An Analysis on Reinforcing of Glass Fibre (GF) in Ordinary Concrete for High Strength

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Abstract-Glass fibre reinforced concrete's (GFRC) higher resistance to cracking and fracture propagation is an essential feature. Fiber composites have enhanced extensibility and tensile strength, especially under flexural stress, due to their ability to stop fractures. The fibres may also hold the matrix together even after significant breaking. There is a dramatic increase in the fibre composite's post-cracking ductility that is unheard of in conventional concrete. The fibre composite's capacity to tolerate repetitive, shock or impact loading would be greatly enhanced if it were to change from a brittle to a ductile material. Concrete's mechanical characteristics are examined through an experimental investigation presented in this thesis. Workability, Compressive Strength, and Flexural Strength Tests were conducted on Glass Fiber Reinforced Concrete with different percentages of Glass Fiber in the mix. (0%, 0.5%, 0.7%, 0.9%, 1.2% and 1.5%). The main aim of this experiment is to study the modes of Glass Fiber cracking failure, crack propagation and flexural strength properties of Glass Fiber Reinforced Concrete of M-20 grade with Glass Fiber being oriented randomly, varying 0%, 0.5%, 0.7%, 0.9% , 1.2% and 1.5% by weight of cement. The results indicated that the use of Glass Fiber is recommended when high strength is required. It increases the inherent tensile strength of concrete itself and arrests the structural micro-cracks imparting more resistance to failure of structure.

Keywords — GFRC, Workability, Concrete, Compressive Strength, Flexural Strength, Glass Fibre.

I. INTRODUCTION

There is limited resistance to cracking and low tensile strength in plain concrete. The concrete has micro-cracks within it, and this leads to brittle collapse owing to the concrete's low tensile strength as a result of the cracks spreading.

The tensile characteristics of the concrete members have been enhanced using restraint techniques and reinforced steel bars. Despite giving tensile strength, neither of these procedures increases the tensile strength of concrete in and of itself. Plain concrete can develop structural fractures even before a force is applied owing to drying shrinkage or volume changes. Additional cracks arise in regions of minor faults as a result of the stress concentration being affected by the cracks spreading and opening up when the member is loaded. Because of numerous obstructions, changes in direction, and the more resistant grains in the matrix, structural fractures progress slowly or in little leaps. Inelastic deformations in concrete are caused by the development of fractures in the concrete. Static and dynamic qualities would be significantly improved by the addition of tiny, tightly spaced and evenly scattered fibres.

Cement, mortar, or concrete are the main components of fibre-reinforced concrete with fibers that are scattered equally throughout the mixture. Wires and lengthy wires or rods are not regarded to be separate fibers in a continuous mesh.

1.1 GFR Concrete:

Cement or cement sand mortar is blended with four to five percent glass fibre by volume. Concrete with extremely high tensile and toughness strength. When stretched, it can withstand loads of up to 4100 N/mm^2. It's both light and strong, and it can be moulded into a wide variety of shapes and forms. Glass fiber is used because:

- Concrete is less permeable.
- It can withstand the most breaking force.
- The degree of structural stiffness rises.
- The rigidity of the fibers eliminates cracks.
- It is possible to use fewer re-bars without losing strength.

 DOI : 10.35291/2454-9150.2022.0453

ISSN : 2454-9150 Vol-08, Issue-07, Oct 2022

- It has better tensile strength than regular concrete.
- It offers significant impact loading resistance.

Spraying, casting, spinning, extrusion, and pressing are all methods used in the production of fiber. The features of the finished product vary depending on the procedure used. Spraying is a more precise way of processing and is by far the most formulated. Fiberglass and cement or sand cement mortar are sprayed into or onto a suitable mould in the simplest kind of spraying. Air is used to compress the mortar slurry into a thin mist for the spray cannon. To feed a chopper and feeder unit on the same gun convection, glass fibre must be provided.

Cement's alkaline state affects the glass fibre that was initially used with it. As a result, a new kind of alkali-resistant fibre glass known as CEM- FIL was created. Compared to fibre glass, alkali resistant fibre reinforced concrete is significantly more durable.

Concrete products with a section thickness ranging from 3 to 12 mm may be made using the glass reinforced cement mortar.In comparison to standard precast concrete products, GFRC may be made as thin as 6 mm, making it lighter.

Figure 1: Silica Glass Fiber

1.2 History of Glass Fiber Reinforced Concrete:

Fibres have been used in building for at least 350 years. Horse hairs were utilised in the mortar, and straw was used to back the bricks. Russia is where the idea for Glass fibre reinforced concrete was hatched. Concrete was made using asbestos fibres. Due to its low alkali resistance and subsequent loss of tensile strength, glass has a tough time being mixed with concrete from the start of its use life. A higher concentration of zirconium dioxide in later glass led to an improved alkali resistance. Such fibre became commercially available in the mid-1960s. Once these materials were available, steel, glass, and synthetics were used. The International Glass Fiber Concrete Association increased quality control for the best production practices and design in the early 1980s, which resulted in a significant increase in tensile, flexural, and impact strength. The construction boom throughout the world has led to an upsurge in GFRC manufacturing. There were times when the global economic crisis had a negative impact on GFRC's growth, but it was still widely used across the world by major architectural firms and institutions.

This is the first time we've seen a fibre reinforced concrete with both exceptional and high performance. Even today, research into fiber-reinforced concrete is ongoing.

1.3 Advantages and Disadvantages of GFRC:

➢ ***Advantages:***

- GFRC is significantly lighter than concrete, with a weight savings of 75%.
- Glass fibre is elastic.
- Their tensile strength is quite strong.
- In addition, they are corrosion-resistant.
- They are extremely resistant to temperature changes.
- GFRC is a heat conductor in a limited capacity.
- For the exterior of the building, it is an excellent material for making alterations to old structures.
- A high grade of weight ratio is achieved due to the flexural characteristic of the product.
- It is utilised extensively on both the ceiling and the wall.
- This concrete's internal reinforcing does not need additional reinforcement.
- Pouring or showering the glass fibre reinforced concrete does not necessitate the use of expensive or heavy machinery.
- It is very easy to cut and very difficult to break.
- The versatility of a glass fibre allows it to be poured or sprayed.
- Spraying the surface leaves no holes or entrances for bugs. Expelling all holes and bug-gaps before solidifying it is readily shaken.

