Glass Fibre Reinforced Fly-Ash Concrete

Shaik Ashfaq Ali¹ & Mohammed Ismail Khan²
¹M.Tech Student in Dept. of Civil Engineering, LIET, Hyderabad
²Assistant professor, Dept. of Civil Engineering, LIET, Hyderabad

Abstract: Glass Fibre Reinforced concrete with fly ash is a recent introduction in the field of concrete technology. It has been extensively used in over 100 countries since its introduction in 1980’s. This product is covered by international standards and has been practiced all over the world. Glass Fibre Reinforced concrete with fly ash has advantage of being lightweight and thereby reducing the overall cost of construction there by bringing economy in construction. This work is only an accumulation of information about Glass Fibre Reinforced concrete with fly ash from all over the internet and some text books.

Glass Fibre Reinforced concrete with fly ash is concrete that uses glass fibres for reinforcement instead of steel and flyash as a cementing material. It is typically cast in a thin section of around 1/2” to 3/4”. Since the fibres cannot rust like steel; there is no need for a protective concrete cover thickness to prevent rusting. With the thin, hollow construction of Glass Fibre Reinforced concrete with fly ash products, they can weigh a fraction of weight of traditional precast concrete.

1. Introduction

Glass fibre (also spelled as glass fibre) is a material consisting of numerous extremely fine Fibres of glass. This is an introduction into the world of Glass Fibre Reinforced Concrete (GFRC), also referred to as Fibre glass Reinforced Concrete (FRC) and Glass Reinforced Concrete (GRC). Since its introduction, GFRC has become extremely popular among the Architect and Design industry. Along with this popularity came some concerns about the quality of the material, and how best to use GFRC. Glassmakers throughout history have experimented with glass fibres, but mass manufacture of glass fibre was only made possible with the invention of finer machine tooling. In 1893, Edward Drummond Libbey exhibited a dress at the World's Columbian Exposition incorporating glass fibres with the diameter and texture of silk fibres. This was first worn by the popular stage actress of the time Georgia Cayvan. Glass fibres can also occur naturally, as Pele’s hair. Glass wool, which is commonly known as “fibreglass” today, was invented in 1938 by Russell Games Slayter of Owens-Corning as a material to be used as insulation. It is marketed under the trade name Fiberglass, which has become a generalized trademark. Glass fibre is commonly used as an insulating material. It is also used as a reinforcing agent for many polymer products; to form a very strong and light fibre-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), popularly known as “fibreglass”.

Fibre reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Fibres include steel fibres, glass fibres, synthetic fibres and natural fibres. Within these different fibres that character of fibre reinforced concrete changes with varying concretes, fibre materials, geometries, distribution, orientation and densities.

Fibre Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibres. Fibre-reinforcement is mainly used in shortcrete, but can also be used in normal concrete. Fibre-reinforced normal concrete are mostly used for on-ground floors and pavements, but can be considered for a wide range of construction parts (beams, pliers, foundations etc) either alone or with hand-tied rebars. Concrete reinforced with fibres (which are usually steel, glass or “plastic” fibres) is less expensive than hand-tied rebar, while still increasing the tensile strength many times. Shape, dimension and length of fibre is important. A thin and short fibre, for example short hair-shaped glass fibre, will only be effective the first hours after pouring the concrete (reduces cracking while the concrete is stiffening) but will not increase the concrete tensile strength.

2. Effects of Fibres in Concrete

Fibres are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact, abrasion and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete, so it cannot replace moment resisting or structural steel reinforcement. Some fibres reduce the strength of concrete. The amount of fibres added to a concrete mix is measured as a percentage of the total volume.
of the composite (concrete and fibres) termed volume fraction \( (V_f) \). \( V_f \) typically ranges from 0.1 to 3%. Aspect ratio \((l/d)\) is calculated by dividing fibre length \((l)\) by its diameter \((d)\). Fibres with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fibre is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increase in the aspect ratio of the fibre usually segments the flexural strength and toughness of the matrix. However, fibres which are too long tend to “ball” in the mix and create workability problems. Some recent research indicated that using fibres in concrete has limited effect on the impact resistance of concrete materials. This finding is very important since traditionally people think the ductility increases when concrete reinforced with fibres. The results also pointed out that the micro fibres are better in impact resistance compared with the longer fibres.

