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ANALYZING THE PERFORMANCE OF REINFORCED CONCRETE WITH GLASS FIBERS: A STUDY

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Abstract *Fibre Reinforced Concrete is a composite material consisting of mixtures of cement, fine and coarse aggregates and discrete, discontinuous, uniformly dispersed suitable fibres such as steel fibres, glass fibres and natural fibres etc., used in civil engineering and other applications. Fibre is a small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat. Conventional concrete has poor tensile strength so its capacity to absorb energy is limited. By strengthening the cement concrete matrix with reinforcing fibrous materials the weakness in the tension zone can be overcome. Compressive strength, Tensile strength and Young's modulus of the materials can be improved by the usage of fibres in concrete. The concrete is porous and the porosity is due to water-voids and air-voids. Due to presence of voids naturally strength of the concrete reduces. The addition of Glass fibres to the cement concrete matrix gradually increases the strength. GFRC has advantage of being light weight and thereby reducing the overall cost of construction, ultimately bringing economy in construction.*

In the present work, 36 specimens were casted and the tests were conducted for compressive strength and split tensile strength for M30 grade concrete mix, where the concrete was reinforced with different percentages i.e., 0%, 0.5%, 1%, 1.5%, 2% and 2.5% of Glass fibres by the volume of cement and strengths were found out for 7,14 and 28 days respectively.

I.INTRODUCTION:

Cement concrete is a well-known construction material in the field of civil engineering and it has a several desirable properties like high compressive strength, stiffness, durability under usual environmental Conditions. At the same time concrete is brittle and possess a very low tensile strength. It is having widespread application and it gives strength at a comparative low cost. The disadvantage of cement concrete is the emission of carbon-di-oxide gas during the production of cement clinker. Concrete has some deficiencies like low tensile strength, a low strain at facture, low post cracking capacity, brittleness and low ductility, limited fatigue life and low impact strength. From many researches it has been shown that, reinforcing concrete in tensile one or in both zones can yield a composite of good compressive and tensile strength. But in order to obtain ductility and durability the cracks should be minimize. The presence of cracks is responsible for weakness of cement concrete. This weakness can be removed by the addition of fibres in the concrete mixture and it increases its toughness or ability to resist the crack and also develops tensile strength and flexural strength. Such a concrete is called as fibre-reinforced concrete.

1.1 Fibre Reinforced Concrete

Fibre reinforced concrete is a composite material comprising of mixture of concrete mortar or cement mortar with discrete, discontinuous, uniformly dispersed appropriate fibres. The addition of fibre to the concrete makes its components tough and ductile. Already many type of fibres been used in concrete but not all the fibres can be used efficiently and economically. Each and every type of fibres has its own properties and boundaries. Addition of fibres into cement concrete not only increases the tensile and flexural strength but also minimizes the cracks. The characteristics like toughness and impact resistance can be improved by addition of fibres to the concrete have been shown by many researchers. Fibres include steel fibres, glass fibres, synthetic fibres and natural fibres. Fibres of various shapes and sizes produced from steel, plastic, glass and natural material are being used. Principles of Fibre Reinforced Matrix

When a load is applied on a body which consist of a fibre embedded in a surrounding matrix, the fibre contributes to the load carrying capacity of the body when the load is transmitted through the fibre ends.The fibre reinforced matrix is essential to fulfil the following functions:

a) The load transfer generally rises as a result of different physical properties of the

fibre and matrix. The incorporation of fibre into brittle cement matrix increases the

fracture toughness of the compound by crack arresting process. As fibre have large

value of failure strains, they give up extensibility in composite problems.
b) To bind the matrix together and to safeguard their surfaces from destruction during
the handling, fabrication and service life of the composite.
c) To disperse the fibres and discrete them so as to evade any catastrophic propagation
of cracks and subsequent failure by adhesion-friction, where composite is under load.

1.2 Types of Fibres

From many decades Fibres are used in construction industry as a productive material. Fibres are small piece of reinforcing material having different characteristic properties. The Fibres can be circular or flat, which is often termed by a parameter called aspect ratio which is well-defined by its length to diameter ratio. Fibre ranges from 30 to 150 is the standard aspect ratio. Fibres can be broadly classified into two types

- Natural Fibres
- Artificial Fibres

1.2.1 Natural Fibres

Fibres are hair-like materials that are continuous filaments or discontinuous or in discrete elongated pieces, similar to pieces of thread. Fibres can be used as component of composite materials. The earliest evidence for humans using fibres is the discovery of wool and dyed flax fibres found in a prehistoric cave in the Republic of Georgia that date back to 36000 BP. The natural fibre consists of plant fibre, animal fibre and a man-made fibre consists of Synthetic fibres and regenerated fibres. Natural fibres can be used as matted into sheets to make products such as felt or paper. Some of the natural fibres used in the reinforced concrete are Cotton, Coir (Coconut fibre) and Vegetable fibres.

1.1.1.1.1 Cotton fibre

Cotton fibre is the most important fibres used in the textile industries world-wide. Picking is highly labour-intensive, and on large scale is often carried out by machine in some countries picking is carried out by hands this picked so called Cotton Wool is baled. In comparison with other natural fibres cotton fibres are weak. The cotton fibres can absorb moist up to 20% off its dry weight, without feeling wet and it is a good conductor of heat. Clothes, carpets, blankets, medical cotton wool and mobs can be manufactured by cotton.

