Studying The Effort Of Fly Ash And Slag On The Properties Of Concrete Mixtures As A Partially Replacement Of Cement And Sand

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Abstract- *Concrete is a widely used construction material for various types of structures due to its structural stability and strength. The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Regrettably, production of cement involves emission of large amounts of carbon dioxide gas into the atmosphere, a major contributor for green house effect and the global warming. Hence it is inevitable either to search for another material or partly put back it by some other material. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact.*

1. Fly ash
2. Granulated Blast Furnace Slag

Keywords- Fly ash, Granulated Blast Furnace Slag, Regrettably, cementitious value.

I. INTRODUCTION

1.1 GENERAL

Concrete is a widely used construction material for various types of structures due to its structural stability and strength. The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Regrettably, production of cement involves emission of large amounts of carbon dioxide gas into the atmosphere, a major contributor for green house effect and the global warming. Hence it is inevitable either to search for another material or partly put back it by some other material.

1. Fly ash
2. Granulated Blast Furnace Slag

1.2 EFFECTS OF DISPOSAL OF FLY ASH WASTE

Since coal contains trace levels of arsenic, barium, beryllium, boron, cadmium, chromium, thallium, selenium, molybdenum and mercury, its ash will continue to contain these traces and therefore cannot be dumped or stored where rainwater can leach the metals and move them to aquifers.

1.4 RESEARCH METHODOLOGY

The following are to be carried out in order to achieve the research objectives.

- To collect the fly ash from thermal power plant RTPP and collect the blast furnace slag from steel plant.
- Sieve the slag by using of 4.75mm sieve.

II. REVIEW OF LITERATURE

2.1 GENERAL

Extensive research work both at national and international level has been done on the use of various admixtures in mortars and concretes with common goal.

2.2 MINERAL ADMIXTURES

Mineral admixtures refer to the finely divided materials which are added to obtain specific engineering properties of cement mortar and concrete. The other, equally important, objectives for using mineral admixtures in cement concrete include economic benefits and environmentally safe recycling of industrial and other waste by-products.

2.3 TYPES OF MINERAL ADMIXTURE

Mineral admixtures can be classified in two groups: Pozzolanic materials and inert filler materials.Pozzolanic materials are mineral admixture contains reactive silica which when added to cement reacts with calcium hydroxide to form C-S-H such as volcanic ash, burnt clay, and fly ash.

2.4 REVIEWS ON FLY ASH

2.4.1What is fly ash: Fly ash is one of the residues generated in coal combustion facilities, and comprises the fine particles that rise with the flue gases.

2.4.2 Where does fly ash come from: Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately gets ignites, generates heat and produces a molten mineral residue. Boiler tubes extract heat from the boiler, cool the flue gases and cause the molten mineral residue to harden and form ash.

2.4.3 Production of flyash: Fly ash is produced from the combustion of pulverized coal in industrial boilers or electric utility boilers. There are four types of coal-fired boilers: (i) pulverized coal (PC), (ii) stoker-fired, (iii) cyclone, and (iv) fluidized-bed combustion (FBC) boilers.

2.4.4 Fly ash classification: There are basically two classes of fly ash as defined by

ASTM C618 as:-

- Class F Fly ash
- Class C Fly ash

Class F Fly ash: The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 20% lime (Cao). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds.

Properties:

- most effectively checks heat gain during concrete curing and is therefore considered an ideal cementitious material in mass concrete and high strength mixes. For the same reason, Class F is the solution to a wide range of summer concreting problems.

Figure2.2 Example of fly ash

Class C Fly ash: Class C fly ash is produced normally from lignite and sub-bituminous coals and usually contains significant amount of Calcium Hydroxide (Cao) or lime (Cockrell et. al., 1970). This class of fly ash, in addition to having pozzolanic properties, also has some cementitious properties (ASTM C 618-99).

2.4.6 Environmental benefits

Fly ash utilization has significant environmental benefits:

(1) It increases the life of concrete roads and structures by improving concrete durability,
(2) It helps in net reduction in energy use and greenhouse gas.

2.4.7 Characterization of fly ash: Coal-based thermal power plants from all over the world facing serious problems of handling and disposal of the fly ash produced. The high ash content (30–50%) of the Indian coal makes this problem more complex.

