparable results (Bijen, 1986; Niyazi Ugur Kockal and Turan Ozturan, 2010, 2011a, 2011b).

i. Sintering

It is the process by which the green pellets are allowed to fuse together at high temperatures normally more than 1200 degree Celcius (Su-Chen Huang et al., 2007; Cheeseman and Virdi, 2005; Mun, 2007; Geetha and Ramamurthy, 2010, 2011; Bijen, 1986, Peter Neumann et al., 1991, Gokhan Baykal et al., 2000, Niyazi et al., 2010, Manikandan et al., 2008). In sintering process, high coal content is acceptable as it helps the process of sintering (Bijen, 1986). But the high energy requirement makes the process undesirable (Peter Neumann et al., 1991; Gokhan Baykal and Ata Gurhan Doven, 2000). But, the properties of aggregates produced by sintering process, shows better durability properties like corrosion resistance, permeability (Niyazi Ugur Kockal and Turan Ozturan, 2010, 2011a, 2011b).

Sintered Fly ash aggregates

ii. Autoclaving:

This process involves addition of some chemical like cement, lime or gypsum in agglomeration stage. This induces bonding property in the material. The green pellets are then cured in pressurized saturated steam at a temperature of 140 degree Celsius. This process helps in reducing bonding material in pellet formation and curing time (Bijen, 1986). But the strength and durability properties does not show much difference compared to normal curing (Manikandan and Ramamurthy, 2008).

iii. Cold bonding:

Artificial aggregates can be formed by different process like autoclaving, cold bonding or sintering (Bijen, 1986; Baykal and Doven, 2000; Mangialardi, 2001). Research studies show better results on usage of various waste products as artificial aggregates. Some of which a remaining residues, heavy metal sludge (SuChen Huang et al., 2007), sewage sludge (Cheeseman and Virdi, 2005; Mun, 2007), bottom ash (Geetha and Ramamurthy, 2010, 2011; Kim and Lee, 2010). Here, in this pilot study, fly ash aggregates are formed by cold bonded technique. Cold bonding is nothing but normal water curing. Pelletizer of 0.55 m in diameter and 0.250 m depth with a rotating speed of 40 rpm is used in the process of pelletization (Figure 2). An angle of 55 o is maintained as per previous studies which give better pelletization efficiency and good grading of pellets (Manikandan and Ramamurthy, 2007). The influence of various binders in the formation of sintered fly ash aggregate is well studied by (Ramamurthy and Harikrishnan, 2006). 8% of Ordinary Portland cement is used as the binder material. Fly ash and the binder are mixed well initially for 2 minutes in pelletizer and then water with $Ca(OH)_2$ is sprayed in to it. Spraying should be done carefully to make sure that the water has been sprinkled not in the same place to avoid slurry muddy balls. The fresh pellets formed were then kept at room temperature for a day to attain initial strength and then water cured for 28 days. The usage of calcium hydroxide gave better initial strength to the pellets which helps in easy handling.

SEM image of fly ash aggregate taken with 20 kV of accelerating potential and 3000X zooming shows dense microstructure formation which proves the better CSH gel formation without interconnected pores.

SEM Image

- **PELLETIZING PROCESS**

The desired grain size distribution of an artificial lightweight aggregate is either crushed or by means of agglomeration process. The pelletization process is used to manufacture lightweight coarse aggregate; some of the parameters need to be considered for the efficiency of the production of pellet such as speed of revolution of pelletizer disc, moisture content and angle of pelletizer disc and duration of pelletization (Harikrishnan and Ramamurthy, 2006). The different types of pelletizer machine were used to make the pellet such as disc or pan type, drum type, cone type and mixer type. With disc type pelletizer the pellet size distribution is easier to control than drum type pelletizer. With mixer type pelletizer, the small grains are formed initially and are subsequently increased in particle size by disc type pelletization (Bijen, 1986). The disc pelletizer size is 570 mm diameter and side depth of the disc as 250 mm, it is fixed in a flexible frame with adjusting the angle of the disc as 35 to 55° and to control for the rotate disc in vertically manner should varying speed as 35 to 55 rpm (Manikandan and Ramamurthy, 2007).

Pelletization machine

EXPERIMENTAL INVESTIGATIONS

- **Experiments on Fly ash aggregates:**

a. Aggregate Crushing Value

The purpose of the test is to have an idea of compressive strength relatively, i.e. its resistance to crushing under compressive load applied gradually and thus to decide its suitability for use in concrete.

Apparatus:

i. A steel cylinder 152 mm diameter with open ends a square base plate with 252 mm sides, a plunger with a piston of dia. 150 mm. Plunger should have a hole 20 mm dia. Across it, little distance below top to insert a rod to lift, or lower the plunger.
ii. A cylinder measures 115 mm dia. And 180 mm high.
iii. I. S. sieves 12.5 mm, 10 mm and 2.36 mm.
iv. Tamping rod 16 mm dia. 45 to 60 cm long.
v. Balance 3 kg weighing up to 1 gm.

