The Study of Tensile Behaviour of Glass Fiber Reinforced Concrete

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***Abstract*— Glass-fiber reinforced concrete (GFRC) is a material made of a cementatious matrix composed of cement, sand, water and admixtures, in which short length glass fibers are dispersed. It has been widely used in the construction industry for non-structural elements, like façade panels, piping and channels. GFRC offers many advantages, such as being lightweight, fire resistance, good appearance and strength. In this study trial tests for concrete with glass fiber and without glass fiber are conducted to indicate the differences in compressive strength and flexural strength by using cubes of varying sizes.This Paper focuses on studying the effect of glass fiber on the properties of concrete mixtures as a partial replacement of cement. The main goal is to investigate the possibility of using glass fiber as a partial replacement of cement in concrete. A series of tests were conducted to study the effect of 10% ,15% and 20% replacement of cement by glass fiber. The compressive strength, split tensile strength and the flexural strength test were determined for the mixes at the curing age of 7 days and 28 days. The results obtained for the above mixes were compared to investigate the effects of partial replacement of cement by glass fiber. Use of glass fiber in concrete can prove to be economical**

Index Terms—GFRC (Glass-fiber reinforced concrete), Cement, Sand, Water, Admixtures
Sub Area : Structural Engineering
Broad Area: Civil Engineering

I. INTRODUCTION TO GLASS FIBRE REINFORCED CONCRETE

Glass Fiber Reinforced Concrete or (GFRC) is a composite that has glass fibers instead of steel strands for its reinforcement. Removing the steel reinforcement not only weakened, but also omitted steel erosion, corrosion, and their future repair costs, steel reinforcement costs, optimal coverage, and etc. In this research, several sources were studied to determine and clarify GFRC's applications in order to compare its featured properties with other fibers. Different figures and tables provided that show and compare physical and mechanical properties of GFRC and other fiber reinforcement. GFRC can be used wherever a light, strong, weather resistant, attractive, fire resistant, impermeable material is required. It has remarkable physical and mechanical assets. GFRC properties are dependent on the quality of materials and accuracy of production method. Despite its wide range applications in architecture the chief goal is to show and introduce important structural purposes, for instance: anti rust characteristics of GFRC made it a good replacement for water and sewer pipes and tanks, a thin protective layer of GFRC on concrete beams and columns can increase their durability in fire as well as low temperatures and generally it is a good replacement for susceptible materials in difficult environments.

Concrete is the most widely used construction material has several desirable properties like high compressive strength, stiffness and durability under usual environmental factors. At the same time concrete is brittle and weak in tension. Plain concrete has two deficiencies, low tensile strength and a low strain at fracture. These shortcomings are generally overcome by reinforcing concrete.

Normally reinforcement consists of continuous deformed steel bars or pre-stressing tendons. The advantage of reinforcing and pre-stressing technology utilizing steel reinforcement as high tensile steel wires have helped in overcoming the incapacity of concrete in tension but the ductility magnitude of compressive strength.Fibre reinforced concrete (FRC) is a concrete made primarily of hydraulic cements, aggregates and discrete reinforcing fibres. FRC is a relatively new material. This is a composite material consisting of a matrix containing a random distribution or dispersion of small fibres, either natural or artificial, having a high tensile strength. Due to the presence of these uniformly dispersed fibres, the cracking strength of concrete is increased and the fibres acting as crack arresters.

II. RECYCLING OF GLASS FIBER

Fiber glass is widely acknowledged as a material that has major advantages over more conventional rivals, such as wood, steel and aluminium. It is less energy-intensive in development and is used extensively for products which decrease carbon emissions-product such as low-energy windows. But what do we do with do with the glass fiber when its usefull life is over. The world is going through a low carbon revolution and the potential for composites to reduce greenhouse gas emissions is clear. But the difficulity of recycling glass fiber reinforced plastic (GRP) is a stumbling block particularly in construction and automotive where the pressure to recycle is high. The European Composites Industry Association (EuCIA) states that GRP is "recyclable and compliant with EU legislation". But at present facilities

Manuscript received Dec 26, 2016
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exit only in Germany to recycle, which for companies in UK, for example, is prohibitively expensive and not environmentally friendly due to the effect of transport, leaving the option only to landfill.

