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Study of Partial Replacement of cement by Mixture of Ground Granulated Blast furnace Slag, Silica fume, and Fly Ash

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Abstract - *Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Concrete plays a vital role in the development of infrastructure Viz., buildings, industrial structures, bridges and highways etc. leading to utilization of large quantity of concrete. The present technical report focuses on investigating characteristics of concrete with partial replacement of cement with Ground Granulated Blast furnace Slag (GGBS), Silica Fume & Fly ash. The topic deals with the usage of GGBS, Silica Fume & Fly ash and advantages as well as disadvantages in using it in concrete. Now a days more cementitious waste materials are produced by the many industries like iron industries (GGBS), coal industries (FLY ASH), paper industries (PAPER ASH) etc. This paper mainly focuses on the strength of the concrete by determining the compressive strength and tensile strength of the concrete by various replacement of Fly ash and GGBS. it is expected that steel bars in concrete will not occur corrosion for 100 years. Ground Granulated Blast furnace Slag (GGBS) is a byproduct from the blast furnaces used to produce iron. The most important objective of this study is to evaluate the possibility of usage of GGBS, Silica Fume & Fly ash in concrete. Concrete is world's most used material for urban development. Concrete is made up of naturally occurring material such as Cement, Aggregate and Water. The cement is major ingredient of concrete and due to rapid production of cement, various environmental problems are occurred i.e. Emission of greenhouse gases such as CO2. The production of Portland cement is energy intensive. Global warming gas is released when the raw material of cement, limestone and clay is crushed and heated in a furnace at high temperature of about 1500 0C. Each year approximately 1.89 billion tons of cement has been produced worldwide. Every one ton of cement produced lead to about 0.9 tons of CO 2 emission and a typical cubic yard of concrete contains about 10% by weight of cement. The researchers are currently found on use of waste material having cementations properties which can be added in cement concrete as a partial replacement of cement without compromising its strength and durability which result in decreases in cement production thus reduction in emission in greenhouse gases i.e.CO2.*

Key Words: **Fly ash, GGBS, Environment problem, compressive strength, tensile strength etc**

1. INTRODUCTION

The cement and water form a paste or gel which coats the sand and aggregate. When the cement has chemically reacted with the water (hydrated), it hardens and binds the whole mix together. The initial hardening reaction usually occurs within a few hours. It takes some weeks for concrete to reach full hardness and strength. Concrete can continue to harden. construction of all sorts of concrete structures Such as dams, bridges, skyscrapers, water and sewerage systems, public buildings, schools, hospitals, shopping centers, airport and rail termini, ports, factories and sporting stadia, houses, foundations, cast beams, floor slabs, walls and stair units, monuments, art and landscape projects; from the good, to the bad and the down-right ugly. Even boat hulls have been made in cast concrete. On its own, concrete has excellent resistance to compression (crushing), but is very poor in tension (stretching). It has been well known that ground granulated blast-furnace slag (GGBS) can increase the abilities to prevent water penetration and chloride penetration, and it can improve the durability of concrete. Also, the use of GGBS for concrete material contributes In Japan; GGBS has been rarely used for bridge superstructures because the increase of strength at early ages is smaller than that of the concrete without GGBS. In this study, the specimens which include normal-strength concrete and high-strength concrete were examined by changing water to binder ratio (W/B). The effectiveness of GGBS on strength and chloride ion diffusion coefficient was measured by migration test. Moreover, the application of GGBS which has the surface area of 6000 cm2/g for prestressed concrete bridge superstructures was presented.

Ground Granulated Blast furnace Slag (GGBS) [1] is a by product from the blast furnaces used to make iron. These operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials from a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimizes the cementitious properties and produces granules similar to coarse sand. This „granulated" slag is then dried and ground to a fine powder. Although normally designated as "GGBS" in the UK, it can also be referred to as "GGBS" or "Slag cement" Concrete is basically a mix of fine aggregate, coarse aggregate and cement. The main problem is the original conventional materials are depleting and we are in hunt for alternate building materials which lands us here on the purpose of GGBS. Being a by product and waste using it effectively up to some extent serves as a step for a greener environment and at the same time keeping in mind that the strength of the concrete doesn't degrade by the usage GGBS.

Effectively concentrating on both the factors have been successful up to a good extent and that's what we CIVIL ENGINEERS are very keen about in the present era of construction.

Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Concrete plays a vital role in the development of infrastructure such as industrial building, residential building, bridges and highways, etc. leading to the utilization of a large quantity of concrete. On the other side, the cost of concrete is attributed to the cost of its components which is scarce and expensive, hence leading to usage of economically alternative materials in its yield. This requirement has drawn the attention of investigators to explore new replacements of ingredients of concrete.