Aggregate crushing value apparatus

Requirement

i. The aggregate impact value should not excess 45 percent. That means any aggregate with A.I.V. more than 45% is not suitable for any concrete work. Below 45% up to 30% it can be used for concrete not used for wearing surfaces.

ii. For concrete used for wearing surfaces such as road work or run ways or air ports A.I.V. less than 10% is considered exceptionally strong.

iii. Aggregate with A.I.V. 10% to 20% is considered as strong.

iv. As per IS 2386 part IV two tests are to be conducted and mean value is to be adopted.

b. Aggregate impact strength

The purpose of the test is to know the toughness i.e. the resistance of the aggregate to impact and thus to decide its suitability for use in concrete.

Toughness and Aggregate Impact value:

Toughness is the property of material which indicates its capacity to withstand impact or sudden shock. Tougher the aggregate, more suitable it is for use in concrete, especially for wearing surfaces such as road surface which is often subjected to load impacts. Toughness is different from compressive strength which is resistance against slow sustained load. Aggregate impact value is a measure of toughness of aggregate. Lower the impact value, stronger the aggregate against impact. Therefore for good quality concrete, aggregate with lower AIV is preferred.

Aggregate impact value

Procedure:

i. Prepare test sample, by sieving the given aggregate. The sample shall pass through 12.5 mm sieve and retained on 10 mm sieve,

ii. Dry the sample in an oven at a temperature between 100°C to 110°C, for four hours. Then allow it to cool.

iii. Fill the cylindrical measure in layers taking care to tamp each layer by a tamping rod. Strike off the top with the rod. Find out weight of this sample [W].

iv. Remove the sample from the measure and fill it in the metal cup fixed to base plate. Tamp it with 25 strokes.

v. Raise the hammer till its lower face is 380 mm above upper surface of the sample and allow it to fall freely on the sample. Give similar 15 blows at an interval of not less than one second.

vi. Remove the crushed aggregate from the cup and sieve it through 2.36 mm sieve, vii Weigh the fraction passing the 2.36 mm sieve [Wl]

c. Aggregate Abrasion Value

Apart from testing the aggregate with respect to its crushing value and impact resistance, the aggregates must be tested with respect to its resistance to wear when used in construction of roads, pavements and wear house floors. I.S 2386 (Part IV) covers two methods for finding out the abrasion value of coarse aggregate namely Deval and Los Angeles abrasion testing machine. However, use of Los Angeles abrasion testing machine gives a better realistic picture of the abrasion resistance of the aggregate. Following are the guidelines for grading of the test sample and specifications for the abrasive charge to be used for the test.

Aggregate abrasion value

Materials

Cement, sand, coarse aggregate, water.

Procedure:

i. Clean the internal surface of the mould thoroughly and place it on a smooth horizontal, rigid and nonabsorbent surface, such as of a metal plate.

ii. Consider a W/C ratio of 0.5 to 0.6 and design mix of proportion about 1:2:4 it is presumed that a mix is designed already for the (test). Weigh the quantity of cement, sand, aggregate and water correctly. Mix thoroughly. Use this fresh prepared concrete for the test,

iii. Fill the mould to about one fourth of its height with concrete. While filling, hold the mould firmly in position,
iv. Tamp the layer with the round end of the tamping rod with 25 strokes, disturbing the strokes uniformly over the cross section:
v. Fill the mould further in 3 layers each time by 1/4 ^ height and tamping evenly each layer as above.
vi. After completion of tamping of the topmost layer strike of the concrete with a trowel or tamping bar, level with the top of mould.
vii. Lift the mould vertically slowly and remove it
viii. The concrete will subside. Measure the height of the specimen of concrete after subsidence.
ix. The slump of concrete is the subsidence, i.e. difference in original height and height up to the topmost point of the subsided concrete in millimeters.

Aggregates passing through 12.5 mm and retained in 10 mm sieve were used for both fly ash aggregates and natural gravel for the Mechanical tests (IS 2386 (Part 4): 1963). The crushing value gives the resistance of aggregate against gradually applied crushing load. Aggregate crushing value, impact value and abrasion resistance were found using IS 2386 (Part 4): 1963. Specific gravity, water absorption, bulk density and void ratio were calculated as per IS 2386 (Part 3): 1963.

PREPARATION OF CONCRETE

- **Mix Proportion**

Mix has been designed as per IS 10262:2009 for 28 days strength of 40 MPa. Table gives the mix proportion for Normal concrete made with natural gravel and fly aggregate concrete. In the proportion, coarse aggregate forms the major volume of 1293 Kg/m 3, which consumes large volume of fly ash.

Mix proportion

Mix	Normal concrete	Fly ash aggregate concrete
Super plasticizers (lit/m³)	0.2	0.1
Cement (kg/m³)	311	311
Water (lit/m³)	140	140
Sand (kg/m³)	737	737
Coarse aggregate (kg/m³)	1293	1293

High range water reducing admixture was used as super plasticizer (SP) in this study. SP content was consumed lesser for fly ash aggregate (FAA) concrete because of its rounded nature that itself improved workability.

