

# EXPERIMENTAL INVESTIGATION ON HIGH-PERFORMANCE FIBRE-REINFORCED CONCRETE USING POZZOLANIC MATERIALS

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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 fulfill 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 superplasticizer, 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 fibre) 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.

## 1. Introduction

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:

- Ease of placement
- Compaction without segregation
- Early age strength
- Long-term mechanical properties
- Permeability
- Density

- Heat of hydration
- Toughness
- Volume stability
- 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.

Concrete materials most high-performance concretes produced today contain materials in addition to Portland cement to help achieve the compressive strength or durability performance. These materials include fly ash, silica fume and ground-granulated blast furnace slag used separately or in combination. At the same time, chemical admixtures such as high-range water-reducers are needed to ensure that the concrete is easy to transport, place and finish. For high-strength concretes, a combination of mineral and chemical admixtures is nearly always essential to ensure achievement of the required strength.

Most high-performance concretes have a high cementitious content and a water-cementitious material ratio of 0.40 or less. However, the proportions of the individual constituents vary depending on local preferences and local materials. Mix proportions developed in one part of the country do not necessarily work in a different location. Many trial batches are usually necessary before a successful mix is developed. High-performance concretes are also more sensitive to changes in constituent material properties than conventional concretes. Variations in the chemical and physical properties of the cementitious materials and chemical admixtures need to be carefully monitored. Substitutions of alternate materials can result in changes in the performance characteristics that may not be acceptable for high-performance concrete. This means that a greater degree of quality control is required for the successful production of high-performance concrete.

## 2. Literature reviews

Potrzebowski researched on the splitting test applied to steel fiber reinforced concrete. He tested on cube specimen cut from flexural test prisms, which were themselves obtained from slabs. The results show

that the splitting tensile strength is strongly influenced by the number of fibers intersecting the failure plane and their orientation. Specimens subjected to the loads perpendicular to the plane of vibration are shown to give consistent results where as specimens loaded parallel to the plane of vibration gave low results.

Bhanja and Sengupta worked on modified water cement ratio law for silica fume concrete. They reported modified relationships have been proposed to evaluate the strength of silica fume concrete. An extensive experiment was carried out to determine the isolated effect of silica fume on concrete and analysing the 28 day strength results of 32 concrete mixes performed over a wide range of water-binder ratios and silica fume replacement percentages, simplified models serve as useful guides for proportioning concrete mixes incorporating silica fume.

Bhanja and Sengupta worked on Influence of silica fume on the tensile strength of concrete. Extensive experimentation was carried out over water-binder ratios ranging from 0.26 to 0.42 and silica fume-binder ratios from 0.0 to 0.3. For all the mixes, compressive, flexural and split tensile strengths were determined at 28 days. The compressive, as well as the tensile, strengths increased with silica fume incorporation, and the results indicate that the optimum replacement percentage is not a constant one but depends on the water-cementitious material (w/cm) ratio of the mix. Compared with split tensile strengths, flexural strengths have exhibited greater improvements. Based on the test results, relationships between the 28-day flexural and split tensile strengths with the compressive strength of silica fume concrete have been developed using statistical methods.

### 3. Materials used in the study

#### GGBS

Ground Granulated Blastfurnace 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.

#### Rice husk ash

Rice husk ash is obtained by burning rice husk in a controlled manner without causing environmental pollution. When it is properly burnt it has high  $\text{SiO}_2$  content and can be used as a concrete admixture. Rice husk ash exhibits high pozzolanic characteristics and contributes to high strength and high impermeability of concrete. Rice husk ash essential consists of amorphous or non crystalline silica with about 85- 90% cellular particle, 5% carbon and 2%  $\text{K}_2\text{O}$ .

#### Silica fume

Silica fume also referred as microsilica or condensed silica fume is another material that is used as an artificial pozzolanic admixture. It is a product resulting from reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. When quartz are subjected to  $2000^\circ\text{C}$  reduction takes place and  $\text{SiO}$  vapours get into fuels. In the course of exit, oxidation takes place and the product is condensed in low temperature zones.

#### Recron Fiber:

Recron Fibrefill is India's only hollow Fibre specially designed for filling and insulation purpose. Made with technology from DuPont, USA, Recron Fibrefill adheres to world-class quality standards to provide maximum comfort, durability, and ease-of-use in a wide variety of applications like sleep products, garments and furniture. Reliance Industry Limited (RIL) has launched Recron 3s fibres with the objective of improving the quality of plaster and concrete.

