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A Study on the Effect 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. In this thesis, the different admixtures were used to study their sole and combined effects on the resistance of concrete in addition to their effects on mechanical and stability properties by the replacement of cement by 10% fly ash and sand replacement 10%, 20%, 30% of slag, cement by 20% fly ash and sand replacement 10%, 20, 30% of slag, cement replacement of 30%fly ash and sand replacement 10%, 20%, 30% of slag. The secondary materials used in our project are pozzolanic materials. The term pozzolana is a siliceous or a siliceous and aluminous material which itself possesses no cementitious value but in presence of water, chemically react with calcium hydroxide to form compounds possessing cementitious properties .The material which having the pozzolanic property known as pozzolanic material. The pozzolanic materials that are used in our project are

1. Fly ash

2. Granulated Blast Furnace Slag

Key words: - Fly ash, Granulated Blast Furnace Slag, Regrettably, cementitious value.

INTRODUCTION

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.

In this thesis, the different admixtures were used to study their sole and combined effects on the resistance of concrete in addition to their effects on mechanical and stability properties by the replacement of cement by 10% fly ash and sand replacement 10%, 20%, 30% of slag, cement by 20% fly ash and sand replacement 10%, 20, 30% of slag, cement replacement of 30%fly ash and sand replacement 10%, 20%, 30% of slag.

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Fly Ash: Fly ash also known as flue-ash is one of the residues generated in combustion coal and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes considerable amounts of silicon dioxide (SiO_2) and calcium oxide (CaO).

In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43% is recycled, often used to increase Portland cement because fly ash is an low-cost replacement for Portland cement used in concrete, while it actually improves strength, separation, and ease of pumping of the concrete. Fly ash is also used as an ingredient in brick, block, paving, and structural fills. This waste is causing problems to human health and environmental pollution.

The challenge for the civil engineering population in the near future will be to realize projects in harmony with the concept of sustainable development, and this involves the use of high-performance materials and products manufactured at sensible cost with the lowest possible ecological impact. Concrete is the most widely used construction material worldwide. However, the production of Portland cement, an essential constituent of concrete, releases large amounts of CO_2 which is a major contributor to the greenhouse effect and the global warming of the planet and the developed countries are considering very severe regulations and limitations on CO_2 emissions. In this scenario, the use of supplementary cementing materials (SCMs), such fly ash, slag and silica fume, as a replacement for Portland cement in concrete presents one viable solution with multiple benefits for the sustainable development of the concrete industry. The most commonly available SCM worldwide is fly ash, a by-product from the combustion of pulverized coal in thermal power stations. Fly ash, if not utilized has to be disposed off in landfills, ponds or rejected in river systems, which may present serious environmental concerns since it is produced in large volumes.

REVIEWOFLITERATURE

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. The main objectives are:

- To combat the environmental hazards from the industrial wastes.
- To modify the properties of traditional concrete to the desired level suitable to the specific circumstances.
- To conserve the natural resources used in the production of construction materials.
- To bring down the increasing cost economics of cement, building blocks and high strength concretes.

In the last decades many experiments and researches have been done to investigate the effects of concrete influenced by the acidic attacks and the impact of chemicals on cementization. Literature relating to blended cements in concrete and the effect of curing regimes on this concrete are numerous. In this chapter, only literature concerning those aspects related to this particular research i. e. the mechanical and durability properties of hardened concrete incorporating fly ash and slag as a mineral admixtures added to concrete made with the Portland cement are discussed. This survey also includes the effect of curing conditions on the various properties of concrete.

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. Unlike chemical admixtures, they are used in relatively large amounts as replacement of cement and/or of fine aggregate in concrete. In the past, natural pozzolans such as volcanic earths, tuffs, trass, clays, and shales, in raw or calcined form, have been successfully used in building various types of structures such as aqueducts, monuments and water retaining structures. Natural pozzolans are still used in some parts of the world. However, in recent years, many industrial waste by-products such as fly ash, slag, silica fume, red mud, and rice husk ash and highly reactive metakaolin has recently become available as a very active pozzolanic material for use in concrete. Unlike fly ash, slag, or silica fume, this material is not a byproduct but is manufactured from a high-purity kaolin clay by calcination at temperatures in the region of 700 to 800°C are rapidly becoming the main source of mineral admixtures for use in cement and concrete.

