EXPERIMENTAL STUDY ON COMPRESSIVE AND FLEXURAL STRENGTH OF USING FIBRE REINFORCEMENT & METAKAOLIN AS PARTIAL REPLACEMENT OF CEMENT

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Abstract - Concrete is probably the most extensively used construction material in the world. The main ingredient in the conventional concrete is Portland cement. The amount of cement production emits approximately equal amount of carbon dioxide into the atmosphere. Cement production is consuming significant amount of natural resources. That has brought pressures to reduce cement consumption by the use of supplementary materials. Availability of mineral admixtures marked opening of a new era for designing concrete mix of higher and higher strength. GROUND GRANULATED BLAST FURNACE SLAG (GGBS) is a new mineral admixture, whose potential is not fully utilized. Moreover only limited studies have been carried out in India on the use of slag for the development of high strength concrete with addition of steel fibres

The study focuses on the flexural strength performance of the blended concrete containing 20% percentage of GGBS and different %s of steel fibres as a partial replacement of OPC. The cement in concrete is replaced accordingly with the percentage of 20% by weight of GGBS and 1%, 2%, 3% by weight of steel fiber. Concrete Samples are tested at the age of 7 and 28 days of curing. Finally, the strength performance of slag blended fiber reinforced concrete is compared with the performance of control mix. From the experimental investigations, it has been observed that, the optimum replacement of 20% of Ground Granulated Blast Furnace Slag to cement and steel fiber of 2% with respect to the weight of cement showed improved better results in flexural strength and proved to be optimum proportion when compared with other proportions with respect to strength and economy.

***Key Words*:** Steel Fibre, Metakaolin, Reinforced concrete, curing, compressive strength.

1.INTRODUCTION

Concrete construction was already known to the Romans, and possibly also to other ancient peoples, but apparently it later fell into disuse. Although the Romans made cement called pozzolana by mixing slaked lime with a volcanic ash from Mount Vesuvius and used it to make concrete for building, the arts were lost during the Dark Ages and were not revived until the eighteenth and nineteenth centuries. A deposit of natural cement rock was discovered in England in 1796 and was sold as “Roman cement.” Various other deposits of natural cement were discovered in both Europe and America and were used for several decades.

The real breakthrough for concrete occurred in 1824 when an English bricklayer named Joseph Aspdin, after long and laborious experiments, obtained a patent for a cement which he called “Portland cement” because its color was quite similar to that of the stone quarried on the Isle of Portland off the English coast. He made his cement by taking certain quantities of clay and limestone, pulverizing them, burning them in his kitchen stove, and grinding the resulting clinker into a fine powder. During the early years after its development, his cement was primarily used in stucco. This wonderful product was very slowly adopted by the building industry and was not even introduced into the United States until 1868. The first Portland cement was not manufactured in the United States until the 1870s.

Most of concrete usage is in the form of reinforced concrete. The beginnings of reinforced concrete go back to 1850, when Lambot constructed a small boat of cement which was shown at the World Fair in Paris, 1855, and is still floating in the Parc de Miraval. In England, W.B. Wilkinson patented a true reinforced concrete floor slab in 1854. Seven years later, F. Coignet published his statement on the principles of the new construction, defining the principles of reinforced concrete and describing the proposed construction of girders, vaults and pipes. He exhibited these structures at the Exhibition of 1867. In 1861, J. Moneir, a Paris gardener, used metal frames as reinforcement for garden tubs and pots. In the same year he took out his first patents.

In the United States, the pioneering efforts were made by Thaddeus Hyatt, originally a lawyer, who conducted experiments on reinforced concrete beams in 1850s. In a perfect correct manner the iron bars in Hyatt’s beams were located in tension zone, bent up near the supports, and anchored in the compression zone. Additionally, transverse reinforced (known as vertical stirrups) was used near the supports. However, Hyatt’s experiments were unknown until 1877 when he published his work privately. As head of the Concrete-Steel Company of San Francisco, E.L. Ransome apparently used some form of reinforced concrete in the early 1870s. He continued to increase the application of wire rope and hoop iron to many structures and was the first person to use and have patented in 1884; the deformed (twisted) bar.

