International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 4, April - 2013

An Investigation On Strength Properties Of Glass Fiber Reinforced Concrete

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Abstract

It is well known fact that plain concrete is brittle in nature; it has low tensile strength and less ductility. Moreover, plain concrete suffers from cracking due to drying shrinkage and various other causes. It has been found that the use of fibers in plain concrete controls shrinkage cracking to a some extent and also improves the tensile properties of concrete. Glass fibers serve the similar purpose with an additional advantage of being used in ornamental concrete *This material is alakali resistant and less dense than steel, so the final product known as 'glass fiber reinforced concrete (GFRC)', is lightweight but strong. GFRC is composed of fine sand, cement, water, admixtures (if required) and alkali-resistant (AR) glass fibers in different ratios. In this paper, effect of using glass fibers on strength properties of concrete has been discussed. 8 different GFRC mixes were cast using different percentages of glass fibers by weight of cement at constant mix and water cement ratios. The properties of concrete like workability, compressive strength, tensile strength, flexure strength, and ultrasonic pulse velocity have been investigated by casting respective concrete samples of standard dimensions in the form of cubes, cylinders and beams. The results show that workability of GFRC decreases by increasing glass fiber content. it was also observed that long term compressive strength of GFRC was marginally improved. However significant improvement in tensile and flexural strength of GFRC at 1.5% glass fiber content was observed as compared to ordinary concrete.*

1. Introduction

GFRC is important cement based composite that uses fine sand, cement, water, admixtures and alkali-resistant (AR) glass fibres. It is mainly used for construction of thin, lightweight exterior building facade and architectural prefabricated cladding panels. The glass fibre reinforcement results in a product which has higher flexural and tensile strengths as compared to normal concrete, allowing its use in thin-wall casting applications. Fibre content varies, but is generally 1% to 5% of the cementitious weight. Some mixes go up to 10% by weight of cement. Increased fibre content may add strength but decrease workability. Glass fibers are usually round and straight with diameters of 0.005 to 0.015 mm [1].

It has been recognized that the addition of small, closely spaced and uniformly dispersed fibres' to concrete would act as crack arrester and would substantially improve its static and dynamic properties. GFRC derives its strength from a high dosage of AR glass fibers; while compressive strength of GFRC can be increased, it is the much higher flexural and tensile strengths that make it superior to ordinary concrete. GFRC has very high tensile strength up to 1020 to 4080 N/mm^2. The alkali resistant glass fibre reinforcement in concrete shows considerable improvement in durability [2]. Shakor & Pimplikar, (2011) concluded that 7 days average compressive strength of concrete is maximum when 1.5 % of glass fibres by weight of cementitious material are used. At lower 0.11% of glass fibers or higher 2 % of glass fibers, about 15% to 20% reduction in strength is observed nevertheless at 28 days, the reduction in strength approaches to 5% to 10%. Percentage of glass fiber of 2% gave a flexural strength of 6.15 MPa, which is 10% more than that obtained at 1.5% [3]. Gornale et al., (2012) compared the strength aspects such as compressive, split tensile and flexural strength of plain and glass fiber reinforced concretes. They examined that increase in compression, flexural, and split tensile strengths for various grades of plain concrete at 3, 7 and 28 days are observed to be 20% to 30%, 25% to 30% and 25% to30% respectively [4]. In 2011, P. Sangeetha, reported that increase in the percentage of glass fiber by weight of concrete (0.1%, 0.2%& 0.3%) increases the compressive and impact strength. The percentage increase in compressive strength was reported to be up to 23% [5]. Mahyuddin Ramli & Kwan Wai Hoe (2010) studied the ultrasonic pulse velocity behavior of high strength concrete by incorporating short discrete glass fibers into high strength concrete. They claimed that all concrete specimens were having good quality [6]. Sudarsana et al., (2011) stated that workability of glass fiber reinforced high performance concrete mixes decreases with increase in the percentage of glass fibers [7].

The work of different researchers on GFRC has been found on concretes cast by using foreign ingredients only. The trend of locally branded concretes manufactured by using indigenous materials found in Pakistan was still demanding a lot of research work. The current investigation was planned to explore the effects of using different percentages of glass fibres on properties of fresh and hardened concrete like workability, compressive strength, tensile strength, flexural strength and ultra-sonic pulse velocity.

2. Experimental program

2.1. Materials

2.1.1. Cement. Portland cement **(**Type I), branded as Fauji cement has been used in this study. Different physical and chemical tests were performed on the cement to confirm its quality before use. The cement had a fineness of 3128 cm^2/gm, initial setting time as 90 minutes, final setting time as 222 minutes, consistency as 29.25%, specific gravity as 3.03, while no expansion was found in the soundness test.