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. Using pozzolans lower the heat of hydration, increase later strength, and increase durability. Inert materials are mineral admixtures which do not affect the strength of concrete and used as workability aids such as hydrated lime, dust of normal weight aggregates, and colouring pigments.

Reviews on Fly Ash

What 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.

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. Coarse ash particles, called as bottom ash or slag, fall to the bottom of the combustion chamber, and the lighter fine ash particles, termed as fly ash, remain suspended in the flue gas. Before exhausting the flue gas, fly ash is removed by particulate emission control devices, such as filter fabric bag houses or electrostatic precipitators

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. The PC boiler type is the most widely used, especially for generating large electric units. The other boilers are more commonly used in industrial or cogeneration facilities. Fly ash is collected from the flue gases by using electrostatic precipitators (ESP) or in filter fabric collectors. The physical and chemical characteristics of fly ash depend on (i) combustion methods, (ii) coal source, and (iii) particle shape.

Types of boilers: In general, there are three types of coal-fired boilers used in electric utility industry. They are as follows:

- Dry - bottom boilers
- Wet – bottom boilers
- Cyclone furnaces
- When pulverized or powdered coal is combusted in a dry–ash, dry-bottom boiler, about 80% of all the ash leaves the furnace as fly ash, entrained in the flue gas.
- When pulverized coal is combusted in a wet bottom (or slag-trap) furnace, about 50% of the ash is retained in the furnace, and the other 50% being entrained in the flue gas.
- In a cyclone furnace, crushed coal is used as a fuel. 20 to 30 % leaves the furnace as dry ash and rest 70 to 80% of the ash is retained as boiler slag.

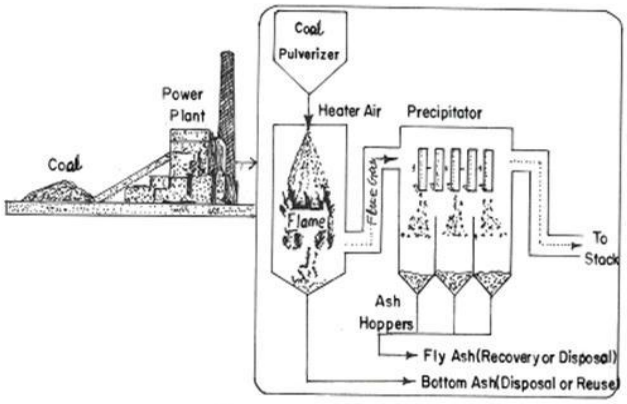

Fig 1: general flow diagram of fly ash production in a dry-bottom coal-fired utility boiler operation

MATERIALS AND METHODS

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. The movement of aggressive substances such as chloride ions and carbon dioxide into concrete which are the main causes of deterioration of concrete structures that affect their integrity and long term serviceability life, is thus very much reduced. The deterioration of concrete is not a result of only aggressive agents, but the overall quality of concrete and also play a major role. In view of this problem, a growing number of concrete structures are constructed or under construction with the use of cement replacement materials. Therefore any attempt to alleviate the deterioration-risk implies producing good performance concrete capable of withstanding the harsh environmental conditions. In this chapter, the materials and methods described together with their properties. In this the tests carried out on different concrete mixes, curing regimes, mix proportions and casting of specimens is discussed.

Fly Ash: The fly ash is collected from local waste scrapers. Fly ash is a pozzolana substance containing aluminous and siliceous material that forms cement in the presence of water. Cement is now partially replaced by its weight by fly ash at varying rates such as 10%, 20%,30%. The specific gravity of fly ash is taken as 2.0. The physical properties of fly ash are shown in the following table

Table: 1 Physical properties of fly ash

S.NO	DESCRIPTION	
1	Specific Gravity	2.0
2	Physical Form	Powder
3	Color	Dark grey

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. Most cement used today is Portland cement. This is carefully proportioned and specially processed combination of lime, silica, iron oxide and alumina. It is usually manufactured from limestone mixed with shale, clay. Properly proportioned raw materials are pulverized into kilns where they are heated to a temperature of 1300 to 1500˚C. The clinker is cooled and ground to fine powder with addition of about 3 to 5% of gypsum. The OPC (53 grade) used in the present work is of Zuari cement.