Specific Gravity: Specific gravity is one of the important physical properties which are needed for the use of coal ashes for geotechnical and other applications. Generally the specific gravity of coal ashes is around 2.0 but it can vary to a large extent (1.6 to 3.1).

2.4.8 Utilization of fly ash in civil engineering works

- Fly ash as Raw material for cement manufacture (for blended cement products)
- Fly ash in Embankment construction

2.4.9 Fly ash utilization in mines

- Mine void filling (underground)
- Reclamation of abandoned surface coal mines

2.4.10 Agricultural application of fly ash

Fly ash as herbicide: Finest fraction of the ash has also been used either as a herbicide or carrier of pesticide with encouraging results. Dusting of domestic kitchen ash over plants (including Tulsi) and vegetable crops (such as brinjal) drives away insects, is a common sight in rural homes of India. Such kitchen ash with high proportion of anhydrous oxides of alkalis and alkaline earth, such as Na2O, K2O, Cao and Mgo, dehydrates (dehydrolyse) animals eating away the plant parts.

2.4.11 Benefits are:

- Reduces drying shrinkage and permeability,
- Lowers the heat of hydration

2.4.12 Disadvantages of fly ash in disposal system

There is risk of pollution to the surrounding environment including soil, vegetation and underground water resources.

2.4.13 Chemical composition: In general, which contains more than 60% SiO_2, and 28% Al_2O_3 by mass and source of fly ash influence its mineralogical composition. Due to the rapid cooling of burned coal in the power plant, fly ashes consist of non-crystalline particles (≤90%), or glass and a small amount of crystalline material. Depending on the system of burning, some unburned coal may be collected with ash particles. In addition to a substantial amount of glassy material, each fly ash may contain one or more of the four major crystalline phases: quartz, mullite, magnetite, and hematite.

2.5 REVIEWS ON GRANULATED BLAST FURNACE SLAG

Slag is primarily made up of Cao (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and Mgo (1-18%). Other elements like manganese, iron, sulfur, and trace amounts of other elements make up about other 5% of slag. The exact concentrations of elements vary slightly depending on where and how the slag is produced. In general increasing the Cao content of the slag results in raised slag basicity and an increase in strength.

Figure 2.5: Example of GBFS

S. N O.	Sieve Size	Wt. retained in gm	Percentage wt. retained	Cumulative % wt. retained (F)	Percentage passing (100-F)
1	4.75 mm	12	1.2	1.2	98.5
2	2.36 mm	103	10.3	11.5	88.5
3	1.18 mm	316	31.6	43.1	56.9
4	600µm	205.5	20.5	63.65	36.35
5	300µm	296.5	29.6	93.3	6.7
6	150µm	6.2	0.62	99.5	0.5
7	Pan	2	0.2	100	0

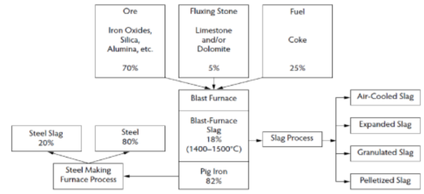

Figure 2.6: shows Flowchart showing production of pig iron and blast-furnace slag

III. MATERIALS AND METHODS

3.1 MATERIALS: The materials used in this present investigation are Ordinary Portland cement (53 grade), water, coarse aggregates, fine aggregates (sand, sag).In recent years, improvements in concrete properties have been achieved by blending cements with cementious admixtures such as fly ash (FA),granulated blast furnace slag (GBFS). Incorporation of these materials in concrete mixes improves the durability concrete.

3.2 Cement: Cement may be described as a material with adhesive and cohesive properties that make it capable of bonding, mineral fragments into a compact whole. It is usually manufactured from limestone mixed with shale, clay.

3.2.1.1 Ordinary Portland Cement (53 grade): Ordinary Portland Cement (OPC) is one of several types of cement being manufactured throughout the world, are some of the more commonly used. OPC is the general purpose cement used in concrete constructions. OPC is a compound of lime (Cao), silica (SiO_2), alumina (AL_2O_3), iron (Fe_2O_3) and sulphur trioxide (SO_3), Magnesium (Mgo) is present in small quantities as an impurity associated with limestone.

