# EXPERIMENTAL INVESTIGATION OF THE MECHANICAL STRENGTH CHARACTERISTICS OF GLASS FIBRE COMPOSITE CONCRETE (GFCC)

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**Abstract:** This research work lays emphasis on the use of glass fibre of two different sizes of 5m and 8mm, to improve the mechanical strength properties of the concrete. Over the decades, there has been a significant increase in the use of fibres in concrete for improving its properties such as the compressive strength, split tensile strength and flexural strength. Among many different types of fibres available today, glass fibre is a recent introduction in the field of concrete technology which has shown considerable improvement in mechanical properties when compared to plainconcrete. Various experimental studies were done to discover the fresh and hardened concrete properties of glass fibre composite concrete using different glass fibre length (10, 12, 16 and 20 mm). Glass fibre length shorter than 10 mm has not been exhaustively investigated to establish its impact on the characteristic strengths of concrete. Plain concrete with addition of glass fibre was used as the control specimen. It was observed during the research work that the workability of the concrete reduced with increase in glass fibre content at varying percentage (0, 0.2, 0.3, 0.4 and 0.5%). The mechanical properties such as the compressive, split tensile and flexural strengths increased with the addition of glass fibre and the optimum glass fibre content of 0.4% has the highest strength at 7, 14 and 28 days curing ages and that glass fibre composite concrete with 5 mm length improves the concrete properties than 8mm glass fibre length.

**Keywords:** Glass fibre composite concrete (GFCC), flexural strength, split tensile

## Introduction

Plain concrete possesses very low tensile strength, limited ductility and little resistance to cracking. Concrete is relatively brittle, and its tensile strength is typically only about one tenths of its compressive strength. Traditionally, steel reinforcing bars are introduced into the concrete at the tensile half to resist bending. With the ever increasing cost of reinforcing bars in a country like Nigeria, it is imperative to source for alternative reinforcement that will reduce the reinforcing bar content of concrete. Introducing glass fibre into concrete will control the cracking due to shrinkage, reduce bleeding of water and improve the compressive, tensile and flexural strength than that of plain concrete. The current work is limited to the use of 5 and 8mm glass fibre lengths at various contents of 0, 0.2, 0.3, 0.4, and 0.5%, respectively while keeping the mix design of 1:2:4 constant.

Many researchers have investigated the use of glass fibre in concrete. Among them is Ferreira *et al*. (2012) that mixed glass fibre and concrete together to form a matrix of glass fibre in hardened concrete. Both fibres and concrete matrices retain their physical and chemical identities, while offering a synergism: a combination of properties that cannot be achieved with either of the components acting alone. In general, fibres are the principal load-carrying members, while the surrounding concrete matrix keeps them in the desired locations and orientation, acting as a load transfer medium among the fibre strands and at the same time protecting the glass fibres from environmental damage. In fact, the fibres provide reinforcement for the matrix and other useful functions in fibre-reinforced composite materials. Glass fibres can be incorporated into a matrix either in continuous or discontinuous (chopped) lengths. It is well knownthat large numbers of short fibres can increase the strength and ductility of the composite while long fibres significantly reduce the workability of the mix. Fig. 1 shows a typical glass fibre matrix.

Amit and Joshi (2014) reported that many research works have established that glass fibre content less than 1% fraction of the volume is the most efficient content in GFRC. The geometric characteristic parameter of glass fibre is its aspect ratio, which the ratio of its length to diameter and this ranges between 30 to 150 for 1mm to about 80mm length with the range of diameters of 0.2 to 0.5 mm. Glass fibre reinforced concrete (GFRC) also called GRC or FRC is a cementitious, composite material, cast in thin shell shapes for use in construction. GFRC can be used wherever a light, strong, weather resistant, attractive and fire retardant material is required. GFRC can be used as wall panels, window surrounds, spandrels, column covers, soffits, cornices, brackets, quoins, railings, pilasters, copings, domes, etc. Landscape and hardscape uses include site furnishings, planters, bollards, urns, tables and fountains. GFRC is used in historical restorations and renovations for the replication of building ornaments of terra-cotta, carved stone and even wood.

**Fig. 1:** Glass fibre matrix

Chandramouli*et al.* (2010) had conducted experimental investigation to study the effect of using the alkali resistance glass fibres on compressive, split tensile and flexural strength on M20, M30, M40 and M50 grades of concrete. The mechanical properties of glass fibre reinforced polyester polymer concrete were evaluated. The author observed that the modulus of rupture of polymer concrete containing 20 per cent polyester resin and about 79 per cent fine silica aggregate is about 20 MPa. The addition of about 1.5 per cent chopped glass fibres (by weight) to the material increases the modulus of rupture by about 20 per cent and the fracture toughness by about 55 per cent

