EFFECT OF SILICA FUME ON ENGINEERING PROPERTIES OF FIBER REINFORCED CONCRETE

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Concrete is a 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. The concrete widely used in large-scale construction demands high strength, high flowability, and high durability. This paper is an attempt to study the various engineering properties of a concrete made with additives such as silica fume, a synthetic fiber and a super plasticizer in different material proportions. Recron 3s fibers manufactured by Reliance Industry Limited, India (RIL) and commonly available in the local retail market of India have been used. The experimental investigations include the X-ray diffraction test, the basic tests for cement, and conventional tests for concrete such as compressive strength, flexural strength and split tensile strength. The capillary 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 silica fumes and Recron fibers enhance the resistance to capillary and porosity problems in concrete, besides enhancing the compressive strength, flexural strength and split tensile strength. Generally it is seen from this investigation that the optimum properties of concrete have been obtained with 20% silica fume replacement and 0.2% fiber content.

Keywords: Synthetic fiber, silica fume, superplasticizer, conventional tests for concrete, 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 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, supplemented with the easy availability of constituent materials of concrete and the knowledge of concrete technology of the contemporary period led to a mass of concrete which was satisfactory during the time under consideration. Strength was emphasized without a thought on the durability of structures. Subsequently, the setback in the health of newly constructed concrete structures in the last two/three decades, the doubts on the service life performance of our constructions and the resulting challenge that confronts us in the alarming and unacceptable rate at which our infrastructure systems suffer from deterioration when exposed to real environments, have led to search for material, which can be used as an alternative or as a supplementary for cement should lead to best possible one in real life situations. As per investigations reported by Alhozaimy *et al.* (1996), Zollo (1997), Bhanja and Sengupta (2005), Safiuddin and Hearn (2005) and Bozkurt and Yazicioglu (2010) 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, satisfying the desired qualities of concrete.

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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 different material proportions. Attempt has also been made to use silica fume in order to replace partly 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 the concrete thus prepared.

2. Experimental Investigations

2.1. *Materials used*

2.1.1. *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 20 mm and 60% of coarse aggregate was of 10 mm size and the rest of 20 mm size. The specific Gravity, water absorption and fineness modulus of coarse aggregates were 2.67, 0.4% and 4.11 respectively.

2.1.2. *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.

2.1.3. *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. The specifications of Recron fibers as given by the manufacturer are as follows.

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

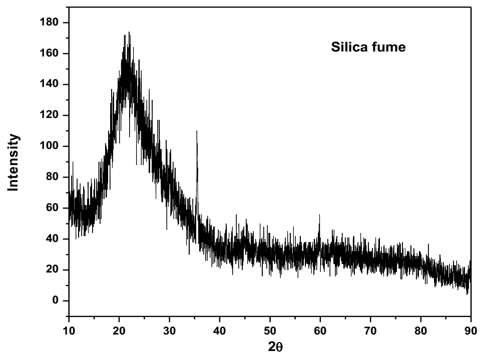

Fig. 1. X-ray diffraction test of silica fume.

2.1.4. *Silica fume*

Silica fume was tried in this study to explore the extent of replacing cement. The specific gravity of silica fume using Le-Chatelier apparatus was found to be 2.36. X-Ray diffraction test was conducted the report of which is presented in Figure 1. As per this report, the material is observed to be in amorphous state having compounds mainly of SiO_2 and CaO.

2.2. *Preparation of fiber reinforced concrete*

First of all consistency tests of cement and silica fume replaced cement 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 silica fume content was varied at 10, 20 and 30% to study the effect of silica fume. The slump was maintained in the range of 50–75 mm to ensure proper workability and to maintain this, admixture such as superplasticizer (local trade name: Sika) was used keeping water cement ratio in the range of 0.35–0.41

(0.35, 0.37, 0.39 and 0.41) and 0.41–0.45 (0.41, 0.42 and 0.45). The super plasticizer concentration varied in the range 0.6%–1.4% (0.6, 0.9, 1.2 and 1.4%) and 1.4%–1.7% (1.4, 1.5 and 1.7%) for fiber reinforced concrete without and with silica fume respectively. Aggregate binder ratio and coarse aggregate to fine aggregate ratio were maintained at 3.08 and 2.38 and 2.34 respectively. Then with different concentrations of silica fume such as 10, 20 and 30%, fiber content was maintained at 0.2%, keeping water cement ratio of 0.422, 0.44 and 0.46, and admixture content of 1.4, 1.6 and 1.7%.

