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EXPERIMENTAL BEHAVIOR OF MINERAL ADMIXTURES ON FIBER REINFORCED CONCRETE

Mirza Mubashir Ahmed Baig[*1], Shyamla Sunil Pratap Reddy[2] & Syed Riyaz[3]
[*1]PG Scholar, Dept. of Civil Engineering, Vaagdevi College of Engineering, Warangal, India
[2]Professor, Dept. of Civil Engineering, Vaagdevi College of Engineering, Warangal, India
[3]Asst. Professor, Dept. of Civil Engineering, Vaagdevi College of Engineering, Warangal, India

ABSTRACT

This paper investigates on analyzing the effects of use of fibers and mineral admixtures in the mechanical properties of high strength concrete. This study involves the use of different mineral admixtures like fly ash, ground granulated blast furnace slag, silica fume along with steel fibers. It also includes determination of mix proportioning with different mineral admixtures and steel fibers, determination of water binder ratio, determination of basic properties of concrete such as tensile strength, compressive strength, flexural strength and water permeability.

One of the main tasks of the construction industry is to increase the strength and reliability of structures while reducing construction costs.

Effective use of fiber reinforced concrete is likely to lead to reduction in reinforcement. In the previous studies, very less research is carried out on use of fibers with a combination of two or more admixtures. Hence, it is felt that there is a need to explore the feasibility of arriving at an optimum mix using a combination of fibers with two or more mineral admixtures, so as to increase the properties at minimum cost.

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.

1. High Performance Concrete

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

2. 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

3. 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).

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

- Seeding
- Revibration
- High speed slurry mixing
- Use of admixtures
- Inhibition of cracks
- Sulphur impregnation
- Use of cementitious aggregate

II. MATERIALS

1. Ground granulated blast furnace slag:

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. 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 proportions 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.

Table 1: Chemical composition (%) of GGBS:

SiO_2	39.18
Al2O3	10.18
Fe2O3	2.02
CaO	32.82
MgO	8.52
Na_2O	1.14
K_2O	0.30

Advantages of using GGBS:

- Reduce heat of hydration
- Refinement of pore structures
- Reduce permeability to the external agencies
- Increase resistance to chemical attack.

2. Rice husk ash

Rice husk ash is obtained by burning rice husk in a controlled manner without causing environmental pollution. When it is properly brunt it has high SiO_2 content and can be used as a concrete admixture. Rice husk ash exhibits

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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% K_2O. The specific surface of RHA is between 40000-100000 m^2/kg.

Table 2: Chemical composition (%) of RHA:

. SiO_2	85.88
K_2O	4.10
SO_3	1.24
CaO	1.12
Na_2O	1.15
MgO	0.46
Al_2O_3	0.47
Fe_2O_3	0.18
P2O5	0.34

3. 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^{0}C reduction takes place and SiO vapours get into fuels. In the course of exit, oxidation takes place and the product is condensed in low temperature zones. In the course of exit, Silica fume rises as an oxidised vapour, oxidation takes place and the product is condensed in low temperature zones. When the silica is condensed, it attains non-crystalline state with ultra fine particle size. The super fine particles are collected through the filters. It cools, condenses and is collected in bags. It is further processed to remove impurities and to control particle size. Condensed silica fume is essential silicon dioxide (SiO_2) more than 90 percent in non crystalline form. Since it is an airborne material like fly ash, it has spherical shape. It is extremely fine with particle size less than 1 micron and with an average diameter of about 0.1 micron, about 100 times smaller than average cement particles. Silica fume has specific surface area of about 20,000m^2/kg, as against 230 to 300 m^2/kg. The use of silica fume in conjunction with superplasticizer has been back bone of modern high performance concrete. High fineness, uniformity, high pozzolanic activity and compatibility with other ingredients are of primary importance in selection of mineral admixture. As Silica fume has the minimum fineness of 15,000 m^2/ kg, whereas the fumed Silica has the fineness of 190,000 m^2/g which is 6 to 7 times finer than Silica fume. Finer the particle of pozzolano, higher will be the modulus of elasticity, which enhances the durability characteristics of the High performance concrete.

Table 3:Chemical composition of silica fumes in %:

· SiO_2	93
Al_2O_3	0.4
CaO	1.2
Fe_2O_3	0.2
MgO	1.2

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. Na_2O	0.1
K_2O	1.1
SO_3	0.3

Advantages of Silica fume:

- High strength concrete made with silica fume provides high abrasion/corrosion resistance.
- Silica fume influences the rheological properties of fresh concrete, the strength, porosity and durability of hardened mass.
- Silica fume concrete with low water content is highly resistant to penetration of chloride ions.
- The extreme fineness of silica fume allows it to fill or pack the microscopic voids between cement particle and especially in the voids at the surface of the aggregate particles where the cement particles cannot fully cover the surface of the aggregate and fill the available space.
- Silica fume can also be proportioned as a water reducer with the reduction in water cementitious material ratio, so it is hydrophilic in nature, thus super plasticizer demand for additional water can be minimised.

