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GLASS FIBER POLYMER ON THE FRESH AND HARDENED PROPERTIES OF CONCRETE

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The study describes an experimental study into the relationship among incorporation of Glass Fiber on the fresh and hardened properties of concrete. The effect of fiber fractions on the slump, compressive strength, splitting tensile strength and flexural strength of Glass Fiber Reinforced Concrete (GFRC) were investigated for volume fraction (VF) of 0%, 1%, 2% and 4%. In order to serve the purpose, concrete cylindrical and prism specimens were made with various rates of fiber-glass polymer. The cylinder specimens were tested at 7 and 28 days for compressive strength and at 28 days for splitting tensile strength, whereas the prism specimens were tested at 28 days for flexural strength. The experimental test results show that the additions of glass fiber polymer to concrete decrease slump, but increase compressive strength, splitting tensile strength and flexural strength. In addition, an analytical model has been proposed to predict slump of fresh concrete.

Keywords: GFRC, Workability, Compressive strength, Tensile strength, Flexural strength, Slump prediction model.

1 INTRODUCTION

Concrete is the most consumed construction material. From its invention in roman era, its applications in different industries have ever been rising. This phenomenon is mainly attributed by its usefulness over other types of construction materials in respect of strength, durability and economy (Yoo *et al.* 2013). However, susceptibility to weak in tension and low fracture strain capacity has severely censored its application (Chandramouli *et al.* 2010). To compensate this brittleness nature of concrete, fiber reinforced concrete is often considered as an alternative. Fiber has been used to reinforce brittle matrix from as early as Biblical period (Brandt 2008). Fibers classify as steel, glass, synthetic and natural, has been incorporated in concrete to strengthen concrete in tension (Coenen *et al.* 1977, Kosmatka *et al.* 2011). Among all these, steel fiber is the most widely used in concrete (Brandt 2008, Islam and Alam 2013, Islam 2017). However, vulnerability of steel fiber to corrosion limits its applications. To resolve this problem glass fiber is often inferred as an alternative. Earlier researches have revealed that incorporation of glass fiber in concrete reduces workability, i.e. slump of fresh concrete. However, the effect of fiber inclusion on compressive strength of concrete is still an issue of argument (Kizilkanat *et al.* 2015). In addition to this, previous studies reported that addition of glass fiber in concrete improves tensile strength, flexural strength, toughness, ductility of plain concrete.

2 MATERIALS

2.1 Cement

Blended hydraulic Portland composite cement, CEM II/BM (S-V-L) was used as cementing material in the study.

2.2 Aggregates

Bholagonj stone and Sylhet sand, locally available materials were used respectively as coarse aggregate (CA) and fine aggregate (FA) in the study. The specific gravity of the coarse aggregate and fine aggregate are respectively 2.66 and 2.45, and unit weight are 1543.27 kg/m^3 and 1667.92 kg/m^3. ASTM C136 was followed to obtain grain size distribution, and represented in Figure 1.

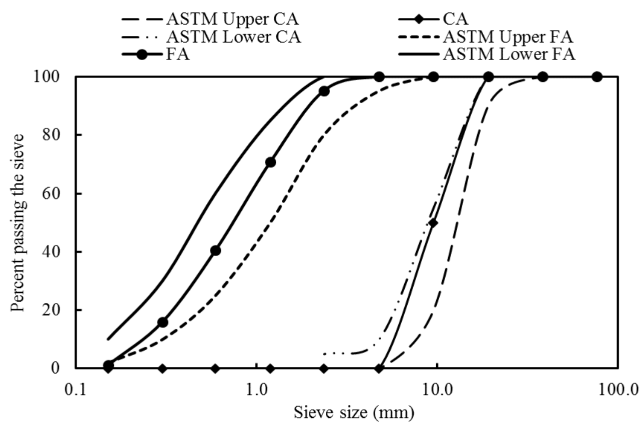

Figure 1. Gradation curves of the aggregates used in this study.

2.3 Glass Fiber Polymer

Glass fiber of density 1700-2250 kg/m^2, compressive and tensile strength of 490-840 kg/cm^2 and 210-320 kg/cm^2 respectively were utilized in this study. The macro fiber possesses young's modulus of 104 MPa, elongation at break was of 0.6% to 1.2%.

2.4 Mix Design and Test Specimens

Four cases of mix proportions were designed by volumetrically varying the fiber content to concrete at different fractions to perform the study. The glass fiber mesh was added at a fraction of 0%, 1%, 2% and 4% respectively. The water to cement ratio (w/c) of 0.45, and the sand to aggregate ratio (s/a) of 0.42 was kept constant for all mixes. The mixture constituents for concrete cylinder and beam specimens are documented in Table 1.