#### Mix design of M30 grade concrete

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their

relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

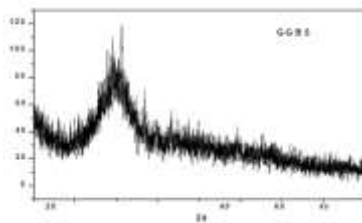
Quantities of material required for making 1m<sup>3</sup> of concrete

**Cement: FA: CA: Water**

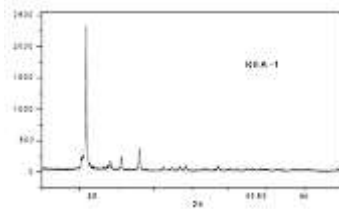
(368.3/368.3) :( 701/368.3) :( 1202/368.3) :( 162/368.3)

**1: 1.90: 3.26: 0.43**

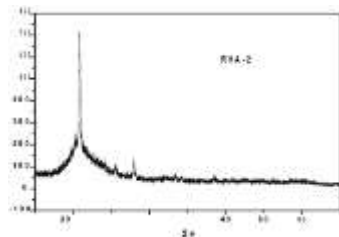
#### 4. RESULTS AND ANALYSIS



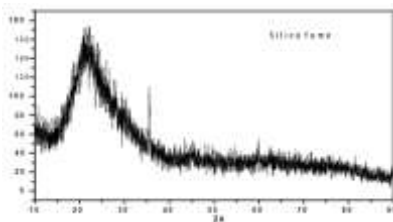
X-Ray Diffraction test of GGBS



X-Ray Diffraction test of RHA-I

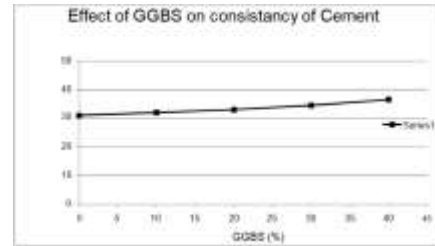


X-Ray Diffraction test of RHA-II

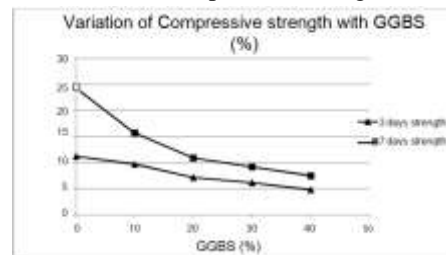


#### X-Ray Diffraction test of silica fume

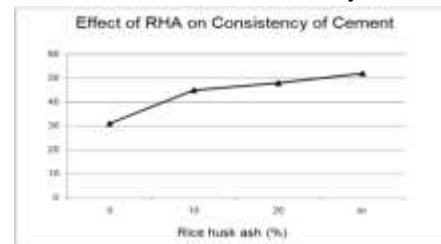
#### Effect of GGBS and RHA on properties of cement



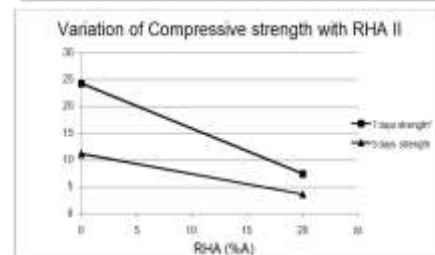
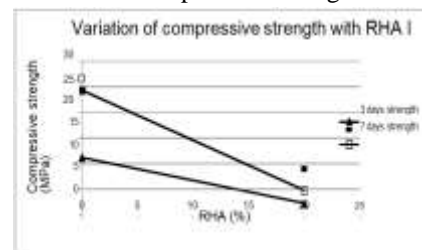
#### Effect of GGBS on Compressive strength of cement



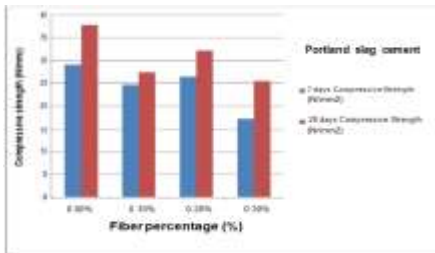
#### Effect of RHA on Normal Consistency of cement



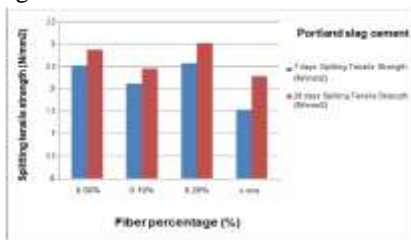
#### Effect of RHA on Compressive strength of cement



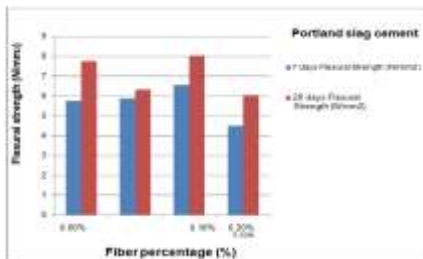
Effect of Recron fiber on Compressive strength using slag cement



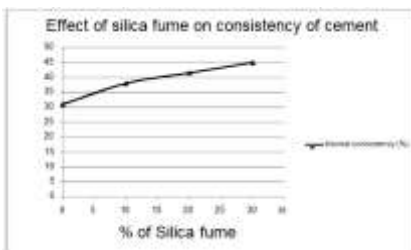
Effect of Recron fiber on Splitting Tensile Strength using slag cement



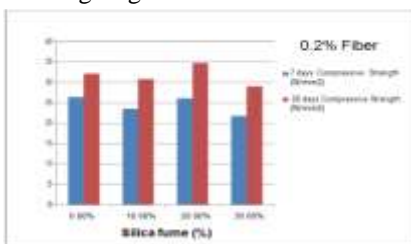
Effect of Recron fiber on Flexural Strength using slag cement



