

Pozzolan Materials Behaviour on Fiber Reinforced Concrete

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Abstract:

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 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.

Key words : Bituminous Concrete (BC), Marshall stability, Flow value, Optimum Polythene Content

1. Introduction

General

1.The set back 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.

2.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. Unfortunately, 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 replace 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.

3.Fly ash, Ground Granulated Blast furnace Slag,

Rice husk ash, High Reactive Metakaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement. A number of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement replacements and the results are encouraging. The strength, durability and other characteristic of concrete depends on the properties of its ingredients, proportion of mix, method of compaction and other controls during placing and curing.

4.With the passage of time to meet the demand, there was a continual quest in human being for the development of high strength and durable concrete. The history of high strength concrete is about 35 years old, in late 1960s the invention of water reducing admixtures lead to the high strength precast products and structural elements in beam were cast in situ using high strength concrete. Since then the technology has come of age and concrete of the order of M60 to M120 are commonly used. Concrete of the order of M200 and above are a possibility in the laboratory conditions. The definition of high strength concretes is continually developing. In the 1950s 34N was considered high strength, and in the 1960s compressive strengths of up to 52N were

being used commercially. More recently, compressive strengths approaching 138N have been used in cast-in-place buildings. The advent of prestressed concrete technology has given impetus for making concrete of high strength. In India high strength concrete is used in prestressed concrete bridges of strength from 35 MPa to 45 MPa. Presently (in 2000) Concrete strength of 75 MPa is being used for the first time in one of the flyover at Mumbai. Also in construction of containment Dome at Kaiga power project used HPC of 60MPa with silica fume as one of the constituent.

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.

Salient Features of HPC:

- High Compressive strength
- Low water-binder ratio
- Reduced flocculation of cement grains
- Wide range of grain sizes
- Densified cement paste
- No bleeding homogeneous mix
- Less capillary porosity
- Discontinuous pores
- Stronger transition zone at the interface between cement paste and aggregate
- Low free lime content
- Endogenous shrinkage
- Powerful confinement of aggregates
- Little micro-cracking until about 65-70 % of fck
- Smooth fracture surface

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. Unfortunately, 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 replace 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.

Considering the grade of cements high strength of cement of grades 43 & 53 are desirable for design of High strength concretes. To achieve the quest of high performance concrete we should accentuate on the replacement of OPC with industrial by-products. The utilization of pozzolanic materials in concrete as partial replacement of cement is gaining immense importance today, mainly on account of the improvements in the long-term durability of concrete combined with ecological benefits. Fly ash (a waste product from coal thermal power plant), ground granulated blast furnace slag, silica fumes (a waste by-product of the manufacture of Silicon or Ferro-silicon alloys from high purity quartz and coal in a submerged-arc electric furnace), rice husk ash (waste by-product from co-generation electric power plant burning rice husk), high reactive metakaoline (HRM) as partial replacement for cement which are largely available in India. To study the effect of partial replacement of cement by these pozzolanic materials, studies have been conducted on concrete mixes with 350 to 500 kg/cum cementitious material at 30%, 40%, and 50% replacement levels of fly ash; 50% and 60% replacement levels of GGBS and 7.5% and 10% replacement levels of HRM.

High Strength Concrete:

- To put the concrete into service at much earlier age, for example opening the pavement at 3-days.
- To build high-rise buildings by reducing column sizes and increasing available space.
- To build the superstructure of long span bridges and to enhance the durability of bridge decks.
- To satisfy the specific needs of special applications, such as durability, modulus of elasticity and flexural strength. Some of these applications include dams, grandstand roofs, marine foundations, parking garages and heavy duty industrial floors. (Note that high strength concrete

does not guarantee durable concrete).

Objectives

- 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.

Earlier researches:

Some of the early research works had done using different pozzolanic materials with the replacement of cement using superplasticizer for the development high performance concrete. Also the development in the field of fiber reinforced concrete along with pozzolanas.

Ismail and waliuddin[5](1996) had worked on effect of rice husk ash on high strength concrete. They studied the effect of rice husk ash (RHA) passing 200 and 325 micron sieves with 10-30% replacement of cement on the strength of HSC. The RHA was obtained by burning rice husk, an agro-waste material which is abundantly available in the developing countries. A total of 200 test specimens casted and tested at 3, 7, 28 and 150 days. Compressive and split tensile strengths of the test specimens. Cube strength over 70 MPa was obtained without any replacement of cement by RHA. Test results indicated that strength of HSC decreased when cement was partially replaced by RHA for maintaining same level of workability. They observed that optimum replacement of cement by RHA was 10-20%, and even from crystalline form of RHA good result may be obtained by fine grinding.