3.1.3 AGGREGATES: The material which is combined with cement and water to make concrete is called aggregate. Aggregate makes 60 to 80 percent of concrete volume. It increases the strength of concrete, reducing the shrinking tendencies of cement and is used as economical filler. Aggregates are divided into fine and coarse categories.

3.1.3.1Fine Aggregates

3.1.3.1.2 Slag: Due to scarcity of suitable river sand for use as fine aggregate in construction applications and recent construction boom has led to an drastic increase in price Additionally various government agencies have put some restrictions on sand quarrying to conserve this diminishing natural resources.

Table 9: Physical properties of slag

S.NO	DESCRIPTION	
1	Specific Gravity	1.71
2	Physical Form	Sized particles
3	Color	Pale white

3.2 METHODS

Parameters tested in this study

- Normal consistency,
- Initial setting & Final setting time
- Workability
- Compressive strength

3.2.1 TESTS ON CEMENT

3.2.1.1 Fineness of Cement by Dry Sieving Method: The degree of fineness of cement is a measure of the mean size of grains in cement. The finer cement has quicker action with water and gains early strength through its ultimate strength remains unaffected. However, the shrinkage and cracking cement will increase with the fineness of cement. Apparatus used to determine the sieve analysis areI.S. Sieve No. 9 (90 Microns), Weighing Balance capacity 5 kg as per IS: 4031(part 1)1996.Weigh 100 grams of the given cement and sift it continuously for 15 minutes on IS. Sieve 9 no air set lumps may be broken down by fingers but nothing should be rubbed on the sieves.

3.2.1.2 Normal Consistency: About 400g of cement was initially mixed with 30 percent mixing of water. The paste was filled in the mould of Vicat's apparatus and care was taken such that the cement paste was not pressed forcibly in the mould and the surface of filled paste was smoothened and leveled.

3.2.1.3 Initial and Final Setting Time: Cement paste was prepared by mixing cement with 0.85 times appropriate mixing water required to give a paste of standard consistency. The mould resting on a nonporous plate was filled completely with cement paste and the surface of filled paste was leveled smooth with the top of the mould. The test was conducted at room temperature of 27 ± 2^0C at a relative humidity of 60%.

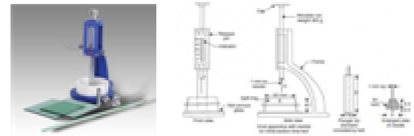

Figure: 3.1: Vicat apparatus with dimensions

3.2.1.4 Soundness: It consists of a small split cylinder of spring brass of 0.5mm thickness, forming a mould with 30mm internal diameter and 30mm high. On either side of the split are attached two indicators are attached with pointed ends AA, the distance from these ends to the Centre of cylinder being 165mm. the mould was placed on a glass sheet and was filled with cement paste formed by gauging 100g of cement with 0.78 times the mixing water required to give a paste of standard consistency. The mould was then submerged in the water at a temperature of 27 ± 2^0C.

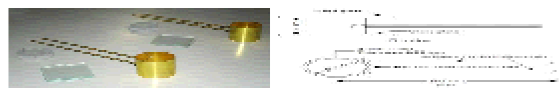

Figure: 3.2:Le Chatelier Apparatus with dimensions

3.2.1.5 Specific Gravity Cement: Specific gravity of cement is defined as, the ratio of dry weight of cement to the weight of equal volume of kerosene added. This test is conducted by Le-Chatliers apparatus this property very important in the mix design. Note down the weight of empty density bottle (W_1). Take a one third of cement in bottle and weigh the bottle (W_2) then fill the bottle with kerosene fully and weigh the bottle with cement and kerosene (W_3). Then clean the bottle and fill the kerosene in the bottle and weigh the bottle with kerosene (W_4).

Specific Gravity of Cement $= (W_2-W_1)/((W_2-W_1)-(W_3-W_4))$

Figure 3.3: Specific gravity apparatus(Density bottle)

3.2.2 TESTS ON AGGREGATES

3.2.2.1 Sieve Analysis of coarse aggregate: Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregate. This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. The apparatus used are a set of IS Sieves of sizes – 80mm, 63mm, 50mm, 40mm,31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm and 75µm. Balance or scale with an accuracy to measure 0.1 percent of the weight of the test sample.

