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REPLACEMENT OF NATURAL AGGREGATE WITH FLY ASH AGGREGATE WITH ALKALI BLINDERS

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Abstract— In thermal power plants, combustion of coal for power generation gives fly ash much quantity as a by-product. It identifies as a cementitious material as well as environmental pollutant. So in the present day's people look at more utilization of fly ash in many structural purposes like back fills, dams, Earthen dams, partial replacement of cement, in road ways and as a light weight aggregates by adding some binders. In this study, concrete grade of M20 is design with fly ash is used as a cementitious material partially as well as complete& partial replacement of natural aggregates with fly ash aggregates. And also conducted the compression tests on these concrete cubes got a comparable result with conventional concrete cubes. The fly ash aggregates are prepared in the proportion of fly ash to cement ratio of 90:10 with alkali - binder ratio is 0.35. Here alkali-activators are 14M of NaOH and 50% of Na2SiO3 solution is added in the ratio of 3.6(Na2SiO3/NaOH). The above proportion of aggregate is fixed in this study by testing 25 trail mortar cubes were tested. In this way got maximum compressive strength is 33.6MPa.at 28days. And also conducted the tests on fly ash coarse aggregates. Crushing value, Impact value, Abrasion values are within the allowable values. So based on the obtained aggregates strength and properties are suitable for sub-base course in road ways. These light weight aggregates are used in the buildings (as non-structural elements) are having good seismic resistance, fire resistance and good sound absorption.

Keywords— Aggregates, Alkali binder, Geo polymer, Gypsum, fly-ash, sodium silicate, sodium hydroxide

I. INTRODUCTION

In present day, population is increasing in significant manner. To meet the basic needs of people, the construction industries have played a vital role. Due to that construction industry, pollution in the atmosphere also increased. Mainly concrete is used in this fields. Concrete having huge quantity of ingredients such as cement, sand, aggregates, water etc. All these ingredients are non-renewable resources. Cement create lots of environmental pollution. Due to cement production, huge amount of harmful gas is released into atmosphere. As a result mainly carbon dioxide content is increasing day by day. By replacing cement by industrial by products, we can reduce carbon dioxide content in atmosphere. Day by day carbon dioxide increased means, indirectly future population will get affected. Fine aggregates are available mainly in rivers. Mainly in river side, digging of sand is very harmful for generation, due to digging the sand, water is not stored properly and the river is not flowing in its path. So chances of getting floods and draughts etc. are very high one of the by-products is fly ash. Fly ash is an argillaceous material obtained from coal at high temperature while producing the electricity. While having the coal at high temperature, there is a chance of 75-80 percentage of fly ash getting released into atmosphere in the world. Fly ash is environmental pollutant, because these are very fine particles of silica, iron oxide, Al2O3& gets combined with air and float as dust. It creates unpleasant environment for humans. . So it has been dumped in a large area of pits. This affects the living area of people. Even though fly ash is used as backfilling, earthen dams etc. there is a need of further increase in usage of fly ash. That usage is up to 16- 20% of total releasing fly ash.

II. MATERIALS ADOPTED

A. Cement

This is the most used binder material in the construction industry from the ancient days. It is calcareous and argillaceous material. Now a days cement is used for preparing concrete whereas in the earlier days it was used only for mortar. In India for the first time there is south India industrial Ltd Company for producing cement in 1904. During 1951-56 in India, the production of cement is about 4.6 million tones. But this production is expected to increase 407 million tons in the year of 2017.

B. Fly-ash

As per IS: 3812 -2003 fly ash is named and identified as binder material in construction industry because of its chemical composition and fineness in particles. It is one of the by-products in the thermal power plant by combustion of coal at high temperature. It identified as the pollutant for human health and environment when it exposed to atmosphere because of its finer particles composed of silica and other constituents which affects human's regular life.In order to reduce that effect, we have to dump that fly ash in dumping pits. And its liberation in huge quantity requires large area of pits, so it will occupies the living area of people. The production of fly ash per annum is about 300 million

tons in the year 2017 in India, when it comes to whole earth this no. will be triple. And the utilization of fly ash is about 50% only (A.K. Jain, Technical Advisor, UltraTech Cement Ltd). Currently as per Indian Standard cement can be replaced upto 35% by fly ash in concrete but research from CANMET and similar institutions has concluded that fly ash up to 50% can be used in concrete without affecting its mechanical and durability properties.