De Sensale[6] (2006) studied on strength development of concrete using rice husk ash. This paper presents a study on the development of compressive strength up to 91 days of concretes with rice-husk ash (RHA), in which residual RHA from a rice paddy milling industry in Uruguay and RHA produced by controlled incineration from the USA were used for comparison. Two different replacement percentages of cement by RHA, 10% and 20%, and three different water/cementitious material ratios (0.50, 0.40 and 0.32), were used. The results are compared with those of the concrete without RHA, with splitting tensile strength and air permeability. It is concluded that residual RHA

provides a positive effect on the compressive strength at early ages, but the long term behavior of the concretes with RHA produced by controlled incineration was more significant. Results of splitting tensile and air permeability reveal the significance of the filler and pozzolanic effect for the concretes with residual RHA and RHA produced by controlled incineration.

Oner A and Akyuz S [7] (2007) studied on optimum level of ground granulated blast furnace slag (GGBS) on compressive strength of concrete. In their study GGBS was added according to the partial replacement method in all mixtures. A total of 32 mixtures were prepared in four groups according to their binder content. Eight mixes were prepared as control mixtures with 175, 210, 245 and 280 kg/m³ cement content in order to calculate the Bolomey and Feret coefficients (KB, KF). For each group 175, 210, 245 and 280 kg/m³ dosages were determined as initial dosages, which were obtained by removing 30 percent of the cement content of control concretes with 250, 300, 350, and 400 kg/m³ dosages. Test concretes were obtained by adding GGBS to concretes in an amount equivalent to Approximately 0 %, 15 %, 30 %, 50 %, 70 %, 90 % and 110 % of cement contents of control

Concretes with 250, 300, 350 and 400 kg/m³ dosages. All specimens were moist cured for 7, 14, 28, 63, 119, 180 and 365 days before compressive strength testing. The test results proved that the compressive strength of concrete mixtures containing GGBS increases as the amount of GGBS increase. After an optimum point, at around 55% of the total binder content, the addition of GGBS does not improve the compressive strength. This can be explained by the presence of unreacted GGBS, acting as a filler material in the paste.

It was found that as the GGBS content increases, the water-to-binder ratio decreases for the same workability. The early strength of GGBS concrete was lower than that of the control concrete. However, as the curing period is extended the strength increase was higher for GGBS concrete. The compressive strength of GGBS concrete increases as the GGBS content is increased up to an optimum point, after which the compressive strength decreases. The optimum level of GGBS content for maximizing strength is at about 55–59% of the total binder content.

Collepari [10] (1998) observed on admixture used

to enhance placing characteristics of concrete. He observed placing characteristics of concrete can be enhanced by using plasticizing and superplasticizing admixtures without any change in the water-cement ratio with respect to the plain mixture. The main ingredients used in superplasticizers are based on sulfonated melamine formaldehyde (SMF) condensate or naphthalene formaldehyde (SNF) condensate. He proposed a new family of products, based on acrylic polymers (AP). These polymers are more effective than those based on SMF or SNF in terms of lower base water-cement ratio at a given slump and lower slump loss. Moreover; the effectiveness of the AP-based superplasticizers does not depend significantly on the mode of addition, whereas the slump level of concrete mixes with SMF- and SNF-based admixtures is much higher with a delayed addition of superplasticizer with respect to that of mixing water. The dispersion of cement particles responsible for the fluidity increase, caused by the superplasticizer addition, is not necessarily related to the electrostatic repulsion associated with zeta potential measurements, as it was found for SMF- and SNF-based admixtures. For the AP-based superplasticizers, the polymer adsorption, rather than the electrostatic repulsion, is responsible for the dispersion of large agglomerates of cement particles into smaller ones, which results in a remarkable increase in the fluidity of cement mixes.

Critical observation from the literature:

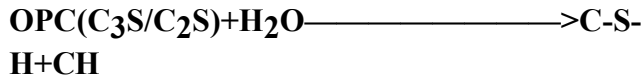
- Not properly defined the use of RHA and GGBS.
- It was observed that not much work has been proceeded to find the optimum use of silica fume to produce good strength and durable concrete.
- The maximum percentage of synthetic fiber to be used in concrete along with silica fume to get good outcome..
- The effect of silica fumes with fiber on capillary and porosity of concrete.