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 silica fume mix, the same was added with cement simultaneously. Samples were prepared with due reference to relevant BIS codes of practice such as BIS10262 (1982), BIS9103 (1999) and BIS456 (2000).

2.3. *Tests conducted*

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 BIS9399 (1959) and BIS5816 (1999).

Before using silica fume consistency test was conducted on silica fume with the replacement of different percentage of cement to analyse the water absorption. Then porosity and capillary absorption test were conducted on half cylinder to analyze the effect of silica fume on voids in different concrete mixes.

2.3.1. *Capillary and porosity test*

In capillary test, concrete cubes cured for 28 days are dried in a hot air oven at about 105°C until constant mass is obtained.

Fig. 2. Capillary absorption test of cubes.

The temperature of specimens is allowed to come down to room temperature and remain there for 6 hours. The sides of the specimen are coated with paraffin to achieve unidirectional flow. The specimens are exposed to water on one face by placing it on slightly raised seat (about 5 mm) on a pan filled with water. The water on the pan is maintained about 5 mm above the base of the specimen during the experiment as shown in the Figure 2. The weight of the specimen is measured at regular interval of 30 minutes up to 2 hr 30 mins to allow small variation of absorption of water. 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.

2.3.2. *Porosity test*

This test was conducted to evaluate the amount of voids present in the specimens prepared. First of all the saturated weights of the specimens cured for 28 days are obtained. Then specimens are dried in oven at about 105°C until constant mass is obtained. Then weight of water absorbed can be converted in terms of its volume. The test is conducted on half cylinder of different mixes of Portland slag cement. The porosity can be calculated using the formula given below.

$$\text{Porosity} = \frac{Vv}{V} = \frac{W_{\text{sat}} - W_{\text{dry}}}{V} = Ww/v$$

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*

It is observed that normal consistency increases to about 45% when silica fume percentage increases upto 30% as shown in Figure 3. Normally consistency of cement depends upon its fineness. As silica fume has greater fineness and, hence greater surface area than cement, the consistency increases with silica fume replacement. This consistency is maintained in this investigation.

3.2. *Effect of fiber addition on properties of concrete*

First of all concrete is prepared with increasing fiber content and different properties are studied to decide the optimum fiber content.

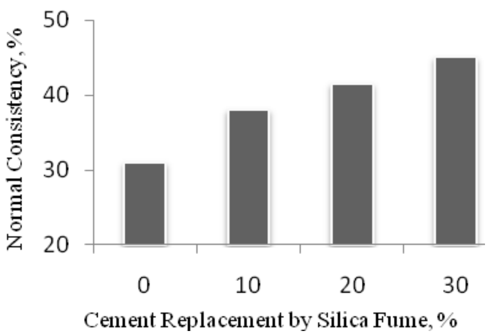

Fig. 3. Effect of silica fume on consistency of cement.

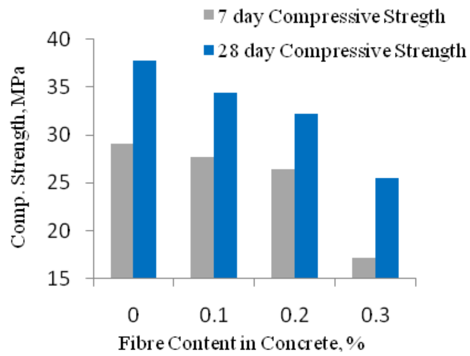

Fig. 4. Variation of compressive strength with fiber content.

3.2.1. *Compressive strength*

As seen in Figure 4 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.

3.2.2. *Split tensile strength*

As shown in Figure 5 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.

3.2.3. *Flexural strength*

The flexural strength as presented in Figure 6 increases upto 0.2% fiber content after which it decreases.

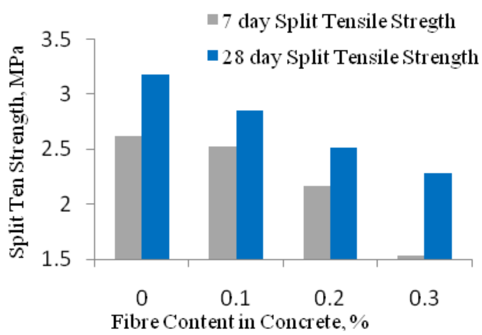

Fig. 5. Variation of tensile strength with fiber content.

