



A COMPREHENSIVE STUDY OF SUPPLEMENTARY CEMENTITIOUS MATERIALS ON FIBER REINFORCED CONCRETE (FRC)

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ABSTRACT

High-performance concrete is defined as concrete that meets special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices. Ever since the term high-performance concrete was introduced into the industry, it had widely used in large-scale concrete construction that demands high strength, high flowability, and high durability. A high-strength concrete is always a high-performance concrete, but a high-performance concrete is not always a high-strength concrete. Durable concrete Specifying a high-strength concrete does not ensure that a durable concrete will be achieved. It is very difficult to get a product which simultaneously fulfills all of the properties. So the different pozzolanic materials like Ground Granulated Blast furnace Slag (GGBS), silica fume, Rice husk ash, Fly ash, High Reactive Metakaolin, are some of the pozzolanic materials which can be used in concrete as partial replacement of cement, which are very essential ingredients to produce high performance concrete. So we have performed XRD tests of these above mentioned materials to know the variation of different constituent within it. Also it is very important to maintain the water cement ratio within the minimal range, for that we have to use the water reducing admixture i.e super plasticizer, which plays an important role for the production of high performance concrete. So we herein the project have tested on different materials like rice husk ash, Ground granulated blast furnace slag, silica fume to obtain the desired needs. Also X-ray diffraction test was conducted on different pozzolanic material used to analyse their content ingredients. We used synthetic fiber (i.e Recron fiber) in different percentage i.e 0.0%, 0.1%, 0.2%, 0.3% to that of total weight of concrete and casting was done. Finally we used different percentage of silica fume with the replacement of cement keeping constant fiber content and concrete was casted. In our study it was used two types of cement, Portland slag cement and ordinary Portland cement. We prepared mortar, cubes, cylinder, prism and finally compressive test, splitting test, flexural test are conducted. Finally porosity and permeability test conducted. Also to obtain such performances that cannot be obtained from conventional concrete and by the current method, a large number of trial mixes are required to select the desired combination of materials that meets special performance.

Keywords: X-Ray Diffraction, l-Diversity, Plasticizer, Synthetic Fiber, Pozzolanic.

I. INTRODUCTION

Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementitious materials, water, aggregate and sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be moulded into any shape hardens into a rock-like mass known as concrete. The hardening is because of chemical reaction between water and cement, which continues for long period leading to stronger with age. The utility and elegance as well as the durability of concrete structures, built during the first half of the last century with ordinary portland cement (OPC) and plain round bars of mild steel, the easy availability of the constituent materials (whatever may be their qualities) of concrete and the knowledge that virtually any combination of the constituents leads to a mass of concrete have bred contempt. Strength was emphasized without a thought on the durability of structures. As a consequence of the liberties taken, the durability of concrete and concrete structures is on a southward journey; a journey that seems to have gained momentum on its path to self– destruction. This is particularly true of concrete structures which were constructed since 1970 or thereabout by which time (a) the use of high strength rebars with surface deformations (HSD) started becoming common, (b) significant changes in the constituents and properties of cement were initiated, and (c) engineers started using supplementary cementitious materials and admixtures in concrete, often without adequate consideration.

The setback in the health of newly constructed concrete structures prompted the most direct and unquestionable evidence of the last two/three decades on the service life performance of our constructions and the resulting challenge that confronts us is the alarming and unacceptable rate at which our infrastructure systems all over the world are suffering from deterioration when exposed to real environments.

1.1. High Performance Concrete

In recent years, the terminology "High-Performance Concrete" has been introduced into the construction industry. The American Concrete Institute (ACI) defines high-performance concrete as concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely when using conventional constituents and normal mixing, placing and curing practices. A commentary to the definition states that a high-performance concrete is one in which certain characteristics are developed for a particular application and environment. Examples of characteristics that may be considered critical for an application are:

1. Ease of placement
2. Compaction without segregation
3. Early age strength
4. Long-term mechanical properties
5. Permeability
6. Density
7. Heat of hydration
8. Toughness
9. Volume stability

10. Long life in severe environments

Because many characteristics of high-performance concrete are interrelated, a change in one usually results in changes in one or more of the other characteristics. A high-performance concrete is something more than is achieved on a routine basis and involves a specification that often requires the concrete to meet several criteria. For example, on the Lacey V. Murrow floating bridge in Washington State, the concrete was specified to meet compressive strength, shrinkage and permeability requirements. The latter two requirements controlled the mix proportions so that the actual strength was well in excess of the specified strength. This occurred because of the interrelation between the three characteristics.

