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Performance of glass Fiber Reinforced Concrete

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ABSTRACT

In this paper, the results are concluded for the experiment carried on concrete using glass fiber and also different properties of concrete are found out using glass fiber. The effect on properties such as the strength of concrete, dry density, wet density, slump, split tension etc. are found out by taking laboratory experiment. The concrete is prepared by using M20 grade and adding the different proportion of glass fiber from 0.5 % to 5 % weight of cement. A laboratory test is taken on concrete cubes of 15 cm size, a cylinder of 15 cm diameter and length of 30 cm and the beam of a size of 15cmXproperties are of an experimental investigation on the cm and 70 cm length. These blocks are cured in the water tank for 7 days and 28 days. It is found out that workability of concrete is reduced by enhancing the quantity of glass fiber. By taking load-deflection behavior it is found out that ductility is increased by increasing the content of glass fiber. It is found out that various parameter of concrete regarding the strengthening of concrete is enhanced by increasing the glass fiber in the concrete. There is the enhancement in the strength in the concrete. Hence it is suggested to use glass fiber in the concrete according to use of concrete.

Keywords: *Glass fiber, Workability, Strength of concrete, Fiber content, Nondestructive test.*

1. GLASS FIBERS

Bunch of Glass Fibre

Glass fiber (or glass fiber) is a material consisting of numerous extremely fine fibers of glass. Glass wool, which is one product called "fiberglass" today, was invented in 1932–1933 by Russell Games Slayter of Owens-Corning, as a material to be used as thermal building insulation.[1] Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as strong or as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fibers are therefore used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fiber-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), also popularly known as "fiberglass". This material contains little or no air or gas, is denser, and is a much poorer thermal insulator than is glass wool. Glass fiber is formed when thin strands of silica-based or other formulation glass are extruded into many fibers with small diameters suitable for textile processing. The technique of heating and drawing glass into fine fibers has been known for millennia; however, the use of these fibers for textile applications is more recent. Until this time, all glass fiber had been manufactured as a staple (that is, clusters of short lengths of fiber) The most common types of glass fiber used in fiberglass is E-glass, which is alumino-borosilicate glass with less than 1% w/w alkali oxides, mainly used for glass-reinforced plastics.

Chemistry

The basis of textile-grade glass fibers is silica, SiO2. In its pure form, it exists as a polymer, (SiO2)n. It has no true melting point but softens up to 20000C, where it starts to degrade. At 17130C, most of the molecules can move about freely. If the glass is then cooled quickly, they will be unable to form an ordered structure. In the polymer, it forms SiO4 groups which are configured as a tetrahedron with the silicon atom at the center and four oxygen atoms at the corners. These atoms then form a network bonded at the corners by sharing the oxygen atoms. The vitreous and crystalline states of silica (glass and quartz) have similar energy levels on a molecular basis, also implying that the glassy form is extremely stable. In order to induce crystallization, it must be heated to temperatures above 12000C for long periods of time.

Structural Properties of GFRC

GFRC derives its strength from a high dosage of AR glass fibers and a high dosage of the acrylic polymer. While the compressive strength of GFRC can be quite high (due to low water to cement ratios and high cement contents), it is the very high flexural and tensile strengths that make it superior to ordinary concrete. Essentially the high dose of fibers carries the tensile loads and the high polymer content makes the concrete flexible without cracking.

GFRC is analogous to the kind of chopped fiberglass used to form objects like boat hulls and other complex three-dimensional shapes. The manufacturing process is similar, but GFRC is far weaker than fiberglass.
While the structural properties of GFRC itself are superior to unreinforced concrete, properly designed steel reinforcing will significantly increase the strength of objects cast with either ordinary concrete or GFRC. This is important when dependable strength is required, such as with cantilever overhangs, and other critical members where visible cracks are not tolerable.

Effect of Fibers in Concrete

Fibres 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 fibres produce greater impact, abrasion and shatter resistance in concrete. Generally, fibres do not increase the flexural strength of concrete, so it cannot replace moment resisting or structural steel reinforcement. Some fibres reduce the strength of concrete.

The amount of fibres added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibres) termed volume fraction (Vf). Vf typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fibre length (l) by its diameter (d). Fibres with a non-circular cross-section use an equivalent diameter for the calculation of aspect ratio.
If the modulus of elasticity of the fibre 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 fibre usually segments the flexural strength and toughness of the matrix. However, fibres which are too long tend to “ball” in the mix and create workability problems.

Some recent research indicated that using fibres 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 fibres. The results also pointed out that the micro fibres are better in impact resistance compared with the longer fibres.