The Moneir German patents were sold to G.A. Wayss and Company of Germany in 1880. Tests of structural strength were conducted by German engineers during the 1880s. Theories and computational methods were published by Koenen and Wayss in 1886.

Test results of Wayss and J. Bauschinger were published in 1887. Many recent innovations in advanced concrete technology have made it possible to produce concrete with exceptional performance characteristics. The durability of concrete structures is always a factor to be considered in aggressive environments. In the case of structures which are continuously in contact with water like offshore structures, parking decks and Dams the penetration of water is the major factor which controls the durability of the structure. Therefore, permeability and the pore system of the concrete are critical to the durability of the structure.

2. Materials

Cement

A high quality binder is necessary for HP-FRC. Cement that yields high compressive strength at the later stage is obviously preferable. The choice of Portland cement for high strength concrete is extremely important. Within a given cement type,

13different brands will have different strength development characteristics because of the variation in compound composition and fineness. The effect of cement characteristics on water demand is more noticeable in HP-FRC because of the higher cement contents. Strength development will depend on both cement characteristics and cement content.

Fine aggregate

The grading and particle shape of the fine aggregate are significant factors in the production of HP-FRC. Particle shape and surface texture can have as great an effect on mixing water requirements and compressive strength of concrete, as do those of coarse aggregate. Fine aggregate of the same grading but with a difference of 1% voids content may result in a remarkable difference in water demand. The optimum gradation of fine aggregate for HP-FRC is determined more by its effect on water requirement than on physical packing.

Coarse aggregate

Machine crushed angular Basalt metal used as coarse aggregate. The coarse aggregate is free from clayey matter, silt and organic impurities etc. The coarse aggregate is also tested for specific gravity and it is 2.68. Fineness modulus of coarse aggregate is 4.20. Aggregate of nominal size 20mm and 10mm is used in the experimental work, which is acceptable according to IS: 383-1970.

Water

Water is an essential component of concrete for mixing and curing. It should be free from harmful impurities, which may hinder the normal hardening process of concrete. Water found satisfactory for mixing is also suitable for curing should not produce any objectional stain or unslight deposition on the concrete surface.

The requirements for water quality for HP-FRC are no more stringent than those for conventional concrete. Usually water for concrete is specified to be of potable quality. This is certainly conservative but usually does not constitute a problem since most concrete is produced near a municipal water supply. Water used for mixing and curing shall be clean and free from injurious amounts of oils, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. The pH value of water shall not be less than 6.

Metakaolin

Metakaolin is obtained from the Kaomine industries PVT LTD at Vadodara on Gujarat state. The specific gravity of Metakaolin is 2.6 and the size of particle is less than 90 microns. The colour of metakaolin is pink.

Chemicals	Percentage (%)
SiO_2	62.62
Al_2O_3	28.63
Fe_2O_3	1.07
MgO	0.15
CaO	0.06
Na_2O	1.57
K_2O	3.46
TiO_2	0.36
LOI	2.00

Table -1: Sample Table format

Admixture

The major difference between conventional cement concrete and HP-FRC is essentially the use of chemical and mineral admixtures. Use of chemical admixtures reduces the water content, thereby reducing the porosity within the hydrated cement paste. The reduction in water content to a very low value with high dosage of chemical admixtures is undesirable and the effectiveness of chemical admixtures such as superplasticizer (SP) principally depends on the ambient temperature, cement chemistry and fineness. The mineral admixtures are generally industrial by products and their use can provide a major economic benefit. Thus, the combined use of mineral and chemical admixtures can lead to economical HP-FRC with enhanced durability.

