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Exeperimental Study on Effects of Aspect Ratio of Glass Fibers in Concrete

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***Abstract*-- Concrete is the world's most consumable product next to water. Concrete is the most used construction material in the civil engineering. Fiber reinforced concrete (FRC) is the concrete containing fibrous material which increases its structural integrity. Glass-fiber reinforced concrete (GFRC) is a material made of a cementatious matrix composed of cement, sand, water in which various lengths of glass fibers are dispersed. It has been widely used in the construction industry for non-structural elements, like façade panels, piping and channels. In the present work, fresh properties and harden properties of glass fiber reinforced concrete are compared. To evaluate the fresh properties, slump cone and compaction factor tests are conducted. To evaluate the harden properties, compression and split tensile tests are conducted for 7 days and 28 days of curing. M20 grade concrete is designed using IS 10262:2009 provision.**

***Keywords*-- Aspect ratio; Compressive strength; Split tensile strength; Slump test; Compaction factor test**

I. INTRODUCTION

"Concrete is a composite material composed of coarse aggregate bonded together with fluid cement which hardens over time". Fiber reinforced concrete it contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers each of which lend varying properties to the concrete. In addition, the character of fiber reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation and densities. Glass fiber is a material consisting of numerous extremely fine fibers of glass. Glass fibers can also occur naturally, as Pele's hair. 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; also popularly known as "fiber glass".

1.1. Advantages And Disadvantages Of Glass Fibre

The following are the advantages of Glass fibers:

1. Glass fiber is high temperature resistance.
2. Nonflammable.
3. Corrosion-resistance.
4. Heat-insulation.
5. Good- sound-insulation (especially glass wool).
6. High tensile strength.
7. Good insulation

Following are the disadvantages of Glass fibers:

1) Glass fibers are Brittle in nature.
2) It having weak abrasive-resistance.

1.2. Roles Of Fibers In Concrete

The major roles of fiber in concrete are

1. Controls cracking:

The synthetic fibers prevent the micro shrinkage cracks developed during hydration, making the structure/ plaster/components inherently stronger. When the loads imposed of concrete approach that of failure cracks will propagate, sometimes rapidly. Addition of synthetic fibers to the concrete and plaster arrests cracking caused by volume change (expansion and contraction), simply by adding of fibers which supports mortar/ concrete in all directions.

2. Increase in strength:

By adding of synthetic fibers to the conventional concrete the compressive strength, split tensile strength and flexural strength will increases. Due to the reduction in crack formation and reduction in water permeability.

3. Reduction in water permeability:

A structure free from micro cracks prevents migration of water or moisture throughout the concrete. This is turn helps prevent the corrosion of steel used for primary reinforcement of the structure. This results in longevity of the structure.

4. Reduction in rebound loss:

Synthetic fibers reduce rebound "splattering" of concrete and shot Crete. This reduces wastage of mortar and speeds up the pace of work. More importantly it saves a great deal of labor employed for the job.

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The gains are higher when plastering is in progress at higher floors, ceiling and outside surface of the buildings.

5 Increase in flexibility:

The modulus of elasticity of synthetic fibers is high with respect of the concrete or mortar binder. Synthetic fiber helps in increasing flexural strength. The post cracking behavior has shown its ability to continue to absorb energy as fibers pull out..

1.3 Applications Of FRC:

Glass fibers have the following applications

- Exterior ornamentations.
- Interior details.
- Landscape furnishings.
- Architectural projects.
- Airfields and runways.
- In rocket launch pads.
- Glass fibers are also used in making of heat and corrosion resistant fabrics.
- Used in automobiles and sports goods also.
- Glass fibers are extensively used for making FRP tanks and vessels.

II. Objectives Of The Study

The following are the main objective of the study

1. To evaluate fresh properties of control concrete of M20 grade and concrete made with 1 and 2% addition of glass fibers by volume of mould of length 12mm and 67mm.For fresh properties, slump cone test and compaction factor tests are conducted.
2. To find out the compressive strength of control concrete of M20 grade and concrete made with 1 and 2% addition of glass fiber of volume of mould of length 12mm and 67mm at7 days and 28 days, tests are conducted.
3. To find out the split tensile strength of control concrete of M20 grade and concrete made with 1 and 2% addition of glass fiber of volume of mould of length 12mm and 67mm at7 days and 28 days, tests are conducted
4. To evaluate the optimum dosage and length of glass fibre for M20 grade of concrete.