The necessity of Fiber Reinforced Concrete

1) It increases the tensile strength of the concrete.
2) It reduces the air voids and water voids the inherent porosity of gel.
3) It increases the durability of the concrete.
4) Fibres such as graphite and glass have excellent resistance to creep, while the same is not true for most resins. Therefore, the orientation and volume of fibres have a significant influence on the creep performance of rebars/tendons.
5) Reinforced concrete itself is a composite material, where the reinforcement acts as the strengthening fibre and the concrete as the matrix. It is therefore imperative that the behavior under thermal stresses for the two materials be similar so that the differential deformations of concrete and the reinforcement are minimized.
6) It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties.

2. PERFORMANCE ANALYSIS

Experimental Analysis

Different test on harden concrete is carried out on concrete and found out results for compressive strength, dry density, workability and another parameter of the concrete of test using glass fiber by using a different proportion of Glass fibers , results which are found out are presented in the table.

Workability and density

Workability, dry density, the wet density of concrete is found out with and without fiber on the concrete cube, beam and cylinder and results are shown in the table.

Workability, Dry Density and Wet Density of GFRC Cube.

Sr. No.	Mix designation	Fiber Content, V_f (%)	Wet Density, Kg/m³	Dry Density Kg/m³ (7days)	Dry Density Kg/m³ (28 days)
1	M0			2656.30	2701.50
2	M_1	0.5	2727.85	2657.60	2690.10
3	M_2	1.0	2715.00	2655.50	2693.35
4	M3	1.5	2695.90	2629.60	2652.30
5	M_4	2.0	2686.80	2627.40	2648.00
6	M_5	2.5	2658.30	2619.20	2635.30
7	M_6	3.0	2658.40	2615.30	2625.30
8	M7	3.5	2654.40	2610.30	2620.30
9	M8	4.0	2652.50	2601.40	2615.00
10	M9	4.5	2629.65	2570.10	2580.75
11	M10	5.0	2575.35	2535.30	2545.70

from above table it is observed that dry density is reduced by increasing fiber content in the concrete

Dry Density and Wet Density of GFRC Cylinder

Sr. No.	Mix designation	Fiber Content, (V_f %)	Wet Density, Kg/m^3	Dry Density, Kg/m^3	Dry Density, Kg/m^3
				7 days	28 days
1	M_0	0.0	2580.30	2530.20	2554.45
2	M_1	0.5	2567.20	2516.50	2535.40
3	M2	1.0	2550.30	2496.20	2510.40
4	M3	1.5	2542.10	2494.30	2505.50
5	M_4	2.0	2538.10	2493.30	2504.60
6	M5	2.5	2530.10	2519.60	2507.30
7	M6	3.0	2532.20	2475.40	2486.80
8	M7	3.5	2515.10	2464.30	2475.30
9	M_8	4.0	2571.10	2445.60	2458.80
10	M9	4.5	2477.80	2447.40	2449.90
11	M10	5.0	2475.30	2408.50	2410.20

from above table, it is observed that dry density is reduced by increasing fiber content in the concrete

Dry Density of GFRC Beam

Sr. No.	Mix designation	Fiber Content, (V_f %)	Dry Density, Kg/m^3	Dry Density, Kg/m^3
			7 days	28 days
1	M0	0.0	2635.70	2673.30
2	M_1	0.5	2615.50	2642.80
3	M2	1.0	2616.60	2642.30
4	M_3	1.5	2615.60	2634.50
5	M_4	2.0	2606.30	2624.50
6	M5	2.5	2596.75	2604.65
7	M_6	3.0	2596.50	2605.10
8	M7	3.5	2582.85	2595.85
9	M8	4.0	2565.30	2575.45
10	M_9	4.5	2555.30	2560.50
11	M10	5.0	2524.50	2535.50

from above table, it is observed that dry density is reduced by increasing fiber content in the concrete

Compressive Strength of GFRC, MPa

Sr. No.	Mix designation	Fiber Content (V_f %)	Compressive Load, (KN)		Compressive Strength (f_{cu}) Eq (3) (Mpa)		% Increase in Compressive Strength over Control Concrete	
			7days	28 days	7days	28 days	7days	28 days
1	M0	0.0	520.0	710.0	23.1	31.6	0.0	0.0
2	M1	0.5	526.7	726.7	23.4	32.3	1.3	2.3
3	M2	1.0	550.0	770.0	24.4	34.2	5.8	8.5
4	M_3	1.5	563.3	796.7	25.0	35.4	8.3	12.2
5	M4	2.0	583.3	823.3	25.9	36.6	12.2	16.0
6	M5	2.5	590.0	826.7	26.2	36.7	13.5	16.4
7	M_6	3.0	593.3	843.3	26.4	37.5	14.1	18.8
8	M_7	3.5	596.7	860.0	26.5	38.2	14.7	21.1
9	M_8	4.0	620.0	890.0	27.6	39.6	19.2	25.4
10	M_9	4.5	626.7	913.3	27.9	40.6	20.5	28.6
11	M10	5.0	630.0	920.0	28.0	40.9	21.2	29.6

from above table, it is observed that compressive strength is increased by increasing fiber content in the concrete