Figure 0.1 Cotton Fibre

1.1.1.1.2 Coir (Coconut fibre)

Coir is obtained from the husk of the fruit of the coconut palm. The trees can grow up to the height of 20m, making harvesting a difficult job. To pick the nuts from the tree trained monkeys or people climb the tree, or a pole with an attached knife is used. The picked coconuts are de-husked with on a spike and after retting, the fibres are extracted from the husk with beating and washing. The coconut fibres are strong, light and easily withstand heat and salt water. After 9-10 months of growth, the nuts are still green in colour and it contains white fibre, this can be used for production of rope, yarn and fishing nets. After 12-13 months of growth, the fibres are brown and can be used for brushes and mattresses.

Figure 0.2 Coir Fibre

1.1.1.1.2.1 Vegetable Fibres

Vegetable fibres are derived from plants. They are classified according to their source in plants as leaf, bast, or seed-hair. The fibres in leaf and bast will provide strength and support to plant structure. Vegetable fibres are usually stiffer but less tough than synthetic fibres. The bast fibres are flax, jute, and hemp. The leaf fibres are abaca and sisal. Vegetable fibres are graded according to colour, lustre, strength, fineness, cleanliness and uniformity.

Figure1.3: Vegetable fibre

1.2.2 Artificial Fibres

Artificial fibres or synthetic fibres are the result of extensive research by scientists to improve on naturally occurring animal and plant fibres. Synthetic fibres are created by forcing, usually through extrusion, fibre forming materials through holes into the air and water forming a thread. Before synthetic fibres were developed, artificially manufactured fibres were made from polymers obtained from petro chemicals. These fibres are called synthetic fibres and also called artificial fibres. Some of the artificial fibres used in the reinforced concrete are Carbon fibres, Polymer fibres, Steel fibres and Glass fibres.

1.1.1.1.3 Carbon Fibres

Carbon Fibre-reinforced plastic (CFP) or Carbon Fibre-reinforced polymer (CFRP) or Carbon Fibre-reinforced thermoplastic (CFRT) is an extremely strong and light fibre-reinforced polymer which contains carbon fibres. Carbon fibres are expensive to produce but whenever high strength-to-weight ratio and rigidity are required will be used in aerospace, automotive and civil engineering to increase the technical applications.

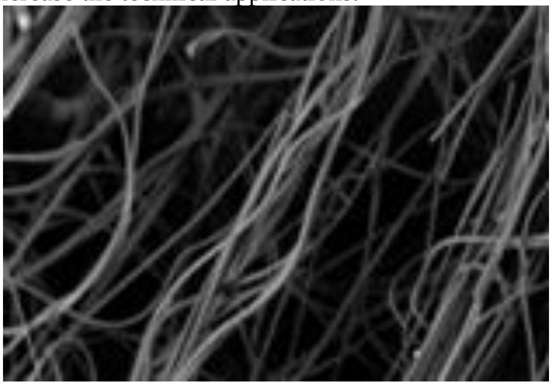

Figure 0.4 Carbon Fibre

1.1.1.1.4 Polymer Fibres

The chemical compounds from which man-made fibres are produced are known as polymers. The polymer fibres are manufactured from whose chemical composition, structure, and properties are significantly modified during the process. Some of the polymers constitute man-made fibres are the same as or similar to compounds that make up plastics, rubbers, adhesives and surface coatings.

Figure 0.5 Polymer Fibre

1.1.1.1.5 Steel Fibres

Steel fibres are the most frequently used fibres. Steel fibres have higher tensile strength. Steel fibres added into the concrete to improve the crack resistance capacity of the concrete. Less labour is required. Less construction time is required. It leads to increase in many properties related to cracking which are ductility, toughness, thermal loading, and the resistance to impact and energy absorption. Some of the types of steel fibres are straight slit, hooked end, crimped and paddled steel fibres.

Figure 0.6 Steel Fibre

Glass fibre Reinforced concrete

Glass fiber reinforced composite materials consist of high strength glass fiber embedded in a cementations matrix. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the components acting alone. In general fibers are the principal load-carrying members, while the surrounding matrix keeps them in the desired locations and orientation, acting as a load transfer medium between them, and protects them from environmental damage.

Glass fibre is a material consisting of numerous finely chopped fibres of glass. Glass wool is one of the products called "fibreglass"; it was invented in 1932-1933 by Russell Games Slayter of Owens-Corning, as a material to be used as thermal building insulation. Glass fibre has roughly comparable mechanical properties to other fibres such as carbon fibres and polymer fibres. Glass fibres are found in continuous or chopped lengths. Fibre lengths of up to 35mm are used in spray applications and 25mm lengths in premix applications. The Glass fibres have advantages like Excellent workability, Homogeneous mix, invisible on the finished surface, glass fibres does not corrode, Glass fibres controls and prevention of cracking in fresh concrete, it is very effective at very low dosage, Glass fibres are safe and easy to handle.

The glass fibres used are of ANTI-CRAK® HD – chopped strands for plastic shrinkage control with fibre length of 12mm, filament diameter of 14µm, modulus of elasticity 72 Gpa, Specific gravity 2.68 and having the aspect ratio of 857:1. The numbers of fibres per Kg is 212 million fibres.

Figure 0.7 Glass Fibre

GFRC History and Application

GFRC was originally developed in the 1940's in Russia, but it wasn't until the 1970's that the current form came into widespread use.

Commercially, GFRC is used to make large, lightweight panels that are often used as façades. These panels are considered non-structural, in that they are designed to support their own weight plus seismic and wind loadings, much in the way glass window curtain walls are designed. The panels are considered lightweight because of the thinness of the material, not because GFRC concrete has a significantly lower density than normal concrete. On average it weighs about the same as ordinary concrete on a volume basis.

Façade panels are normally bonded to a structural steel frame which supports the panel and provides connection points for hanging.

Structural Properties of GFRC

GFRC derives its strength from a high dosage of AR glass fibers and a high dosage of acrylic polymer. While 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.