Incineration of GRP is not practical since about 50-70% of the material is mineral and would be left as ash, which still needs to be land filled. GRP typically consist E-glass, which is usually alumino-borosilicate, along with an organic resin and often calcium carbonate filler. When fed into a cement kiln the organic resin burns providing energy (about 12 MJ\kg of waste) and the mineral constituents provide feedstock for the cement clinker. The clinker is ground to form cement. Any calcium carbonate calcines (releasing carbon dioxide) to calcium oxide, the primary component of Portland cement. Alumina and silica also have cementatious properties in an alkaline environment and are typically present in Portland cement at about 25%, and in much higher proportions in cement alternatives from fly-ash and slag. Boron, which is found in most E-glass, can cause a reduction in early strength during the setting of cement, but as long as proportions are kept low it is not considered a problem.

III. RESEARCH OBJECTIVES

This project focuses on studying the effect of glass fiber on the properties of concrete mixtures as a partial replacement of cement. The main goal is to investigate the possibility of using glass fiber as a partial replacement of cement in concrete. Furthermore objectives of this study are as follows:-

1. To partially replace cement content in concrete as it directly influences economy in construction.
2. To study its contribution in strength development and durability of concrete.
3. To provide necessary data to concrete and block manufacturers on the applicability of glass fiber in concrete.

In the concrete specimens I replaced the amount of cement with glass fiber. The glass fiber was used in the amount of 10%, 15% and 20%. After performing the tests I found that Slump of concrete mix increases from 50mm for the reference mix to 110mm for the mix containing 30% glass fiber. The compaction factor increased as the percentage of glass fiber increases and increased in comparison with the conventional concrete At 10% and 20% replacement of cement by glass fiber, the % increase in compressive strength at 7 days is about 11% and 18% respectively and the % increase at 28 days is about 10% and 19% respectively. At 30% replacement, the decrease in the strength is measured to be 12% and 29% at the age of 7 and 28 days respectively. At 10% and 20% replacement, the percentage increase in flexural strength is about 8% and 9% at the age of 7 days and 12% and 15% at the age of 28 days respectively. At 30% replacement, the decrease in the strength is measured to be 9% and 15% respectively at the age of 7 and 28 days. There is an increase of approximately 12% and 10% in the split tensile strength of concrete containing 10% glass fiber when replaced by cement. The strength at 20% and 30% replacement is reduced to 5% and 12% at the age of 7 days and 7% and 19% approximately at the age of 28 days respectively. With the increase in the glass fiber the sorptivity value decreases and the % decrease was about 6%, 9.8%, and 19% for 10%, 20% and 30% replacement of cement by glass fiber respectively as compared to the conventional mix.

IV. PROPOSED METHODOLOGY AND ALGORITHM

The technology of GFRC concrete was based on adding or partially replacing Portland cement with amounts of fine material such as glass fiber without modifying the water content compared to common concrete. The materials procured for obtaining this composition were OPC, aggregates (fine and coarse), glass fiber, and the water. After procurement, testing of materials was done to achieve the desired properties of all the materials in order to obtain the desired strength at the end. Once testing of materials was done, mix trials were practiced in order to choose a optimal w/c ratio. After selection of w/c ratio, mix design was prepared and all the materials are proportioned in accordance to the mix design. However, hardened concrete becomes a strong, durable, and practically impermeable building material that requires no maintenance after completion of proper proportioning, mixing, placing, curing, and consolidation.

V. TESTING OF MATERIALS

Tests on cement Cement is the most important constituent of concrete which is also responsible for heat generation at early ages of concrete hardening. The 43 grade ordinary Portland cement (OPC) was used in all the experiments performed in the laboratory as this type of cement was typically used to achieve high strength in concrete. Some common properties of 43 grade cement

VI. METHODOLOGY

A nominal mix of concrete of proportion 1:1.5:3 (M-20) was adopted for the present study. The first mix Mx-0 was control mix having only cement as binder. The Mx-1, Mx-2, Mx-3 mix represent the replacement of cement by glass fiber by 10%, 15%, 20% respectively. Materials once proportioned and mixed together to obtain a concrete paste, specimens were casted and cured for performing various tests to analyze the properties of the concrete containing glass fiber. Tests performed were as follows:-

Fresh concrete tests

- Slump Cone test
- Compaction Factor Test

Hardened Concrete Tests:-

- Compressive Strength Test
- Flexural Strength Test
- Split Tensile Strength Test

Durability Tests:-

- Water Absorption Test
- Sorptivity Test

VII. MIX DESIGN FOR M20 GRADE OF CONCRETE

Mix design was carried out as per IS: 10262-2009. It provides the guide lines for proportioning concrete mixes as per the requirements using the concrete making materials including other supplementary materials identified for this purpose. The proportioning was carried out to achieve specified characteristics at specified age, workability of fresh concrete and durability requirements.