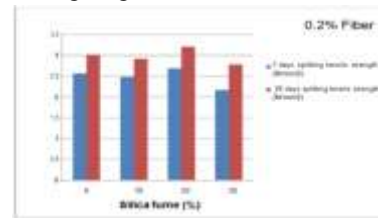
Effect of silica fume on normal consistency of cement



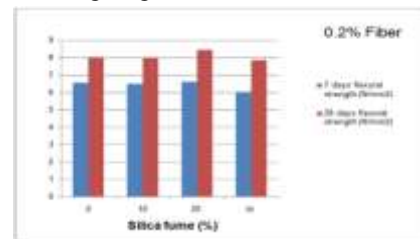
Effect of silica fume on Compressive strength with 0.2% fiber using slag cement



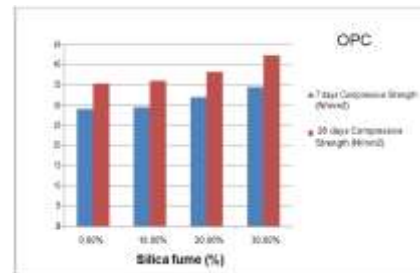
Effect of silica fume on splitting tensile strength with 0.2% fiber using slag cement



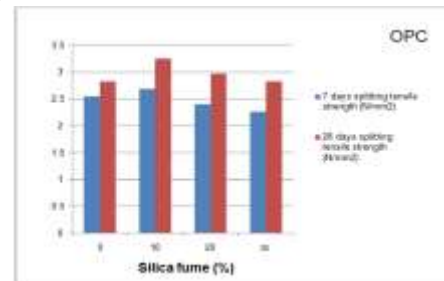
Effect of silica fume on flexural strength with 0.2% fiber using slag cement



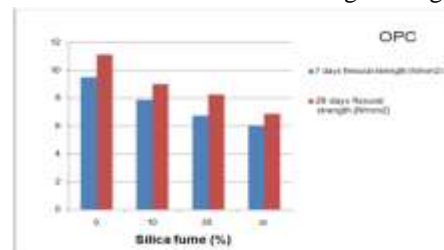
Effect of silica fume on Compressive strength using OPC



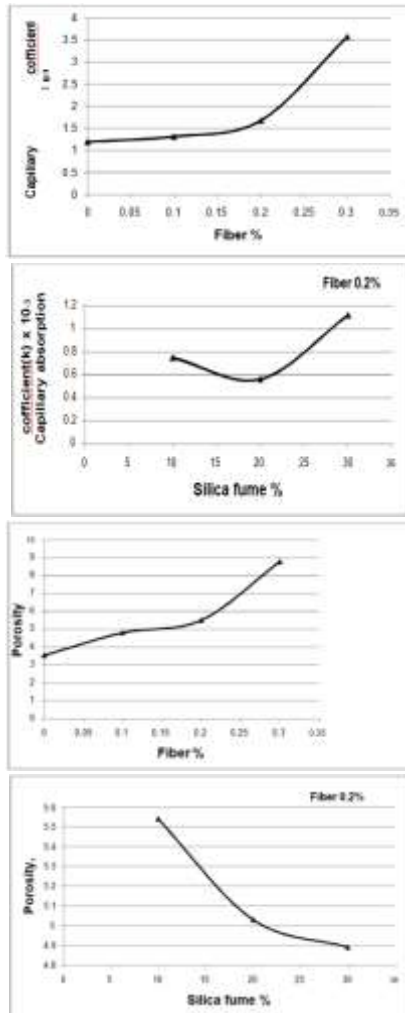
Effect of silica fume on splitting tensile strength using OPC



Effect of silica fume on flexural strength using OPC



Capillary absorption coefficient (k) for different fiber content



## 5. Conclusions

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,

1. 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.

2. 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.
3. With the use of superplasticizer it possible to get a mix with low water to cement ratio to get the desired strength.
4. 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.
5. As the replacement of cement with different percentages with Silica fume increases the consistency increases.
6. 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.
7. So it is inculcated that 0.2% Recron fiber and 20% SF is the optimum combination to achive the desired need.
8. In case of OPC the compressive strength is increasing as the percentage of silica fume increases from 0-30% and 0.2% Recron fiber and it is about 20% more than strength of normal concrete with OPC.
9. The splitting tensile strength increases about 15% at 10% SF and constant 0.2% Recron fiber, then decreases with increasing the SF percentage. Flexural strength is not giving good indication and goes on decreasing and it is about 40% decrement as the SF percentage increases to 30%.
10. Ordinary Portland cement gives good compressive strength result as compared to

Portland slag cement in case of mix with SF and 0.2% Recron.

11. The capillary absorption coefficient (k) with decreases great sign as SF percentage increases at constant fiber percentage i.e 0.2%. At 20% SF content the k value decreases progressively with 70% reduction that to without SF content concrete.
12. The porosity value also decreases as the SF value increases from 0-30% in Recron fiber reinforced concrete.

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