GFRC does not replace reinforced concrete when true load carrying capacity is required. It's best used for complex, three dimensional shells where loads are light. Applications where GFRCmakes the most sense are fireplace surrounds, wall panels, vanity tops and other similar elements. GFRC's advantage is minimized when ordinary flat countertop-shaped pieces are being made. While the weight savings due to reduced thickness is maintained, the effort of forming, mixing and casting are similar or the same.

1.3 Classification of Fibre Reinforced Concrete

1.3.1 Low volume Fraction (<1 percent).

- The fibres are used to reduce shrinkage cracking. These fibres are used in pavements and slabs that have large exposed surface leading to high shrinkage crack.
- Disperse fibres offer various advantages of wire mesh and steel bars to reduce shrinkage cracks.
- The fibres are uniformly distributed in three-dimensions making an efficient load distribution.
- The fibres are less sensitive to corrosion than the reinforcing steel bars.
- The fibres can reduce the labour cost of placing the bars and wire mesh.

1.3.2 Moderate volume fraction (between 1 and 2 percent)

- The presence of fibres at this volume fraction increases the modulus or rupture, fracture toughness and impact resistance. These composites are used in construction methods such as shotcrete and in structures that require energy absorption capability, improved capacity against delamination, spalling and fatigue.

1.3.3 High volume fraction (>2 percent)

- The fibres used at this level lead to strain-hardening of the composites. Because of this improved behaviour, these composites are often referred as high-performance fibre-reinforced composites (HPFRC). In the last decade, even better composites were developed and are referred as ultra-high-performance fibre-reinforced concretes.

The Fibers in GFRC- How They Work

The glass fibers used in GFRC help give this unique compound its strength. Alkali resistant fibers act as the principle tensile load carrying member while the

polymer and concrete matrix binds the fibers together and helps transfer loads from one fiber to another. Without fibers GFRC would not possess its strength and would be more prone to breakage and cracking.
Understanding the complex fiber network in GFRC is a topic in and of itself. *Stay tuned,*
Casting GFRC
Commercial GFRC commonly uses two different methods for casting GFRC: spray up and premix. Let's take a quick look at both as well as a more cost effective hybrid method.
Spray-Up
The application process for Spray-up GFRC is very similar to shortcrete in that the fluid concrete mixture is sprayed into the forms. The process uses a specialized spray gun to apply the fluid concrete mixture and to cut and spray long glass fibers from a continuous spool at the same time. Spray-up creates very strong GFRC due to the high fiber load and long fiber length, but purchasing the equipment can be very expensive ($20,000 or more).
Premix
Premix mixes shorter fibers into the fluid concrete mixture which is then poured into moulds or sprayed. Spray guns for premix don't need a fiber chopper, but they can still be very costly. Premix also tends to possess less strength than spray-up since the fibers and shorter and placed more randomly throughout the mix.
Hybrid
One final option for creating GFRC is using a hybrid method that uses an inexpensive hopper gun to apply the face coat and a handpacked or poured backer mix. A thin face (without fibers) is sprayed into the molds and the backer mix is then packed in by hand or poured in much like ordinary concrete. This is an affordable way to get started, but it is critical to carefully create both the face mix and backer mix to ensure similar consistency and makeup. This is the method that most concrete countertop makers use.
Some of the many benefits of GFRC include:

- **Ability to Construct Lightweight Panels**– Although the relative density is similar to concrete, GFRC panels can be much thinner than traditional concrete panels, making them lighter.
- **High Compressive, Flexural and Tensile Strength**– The high dose of glass fibers leads to high tensile strength while the high polymer content makes the concrete flexible and resistant to cracking. Proper reinforcing using scrim will further increase the strength of objects and is critical in projects where visible cracks are Literature Review

II.LITERATURE REVIEW

A brief review of literature surveys which are concerning to various parameters like mechanical properties and strength properties of Glass Fibre Reinforced Concrete are discussed in this chapter.

[1]ShrikantHarle and Prof. Ram Meghe have conducted compressive strength and tensile strength on M-30 grade of concrete for 28 days' strength using Alkali Resistant (AR) Glass Fibres of 0.03% and 0.5% by weight of concrete and have observed 15% to 20% increase in strength. Glass Fibres used here is Cem-Fill Anti Crack which are usually are usually round and straight with diameters from 0.005 mm to 0.015 mm. They can be also bonded together to produce the bundle of glass fibers with diameter up to 1.3 mm.

[2]Dr.P.SrinivasaRao, ChandraMouli.K and Dr.T.Seshadri have experimented on Sulphate Resistance, Rapid Chloride Permeability, Workability and Bleeding on use of Glass Fibres in Concrete. Concluding that the durability of concrete from the aspect of resistance to acid attack on concrete increases by adding AR-glass fibers in concrete. It was observed that there was no effect of sulphates on concrete. Chloride permeability of glass fibre reinforced concrete shows less permeability of chlorides into concrete when compared with ordinary concrete. The glass Fibres Bridge across the cracks causing interconnecting voids to be minimum.
[3]Kavita S Kene, Vikrant S Vairagade and SatishSathawane have concluded from their experiments of Glass Fibre Reinforced Concrete that .5% reduces cracks by addition of steel fibres under different loading conditions and the brittleness of concrete can also be improved by addition steel fibres than glass fibres. Since concrete is very weak in tension, the steel fibres are beneficial in axial-tension to increase tensile strength.
[4]R.Gowri, M.AngelineMary, have observed that higher percentages of Glass wool fibres greater than one percentage affect the workability of concrete, and may require the use of super plasticizers (workability agents) to maintain the workability. As the percentage of fibre content by total weight of the concrete increases from 0.025%-0.075% the compressive strength of the concrete also increases from 5.15% to 15.68% at 28 days. Also from the split tensile strength test it was found that, the strength at 28 days' increases by 20.41% to 29% due to the addition of glass wool fibres varying from 0.025%-0.075%. The flexural strength of glass wool fibre concrete is also found have a maximum increase of 30.26% at 0.075% of fibre content. It was observed that, the percentage increase in the strength of glass wool fibre reinforced concrete increases with the age of concrete. Also it was found from the failure pattern of the specimens, that the formation of cracks is more in the case of concrete without fibres than the glass wool fibre reinforced concrete. It shows that the presence of fibres in the concrete acts as the crack arrestors. The ductility characteristics have improved with the addition of glass wool fibres. The failure of fibre concrete is gradual as compared to that of brittle failure of plain concrete.