Reaction Mechanism of Ground Granulated Blast furnace Slag:

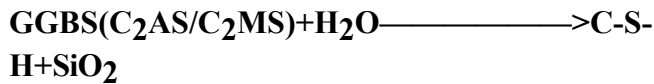
Although GGBS is a hydraulically latent material, in presence of lime contributed from cement, a secondary reaction involving glass (Calcium Alumino Silicates) components sets in. As a

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:

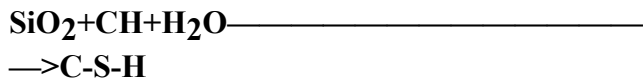
Product of hydration of OPC



Product of hydration of GGBS



Reaction of pozzolanic material



Pozzolanic Action:

Silica fume is much more reactive than any other natural pozzolana. The reactivity of a pozzolana can be quantified by measuring the amount of $\text{Ca}(\text{OH})_2$ in the cement paste. 15 percentage of silica fume reduces the $\text{Ca}(\text{OH})_2$ of cement sample from 24% to 90% at 90 days and from 25% to 11% in 180 days. The effect of silica fume can be explained by two mechanism i.e pozzolanic reaction and micro filler effect. The first product is calcium- silicate-hydrate (C-S-H) gel, that is cementitious and binds the aggregate together in concrete and $\text{Ca}(\text{OH})_2$. The C-S-H formed by the reaction between microsilica and the product $\text{Ca}(\text{OH})_2$ which comprises 25% of volume of hydration product

FIBER:

An overview on Fibre:

In recent years, several studies have been conducted to investigate the flexural strengthening of reinforced concrete (RC) members with fiber reinforced composite fabrics. Recently, the use of high strength fiber-reinforced polymer (FRP) materials has gained acceptance as structural reinforcement for concrete.

In this composite material, short discrete fibers are randomly distributed throughout the concrete mass. The behavioral efficiency of this composite material is far superior to that of plain concrete and many other construction materials of same cost. Due to this benefit, the use of FRC has steadily increased during

last two decades and its current field of application includes airport and highway pavements, earthquake resistant and explosive resistant structures, mines and tunnel linings, bridge deck overlays, hydraulic structures, rock slope stabilization. Extensive research work on FRC has established that the addition of various types of fibers such as steel, glass, synthetic and carbon, in plain concrete improves strength, toughness, ductility, and post cracking resistance etc. The major advantages of fiber reinforced concrete are resistance to microcracking, impact resistance, resistance to fatigue, reduced permeability, improved strength in shear, tension, flexure and compression.

The character and performance of FRC changes with varying concrete binder formulation as well as the fiber material type, fiber geometry, fiber distribution, fiber orientation and fiber concentration.

Fiber materials:

According to terminology adopted by the American Concrete Institute (ACI) Committee 544, Fiber Reinforced Concrete, there are four categories of FRC based on fiber material type. These are Steel Fiber Reinforced Concrete, Glass Fiber Reinforced Concrete, Synthetic Fiber Reinforced Concrete, including carbon fibers; and Natural Fiber Reinforced Concrete.

Fiber geometry:

Individual fibers are produced in an almost limitless variety of geometric forms including,

Prismatic: Rounded or polygon cross-section with smooth surface or deformed through out or only at the ends.

Irregular cross-section: cross-section varies along the length of the fiber.

Collated: Multifilament (alternatively termed branching or fibrillated) or monofilament networks (or bundles) that are usually designed to separate during FRC production (mixing).

RESULTS AND DISCUSSION

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(1mm 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.

RESULT:

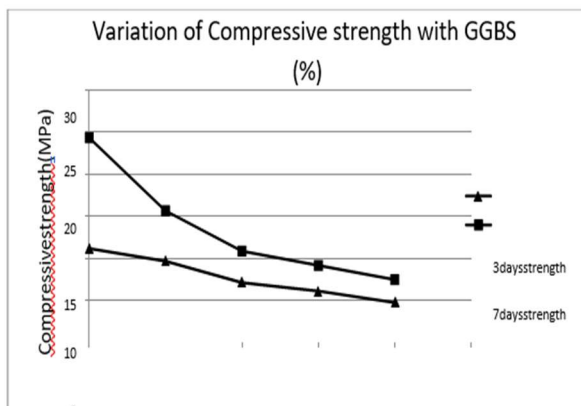


Fig.4.6.Variation of Compressive strength of mortar with different GGBS %

Effect of RHA on Normal Consistency of cement:

