Experimental Study on Properties of Glass Fibre Reinforced Concrete

Gagandeep[1], Amanpreet Tangri[2], Vikram Singh[3]
[1, 2,3]*Assistant Professor Department of Civil Engineering,*
[1, 2,3]*Chandigarh University, Mohali, Punjab, India*
Email: deepg0607@gmail.com[1],amanpreet.civil@cumail.in[2], vikram.civil@cumail.in[3]

Abstract- Concrete being brittle is weak in tension. The inclusion of fibres in concrete have significantly improves its compressive as well as tensile strength. The use of different types of fibres & their orientation in the matrix have shown positive responses among the researchers. In the present study alkali resistant glass fibres were used in the concrete mixes. A total of 8 mixes were prepared by varying the percentages of glass fibres and grade of concrete mixes. Based on the laboratory results the compressive and tensile strength was reported to increase up to 26.19% and 25.4%. However the workability of concrete mixes is not much affected by the addition of fibres. The tensile strength of concrete is improved which shows the use of glass fibres in concrete mixes may reduce its shortcoming of low tensile strength without affecting its workability and compressive strength.

Keywords- Compressive Strength; Split Tensile Strength; Glass Fibers; Grade of concrete.

1. INTRODUCTION

Concrete is the most versatile construction material of use next to water. The simplest reason for its extensive use in the construction of almost all civil engineering works is that the properties can be controlled within a wide range by using appropriate ingredients and by special mechanical, physical and chemical processing techniques**.** Concrete is the most widely used construction material having several desirable properties like high compressive strength, stiffness and durability under usual environmental conditions. Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. This shortcoming is offset by providing steel bars at appropriate locations at the time of casting the members to take up the tensile stresses and sometimes the compressive stresses if required**.** Normally reinforcement consists of continuous deformed steel bars or pre-stressing tendons. The advantage of reinforcing and prestressing technology utilizing steel reinforcement as high tensile steel wires have helped in overcoming the incapacity of concrete in tension but the durability and resistance to cracking is not improved. These properties can be improved by the use of fibres in the concrete. It has been revealed that concrete reinforced with a permissible amount of fibre acquires better performance in compression, flexure, toughness and energy absorption, in which the degree of improvement relies on the types of fibres used. Experiments have been carried out by several investigators using fibres of glass, carbon, asbestos, polypropylene etc**.** Moreover fibres also helps in restricting the growth of micro-cracks at the mortar-aggregate interface thus transforming an inherently brittle matrix i.e. cement concrete with its low tensile and impact resistances, into a strong composite with superior crack resistance, improved ductility and distinctive post cracking behavior prior to failure**.**

Glass fibre–reinforced concrete (GFRC) is a type of concrete which basically consists of a cementitious matrix composed of cement, sand, coarse aggregate, water, polymer and admixtures, in which short length glass fibres are dispersed. In general, fibres are the principal load-carrying members, while the surrounding matrix keeps them in the desired locations and orientation, acting as a load transfer medium between the fibres and protecting them from environmental damage. In fact, the fibres provide reinforcement for the matrix and other useful functions in fiber-reinforced composite materials. Glass fibres can be incorporated into a matrix either in continuous or discontinuous (chopped) lengths. Glass fibres have large tensile strength and elastic modulus but have brittle stress strain characteristics and low creep at room temperature. Glass fibres are usually are usually round and straight with diameters from 0.005 mm to 0.015 mm**.** Different types of glass fibres are available in the market having different length, diameter and aspect ratio. In the present study alkali resistant glass fibres were used throughout the experiments. The study comprises of a comparative study of some of the properties of concrete for two different grades of concrete by varying the percentages of fibres.

2. EXPERIMENTAL PROGREAM

The experimental Programme involves various processes of material testing, mix proportioning, mixing, casting and curing of test specimens which is elaborated in the following sections. All the experiments were done in the material testing laboratory.

2.1 Materials Used

The materials used for the preparation of concrete mix include cement, fine aggregates, coarse aggregates and glass fibres. Each material was tested &its physical properties are described below.

2.1.1 Cement

Ordinary Portland cement of 43 grade were used, conforming to recommendations stated in IS 4031(1999). The normal **Fine Aggregate** Coarse sand locally available to us was used as fine aggregate. The test procedures as mentioned in IS-383(1970) were followed to determine the physical properties of fine aggregate as shown in Table 1.

2.1.2 Coarse Aggregate

Two single sized crushed stone aggregates ranging from 12.5 mm to 2.36 mm and 20 mm to 4.75 mm (10mm and 20mm sizes) were used in respective proportions in concrete mixes. The aggregates were tested in accordance to IS-383: (1970). The results obtained are tabulated in Table 2.