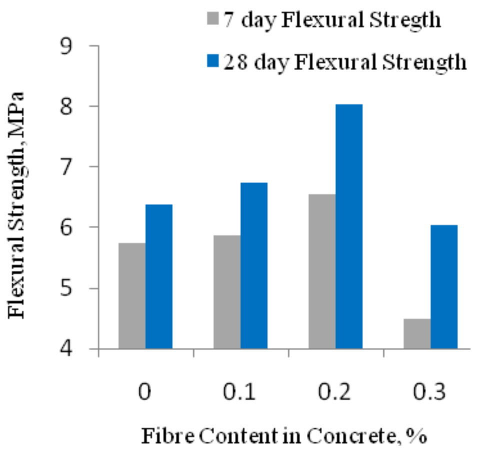

Fig. 6. Variation of tensile strength with fiber content.

3.2.4. *Absorption and porosity*

As shown in Figures 7 and 8, the absorption and porosity increase with fiber content. However, it is significant after 0.2%.

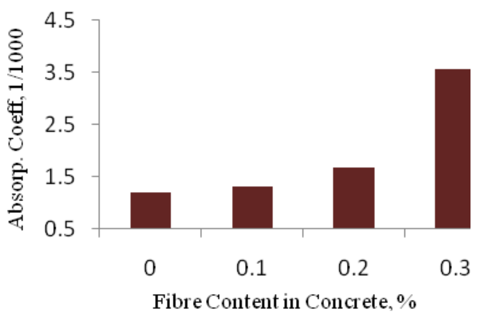

Fig. 7. Variation of absorption coefficient with fiber content.

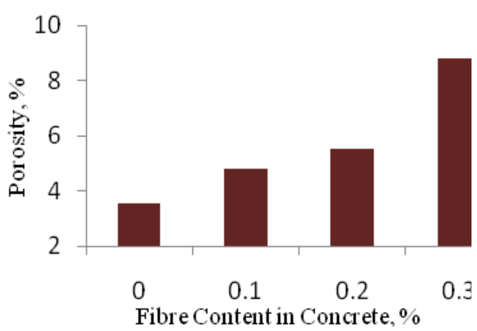

Fig. 8. Variation of porosity with fiber content.

Considering the above results particularly the flexural strength result, it may be concluded that 0.2% fiber content should be optimum. This has been used in further investigations.

3.3. *Effect of silica fume replacement on properties of concrete*

In second stage, keeping 0.2% fiber content by weight in concrete constant, concrete is prepared with increasing silica fume content replacing the cement and the same set of properties are studied to decide the optimum dosage of silica fume replacement.

3.3.1. *Compressive strength*

As seen in Figure 9 the compressive strength (7 days as well as 28 days) of cubes increases with silica fume content till 20%, beyond which it decreases.

3.3.2. *Split tensile strength*

As seen in Figure 10, similarly the split tensile strength (7 days as well as 28 days) of cubes increases with silica fume content till 20%, beyond which it decreases.

3.3.3. *Flexural strength*

As seen in Figure 11 the flexural strength (7 days as well as 28 days) of cubes increases

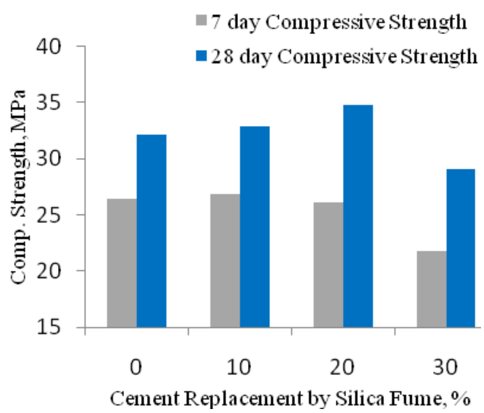

Fig. 9. Variation of compressive strength with silica fume content.