2.1.2. Fine aggregate. Locally available Lawrancepur sand was used as fine aggregate. As per results of physical testing, the sand has values of fineness modulus, specific gravity & water absorption as 2.96, 2.71 and 1.20% respectively. The results of sieve analysis performed on the fine aggregates as per ASTM C136-06 has been shown in Table 1.

2.1.3. Coarse aggregate. Margalla Crush conforming to B.S. 882:1992 was used as coarse aggregate. It was passing through 20 mm and retained on 5 mm sieve. The coarse aggregate has values of fineness modulus, specific gravity & water absorption as 1.98, 2.68, and 0.75% respectively. Sieve analysis results of coarse aggregates are shown in Table 2.

2.1.4. Water. Normal tap water available in the concrete laboratory of UET Taxila, fit for drinking, was used to cast concrete samples.

Table 1: Sieve analysis results of fine aggregates

Sieve Size (in)	Weight Retained (gram)	Percentage Retained (%)	Cumulative Passing (%)	Cumulative Retained (%)
3/8 in.	0	0	100	0
# 4	21	2.1	97.9	2.1
# 8	92	9.2	88.7	11.3
#16	258	25.8	62.9	37.1
#30	270	27	35.9	64.1
#50	214	21.4	14.5	85.5
#100	106	10.6	3.9	96.1
Pan	39	3.9	0	--
Total				296.2
Fineness modulus				2.96

Table 2: Sieve analysis results of coarse aggregate

Sieve Size (in)	Weight Retained (gram)	Percentage Retained (%)	Cumulative Passing (%)	Cumulative Retained (%)
20	0	0	100	0
12.5	794	26.47	73.53	26.47
10	1368	45.60	27.93	72.07
5	820	27.33	0.60	99.4
Pan	18	0.60	0	--
Total				197.94
Fineness modulus				1.98

2.1.4. Glass fibres. AR-D (Alkali resistant-water dispersed) glass fibre chopped strand imported from China were used in this research. The sizing systems of these fibres allow its well dispersion into water in 10 seconds. Also the required dosage of these fibres is less in concrete. The specifications of glass fibres are shown in Table 3. Scanning electron microscopic image of glass fibres is shown in figure 1.

Table 3. Technical characteristics of glass fibers

Tex of Strands (Tex)	Filament Diameter (μm)	Chop Length (mm)	Moisture Content (%)	Sizing Content (%)	ZrO_2 Content
98±10 JC/T572-2002	15	12	≤0.6 JC/T572-2002	1.0±0.2 JC/T572-2002	14.5%

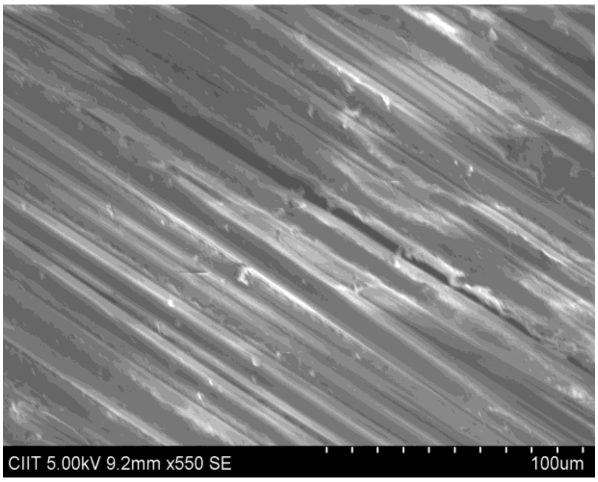

Figure 1. Scanning electron microscopic image of G.F.

2.2 Casting Schedule

2.2.1. Mix Design. A total no. of 8 mixes were cast using different percentages of glass fibres by weight of cement. The proportion of cement, sand, water and coarse aggregate was kept same for all mixes. Various parameters used in the research are given below:

- Concrete mix ratio: 1:1.5:3
- Water cement Ratio: 0.60
- Glass fibre percentages by weight of cement: 0%, 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, and 3.5%
- Mix with 0% GF content was declared as control mix.

2.2.2. Casting of Test Samples. A total no. of 96 cubes were cast for compressive strength and ultrasonic pulse velocity tests, 96 cylinders for split cylinder test and 24 beams for flexural strength test. Detailed break-up along with dimensions of samples is given in Table 4.