Ground Granulated Burnt Furnace Slag

GGBS is a waste product in the manufacture of iron by blast furnace method. The molten slag is lighter and floats on the top of the molten iron. The process of granulating the slag involves cooling the molten slag through high-pressure water jets. This rapid cooling of slag results in formation of granular particles generally not larger than 5 mm in diameter. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching, optimizes the cementitious properties and produces granules similar to a coarse sand. The granulated slag is further processed by drying and then ground to a very fine powder, which is GGBS (ground granulated blast furnace slag). Grinding of the granulated slag is carried out in a rotating ball mill.
Blast furnace slag is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500oC to 1600oC. The molten slag has a composition of 30% to 40% silicon dioxide (SiO2) and approximately 40% CaO, which is close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which mainly consists of siliceous and aluminous residues is then rapidly water-quenched, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size which is known as ground granulated blast furnace slag (GGBS). The production of GGBS requires little additional energy compared with the energy required for the production of Portland cement.

The replacement of Portland cement with GGBS will lead to a significant reduction of carbon dioxide gas emission. GGBS is therefore an environmentally friendly construction material. It can be used to replace as much as 80% of the Portland cement when used in concrete. GGBS concrete has better water impermeability characteristics as well as improved resistance to corrosion and sulphate attack. As a result, the service life of a structure is enhanced and the maintenance cost reduced. High volume eco-friendly replacement slag leads to the development of concrete which not only utilizes the industrial wastes but also saves significant natural resources and energy. This in turn reduces the consumption of cement.

3. Mix Design

MIX DESIGN PROCEDURE

Target Strength for Mix Proportioning

F'ck = fck+ 1.65 x s

"Where" F'ck= Target average compressive strength at 28 days,

Fck= Characteristic compressive strength at 28 days, s = standard deviation

From Table 1, Standard deviation, s = 5.0 N/mm2

Therefore, Target Strength =30+1.6x5.0 = 38.25 N/mm^2

- Selection of Water-Cement Ratio:

From Table 5 of IS 456, FOR SEVERE EXPOSURE Maximum water cement Ratio = 0.45

Selection of water content:

- From Table 2,maximum water content = 186 litres (for 25 to 50 mm Slump range) for 20mm aggregate

- Calculation of Cement Content
- Water-cement ratio = 0.45
- Cement content = 186/ 0.45

=413 kg/m^3

- From Table 5 of IS 456, minimum cement content for 'SEVERE'condition = 320 kg/m^3

413 Kg/m3> 300 Kg/m^3

Hence, OK..

Fineness of cement

Brand of Cement: Bharathi Opc grade53.

Trail No.	1	2	3
Weight in cement (g)	100	100	100
Quantity of Cement Retained (%)	3	2.4	2.4

Table3: Fineness of cement

Result: Fineness of the given cement: **2.6 %**

As per IS: 269 the residue of cement sampled on the sieve 90 micron after sieving should not exceed 10% and hence it is with in its limit.

The following tabular column shows the physical Tests results of Bharathi opc cement