III. Materials And Methodology

1. Cement

In this present work Zuwari cement of 43grade ordinary Portland Cement (OPC) was used for casting cubes and cylinder for all concrete mixes.

The cement was of uniform color i.e. Grey with a light greenish shade and was free from any hard lumps. The various tests conducted on cement are specific gravity, initial and final setting time and compressive strength. Testing on cement was done as per IS codes. The results obtained are presented in the table 1.

Table 1
Physical properties of cement

Particulars	Experimental Results	As per standard IS 8112:2013
Specific gravity	3.15	---
Setting time (minutes)		
Initial setting time	45 minutes	30 minutes (Minimum)
Final setting time	560 minutes	600 minutes (Maximum
Compressive strength		
3 days	22.79MPa	16MPa (minimum)
7 days	34.52MPa	22MPa (minimum)
28 days	46.28MPa	43MPa (minimum)

2. Fine Aggregate

The sand used for this project was locally procured and conformed to grading zone II as per IS: 383-1970. The physical properties of the river sand are as shown in the table 2.

Table 2
Physical properties of FA

Particulars	Experimental Results
specific gravity	2.66
Fineness modulus	3.06
water absorption	1.3%
free moisture content	0%

3. Coarse Aggregate

Locally available coarse aggregate having the maximum size of 20mm were used in the present work. The physical properties of the coarse aggregate are as shown in the table 3.

Table 3
Physical properties of CA

Particulars	Experimental Results
specific gravity	2.7
water absorption	0.3%
free moisture content	0%

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4. Water

Potable tap water was used for the preparation and curing of the specimens.

5. Glass Fibres

In this present work the glass fibers used are of Anti-Crack HD with modulus of elasticity 72 GPa, Filament Diameter 14 microns, specific gravity 2.7, length 12 mm and 67mm.The samples of glass fibers having length of 12mm and 67mm are as shown in the figure 1.

12 mm length | 67 mm length

Fig 1: samples of glass fibers of different length

IV. Mix-Design

The proportioning of the ingredients of concrete is an important phase of concrete technology as it ensures quality and economy. In pursuit of the goal of obtaining concrete with desired performance characteristics the selection of component materials is the first step, the next step is a process called mix design by which one arrives at the right combination of the ingredients. The mix design procedure adopted in the present work to obtain M20 grade concrete is in accordance with IS: 10262-2009. The specific gravities, mix proportion, mix designation of the materials used are as tabulated in the below table 4,5 and 6 respectively.

Table 4
Specific gravities of materials used

Materials	Specific gravity
Cement	3.15
Fine aggregate	2.66
Coarse aggregate	2.70

Table 5
Mix proportion

W/C ratio	Water (kg/m^3)	Cement (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)
0.55	211.08	383.78	785.38	1006.4

Table: 6
Mix designations

Mix	Description
M0	Control concrete of grade M20
M1	1% of 12mm length glass fiber
M2	2% of 12mm length glass fiber
M3	1% of 67mm length glass fiber
M4	2% of 67mm length glass fiber

V. Casting Of Specimen And Testing Procedure

Cement, sand and aggregates were taken in the mix proportion 1:2.04:2.62 which correspond to M20 grade concrete. The concrete was produced by mixing all the ingredients homogeneously. To this dry mix, required quantity of water was added (w/c ratio=0.55) and the entire mix was again homogeneously mixed and respective proportion of glass fiber is added (Fig 2) and mixed thoroughly. This wet concrete was poured into the moulds which was compacted both through hand compaction in three layers as well as through vibrator. After the compaction, the specimens were given smooth finish and taken out of the table vibrator. After 24 hours, the specimens were demoulded and transferred to curing tanks where they were allowed to cure for required number of days.