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. SO_3 is added at the grinding stage to retard the setting time of the finished cement. When cement raw materials containing the proper proportions of the essential oxides are ground to a suitable fineness and then burnt to incipient fusion in a kiln, chemical combination takes place, largely in the solid state resulting in a product aptly named clinker. This clinker, when ground to a suitable fineness, together with a small quantity of gypsum (SO_3) is Portland cement. In fact, cement powder is "nothing else" other than a combination of oxides of calcium, silicon, aluminum and iron. The cement used throughout the test program was Ordinary Portland Cement (OPC) of 53 grade confirming to IS 4031:1988 was used in the present study. The specific gravity of cement is taken as 3.0. The chemical and physical properties of cement are presented in following tables.

Chemical composition O.P.C: Although Portland cement consists essentially composed of four major oxides: lime (Cao), silica (SiO_2), alumina (Al_2O_3), and iron (Fe_2O_3) and also Portland cement contains small amount of magnesia (Mgo),alkalies(Na2O and K2O), and sulfuric anhydrite (SO3).

Table 2: Chemical composition Limits of Oxides in Portland cement are given below

S.NO	Oxide Composition	Percent Content
1	Lime, Cao	63
2	Silica,SiO_2	20
3	Alumina,Al_2O_3	6
4	Iron oxide,Fe_2O_3	3
5	Magnesia, Mgo	1.5
6	Sulphur trioxide, SO_3	2
7	Potassium oxide,K_2O	1
8	Sodium oxide,Na_2O	1
9	Tricalcium silicate,C_3S	54.1
10	Dicalcium silicate,C_2S	16.6
11	Tricalcium aluminate,C_3A	10.8
12	Tetra calcium aluminoferrite,C_4AF	9.1

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.

Fine Aggregates

Sand: Naturally available sand is used as fine aggregate in the present work. The most common constituent of sand is silica, usually in the form of quartz, which is chemical inert and hard. The sand is free from clayey matter, silt and organic impurities etc. Hence used as a fine aggregate in concrete. The size of sand is that passing through 4.75 and retained on 150 micron IS sieve. The specific gravity of Sand is taken as 2.62. Sand is tested for specific gravity, in accordance with IS: 2386-1963.

RESULTS AND DISCUSSIONS

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.

The use of cementitious and pozzolanic siliceous industrial by-products as mineral admixtures-in concrete can bring improvements in engineering properties of concrete (strength, impermeability and general durability). Normal pozzolan additives due to their low surface area and reactivity are not generally able to improve the early strength which is crucial to the strength and stability of structural concrete applications and durability of concrete. The problem, though, could be solved by using a mixture of normal (such as fly ash and slag) and a highly reactive pozzolan, to produce a durable concrete which does not suffer from low early strength. Also the durability of concrete during its service life may be significantly affected by the environmental conditions to which it is exposed, and in order to produce a concrete of high quality, the placing of an appropriate mix must be followed by a planned curing system in a suitable environment during the early stages of hardening.

This part presents and discusses the results of this investigation on the effect of curing conditions on the engineering properties such as of various concrete mixes made with cement replacement materials such as fly ash (FA), granulated blast furnace slag (GBFS). The results obtained are used to analysis the effect of these cement replacement materials on the above engineering properties. Based on the various tests that are conducted in laboratory is to analysis the strength and durability characteristics and their results correlate with the study and derive positive result and improvement. The results of the present investigation are presented both in tabular and graphical forms in order to facilitate the analysis; interpretation of the results is carried on each phase of the experimental work. This interpretation of the results obtained is based on the current knowledge available in the literature as well as on the results obtained. The significance of the results is assessed with reference to the standards specified by the relevant IS codes.