2.1.3 Glass Fibre

Cem-Fil Anti-Crack, HD-12mm, Alkali Resistant glass fibres were used throughout the experimental work. From the micro to the macro fibre range, these fibers control the cracking processes that can take place during the life-span of concrete. The specifications of these fibres are presented in Table 3.

2.1.4 Water

As per recommendation of IS: 456 (2000), the water to be used for mixing and curing of concrete should be free from materials. Therefore potable water was used in the present study in all operations demanding control over water quality.

Fig 1: Glass Fibres used

2.2 Properties of Materials:-

The properties of material used for the experimental work is mention in table below which represents the observed and recommended value as per IS Code.

Table 1:- Physical Properties of Fine aggregate

Physical Properties	Observed values	Recommended values
Grading Zone	1	-
Fineness modulus	3.173	2.9-3.2
Specific Gravity	2.632	2.6-2.67

Table 2: Physical Properties of coarse aggregate

Physical Properties	Observed values		Recommended values
	10mm aggregate	20mm aggregate	
Fineness Modulus	6.28	7.11	6.5-8.0
Aggregate crushing value (%)	18.15	25.13	Not more than 45%
Aggregate impact value (%)	28.63	22.10	Not more than 45%

Table 3: Physical Properties of Glass Fibre

Physical Properties	Recommended values by the supplier
Specific gravity	2.68
Elastic Modulus (Gpa)	72
Tensile Strength (Mpa)	1700
Length (mm)	12

2.3. Methodology

The mix proportioning procedure for the concrete was done according to IS 10262: 2009. The proportioning is carried out to achieve specified characteristics at specified age, workability of fresh concrete and durability requirements. Concrete grades used for research M 20 & M 30 were proportioned according to the procedure as mentioned in the IS Code.

2.4. Mix Proportioning

The basic mix proportion for M 20 & M 30 grade of concrete is cement, fine aggregate, coarse aggregate and water: 1.0:2.2:3.6 & 1.0:1.35:2.28 respectively. Mix 1 & Mix 5 contains 0% glass fiber. Mix 2, 3 & 4 contains 0.02%, 0.04% & 0.06% glass fibre by weight. Similar percentages of glass fibres are repeated for Mix 6, 7 & 8. Two Control mixes are proportioned by the absolute volume method. A total of 8 mixes were studied. Water/cement ratio of 0.50 & 0.42 for M 20 & M 30 were maintained for all the concrete mixes. Details of these mixes are presented in Tables 4.

2.5. Mixing of Concrete, Casting and Curing of test Specimens

Machine mixing was done during the entire process of casting of specimens. Initially the dry mix constituents of the mix namely cement, fine aggregate and coarse aggregate was mixed for two minutes in the mixer and then the water were added and mixing continued for another 2 minutes. The total mixing time was kept at 4 minutes until a homogeneous mixture was obtained. Compaction was achieved by means of vibration table. All specimens were de molded after 24 hours and stored in water until the age of testing.

3. EXPERIMENTAL TESTING

The fresh concretes were tested for slump. However the hardened concrete were tested for compressive strength and split tensile strength discussed below.

3.1. Workability Test

Workability tests were performed using Slump moulds as it is the quick measure of workability of concrete mixes. The slump test was done in accordance with the IS 1199-1959.

3.2. Compressive Strength Test

Compressive strength test was performed according to IS 516: 1959.Cubes of specimen of size 150 mm x 150 mm x 150 mm were prepared for each mix. After 24 hours the specimens were de molded and cured in water for 28 days until testing. For specimens with uneven surfaces, capping was used to minimize the effect of stress concentration. The compressive strength reported is the average of three results obtained from three identical cubes.

Table 4: Mix details of Glass Fiber Concrete Mixes

MIX NO.	Grade of concrete	W/C	% Of glass fibre	Cement (kg/m3)	Fine aggregates (kg/m3)	Water content (litre)	Coarse aggregates (kg/m3)
M-1	M 20	0.50	0	320	704	160	1141
M-2			0.02				
M-3			0.04				
M-4			0.06				
M-5	M 30	0.42	0	380	646	159.6	1150
M-6			0.02				
M-7			0.04				
M-8			0.06				

3.3. Split Tensile Strength Test

The splitting tests are well known indirect tests used for determining the tensile strength of concrete. The test consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive platens. The test were performed according to the procedure adopted in IS 5816: 1999. Cylinders of specimen size 150 mm x 300 mm were prepared for each mixes. The tensile strength reported is the average of three results obtained from three identical cylinders.