A high-strength concrete is always a high-performance concrete, but a high-performance concrete is not always a high-strength concrete. ACI defines a high-strength concrete as concrete that has a specified compressive strength for design of 6,000 psi (41MPa) or greater. Other countries also specify a maximum compressive strength, whereas the ACI definition is open-ended. The specification of high-strength concrete generally results in a true performance specification in which the performance is specified for the intended application, and the performance can be measured using a well-accepted standard test procedure. The same is not always true for a concrete whose primary requirement is durability.

Durable concrete Specifying a high-strength concrete does not ensure that a durable concrete will be achieved. In addition to requiring a minimum strength, concrete that needs to be durable must have other characteristics specified to ensure durability. In the past, durable concrete was obtained by specifying air content, minimum cement content and maximum water-cement ratio. Today, performance characteristics may include permeability, deicer scaling resistance, freeze-thaw resistance, abrasion resistance or any combination of these characteristics. Given that the required durability characteristics are more difficult to define than strength characteristics, specifications often use a combination of performance and prescriptive requirements, such as permeability and a maximum water-cementitious material ratio to achieve a durable concrete. The end result may be a high-strength concrete, but this only comes as a by-product of requiring a durable concrete.

There are special method of making high strength concrete such that,

- 1. Seeding**
- 2. Revibration**
- 3. High speed slurry mixing**
- 4. Use of admixtures**
- 5. Inhibition of cracks**
- 6. Sulphur impregnation**

1.2 Earlier Researches

Some of the early research works had done using different pozzolanic materials with the replacement of cement using super plasticizer for the development high performance concrete. Also the development in the field of fiber reinforced concrete along with pozzolanas. So below an over view of different studies has been represented.

Aitcin[1] (1995) cited on development in the application of high performance concrete. Over the last few years,



the compressive strength of some of the concrete used has increased dramatically. In 1988, a 120 MPa concrete was delivered on site, while, until relatively recently, 40 MPa was considered indicative of high strength. The spectacular increase in compressive strength is directly related to a number of recent technological developments, in particular the discovery of the extraordinary dispersing action of super plasticizers with which flowing concretes can be made with about the same mixing water that is actually required to hydrate all the cement particles or even less. The reduction in water/cement ratio results in a hydrated cement paste with a microstructure so dense and strong that coarse aggregate can become the concrete's weakest constituent.

Ajdukiewicz and Radomski[2] (2002) delve into Trends in the Polish research on high-performance concrete. They analysed the main trends in the research on high-performance concrete (HPC) in Poland. There they sighted on some examples of the relevant investigations. The fundamental engineering and economical problems concerning the structural applications of HPC in Poland are presented as well as the needs justifying the increased use of this material are briefly described.

Aitcin[3] (2003) studied on the durability characteristics of high performance concrete. He examined durability problems of ordinary concrete can be associated with the severity of the environment and the use of inappropriate high water/binder ratios. High-performance concrete that have a water/binder ratio between 0.30 and 0.40 are usually more durable than ordinary concrete not only because they are less porous, but also because their capillary and pore networks are somewhat disconnected due to the development of self-desiccation. In high-performance concrete (HPC), the penetration of aggressive agents is quite difficult and only superficial. However, self-desiccation can be very harmful if it is not controlled during the early phase of the development of hydration reaction, therefore, HPC must be cured quite differently from ordinary concrete.