➢ ***Disadvantages:***

- A decrease in ductility is seen. The capacity of a solid substance to deform under stress is known as ductility.
- In comparison to conventional concrete, the price of glass fibre reinforced is greater.
- The use of chemicals and a polymer is necessary because of the presence of glass fibres in the concrete.
- Glass fiber-reinforced concrete is difficult to knead. For the most part, this type of cement is mixed and poured by a temporary worker.
- The mixture can be fine-tuned, but if it is not properly poured or connected, it may separate. Using material will allow the concrete to follow and have a more stable finish.
- Difficulty of mixing glass fibre reinforced concrete.

 DOI : 10.35291/2454-9150.2022.0453

1.4 Structural Importance of GFRC:

In comparison to unreinforced concrete, glass fiber-reinforced concrete is the best option. With regular or glass fibre reinforced concrete, steel reinforcement will strengthen the structural integrity of the building. For example, with overhangs, cantilever and other elements where obvious fractures cannot be permitted, this is critical. Using glass fibre reinforced concrete as a substitute for conventional reinforced concrete is not a good idea if you need to support a large amount of weight. A low water-cement ratio and a high cement content result in a high compressive strength in glass fibre concrete. There are no comparisons to be made between it and regular concrete due to its superior tensile and flexural strengths. The significant usage of fibre and the use of polymer content ensure that the concrete is flexible and does not fracture under tensile pressures. Wall panels, fireplaces, vanity tops, and other aspects are better suited to the glass fibre reinforced concrete material. Where regular countertop-shaped pieces are created, the weight saving is maintained owing to the reduction in thickness and the mixing, shaping, and casting processes are fairly comparable. The glass fibre advantage is diminished.

1.5 Uses of GFRC:

- Buildings are clad with glass fibre.
- It is utilised in both permanent and temporary formwork.
- It is employed in the construction of walls and ceilings in the building of structures.
- Landscaping and water features commonly make use of glass fibres.
- It is utilised extensively in the finishing process.
- It's great for models and pre-assembled boulders and stones since it may be poured in any desired direction.
- It is used as decorative grills and sun breakers.

1.6 How fiber works in GFRC:

Glass fibre reinforcement is a common way to improve a material's mechanical qualities. In concrete, fibres are utilised to minimise shrinkage and fissures. Fibers lower the permeability, which in turn reduces the amount of blood that may leak. Fiber is used to great effect in the production of excellent concrete. Fibers have no effect on the concrete's flexural strength. Steel bars and their resisting properties cannot be substituted by fibres. Load is transferred from one fibre to the next by shear stresses in the matrix, which are applied to the alkali-resistant glass fibres that connect polymer and concrete. Enough fibre must be present to prevent the glass-reinforced component from fracturing or shattering. Fiber is a good indicator of how well a material resists a load. To achieve the required tensile strength, the fibre must be stiff as well as strong. The physical features of glass fibre and their inexpensive cost have made them a better alternative than other fibres.

Glass fibre reinforced concrete employs a high loading of glass fibre to give enough material for the cross sectional area in order to resist the tensile load. If the fibres are placed in a non-consistent manner, they will require a greater number of fibres in order to resist tensile stress. A tiny percentage of the total amount of randomly oriented fibre is pointed in the correct direction, which explains why this is the case. Glass fibre concrete is reinforced with three layers of steel.

1.6.1 Three Dimensional (3D):

When fibres and concrete are combined precisely and poured into moulds, the three-dimensional effect is achieved. In concrete, the fibres are spread out in all directions. Few fibres are able to withstand tensile loads in a certain direction because of the randomness and three-dimensional positioning. Reinforcing at this level is inefficient and necessitates high fibre loads.

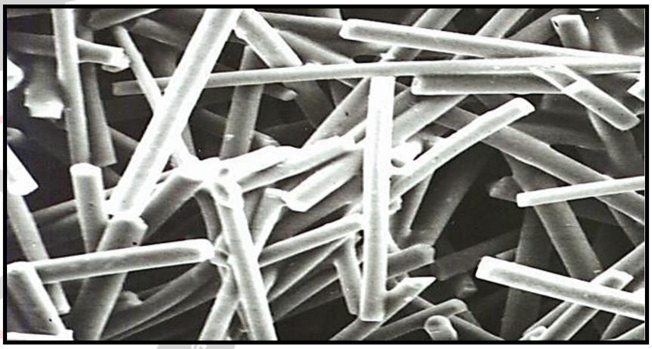


Figure 2: Random Three Dimensional Fibers Two Dimensional

1.6.2 Two Dimensional (2D):

The threads of a two-dimensional picture are arranged at random on a flat surface. In the end, the farm's form was confirmed by the fibres sprayed. Because the location of fibres inside a horizontal plane fluctuates, two-dimensional reinforcing is inefficient.

When it comes to structural engineering, reinforcement is placed towards the bottom of a structure since the area where the tensile loads are the greatest has the most fibres.

Figure 3: Two Dimensional Fibers

 DOI : 10.35291/2454-9150.2022.0453

1.7.3 One Dimensional (1D):

The most effective kind of reinforcing for tensile loads is steel reinforcement, which is positioned totally within the tension zone. This prevents reinforcement from being wasted in regions that do not cause tensile stresses, which makes steel reinforcement the most efficient type of reinforcing. For this reason, the design of the members makes use of steel reinforcement.