Table 1. Mix proportions for concrete cylinder and beam specimens.

<table>
<tr><th>Volume Fraction (VF) (%)</th><th>Coarse Aggregate (kg/m^3)</th><th>Fine Aggregate (kg/m^3)</th><th>Cement (kg/m^3)</th><th>Water (kg/m^3)</th></tr>
<tr><td>0</td><td rowspan="4">1534.15</td><td rowspan="4">1023.23</td><td rowspan="4">7.05</td><td rowspan="4">3.17</td></tr>
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2.5 The Experiment's Methods

For each of the four cases shown in Table 1, a total of 1.07 ft^3 (0.03 m^3) of concrete was prepared to conduct slump test as per ASTM C143, and thirty-two 4 in X 8 in (10 cm X 20 cm) concrete cylinders and eight 4 in X 4 in X 11.5 in (10 cm X 10 cm X 29 cm) beams were also prepared to determine the mechanical properties of hardened concrete. Concrete cylinders were tested as per ASTM C39 at 7 and 28 days to determine the compressive strength of concrete and for splitting tensile cylinders test as per ASTM C496 at 28 days. The stress-strain responses of specimens also recorded for compressive strength at 28 days. The beam specimens were subjected to center point loadings as per ASTM C293 to measure the flexural strength at 28 days.

3 RESULTS & DISCUSSIONS

3.1 Compressive Strength and Splitting Tensile Strength

Compressive strength test result, at 7 days and 28 days has been demonstrated in Figure 2. At 7 days, reduction in average compressive strength was attributed for VF of 1% and 4%, as shown in Figure 2. Nevertheless, VF of 4% showed an increase in compressive strength to control at 28 days alone. For rest of the investigated cases, a reduction in compressive strength with glass fiber incorporation. However, it was noticed that presence of glass fiber prevented development of crack width in concrete.

Influence of fiber addition on tensile strength of hardened concrete has been demonstrated in Figure 3. Overall, an increase in tensile strength is observed at 28 days, 1.67% and 14.45% enhancement in tensile strength respectively for VF 2% and VF 4%. However, VF 1% shows a decline in tensile strength by 10.89%. It was also noticed that presence of glass fiber limits complete split of concrete by abridging the crack and transferring stress. These eventually prevent complete rupture of concrete, and shows numerous micro crack in concrete.

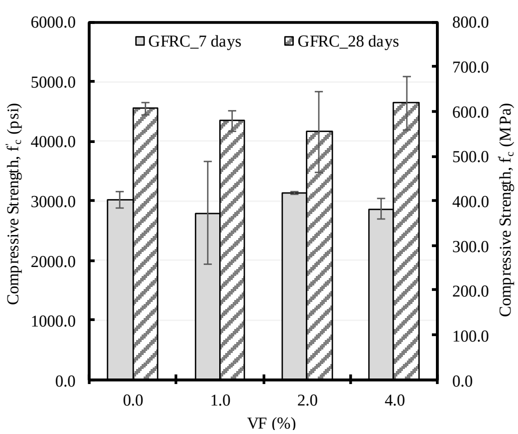

Figure 2. Influence of fiber incorporation on compressive strength of concrete.

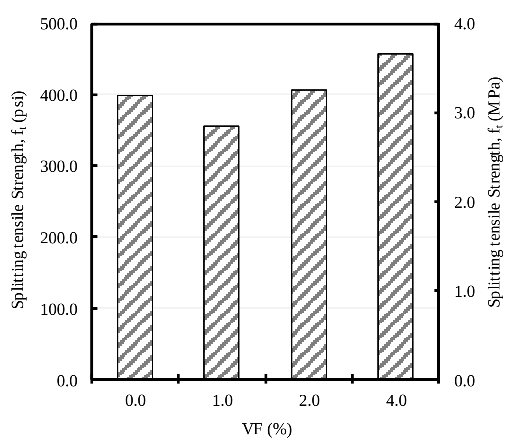

Figure 3. Influence of fiber addition on splitting tensile strength of concrete.

3.2 Stress-Strain Response

Stress-strain responses recorded at 28 days has been illustrated in Figure 4. The slopes of stress-strain responses are quite similar, however an increase in strain capacity with increase in fiber fractions is also depicted from Figure 4. In case of VF 1% and VF 2%, there are not noticed any significant enhancement in terms of both stress and strain capacities. However, for VF of 4% there were significant increase in both compressive strength and strain, as shown in Figure 4.

