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COMPARISION OF COMPRESSIVE STRENGTH OF ORDINARY PORTLAND CEMENT CONCRETE WITH FIBER REINFORCED CONCRETE

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Abstract— Fiber Reinforced Concrete (FRC) is a new structural material which is gaining increasing importance. Concrete is weak in tension and has a brittle character. Early applications include addition of Straw to mud bricks, horse hair to reinforce plaster and asbestos to reinforce pottery. Use of continuous reinforcement in concrete (reinforced concrete) increases strength and ductility, but requires careful placement and labor skills. Alternatively, introduction of fibers in discrete form in plain or reinforced concrete may provide a better solution. Addition of fibers to concrete makes it a homogeneous and isotropic material. When concrete cracks, the randomly oriented fibers start functioning, arrest crack formation and propagation, and thus improve strength and ductility. The failure modes of FRC are either bond failure between fiber and matrix or material failure.This study focuses on comparison of compressive strengths of Ordinary Portland Cement Concrete with Fiber Reinforced Concrete. For the study the test we have conducted are concrete compressive strength test and slump test of concrete. By using M20 grade of cement and the fibers we used are steel fiber and glass fiber, after comparing different results of samples tested, the 7days compressive strength of Ordinary Portland Cement Concrete is 19.81N/mm2, 7days compressive strength of Steel Fiber Reinforced Concrete is 20.38N/mm2 and 7days compressive strength of Glass Fiber Reinforced Concrete is 21.81n/mm2. The results were found after experimentation done on sample in concrete laboratory at Ultra Tech ready mix plant.
Keywords—Fiber Reinforced Concrete, Glass Fiber, Steel Fiber, Grade M20

I. INTRODUCTION

A. *Fiber*

Fiber is a class of materials that are continuous filaments or are in discrete elongated pieces, similar to lengths of threads. Human uses for fibers are diverse. They can be spun into strings or rope, used as a component of composite materials or matted into sheets to make products such as paper. Fibers are often used in the manufacture of other materials. The strongest engineering materials are generally made as fibers, for example carbon fibers.

B. *Fiber Properties*

There are several primary properties necessary for a polymeric material to make an adequate fiber:

- Fiber length to width ratio
- Fiber uniformity
- Fiber strength and flexibility
- Fiber extensibility and elasticity
- Fiber cohesiveness

Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers. Within these different fibers that character of fiber reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation and densities. Fiber-reinforcement is mainly used in shotcrete, but can also be used in normal concrete.

C. Effect Of Fibers In Concrete

Fibers are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. Some fibers reduce the strength of concrete. The amount of fibers added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibers) termed volume fraction (Vf). Vf typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fiber is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increase in the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix. However, fibers which are too long tend to “ball” in the mix and create workability problems.Some recent research indicated that using fibers in concrete has limited effect on the impact resistance of concrete materials. This finding is very important since traditionally people think the ductility increases when concrete reinforced with fibers..

II. DIFFERENT TYPE OF FIBERS

Following are the different type of fibers generally used in the construction industries.

- Steel Fiber Reinforced Concrete
- Polypropylene Fiber Reinforced (PFR) cement mortar & concrete
- Glass-Fiber Reinforced Concrete
- Asbestos Fibers
- Carbon Fibers

Figure 1. *Steel fibers*

Figure 2. *Polypropylene fiber reinforced cement-mortar & concrete*

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Figure 3. *Glass-fiber*

Figure 4. *Chopped glass fiber*

Figure 5. *Asbestos fiber*

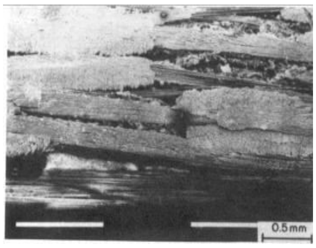

Figure 6. Carbon fibers

III. FACTORS EFFECTING PROPERTIES OF FIBER REINFORCED CONCRETE

Fiber reinforced concrete is the composite material containing fibers in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depends upon the efficient transfer of stress between matrix and the fibers. The factors are briefly discussed below:

A. Relative Fiber Matrix Stiffness

The modulus of elasticity of matrix must be much lower than that of fiber for efficient stress transfer. Low modulus of fiber such as nylons and polypropylene are, therefore, unlikely to give strength improvement, but the help in the absorption of large energy and therefore, impart greater degree of toughness and resistance to impart. High modulus fibers such as steel, glass and carbon impart strength and stiffness to the composite.Interfacial bond between the matrix and the fiber also determine the effectiveness of stress transfer, from the matrix to the fiber. A good bond is essential for improving tensile strength of the composite.