Types of fly ash:

Class-C: In the power plants for generating electricity, burning of Lignite or Sub-Bituminous coal produces class-C type of fly ash. The released fly ash having more percentage of calcium oxide about 20%. It will produce somewhat more strength than class- F fly ash. The property of this class is somewhat nearer to cement properties. It doesn't require any activator to harden, just by adding water it hardens itself. This class of fly ash has alkalis and SO4 content, that's why it is not preferred to use in concrete

Class-F: In the power plants for generating electricity, burning of Anthracite and Bituminous coal produces class-F type of fly ash. This class of fly ash having calcium oxide content of less than 7%. Retaining pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime and hydrated lime mixed with water to react and produce cementitious compounds. Instead, adding cementitious materials add chemical activator such as sodium silicate (water glass) to a Class F ash to form a geopolymer.

D. Steel Slag:

In this study steel slag is also adopted for mix proportions for fly ash aggregate preparation. Steel slag, is a by-product while manufacturing steel, which is formed during the parting of the liquefied steel from impurities in steel -making furnaces. The slag occurs as a molten liquid and is a composite solution of silicates and oxides that hardens upon cooling. At present total production of steel slag in India is about 12 million tons per annum (Indian Minerals year book, 2015), which is far behind the advanced countries. For this study steel slag is taken from steel plant in Visakhapatnam.

E. Alkali Activators:

Sodium Hydroxide (NaoH):

Sodium hydroxide also known caustic soda, it is an inorganic compound. It is a white solid and highly caustic metallic base and alkali of sodium which is available in pellets, flakes, granules, and as prepared solutions at different concentrations. Sodium hydroxide is highly soluble in water.

Sodium Silicate (Na2SiO3):

Sodium silicate is also called as water glass or liquid glass, these materials are available in aqueous solution and in solid form. The pure composition is colorless or white, but commercial samples are often greenish or blue owing to the presence of iron containing impurities.

F. Aggregates:

These aggregates are just acts like a backbone to the concrete while bearing of loads on concrete. These aggregates occupy about 80% (both fine& coarse aggregates) of volume of concrete. The aggregates are two types based on size of aggregates. Size below 4.75mm is fine aggregates and greater than 4.75mm are coarse. This limit is 20mm for RCC.

Fine aggregates:

These fine aggregate are used full to fill the gap between coarse aggregates in the concrete. Also we can achieve concrete with economy because of using these fine aggregate.

***Coarse aggregate*:**

The mechanical properties of coarse aggregate will consume a more effect in conventional concrete strength. The main limitations of coarse aggregate are shape, texture, grading, cleanliness and nominal maximum size. These properties are considering to contain strength, stiffness, bonding capacity and absorption. Rough texture and angular coarse aggregate provide greater mechanical bond and are generally more suitable for use in high strength concrete than smooth texture aggregates. Depending on the required proportion of mortar mix for preparation of fly ash pellets was fixed by better strength obtained among casted of 25 trail mortar cubes. In this study a total of 25 types of trail mortar cubes were casted. And some of cubes are shown below.

Fig. 1 Cubes of different proportions

G. Preparation Of Fly Ash Aggregates:

Preparation of artificial aggregates with fly ash was already done by adopting pellatization process by adding some binders to fly ash along W/b ratio or with alkali/ binder ratio. So far different researchers tried binders such as cement, clay, bentonite, limestone powder, kaiolite, metakaiolite, Ca(OH)2 solution, NaOH solution, Na2SiO3 solution for chemical and physical activation of fly ash, that will lead to strengthen the fly ash by curing the prepared pellets in any of the method viz. cold bonding, sintering and auto-claving process.

In this study, Fly ash added with cement & steel slag in different proportions such that fly ash content is maximum quantity and other two binders are adjusted in remaining quantity. Along with proportions of mortar dry mix, we prepare 3 different mixes by i) adding water, ii) different concentrations of (5, 9, 14 &19 Molarity) NaOH solution and iii) both NaOH solution& Na2SiO3solution (35% & 50%) . With these proportions a total of 24 trail mortar cubes were casted. Among all these, the proportion of fly ash with cement in ratio of 90:10, alkali to binder ratio is 0.35(14M NaOH and 50% of Na2SiO3) with Na2SiO3/NaOH is 3.6 got better strength.

First prepare the solutions of 14M NaOH and 50%of Na2SiO3 and wait for minimum of 1 hour because of the high concentration to mix. Now prepare the dry mix of fly ash & cement in ratio of 90:10 as per weight.

Now mix it in a mixer and pour in a tray and compact mix to required thick (10mm& 20mm), and then cut that compacted mix with the help of pan cutter of having some shapes of holes, with help ofthat press the compacted mix, then we got regular (square& rectangle)shaped aggregates and then wait for 10 to15minutes, in the mean while aggregates get some what hardened because of alkali solution.