Table 4. Casting schedule and details of test specimens

Test details	Specimen details	Age (days)				Total (1 mix)	Total (8 mixes)
		3	7	28	56		
Compressive strength Test / UPV Test	Cubes (150 × 150 x 150 mm)	3	3	3	3	12	96
Split cylinder test	Cylinders (150 mm high ×300 mm dia.)	3	3	3	3	12	96
Flexural strength test	Beams (100 × 100 × 500 mm)	-	-	3	-	3	24

3. Results and discussion

3.1. Workability

Slump test was carried out conforming to ASTM C143 on each mix to ascertain workability of GFRC as well as control mixtures. The results of slump tests are plotted in figure 4.

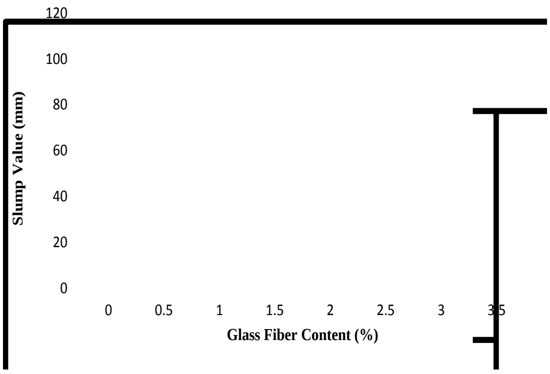

Figure 2. Slump values versus glass fibre content

There is gradual decrease in the slump values with an increase in GF dose, which indicates that addition of GF content is associated with an increase in water demand. Thus some water reducing admixtures may be used to get required workability of concrete without compromising on strength. Sudarsana et al. concluded similar results in their work regarding workability of cocnrete carried out in 2011.

3.1. Compressive strength

Effect of adding glass fibres in different ratios on compressive strength of concrete was studied by testing cubes of standard dimensions conforming to BS 12390: Part 3 [8]. Cubes were tested at the age of 3, 7, 28, and 56 days. Results are plotted in figure 3. Figure 4 represents the change in compressive strength values as compared to control specimen. Strength activity index for each mix was also calculated using ASTM C 618 (ASTM, 2008b) and is given in Table 5. Strength activity index may be defined as "ASI = (A /B) x 100 %" where A is the average compressive strength of blended concrete cubes and B is the average compressive strength of control specimen without glass fibre content.

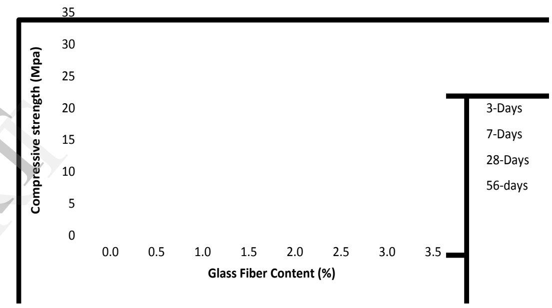

Figure 3. Variation of cube compressive strength with glass fibre content

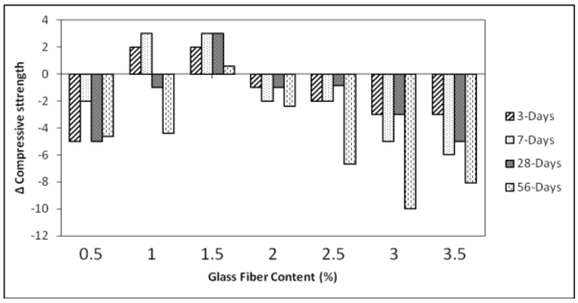

Figure 4. Increase/decrease in cube compressive Strength with glass fibre content

Results show that there is a marginal increase in 3 & 7 day's compressive strength for 1% addition of GF while compressive strength increases at all ages for 1.5 % addition of GF content as compared to control specimen. However, 56 days compressive strength has only 2% net increase compared with control specimen. Other percentages of glass fibre show a reduction in the compressive strength with reference to control mix. Compressive strength at 1.5% mix ratio of GF content is 18%, 15%, 13% & 2% more as compared to that of plain concrete at 3, 7, 28, & 56 days respectively. Shakor et al. also worked on GFRC in 2011 and concluded that compressive strength is maximum at 1.5% addition of glass fibres by weight of cement.