Field experience in the North Sea and in Canada has shown that HPCs, when they are properly designed and cured, perform satisfactorily in very harsh environments. However, the fire resistance of HPC is not as good as that of ordinary concrete but not as bad as is sometimes written in a few pessimistic reports. Concrete, whatever its type, remains a safe material, from a fire resistance point of view, when compared to other building materials.

II. SCOPE AND OBJECTIVE OF PRESENT WORK:

The objective of the present work is to developed concrete with good strength, less porous, less capillarity so that durability will be reached. For this purpose it requires the use of different pozzolanic materials like rice husk ash, ground granulated blast furnace slag, silica fume along with fiber. So the experimental programme to be undertaken;

- To determine the mix proportion with rice husk ash, ground granulated blast furnace slag and silica fume with fiber to achieve the desire needs.
- To determine the water/ binder ratio, so that design mix having proper workability and strength.
- To investigate different basic properties of concrete such as compressive strength, splitting tensile strength, flexural strength etc and comparing the results of different proportioning.
- Determination of porosity and capillary of different proportioned concrete.



2.1. Ground Granulated Blast Furnace Slag

Ground Granulated Blast furnace slag (GGBS) is a by-product for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is produced which is instantaneously tapped and quenched by water. This rapid quenching of molten slag facilitates formation of “Granulated slag”. Ground Granulated Blast furnace Slag (GGBS) is processed from Granulated slag. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolanic material.

However, if slag is slowly air cooled then it is hydraulically inert and such crystallized slag cannot be used as pozzolanic material. Though the use of GGBS in the form of Portland slag cement is not uncommon in India, experience of using GGBS as partial replacement of cement in concrete in India is scanty.

GGBS essentially consists of silicates and alumino silicates of calcium and other bases that is developed in a molten condition simultaneously with iron in a blast furnace. The chemical composition of oxides in GGBS is similar to that of Portland cement but the proportion varies.

The four major factors, which influence the hydraulic activity of slag, are glass content, chemical composition, mineralogical composition and fineness. The glass content of GGBS affects the hydraulic property, chemical composition determines the alkalinity of the slag and the structure of glass. The compressive strength of concrete varies with the fineness of GGBS.

Ground granulated blast furnace slag now a day’s mostly used in India. Recently for marine out fall work at Bandra, Mumbai. It has used to replace cement to about 70%. So it has become more popular now a day.

2.2 Performance of Ground Granulated Blast Furnace Slag in Concrete

The replacement of cement with GGBS will reduce the unit water content necessary to obtain the same slump. This reduction of water content is more pronounced with increase in slag content and also on the fineness of slag. This is because of the surface configuration and particle shape of slag being different than cement particle. Surface hydration of slag is slightly slower than that of cement. Reduction of bleeding is not significant with slag of 4000 cm²/g fineness but significant when slag fineness of 6000 cm²/g and above.

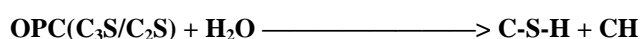
Advantages of using GGBS:

- [1] Reduce heat of hydration
- [2] Refinement of pore structures
- [3] Reduce permeability to the external agencies
- [4] Increase resistance to chemical attack.

2.3 Reaction Mechanism of Ground Granulated Blast furnace Slag:

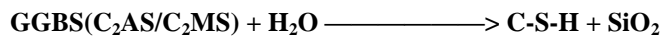
Although GGBS is a hydraulically latent material, in presence of lime contributed from cement, a secondary reaction involving glass (Calcium Alumino Silicates) components sets in. As a consequence of this, cementitious compounds are formed. They are categorized as secondary C-S-H gel. The interaction of GGBS and Cement in presence of water is described as below:

Product of hydration of OPC

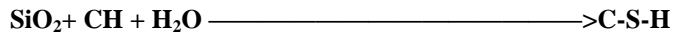




Product of hydration of GGBS



Reaction of pozzolanic material



The generation of secondary gel results in formation of additional C-S-H, a principal binding material. This is the main attribute of GGBS, which contributes to the strength and durability of the structure. The diagrammatic representation of secondary gel formation is shown below.