Preparation of test samples

Cube moulds of 150 x 150 x 150 mm were used for compressive strength study. Moulds were properly maintained by cleaning and oiling before each casting. Vibrating table was used for better compaction and filled in three layers.

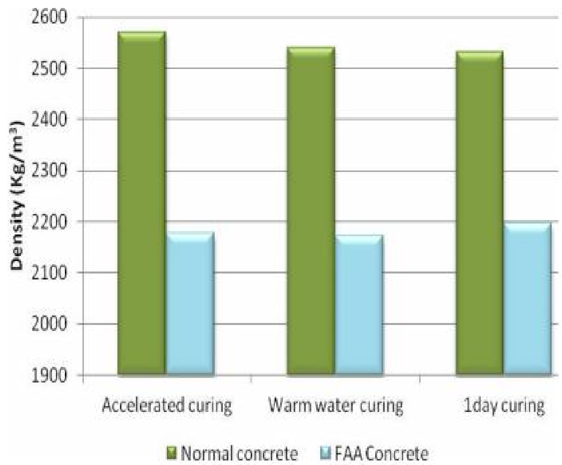
RESULT AND DISCUSSION

- **Concrete properties**

The property of cold bonded artificial aggregate concrete experimentally determined. The workability of fresh concrete is tested by slump cone test, water absorption by porosity strength of concrete by compressive strength test. The slump of lightweight concrete measured 30 minutes after batching was 50 mm.

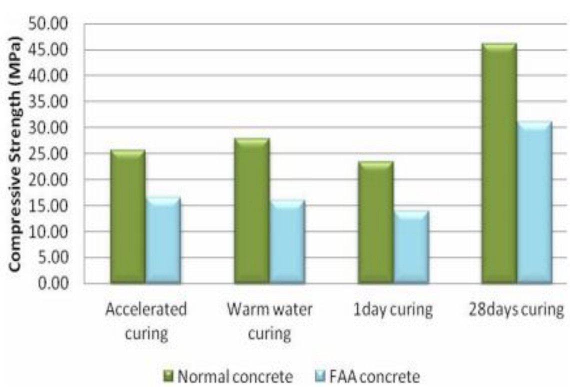
Slump cone test

Concrete with fly ash exhibited better workability which can be justified by the reduced SP usage. The density of concrete was much lesser for FAA concrete. This is due to the light weight of fly ash aggregate which is used in the manufacturing of light weight concrete. There is 15% decrease in density for FAA concrete compared to normal concrete which was increasing for warm water by 2% and 3% increase was seen for accelerated curing. The light weight concrete is widely used all over the world for various applications in recent days.



Density of normal and FAA concrete

When it comes to strength aspect, the compressive strength of normal concrete was 68% greater than the FAA concrete in the first day, which was reduced to 48% in 28 days. Further, as hydration process of fly ash occurs only on later days, early strength gain will be lesser but it increases gradually with age of curing. Though FAA concrete shows lower values of compressive strength compared to normal aggregate, it satisfies the minimum criteria to be used as structural concrete material. The possibility of production of fly ash aggregate in large volumes and the merits are discussed by (Verma et al., 1998) and it can be utilized for block making and other applications too (Garg et al., 1995).



Compressive strength of normal and FAA concrete

CONCLUSIONS

As a pilot study, fly ash aggregates has been made by pelletizing and cold bonding technique and the property of the obtained aggregates has been compared with natural gravel and results are found to be comparable.

i. The rounded shape of fly ash aggregate gives better workability compared to the angular natural gravel.
ii. Crushing and impact value shows value much lesser than the allowable limit. Abrasion value is too low but still cannot be used as a high way material due to its high percentage of water absorption. Though both natural and artificial aggregates shows crushing and impact value within the limit of 45%, fly ash aggregate shows 31.8% lower value than the natural aggregate for crushing and 26.4% higher impact value. But abrasion nearly equal for both cases.
iii. Low specific gravity compared to natural gravel proves it to be a light weight aggregate material and fly ash has been consumed in large volume when it is used as a coarse aggregate replacement material due to its occupation of large volume in concrete. This in turn reduces the problem of dumping as landfills to greater extent.
iv. The water absorption of fly ash aggregate is 9 times higher than that of natural gravel which is the major disadvantage which can be eliminated by various treatment methods that are available like treating with water glass etc.,
v. Concrete with density 2150 kg/m 3 can be achieved using fly ash aggregates while density of normal concrete mix goes up to 2580 kg/m3.
vi. Though compressive strength of FAA concrete is 48% lesser compared to normal concrete mix, it exceeds the value of 17 MPa that has been fixed as minimum criteria for concrete to be used as a structural material.

Since, fly ash aggregates shows results comparable with natural gravel and the natural resource is in the side of depletion, fly ash aggregates can be considered as a replacement material for coarse aggregate. Also, it improves the property of concrete as fly ash is a pozzolanic material. The obtained aggregates can be considered for various applications like wall panels, masonry blocks, roof insulation material, structural load bearing elements etc.,

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