Table 4: physical Tests results of Bharathi opc cement

- WEIGHT OF BEAM (100X100X500) = 14.2 Kgs
- As the ratio is 1: 1.68: 2.92: 0.48

1x + 1.68x + 2.92x + 0.45x = 14.2

6.05x =14.2

x = 2.34

Therefore Ratios of C: FA: CA: W in Kgs are 2.34: 3.93: 6.83: 1.053

20 % of GGBS with respect to the weight of cement is 468 gms

1% of STEEL FIBRES with respect to the weight of cement is 23 gms

2% of STEEL FIBRES with respect to the weight of cement is 46 gms

3% of STEEL FIBRES with respect to the weight of cement is 69 gms

Hence these are the Final Mix Proportion of Materials for 1 PRISM

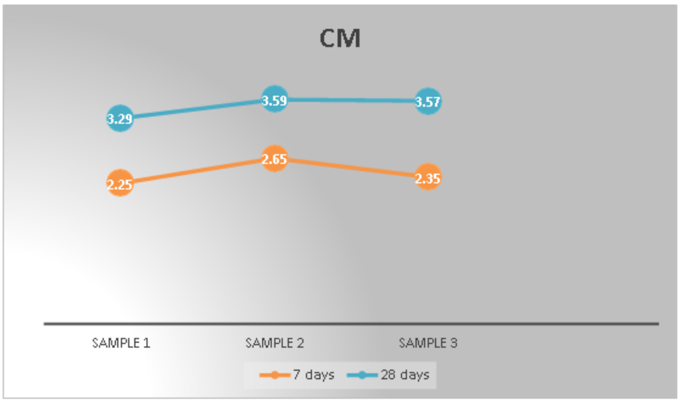
The work plan followed in the project is shown in the table 6.5 Mix 1 : 20% of GGBS replacement with respect to the weight of cement
Mix 2 : 20% of GGBS replacement with respect to the weight of cement an 1% SF Mix 3 : 20% of GGBS replacement with respect to the weight of cement an 2% SF Mix 4 : 20% of GGBS replacement with respect to the weight of cement an 3% SF

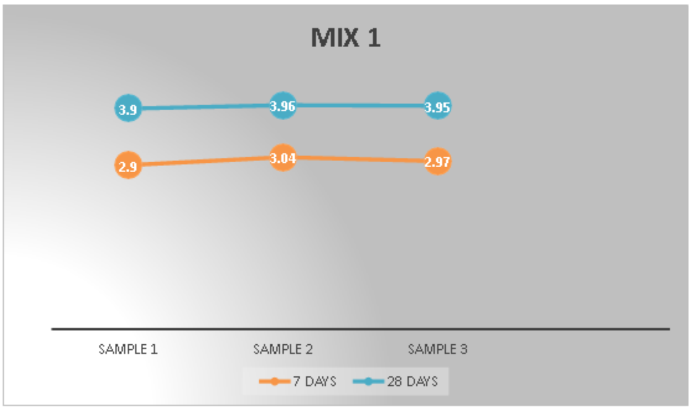
4. RESULTS AND DISCUSSION

COMPARISION OF FLEXURAL STRENGTH

Compressive strength test was carried on HPFRC with and without different mineral admixtures (GGBS and STEEL FIBRES) by using NWC. The 100 x 100 x 500 mm prisms were tested for flexure test under 7 and 28 days period of normal water curing.