3. Materials Used

3.1. Cement

Pozzolano Portland cement is used in the project work, as it is readily available in local market. The cement used in the project work has been tested for various proportions as per IS: 4031-1988 and found to be conforming to various specifications of IS: 1489-1991. The specific gravity was 3.02 and the fineness was 3200 cm²/gm.

3.2. Coarse Aggregate

Crushed angular granite metal from a local source was used as coarse aggregate. The specific gravity was 2.71, Flakiness index of 4.58 % and elongation index of 3.96 %. The coarse aggregate used in the project work are 20 mm down grade.

3.3. Fine Aggregate

River white sand was used as fine aggregate. The specific gravity was 2.55 and fineness modulus was 2.93 respectively. The fine aggregate used in the project work is 4.75 mm down grade.

3.4. Glass Fibre

The glass fibres used are of Cem-Fil Anti-Crack HD with modulus of elasticity 72 Gpa, filament diameter 14 microns, specific gravity 2.68, length 12 mm and having the aspect ratio of 857.1. The numbers of fibres per Kg is 212 million fibres.

3.5. Fly Ash

Fly ash is comprised of the non-combustible mineral portion of coal consumed in a coal fueled power plant. Fly ash particles are glassy, spherical shaped “ball bearings” typically finer than cement particles that are collected from the combustion airstream exiting the Power plant. There are two basic types of fly ash: Class F and Class C. Both types react in concrete in similar ways. Both Class F and Class C fly ashes undergo a “pozzolanic reaction” with the lime (calcium hydroxide) created by the hydration (chemical reaction) of cement and water, to create the same binder (calcium silicate hydrate) as cement. In addition, some Class C fly ashes may possess enough lime to be self cementing, in addition to the pozzolanic reaction with lime from cement hydration. The main benefit of fly ash in concrete is that it not only reduces the amount of non-durable calcium hydroxide (lime), but in the process converts it into calcium silicate hydrate (CSH), which is the strongest and most durable portion of the paste in concrete. Fly ash also makes substantial contributions to workability, chemical resistance and the environment.

4. Test Methods

4.1. Workability

The workability tests were performed using standard sizes of Slump Moulds as per IS: 1199 - 1999 and Compaction Factor apparatus which was developed in UK and is described in IS: 1199-1990.

4.1.1. Slump Test. This is a test used extensively in site work all over the world. The slump test does not measure the workability of concrete, although ACI 116R-90^4.46 describes it as a measure of consistency, but test is very useful in detecting variations in the uniformity of a mix of given nominal proportions. The slump test is prescribed by IS: 1199-1999. The mould for the slump test is a frustum of a cone, 300mm (12 in) high. It is placed on a smooth surface with the smaller opening at the top, and filled with concrete in three layers. Each layer is tamped 25 times with a standard 16mm (5/8 in.) diameter steel rod, rounded at the end, and the top surface is struck off by means of a sawing and rolling motion of the tampering rod. The mould must be firmly held against its base during the entire operation; this is facilitated by handles or foot rests brazed to the mould.
Immediately after filling, the cone is slowly lifted, and the unsupported concrete will now slump hence the name of the test. The decrease in the height of the slumped concrete is called slump, and is measured to the nearest 5mm (1/4 in.). The decrease is measured to the highest point according to IS: 1199–1999. In order to reduce the influence on slump of the variation in the surface friction, the inside of the mould and its base should be moistened at the beginning of every test, and prior to lifting of the mould the area immediately around the base of the cone should be cleaned of concrete which may have dropped accidentally. If instead of slumping evenly all around as a true slump (Fig-1), one half of the cone slides down an inclined plane, a shear slump is said to have taken. The Description of workability and magnitude of slump are shown in table-1.