Table :-Quantity of Materials Used

Mix designation	Water	Cement	Fine aggregate	Coarse aggregate	Glass fiber
Mx-0	184lt/m^3	430 kg/m^3	661.462 kg/m^3	1169.482 kg/m^3	0 kg/m^3
Mx-1	184lt/m^3	386.8kg/m^3	661.462 kg/m^3	1169.482 kg/m^3	43.2 kg/m^3
Mx-2	184lt/m^3	343.6kg/m^3	661.462 kg/m^3	1169.482 kg/m^3	64.7 kg/m^3
Mx-3	184lt/m^3	300.4kg/m^3	661.462 kg/m^3	1169.482 kg/m^3	86.4 kg/m^3

In the nominal mix, i.e. the mix containing cement as only binder material, the actual quantity obtained was increased by a factor of 1.20 from the wastage point of view. But this factor was reduced to 1.17 for the other mixes later on to save the materials.

VIII. CASTING OF SPECIMENS

To cast concrete samples, 150mm×150mm×150mm standard dimension cube moulds were casted for carrying out compressive strength test and total no. of samples casted are 24 for all the mixes, 3 samples each for testing at the age of 7and28 days respectively. Similarly for flexural strength test, beams specimens of dimensions 500mm×100mm×100mm moulds were casted in 24 no. Cylindrical specimens of dimensions 150mm diameter and 300mm length were casted for performing split tensile strength,. For investigating durability properties, i.e. for performing water absorption test and cube specimens of dimensions 100mm×100mm×100mm and 70.7mm×70.7mm×70.7mm were casted, 12 each for all the mixes which are to be tested at the age of 28 days respectively.

Fig:-3.2:-Casted Specimens

IX. ANALYSIS

The mix proportion for M20 designed was 1: 1.54: 2.71 and W/C ratio of 0.43 was used in casting. Slump and compaction factor tests were tested when the concrete in fresh state. For performing compressive strength, split tensile strength and flexural strength the cubes, cylinders and beams were tested at the age of 7 days and 28days. For durability results too, cubes of different dimensions casted were tested at the age of 28 days.

X. SLUMP FLOW TEST

The results show that the concrete containing glass fiber was complying with the requirements found in the literature. Thus, concrete was assumed to having a good consistency and workability after replacement of cement by glass fiber. Figure 4.1 shows the slump value for concretes with varying amounts of glass fiber as partial replacement of cement. There was a systematic increase in slump as the glass fiber in the mix increases. The slump ranged around 50mm for the reference mix (i.e. 0% glass fiber) to 110mm at 20% glass fiber.

Table No.:- Slump and Compaction Factor Value

S.No.	Mix Designation	Slump(mm)	Compaction Factor
1	Mx-0	50	.86
2	Mx-1	60	.874
3	Mx-2	80	.897
4	Mx-3	110	.921

XI. COMPACTION FACTOR TEST

It was clear from results that the value for compaction factor increases with the increase in the glass fiber content. So the consistency of mix increases and hence the mix is easily workable. Compaction Factor values are shown in Table 4.1 and curve for compaction factor is shown in Figure 4.2.