[5]Suresh Babu.R, Rakesh.A.J and Ramkumar.V.Rhave observed that the addition of glass fibre in concrete offers a holistic solution to the problem of permeability in concrete, increase the concrete strength and at the same time reducing the environmental impact. The permeability index value gets reduced due to addition of glass fibre, it is about 6.4% by the addition of 0.5%, 12.6% by the addition of 1% and 26.3% by the addition of 1.5% of glass fibre in M-25 concrete when compared to control concrete. Similarly, for M-50 concrete, the permeability value is about 8.7% by addition of 0.5% of glass fibre, 15% by addition of 1% of glass fibre and 30.1% by addition of glass fibre to that of control concrete. The compressive strength increased by about 16.4% by the addition of 0.5%, 24.7% by the addition of 1% and 47.3% by the addition of 1.5% of glass fibre in M-25 concrete when compared to 0% of glass fibre in concrete. Similarly, for M-50 concrete, the permeability value is about 14.3% by addition of 0.5% of glass fibre, 22.3% by addition of 1% of glass fibre and 43.5% by addition of glass fibre to that of 0% glass fibre in concrete. The addition of glass fibre in concrete will have better effect on high grade of concrete for permeability and lower grade of concrete for compression test due to quantity of cement content, water-cement ratio and the ratio of fine aggregate to coarse aggregate.

[6]AvinashGornale, S Ibrahim Quadri, S MehmoodQuadri, Syed MdAkram Ali, Syed ShamsuddinHussaini. It has been observed that the workability of concrete decreases with the addition of Glass Fibres. But this difficulty can be overcome by using plasticizers or super-plasticizers.The increase in Compression strength, Flexural strength, Split tensile strength for M-20, M-30 and M-40 grade of concrete at 3, 7 and 28 days are observed to be 20% to 30%, 25% to 30% and 25% to30% respectively when compared with 28 days strength of Plain Concrete It has been also observed that there is gradual increase in early strength for Compression and Flexural strength of Glass Fibre Reinforced Concrete as compared to Plain Concrete, and there is sudden increase in ultimate strength for Split tensile strength of Glass Fibre Reinforced Concrete as compared to Plain Concrete.

[7]J.A.O.Barros, J.A.Figueiras, C.V.D.Veenhave concluded that in fibre reinforced cement based materials, it can be pointed out that, for the fibre contents usually employed in practice, and the post-peak tensile behaviour is the most improved material characteristic. However, difficulties in carrying out valid direct tensile tests have limited the research in this field. The scarcity of investigation on the tensile behaviour of glass fibre reinforced concrete (GFRC) is also probably due to the ageing problems of GFRC systems and the work concerned with the tensile behaviour of GFRC specimens with 28 days of age. The following conclusions can be summarized:

- Fracture energy of cement based materials insignificantly increased by adding glass fibre to the mix composition.
- The tensile strength is largely determined by the fibre orientation which depends on the mixing method. Tensile strength between 4.5 MPa and 5.5 MPa is found for GFRC mixes made with the premix method.
- Smeared crack models based on finite element techniques wherein softening laws and fracture mechanics concepts are included can capture the experimental response.

3.1Workability of Cement Concrete by Slump Test

AIM:
To determine, workability of cement concrete by slump cone test.

APPARATUS:
1. Slump cone
2. Tamping rod
3. Tray
4. Weighing Balance

THEORY:
Unsupported concrete when it is fresh will flow to the sides and sinking in height take place. This vertical settlement is known as slump. Slump is a measure indicating the consistency or workability of cement concrete and slump also gives an idea of W/C ratio needed for concrete to be used for different works. Concrete is said to be workable if it can be easily mixed, placed, compacted and finished. A workable concrete should not show any segregation or bleeding. Segregation tries to separate out from the finer material and we get concentration of coarse aggregate at one place. This result in large voids, less durability and less strength. Bleeding of concrete is said to occur when excess water comes up at the surface of concrete. This causes small pores through the mass of concrete and is undesirable.

PROCEDURE:
- Take the calculated amount of coarse aggregate, fine aggregate and cement. The volume of concrete mix should not be less than $0.00583m^3$ (volume of slump cone).
- Mix the dry constituents thoroughly to get a uniform colour.
- Take off the top with a trowel or tamping rod so the mould is exactly filled.
- Remove the cone immediately raising it slowly and carefully in vertical direction.

- As soon as the concrete settlement comes to a stop measure the subsidence of concrete which gives the slump.

3.2 Normal Consistency of Cement

AIM:
To determine standard consistency of given cement sample.

APPARATUS:
1. Vicat Apparatus
2. Trowel
3. Measuring Jar
4. Balance
5. Stopwatch
6. Glass Plate

THEORY:
Consistency is defined as the percentage water to be added to get a paste such that the plunger penetrates up to a mark 5-7mm from bottom. It is the paste of certain standard solidity which is used to fix the quantity of water to be mixed in cement before performing tests for tensile strength, setting time and soundness.

