EXPERIMENTAL STUDY ON COMPRESSIVE & FLEXURAL STRENGTH BY USING FIBRE REINFORCEMENT AND 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 fibers. The study focuses on the flexural strength performance of the blended concrete containing 20% percentage of GGBS and different %s of steel fibers 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.

Keywords: steel fibers, GGBS, slag blended fiber reinforced concrete, metakaolin

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 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.

1.1 New Age Concrete :
Improvement of quality of structural materials is a general trend which may be observed in our civilization. At different periods that trend has a foem of a steady continuous function or of a step function. High Performance Concretes appeared a few years ago and now develop rapidly representing a new generation of composite materials in building and civil engineering. Without any doubt their application will be increased in many kinds of structures where special requirements are imposed.

1.2 High Performance Fibre Reinforced Concrete (Hpc):
High Performance Fibre Reinforced Concrete (HPFRC) is a concrete meeting special combinations of performance and uniformity requirements that cannot be always achieved routinely by using conventional constituent sand normal mixing. This leads to examine the admixtures to improve the performance of the concrete.

1.3 Flexural Strength of Fiber Reinforced Concrete :
Steel fibers are generally found to have aggregate much greater effect on the flexural strength of FRC than on either the compressive or tensile strength, with increases of more than 100% having been reported. The increases in flexural strength are particularly sensitive, not only to the fiber volume, but also to the aspect ratio of the fibers, with higher aspect ratio leading to larger strength increases. The fiber effect in terms of the combined parameter Wl/d, where l/d is the aspect ratio and W is the weight percent of fibers. It should be noted that for Wl/d > 600, the mix characteristics tended to be quite unsatisfactory. Deformed fibers show the same types of increases at lower volumes, because of their improved bond characteristics.

1.4 Background of the research work :
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.

1.5 Objective and scope:
The main objective of this research is to study the flexural behavior of the FRC with GGBS as partial replacement of cement for the desired concrete mix.

- To determine the flexural Strength of Fiber reinforced concrete mix using 1%, 2% and 3% hooked end steel fibers with 20% of GGBS as partial replacement of cement
- To compare the flexural strength of all different proportions and desirable proportion is suggested.

2. Materials Used In Project

2.1 Composition of High Performance Fiber Reinforced Concrete:

Ingredients of UHP-FRC are almost same as those of CCC. But, because of lower water cement ratio, presence of mineral and chemical admixtures etc., the HP-FRCs usually have many features which distinguish them from CCCs. HP-FRC is prepared through a careful selection of each of its ingredients. Effective production of UHP-FRC that consistently meets requirements for workability and strength development places more stringent requirements on material selection than for CCC. From practical considerations, in concrete constructions, apart from the final strength, the rate of development of strength is also very important. The HP-FRC usually contains both mineral and chemical admixtures. Hence, the rate of hydration of cement and the rate of strength development in HP-FRC is quite different from that of CCC. For HP-FRCs, however, all the components of the concrete mixture are pushed till their limits. Therefore, it is necessary to pay careful attention to all aspects of concrete production, i.e., selection of materials, mix design, handling and placing. In essence, the proportioning of HP-FRC concrete mixtures consists of following interrelated steps,

a.) Selection of suitable ingredients – cement, aggregates, water, mineral and chemical admixtures.

b.) Determination of the relative quantities of these materials in order to produce, as economically as possible, a concrete that has the rheological properties, strength and durability.

c.) Careful quality control of every phase of the concrete making process.

2.2 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, different 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.

2.3 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.

2.4 Coarse Aggregate:

In the proportioning of HP-FRC, the aggregates require special consideration since they occupy the largest volume of any ingredient in the concrete, and they greatly influence the strength and other properties of the concrete. Usually, HP-FRCs are produced with normal weight aggregate. However there have been reports of HP-FRC produced using lightweight aggregates for structural concrete and heavy weight aggregates for high density concrete. The coarse aggregate will influence significantly the strength and structural properties of the concrete. For this reason, a coarse aggregate should be chosen that is sufficiently hard, free of fissures or weak planes, clean and free of surface coatings. Smaller size aggregates have been shown to provide higher strength potential.

2.5 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 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.

Fig.1 Ground Granulated Burnt Furnace Slag

3. STEEL FIBRES

Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers. Now, why would we wish to add such fibers to concrete? Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes discontinuous fibers is to bridge across the cracks that develop provides some post- cracking "ductility". If the fibers are sufficiently strong, sufficiently bonded to material, and permit the FRC to carry significant stresses over a relatively large strain capacity in the post-cracking stage.