II. LITERATURE REVIEW

The behaviour of steel and glass Fiber Reinforced Concrete Composites was studied experimentally by Kavita Kene and colleagues. Alkali-resistant glass fibres with zero and 25 percent by weight of cement in 12 mm cut length are combined with steel fibres of 0 percent and 0.50 percent volume fraction. Results of a study on Fiber Reinforced Concrete were compared (2012).

At higher loads, G. Jyothi Kumari, et al found that silica-coated Glass fibre reinforced polymer (GFRP) flats shear reinforcement in concrete beams weakened the concrete beams' structural integrity. As a further observation, they found that GFRP flats, used as shear reinforcement, are fairly ductile. There are two factors that determine the tensile strength of composite materials: fibre orientation and fibre to matrix ratio (2013).

Studies on glass fiber-reinforced concrete's durability were undertaken by Dr. P. Srinivasa Rao and his colleagues. The workability, acid resistance, sulphate permeability, were all investigated using alkali-resistant glass fibres. Alkali-resistant glass fibres were added to the concrete to boost its durability. Glass fibres in concrete, according to the results of an experiment, reduce bleeding. The acid resistance of concrete had been improved by the use of glass fibres (2012).

Glass fibre reinforced plastic bars as reinforcing materials for concrete constructions were examined by S. H. Alsayed and colleagues, et al. Recommendation 283: Review on the Performance of Glass Fiber Reinforced Concrete 283 was used to correctly evaluate concrete beams reinforced with GFRP bars' flexural capacity. In addition, the study found that GFRP bars had a low coefficient of friction.

Intermediate and long beams reinforced with FDRP bars may be designed using modulus of elasticity and deflection criteria (2001)

An investigation of the performance of Glass Fiber Reinforced Concrete was carried out by Yogesh Murthy, et al. According to the findings of the research, adding glass fibre to concrete not only enhances its qualities and reduces its cost, but it also provides an efficient way for industry to dispose of glass waste. There was an almost 30% improvement in flexural strength with 1.5 percent glass fibre in the beam, according to the study. The decrease in droop that has been seen as the amount of glass fibre has increased (2012).

Concrete made with GFRC is stronger, according to Avinash Gornale and his colleagues. At 3, 7, and 28 days after incorporating glass fibres into concrete, M20, M30, and M40 grades of concrete showed a 20–30% improvement in compressive strength, flexural strength, and split tensile strength when compared to plain concrete (2012).

The trnd in concrete technology at the moment for the purposes of this study is to increase concrete's strength and durability at a reduced cost so that it may be used in modern building. Adding fibres of either natural or synthetic origin to concrete can accomplish these goals. By altering the quantity of fibre in concrete from 0.025 percent to 0.075 percent, evaluated (2013).

A research by T. Subramani and C. Sumathi Since the previous two decades, concrete has been employed in a variety of constructions around the world. Concrete has been used specifically on a few infrastructure projects in the recent past as well. In order to enhance the performance of concrete, chemical and mineral additions have been more important since the invention of the material. Improvements in these admixtures have been a major factor in much of the progress made during the project.

T.S. Thandavamoorthy and C. Selin Ravikumar, according to the study, the usage of fibres in concrete for increasing its qualities has increased significantly such as its tensile and ductile strength. The fibre concrete may also be utilised to retrofit concrete buildings. Concrete technology has just recently begun to use glass fibre, one of the various types of fibres currently accessible.

Following passing away of Kavita S. Kene Concrete is the building material that is utilised the most all around the world. Fiber-reinforced concrete has small, irregular fibres that are equally dispersed throughout (FRC). Glass, aramid, asbestos, polypropylene, steel, G.I., carbon and jute are just a few of the materials that may be employed in FRC fibres.

In addition to cement, sand, water, and admixtures, glass-fiber reinforced concrete (GRC) also contains short-length glass fibres scattered, S. S. Pimplikar conducted an experiment.

Thomas Subramani and Amir Mumtaz As a result of this discovery, Glass fibres in concrete are being studied. To meet the stated goals of this experiment, sand has been

 DOI : 10.35291/2454-9150.2022.0453

substituted with Glass fibres by 5, 10, and 15% in the production of Concrete.

Athar Thanon Derwood, Eethar Efforts were made to generate a natural gypsum plaster that could be reinforced with bar chip fibres by adding 1% admixture (Super plasticizer). A range of bar chip percentages were employed, including 0, 0.5, 0.75, 1, 1.25, and 1.5 percent. This gypsum plaster's compressive and flexural strengths are examined.

In the writings of A. Meher Prasad and Devdas Menon, Glypsum plaster, reinforced with glass fibres, makes up the bulk of the GFRG wall panel. The panels can be utilised as load-bearing walls since they are hollow.

S.H. Deshmukh, J.P. Bhusari, and A.M. Zende are the authors. Building materials such as concrete are susceptible to cracking due to the fact that they are both plastic and rigid at the same time. Even more worrisome is the fact that concrete is weak in its ability to withstand cracking.

III. RESEARCH METHODOLOGY

Cement, sand, and coarse aggregate are the ingredients utilised to evaluate the strength properties of fibre glass reinforced concrete in accordance with standard regulations. Following the aforementioned testing, the material mix design was carried out. Ordinary mixtures were created to determine the amount of plasticizer needed to obtain the desired workability after the proportions of the other components of the concrete mix had been fixed. 18 distinct concrete mixtures totaling variable percentages of fibre glass were created. Three beams in each of fifteen distinct places, with variable percentages of fibre glass, were cast, totaling 36 cubes and 36 beams. Mixture characteristics include compressive and flexural strength.

The experiment was set up so that it could investigate how the strength characteristics of concrete would change.

3.1 Materials Used:

3.1.1 Cement:

In this study, the ordinary Portland cement (OPC) of 43 grades was used.

Table 1: Properties of Cement

Initial setting	90 min
Final setting	600 min
Normal consistency	28%
Compressive strength	41.15 N/ mm2
Specific gravity	3.14

3.1.2 Coarse Aggregate:

The Crushed angular aggregate of size 20 mm and 10 mm was used. Coarse aggregate has the following properties.