PROCEDURE:
- Fix the standard consistency plunger to the Vicat apparatus and note down the initial reading allowing the plunger to touch bottom glass plate.
- Take 400g of cement.
- Add about 24% of water and mix thoroughly and level the surface
  of the paste.
- Allow the needle to penetrate and note down the final reading

3.3 Setting Time of Cement

AIM:
To determine the initial setting time and final setting time of cement.

THEORY:
The initial set is a stage in the process of hardening after which any crack that may appear will not reunite on the other hand finally set when it has obtained sufficient strength and hardness.

APPARATUS:
1. Vicat apparatus
2. Trowel
3. Measuring Jar
4. Balance, Stopwatch
5. Glass plate.

PROCEDURE:
- Take 400grams of cement and add 0.85P water, where P = standard consistency.
- Thoroughly mix, the gauging time is kept between 3-5 minutes.
- Level the top surface and start the stopwatch at the instant when the water is added.
- Note down the initial reading by touching the needle to the bottom glass plate.
- Release the needle at a regular interval until the needle fails to penetrate the block for about 5mm measured from the bottom of the mould.
- For finding the final setting time replace the needle and release the needle at regular interval until a stage at which the needle fails to make a indent. This is called the final setting time.

3.4 Specific Gravity of Cement

AIM:
To determine the specific gravity of cement.

APPARATUS:
1. Weighing balance
2. Specific gravity bottle
3. Kerosene
4. Cement

THEORY:
The specific gravity of cement is the ratio of the weight of a given volume of substance to the weight of an equal volume of water. Specific gravity is normally used in mixture proportioning calculations. The specific gravity of Portland cement is generally around **3.15** while the specific gravity of Portland-blast-furnace-slag and portland-pozzolan cements may have specific gravities near **2.90**.

PROCEDURE:
- Weigh the dry specific gravity bottle, W_1g.
- Fill the bottle with water, let the weight be W_2g.
- Remove the water and fill the bottle with kerosene, let the weight be W_3g.
- Pour some of the kerosene out and introduce, weighed quantity of cement into the body. Roll the bottle gently into inclined position until no further air bubbles rise to surface. Fill the bottle to the top with kerosene and weigh it. Let the weight be W4g.
  - Then,

Specific gravity of kerosene (S_k) = $\frac{(W_3 - W_1)}{(W_2 - W_1)}$

Specific gravity of cement (S_c) = $\frac{W_5\,(W_3 - W_1)}{(W_5 + W_3 - W_4)(W_2 - W_1)}$

3.5 Specific Gravity and Water Absorption Test on Aggregates

AIM:
To determine the Specific gravity and water absorption of coarse aggregates.

APPARATUS:
1. Density basket
2. Weighing balance
3. Water tank
4. Tray
5. I.S sieves - 10mm and 20mm

THEORY:

Specific gravity is a measure of a material's density (mass per unit volume) as compared to the density of water at 73.4°F (23°C). Stones having low specific gravity are generally weaker than those with higher specific gravity values. Absorption, which is also determined by the same test procedure, is a measure of the amount of water that an aggregate can absorb into its pore structure.

PROCEDURE:

- Take about 2kg of given aggregates passing through I.S 20mm sieve and retained on 10 mm sieve
- Keep the aggregate in density basket and then immerse the bucket in water.
- Allow the aggregate and basket to be in the water for 24 hours
- After 24 hours find the suspended weight of the basket with aggregate
- Remove the basket up of the water and remove the aggregate
- Keep the empty basket back into the water and find the suspended weight
- Wipe the surface of the aggregates using a cloth to make them surface dry
- Find the weight of surface dry aggregates.
- Keep the aggregates in oven at 110 °C for 24 hours.
- Now find the weight of oven dried aggregates.
- Calculate the specific gravity and water absorption from the relation:

$$\text{Specific gravity} = \frac{W_4}{W_3-(W_1-W_2)}$$

$$\text{Water absorption} = \frac{W_3-W_4}{W_4} \times 100 \ldots\ldots\%$$

Design/Experimentation

Cement, m-sand and coarse aggregates are weighed and batched according to the mix proportions of M30 grade concrete proportioned as per the guidelines in IS-10262-2009. The varying percentages of glass fibres by 0%, 0.5%, 1%, 1.5%, 2% and 2.5% of cement were casted and test done for 7 and 28 days.

Initially weighed cement, m-sand and coarse aggregate are mixed properly in dry condition. To the same mix, add varying percentages 0%, 0.5%, 1%, 1.5%, 2% and 2.5% of glass fibres by the weight of cement and mix properly to get the mix with uniformly dispersed fibres. Add 0.5% of Super Plasticizer Conplast-SP430 by the weight of cement to the water and mix thoroughly. The mixed water is added to the dry mix and mix properly as shown in figure 3.5. Cube dimension 150mm x 150mm x 150mm for compressive strength, Cylinder dimension 150mm diameter x 300mm height for split tensile strength were casted, cured in water for 7 and 28 days respectively as shown in figure 4.5 and tested for 7 and 28 days respectively.

Cubes and Cylinders were casted to find compression strength and split tensile strength of varying percentages 0%, 0.5%, 1%, 1.5%, 2% and 2.5% of glass fibres. The graph of compressive strength versus percentage of glass fibres added was plotted, the percentage of glass fibre achieving greater compressive strength is found for 7 and 28 days respectively. The graph of split tensile strength versus percentage of glass fibres added was plotted, the percentage of glass fibre achieving greater split tensile strength is found for 7 and 28 days respectively.

