Effect of Synthetic Fibres on Concrete with GGBFS Replaced Cement

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Abstract

Concrete is used widely in many construction activities. As cement is getting costlier and demand is growing more day by day, investigators have been trying to replace cement with other materials to save money either by maintaining the properties using waste materials or by enhancing the properties using selected materials. This paper is an attempt to study the various engineering properties of a concrete made with cement replaced by ground granulated blast furnace slag. To maintain the engineering properties, a synthetic fiber namely Recron 3s fibers manufactured by Reliance Industry Limited, India (RIL) and commonly available in the local retail market of India, has been used in various proportions. The experimental investigations include basic tests for cement, and conventional tests for concrete such as compressive strength, split tensile strength and flexural strength have been taken up. The capillary tests and porosity tests have been also conducted to study the effects of concrete in respect of resistance to seeping or dampening. It has been observed that the Recron fibers to the extent of 0.2% fiber content maintain the satisfactory properties of concrete. However, the resistance to capillary action and porosity problems in concrete is improved considerably.

Keywords: Synthetic Fiber, ground granulated blast furnace slag, Superplasticizer, capillary test and porosity test

1. Introduction

Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementitious materials, water, aggregates 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 a stronger mass with age. The last century saw concrete structures, built during the first half with ordinary Portland cement (OPC) and plain round bars of mild steel, supplemented with the easy availability of constituent materials of concrete. 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. The search for any 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. As per investigations reported by Alhozaimy et al. (1996), Zollo (1997), Safiuddin and Hearn (2005) and Bozkurt and Yazicioglu (2010) fly ash, ground granulated blast furnace slag (GGBFS), 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, satisfying the desired qualities of concrete.

Qian Jueshi and Shi Caijun (2000) studied on high performance cementing materials from industrial slag. They found that most industrial slags were used without taking full advantage of their properties or disposed rather than used. The industrial slags, which have cementitious or pozzolanic properties, should be used as partial or full replacement for Portland cement rather than as bulk aggregates or ballasts because of the high cost of Portland cement, which is attributable to the high energy consumption for production. According to Ganesh Babu and Sree Rama Kumar (2000) the utilisation of supplementary cementitious materials is well accepted because of several improvements possible in the concrete composites and due to the overall economy.

This paper is an attempt to study the various engineering properties of a concrete made with additives such as a synthetic fiber and a super plasticizer in combination with Portland slag cement in different material proportions. Attempt has also been made to use GGBFS in order to replace partly the Portland slag cement. Recron 3s fibers manufactured by Reliance Industry Limited, India (RIL) and commonly available in the local retail market have been used. The capillary and porosity tests have been also conducted to study the effects of concrete in respect of resistance to seeping or dampening of concrete thus prepared.

2. Experimental Investigations

2.1 Materials used

Aggregates: The fine aggregate comprised of sand of Zone-II, according to Bureau of Indian Standard (BIS) 383 (1970). As per the same code, the maximum size of coarse aggregate was 20mm and 60% of coarse aggregate was of 10mm size and the rest of 20mm size. The specific Gravity, water absorption and fineness modulus of coarse aggregates were 2.67, 0.4% and 4.11 respectively.

Cement: The commonly used Portland Slag Cement (PSC) has been used in this study. Its physical properties such as specific gravity, initial setting time (min) and final setting time (min) are 2.96, 125 and 235 respectively.

Synthetic fiber: Synthetic fiber namely Recron fiber, which is very commonly, affordably and abundantly available in India, manufactured by Reliance Petrochemicals has been used to prepare fiber reinforced concrete.

Ground granulated blast furnace slag (GGBFS): GGBFS is a non-metallic product essentially consists of silicates and alumino silicates of calcium and other bases. The four major factors, which influence the hydraulic activity of slag, are glass content, chemical composition, mineralogical composition and fineness. It has specific surface of about 400-500 m^2/kg (Blaine). It has been used as partial replacement of cement because of its advantages like lower energy cost, higher abrasion resistance, lower hydration heat evolution, higher later strength development. Specific gravity test conducted using Le-Chatelier apparatus is found to be 2.77.