Table 2: Properties of Coarse Aggregate Size of 20 mm

Specific gravity	2.76
Void ratio	45.45%
Water absorption	1%

Table 3: 20 mm Coarse Aggregate Sieve Analysis

S.No.	Sieve size (mm)	Percentage Passing	Percentage passing from 20 mm single size aggregate as per IS
1.	40	100	100
2.	20	89.68	85-100
3.	10	0.7	0-20
4.	4.75	0.040	0-5

Table 4: Properties of Coarse Aggregate of Size 10 mm

Specific gravity	2.58
Void ratio	46.25%
Water absorption	1%

Table 5: Sieve Analysis of Coarse Aggregate of size 10 mm

S.No.	Sieve size (mm)	% passing	% passing for 10mm single size Aggregate as per IS
1.	40	-	-
2.	20	-	-
3.	12.5	100	100
4.	10	92.6	85-100
5.	4.75	7.77	0-20

3.1.3 Fine Aggregate:

The river sand was used as fine aggregate in this study. The fine aggregate has the following properties.

Table 6: Properties of Fine Aggregate

Specific gravity	2.35
Void content	26.25%
Fine modulus	2.8
Water absorption	1.4%

Table 7: Fine Aggregate Sieve Analysis

S. No.	Sieve Size	% Passing	% Passing from Standard Sieve
1.	4.75mm	96.4	90-100
2.	2.36mm	91.2	75-100
3.	1.18mm	73.5	55-90
4.	600	52.4	35-59
5.	300	30.7	8-30
6.	150	9.8	0-10
7.	Pan	-	-

3.1.4 Water and Plasticizer:

The potable water along with Naphthalene Polymer was used in this study.

3.1.5 Glass fiber:

The Silicon fiberglass was used with modulus of elasticity seventy-two G pa, with diameter of fourteen microns, specific gravity 2.78, and length 12 mm.

Figure 4: Silica Glass Fibers Used in the Study

 DOI : 10.35291/2454-9150.2022.0453

3.2 Physical Properties Of Materials:

1) Specific Gravity:

Specific gravity is employed in the, allowing us to compute the theoretical value of the concrete per unit volume. Specific gravity is used to calculate the compaction factor for the workability measurement. Specific gravity is utilized to determine a material's superior quality and strength. The formula below was used to determine the specific gravity of the aggregate.

Specific Gravity = Weight of dry aggregate / Weight of equal volume of water

Table 8: Specific Gravity of Aggregate

Materials	Specific gravity
Coarse Aggregate (10mm)	2.66
Coarse Aggregate (20mm)	2.65
Fine Aggregates	2.42

2) Flakiness Index Test:

The flakiness index tests determines quality of aggregate based on its least and maximum dimension. This test is invalid if the particle size is less than 6.3mm. This test uses a metal thickness gauge to ascertain results. A sufficient number of aggregates were used at least 200 pieces were needed to complete the test. Weight was applied to the particle stream through the gauge. The weight of all the particles that passed through the thickness gauge was used to calculate the flakiness index.

3) Elongation Index Test:

This test is invalid if the particle size is less than 6.3mm. This test uses a metal thickness gauge to ascertain results. A sufficient number of aggregates were used; at least 200 pieces were needed to complete the test. Weighting was applied to the quantity of particles kept on the gauge. More than ten to twelve percent of the particles are regarded as undesirable.

4) Moisture Level:

The free water that is retained on the aggregate's surface is referred to as the moisture content. Determining the surface water content of the aggregate is crucial for assessing the quality of the concrete, particularly with regard to its strength and workability. Dry aggregate absorb more water, affecting the workability of concrete, and vice versa.

The quality of concrete is impacted by the moisture level of both fine and coarse material. There is a layer of film that develops around the particles due to the water present. The moisture levels were determined to be low in both instances. After particles have been submerged in water for twenty-four hours, the aggregate's moisture content may be calculated by comparing the aggregate's new weight to that of the dry sample. Aggregate absorption is defined as the increase in aggregate mass relative to the aggregate mass of a sample. The crushing and impact values were deemed satisfactory. It was determined that the aggregate quality was enough to withstand crushing load and toughness impact.

Fine and coarse aggregate have different moisture requirements, and both effect concrete quality. The particles are encased in a thin layer of water. It was discovered that the moisture levels were low in both instances. Water content in aggregates is particles are submerged in water for 24 hours, and the rise in aggregate weight is compared to the weight of the dry sample. Aggregate absorption is the process through which a given aggregate gains mass relative to a given sample aggregate. The crushing and impact values were deemed acceptable. Crushing load and toughness impact testing revealed that the aggregate quality was adequate.

5) Aggregate Crushing Value Test

It gives measure of the resistance of an aggregate sample to crushing under a gradually applied compressive load. Test is carried on aggregate passing through 12.5 mm sieve are retained on 10 mm sieve. Aggregate is placed in the mould and a load of forty ton is applied gradually through a plunger within 10 minutes of time. After removing the load, the material broken to finer than is separated and sieved through a 2.36 mm standard sieve.

$$\text{Aggregate crushing value} = \frac{W2}{(W1 - W)} \times 100$$

Where;

W2 =Weight of fraction passing through the appropriate sieve.

W1-W =Weight of surface dry sample.

Figure 5: Aggregate Crushing Value Apparatus

6) Aggregate Impact Value Test:

It is the material's resistance to failing as a result of shock or an abrupt impact. Particles must pass through a 12.5

 DOI : 10.35291/2454-9150.2022.0453

mm sieve and be retained on a 10 mm standard sieve. They must also be filled in three layers, tamped twenty-five times, and hoisted to a height of 388 mm before being allowed to fall freely onto the aggregate. After being taken out, the crushed aggregate is sieved using a 2.36 mm standard sieve. The weight of the aggregate that passes through the sieve. The aggregate impact value is the weight of the particles divided by the total weight of the sample expressed as a percentage.

$$\text{Aggregate Impact value} = \frac{\text{Weight of particles passing 2.36mm sieve}}{\text{Weight of oven dried sample}} \times 100$$

The impact-crushed value is restricted to forty-five percent for concrete.

