A Investigation on the Sustainability of Pozzolona in Cement Concrete

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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 fibe) 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.**

***Index Terms*—GGBS, Rice Husk, Cement, Concrete, Pozzolona.**

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. 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.

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. 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 reasons for these demands are many, but as engineers, we need to think about the durability aspects of the structures using these materials. With long term durability aspects kept aside we have been able to fulfil the needs. The concrete of these properties will have a peculiar Rheological behaviour. Now a day the construction industry turning towards pre-cast elements and requirement of post-tensioning has made the requirement of the high strength of concrete invariable and the engineers had to overcome these drawbacks, which to a great extent we have been able to do. The construction today is to achieve savings in construction work. This has now turned into one of the basic requirement of concreting process.

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.

II. LITERATURE REVIEW

As our aim is to develop concrete which does not only concern on the strength of concrete, it also having many other aspects to be satisfied like less porous, capillary absorption, durability. So for this we need to go for the addition of pozzolanic materials along with superplasticizer with having low water cement ratio. The use of silica fume is many, which is having good pozolanic activity and is a good material for the production high performance concrete. Also now a days one of the great application in various structural field is fiber reinforced concrete, which is getting popularity because of its positive effect on various properties of concrete. 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. So below an over view of different studies has been represented.

Aitcin (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 superplasticizers 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. Silica fume, a highly reactive pozzolana, considerably enhances the paste/aggregate interface and minimizes debonding. Lastly, the use of supplementary cementitious materials, such as fly ash and especially slag, helps solve slump loss problems which become critical at low w/c ratios.

Ajdukiewicz and Radomski(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 (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.

Al-Khalaf and A. Yousif (1984) examined on use of RHA in concrete. They studied the actual range of temperature require to burn rice husk in order to get the desired pozzolanic product, use of rice husk as partial replacement of cement on compressive strength and volume changes of different mixes. And showed that up to 40% replacement can be made with no significant change in compressive strength compared with the control mix. He tested on mortar cube, by testing on 50 mm cubes. In his investigation alsohe deduced that the most convenient and economical burning conditions required to convert rice husks into a homogenous and well burnt ash is at 500^0 C for 2 hours. Also for a given grinding time, there is a considerable reduction in the specific surface area of RHA as burning temperature increases. For mortar mix with constant RHA content, the water requirement decreases as the fineness of the ash increases. The minimum pozzolanic activity can be obtained, when the ash has a specific surface of about 11,500 cm^2/gm. The strength of cement-RHA mortar approaches the strength of the corresponding plain mortar when the specific surface of RHA about 17000cm^2/gm. For 1:2 and 1:3 mortar mixes of standard consistency the maximum percentage of rice husk ash that can be replaced by weight of cement without 60 days strength being less than that of plain mortar was 30% and 40 % respectively. Also he found higher the percentage or RHA, higher is the volume change characteristic corresponding to plain mortar.

Ismail and waliuddin (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 l0-30% 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 (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/cementicious 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 (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.

III. MATERIALS AND METHODS

1) Materials

- Ground Granulated Blast Furnace Slag (GGBS)
- Rice Husk Ash
- Silica Fumes
- Superplasticizer
- Cement
- Aggregate
- Fiber

2) Methodology

The husk of rice is a material that can satisfy the engineering needs in accordance with the chemical and physical features. So in this assessment, we will devote a lot of attention to RHA that is possibly the product that can replace cement partially and can also get the needed tests for strength on the cubes of mortar. Talking about GGBS, we can say that it is a non-metal and comes with some silicates such as from aluminum and calcium etc. The quad for factors that affect the hydraulic features of these slags and the content of glass, the composition which could either be chemical mineral or the ability to be fine. The materials in granules if getting a further grind to lesser than about 45 microns may achieve some specific surface reaching 400 meter square per kilogram to 600 meter square per kilogram. But in this assessment, we have made use of the GGBS that gets passed from a sieve of 75 microns. It has a surface that can range from 275 meter square per kilogram to 550 meter square per kilogram. We will employ GGBS as the smaller replacement need for the cement since the pros like less cost of energy, more resistance to abrasion and less heat of hydration etc. can be found.