2.2 Preparation of fiber reinforced concrete

First of all consistency tests of cement with replacement of GGBFS were conducted. In case of fiber reinforced concrete, Recron fiber in different percentages i.e 0, 0.1, 0.2 and 0.3% to the weight of concrete was used. For each fiber concentration GGBFS was varied at 10, 20, 30 and 40% to study the effect of GGBFS replacement. The slump was maintained in the range of 50-75mm to ensure proper workability and to maintain this, admixture such as superplasticizer (local trade name: Sika) was used suitably varying water cement ratio. The super plasticizer concentration also varied for fiber reinforced concrete without and with GGBFS. Then with different concentrations of GGBFS, fiber content was maintained at 0.2%, keeping appropriate water cement ratio and admixture dosage.

All mixtures were mixed in a conventional rotary drum concrete mixer. The mixer was first loaded with the coarse aggregate and a portion of the mixing water, then sand, cement and the rest of water were added and mixed for 3 min. The fibers in the case of fibrous mixtures were randomly distributed. The admixture Sika was added to the mixing water and in case of GGBFS, the same was added with cement simultaneously. Samples were prepared with due reference to relevant BIS codes of practice such as BIS 10262 (1982), BIS 9103 (1999) and BIS 456 (2000).

2.3 Tests conducted

Besides consistency tests, compressive strengths of mortars without fibres were tested. The specimens of concrete cubes, cylinders and prisms were prepared as per normal procedures and then subjected to compressive strength, splitting tensile strength and flexural strength tests respectively as per relevant BIS codes of practice such as BIS 9399 (1959) and BIS 5816 (1999). Then porosity and capillary absorption test were conducted on half cylinder to analyze the effect of GGBFS on voids in different concrete mixes.

Capillary and Porosity Test: The capillary absorption coefficient (k) was calculated by using formula:

$$k = \frac{W}{A \times \sqrt{t}}$$

where, W = Amount of water absorbed in gm

A = Cross sectional area in cm^2 contact with water

t = Time in seconds

Porosity test: The porosity can be calculated using the formula given below.

$$\text{Porosity} = {}^{Vv}/_{V} = {}^{Wsat - Wdry}/_{V}$$

$$= {}^{Ww}/_{V}$$

where, Vv = volume of voids in cc

V = total volume of specimen in cc

W_{sat} = Weight of saturated cube

W_{dry} = Weight of dry cube (before saturation)

W_w = Weight of water absorbed in the Cube

3. Analysis of Test Results and Discussions

3.1 Consistency of cement

As shown in figure 1 normal consistency increases with cement replacement. Normally consistency of cement depends upon its fineness. As GGBFS has greater fineness and, hence greater surface area than cement, the consistency increases with GGBFS replacement.

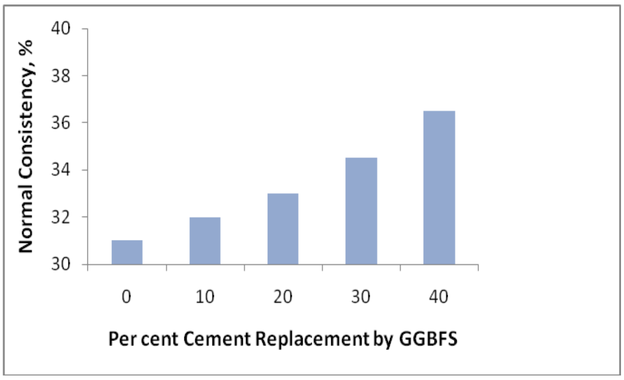

Figure 1. Effect of GGBFS on Consistency of Cement

3.2 Effect of GGBFS Replacement on Properties of Concrete

In First stage, concrete is prepared without fibre addition, but with increasing GGBFS content replacing the cement and the following set of engineering properties are studied to decide the optimum dosage of GGBFS replacement. ***Compressive strength:*** As seen in figure 2 the compressive strength (3 days, 7 days and 28 days) of cubes decreases with GGBFS content. It is also observed that upto 20% replacement acceptable strength can be obtained.