III. RESULTS AND DISCUSSION OF XRD TEST

XRD was conducted on RHA-I, RHA-2, GGBSS and Silica fume, to idealize the different chemical composition of these pozzolanic material. Test was performed at an angle 45° with 2θ equal to 90° and different graphs are obtained, which were analysed using “X-pert High Score” software.

In case of GGBS from the graph it is inculcated that compound purely in amorphous form. Here we got the formation of $\text{Mg}_2\text{Al}_2\text{O}_4$ corresponding to no. 74-1133 and Mg_2SiO_4 with no.74-1680. From the XRD graphs of RHA-I and RHA-II obtained from X-pert High Score software, it was visualised that RHA-I (black type) somehow is in crystalline form as compared to RHA-II (white type). But in both the form of rice husk ash we found cristaballite low temperature silica type with no. 76-0939 as to that of software. The graph shows silica fume also is in amorphous state with having compound SiO_2 and CaO with nos. 03-0865 and 80-2146 respectively in the software used.

3.1 Effect of Ggbs and Rha on Properties of Cement

To know the properties of GGBS and RHA on mortar we performed different tests

- Consistency test
- Compressive strength

The amount of water required to produce a standard cement paste to resist a specified pressure is known as normal or standard consistency. In other word it is the limit of water required at which the cement paste resist the penetration of standard plunger (1 mm diameter) under a standard loading up to a distance of 5-7 mm from the base of Vicat apparatus. The consistency of cement depends on its type and fineness. More water is required in cement with higher fineness value. The water quantity was calculated by $[(P/4) + 3]$ % of 800 gm. Consistency test was performed with both GGBS and rice husk ash of different percentage content. That is GGBS with 0, 10, 20, 30, 40 % and RHA with 0, 10, 20, 30 %.

Then mortars of standard size were casted with different percentage of GGBS (0%, 10%, 20%, 30%, 40%) and RHA (0% and 20%) with the replacement of cement. Portland slag cement and sand of zone- II was used in this experiment. Then compression test was conducted of mortars in Compression testing machine.



3.2 Test Result:

% of cement replaced by GGBS (%)	Consistency (%)
0	31.0
10	32.0
20	33.0
30	34.5
40	36.5

Table. 3.2.1. Effect of GGBS in normal consistency of cement:

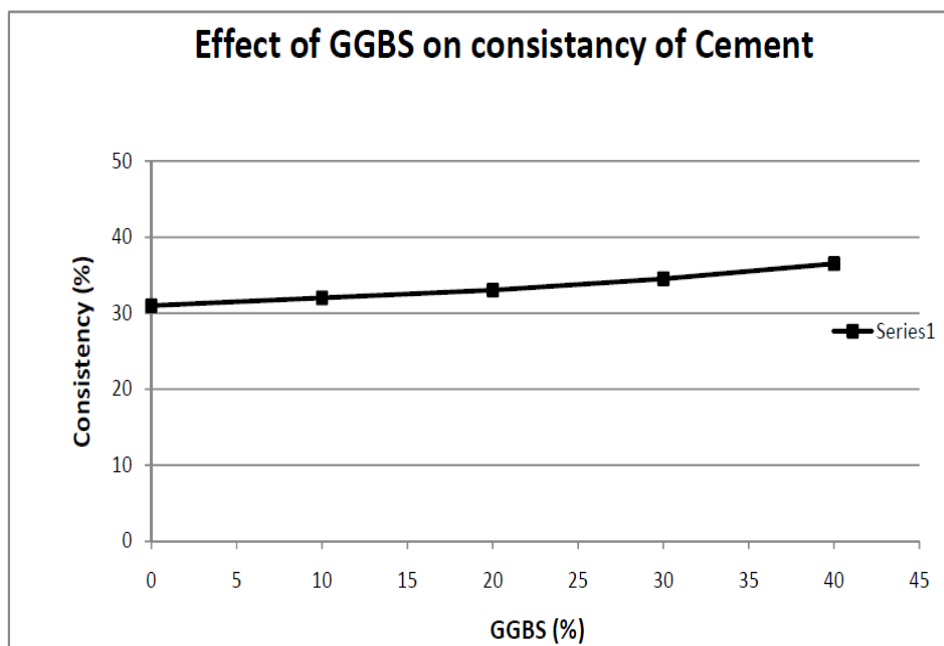


Fig. 3.2.1 Variation of Consistency of cement containing different % of GGBS

% of GGBS with cement replacement	3 days strength (MPa)	7 days strength (MPa)
0	11.176	24.31
10	9.66	15.63
20	7.117	10.85
30	6.10	9.15
40	4.74	7.46