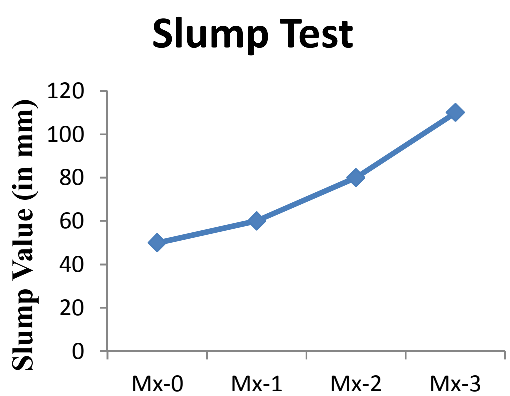

Fig:- Slump Test Curve

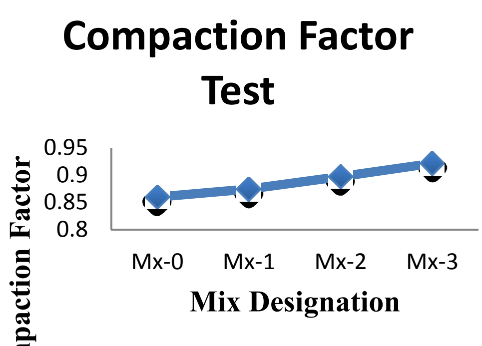

Fig:-4.2:- Compaction Factor Curve

XII. COMPRESSIVE STRENGTH TEST

The compressive strength results for concrete containing different percentages of Glass fiber (GFRC) are presented in Table 4.2, 4.3 and Figure 4.3, 4.4 and 4.5. The compressive strength of plain concrete was also listed for reference and comparison. It can be seen that in general, compressive strength of concrete containing 20% glass fiber shows higher or maximum strength as compared to the conventional concrete. There was an increase of approximately 11% and 18% in the compressive strength of concrete containing 10% and 20% glass fiber when replaced by cement as compared to that of plain concrete at the age of 7 days respectively. Similarly, at the age of 28 days increase in strength was about 9% and 19% for 10 and 20% replacement of cement by glass fiber respectively. But at 25 and 30% replacement, compressive strength was reduced to 12% and 29% at the age of 7 and 28 days respectively.

Table No.:- Compressive Strength at 7 days

Mix Description	Sample No.	Compressive Strength (N/mm2)	Average Compressive strength (N/mm2)
Mx-0 (100% Cement)	1 2 3	16.44 16.00 15.56	16.00
Mx-1 (10% GFRC + 90% Cement)	1 2 3	17.90 17.40 16.90	17.70
Mx-2 (15% GFRC + 85% Cement)	1 2 3	18.00 18.10 17.90	18.00
Mx-3 (20% GFRC +80% Cement)	1 2 3	19.00 18.70 18.40	18.70

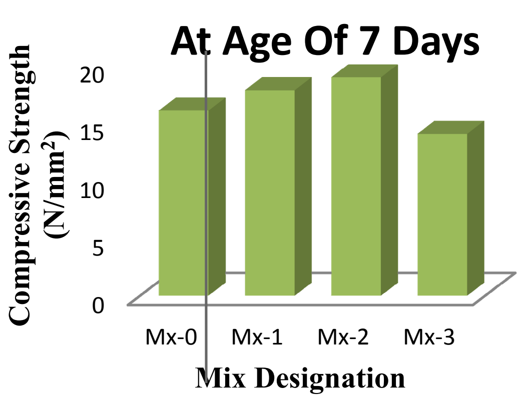

Fig: Compressive Strength at 7 Days

Table :Compressive Strength at 28 Days

Mix Description	Sample No.	Compressive Strength (N/mm2)	Average Compressive Strength (N/mm2)
Mx-0 (100% Cement)	1 2 3	27.11 26.89 26.22	26.74
Mx-1 (10% GFRC + 90% Cement)	1 2 3	28.78 28.56 27.67	28.34
Mx-2 (15% GFRC + 85% Cement)	1 2 3	29.80 29.60 30.10	29.83
Mx-3 (20% GFRC +80% Cement)	1 2 3	31.44 31.00 31.11	31.18

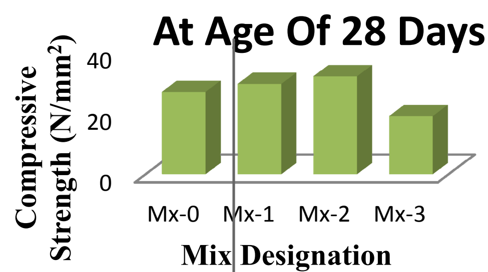

Fig:- Compressive Strength at 28 Days

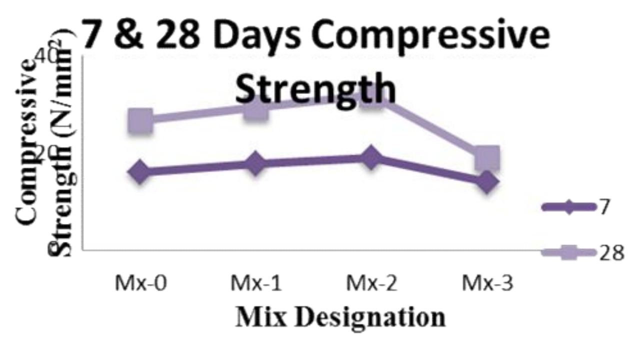

Fig:- Compressive Strength Curve at 7 and 28 Days

DISCUSSIONS

An increasing trend in strength was observed with increasing replacement of cement with glass fiber up to 20%. Beyond 20%, the compressive strength started to fall steadily. The increase in the strength upto 20% replacement of cement with glass fiber may be due to the pozzolanic reaction of glass fiber. However, beyond 20%, the dilution effect takes place over and the strength starts to drop. Thus it can be concluded that 20% replacement of cement with glass fiber was the optimum percentage with which cement can replaced. Unit weight of concrete without glass fiber was higher than with glass fiber. As the specific gravity of glass fiber used was 2.60 which was much lower than the specific gravity of cement which was 3.12 so this much difference was attributive.