<table>
<thead>
<tr>
<th>Description of Workability</th>
<th>Slump</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
</tr>
<tr>
<td>No Slump</td>
<td>0</td>
</tr>
<tr>
<td>Very Low</td>
<td>5-10</td>
</tr>
<tr>
<td>Low</td>
<td>15-30</td>
</tr>
<tr>
<td>Medium</td>
<td>35-75</td>
</tr>
<tr>
<td>High</td>
<td>80-155</td>
</tr>
<tr>
<td>Very High</td>
<td>160 to Collapse</td>
</tr>
</tbody>
</table>

**Table-1 Description Of Workability And Magnitude Of Slump**

### 4.2. Compressive Strength

**Test Specimen: Cubes**

The Steel mould of size 150 x 150 x 150 mm is well tighten and oiled thoroughly. They were allowed for curing in a curing tank for 28 days and they were tested in 200-tonnes electrohydraulic closed loop machine. The test procedures were used as per IS: 516-1979, which is as follows,

**Apparatus: Testing Machine**

The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate 140kg/cm²/min.

**Age at Test:** Tests shall be made at recognized ages of the test specimens, the most usual being 7 and 28 days. Ages of 13 weeks and one year are recommended if tests at greater ages are required. Where it may be necessary to obtain the early strengths, tests may be made at the ages of 24 hours ±1/2 hour and 72 hours ±2 hours. The ages shall be calculated from the time of the addition of water to the dry ingredients.

**Number of Specimens:** At least three specimens, preferably from different batches, shall be made for testing at each selected age.

**Procedure:** Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition. Surface water and grit shall be wiped off the specimens and any projecting fins removed. Specimens when received dry shall be kept in water for 24 hours before they are taken for testing. The dimensions of the specimens to the nearest 0.2mm and their weight shall be noted before testing.

**Placing the Specimen in the Testing Machine:** The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression platen. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine. As the spherically seated block is brought to bear on the specimen, the movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load shall
be applied without shock and increased continuously at a rate of approximately 140kg/cm²/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

Calculation: The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area, calculated from the mean dimensions of the section and shall be expressed to the nearest kg per sq cm. Average of three values shall be taken as the representative of the batch provided the individual variation is not more than ±15 percent of the average. Otherwise repeat tests shall be made.

4.3. Flexural Strength

Test Specimen: Beams
The Steel mould of size 500 x 100 x 100 mm is well tighten and oiled thoroughly. They were allowed for curing in a curing tank for 28 days and they were tested in universal testing machine. The test procedures were used as per IS 516-1979.

Apparatus: Testing machine
The testing machine may be of any reliable type of sufficient capacity for the tests and capable of applying the load at the rate of 400kg/min for 15.0 cm specimens and at the rate of 180 kg/min for the 10.0 cm specimens. The permissible errors shall be not greater than ±0.5 percent of the applied load where a high degree of accuracy is required and not greater than ±1.5 percent of the applied load for commercial type of use. The bed of the testing machine shall be provided with two steel rollers, 38mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60cm for 15.0 cm specimens or 40cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span that is, spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.

Procedure: Test specimens stored in water at a temperature of 24° to 30°C for 48 hours before testing shall be tested immediately on removal from the water whilst they are still in a wet condition. The test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted.

