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EXPERIMENTAL STUDIES ON STRENGTH PROPERTIES OF GLASS FIBER REINFORCED CONCRETE

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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 M20 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 and 14days 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

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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.

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

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.

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 .1 Cotton Fibre

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

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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.

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.

Figure .2 Coir Fibre

Figure.3 : Vegetable fibre

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.

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.

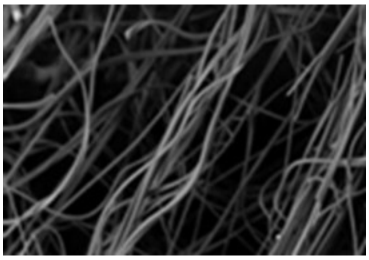

Figure.4 Carbon Fibre

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.

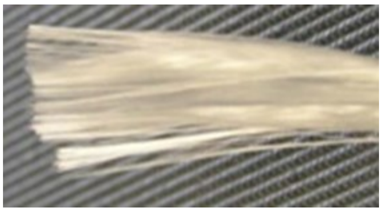

Figure .5 Polymer Fibre

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

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resistance to impact and energy absorption. Some of the types of steel fibres are straight slit, hooked end, crimped and paddled steel fibres.

Figure .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.

Figure .7 Glass Fibre

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

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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.

III. 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

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

Figure 3.3 : Solution of Super Plasticizer and Water

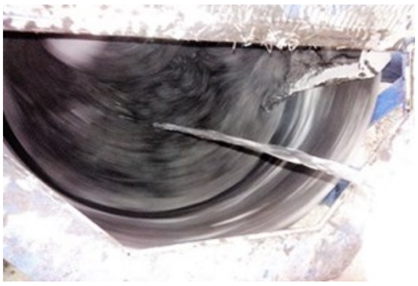

Figure 3.4 Mixing of Solution to aggregates and glass fibres

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

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affected the properties of the fresh and hardened concrete.

Figure 3.7 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	90 min	Not less than 39 min
	Final Setting Time	380 min	Not more than 600 min
2.	Standard Consistency	32%	-----
3.	Specific Gravity	3.09	-----
4.	Compressive Strength (As provided by Manufacturer)		
	3 days	39.5 N/mm^2	Not less than 27 N/mm^2
	7 days	51 N/mm^2	Not less than 37 N/mm^2
	28 days	70 N/mm^2	Not less than 53N/mm^2

Figure 3.8 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 3.9 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

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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 3.10 Coarse Aggregate

IV. 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

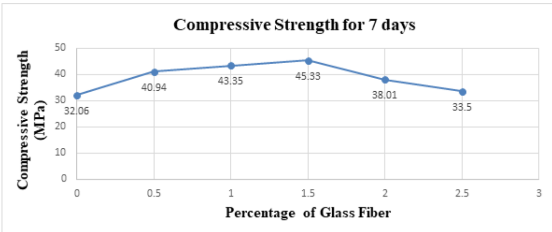

Figure 4.1.2.1 Variation of Compressive strength of Glass fibre reinforced concrete with different percentage variations of Glass Fibres

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

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quantity is graphically shown in the above figure.

V. CONCLUSION AND FUTURE WORK

5.1 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.

c) 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.

5.2 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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