Komal and Bharti (2013) reported in their investigation on the mechanical properties of glass fibre reinforced concrete by making use of cement-filing crack HD (AR-glass fibre) with modulus of elasticity 72Gpa, filament diameter is 14microns, specific gravity of 2.68 and length of 12mm. Compressive, flexural and tensile strengths using M20 grade for the concrete mix were experimentally investigated with glass fibre content ranges between 0 and 1% by weight. They observed an increase in compressive strength is up to 37% and the flexural strength increased by 130% with 0.33% of glass fibre addition but at 1.0% of glass fibre addition, the compressive strength depleted by 4.14%. Also, the percentage increase in flexural strength of GFRC using fibre content of 0.33 and 1.25% steel (12 mm reinforcement bar) is observed to be 150% when compared to glass fibre only. In order to prevent the corrosion of glass fibre exposed to harsh environment, Alkaline Resistant glass fibre has shown good performance. Also, GFRC can be used for blast resisting structure, dams, hydraulic structure. Tajne and Bhandari (2014) experimentally investigated the compressive, tensile and flexural strengths of GFRC for M20 and M25 concrete cured for 7 and 28 days. No report on the proportion by weight of glass fibre used. However, they found that at 28 days, the strength increased between 12 and 20% over plain concrete in general. Also Deshmukh*et al.* (2012) also carried out experiments to determine the compressive, tensile and flexural strength of GFRC, M20 grade using 0, 0.03, 0.06 and 0.1% glass fibre content but no mention of the length of the fibre. They observed that the optimum strengths were recorded at 0.1% of glass fibre. Their work is not conclusive because the peak is not established. It has been established by Mufti *et al.* (2007) that glass fibre is highly corrosion resistant as opposed to reinforcing steel that corrodes aggressively when exposed to salty water. This puts glass fibre usage in the corrosive environment as an alternative to reinforcing steel. Although, its modulus is far less than steel but that is compensated for by its higher tensile strength. Pshtiwan and Pimplikar (2011) conducted experiments on GFRC using M20 concrete with 0.11, 1.5 and 2.0% of glass fibre. They found that the optimum compressive and flexural strengths occurred at 1.5% fibre content. Ironically, tensile strength pattern is not conclusive. The current study investigated the length variation on the characteristic strength of concrete at varying fibre contents.

## Methods and Materials

The experimental processes require some material preparation and mix design to produce M20 concrete. The glass fibres are cut into 5 and 8mm lengths before being added to concrete mix. The fibres were mixed with concrete in a random manner to distribute the fibres uniformly in the concrete matrix. The mix design used for all the concrete preparation is 1:2:4 with 0.6 water-cement ratio.

***Portland cement***

Cement used in this study is Ordinary Portland cement (OPC 42 grade) conforming to BS EN 12620. The cement passes through sieve size 4mm completely and stored on the wooden pallets in dry and humidity free environment to prevent hardening. Cement is the binder for the concrete mix. It is composed of chemical element such as; alumina, silica, iron and gypsum.

***Coarse aggregate***

The coarse aggregate is obtained from the crushed granite stones retained on 4.75 mm sieve size. It is well graded and all impurities and flaky pieces were removed before being used. The coarse aggregates conform to BS EN 12620.

***Fine aggregate***

The river washed sand that passed through 90 µ sieve size and of finesse modulus of 2.755. The fine aggregates conform to BS EN 1260.

***Water***

The water used in the production of the concrete is clean and potable, free of impurities and of pH values between 6 and 8. The amount of water relative to amount of cement changes how easily the concrete flows, but also affects the final strength of the concrete. The same amount of water was maintained in this experimental work.

***Glass fibre***

The glass fibres were sourced locally and they were cut into two main lengths of 5 and 8mm for the concrete production. Each cluster is used at 0, 0.2, 0.3, 0.4 and 0.5% by weight of concrete specimen. The glass fibre is alkaline resistant type denoted as AR Glass. The characteristic information of the glass fibre used is presented in Table 1.

**Table 1: Properties of Alkali Resistance Glass Fibre**

| Fibre | AR Glass |
|---|---|
| Specific gravity | 2.67 |
| Elastic modulus (Gpa) | 72 |
| Tensile strength (Mpa) | 1700 |
| Diameter (micron) | 14 |
| Aspect ratio | 857.1 |
| Length (mm) | 5 and 8 |

***Test specimen sizes***

The compressive strength specimen is150 x 150 x 150 mm cubes and the split tensile strength test specimen size is 150mm diameter and 300mm length cylinders and the flexural test specimen size is square cross-section beam of 150×150 mm and length of 700 mm.

## Results and discussion

The concrete samples were cured for 7, 14 and 28 days before being tested for compressive, split tensile and flexural strengths. The results of various tests are presented in the following sections.

***Compressive strength***

Figures 2 and 3 show the plots of compressive strength for various glass fibre contents (0, 0.1, 0.2, 0.3, 0.4 and 0.5%) at 7, 14 and 28days curing ages for 5 and 8mm fibre lengths respectively. The optimum compressive strength was observed at 0.4% glass fibre the strength falls as the fibre content is increased beyond 0.4% for all curing ages. The maximum compressive strength also occurred at 28 day for 5 mm length with an increase of 20% over the plain concrete. Generally, the compressive strength increases for all the curing ages considered. Comparing the plots for 8mm fibre glass length, the same behaviour is observed but at reduced level.