Ground Granulated Blast furnace Slag (GGBS) is a byproduct from the blast furnaces used to make iron. These operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials from a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be utilized for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimizes the cementitious properties and produces granules similar to coarse sand. This granulated slag is then dried and ground to a fine powder. It can also be referred to as "GGBS" or "Slag cement". The chemical composition of the GGBS was given in table 1.1. The primary problem is the original conventional materials are consumed and we are in the search for alternate building materials which lands us here for the use of GGBS.

Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also proceeds to gain strength over a longer period in production conditions. This issue in lower heat of hydration and lower temperature rise, and makes avoiding cold joints easier, but may also affect construction schedules where the quick mount is required. The last phase of the GGBS was shown in the figure 1.1.

So far in the literatures most of the work has done in the M30, M40 grade of concrete and very few has covered in the M20 grade of concrete using GGBS. Hence it is worth the experimenting to replace the GGBS in M25 grade of concrete and to find its optimum replacement level. The primary aim of this probe is to examine the mechanical behavior of concrete in the presence of GGBS, compared with conventional concrete. The compressive strength, split tensile strength, flexural strength of the concrete with GGBS were tested and analyzed in this study.

The various construction activities performs at site and require several material such as concrete ,steel, bricks, stones, glass, clay, mud, wood, admixtures etc.

However the cement concrete remains the main construction material used in construction industries. For its suitability and adoptability with respect to the changing environment economize and lead to proper utilization of energy. To achieve this major emphasis must be laid on the use of wastes and byproduct in cement and concrete used for new constructions. The future global challenge for the construction industry is clearly to meet the worlds growing needs while at the same time limiting the impact of its burdens by drastic improvement activities. Due to exponential growth of urbanization and industrialization byproduct from industries are becoming an increasing concern for recycling and waste management. Ground Granulated Blast Furnace slag (GGBS) is a byproduct from iron and steel industries. GGBS is very useful in the design and development of high quality cement paste/mortar and concrete. GGBS is a byproduct from the blast furnaces used to make iron or steel. Blast furnaces are fed with controlled mixture of Iron Ore, Coke and limestone and operated at a temperature of about 1500' C. When iron-Ore, coke and limestone melt in the blast furnace, two product are produced 1) The molten iron and 2) molten slag. The molten slag is lighter and floats on the top of the molten iron. The molten slag comprises of mostly silicates and alumina from the original iron Ore, combined with some oxides from limestone. The process of granulating the slag involves cooling of molten slag through high pressure water jet. This rapidly quenches the slag and forms granular particles generally not bigger than 5 mm. The rapid cooling prevents the formation of larger crystals and the resulting granular material compromise around 95 % non crystalline calcium-alumina silicates. The granulated slag is further processed by drying and then grinding in a vertical roller mill or rotating ball mill to a very fine powder which is GGBS.GGBS reacts like a Portland cement when in contact with water. Bulk GGBS is stored and handled in conditions identical to that of Portland cement. Bulks storage is in watertight silos and Transportation is by bulk tankers as for Portland cement.

2. REQUIRED MATERIAL

1. Ground Granulated Blast furnace Slag= 25 kg
2. Silica fume= 10 kg
3. Fly Ash= 10 kg
4. Cement= 50 kg
5. Aggregate= 150 kg,
6. Sand= 150 kg
7. Water= 500 lit.

3. MATERIAL DISCRIPTION

The materials used in this experiment were GGBS, FLY ASH, fine aggregate, coarse aggregate, Cement, Silica Fume and water.

Ground Granulated Blast furnace Slag (GGBS) is a byproduct from the blast furnaces used to produce iron. These operate at a temperature of about 15000C and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials from a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimizes the cementitious properties and produces granules similar to coarse sand. This „granulated‟ slag is then dried and ground to a fine powder. Although normally designated as "GGBS" in the UK, it can also be referred to as "GGBS" or "Slag

Fly Ash is a byproduct of coal-fired electric generating plants. For immediate combustion the pulverized coal is blown into the burning chamber of the furnace. After the burning of coal the ash that is heavier in weight would fall down but the lighter weight ash would fly out thus it is known as fly ash. Fly Ash is used in the following applications, in addition to Ready-mix concrete, Concrete block & pipe, Cement manufacture, Mineral filler for asphalt roads, Soil stabilization, Structural fill, Waste stabilization/treatment, Specialty applications. Fly ash is also known as pulverized fuel ash, which is a product of coal combustion that is when the coal is burned in thermal power plant ash is created. Fly ash and lime combination could reduce CO2 emission and it requires less energy to produce cement leads to green concrete.