The important properties of steel fiber reinforced concrete (SFRC) are its superior resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fibre composites possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under Flexural loading; and the fibers are able to hold the matrix together even after extensive cracking. The net result of all these is to impart to the fiber composite pronounced post cracking ductility which is unheard of in ordinary concrete.

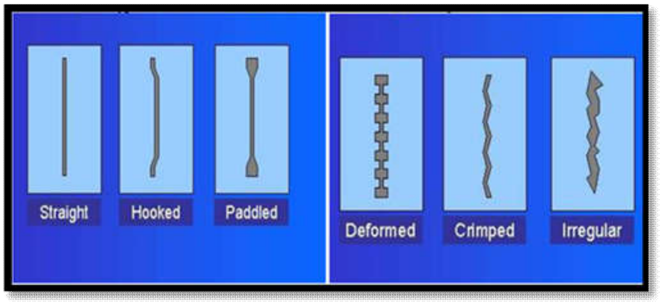

Fig.2 Types of Steel Fibers

The use of SFRC over past thirty years has been so varied and so widespread, that it is difficult to categorize them. The common applications are pavements, tunnel linings, pavements and slabs, shortcrete airport pavements, bridge deck slab repairs and so on. There has also been some recent experimental work on roller compacted concrete reinforced with steel fibers. The list is endless, apparently limited only by the ingenuity of the engineers involved. The fibers themselves are unfortunately, relatively expensive; a 1% steel fiber addition will approximately double the material cost of concrete, and this has tended to limit the use of SFRC to special applications.

Fig.3 Steel Fibers

Table 1.1 Physical Compositions Of STEEL FIBRES

Sno	Properties	Description
1	HOOKED END	BOTH SIDES
2	DIAMETER	0.3 – 0.7 mm
3	LENGTH	35 mm
4	DENSITY	7900 kg/mm^3
5	YOUNGS MODULUS	21*105 N/mm^2
6	RESISTENCE TO ALKALIES	GOOD
7	RESISTENCE TO ACIDS	POOR
8	HEAT RESISTIVITY	GOOD
9	TENSILE STRENGTH	500 – 2000 N/mm^2

10	SPECIFIC GRAVITY	7.90
11	ASPECT RATIO	60
12	ELONGATION	5% - 35%

Table 1.2 Chemical compositions of GGBS

Constituents	In %
SiO_2	33.52
FeO	1.28
Al_2O_3	19.81
CaO	34.77
MgO	7.38
MnO	0.45
TiO_2	0.88
S	0.89
K_2O	0.39
Na_2O	0.23

4. RESULTS AND DISCUSSIONS:

Experimental studies have been undertaken to evaluate the Flexural strength of HPC using different mineral admixtures. The test results are followed accordingly,

4.1 Comparison 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.

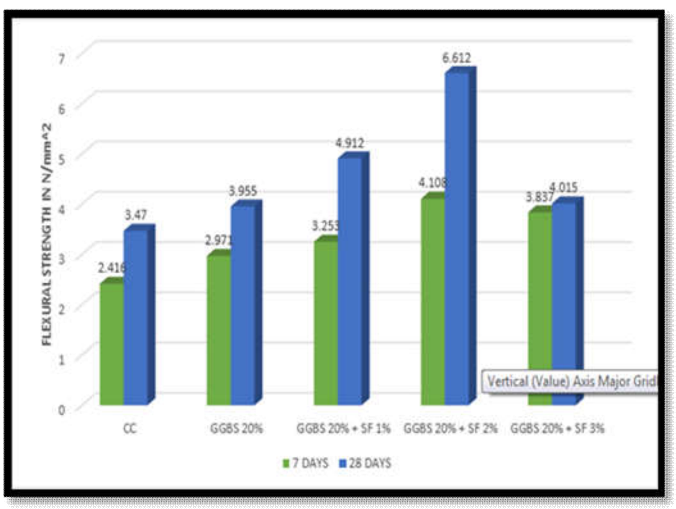

Fig.4 Variation of Flexural strength with GGBS and STEEL FIBRES

Table1.3 Flexural strength of HPFRC

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

4. CONCLUSION

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 fiber reinforced concrete with respect to Flexural strength results based on NWC were discussed.

Based on the experimental investigations carried out, the following conclusions are drawn

- 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 fiber content up to the optimum value. The optimum value for flexural strength of steel fiber reinforced cement concrete was found to be 2 %.
- The percentage increase in the Flexural strength of admixture mixed concrete(GGBS 20%) and 2% steel fiber 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 fibers
- Finally the proportion of 20% GGBS with 2% steel fibers is recommended with respect to flexural strength and economical FRC mix.

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