7.1.1 CONTROL MIX





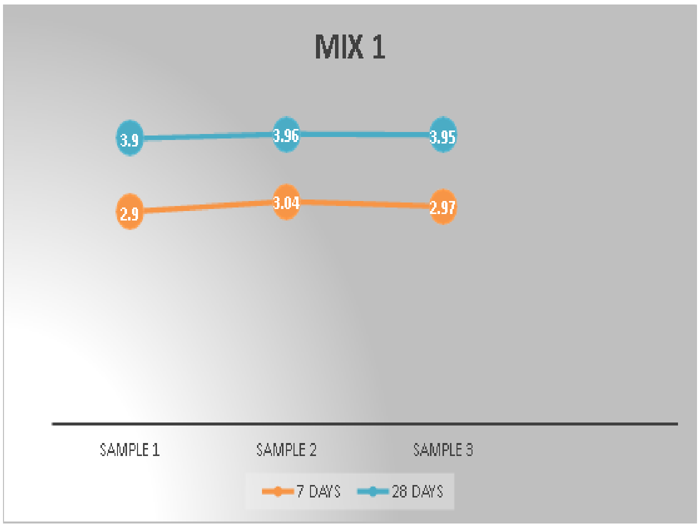
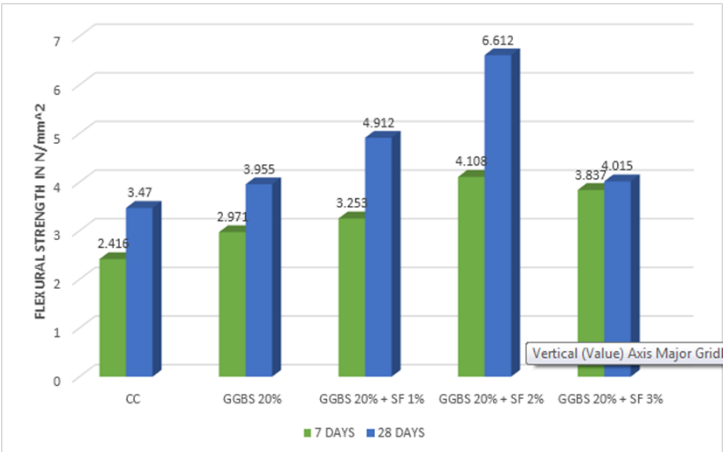
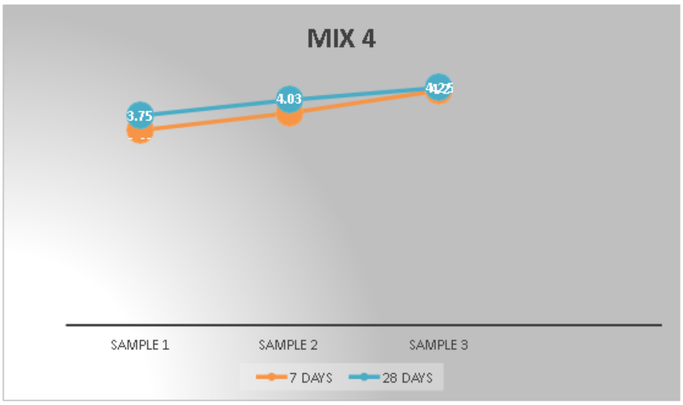


Table 7.1 Flexural strength of Beam samples in different proportions

CM	2.25 2.65 2.35	2.41	3.29 3.59 3.57	3.47
MIX1	2.90 3.04 2.96	2.97	3.90 3.96 4.00	3.95
MIX2	3.00 3.50 3.25	3.25	4.73 4.50 5.50	4.91
MIX3	3.80 4.10 4.40	4.10	6.00 7.22 6.61	6.61
MIX4	3.49 3.80 4.20	3.83	3.75 4.25 4.03	4.01

Mix	Average Flexural Strength (N/mm^2)	
	7 days	28 days
Control Mix	2.416	3.470
Mix 1	2.971	3.955
Mix 2	3.253	4.912
Mix 3	4.108	6.612
Mix 4	3.837	4.015





5. CONCLUSIONS

The main aim of the present investigation was to study the Flexural strength properties of HPFRC. Comparison between conventional concrete vs. high performance concrete vs. high performance fibre reinforced concrete with respect to Flexural strength results based on NWC were discussed.

- The Flexural strength of HPC where GGBS is added as admixture with partial replacement of cement has shown increase in Flexural strength as the amount of admixture is increased when compared to a control mix
- The flexural strength of concrete goes on increasing with the increase in fibre content up to the optimum value. The optimum value for flexural strength of steel fibre reinforced cement concrete was found to be 2 %.
- The percentage increase in the Flexural strength of admixture mixed concrete(GGBS 20%) and 2% steel fibre with the control mix for 7 days and 28 days is 41.18% and 47.5% respectively
- The percentage increase in the Flexural strength of FRC of 1% SF with the GGBS 20% mixed concrete for 7 days & 28 days is 25.73% and 29.35% respectively
- The percentage increase in the Flexural strength of FRC of 3% showed decreased results than optimum value of 2% steel fibres
- Finally the proportion of 20% GGBS with 2% steel fibres is recommended with respect to flexural strength and economical FRC mix

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