Calculation: The flexural strength of the specimen shall be expressed as the modulus of rupture fb, which, if ‘a’ equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, shall be calculated to the nearest 0.5kg/sq cm as follows:

\[ f_b = \frac{p \times l}{b \times d^2} \]

when ‘a’ is greater than 20.0cm for 15.0cm specimen, or greater than 13.3cm for a 10.0cm specimen, or

\[ f_b = \frac{3p \times a}{b \times d^2} \]

when ‘a’ is less than 20.0cm but greater than 17.0cm for 15.0cm specimen, or less than 13.3cm but greater than 11.0cm for a 10.0cm specimen where

- \( b \) = measured width in cm of the specimen,
- \( d \) = measured depth in cm of the specimen at the point of failure,
- \( l \) = length in cm of the span on which the specimen was supported, and
- \( p \) = maximum load in kg applied to the specimen.

If ‘a’ is less than 17.0cm for a 15.0cm specimen or less than 11.0cm for a 10.0cm specimen, the results of the test shall be discarded.

4.4. Split Tensile Strength

Test Specimen: Cylinder
The cylindrical specimen shall have diameter not less than four times the maximum size of the coarse aggregates and not less than 150 mm. The lengths of the specimens shall not be less than the diameter and not more than twice the diameter. For routine testing and comparison of results, unless otherwise specified the specimens shall be cylinder 150 mm in diameter
and 300 mm long. The test procedure were used as per IS 5816-1999.

Apparatus: Testing Machine
Any compression machine of reliable type, of sufficient capacity for the test and capable of applying the load shall be used. It shall comply with the requirements given in IS 516 as far as applicable except that the bearing faces of both platens shall provide a minimum loading area of 12 mm the length of the cylinder or cube, as the case may be so that the load is applied over the entire length of the specimen. If necessary, a supplementary bearing bar or plate of machined steel may be used.

Age at test: Test shall be made at the recognized ages of the test specimens, the most usual being 7 and 28 days. Tests at any other age at which the tensile strength is desired may be made, if so required. The ages shall be calculated from the time of the addition of water to the dry ingredients. The age at test shall be reported along with the results.

Number of specimen: At least three specimens shall be tested for each age of tests.

Procedure: Specimens when received dry shall be kept in water for 24 h before they are taken for testing. Unless other conditions are required for specific laboratory investigation specimen shall be tested immediately on removal the water whilst they are still wet. Surface water and grit shall be wiped off the specimens and any projecting fins removed from the surfaces which are to be in contact with the packing strips.

Placing of the Specimen in the Testing Machine: The bearing surfaces of the testing machine and of the loading strips shall be wiped clean. Cylindrical specimens shall be ensured that the upper platen is parallel with the lower platens.

Calculation: The measured splitting tensile strength fct of the specimen shall be calculated to the nearest 0.05 N/mm² using the following formula:

\[ \sigma = \frac{2P}{\pi l d} \]

Where \( P \) = maximum load in Newton’s applied to the specimen.

\( l \) = length of the specimen as, and

\( d \) = cross sectional dimension of the specimen

5. Results And Discussions

5.1. Workability

The workability of M-20, M-30 and M-40 grades of concrete without and with Glass Fibres was estimated in terms of Slump test and Compaction factor. The results are shown as follows.

5.1.1. Slump Test. The Slump test was conducted as per IS: 1199-1999. The method of conducting Slump test is explained in 4.1.1. The results of Slump test M-20, M-30 and M-40 grades of concrete without and with Glass Fibres were 30 mm and 10 mm respectively. From the experimental results it was observed that on the addition of 0.03% of Glass Fibres to concrete there was substantial amount of loss in the slump. Hence, the workability decreases with the increase in volume of fibres.

5.1.2. Compaction Factor. The Compaction Factor test was conducted as per IS:1199-1999. The method of conducting Compaction Factor test is explained in 4.1.2. The results of Compaction Factor test are tabulated below.