Flexural Strength of GFRC Beam, MPa

	Mix designation	Fiber content, (V_f %)	Flexural Load, KN		Flexural Strength (f_{cr}), MPa Eq (7)		% Increase in Flexural Strength	
			7 days	28 days	7 days	28 days	7 days	28 days
1	M0	0.0	15.96	21.00	2.84	3.73	0.00	0.00
2	M_1	0.5	20.33	26.35	3.61	4.68	27.38	25.48
3	M2	1.0	20.67	26.67	3.67	4.74	29.51	27.00
4	M_3	1.5	21.00	27.33	3.73	4.86	31.58	30.14
5	M4	2.0	22.33	29.67	3.97	5.27	39.91	41.29
6	M_5	2.5	23.33	30.33	4.15	5.39	46.18	44.43
7	M_6	3.0	23.67	31.00	4.21	5.51	48.31	47.62
8	M_7	3.5	24.33	31.67	4.33	5.63	52.44	50.81
9	M8	4.0	24.67	32.00	4.39	5.69	54.57	52.38
10	M_9	4.5	23.33	31.13	4.15	5.53	46.18	48.24
11	M10	5.0	22.67	30.67	4.03	5.45	42.04	46.05

from above table, it is observed that Flexural strength is increased by increasing fiber content in the concrete

Split Tensile Strength of Concrete, MPa

	Mix design ation	Fibre Content, (V_f %)	Split Load, KN		Split Tensile Strength (f_t), (MPa), Eq^{n}12		% Increase in Split Tensile Strength over Control Concrete	
			7days	28 days	7days	28 days	7days	28 days
1	M0	0.0	138.85	182.95	1.96	2.58	0.00	0.00
2	M_1	0.5	140.25	183.70	1.98	2.59	1.02	0.39
3	M_2	1.0	142.65	188.90	2.01	2.67	2.55	3.49
4	M_3	1.5	144.30	191.65	2.04	2.69	4.08	4.26
5	M_4	2.0	159.95	215.90	2.26	3.05	15.31	18.22
6	M_5	2.5	174.95	234.50	2.47	3.31	26.02	28.29
7	M6	3.0	198.85	266.00	2.81	3.76	43.37	45.74
8	M_7	3.5	203.10	268.90	2.87	3.79	46.43	46.90
9	M8	4.0	207.50	273.65	2.98	3.87	52.04	50.00
10	M_9	4.5	208.95	275.90	2.95	3.90	50.51	51.16
11	M10	5.0	209.90	276.50	2.96	3.90	51.02	51.17

from above table, it is observed that split tensile strength is increased by increasing fiber content in the concrete

Maximum Fiber Content Maximum Strength

Strength (MPa)	Pertinent Quantities			
	Strength Of Normal Concrete	Glass Fiber content , (V_f)%	Max. Value of Strength, MPa	Percentage increase in Strength over normal Concrete
Compressive strength	31.60	5.0	40.50	29.60 %
Flexural strength	3.73	4.0	5.69	52.54 %
Split Tensile Strength	2.58	5.0	3.90	51.16 %

3. CONCLUSION

In this case study, it is found out that whether the use of glass fiber in concrete is useful or not, if it is useful then at what proportion should be added is determined by carrying out different laboratory test on hardening concrete of M20 grade. In this case cubes of size 15 cm , a beam of size 15X15X70 cm and cylinder of size 15 cm diameter and 30 cm length are casted and cured for 7 days and 28 days then compressive strength is determined . Fiber is added by the proportion of 0.5% to 5% by weight of cement and then compressive strength , flexural strength, split cylinder test are worked out. After worked out by these test it is found out that compressive strength is increased by 29.60% by adding 5% of Glass fiber by weight of cement, flexural strength is increased by 52.54% by adding of 4 % of glass alkali by weight of cement and split tensile strength is increased by 51.16 % by adding 5% of glass alkali by the weight of cement. It is also found out that workability of concrete is reduced by adding glass fiber and ductility is increased by adding glass fiber. Crack width of GFRC is less than normal concrete. Overall it is observed that strength and other parameter are enhanced by using glass fiber. hence it is proved that glass fiber is good admixture for enhancement of Concrete.

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