Figure 3.1 Mixing of coarse aggregate and fine aggregate

Figure 3.2 Mixing of glass fibres, Cement, coarse & fine aggregate

Figure 3.3 : Solution of Super Plasticizer and Water

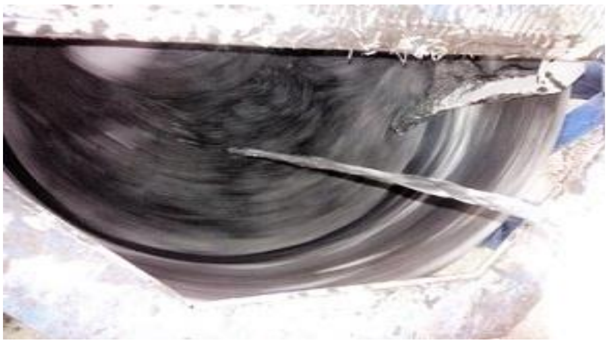

Figure 3.4 Mixing of Solution to aggregates and glass fibres

Figure 3.5 Casting of M30 grade Glass Fibre Reinforced Concrete

Figure 3.6 Curing of Specimens

3.1Materials Used

In this present work to cast the specimens the following materials are used

1) Potable water for mixing and curing of concrete.
2) Ordinary Portland Cement 53 grade confirming to IS: 12269-1987
3) Manufacturer sand, confirming to IS: 383-1970
4) Coarse aggregate, confirming to IS: 383-1970
5) Glass fibres of effective length 12mm and equivalent diameter 14μm having the aspect ratio of 857:1.
6) Chemical Admixture: Super Plasticizer Conplast-SP430.

3.1.1 Water

In this present work the water used in design mix is potable water from the supply network system; so, it was free from suspended solids and organic materials which might have affected the properties of the fresh and hardened concrete.

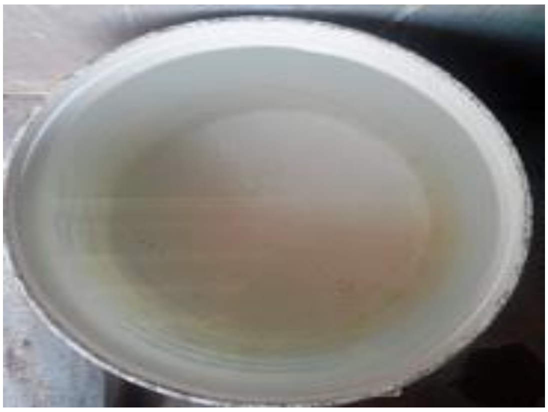

Figure 3.1.1 Potable Water for mixing and curing.

3.1.2 Cement

Here, in this present work the Ordinary Portland Cement (53 Grade), confirming to IS: 12269-1987 has been used as shown in figure. Chemical composition of cement is given in table and Physical properties of the cement were determined and the requirements as per IS: 12269-1987 is given in Table.

Table3.1.2 Chemical composition of Cement

Oxides	% content
CaO	60-67
SiO_2	17-25
Al_2SO_3	3-8
Fe_2O_3	0.5-6.0
MgO	0.1-0.4
Alkalies	0.1-1.3
SO_3	1.0-3.0

Table 3.1.2 Physical Properties of Cement

Sl. No	Properties	Obtained Values	Requirements as per IS: 12269-1987
1.	Setting Time Initial Setting Time Final Setting Time	 90 min 380 min	 Not less than 39 min Not more than 600 min
2.	Standard Consistency	32%	-----
3.	Specific Gravity	3.09	-----
4.	Compressive Strength (As provided by Manufacturer) 3 days 7 days 28 days	 39.5 N/mm^2 51 N/mm^2 70 N/mm^2	 Not less than 27 N/mm^2 Not less than 37 N/mm^2 Not less than 53 N/mm^2

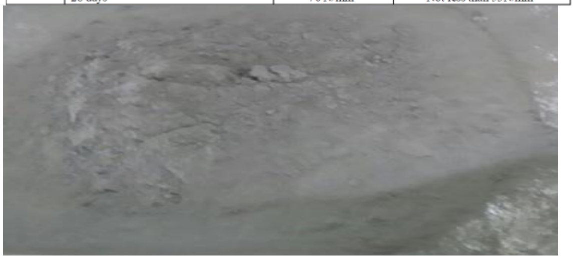

Figure 3.1.2 Ordinary Portland cement - 53 Grade

3.1.3 Fine aggregates

Fine aggregate (Manufacturer sand) passing through IS Sieve Designation of 4.75mm sieve has been used with water absorption of 1.5% as shown in figure. The result of sieve analysis conducted is tabulated in Table and it confirms to Zone I as per the specifications of IS: 383-1970.

Table 3.1.3 Characteristics of Fine Aggregates and Test results

Characteristics of Fine Aggregate (Manufacturer Sand)					
1.	Specific Gravity		2.62		
2.	Fineness Modulus		2.64		
3.	a) Dry compacted bulk density		1665 kg/m^3		
	b) Loose bulk density		1453 kg/m^3		
4.	Sieve Analysis:				
IS Sieve Designation	Cumulative Percentage		Specification as per IS: 383-1970 (Percentage Passing)		
	Retained	Passing	**Zone I**	Zone II	Zone III
4.75mm	1.65	98.35	**90-100**	90-100	90-100
2.36mm	8.32	91.68	**60-95**	75-100	85-100
1.18mm	31.66	68.34	**30-70**	55-90	75-100
600µm	66.23	33.77	**15-34**	35-90	60-79
300µm	82.89	18.11	**5-20**	8-30	12-40
150µm	98.96	1.04	**0-10**	0-10	0-10

Figure 3.1.3 Fine Aggregate (Manufacturer Sand)

3.1.4 Coarse aggregates

Coarse Aggregate of size 20mm maximum and retained on IS Sieve Designation of 12.50 mm sieve has been used with water absorption of 1% as shown in figure. The result of sieve analysis of combined aggregates are conducted and tabulated in Table and it confirms to as per the specifications of IS: 383-1970 for graded aggregates.