Figure 6: Aggregate Impact Value Apparatus

3.3 Test Variable:

Two variables have been used for experiment purpose. On the basis of these variables comparison between the mixes has been done.

1) Glass fiber percentage for both beams and cubes.
2) Position of fibers for only beams which are distributed randomly.

3.4 Mix Design:

According to Indian standard code, the concrete mix was performed. Glass fibre was added to a batch of M20 grade concrete.

1) Target mean strength of concrete:

In accordance with Indian norms, the desired median concrete strength has a tolerance factor of 1.66 and a standard variation of 4.0 N/mm^2.

$F = 20+4 \times 1.66$; $F= 26.7 N/mm^2$

2) Water cement ratio selection:

Desired mean target strength with selected water cement ratio=0.40

3) Selection of sand and water content:

Water/cubic meter = 170 kg/m3

Percentage of sand as per total aggregate volume = 0.34 or 34 percent

Total cement required = 400 kg/m^3.

The M20 grade of concrete used is shown in table, the admixture is added with cement as one percent. The mix design for M-20 grade of concrete is by weight.

Table 9: M-20 Mix Design

Cement	Sand	Coarse Aggregate	Water
1.02	1.53	3.06	0.57

4) Water Cement Ratio:

The ratio of the weight of water to the weight of cement is the definition of the term "water cement ratio." The strength of the cement paste is directly proportional to the strength of the concrete. It is clear that a lower water-to-cement ratio enhances both the strength of concrete and the pace at which it sets, and this ratio is the one that is utilised when the concrete is vibrated in order to obtain a high level of strength. When concrete is mixed by hand, the water-to-cement ratio must be greater than normal in order to provide the desired workability. However, this comes at the expense of strength.

Concrete contains water for two reasons. Cement hydration and workability for hydration purposes, 13 litres of water are utilised every bag of cement. To get the requisite workability, more water is used.

Table 10: Various Mixes Used in the Study

S. No.	Fiber Glass%	W/C Ratio	Mix properties(kg/ m^3)			
			Plasticizer	Glass fiber	Sand	Aggregate
1	0	0.4	0	0	600	1126
2	0.5	0.4	4	2	600	1126
3	0.7	0.4	4	0.28	600	1126
4	0.9	0.4	4	3.6	600	1126
5	1.2	0.4	4	4.8	600	1200
6	1.5	0.4	4	6	600	1200

It was found that adding more water to the concrete makes it easier to handle, position, and compact. Concrete will bleed if we employ a high water-to-cement ratio since the workability will increase. Water and cement sand will accumulate on top of the concrete as we lay and crush it. It causes the water to evaporate over time and renders the concrete permeable. The permeability increases as a result of the production of porosity, which lowers the concrete's strength. It has been demonstrated that concrete with up to 5% of voids loses 30% of its strength, and concrete with up to 15% of cavities loses 50% of its strength. Shrinkage cracks develop on the upper surface of the strength when the concrete loses strength.

A study found that putting, moving, and compacting concrete is more difficult when the water-to-cement ratio is lower. The formation of a honeycomb structure occurs if the reinforcement is not covered by

 DOI : 10.35291/2454-9150.2022.0453

concrete. In addition to reducing concrete's strength, it will reduce its ability to last. Therefore, it is essential to employ precise. For better-quality concrete, increase the water-to-cement ratio. Below table is a list of some realistic water cement ratio values.

Table 11: Practical Values for w/c Ratio

Grade of Concrete	Proportion	w/c Ratio
M15	1:2:4	0.6-0.65
M20	1:1.5:3	0.5-0.60
M25	1:1:2	0.45-0.50

5) Method of Mixing:

Following the proper batching, concrete is mixed to create a homogenous mass that is uniform in colour and consistency. There are two approaches to blending.

- **Hand Blending:**

As the concrete cannot be mixed carefully and effectively, it is worth adding 10% additional cement. This method of mixing is suited for small scale, less than fifty bags of cement. Materials for hand mixing should be prepared on a platform that is waterproof, such as brick, wood, or steel plates. On top of coarse and fine aggregate, cement is offered and completely mixed in the necessary amount. Mix at least three times while the mixture is dry. Water is then added and continually blended to get a uniform colour.

Figure 7: Hand Mixing

- **Machine Mixing**

This mixing technique, commonly referred to as a concrete mixer, is favoured for large-scale projects involving more than fifty bags of cement. If the optimum water-to-cement ratio and mixing time are maintained, concrete can be mixed consistently in a machine. Compared to manual mixing, concrete is mixed more consistently. Transporting concrete should be done in a way that prevents segregation and water loss. The concrete is transported using a variety of tools and techniques. Up until the concrete is put, homogeneity of the concrete must be maintained. To achieve the finest effects, concrete must be put in the proper manner. Before the cement begins to set, the concrete needs to be compacted and poured. Concrete must be put and compacted carefully to maintain the homogeneity acquired after mixing in order to ensure equality.

Concrete needs to be compacted in order to eliminate air and produce dense concrete.

a) Hand compaction is the typical method of compaction.
b) Compaction through mechanical means.

Vibrators are typically not available in remote areas, hence hand compaction is favoured. Here, a 16 mm bar is used to compact the concrete. Vibrating machinery is used to perform mechanical compaction.

3.6 Concrete Grade:

Concrete's compressive strength is its most crucial quality. Standard tests on concrete beams and cube specimens are used to measure this. The grade of concrete is identified by a number that represents its typical strength in M Pa. In this study, concrete of the M 20 grade was employed.