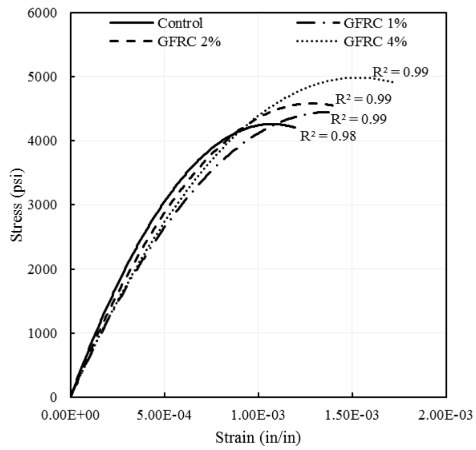

Figure 4. Stress-strain response at 28 days.

3.3 Flexural Strength

Beam test recorded results at 28 has been illustrated in Figure 5. Overall an enhancement in flexural strength is overserved with fiber addition, as shown in Figure 5. Figure 5 shows approximately 33% enhancement in flexural strength capacity for both VF of 1.0% and 2.0%, whereas about 53% gain in flexural strength was achieved for VF 4.0%.

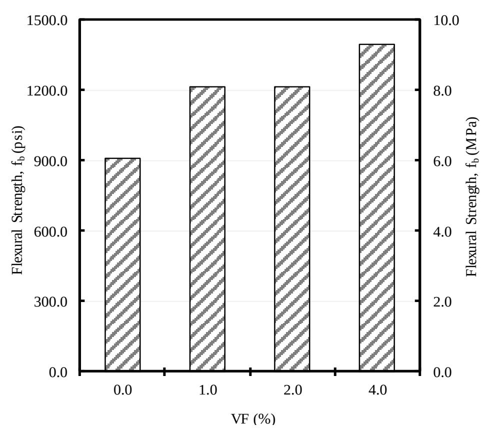

Figure 5. Influence of fiber addition on flexural strength of concrete.

3.4 Proposed Model for the Prediction of Slump of GFRC

Figure 6 shows the effect of the glass fiber content on the slump of GFRC. As can be shown, the slump value decreased linearly with an increase in fiber content. The simple model that described the data set with R^2 value of 85% is shown in Eq. 1. The Prob (F) and F-ratio values of Eq. 1 shown to be 0.078 and 11.23, respectively. The t-ratio for the regression parameters a and b were found to be more than 1.0. These showed a very good evidence that the propose model is more likely to predict the nearly accurate slump value of the GFRC. The proposed model was used to determine the analytical slump value of GFRC and compared with the experimental values obtained from this study. The results are shown in Figure 7. As can be seen, the predicted slump values obtained from the proposed model showed a very good alignment having R^2 values of 84% with the actual slump values generated from the experimental procedures.

$$S_f = a\ V_f + b \tag{1}$$

Where: S_f is the slump value of GFRC in cm; V_f is the fiber content in percentage; a and b are the coefficients and their values are -1.0486 and 5.36, respectively.

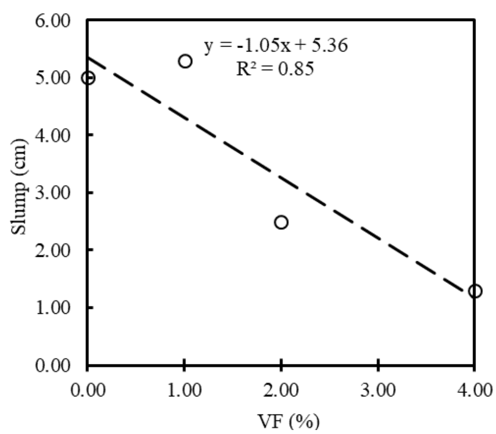

Figure 6. Influence of fiber addition on slump of concrete.

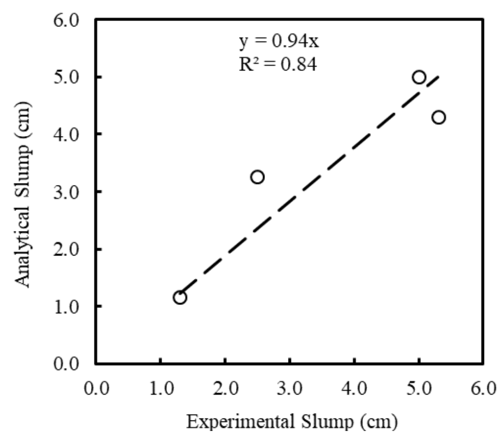

Figure 7. Relationship between analytical slump and experimental slump.

CONCLUSIONS

The findings of this study can be summarized as follows:

(a) Incorporation of glass fiber increases viscosity of concrete and thus reduces flowability.

(b) Effect of addition of fiber is not noteworthy on concrete compressive strength and modulus of elasticity.

(c) Effect of fiber incorporation on tensile strength of concrete is not quite appreciable.

(d) Fiber incorporation increase flexural strength of plain concrete remarkably.

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