Fig2 : Addition of fibers to wet mix

For evaluating the compressive strength, specimens of dimensions 150× 150×150mm were prepared. They are tested on 3000kN capacity compression testing machine as per IS 516 – 1959. The compressive strength is calculated by using the equation,

$$f_{ck} = P/A$$

Where,

f_{ck} = compressive strength of the specimen(in MPa).
P = Maximum load applied to the specimen (in N).
A = Cross sectional area of the specimen (in mm^2).

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For evaluating the split tensile strength, cylindrical specimens of diameter 150mm and length 300mm were prepared. Split tensile strength test was carried out on 3000kN capacity compression testing machine as per IS 5816 – 1999. The split tensile strength is calculated using the equation,

$$f_{sp} = 2P/(\pi DL)$$

Where,
fsp = split tensile strength of concrete (in MPa).
P = Load at failure (in N).
L = Length of cylindrical specimen (in mm).
D = Diameter of cylindrical specimen (in mm).

VI. Experimental Results

Fresh properties of concrete: - The test conducted on fresh properties of control concrete and concrete made with different l/d ratios of glass fibre and different dosages of glass fibre. The tests conducted for workability of concrete were slump test and compaction factor test; results are represented in Table 7 and 8also with figure 3 and 4 respectively.

Table 7
Slump test results

Sl.no	Mix	Slump(mm)
1	M0	100
2	M1	93
3	M2	94
4	M3	97
5	M4	98

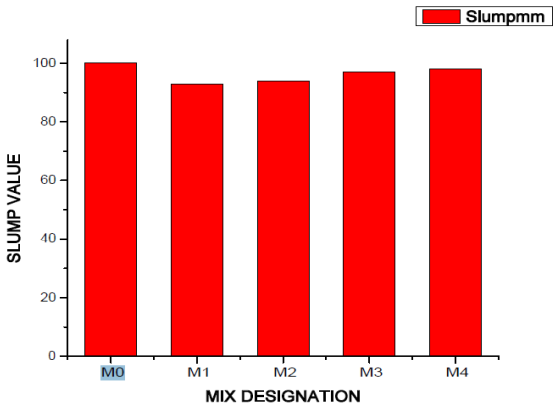

Fig 3:Variation of slump for different mixes

Table 8
Compaction factor test values

Sl.no	Mix	Compaction factor
1	M0	0.92
2	M1	0.94
3	M2	0.90
4	M3	0.95
5	M4	0.91

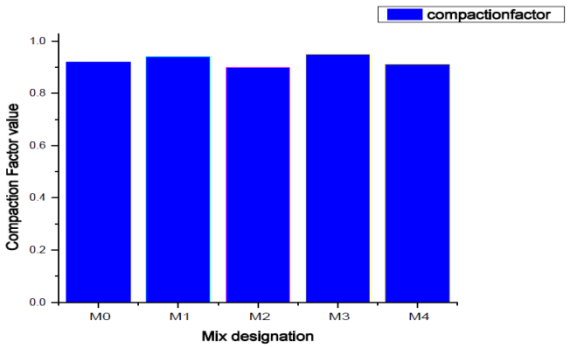

Fig4:Variation of compaction factor for different mixes

Hardened properties of concrete:

Compressive strength test results: For each concrete mix, the compressive strength is determined on three 150X150X150mm cubes at 7 and 28 Days of curing. Following Table 9 and Fig 5shows the compressive strength test results of control concrete and concrete made with different l/d ratios of glass fibre and different dosages of glass fibre.

Table 9:
Overall Results of Compressive Strength

Mix	Compressive strength (N/mm^2)	
	7 Days	28 Days
M0	19.32	23.40
M1	22.67	25.50
M2	24.78	27.83
M3	27.61	29.57
M4	29.08	30.6

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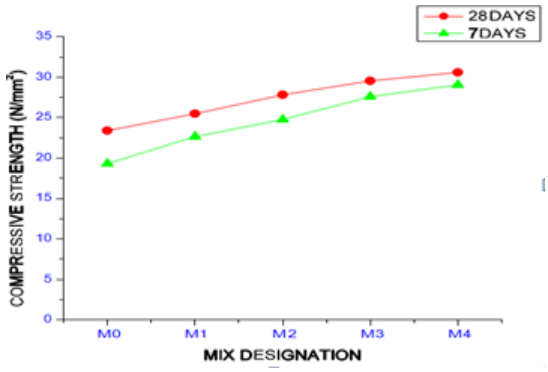

Fig 5:Performance of fibers on compressive strength

Split tensile test results: The test has been conducted after 7 and 28 days of curing. Split tensile test conducted on 150mm diameter and 300mm length cylinder as per IS: 5186-1999. Following Table 10 and Fig 6shows the split tensile test results of control concrete and concrete made with different l/d ratios of glass fibre and different dosages of glass fibre.