Table 5. Strength activity index for compressive strength test

G.F (%)	SAI			
	3-days	7-days	28-days	56-Days
0	100%	100%	100%	100%
0.5	55%	90%	78%	84%
1	118%	115%	96%	85%
1.5	118%	115%	113%	102%
2	91%	90%	96%	92%
2.5	82%	90%	96%	77%
3	73%	75%	87%	66%
3.5	73%	70%	78%	73%

3.2. Ultrasonic pulse velocity strength

Ultrasonic pulse velocity test was carried out on test samples at all ages according to ASTM C 597. Figure 5 & 6 gives graphical representation of UPV compressive strength results. Figure shows that at 0.5% mix ratio, UPV compressive strength is less than control specimen for all ages. With an increase in the GF content, it increases gradually and reaches at its maximum value at 1.5% mix ratio, which is more than that of the control specimen and then it gradually decreases and becomes again less than that of control specimen. Strength activity index for all mixes is are given in Table 6.

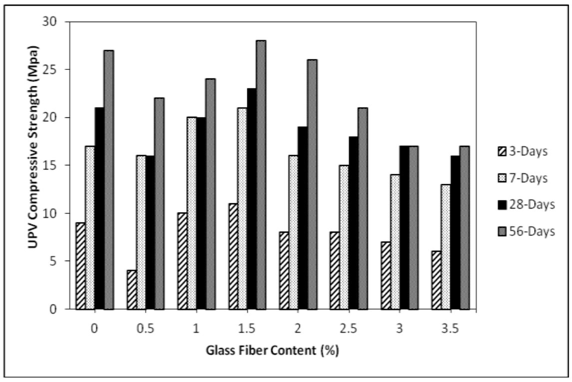

Figure 5. Variation of UPV compressive strength with glass fibre content

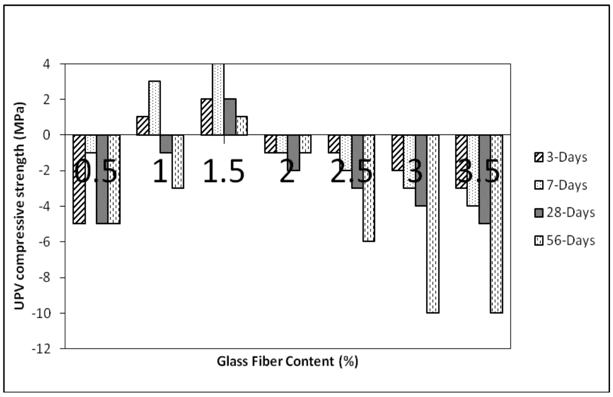

Figure 6. Increase/decrease in UPV compressive strength with glass fibre content

Table 6. Strength activity index for UPV compressive strength

G.F (%)	SAI			
	3-days	7-days	28-days	56-Days
0	100%	100%	100%	100%
0.5	55%	90%	78%	84%
1	118%	115%	96%	85%
1.5	118%	115%	113%	102%
2	91%	90%	96%	92%
2.5	82%	90%	96%	77%
3	73%	75%	87%	66%
3.5	73%	70%	78%	73%

Figure 7 show comparison of UPV compressive strength with cube crushing strength at all testing ages. It is clear from both figures that UPV compressive strength values are less than actual strength (cube crushing strength).

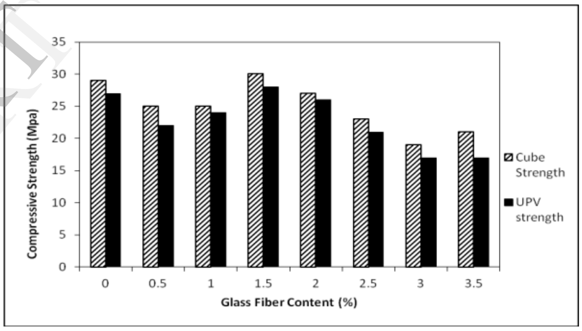

Figure 7. Comparison of 56-days Cube and UPV compressive strength with glass fibre content

3.3. Split cylinder strength

For all mixes, split cylinder test was carried out as per ASTM C496-71 to study the effect of mixing glass fibres on tensile strength of concrete. Results are summarized in figure 8 while changes in split cylinder strength values of blended samples with respect to control sample are given in figure 9. Strength activity index vaues for split cylinder strength are given in Table 7.

3 and 7-day split tensile strength of concrete increases with respect to control mix at 1%, 1.5% and 2% of glass fiber's content. 28 and 56-days split tensile strength of concrete increases with respect to control mix at 1.5% and 2% of glass fiber content. Other percentages of glass fiber show a reduction in the split tensile strength with reference to control mix. Again for all ages, glass fiber reinforced concrete gave best results at a mix ratio of 1.5% by weight of cement. These are 18%,

26%, 13% & 11% more than control sample at 3, 7, 28, and 56 days respectively.