B. Volume of Fibers

The strength of the composite largely depends on the quantity of fibers used in it. Fig 1.1 and 1.2 show the effect of volume on the toughness and strength. It can see from Fig 1.1 that the increase in the volume of fibers, increase approximately linearly, the tensile strength and toughness of the composite. Use of higher percentage of fiber is likely to cause segregation and harshness of concrete and mortar.

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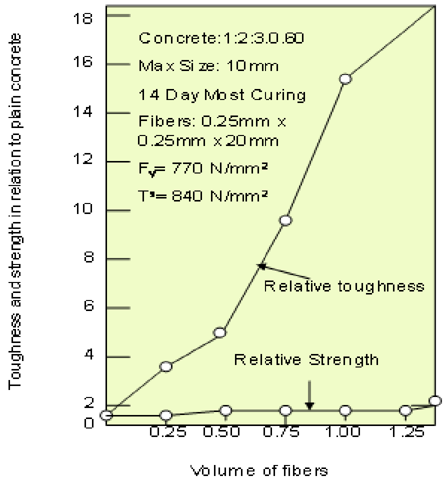

Figure 7. *Effect of volume of fibers in flexure*

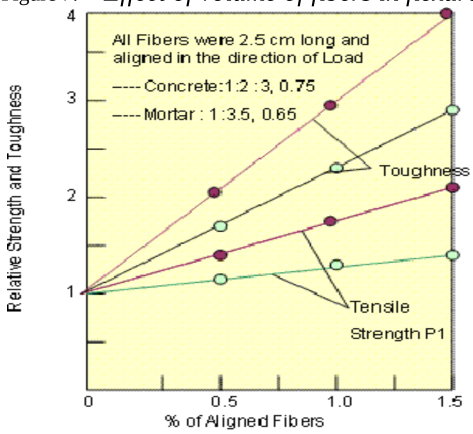

Figure 8. *Effect of volume of fibers in tension*

C. *Aspect Ratio of the Fiber*

Another important factor which influences the properties and behavior of the composite is the aspect ratio of the fiber. It has been reported that up to aspect ratio of 75, increase on the aspect ratio increases the ultimate concrete linearly. Beyond 75, relative strength and toughness is reduced. Table 1.1 shows the effect of aspect ratio on strength and toughness.

TABLE1. ASPECT RATIO OF THE FIBER

Type of concrete	***Aspect ratio***	***Relative strength***	***Relative toughness***
Plain concrete	0	1	1
With	25	1.5	2.0
Randomly	50	1.6	8.0
Dispersed fibers	75	1.7	10.5

D. *Workability and Compaction of Concrete*

Incorporation of steel fiber decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Even prolonged external vibration fails to compact the concrete. The fiber volume at which this situation is reached depends on the length and diameter of the fiber.Another consequence of poor workability is non-uniform distribution of the fibers. Generally, the workability and compaction standard of the mix is improved through increased water/ cement ratio or by the use of some kind of water reducing admixtures.

E. Size of Coarse Aggregate

Maximum size of the coarse aggregate should be restricted to 10mm, to avoid appreciable reduction in strength of the composite. Fibers also in effect, act as aggregate. Although they have a simple geometry, their influence on the properties of fresh concrete is complex. The inter-particle friction between fibers and aggregates controls the orientation and distribution of the fibers and consequently the properties of the composite.

F. Mixing

Mixing of fiber reinforced concrete needs careful conditions to avoid balling of fibers, segregation and in general the difficulty of mixing the materials uniformly. Increase in the aspect ratio, volume percentage and size and quantity of coarse aggregate intensify the difficulties and balling tendency. Steel fiber content in excess of 2% by volume and aspect ratio of more than 100 are difficult to mix.

IV. EXPERIMENT

The main objective of the experiment is comparison of OPCC and FRC which includes slump cone test and compressive strength test. The results can be interpreted through the graphs and tables obtained.

A. Tests On Concrete

1) Compressive Strength Test:

The testing is done in a laboratory off-site. The only work done on-site is to make a concrete cube for the compression test. The strength is measured in Mega Pascal (M Pa) and is commonly specified as a characteristic strength of concrete measured at 28 days after mixing. The compressive strength is a measure of the concrete's ability to resist loads which tend to crush it.

a) Apparatus for compression test:

- Cubes of size (150 mm x 150 mm)
- Small scoop
- Bullet-nosed rod (600 mm x 16 mm diameter)
- Steel float
- Steel plate
- Compressive strength testing machine

b) Procedure for cube casting:

- Clean the cube mould and coat the inside lightly with form oil, then place on a clean, level and firm surface, i.e. the steel plate. Collect a sample.
- The mould is then filled in three layers. Fill 1/3 the volume of the mould with concrete then compact by tamping 35 times. Cubes may also be compacted by vibrating using a vibrating table.
- Fill the cone to overflowing and tamping 35 times into the top of the first layer, then top up the mould till overflowing.
- Level off the top with the steel float and clean any concrete from around the mould.
- Cap, clearly tag the cube and put it in a cool dry place to set for at least 24 hours.
- After the mould is removed the cube is sent to the laboratory where it is cured and crushed to test compressive strength.