Then place these aggregates in pan mix along with sand and rotate 2 to 3 minutes, we got rounded irregular(cubical angular) shaped aggregates with rough texture. We can prepare more quantity of aggregates at a time based on size of tray and cutter.

Stepwise preparation of fly ash aggregates:

Step 1: Prepare the alkali solution of required concentration (14M NaOH and 50% of Na2SiO3) and wait for 1 hour. Then take fly ash and cement in the ratio of 90:10 as per weight. Now mix these paste by hand or by using mixer.

Step 2: Now that paste is transfer to tray and compact to required thick

Step3: Cutting of compacted paste with the help of honey comb structure type plate.

Step 4: After 10-15 minutes these pieces of fly ash paste gets strenghtened some what, then we keep that aggregates in mixer and rotate for 3-5 minutes then we obtained cubically angular shaped aggregates.

Step5: These aggregates cured at ambient air condition at minimum of room temperature. It doesn't require any external energy for curing. Before going to use this fly ash pellets we have to spray water on to the bulk of fly ash pellets. So that the water absorption of fly ash aggregates comes down.

Even though the methodology adopted in this project requires two more equipment than pellatizing process, the time taken for preparation of fly ash aggregates is almost same. But in this methodology of preparation of fly ash aggregates we got cubical with angular shaped aggregates. Whereas in pellatizing process rounded aggregates are obtained]

III. **TESTING OF FLY ASH AGGREGATES**

After 28 day of ambient air curing, these aggregates are taken for the coarse aggregate tests as explained

A. Aggregate crushing value test:

This test is conducted as per IS: 2386-1963 (Part -IV) to know the resistance of aggregate under the gradually applied loads. This value is expressed in terms of percentage obtained by ratio of weight of crushed aggregates (passed 2.36 mm sieve) by applied load of 40 tones at rate of 4 tones per min to the weight of total aggregates taken in the standard mold of 11.5 cm diameter & 18 cm height.

First take aggregates of 12.5mm passed and 10mm retained are filled in the standard mold of 11.5cm diameter & 18 cm with proper tamping. Weigh aggregates in mold. Then take that aggregates in the mold of size 15.2 cm diameter and 14 cm height. Put this mold in compression testing machine. Apply the load of 40 tones at the rate of 4 tones per min. Now take out the mold and sieve the crushed aggregates with the sieve of 2.36mm and weigh the passed aggregates. he obtained value is aggregate crushing value, if it is low represents the good aggregates and vise-versa. Aggregate crushing value= (weight of crushed aggregate passing 2.36 mm sieve/ weight of total aggregates) x 100. Test values **= (1.995-1.336) X 100/1.995 = 33.03%**

B. Aggregate impact value test:

This test is conducted as per IS: 2386-1963 (Part-IV) to know the toughness of aggregates when impact loads acting on it. This value is expressed in terms of percentage obtained by ratio of weight of aggregates (passing through 2.36mm) subjected to 15 blows of 14 kg weight to the total aggregates taken in the mold of 75mm diameter & 50mm height and multiplied by 100.

First take aggregates which passed through 12.5mm sieve but retained on 10 mm sieve. These are filled in the standard mold of 75mm diameter & 50 mm height with proper tamping. Weigh the aggregates in mold. Then take aggregates in the mold of 100mm diameter & 50mm height, laid that mold in the impact testing machine and subjected to 15 blows with 14 kg hammer falling from height of 380 mm. Then take out that crushed aggregates in sieve of size 2.36mm and weigh the passed aggregates. Now to obtain the value of impact ratio of weight in step III to the weight in step I multiplied with 100. Aggregate impact value= (weight of crushed aggregate passing 2.36 mm sieve/ weight of total aggregates)* 100. Test values: Impact value of aggregates = (W4/W3) x100 = 34.65%

C. Los-Angeles Abrasion Test:

This test is conducted as per IS: 2386-1963(Part-IV) to know the hardness of aggregate when subjected to traffic movements on the road that will leads to wearing of aggregates. This value is expressed in terms of percentage obtained by ratio of weight of aggregates (passing through 1.7mm) subjected to 500 rotations in 70 cm diameter & 50 cm length hollow cylinder to the total aggregates taken (5kg) and multiplied by 100.

Abrasion value = (weight of aggregate passing 1.7 mm sieve/ weight of total aggregates) X 100= 28%

D. Specific gravity test:

This test is conducted as per IS: 2386-1963(Part-III) to know the specific gravity of aggregate. It is calculated under following procedure.