SPLIT TENSILE STRENGTH TEST

The Split Tensile strength results for concrete containing different percentages of Glass fiber (GFRC) are presented in Table 4.6, 4.7and Figure 4.9, 4.10 and 4.11. Likewise the compressive strength it can be seen that in general, concrete containing 10% glass fiber shows higher or maximum strength as compared to the conventional concrete. There is an increase of approximately 12% and 10% in the split tensile strength of concrete containing 10% glass fiber when replaced by cement as compared to that of plain concrete at the age of 7 and 28 days respectively. The strength at 15% and 20% replacement is reduced to 5% and 12% at the age of 7 days and 7% and 19% approximately at the age of 28 days respectively

Table :Split Tensile Strength at 7 Days

Mix Description	Sample No.	Split Tensile Strength (N/mm2)	Average Split Tensile Strength (N/mm2)
Mx-0 (100% Cement)	1 2 3	1.839 1.698 1.698	1.745
Mx-1 (10% GFRC + 90% Cement)	1 2 3	2.20 2.10 2.15	2.15
Mx-2 (15% GFRC + 85% Cement)	1 2 3	1.858 1.717 1.646	1.752
Mx-3 (20% GFRC +80% Cement)	1 2 3	1.557 1.526 1.405	1.495

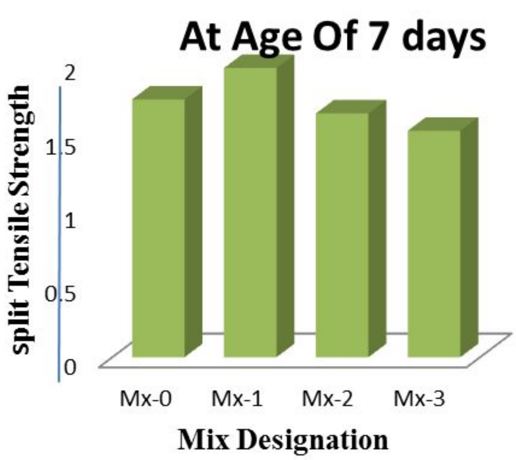

Fig:-Split Tensile Strength at 7 Days

Table :Split Tensile Strength at 28 Days

Mix Description	Sample No.	Split Tensile Strength (N/mm2)	Average Split Tensile strength (N/mm2)
Mx-0 (100% Cement)	1 2 3	3.112 2.829 2.688	2.876
Mx-1 (10% GFRC + 90% Cement)	1 2 3	3.64 3.14 3.05	3.29
Mx-2 (15% GFRC + 85% Cement)	1 2 3	2.86 2.72 2.72	2.77
Mx-3 (20% GFRC +80% Cement)	1 2 3	2.51 2.43 2.30	2.41