Synthetic Fiber or the fiber or Recron is employed in our concrete when we make the concrete reinforced with fibers. We will employ the fibers of Recron in distinct amounts and these are 0 percent, 0.1 percent, and 0.2 percent, and 0.3 percent to the concrete mass and we examine it for about 7 days and then for about 28 days to find the strength in compression, tension in splitting and strength in flexure in the matter against concrete that is normal and we also take the cement and the water ratio in between 0.35 and 0.41. And then as the percentages of the fumes of silica varies which is 10 percent, and 20 percent, and 30 percent etc. while keeping the percentage of fibers at around 0.2 percent of the cubes and cylinder and even the prisms were made to test and to know the changes in the strength of compression, tension in splitting and strength of flexure. We employed a couple of cement variants in our study and these were PSC and OPC of the grade 53. We will do an XRD test to know the composition of the chemicals of the fumes of silica, RHA, GGBS. Apart form this, we test porosity and the absorption test by capillary action on distinct samples to know the action of fumes of silica on concretes.

IV. RESULTS

1) Results for Material Testing

a) Cement

	Portland Slag Cement	Ordinary Portland Cement
Specific Gravity	2.96	3.1
Initial Setting Time	125	90
Final Setting Time	235	190
Fineness	340 m2/kg	340 m2/kg

b) Aggregate

In this study it was used the sand of Zone-II, known from the sieve analysis using different sieve sizes (10mm, 4.75mm, 2.36mm, 1.18mm, 600µ, 300µ, 150µ) adopting IS 383:1963.

The coarse aggregate used here with having maximum size is 20mm. We used the IS 383:1970 to find out the proportion of mix of coarse aggregate, with 60% 10mm size and 40% 20mm.

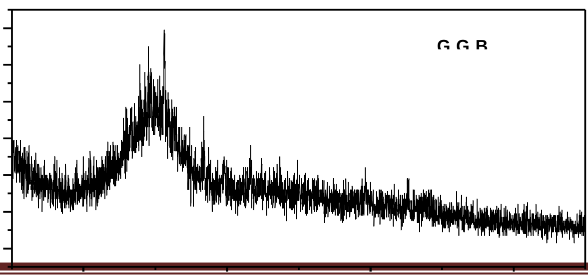
	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.65	2.67
Water Absorption	0.6%	0.4%
Fineness Module	2.47	4.01

c) Fiber

In this project work it was used Recron fiber. It is a type of synthetic fiber. In different weight fraction (0.0%, 0.1%, 0.2%, 0.3%) to concrete it was used.

d) Ground granulated blast furnace slag (GGBS)

As pozzolanic activity greatly depends on fineness, so GGBS passing through 75 micron whose fineness of order of 275-550 m2/kg was used. Specific gravity test was conducted using Le-Chatelier apparatus and found to be 2.77. X-Ray diffraction test was conducted shown below in figure

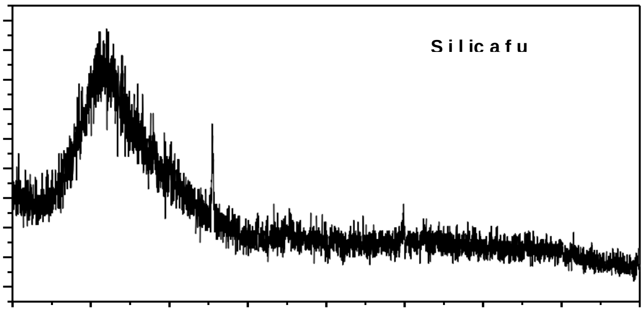


e) **Rice Husk**

In this study we have used two types of Rice husk Ash. First type which was low burned having greater percentages of carbon (which is having negative impact on strength development), so looking black and second type is looking white because it was being burnt in higer temperature. Here in second type of RHA the percentage of carbon is low. The specific gravity test was carried out using Le- Chatelier apparatus and found to be 2.21 for RHA– I and 2.20 for RHA-II. X-Ray diffraction test was carried out

f) Silica Fume

Silica fume is used in different percentage (0%, 10%, 20%, 30%) with the replacement of cement for its greater pozzolanic activity along with fiber. The specific gravity of silica fume was found out using Le-Chatelier apparatus and found to be Specific gravity- 2.36. X-Ray diffraction test was conducted



V. CONCLUSION

- 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.
- 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. 28days split tensile and flexural strength increases further, about 12% and 10% that of normal concrete.
- So it is inculcated 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.

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