3.7 Method of Concrete Mixes Preparation:

The weight of the test cubes and the unit weights of the ingredients were used to calculate the proportions of the cement, sand, coarse aggregates, and water in the concrete mix. The table below contains information on the size, shape, and quantity of specimens utilised in the investigation. All of the ingredients should be at room temperature before combining the asphalt.

To ensure that the material is uniform, it should be mixed thoroughly, either by hand or using a mixer. Care should be taken to prevent the introduction of foreign components into the mixture.

Table 12: Details of Shape, Size and Number of Specimen

S. No.	Shape	Size
1	Strength test cube	15×15×15cm
2	Beam	50×10×10cm

Figure 8: Concrete Cubes Casting

3.7.1 Compaction:

As depicted in the images, five cm thick layers of concrete mix were poured into the specimen. These test specimens

 DOI : 10.35291/2454-9150.2022.0453

were then compressed to reduce air voids and achieve maximum concrete compaction without excessive particle dispersion or segregation. Vibrators were used to condense each layer. With the use of a trowel, the concrete's surface was leveled after the topmost layers were compacted.

3.7.2 Curing:

After adding water to the dry test specimens, they were kept in a constant location for 24 hours at a temperature of 27 degrees Celsius, in slightly moist air that was not less than 90% relative wetness material. Following labelling, specimens were taken out of the moulds. The cubes and beams were then stored in the curing tank until the testing date. Every seven days, the water in the curing tank was replaced and maintained at a temperature of 27 degrees Celsius.

3.7.3 Workability:

- The interior dimensions of the frustum cone used in the slump test are as follows:
- The diameter of the bottom is 20 cm.
- The diameter of the top is 10 cm, and the height is 30 centimeters.
- Three layers of concrete were poured into the moulds.
- With a normal 16 mm diameter steel rod, the steel rod was used to tamp each layer 25 times.
- The top surface of the mould was tamped and the concrete smoothed using a trowel when the mould was entirely filled with concrete.
- To remove the mould, we first raised it carefully in the vertical direction, allowing the concrete to sink.
- The term "slump" refers to the decrease in height in the centre of the slumped concrete.
- Cones were positioned next to depressed concrete, and a temperature rod was set above the cones such that it could also reach the slumped concrete area.

Figure 9: Slump Test for Workability

3.8 Concrete Testing:

The effect of fiber glass on strength properties of concrete was determined on the basis of quantity listed below in table, just after the mixing and the curing periods of concrete.

Table 13: Tests Conducted in the Study

S. No.	Name of Test	IS Specification
1.	Compressive Strength	IS:516-1959
2.	Flexural Strength	IS:516-1959

3.8.1 Compressive Strength Test (CST):

One of the most important and practical features of concrete is its strength. The compressive strength is sometimes employed to quantify qualities where strength in shear or tension is crucial. Compressive strength tests at seven and twenty-eight days, as well as a flexural tensile strength test at twenty-eight days, were used to evaluate the study's mixes. For each test result, the average of three test specimens was used. After being removed from the curing tank, the specimens were analysed right away.

Compressive Strength

Most of concrete's valuable attributes may be determined by its compressive strength. One of concrete's most important and practical features is its strength. The compressive strength can be used to quantify shear or tension strength in particular circumstances where these attributes are of vital concern. In addition to the kind of cement, water-cement ratio, and the grade of concrete, other elements influence concrete's compressive strength. Compressive strength tests were performed using cubes of specified size. 0.0, 0.5, 1, 1.5, 2, and 3 percent of fibre was used. Concretized cubes are accepted as the standard specimen in certain standard codes. As a result, concrete's compressive strength may be utilised to estimate its hardness rating. The majority of the moulds of the works were utilised on a regular basis. In order to avoid any pours, the concrete was poured into the mould and then appropriately tempered. After 24 hours, these moulds were removed and the test specimens were placed in water for cure. These specimens had their top surfaces sanded and polished. Pouring and spreading cement paste evenly over the whole specimen surface was the method used to accomplish this. After seven and 28 days of curing, these specimens were evaluated on a compression testing equipment. At a rate of one hundred forty kilograms per square meter per minute, the specimen was subjected to a steady increase in pressure. The compressive strength of concrete is determined by dividing the entire area of the specimen by the load at the failure point.

 DOI : 10.35291/2454-9150.2022.0453

International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-08, Issue-07, Oct 2022

Figure 10: Loading on Cube under Compressive Testing Machine (CTM)

3.8.2 Flexural Strength Test (FST):

The maximum strength a material possesses or a concrete's capacity to resist deformation when subjected to a bending moment is called flexure strength. By adding weight to a concrete cube, it is measured. The Modulus of Rupture (M pa), which represents the flexural strength, is calculated according to accepted procedures. Depending on the volume, shape, and size of the aggregate utilised in the study, it ranges from ten to twenty percent of the compressive strength. For a certain set of materials and mix designs, laboratory tests yield the greatest outcomes. Compared to the modulus of stiffness derived via center-point loading, the third-point loading modulus is smaller. On cubes of conventional size, tests for compressive strength were conducted. At rates of 0.0, 0.5, 0.7, 0.9, 1.2, and 1.5 percent, fibre was introduced. Concrete was softened after being put into the mould properly in order to prevent pours. The test specimens were placed in water for curing after the moulds had been on them for twenty-four hours. These specimens have an even, smooth top surface. This was accomplished by evenly applying and spreading cement paste over the entire specimen. After seven days and twenty-eight days of curing, these specimens were then evaluated on compression testing equipment. Load was gradually applied at a rate of 140 kg/cm2 per minute until the specimen broke.