Table 10
Overall Results of Split tensile Strength

Mix	Split tensile strength (N/mm^2)	
	7 Days	28 Days
M0	2.41	2.91
M1	2.64	3.21
M2	2.79	3.65
M3	3.08	3.97
M4	3.76	4.16

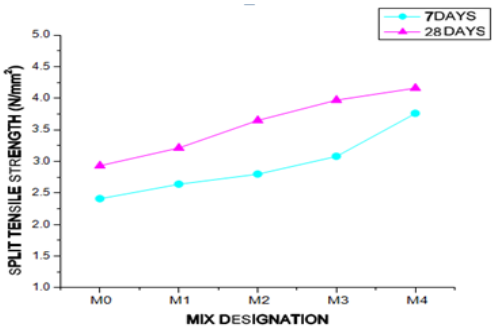

Fig 6:Performance of fibers on split tensile strength

VII. Observations And Discussions

From the experimental results and graphs, the following observations are made:

1. The slump of reference mix M0 is 100mm. For Fibre Reinforced Concrete, the slump value decreased when compared to reference mix. As the length of fibre increases slump increases for higher volume fractions.
2. The compaction factor for reference mix M0 is 0.9. For Fibre Reinforced Concrete, the compaction factor decreased when compared to reference mix. As the length of fibre increases compaction factor increases for higher volume fractions.
3. For 7 days curing, it is observed that compressive strength without fibres is 19.32 N/mm^2. The compressive strength increases for 12mm length fibre at 1 and 2% volume by 17.34 and 28.26% respectively. Also for 67mm length fibre at 1 and 2% by volume, it increased by 42.9 and 50.52% respectively.
4. For 28 days curing, it is observed that compressive strength without fibres is 23.4 N/mm^2. The compressive strength increases for 12mm length fibre at 1 and 2% volume by 8.97 and 18.93% respectively. Also for 67mm length fibre at 1 and 2% by volume, it increased by 26.36 and 30.76% respectively.
5. For 7 days curing, it is observed that split tensile strength without fibres is 2.41 N/mm^2. The split tensile strength increases for 12mm length fibre at 1 and 2% volume by 9.543 and 16.099% respectively. Also for 67mm length fibre at 1 and 2% by volume, it increased by 27.80 and 56.01% respectively.
6. For 28 days curing, it is observed that split tensile strength without fibres is 2.933 N/mm^2. The split tensile strength increases for 12mm length fibre at 1 and 2% volume by 9.54 and 24.45% respectively. Also for 67mm length fibre at 1 and 2% by volume, it increased by 35.35 and 41.83% respectively.
7. The increment strength may be due to presence of glass fibre in the interfacial transition zone. The glass fibre surface produces good bond in the matrix of the mix. During application of load, the stress transfer may takes place in the matrix through the fibres, also fibres have good adhesive nature with the concrete. so that it may not deboned easily and also it takes more energy to failure.
8. From the thorough inspection of tested specimen, it can be noticed that concrete cylinders with glass fibres did not split into two pieces after attaining the failure load. This may be due to glass fibre may act as bridge between the two fractions.

VIII. CONCLUSIONS

1. The slump value decreases as the % of glass fiber increases. But, as the length of fiber increases slump increases.
2. The compaction factor decreases as the % of glass fiber increases. But, as the length of fiber increases compaction factor increases.
3. The compressive strength increases as volume of glass fiber content increases in the concrete. Also as length of fiber increases the compressive strength increases.
4. The split tensile strength increases as volume of glass fiber content increases in the concrete. Also as length of fiber increases the split tensile strength increases.
5. Glass fiber of higher length showed more strength, than the glass fiber of shorter length.
6. Hence glass fiber of more aspect ratio is preferable than glass fiber of less aspect ratio.

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