Take the pycnometer of empty bottle and weigh it (W1). Now fill the bottle with aggregates in 1/3rd volume (W2). Fill the remaining volume with water and take weight (W3). Now take the weight of bottle with full of water (W4). Specific gravity of aggregates= (W2-W1**)/** ((W2-W1)-(W3-W4))=1.723

E. Water absorption value:

This test is conducted as per IS: 2386- 1963 (Part-III) to know the water absorption of coarse aggregates.

First take the aggregates without any fines around and take one wire bucket of weight 2 kg (W1). Fill the aggregates into bucket for 1/3rd volume and take weight (W2). Now soak this bucket in water so that bucket should be jolted 25 times. Retain that bucket with aggregates in water for 24 hours. Then take out that bucket and weigh that is W3. The water absorption of aggregates**=** (W3-W2)x100/(W2-W1)=19.1%

F. Bulk Density of Coarse Aggregate:

This test is conducted as per IS: 2386-1963 (Part-III) to know the density of aggregate. First take the known volume container about 15 liter capacity for coarse aggregates (V). Fill the aggregates into that container, weigh that aggregates by taken out from container (W).For calculation of density of aggregate= (W/V)x 100 Test values = 1.16 g/cc

***G. Voids ratio test*:**

This test is conducted as per IS: 2386-1963 (Part-III) to know the amount of voids present in the given volume of aggregates.

The formula for finding the percentage of voids = (specific gravity – density)x 100/specific gravity =100 x (1.723-1.16)/1.723=32.67%.

IV. **DESIGN, CASTING AND TESTING OF CONCRETE CUBES WITH FLY ASH AGGREGATES**

In the concrete, the major volumes of ingredients are aggregates. For getting more aggregates for making of concrete we are blasting the hills for coarse aggregates and for fine aggregates digging the river beds. That will create environmental unbalance. So to avoid that, this study will alter the usage of coarse aggregates in concrete by replacing the fly ash aggregates as well as fly ash is partial replace of binders in concrete. So this will helps to decrease the usage of cement and coarse aggregates, which will leads to decrease the environmental pollution. The resulting concrete is obtained as eco-friendly. Apart from this the more utilization of fly ash is achieved in this way.

We can prepare concrete with low price, liberation of CO2 gas reduced into atmosphere during hydration process in concrete and more utilization of fly ash takes place.

Casting of M-20 Concrete Cubes:

While casting of concrete cubes of size 15cm X 15cm X 15cm with replacement of fly ash aggregates to natural aggregates completely and partially, look after the workability of mix, because of fly ash aggregates had more water absorption value. So before start the mixing fly ash aggregates should get watering. Now mix the ingredients as per calculations by hand or mixer.

A. Testing of Concrete Cubes:

The testing of concrete cubes is based on the IS: 516-1959 at 28 days.

V. CONCLUSIONS

The mix of target mean strength is 26.6MPa with replacement of cement with fly ash (40% of total binder material) and replacement of natural aggregates with fly ash aggregates (60% of total coarse aggregates) got maximum strength of 21.3 MPa at 28 days.

The main aim of this thesis is the use of fly ash as both cement replacement and an aggregate replacement in concrete. So that the consumption of fly ash will be maximum. By this work the following conclusions can be made:

a) Even though Steel slag having more percent of calcium oxide and a smaller amount of silica & iron oxide, it doesn't participate in hydration reaction. So that the % increase in usage of steel slag in cementitious material the bonding nature will reduced there by reduction in strength of concrete and paste.
b) Fly ash added with cement in the ratio of 90:10 with alkali binder ratio is 0.35 of concentration 14M NaOH& 50% Na2SiO3 got maximum compressive strength of 33.6MPa.
c) The fly ash aggregates prepared with the above proportion of paste having good aggregate properties & well within the permissible limits. Based on the obtained properties of fly ash aggregates, we can use those aggregates for the light weight non-structural elements as well as sub-base coarse in the pavements. We can use this fly ash aggregates in the seismic resistance buildings.
d) The obtained fly ash aggregates properties are: Aggregate Crushing Value 33.03%, Aggregate Impact Value 34.65%, Aggregate Abrasion Value 28%, Specific Gravity1.723, Water Absorption 19.16%, Bulk Density 1.16g/Cc, Voids Ratio 32.67%.
e) Concrete prepared with the replacement of fly ash (40%) in cement and replacement of fly ash aggregates (60%) in coarse aggregates got maximum compressive strength of 21.3MPa in 28 days with density of 21.5 kN/m3.

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