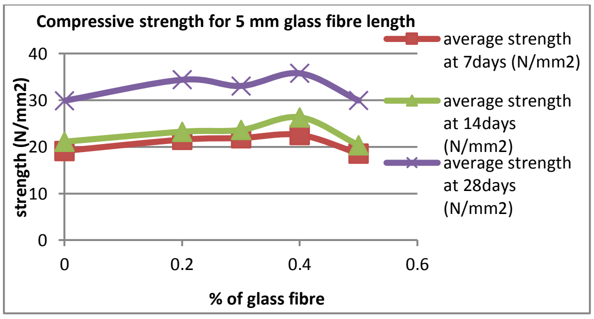


**Fig. 2:** compressive strength test for 5 mm glass fibre length

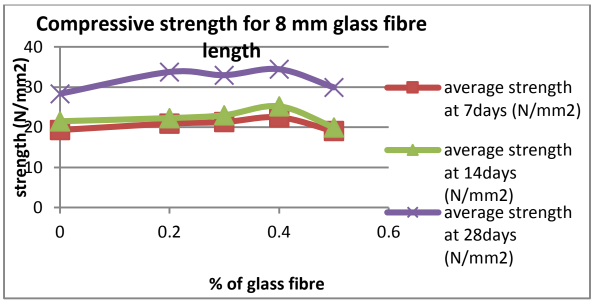


**Fig. 3:** compressive strength test for 8 mm glass fibre length

### *Split tensile strength*

Figures 4 and 5 show the plots of split tensile strength for various glass fibre contents (0, 0.1, 0.2, 0.3, 0.4 and 0.5%) at 7, 14 and 28days curing ages for 5mm and 8mmfibre lengths, respectively. The optimum split tensile strength was observed at 0.4% glass fibre the strength falls as the fibre content is increased beyond 0.4% for all curing ages. The maximum compressive strength also occurred at 28 day for 5 mm length with an increase of 33% over the plain concrete. Generally, the compressive strength increases for all the curing ages considered. The same phenomenon was observed for 8mm fibre glass length.

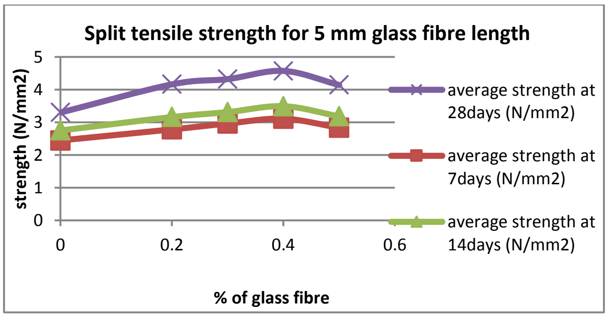


**Fig. 4:** Split tensile strength for 5 mm glass fibre length

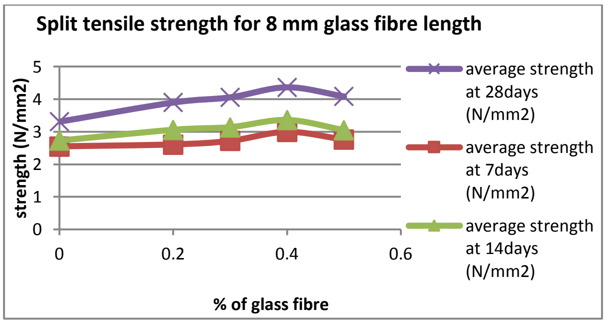


**Fig. 5:** Split tensile strength for 8mm glass fibre length

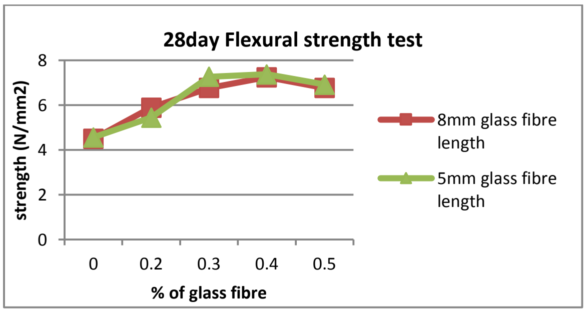


**Fig. 6:** 28 days flexural strength test between 5 and 8 mm fibre length

### *Flexural strength*

Figure 6 shows the plot of flexural strength GFRC with increasing content of glass fibre (0, 0.1, 0.2, 0.3, 0.4 and 0.5%) having 5 and 8mm fibre lengths at 28days curing. Both curves are not significantly different but the optimum value for both lengths is observed at 0.4% of fibre content. This represents about 61% increase over plain concrete.

## Conclusion

From the above discussed results, it evident that glass fibre improves the mechanical strengths of concrete considerably. The optimum glass fibre content of 0.4% produced the highest compressive, tensile and flexural strengths. This increase over the plain concrete ranges between 20% for compression and 61% for flexure. The length of fibre plays a significant role in its strengths as the strength of 5 mm long fibre are significantly higher than that of 8mm long fibre with the exception of the flexural strength which shows a relatively insignificant difference between two lengths.

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