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive Pozzolana. Concrete containing silica fume can have very high strength and can be very durable.
It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete.
Silica fume is a byproduct in the carbothermic reduction of high-purity quartz with carbonaceous materials like coal, coke, wood-chips, in electric arc furnaces in the production of silicon and ferrosilicon alloys.
Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material. Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength & Abrasion resistance. These improvements stem from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste
Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions and those of humid continental roadways and runways (because of the use of deicing salts) and saltwater bridges.

4. METHODOLOGY

Crumb rubber sample will be collected from location of Solapur-Maharashtra from the periphery of Akluj motar garage And other sample is cement, sand, aggregate collected from location of in Akluj city. from this work, it will help to improve the characteristics/ properties of the concrete by analyzing the compressive Strength of concrete and its effect on the properties of the concrete .The compressive Strength, durability, toughness of the concrete will be improved with some additives with the replaced of coarse aggregate such as pieces of tires. Tire rubber may replace air entraining Tire rubber may replace air entraining in cold weather applications and; it will studied that the influences of improvement of compressive Strength, Splitting tensile test ,Flexural test , toughness of concrete and other properties of the concrete.

Following test will be conducted on these concrete blocks

1) Gradation (Generally Uniformly Graded)
2) Specific Gravity
3) Toughness
4) Absorption Capacity
5) Unit Weight
6) Air Content
7) Stiffness
8) Durability
9) Compressive strength test
10) Splitting tensile test
11) Flexural test
12) Modulus of Elasticity
13) Shrinkage
14) Interfacial Transition Zone (ITZ)

5. OBJECTIVIES

The main objectives of this study are
● To determine the performance of concrete by partial replacement of cement by Ground granulated blast furnace slag, Silica Fume & Fly ash
● To determine the compressive strength and split tensile strength of concrete for 7 days, 14 days and 28 days curing.
● To determine the most optimized mix of GGBS, Silica Fume & Fly ash based concrete.

6. RESULTS

Test Results on Cement

Ordinary Portland cement conforming to IS 269-1976 and IS 4031-1968 was adopted in this work. The cement used is 53 grades. The test conducted on cement. Factors like fineness, initial setting time, specific gravity etc. was considered in selecting the type of cement.

Sr. No.	Type Of Test	Values Obtained	Is Specifications
1	Sieve analysis category	Zone I	IS 383–1970
2	Specific Gravity	2.64	IS 2386–1963

Test Results on Fine Aggregate

Fine aggregate (sand) used for HPC is properly graded to give minimum void ratio. River sand fineness conforming to zone I of IS: 383. Sand was tested as per IS: 2386

Sr. No.	Type of Test	Values Obtained	IS SPECIFICATIONS
1	Fineness Test by Sieving	97.2%	IS 269 – 1976
2	Normal Consistency of cement	32.8%	IS 4031
3	Initial Setting time	40 Minutes	IS 4031
4	Specific Gravity	3.12	IS 4031

Tests on GGBS

GGBS of 120 Grade confirming to IS 12089 – 1987 was adopted in this work

Sr. No.	Type of Test	Values Obtained	IS SPECIFICATIONS
1	Specific Gravity	2.85	IS1727 - 1967

Tests on Coarse Aggregate

Sr. No.	Type Of Test	Values Obtained	Is Specifications
1	Crushing Value	24.36	IS 2386-1963
	Impact Value	17	IS 2386-1963
2	Specific Gravity	2.63	IS 2386–1963

Slump Cone test

The concrete slump test measures the consistency of fresh concrete before it sets as per IS: 1199-1959. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows.

Sr. No.	GGBS CONTENT	Slump in mm
1	00	100
2	10	80
3	20	110
4	30	130

Compaction Factor Test

Compacting factor of fresh concrete is done to determine the workability of fresh concrete by compacting factor test as per IS: 1199 – 1959.

Mix Design

Mix proportion used in this study is 1:2.01:3.04 (M35) with water cement ratio of 0.46 and super plus 0.7%.

7. CONCLUSIONS

Based on the experimental investigation the following conclusions are,

1) It is observed that GGBS based concrete have achieved an increase in strength for 20% replacement of cement at the age of 7 and 28 days.

2) The replacement of cement by GGBS not only increases the compressive strength but also reduces the cement content which decrease in emission of $CO2$

3) The most optimized mix of GGBS based concrete is found to be 30% from both compressive and split tensile strength of concrete. However, beyond 30% of replacement, the strength decreases.

4) As far as cost is concerned, the cost of GGBS in the market including packaging and transporting is three times less than that of OPC.

Therefore, the partial replacement of OPC in concrete by GGBS, is not only economical but also facilitates environmental friendly disposal of the waste slag into a useful product, which is generated in huge quantities from the iron and steel industries.

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