4. RESULTS AND DISCUSSION

The results obtained are presented in Table 5. Result shows that as the percentage of glass fibers increases in the mix there is corresponding increase in the strength. Apart from this workability of the mixes is also affected by the addition of fibers.

Table 5: Compressive & Tensile strength of Glass Fiber Reinforced concrete

Mix No.	Grade of Concrete	% of Glass Fibre	Mean Compressive Strength (Mpa)	Mean Tensile Strength (Mpa)
M-1	M 20	0	26.16	3.20
M-2		0.02	35.66	4.25
M-3		0.04	38.73	5.05
M-4		0.06	41.28	5.76
M-5	M 30	0	37.80	4.19
M-6		0.02	50.93	5.67
M-7		0.04	55.73	5.91
M-8		0.06	61.29	7.17

4.1. Effect of percentage of fibers on workability of concrete

The result shows that workability of the concrete is solely affected by addition of fibers in the mixes. The slump value for M 20 grade of concrete was observed to be 100 mm. With the addition of fibers the value of slump reduces and is reported between 90 to 100 mm. The slump value for M 30 grade of concrete mixes was observed to be 75 mm. On inclusion of fibers in the mixes the slump value again decreases and is reported between 65 mm to 75 mm. Thus a bit harsh mixes are obtained as the percentages of fibers are increased. Fig. 4 illustrates the variation in slump value on addition of glass fibers.

4.2. Effect of percentage of fibers on compressive strength of concrete

The compressive strength of concrete mixes was observed to be increasing as the inclusion of fibers increases. The addition of 0.02% glass fibers by weight of concrete mix, increases the strength to 26.6% for M 20 grade of concrete and 25.78% for M 30 grade of concrete. On further addition of 0.02% of fibers the average increase in strength is reported as 7% for M 20 grade & 8.8% for M 30 grade of concrete mix. This shows that as we go for higher grade of concrete, increases in percentage of fibers increases the strength rapidly. Fig. 5 clearly shows the increase in strength for two different grade of concrete.

4.3. Effect of percentage of fibers on tensile strength of concrete

The result shows that there is a significant improvement in the tensile strength of concrete with the addition of glass fibers. Addition of 0.02% glass fiber increases the tensile strength to 24.7% for M 20 grade of concrete and 26.10% for M 30 grade of concrete. Further addition of 0.02% of fibers the average increase in strength is reported as 14% for M 20 grade & 15.8% for M 30 grade of concrete mix. Fig. 6 shows the effect of percentage of fibers on tensile strength of concrete.