Flexural Strength = PL/bd^2

Where:

P=failure load in N

L=effect span of the beam

b= width of beam

d= depth of beam

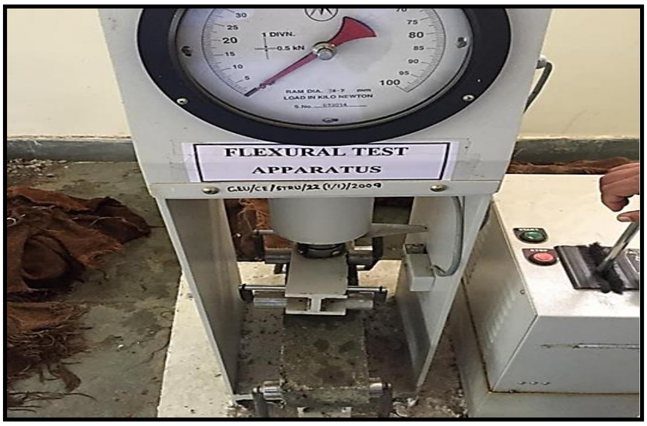


Figure 11: Loading on Beam under Flexural Testing Machine (FTM)

IV. RESULTS & DISCUSSIONS

The processes used to produce the experimental results, including material testing, mixture proportions, mixing, casting, and curing of cubes, are described in further detail in the sections below. The lab served as the location for all of the experiments.

Table 14: Details of Specimens Prepared for Study

Mix No.	Mix Design	% of GF Used
1.	M1	0.0
2.	M2	0.5
3.	M3	0.7
4.	M4	0.9
5.	M5	1.2
6.	M6	1.5
7.	B1	0.0
8.	B2	0.5
9.	B3	0.7
10.	B4	0.9
11.	B5	1.2
12.	B6	1.5

4.2 Compressive Strength (CS):

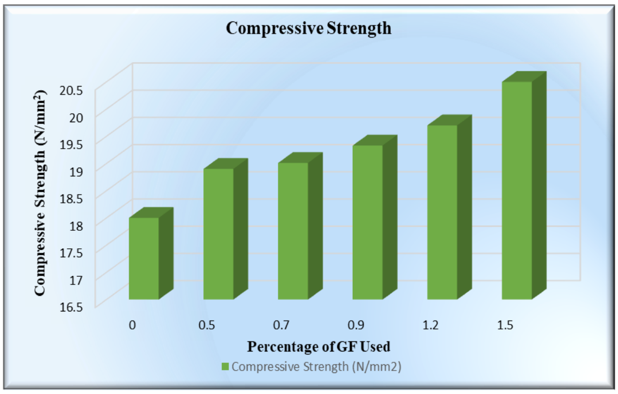
The compressive strength obtained is the average of three results obtained from three same cubes. The compressive strength of fiber glass concrete cube was found out after seven, fourteen and twenty-eight days for cubes and at after twenty- eight days for beams. The results of compressive strength after testing is given below:

4.3.1 Seven Days Compressive Strength:

Results of compressive strength of fiber glass concrete mix cube after seven days for M-20 grade of concrete is shown in below graph 1.

The below graph 1 shows the variation between the Compressive strength and percentage of fiber glass. The fiber glass is added at the rate of 0, 0.5, 0.7, 0.9, 1.2, and 1.5 percent. Out of these results, it was found that the compressive strength is very high at 1.5 percent after seven days and is 20.5 N/mm^2.

 DOI : 10.35291/2454-9150.2022.0453

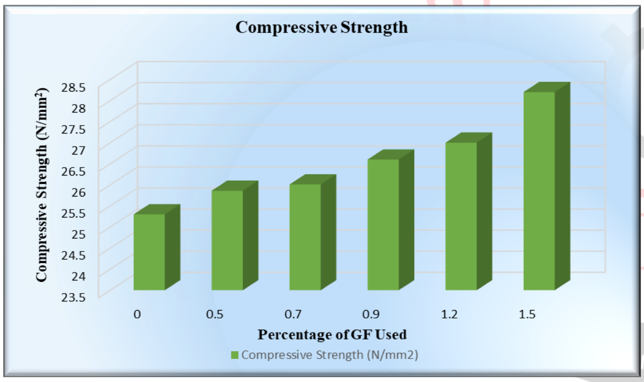


Graph 1: Seven Days Disparity between CS & percentage of GF Used

4.3.2 Fourteen Days Compressive Strength:

Results of compressive strength of fiber glass concrete mix cube after 14 days for M20 grade of concrete is shown in below graph 2:

The below graph 2 shows the variation between the Compressive strength and percentage of fiber glass. The fiber glass is added at the rate of 0, 0.5, 0.7, 0.9, 1.2, and 1.5 percent. Out of these results, it was found that the compressive strength is very high at 1.5 percent after seven days and is 28.2 N/mm^2.

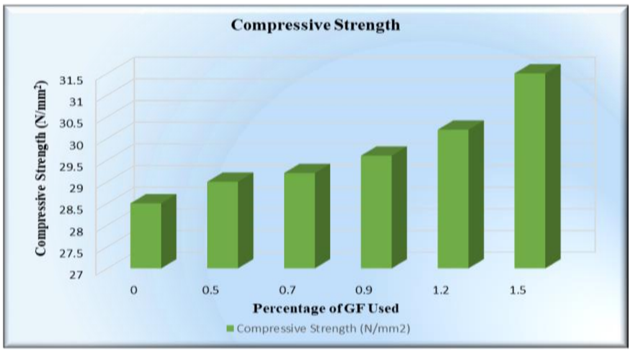


Graph 2: Fourteen Days Disparity between CS & percentage of GF Used

4.3.3 Twenty-Eight Days Compressive Strength:

Results of compressive strength of fiber glass concrete mix cube after twenty- eight days for M-20 mix of concrete is shown in below graph 3.

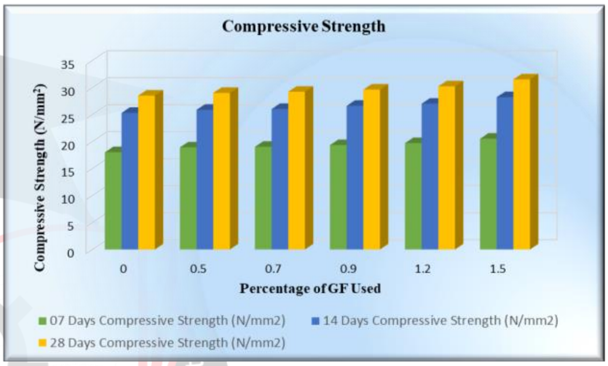
The graph 3 shows the variation between the Compressive strength and percentage of fiber glass. The fiber glass is added at the rate of 0, 0.5, 0.7, 0.9, 1.2, and 1.5 percent. Out of these results it was found that the compressive strength is very high at 1.5 percent after for twenty-eight days is 31.5 N/mm^2.