4. Cement

Ordinary port land cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. It is of three type, 33 grade, 43 grade, 53 grade. One of the important benefit is the faster rate of development of strength.

5. Aggregate

Aggregate properties greatly influence the behaviour of concrete, since they occupy about 80% of the total volume of concrete. The aggregate are classified as
(I) Fine aggregate
(II) Coarse aggregate

Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. Coarse aggregate form the main matrix of the concrete, where as fine aggregate form the filler matrix between the coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension.

6. 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.

Only 0.2-0.4% by cement RECRON 3s is sufficient for getting the above advantages. Thus it not only pays for itself, but results in net gain with reduced labour cost & improved properties. So we can briefly summarize the advantages of Recron 3s fiber as,

- ❖ Control cracking
- ❖ Increase flexibility

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- Reduction in water permeability
- Reduction in rebound loss in concrete
- Safe and easy to use

This can be used in various aspects such as

1. PCC and RCC plastering
2. Shortcrete and gunniting
3. Slabs, footings, foundations, walls and tanks
4. Pipes, prestressed beam etc

Table 4: Specification of Recron:

Denier	1.5d
Cut length	6mm,12mm,24mm
Tensile strength	About 6000 kg/cm^2
Melting point	250^o C
Dispersion	Excellent
Acid resistance	Excellent
Alkali resistance	good

III. EXPERIMENTAL PROGRAM

1. Cement

Table 5: Properties of Ordinary Portland cement:

Specific gravity	3.1
Initial setting time (min)	90
Final setting time (min)	190

2. Fine 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.

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Table 6: Properties of fine aggregate:

Properties	Results Obtained
Specific Gravity	2.65
Water absorption	0.6%
Fineness Modulus	2.47

3. Coarse aggregate

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.

Table 7: Properties of coarse aggregate:

Specific gravity	2.67
Water absorption	0.4%
Fineness modulus	4.01

4. 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.

5. 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 m^2/kg was used. Specific gravity test was conducted

6. Rice husk ash

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.

7. 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.

8. Effect Of Ggbs And Rha On Properties Of Cement

Table 8: Effect of GGBS in normal consistency of cement:

% of cement replaced by GGBS (%)	Consistency (%)
0	32
10	34

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20	35
30	36
40	37

Variation of Consistency of cement containing different % of GGBS

Table 9: Effect of GGBS on Compressive strength of cement:

% 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

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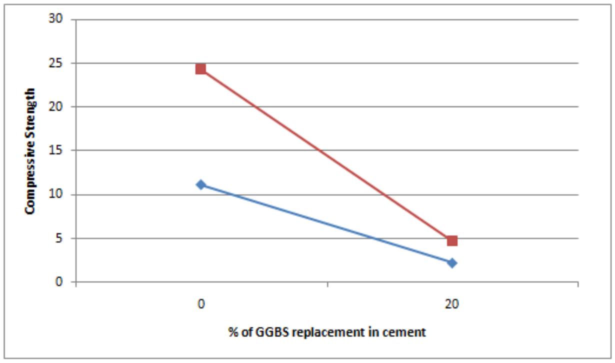

Fig.. Variation of Compressive strength of mortar with different GGBS %

Table10: 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

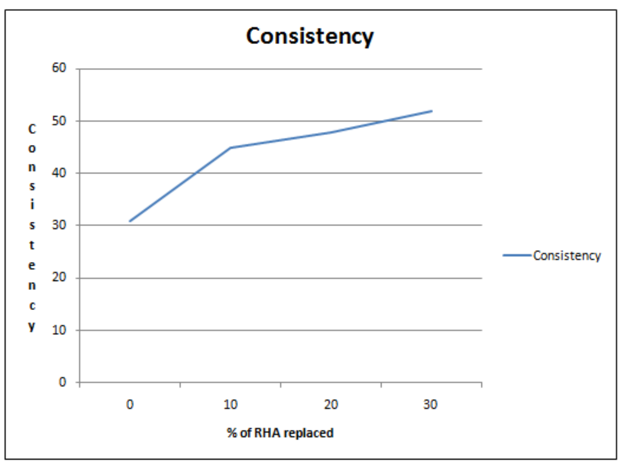

Table 11: Effect of RHA on Compressive strength of cement:

% of cement replaced by RHA	3 days strength (MPa)	7 days strength (MPa)
0	11.176	24.31
20% (RHA I)	2.23	4.74
20% (RHA II)	3.65	7.45