% of cement replaced by RHA	Consistency(%)
0	31.0
10	45.0
20	48.0
30	52.0

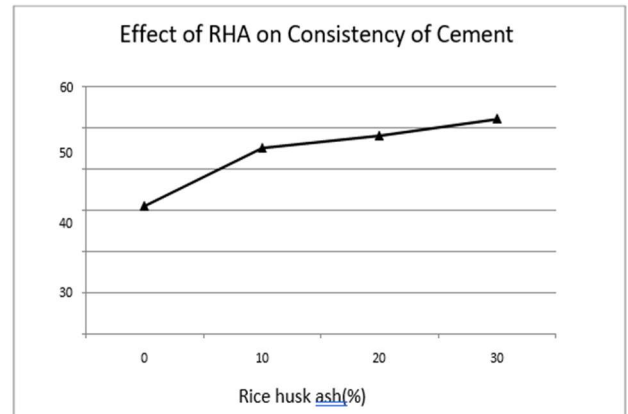


Fig.4.7 Variation in Consistency of cement with different % of RHA

DISCUSSION:

It is observed here that the consistency percentage is increasing as the percentage of GGBS increases as a cement replacement, but the change is not so abrupt. But found that as we go on increasing the percentage of Rice husk ash the consistency percentage increases rapidly. The variation of compressive strength of mortar mix with different proportion of GGBS partial replacement of cement is shown in fig. It was observed that 3 days and 7 days compressive strength reduces about 13% and 35% that is from 11.176 MPa to 9.66 MPa and 24.31 to 15.63 respectively, as GGBS percentage increases from 0 to 10%. If percentage of GGBS was further increased the compressive strength reduces greatly. Finally when the GGBS percentage increased to 40% the strength reduces by about 60% and 70% in 3 days and 7 days respectively of its initial values. So it was concluded that the use of GGBS specially in Portland slag cement leading to adverse effect on strength of mortar.

TEST RESULT:

Effect of Recron fiber on Compressive strength using slag cement:

Fiber content (%)	7 days compressive Strength (N/mm ²)	28 days compressive Strength (N/mm ²)
0.0	29.036	37.77
0.1	24.63	27.4067
0.2	26.43	32.148
0.3	17.2	25.48

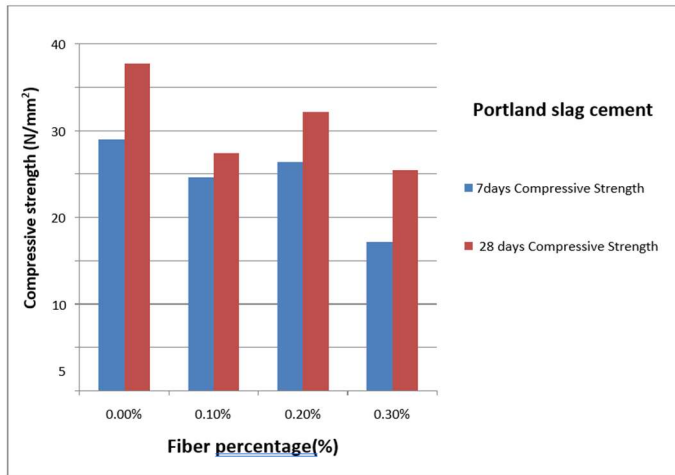


Fig.4.13 Effect of Recron fiber on compressive strength

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,

- As the replacement of cement with different percentages with Silica fume increases

The consistency increases.

- 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. 28 days split tensile and flexural strength increases further, about 12 % and 10 % that of normal concrete.
- So it is culcated that 0.2% Recron fiber and 20 % SF is the optimum combination to

Achive the desired need.

- 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.

- 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%.
- Ordinary Portland cement gives good compressive strength result as compared to Portland slag cement in case of mix with SF and 0.2 % Recron.
- 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.
- The porosity value also decreases as the SF value increases from 0-30 % in Recron

Fiber reinforced concrete.

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.
- Replacing cement with different percentage of silica fume to judge the optimum percentage of silica fume to be used to get better strength result.
- Research on Recron fiber and silica fume with greater fineness as a partial cement replacing material, by which we can minimise the cost and at the same time achieve the durability and strength for the production of High Performance

Concrete.

- It requires a proper mixing proportions for the development of high strength, high

performance concrete which may not be possible manually. So it needs some global optimisation techniques to develop the desired result with greater accuracy and time saving.

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