Table 3.1.4 Characteristics of Coarse Aggregates and Test results

Characteristics of Coarse Aggregate of size 20mm				
1.	Specific Gravity		2.68	
2.	Fineness Modulus		6.62	
3.	a) Dry compacted bulk density		1541 kg/m^3	
	b) Loose bulk density		1403 kg/m^3	
4.	Shape		Angular	
5.	Sieve Analysis:			
IS Sieve Designation	Cumulative Percentage		Specification as per IS: 383-1970 in respect of nominal size 20mm aggregate (Percentage Passing)	
	Retained	Passing	**Graded**	Single sized
40.00mm	0	100	**100**	100
20.00mm	4.20	95.80	**95-100**	85-100
12.50mm	70.77	29.23	----	----
10.00mm	73.70	26.30	**25-55**	0-20
04.75mm	95.86	4.14	**0-10**	0-5

Figure 3.1.4 Coarse Aggregate

3.1.5 Glass Fibres

Glass Fibres of effective length of 12mm and equivalent diameter 14µm, having the aspect ratio 857:1 as shown in the figure. Glass fibres Anti-Crack HD Alkali Resistant manufactured by Owen Corning the following Table shows the properties of the Glass fibre as per manufacturer.

Table 3.1.5 Properties of Glass Fibres

1.	Product Form	Monofilament as a result of disposal of fibres on contact with moisture.
2.	Material	Alkali Resistant Glass
3.	Elastic Modulus	72 Gpa
4.	Filament Diameter	14 µm
5.	Specific Gravity	2.68
6.	Length	12mm
7.	Zirconia Content	16.7%
8.	Aspect ratio	857 : 1
9.	Specific Surface Area	105 m^2/kg
10.	Chemical Resistance	Very high
11.	Electrical Conductivity	Very low
12.	Softening point	860ºC – 1580ºF
13.	Tensile Strength	1000 – 1700 Mpa

Results and Discussions

The Various tests conducted on Glass Fibre Reinforced Concrete (GFRC) with Varying percentages of 0%, 0.5%, 1%, 1.5%, 2% and 2.5%. In this chapter the test results are presented numerically and graphically.

4.1 Experimental Test Results

4.1.1 Workability Test Results

The Slump test is conducted to know the Workability of Concrete as shown in the figure. The results of workability tests on different varying percentages of 0%, 0.5%, 1%, 1.5%, 2% and 2.5% are tabulated in the table 4.1.1

Table 4.1.1 : Workability test results of different percentage variations of glass fibres

Percentage of Glass fibres added	Obtained slump in mm
0	102
0.5	96
1.0	92
1.5	89
2	85
2.5	80

Figure 4.1.1 Slump Test

4.1.2 Compressive Strength Test Results

4.1.2.1 Compressive Strength Test Results for 7 days

The compressive strength of Glass Fibre reinforced concrete with the different percentage variations of 0%, 0.5%, 1%, 1.5%, 2% and 2.5% are tested and the obtained results are tabulated in the table and their different variations are plotted in figure for 7 days.

Table 4.1.2 Tabulation for Compressive strength test results of Glass fibre reinforced concrete for 7 days.

Percentage of Glass Fibre added in percentage	Load (kN)			Average Load (kN)	7 days Compressive Strength (Mpa)
	specimen 1	specimen 2	Specimen 3		
0	721.3	715.0	727.8	721.37	32.06
0.5	889.6	951.5	922.2	921.10	40.94
1.0	997.0	953.3	975.6	975.30	43.35
1.5	**1029.6**	**1014.3**	**1015.9**	**1019.93**	**45.33**
2	850.4	840.9	874.7	855.33	38.01
2.5	734.0	761.3	765.8	753.70	33.50

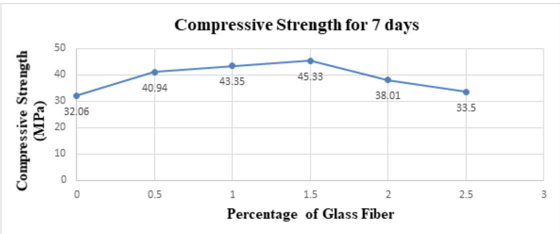

Figure 4.1.2.1 Variation of Compressive strength of Glass fibre reinforced concrete with different percentage variations of Glass Fibres

The compressive strength of Glass fibre reinforced concrete enhance with increase in Glass Fibre quantity up to 1.5% and decreases beyond that. From the above table the maximum strength of Glass fibre is 45.33Mpa is observed. Change in strength with respect to percentage of glass fibre quantity is graphically shown in the above figure.

4.1.3 Compressive Strength Test Results for 28 days

The compressive strength of Glass Fibre reinforced concrete with the different percentage variations of 0%, 0.5%, 1%, 1.5%, 2% and 2.5% are tested and the obtained results are tabulated in the table and their different variations are plotted in figure for 28 days.

Table 4.1.3 Tabulation for Compressive strength test results of Glass fibre reinforced concrete for 28 days.