Table 3.2.2 Effect of GGBS on Compressive strength of cement:

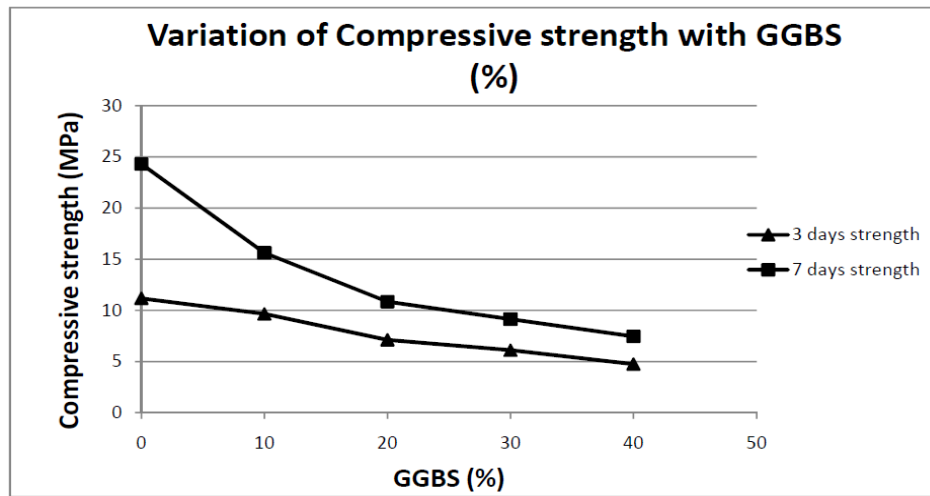


Fig. 3.2.2 Variation of Compressive strength of mortar with different GGBS %

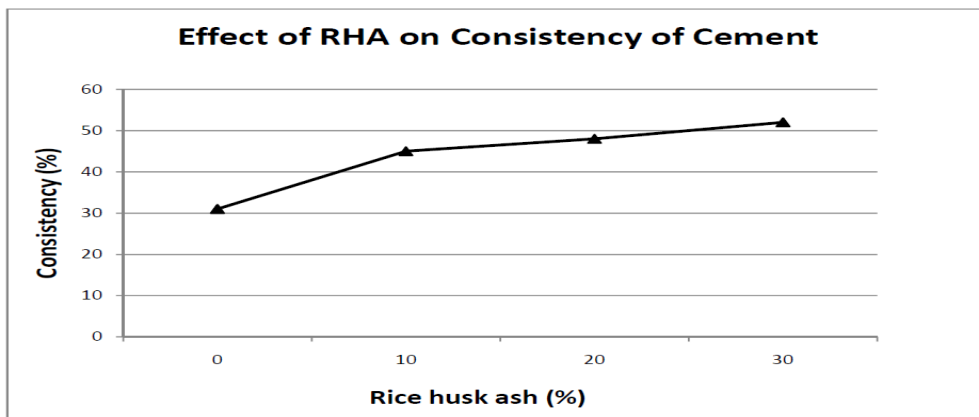


Fig. 3.2.3 Variation in Consistency of cement with different % of RHA

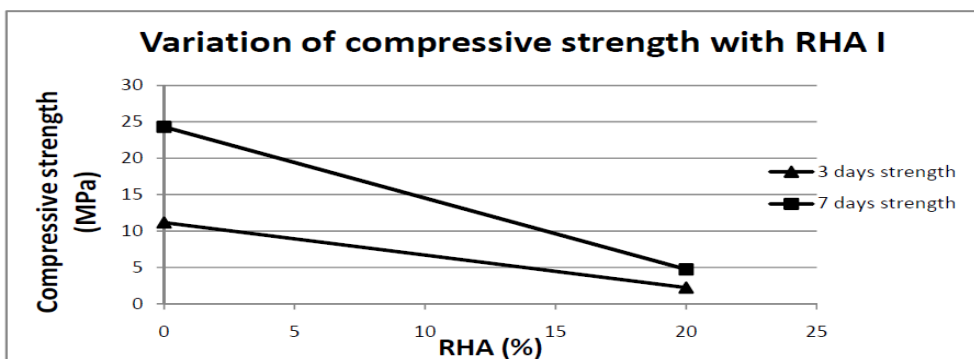


Fig. 3.2.4 Variation in Compressive strength of mortar with use of RHA I

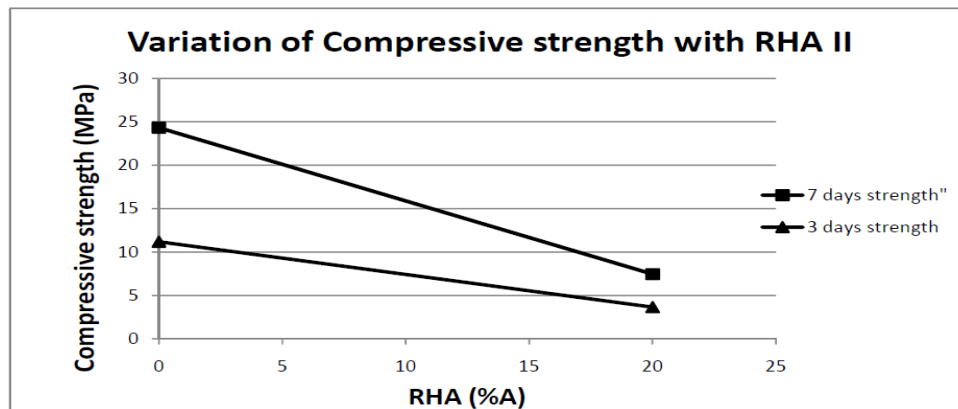


Fig. 3.2.5 Variation in Compressive strength of mortar with use of RHA II

IV. CONCLUSION:

In this present study with the stipulated time and laboratory set up an afford has been taken to enlighten the use of so called pozzolanic material like ground granulated blast furnace slag, rice husk and silica fume in fiber reinforced concrete in accordance to their proficiency. It was concluded that,

- Use of GGBS as cement replacement increases consistency. Although fineness greatly influenced on proper pozzolanic reaction still GGBS passing 75 micron sieve not giving good strength of mortar. Using GGBS more than 10% in Portland slag cement the strength reducing rapidly.
- With replacement of cement with RHA the consistency increases. Use of RHA which burned properly in controlled temperature improves the strength of mortar. But use of RHA not giving satisfactory strength result.
- With the use of superplasticizer it possible to get a mix with low water to cement ratio to get the desired strength.
- In case of Portland slag cement with the use of Recron fiber , the 28 days compressive strength at 0.2% fiber content the result obtained is maximum. The 28 days splitting tensile and flexural strength also increases about 5% at 0.2% fiber content to that of normal concrete. Further if fiber percentage increases then it was seen a great loss in the strength.
- With Portland slag cement keeping 0.2% Recron fiber constant and varying silica fume percentage the compressive, splitting tensile, flexural strength affected remarkably. Using 20% silica fume with 0.2% fiber percentage the 28 days compressive strength increases 7% more than concrete with 0.2% fiber only. 28days split tensile and flexural strength increases further, about 12% and 10% that of normal concrete.

V. SCOPE OF FURTHER WORK:

The research work on pozzolanic materials and fiber along with pozzolanas is still limited. But it promises a great scope for future studies. Following aspects are considered for future study and investigation;



- Percentage and actual fineness of GGBS require as partial cement replacement for good strength development.
- Use of RHA as cement replacement with properly burned in controlled temperature and grinded which may lead proper strength development.

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