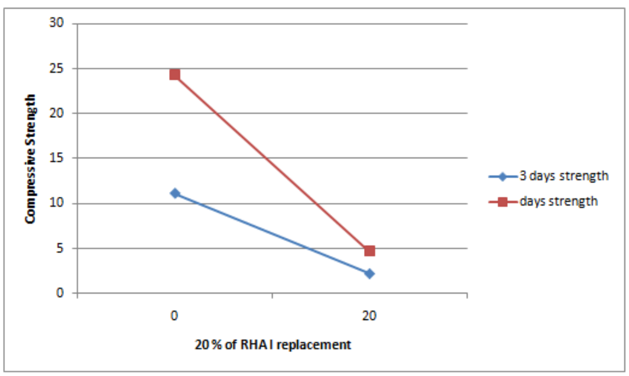

Fig. Variation in Compressive strength of mortar with use of RHA I

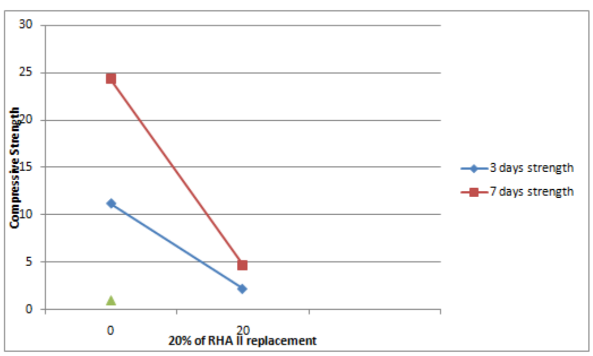

Fig. Variation in Compressive strength of mortar with use of RHA II

9. Mix Proportioning Of Recron-Fiber Reinforced Concrete

To maintain this admixture Sika was used keeping water cement ratio in the range of 0.35-0.41 (0.35, 0.37, 0.39, 0.41) and 0.41-0.45 (0.41, 0.42, 0.45) and super plasticizer rages from 0.6%-1.4% (0.6, 0.9, 1.2, 1.4%) and 1.4%-1.7% (1.4, 1.5, 1.7%) for ordinary fiber reinforced concrete and FRP with the addition of silica fume respectively. Aggregate binder ratio= 3.08, coarse aggregate to fine aggregate ratio= 2.34. In case OPC, mix was obtained with water cement ratio 0.38 and admixture at 0.8% for normal concrete mix.

Fig. Determination of compressive strength of cube

Fig. Determination of splitting tensile strength of cylinder

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Fig. Determination of Flexural strength of prism

IV. TEST RESULT

Table 12 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

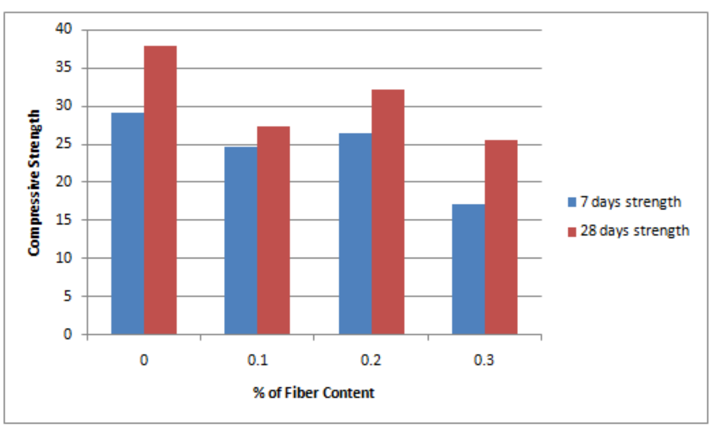

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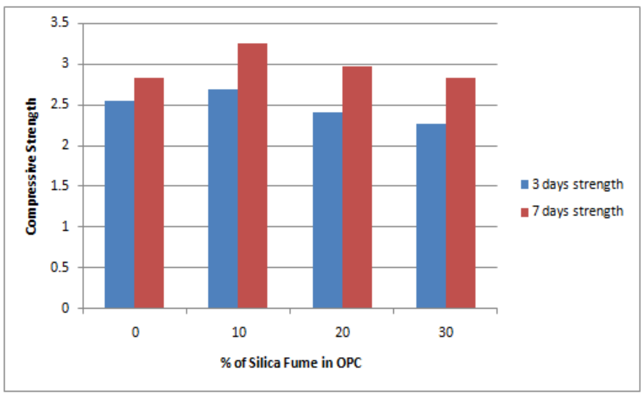
Table 13 Effect of silica fume on splitting tensile strength using OPC:

Silica fume (%)	7 days splitting tensile strength (N/mm^2)	28 days splitting tensile strength (N/mm^2)
0.0(0%fibre)	**2.546**	**2.829**
10.0(0.2%fibre)	**2.687**	**3.253**
20.0(0.2%fibre)	**2.405**	**2.970**
30.0(0.2%fibre)	**2.263**	**2.829**



V. 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 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

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