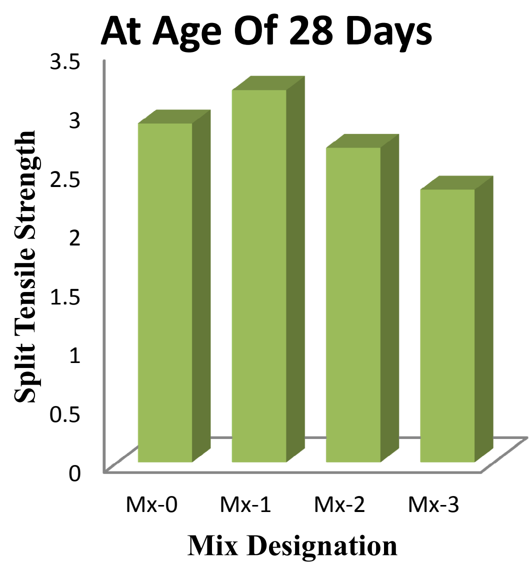

Fig: Split Tensile Strength at 28 Days

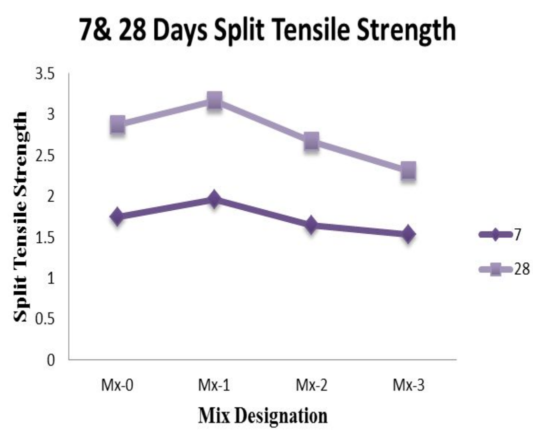

Fig:- Split Tensile Strength Curve at 7 and 28 Days

XIII. WATER ABSORPTION TEST

The reference mix absorbs more water as compared to other mixes. 10% replacement level of cement by glass fiber was found to be optimal from the water absorption point of view as at this % of replacement, water absorption is minimum as compared to all other mixes and after this replacement level, % water absorption increases but is less than reference mix and shows that the durability of concrete is enhanced by addition of glass fiber. Glass fiber can be safely used even upto 20% replacement of cement as the water absorption for all the mixes containing GFRC was found to be less than reference mix without GFRC.

CONCLUSIONS

The present investigation was undertaken to study the effect of GFRC on characteristic strength of concrete. To achieve the objectives of the present study, cement was replaced by GFRC in different percentages i.e. 10%, 15%, and 20% respectively. The compressive strength, split tensile strength and the flexural strength test were determined for the mixes at the curing age of 7 days and 28 days. The results obtained for the above mixes were compared to investigate the effects of partial replacement of cement by GFRC on the above strength parameters of concrete

On the basis of experiments performed, following conclusions can be drawn:-

1. Use of glass fiber in concrete can prove to be economical .
2. Use of glass fiber in concrete prove to be environment friendly thus paving way for greener concrete.
3. Use of glass fiber in concrete will preserve natural resources particularly river sand and thus make concrete construction industry sustainable
4. The performance test results conducted in this research confirm that the properties of those special mixed concretes are satisfactory.
5. The properties tested include workability, air content, density, compressive strength, tensile strength, and water absorption.
6. Moreover, it is found that water absorption is strongly related to the strength of the concrete.
7. It has been concluded that 20% glass fiber could be incorporated as cement replacement in concrete without any long term detrimental defects.

Slump Test

1. Workability of concrete mix increases with increase in glass fiber content.
2. Slump of concrete mix increases from 50mm for the reference mix to 110mm for the mix containing 20% glass fiber.

Compaction Factor Test

1. The compaction factor increased as the percentage of glass fiber increases and increased in comparison with the conventional concrete.

Compressive Strength Test

2. The amount of incorporated glass fiber largely influenced properties of the cement mortar. It was evident from these results that ground glass could enhance the properties of the final concrete product if used at the right level of replacement.
3. Cement can be replaced by glass fiber up to 20% by weight showing increase in compressive strength at 28 days beyond which strength decreases.
4. At 10% and 15% replacement of cement by glass fiber, the % increase in compressive strength at 7 days is about 11% and 18% respectively and the % increase at 28 days is about 10% and 19% respectively.
5. At 15 and 20% replacement, the decrease in the strength is measured to be 12% and 29% at the age of 7 and 28 days respectively.

FLEXURAL STRENGTH TEST

1. Flexural strength increases with increase in glass fiber up to 20% as compared to conventional mix and then starts decreasing with further increase in GFRC.
2. At 10% and 15% replacement, the percentage increase is about 8% and 9% at the age of 7 days and 12% and 15% at the age of 28 days respectively.
3. At 15 and 20% replacement, the decrease in the strength is measured to be 9% and 15% respectively at the age of 7 and 28 days.

Split Tensile Strength

1. Splitting tensile strength increases at 10% of replacement of cement by glass fiber as compared to conventional mix and then decreases with increase in glass fiber content.
2. There is an increase of approximately 12% and 10% in the split tensile strength of concrete containing 10% glass fiber when replaced by cement as compared to that of reference concrete at the age of 7 and 28days respectively
3. The strength at 15% and 20% replacement is reduced to 5% and 12% at the age of 7 days and 7% and 19% approximately at the age of 28 days respectively.

Water Absorption Test

1. With increase in glass fiber content, durability of concrete increases.
2. The % water reduction at 10% is considered to be optimal as at this % of replacement, there is maximum decrease in absorption of water as compared to reference mix, beyond this replacement water absorption increases but is less than the reference mix.
3. The % decrease is about 18% for mix containing 10% glass fiber, 13% and 7% for mix containing 15% and 20% glass fiber as cement replacement as compared to reference mix.

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