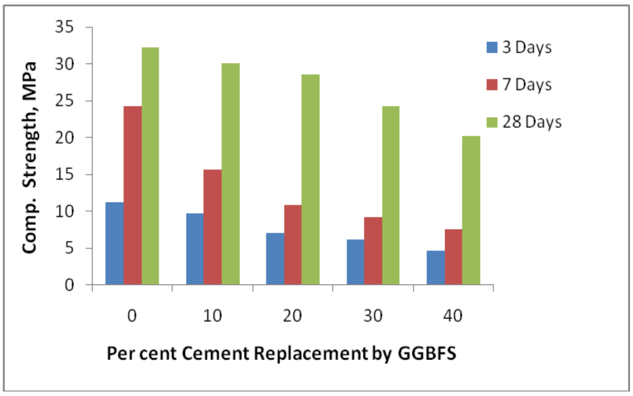

Figure 2. Variation of Compressive Strength with GGBFS Replacement

Split tensile strength: As seen in figure 3, similarly the split tensile strength (7 days as well as 28 days) of concrete decreases with GGBFS replacement.

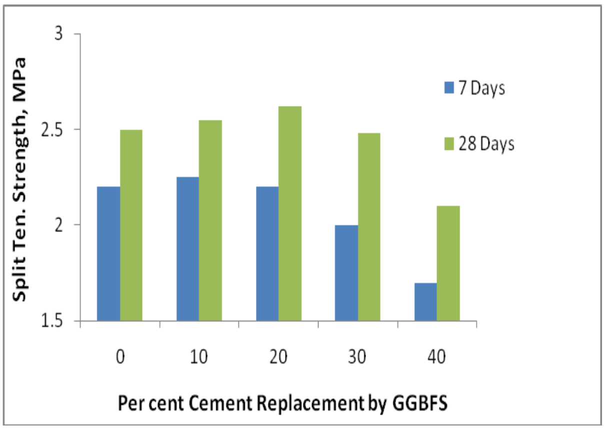

Figure 3. Variation of Tensile Strength with GGBFS Replacement

Flexural strength: As seen in figure 4 the flexural strength (7 days as well as 28 days) of concrete also decreases with GGBFS Replacement.

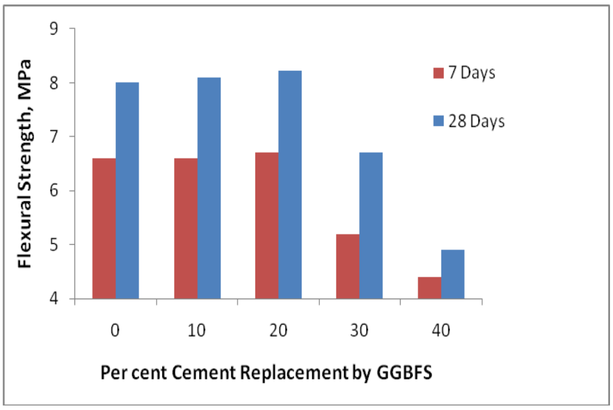

Figure 4. Variation of Flexural Strength with GGBFS Replacement

Capillary absorption and porosity: As seen in figure 5 and 6, the capillary absorption coefficient and porosity decrease with GGBFS replacement. However, the former is more phenomenal. The porosity of concrete decreases with GGBFS replacement, but at a slow rate. These two features are an added advantage of GGBFS replacement.