- The normal consistency of cement sample prepared with replacement of Cement by Fly Ash ranging from 10, 20 and 30%.
- Both the initial and final setting time of cement sample prepared with replacement of cement with by fly ash ranging from 10, 20 and 30%. If the difference is less than 30 minutes, the change is considered to be insignificant and if it is more than 30 minutes, the change is considered to be significant.
- The sieve analysis of fine and coarse aggregate which is used for the present experimental work.
- The workability test of fresh concrete was measured by the partial replacements of mineral admixtures.
- The average compressive strength of concrete of at least three cubes (150*150*150 mm) prepared with mineral admixture under consideration is compared with that of three cubes prepared with ordinary cement (for 3 days, 7 days, 28 days, 60 days and 90 days).
- The average split tensile strength of concrete of at least three cylinders prepared with mineral admixture under consideration is compared with that of three cylinders prepared with ordinary cement and normal sand (for 3,7 and 28 days).
- The water absorption test of concrete of at least three cubes prepared with mineral admixture under consideration is compared with that of three cubes prepared with ordinary cement and normal sand.

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. Raising the water content or adding chemical admixtures will increase concrete workability. Excessive water will lead to increased bleeding and/or segregation of aggregates (when the cement and aggregates starts to separate), with the resulting concrete having reduced quality. The use of an aggregate with an undesirable gradation can result in a very harsh mix design with a very low slump, which cannot be readily made more workable by addition of reasonable amounts of water.

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. After the top layer has been rodded, the concrete is struck off level with a trowel and tamping rod. The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside. This subsidence is referred as 'slump' of concrete. The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. The difference in height in 'mm' is taken as slump of concrete.

Fig.1 Slump Cone Apparatus **Fig. 2. Measuring Slump Fall**

Test results

1. Slump in terms of millimeters to the nearest 5 mm = 49.5mm
2. Shape of the slump:SHEAR
3. Referring to the selection of data, we have a slump value within the Range (60 – 180 mm).

Table 3: Workability of concrete with replacement of fly ash and slag

S.NO	Details of Material	Slump in mm
1	90%cement +10%FA and 90%sand+10%slag	45
2	90%cement +10%FA and 80%sand+20%slag	47
3	90%cement +10%FA and 70%sand+30%slag	50
4	80%cement +20%FA and 90%sand+10%slag	53
5	80%cement +20%FA and 80%sand+20%slag	56
6	80%cement +20%FA+70%sand30%slag	58
7	70%cement +30%FA and 90%sand+10%slag	54
8	70%cement +30%FA and 80%sand+20%slag	57
9	70%cement +30%FA and 70%sand+30%slag	59

CONCLUSIONS

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 and cylinders were cured and tested for compressive strength and split tensile strength for 3days, 7days, 14days, 28days, 56days, 90days and results were noted. Based on experimental investigation conducted following conclusions are made.

- ✓ With increasing of fly ash and slag percentages in concrete then the workability should be increased gradually as compared to normal concrete.
- ✓ By using of fly ash and slag in concrete the water absorption quantity should be increased gradually because of slag absorbed more quantity of water.
- ✓ The most interesting finding was that Fly Ash retards the initial setting and accelerates the final setting of concrete mortar.
- ✓ The experimental results show that the pozzolanic activity of fly ash and slag waste increases with increase of time.
- ✓ The physical properties of cement with the replacement of fly ash and slag were found to be increase with the increasing of the percentages of admixtures.
- ✓ The Compressive strength of concrete for 10% FA and 10% GBFS is more compared to that for 10% FA and 20% GBFS and 10% FA and 30% GBFS.
- ✓ The Compressive strength of concrete for 20% FA and 10% GBFS is more compared to that for 20% FA and 20% GBFS and 20% FA and 30% GBFS.
- ✓ The Compressive strength of concrete for 30% FA and 10% GBFS is more compared to that for 30% FA and 20% GBFS and 30% FA and 30% GBFS.
- ✓ The maximum strength had attained 39.59% increased at 10 % FA and 10% GBFS replacement when compared to controlled concrete.
- ✓ The split tensile strength values were found to be gradually decreased while the combination of percentage replacement of admixtures is increased.

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