3.3DETAILS OF MIXES

Concrete mix design in this experiment was designed as per the guidelines specified in by IS10262-1982 and ACI committee. All the samples were prepared based on the design trail mix of M20 grade of concrete was used in the present investigation. In this the mineral admixtures were used to replace cement by various percentages such as (10, 20, and 30) of cement weight and the percentage of aggregates was kept constant for all mixes.

3.4 TESTS ON CONCRETE

3.4.1 Compressive Strength Test: Remove the specimen from water after specified curing time and wipe out excess water from the surface. Take the dimension of the specimen to the nearest 0.2m. Clean the bearing surface of the testing machine. Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast..

Figure 3.8:Compressive testing machine

IV. RESULTS AND DISCUSSIONS

4.1 GENERAL

Concrete is the most widely used manufactured material in the construction industry. It's the most important property is durability which relates the performance of the material to its service life under various environmental conditions. The ability of concrete to withstand and satisfactorily and for long periods the effects of load, time, and environment depends very much on how the engineering properties of the material are constituted initially and how they are allowed to develop with age.

4.2 TESTS FOR WORKABILITY

Workability is the ability of fresh (plastic) concrete mix to fill the form/mould properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration) and can be modified by adding chemical admixtures.

4.2.1. Slump Cone Test: Slump test is the most commonly method for measuring the consistency of concrete which can be employed either in laboratory or at site of work. The internal surface of the mould is thoroughly cleaned and freed from moisture and adherence of any old set concrete before commencing the test. The mould is placed on a smooth, horizontal, rigid and non-absorbent surface. The mould is then filled in four layers, each approximately ¼ of the height of the mould. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section.

 

Fig.4.1 Slump Cone Apparatus Fig4.2. Measuring Slump Fall

4.4 TESTS ON CEMENT

S.NO	TEST NAME	VALUE
1	Specific Gravity of Cement	3.0
2	Standard Consistency of Cement	34%
3	Initial and Final Setting Time	40min , 380min
4	Fineness of cement	3%

4.7 TEST RESULTS ON CONCRETE

Compression test is the most common test conducted on hardened concrete, partly because it is easy test to perform and partly because most of desirable characteristic properties of concrete are qualitatively related to its compressive strength. Compression test is carried out on specimens of cubical shape. The size of specimen is 15×15×15 cm.

4.7.1COMPRESSIVE STRENGTH RESULTS

4.7.2 SPLIT TENSILE TEST:

Fly ash and Blast furnace slag replaced as cement sand in concrete to determine the split tensile strength for 3, 7, 14, 28 days curing of the concrete cylinders by using compressive strength testing machine. At room temperature these cubes were cured.

V. CONCLUSIONS

5.1. CONCLUSIONS OF THE STUDY

Fly Ash and GBFS is used in production of concrete cubes and cylinders replacement cement by fly ash dosage of 10% at replacement sand by slag dosage of 10%, 20%, 30%, replacement cement by fly ash dosage of 20% at replacement of sang by slag dosage of 10%, 20, 30%, replacement of cement by fly ash dosage of 30% at replacement of sand by slag dosage of 10%, 20%,30%.These cubes.

VI. APPENDIX

M-20 CONCRETE MIX DESIGN
As per IS 10262-1982 & IS 456-2000:

CALCULATIONS FOR M20 MIX DESIGN:
(As per IS 10262-1982 & IS 456-2000)

4.6.1STIPULATIONS FOR PROPORTIONING

1. Grade designation = M_{20}
2. Type of cement confirming to IS 12269-1987 = OPC 53 grade
3. Maximum nominal aggregate size =20 mm
4. Minimum cement content (MORT&H 1700-3 A) = 250 kg/m^3
5. Maximum water cement ratio (MORT&H 1700-3 A) = 0.5
6. Workability (MORT&H 1700-3 A) = 25 mm (slump)
7. Exposure condition = Normal
8. Degree of supervision= Good
9. Type of aggregate crushed= Angular Aggregate
10. Maximum cement content (MORT&H Cl. 1703.2) = 540 kg/m^3
11. Chemical admixture type super plasticizer co to IS-9103