Percentage of Glass Fibre added in percentage	Load (kN)			Average Load (kN)	28 days Compressive Strength (Mpa)
	specimen 1	specimen 2	specimen 3		
0	933.7	920.2	938.2	930.70	41.36
0.5	1206.0	1190.2	1158.7	1184.97	52.67
1.0	1341.6	1323.1	1319.2	1327.97	59.02
1.5	**1384.7**	**1422.4**	**1406.0**	**1404.37**	**62.42**
2	1170.7	1221.5	1199.0	1197.07	53.20
2.5	963.1	953.1	984.4	966.87	42.97

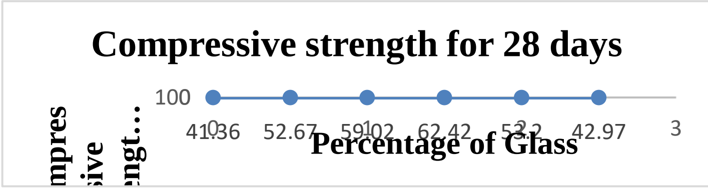

Figure 4.1.3 Variation of Compressive strength of Glass fibre reinforced concrete with different percentage variations of Glass Fibres.

The compressive strength of Glass fibre reinforced concrete enhance with increase in Glass Fibre quantity up to 1.5% and decreases beyond that. From the above table the maximum strength of Glass fibre is 62.42Mpa for 28 days is observed. Change in strength with respect to percentage of glass fibre quantity is graphically shown in the above figure.

4.1.4 Comparison between Compressive Strength Test Results for 7 and 28 days

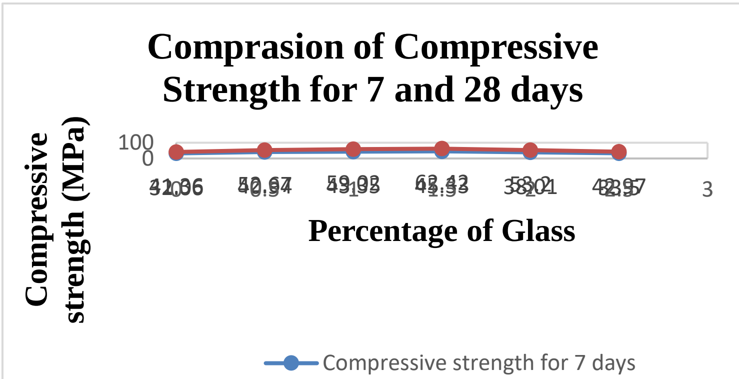

Figure 4.1.4 Comparison between 7 and 28 days for Compressive strength of Glass fibre reinforced concrete with different percentage variations of Glass Fibres.

The comparison between 7 and 28 days' compressive strength of Glass fibre reinforced concrete results with the different percentage variations of 0%, 0.5%, 1%, 1.5%, 2% and 2.5% are presented in the above table and their variations are plotted in the figure. Strength enhance with increase in Glass Fibre quantity up to 1.5% and decreases beyond that for 7 and 28 days respectively. From the above table the maximum strength of Glass fibre is 45.33Mpa for 7 days is observed and from the above table the maximum strength of Glass fibre is 62.42Mpa for 28 days is observed.

Figure 4.1 Casting of Cubes

Figure 4.2 Testing of Cubes.

Figure 4.3 Cube after failure under Compression load.

Conclusion and Future work

V.CONCLUSION

Based on the present experimental investigation conducted and the analysis of test results, the following conclusions can be drawn:

1) Glass fibre helps concrete to increase compressive strength until indicated limit. It also has a good resistance for tension.
2) The compressive strength of Glass Fibre Reinforced concrete increases in the amount of glass fibre quantity up to 1.5% and further decreases beyond.
    a) The compressive strength of Glass Fibre Reinforced Concrete was increased by 13.27% of normal concrete for 7 days.
    b) The compressive strength of Glass Fibre Reinforced Concrete was increased by 21.06% of normal concrete for 28 days.

From the test results it is observed that the Glass Fibre of 1.5% gained better compressive strength when compared to other percentages.

3) The split tensile strength of Glass Fibre Reinforced concrete increases in the amount of glass fibre quantity up to 1.5% and further decreases beyond.
    a) The split tensile strength of Glass Fibre Reinforced Concrete was increased by 0.53% of normal concrete for 7 days
    b) The split tensile strength of Glass Fibre Reinforced Concrete was increased by 0.87% of normal concrete for 28 days

c) From the test results it is observed that the Glass Fibre of 1.5% gained better split tensile strength when compared to other percentages.

4) . At higher percentage greater than 1.5%, there is a degradation of compressive strength and split tensile strength because the increase in weight of glass fibres results in loss of cohesiveness between the particles of the concrete.
5) In the present experimental investigation shows that the presence of glass fibres in the concrete acts as Crack Arrestors.
6) At higher percentage greater than 1.5%, there is a degradation of compressive strength and split tensile strength because the increase in weight of glass fibres results in loss of cohesiveness between the particles of the concrete.
7) In the present experimental investigation shows that the presence of glass fibres in the concrete acts as Crack Arrestors.

SCOPE OF FUTURE WORK

1. Further study can be done for determining the deflections.
2. Further study can be done on suitable optimum dosage of glass fibre for producing durable concrete.
3. Studies can be further continued in the Durability effects on Glass fibre reinforced concrete viz.,
    i) Sulphate attack
    ii) Chlorine attack
    iii) Freezing and Thawing
    iv) High temperature
4. Studies can be further extended on the permeability characteristics of Glass fibre reinforced concrete with different percentages of fibres and different aspect ratios of glass fibres by rapid chloride permeability test.
5. Further study can be done on Behaviour under different types of loading. Some of them are,
    i) Impact loads
    ii) Earthquake loads
    iii) Blast loads

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