Figure 9. Casted cubes

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Figure 10. Cube curing tank

B. Digital Compression Testing Machine:

Digital compression testing machine is used to determine compressive strength of hardened concrete specimen.

C. Concrete Slump Test:.

Workability of concrete is mainly affected by consistency i.e. wetter mixes will be more workable than drier mixes, but concrete of the same consistency may vary in workability. It can also be defined as the relative plasticity of freshly mixed concrete as indicative of its workability.

a) Tools and apparatus used for slump test (equipment):

- Slump Cone Dimensions:
- Small scoop
- Bullet-nosed rod (600 mm long x 16 mm dia)
- Slump plate (500 mm x 500 mm)

Figure 11. *Slump test*

TABLE2. SLUMP VALUES FROM TEST:

SLUMP VALUES	OPCC	GFRC	SFRC
Initial	60	58	52
30min later	48	46	40
1hr later	28	26	16

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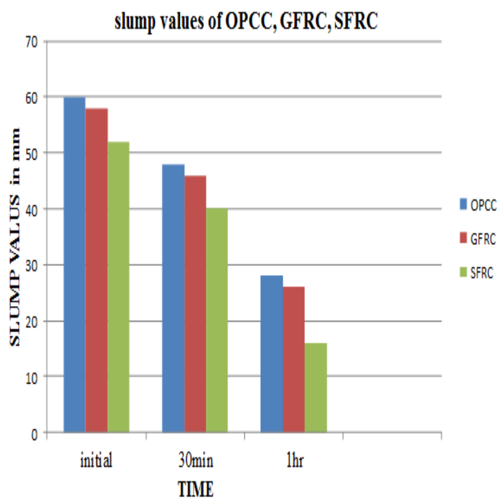

Graph: Strength variation of OPCC, GFRC, SFRC

TABLE3. MIX DATA OF OPCC

Concrete Grade			*M20*					
OPC BRAND	***ULTC OPC 53grade***							
Mix proportion	***W/C*** ***0.53***		***CA :FA*** ***100.00 : 0.00***		***Admixture dosage, % by weight. of cement***			***0.00%***
Material	***Batch Quantity, SSD Condition (kg)***		***WA (%)***	***MC (%)***	***Moisture Adjustment***		***Corrected Batch Quantity(kg)***	***Unit***
	1m3 of concrete require	***0.030 m3 of concrete require***			**(%)**	**(kg)**		
Cement	300	10.125	0.00	0.00	0	0	10.125	Kg
Fly ash	0	0	0.00	0.00	0	0	0	Kg
20mm	659	22.24125	0.50	0.00	0.50	0.111	22.13	Kg
12.5mm	437	14.74875	0.50	0.00	0.50	0.074	14.68	Kg
Natural Sand	0	0	1.00	0.00	0.00	0.00000	0.00	Kg
Manufacture Sand	837	28.24875	0.00	0.00	1.00	0.282	27.97	Kg
Water	160	5.4	0.00	0.00	0	0.467	5.87	Kg
Admixture(WPC)		0	0.00	0.00	0	0	0	gm
Mix proportion	Cement	1	FA	0.00	CA	3.65	W/C	0.53
Slump:	Initial	60	120					
				Fresh Density (kg/m3)			2393	

TABLE4. *MIX DATA OF SFRC*

Material	*Batch quantity (kg)*		*Water absorption (%)*	*Moisture content (%)*	*Moisture adjustment*		*Corrected quantity (kg)*	*Unit*
	1m3	*0.030 m3*			(%)	(kg)		
Cement	210	6.3	0.00	0.00	0	0	6.3	Kg
Fly ash	110	3.3	0.00	0.00	0	0	3.3	Kg
20mm	665	19.95	0.00	0.00	0.50	0.100	19.85	Kg
12.5mm	435	13.05	0.00	0.00	0.50	0.065	12.98	Kg
Natural sand	0	0	0.00	0.00	0.00	0.00	0.00	Kg
Manufactured sand	805	24.15	1.00	0.00	2	0.483	23.67	Kg
Water	160	4.8	0.00	0.00	0	0.648	5.45	Kg
Steel fiber	15	0.45	0.00	0.00	0	0	450	gms
Mix proportion	Cement	1	FA	2.52	CA	3.44	W/C	0.50
Slump	Initial	60	120					
Fresh density (Kg/m3)= 2400								