4.6.2 TEST VALUE FOR MATERIAL

1. Anjani cement used OPC= 53 grade
2. Specific gravity of cement= 3.0
3. Specific gravity of water= 1.00
4. Chemical admixture= Not Used
5. Specific gravity of coarse aggregate= 2.65
6. Specific gravity of fine aggregate= 2.43
7. Water absorption of coarse aggregate= 1.61%
8. Water absorption of fine aggregate= 1.93%
9. Free (surface) moisture of coarse aggregate= Nil
10. Free (surface) moisture of sand= 6.41%

4.6.3 TARGET STRENGTH FOR MIX PROPORTIONING:

1. **Target mean strength=** 28 N/mm^2
   $f'_{ck} = f_{ck} + 1.6*5$
2. **28 days of Characteristic strength** = 20 N/mm^2
3. **Maximum water cement (10262-table-2)** = 186 Lit
4. **Estimated water content for 25 mm slump** = 145 Lit
5. **Superplasticiser used =** Nil

4.6.4 CALCULATIONS OF CEMENT CONTENT

1. **Water cement ratio** = 0.5
2. **Cement content (145/0.5)=** 290 kg/m^3

This is greater than 250 kg/m^3

4.6.5 PROPORTION OF VOLUME OF FINE AGGREGATE & COARSE AGGREGATE CONTENT:

1. **Volume of coarse aggregate as per table 3 of IS 10262** = 62.00%

Providing volume of coarse aggregate = 65.00%

2. **Adopting volume of fine aggregate (1-0.65)** = 35.00%

4.6.6 MIX CALCULATION

1. Volume of concrete = 1.0
2. Volume of cement in m^3= 0.11

(Mass of cement) / (specific gravity of cement) x 1000

3. Volume of water in m^3 = 0.145

(Mass of water) / (specific gravity of water) x 1000

4. Volume of admixture @ 0% in m^3= Nil

(Mass of admixture) / (specific gravity of admixture) x 1000

5. Volume of all in aggregate in m^3=0.745

Serial number 1 – (serial number 2+3+4)

6. Volume of coarse aggregate in m^3=0.484

Serial number 5 x 0.65

7. Volume of fine aggregate in m^3=0.261

Serial number 5 x 0.35

8. Mass of coarse aggregate in kg/m^3=955.53

(0.745x0.484x2.65x1000

9. Mass of fine aggregate in kg/m^3=472.50
   (0.745x0.261x2.43x1000)

4.6.7 MIX PROPORTIONS:

1. **Mass of water** =145 kg/m^3
2. **Mass of cement** = 290 kg/m^3
3. **Mass of fine aggregate** =472.50 kg/m^3
4. **Mass of coarse aggregate**=955.53 kg/m^3
5. **Mass of admixture** =Nil

6. Water cement ratio =0.5

9) Correction for water absorption and free moisture

Water = 145 kg
Coarse aggregates = 955.53 kg
Fine aggregates = 472.50 kg

Water absorption

Coarse aggregates = 0.82%
Fine aggregates-sand =1.93%

Free moisture

Coarse aggregates = Nil
Fine aggregates-sand = 6.41%

Extra quantity of water to be added for absorption

Coarse aggregates at 0.82% = $\frac{0.82}{100} X955.53$ = 7.83 kg
Fine aggregates at1.93% = $\frac{1.93}{100} X472.50$ = 9.11 kg

Quantity of water to be deducted for free moisture

Coarse aggregates at 0% = 0
Fine aggregates at 6.41% = $\frac{6.41}{100} X472.50$ = 23.14 kg
Actual quantity of water required = 145.0+ (9.11+7.83) + (0+23.14) = 185.08 kg
Actual quantity of sand required = 472.50-9.11+23.14 = 486.53 kg
Actual quantity of coarse aggregates required= 955.53-7.83 = 947.7 kg

10) Mix proportion

Cement = 290 kg
Water = 185.08 kg
Fine aggregates = 486.53 kg
Coarse aggregates = 947.70 kg

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