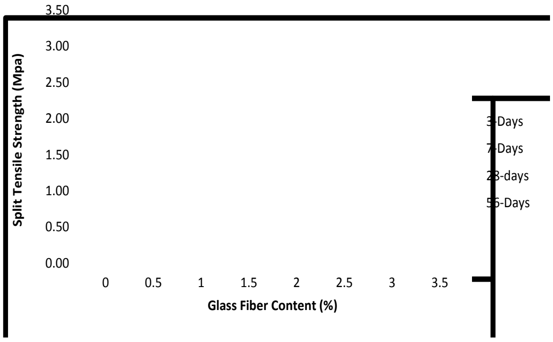

Figure 8. Variation of split cylinder tensile strength with glass fibre content

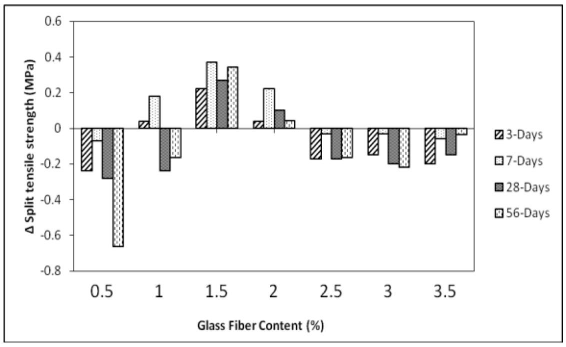

Figure 9. Increase/decrease in Split cylinder tensile strength with glass fibre content

Table 7. Strength activity index for split cylinder tensile strength

G.F (%)	SAI			
	3-days	7-days	28-days	56-Days
0	100%	100%	100%	100%
0.5	80%	95%	89%	75%
1	103%	113%	90%	94%
1.5	118%	126%	111%	113%
2	103%	115%	104%	102%
2.5	86%	98%	93%	94%
3	88%	98%	92%	92%
3.5	84%	96%	94%	99%

3.4. Flexural strength

Three point modulus of rupture test conforming to ASTM C 78-02 was performed on control as well as blended samples at the age of 28 days, to ascertain their flexural strength. Results are shown in figure 10 & 11. Strength activity index values, given in Table 8 reveal that no mix ratio of GFRC exhibit flexural strength less than that of control sample. Also MOR values for 1.5% and 2% mix ratios are 50% more than that for control sample.

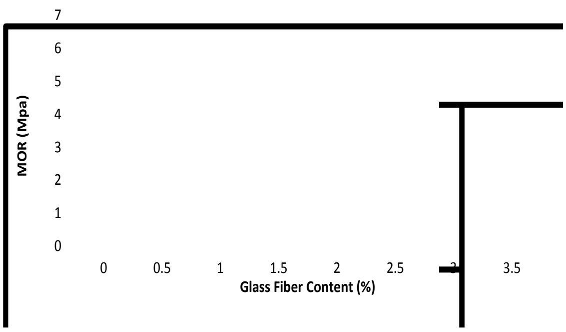

Figure 10. Variation of flexural strength with glass fibre content

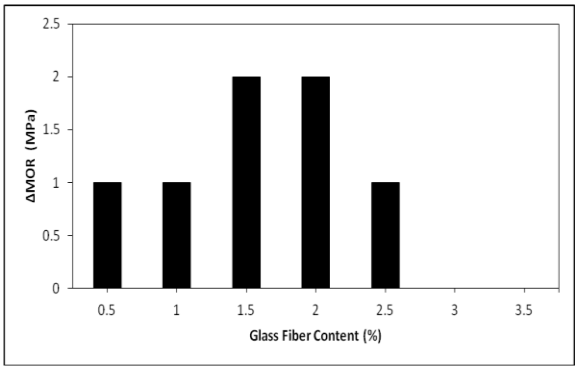

Figure 11. Increase/decrease in flexural strength with glass fibre content

Table 8. Strength activity index for flexural strength

G.F (%)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5
SAI (%)	100	125	125	150	150	125	100	100

4. Conclusions

- Flexural strength of glass fiber reinforced concrete increases more than 1.5 times at 1.5 & 2.0% mix ratios with respect to control mix.
- Compressive strength of GF blended concrete is more than control sample at 1.5% mix ratio. The same is also verified from ultrasonic pulse velocity test of samples.
- UPV compressive strength values are lesser than corresponding cube compressive strength values.
- Split cylinder strength values are also maximum at 1.5% mix ratio for all testing ages. These are 18%, 26%, 13% & 11% more than control sample at 3, 7, 28, and 56 days respectively.
- Workability of GFRC decreases by increasing glass fiber content. Thus some water reducing admixtures may be recommended to get required workability of concrete without compromising on strength.

5. References

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