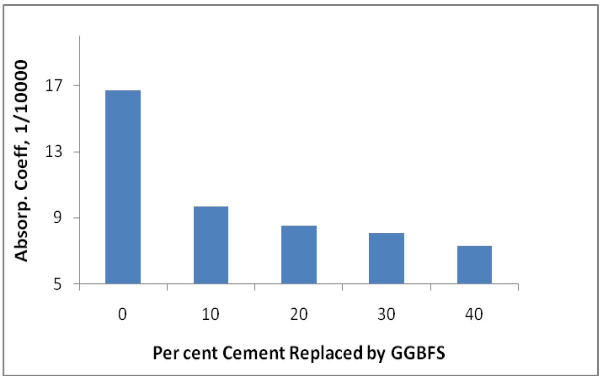

Figure 5. Variation of Capillary Absorption with GGBFS Replacement

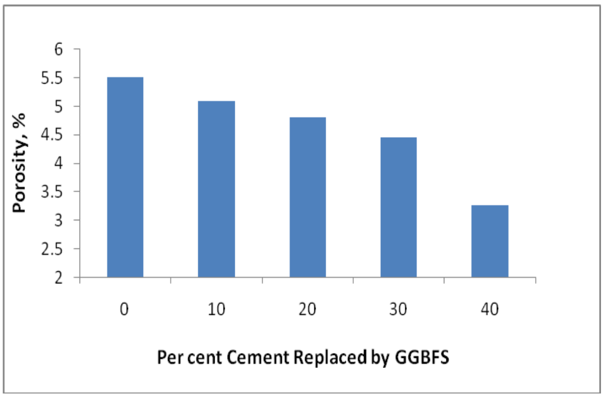

Figure 6. Variation of Porosity with GGBFS Replacement

Considering the above results particularly the compressive strength results, it may be concluded that 20% GGBFS Replacement should be optimum. This has been used in further investigations.

3.3 Effect of Fiber Addition on Properties of Concrete

In the second stage, keeping GGBFS Replacement of 20% as constant, concrete is prepared with increasing fiber content and different properties are studied to decide the optimum fiber content.

Compressive strength: As seen in figure 7 the compressive strength (7 days as well as 28 days) of cubes decreases with increase in fiber content, however, the rate is more pronounced after 0.2% fiber content.

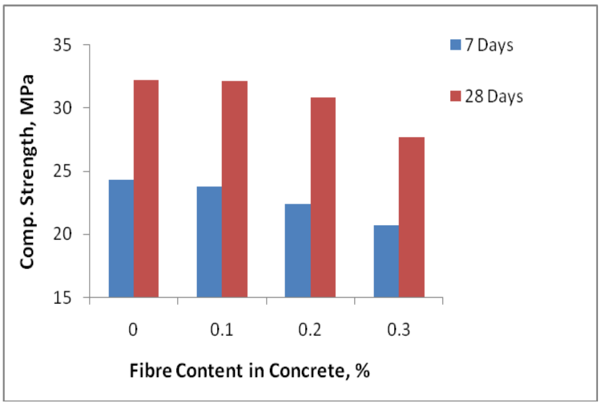

Figure 7. Variation of Compressive Strength with Fiber Content

Split tensile strength: As shown in figure 8 it is clear that the split tensile strength behaves almost in the similar way, as compressive strength. It can be added that the decrease is more pronounced after 0.2% fiber content.

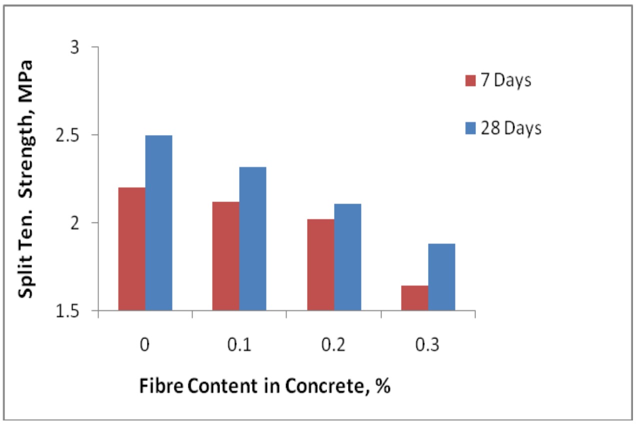

Figure 8. Variation of Tensile Strength with Fiber Content

Flexural strength: The flexural strength as presented in figure 9 increases upto 0.2% fiber content after which it decreases.