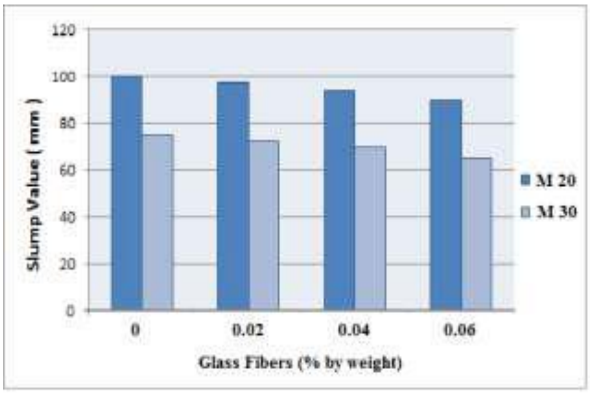

Fig.1: Effect of % age of fibers on slump value of concrete mixes

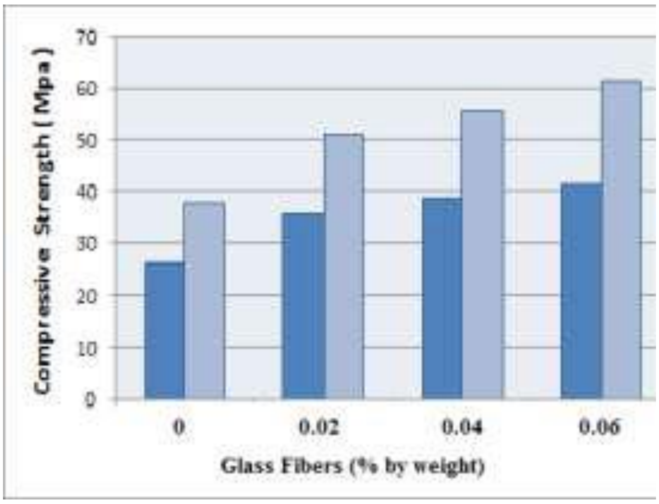

Fig.2: Effect of % age of fibers on compressive strength of concrete

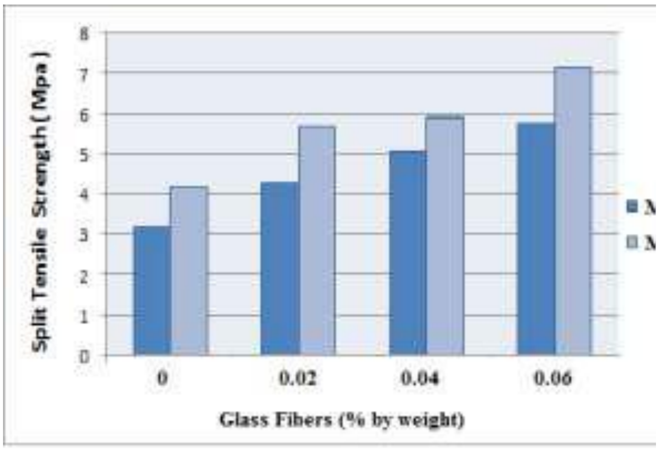

Fig.3: Effect of %age of fibers on tensile strength of concrete

5. CONCLUSIONS

Based on the experimental study on concrete mixes, the following conclusions could be made:

1. The use of alkali resistant glass fibers significantly improves the compressive as well as tensile strength irrespective of affecting the workability of concrete mixes.
2. The slump value is not much affected by the addition of fibers irrespective of grade of concrete mixes. For M 20 grade the slump value varies between 90 to 100 mm and that for M 30 grade it varies between 65 to 75 mm.
3. The compressive strength of concrete show a marginal increase on addition of fibres to concrete mixes. Increased strength was reported as 26.6% and 25.78% for M 20 and M 30 grade of concrete. However further addition of fibres improves average strength up to 7% for M 20 grade and 8.8% for M 30 grade of concrete
.4. The tensile strength of concrete also shows an increasing trend. For M 20 & M 30 grade of concrete increased tensile strength were observed to be 24.7% and 26.10%. Again further inclusion of fibres significantly improves the average tensile strength.
5. The percentage increase in strength for higher grade of concrete is marginally high.

REFERENCES

[1] Alan J. Brookes, “Cladding of Buildings”, Third Edition Published 2002, (pp 82).
[2] Arnon Bentur and Sidney Mindess, “Fibre Reinforced Cementitious Composites”, Second Edition 2007, Chapter 8, (pp 278).
[3] J.G. Ferreira, F.A. Branco 2005, “Structural application of GRC in telecommunication towers”, Construction and Building Materials Journal, Published August 2005.
[4] Majumdar, A.J. (1974), “The role of the interface in glass fibre reinforced cement”, Building Research Establishment, Published 1974, Current Paper (cp 57- 74).
[5] M. Levitt 1997 “Concrete materials problems and solutions”, “GRC and Alkali-Glass reaction”, First Edition 1997, (pp 22-24).
[6] M.W. Fordyce and R.G. Wodehouse, “GRC and buildings”, Published First Edition 1983.
[7] Perumelsamy N. Balaguru and Surendra P. Shah, “Fibre reinforced cement composites”, February 1992, Chapter 13, (pp 351).
[8] Dr. P. Perumal and Dr. J. Maheswaran, “Behavioural study on the effect of AR-Glass Fibre reinforced concrete”, NBW & CW October 2006, (pp 174-180).
[9] R .N. Swamy, “Testing and Test Methods of Fibre Cement Composites”, Published 1978, (pp 42-43).
[10] Surendra P. Shah, James I. Daniel, Darmawan Ludirdja, “Toughness of Glass Fiber reinforced concrete panels subjected to accelerated aging”, PCI Journal, September-October 1987, (pp 83-88).
[11] U. M. Ghare, “Manufacture of Glass Fibre Reinforced Concrete Products”,

[12] Perumalasamy N.Balaguru shah " fiber reinforced cement composites ."
[13] Arnon Bentur and Sidney Mindess, "Fibre Reinforced Cementitious Composites", Second Edition 2007, Chapter 8, (pp 278)
[14] Alan J. Brookes, "Cladding of Buildings", Third Edition Published 2002, (pp 82).
[15] U. M. Ghare, "Manufacture of Glass Fibre Reinforced Concrete Products", Unit 1, Division of YOGI group UAE, August 2008.