TABLE5. MIX DATA OF GFRC

D. Concrete grade								
Material	***Batch quantity (kg)***		***Water absorption (%)***	***Moisture content (%)***	***Moisture adjustment***		***Corrected quantity (kg)***	***Unit***
	1m3	***0.030 m3***			***(%)***	***(Kg)***		
Cement	***210***	***6.3***	***0.00***	***0.00***	***0***	***0***	***6.3***	***Kg***
Fly ash	***110***	***3.3***	***0.00***	***0.00***	***0***	***0***	***3.3***	***Kg***
20mm	***665***	***19.95***	***0.00***	***0.00***	***0.50***	***0.100***	***19.85***	***Kg***
12.5mm	***435***	***13.05***	***0.00***	***0.00***	***0.50***	***0.065***	***12.98***	***Kg***
Natural sand	***0***	***0***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***Kg***
Manufactured sand	***805***	***24.15***	***1.00***	***0.00***	***2***	***0.483***	***23.67***	***Kg***
Water	***160***	***4.8***	***0.00***	***0.00***	***0***	***0.648***	***5.45***	***Kg***
Glass Fiber	***0.6***	***0.018***	***0.00***	***0.00***	***0***	***0***	***18***	***gms***
Mix proportion	***Cement***	***1***	***FA***	***2.52***	***CA***	***3.44***	***W/C***	***0.50***
Slump	***Initial***	***60***	***120***					
Fresh density (Kg/m3)= 2386								

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V. RESULTS

A. Typical Compressive Strength of Concrete:

Followings are the actual result of Concrete Designed with fiber reinforcement. Proportions are by weight Mix Design M20 concrete. Results are as follows:

TABLE6. COMPARISON OF 7DAYS COMPRESSIVE STRENGTHS OF OPCC, GFRC, SFRC

s.no	*Samples*	*OPCC*	*GFRC*	*SFRC*
1	S1	19.00	19.32	21.42
2	S2	20.12	20.35	21.91
3	S3	20.32	21.47	22.10
4	Avg	19.81	20.38	21.81

TABLE7. COMPARISON OF 7DAYS COMPRESSIVE STRENGTHS OF OPCC, GFRC, SFRC

No of days	**Samples**	**Weight of block (Kg)**	**Compressive strength of OPCC (N/mm2)**
7 day compressive strength	S1	8.22	19.00
	S2	8.12	20.12
	S3	8.11	20.32
	Avg		19.81
	Samples	Weight of block (Kg)	Compressive strength of GFRC (N/mm2)
	S1	8.01	19.32
	S2	8.10	21.47
	S3	8.13	20.35
	Avg		20.38
	S3	8.13	20.35
	Avg		20.38
	Samples	Weight of block (kg)	Compressive strength of SFRC (N/mm2)
	S1	8.01	22.10
	S2	8.12	21.42
	S3	8.20	21.91
	Avg		21.83

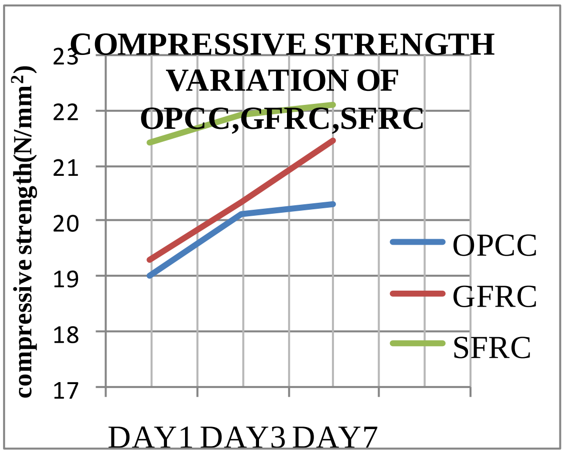

Figure 12. Graph: Strength variation of OPCC, GFRC, SFRC

- Avg compressive strength for 7 days of OPCC = 19.81N/mm2 (99.066%)
- Avg compressive strength for 7 days of GFRC = 20.38 N/mm2 (101.9%)
- Avg compressive strength for 7days of SFRC = 21.81 N/mm2 (109.05%)
-

VI. CONCLUSION

- The following conclusions can be withdrawn from the work performed
- During testing it has been noted that addition of fibers could improve the compressive strength. From the above experiment it is observed that Fiber Reinforced Concrete compressive strength is comparatively more than the Ordinary Portland Cement Concrete, relatively the slump value decreases.
- Although fiber reinforced concrete has been used widely throughout Western Europe and the rest of the world, its application in the India is so far, relatively limited with industrial floors being the most common application. The lack of a formally accepted design standard may be an influence on this situation.

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