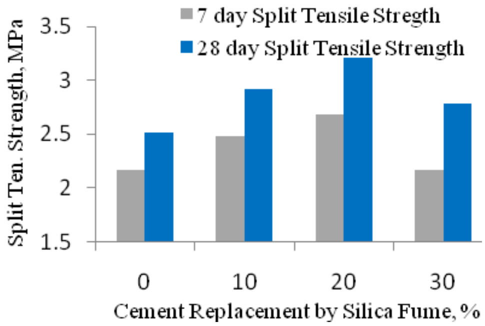

Fig. 10. Variation of tensile strength with silica fume content.

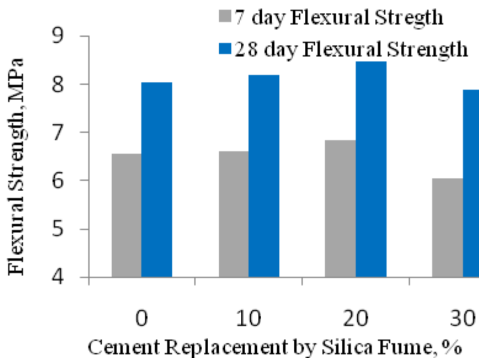

Fig. 11. Variation of compressive strength with silica fume content.

with silica fume content till 20%, beyond which it decreases. This trend may be due to the more fineness and higher pozzolonic action of the mixture.

3.3.4. *Capillary absorption and porosity*

As seen in Figure 12 the capillary absorption coefficient and porosity decreases with silica fume content till 20%, after which it increases. This may be due to the fact that with higher silica fume, cementing action decreases. However, as presented in Figure 13, the porosity of concrete decreases with silica fume replacement, but at a slow rate. These two features are an added advantage of using these two ingredients.

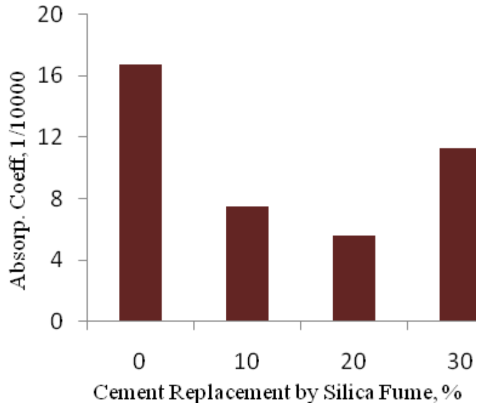

Fig. 12. Variation of capillary absorption with silica fume content.

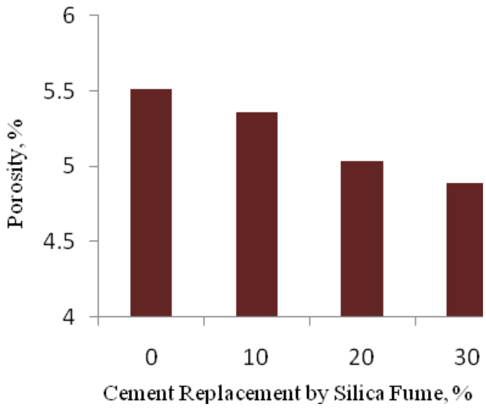

Fig. 13. Variation of porosity with silica fume content.

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 a synthetic fiber which is commonly available in the local market under the trade name Recron 3S and then, to replace cement by a pozzolanic material such as silica fume. The following conclusions are drawn.

- The normal consistency increases with replacement of cement by pozzolanic material such as silica fume.
- In case of normal concrete, addition of synthetic fiber such as Recron 3S does

not increase the compressive strength. However, the decrease is not significant upto 0.2% fiber addition and more pronounced thereafter.

- The flexural strength increases upto 0.2% fiber content and thereafter decreases.
- The capillary absorption coefficient and porosity increase with addition of fibers. The increase is more pronounced after 0.2% fiber addition.
- Hence it is decided to go for 0.2% fiber addition in concrete for further investigations.
- Replacement of cement by silica fume increases the compressive strength, split tensile strength and flexural strength of concrete till the replacement of silica fume is upto 20% by weight after which they decrease.
- Similarly the capillary absorption parameter decreases with silica fume replacement upto 20% after which the value of this parameter increases, while the porosity reduces with silica fume replacement.
- Considering the above observations, it is concluded that within the range of tests conducted, 0.2% fiber addition with 20% silica fume replacement of Portland slag cement would improve the dampening or seeping action of water in concrete besides satisfying other conventional criteria.

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