Graph 3: Twenty-Eight Days Disparity between CS & percentage of GF Used

4.3.4 Comparison of Compressive Strengths (Seven, Fourteen and Twenty Eight Days):

The below graph 4 shows the comparison between seven, fourteen and twenty eight day of compressive strengths of M-20 fiber glass concrete.



Graph 4: 07 Days, 14 Days & 28 Days Disparity between CS & percentage of GF Used

4.3 Flexural Strength (FS):

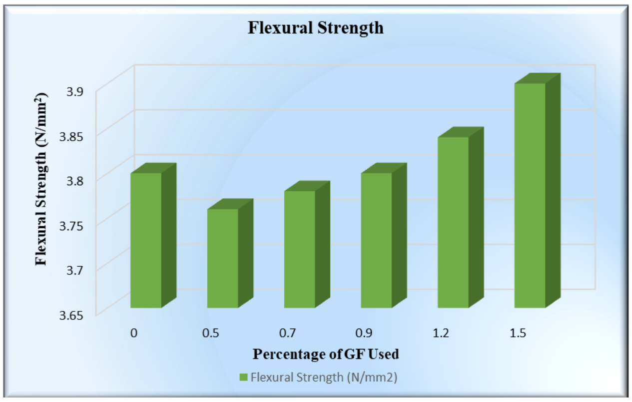
The flexural strength of fiber glass concrete cubes after twenty-eight days is shown in below graph 5.

4.3.1 Twenty-Eight Days Flexural Strength:

Results of FS of fiber glass concrete mix cube after twenty- eight days for M-20 mix of concrete is shown in below graph.

The graph 5 represents the Flexural strength and percentage of fiber glass. The fiber glass is added at the rate of 0.0, 0.5, 0.7, 0.9, 1.2, and 1.5 percent. Out of these, the Flexural strength is very high at 1.5 percent after for twenty-eight days 3.9 N /mm^2.

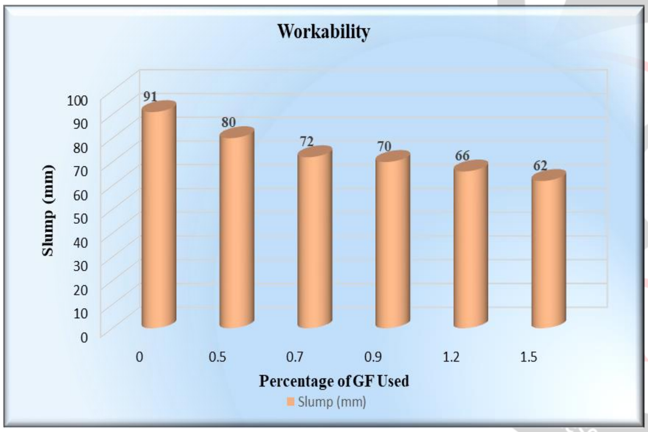
 DOI : 10.35291/2454-9150.2022.0453



Graph 5: Twenty-Eight Days Disparity between FS & percentage of GF Used

4.4 Workability:

Workability test was performed by using slump moulds, as it is the quick measure of workability of concrete mixes than others. The graph 6 represents the graph between the Slump and percentage of fiber glass. The fiber glass is added at the rate of 0.0, 0.5, 0.7, 0.9, 1.2, and 1.5. According to graph the slump value goes on decreasing as the percentage of fiber glass is increased.



Graph 6: Comparison between Workability & Percentage of GF Used

V. Conclusion & Scope

5.1 Conclusion:

- The compressive strength of M-20 grade concrete increased by 1.5 percent at seven, fourteen, and twenty-eight days, according to the results of this investigation.
- A 1.5 percent improvement in flexural strength for M-20 concrete at twenty-eight days is noted.
- Compressive strength has been shown to be somewhat increased when compared to regular concrete.
- The inclusion of fibre lowered the workability of concrete by 1%.
- Compressive strength after seven days is 1.5 percent, 20.5 N/mm^2 after 14 days, and 31.5 N/mm^2 after twenty-eight days.
- For twenty-eight days, the flexural strength is 3.9 N/mm^2, which is extremely high at 1.5 percent.
- It has been shown that the slump gradually decreases as compared to conventional concrete.

5.2 Scope:

The following are a few suggestions for further research based on the findings of this study:

- Other concrete classes, such as common Portland cement grades 33 and 53, can be tested for workability.
- Water cement ratios of 0.45 and 0.50 can be used to test workability.
- The compressive strength of glass fibre may be tested by adding it to cement at a rate of 3.5-04 percent.
- The flexural strength of glass fibre may be tested by adding it to cement at a rate between 3.5 percent and 4 percent

Acknowledgment

I wish to express my special thanks and deepest regards to my supervisor Mr. Brahmjeet Singh, Assistant Professor, Civil Engineering Department, for providing me invaluable guidance, suggestions, and support, which have helped me to submit this thesis report in time. Without his wise counsel and able guidance, it would have been impossible to complete the present work.

I also extend my sincere gratitude and thanks to Dr. Sandeep Singla, Head of Department for valuable advice and suggestions during the dissertation work.

The paucity of words does not compromise for extending my thanks to family, whose love, inspiration and blessing helped me in completing the research report. I wish to thank all my batch mates of Master of Technology for their time-to-time suggestions and cooperation.

In the last but not the least, I thank and owe my deepest regards to all who have helped me directly or indirectly.

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