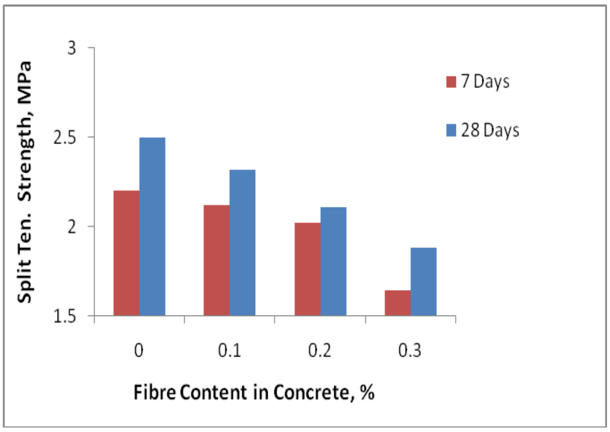

Figure 9. Variation of Tensile Strength with Fiber Content

Capillary absorption and porosity: As shown in figures 10 and 11, the capillary absorption decreases with 0.1% fibre addition, while porosity increases with fiber content. However, significant changes appear after 0.2%.

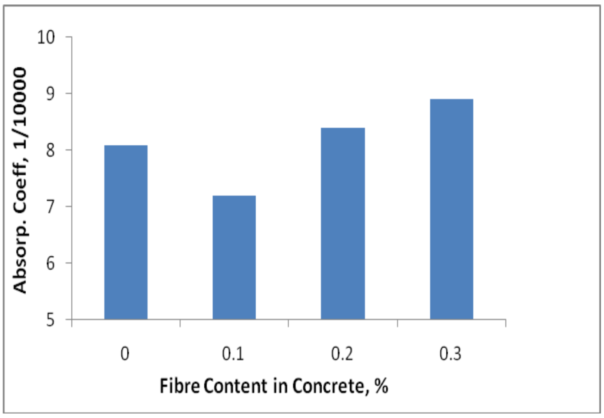

Figure 10 Variation of Absorption Coefficient with Fiber Content

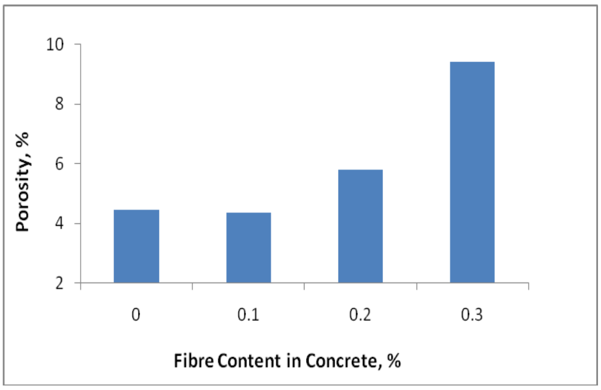

Figure 11 Variation of Porosity with Fiber Content

4 Conclusions

Using Portland slag cement and locally available aggregates, ‘Sika’ superplasticizer and water, an attempt has been made to study first, the effect of part replacement of cement by ground granulated blast furnace slag on engineering properties of concrete. As there is decreasing trend of the characteristics, a synthetic fiber which is commonly available in the local market under the trade name Recron 3S has been added in varying proportions. The following conclusions are drawn.

- The normal consistency increases with replacement of cement by pozzolanic material such as GGBFS.
- In case of normal concrete, part replacement of cement by GGBFS decreases the compressive strength. However, satisfactory results are obtained with 20% replacement. Hence it is decided to go for 20% replacement for preparation of concrete for further investigations.
- Addition of fibres decreases the compressive strength and split tensile strength, with phenomenal change after 0.2%. Flexural strength of concrete increases with fibre addition upto 0.1 % by weight after which they decrease.
- Similarly the capillary absorption parameter decreases with fibre content upto 0.1% after which the value of this parameter increases, while the porosity increases with fibre content, but significant being after 0.1-0.2%.
- Considering the above observations, it is concluded that within the range of tests conducted, 20% GGBFS replacement of Portland slag cement with 0.2% fiber addition with would improve the dampening or seeping action of water in concrete besides satisfying the other conventional criteria.

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