<table>
<thead>
<tr>
<th>Concrete Mix</th>
<th>Without GF &amp; FA</th>
<th>With GF &amp; FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-20</td>
<td>0.945</td>
<td>0.930</td>
</tr>
<tr>
<td>M-30</td>
<td>0.930</td>
<td>0.915</td>
</tr>
<tr>
<td>M-40</td>
<td>0.905</td>
<td>0.880</td>
</tr>
</tbody>
</table>

Table-2 Compaction Factor

5.2. Compressive Strength Test

The Compressive Strength test was conducted as IS: 516-1979. The method of conducting the test is explained in 4.2. The results of Compressive Strength tests conducted on different grades of concrete without and with are tabulated below,

Chart-1 Variation of Compressive Strength of M-20 concrete without and with Glass Fibres and fly ash.

The increase in Compressive strength for M-20 grade of concrete at 3, 7 and 28 days are observed to be 29.33% when compared with 28 days strength of Plain Concrete.
Chart-2 Variation of Compressive Strength of M-30 concrete without and with Glass Fibres and fly ash.

The increase in Compressive strength for M-30 grade of concrete at 3, 7 and 28 days are observed to be 21.70% when compared with 28 days strength of Plain Concrete.

Chart-3 Variation of Compressive Strength of M-40 concrete without and with Glass Fibres and Fly ash.

The increase in Compressive strength for M-40 grade of concrete at 3, 7 and 28 days are observed to be 23.34% when compared with 28 days strength of Plain Concrete.

5.3. Split Tensile Test

The Split Tensile Strength test was conducted as per IS 5816-1999. The method of conducting the Split Tensile Strength test is explained in 4.4. The results of Split Tensile Strength tests conducted on different grades of concrete are tabulated below.

Chart-4 Variation of Split tensile Strength of M-20 concrete without and with Glass Fibres and Fly ash.

The increase in Split tensile strength for M-20 grade of concrete at 3, 7 and 28 days are observed to be 29.75% when compared with 28 days strength of Plain Concrete.

Chart-5 Variation of Split tensile Strength of M-30 concrete without and with Glass Fibres and Fly ash.

The increase in Split tensile strength for M-30 grade of concrete at 3, 7 and 28 days are observed to be 26.34% when compared with 28 days strength of Plain Concrete.

Chart-6 Variation of Split tensile Strength of M-40 concrete without and with Glass Fibres and Fly ash.

The increase in Split tensile strength for M-40 grade of concrete at 3, 7 and 28 days are observed to be 30.18% when compared with 28 days strength of Plain Concrete.

5.4. Flexural Strength Test

The Flexural Strength test was conducted as per IS 516-1979. The method of conducting the Flexural Strength test is explained in 4.3. The results of Flexural Strength tests conducted on different grades of concrete without and with Glass Fibres and fly ash are tabulated below.

Chart-7 Variation of Flexural Strength of M-20 concrete without and with Glass Fibres and Fly ash.
The increase in Flexural strength for M-20 grade of concrete at 28 days are observed to be 30.84% when compared with 28 days strength of Plain Concrete.

![Chart-8 Variation of Flexural Strength of M-30 concrete without and with Glass Fibres and fly ash.](image)

The increase in Flexural strength for M-30 grade of concrete at 28 days are observed to be 28.90% when compared with 28 days strength of Plain Concrete.

![Chart-9 Variation of Flexural Strength of M-40 concrete without and with Glass Fibres and fly ash.](image)

The increase in Flexural strength for M-40 grade of concrete at 28 days are observed to be 29.39% when compared with 28 days strength of Plain Concrete.

6. Conclusion

Glass Fibres and fly ash Reinforced Concrete is an engineered material has excellent properties that can be conveniently used for many construction works and it is a suitable material for architects to give life to their imaginations as structures by properly using this flexible material. A properly designed, manufactured and installed GFRC system will provide an innovative and aesthetically pleasing appearance, while often reducing overall cost, onsite labor requirements and shortening construction schedules. Glass Fibres and fly ash Reinforced Concrete (GFRFC) offers an endless variety of decorative and ornamental shapes and forms at affordable prices. 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% to 30% 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 Fibres and fly ash Reinforced Concrete as compared to Plain Concrete.

7. References


