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***Journal of Scientific and Engineering Research*, 2016, 3(3):401-407**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

An experimental study of the effect of glass fibre reinforcement on the mechanical properties of concrete

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Abstract Concrete without any fibres will develop cracks due to shrinkage in volume. The development of this micro crack causes elastic deformation of concrete. Plain concrete is a brittle material, having low values of modulus of rupture and strain capacity is low. In order to enhance high flexural strengths and to reduce shrinkage, glass fibres were used to reinforce plain concrete.

The main objective of this research is to study the effect of glass fibres reinforcement on the mechanical properties of Portland cement. Experiments were carried out to determine compressive strengths, ultimate drying shrinkage, consistency and setting times of both plain concrete and concrete reinforced with glass fibre. Ultimate drying shrinkage decreased exponentially as the sand/cement ratio increased. Increasing the glass fibres percentage assisted tremendously in reducing the drying shrinkage of the concrete-glass fibre aggregate. Compressive strengths of the concrete/glass fibres aggregates were measured after 7, 14, 21 and 28 days of curing. Compressive strength in all the samples increased with increasing percentages of glass fibres. It was observed that increase in percentage of glass fibre facilitated early initial and final setting times

Keywords Portland cement, mechanical properties, concrete, glass fibres reinforcement, drying shrinkage, compressive strengths, consistency, setting times.

Introduction

Concrete is the most widely used construction material which 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 short comings are generally overcome by reinforcing concrete with glass fibre. 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 magnitude of comparative strength.

The fundamental reason for introducing glass fibres into a cement based matrix is to impart tensile strength and toughness, cement mortars and concretes being weak and unreliable in tension [1].

When glass fibres are combined with a cementations matrix the result is the fibrous composite glass-fibre-reinforced cement – GRC. The two distinct parts are the cement or mortar based matrix, which is essentially brittle with low and unreliable tensile strength, and the reinforcing alkali-resistant glass fibres which have high tensile strength. The combination of the two results in a composite material with its own distinctive properties, which may be formed into relatively thin sections [2]. Proper curing is carried out on the combination of the various constituents of the GRC in order to guarantee the attainment of its potential properties.

Glass reinforcement cement (GRC) is the newest member of a growing and diverse range of fibre reinforced composites. GRC has been recognized for perhaps the past 50 years as a potentially very important composite system; which could demonstrate important mechanical and physical properties [1].

A lot of investigative work has been carried out on the properties and performance of GRC [3- 9].

The mechanical and physical properties of the classes of GRC under the headings of strength, movement and performance were investigated by [1].

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 fibers, either natural or artificial, having a high tensile strength. Due to the presence of these uniformly dispersed fibers, the cracking strength of concrete is increased and the fibers acting as crack arresters. Fibers suitable of reinforcing concrete having been produced from steel, glass and organic polymers. Many of the current application of FRC involve the use of fibers ranging around 5% by volume of concrete. Recent attempts made it possible to incorporate relatively large volumes of steel, glass and synthetic fibers in concrete. Result of tensile tests done on concretes with glass, polypropylene and steel fibers; indicate that with such large volume of aligned fibers in concrete, there is substantial enhancement of the tensile load carrying capacity of the matrix. This may be attributed to the fact that fibers suppress the localization of micro-cracks into macro-cracks and consequently the apparent tensile strength of the matrix increases.

Cement is a fine mineral powder manufactured with very precise processes. Mixed with water, this powder transforms into a paste that binds and hardens when submerged in water. Because the composition and fineness of the powder may vary, cement has different properties depending upon its makeup. Cement is the main component of concrete. The cement is made based on the chemical composition of the raw materials that are used and the addition of complementary constituents (components) during the stages of grinding and refining. Each cement type has specific applications. These include residential construction of concrete for harsh environments or in highly corrosive conditions [10].

Cement manufacture causes environmental impacts at all stages of the process. These include emissions of airborne pollution in the form of dust, gases, noise and vibration when operating machinery and during blasting in quarries, and damage to countryside from quarrying. Equipment to reduce dust emissions during quarrying and manufacture of cement is widely used, and equipment to trap and separate exhaust gases are coming into increased use. Environmental protection also includes the re-integration of quarries into the country side after they have been closed down by returning them to nature or re-cultivating them. [11]

Glass fiber is chemical inorganic fiber, obtained from molten glass of a specific composition. This glass is compound of quartz and, limestone, kaolin, calcium fluoride (fluorspar,) boric acid, atrium sulfate, and clay. Glass fiber is made of natural materials, so that its products are ecologically pure and not harmful to human health [12]. Glass fiber can be twisted, wrapped, woven and treated like any other fiber. Its many rare characteristics render it especially valuable: highly bending, puling, and pressure resistance, high temperature resistance, low hydroscopic, resistance against chemical and biological influences, comparatively low density. Glass fiber is highly light permeable and can be a semiconductor. Glass fiber products have excellent electronic, heat, and sound insulation capacities.

Material and Methods

A concrete mix (Plate 1) was prepared using sand, crushed stones that were made to pass through 4.75 mm sieve size and 53 Grade Dangote cement. The Cement-sand ratio was1:3 based on International Standard (IS) 10262:1982 to achieve a target on compressive strength of 20 MPa. The water in the mix was 60% of dry materials. The concrete was casted after the addition glass fibre of varying percentages of 5%, 10%, 15% and 20% volume fraction of the concrete. The samples were prepared in the form of cubes 50 mm x 50 mm x 50 mm. After casting (Plate 2), the test specimens were kept for 24 hours before they were taken to the curing tank (Plate 3) for between 7 and 28 days.

Determination of initial and final setting times

A cement paste (Plate 4) was prepared by mixing the cement with 0.6 times the water required to give a paste of standard consistency. The Vicatmould was completely filled with the cement paste gauged. The mould was allowed to rest on a porous plate. The surface of the paste was leveled with the top of the mould. The cement block thus formed was used for the setting time test. The time taken for the paste to change from fluid to a rigid state, by the use of the Vicat apparatus, was observed in conformity to IS 5513 – 1976. The initial setting time was determined with the 1mm diameter needle on the apparatus acting under a prescribed weight of standard consistency. The permissible variation at a load of 1000 g should be $\pm$ 1.0 g. Initial setting time occurred when the needle penetrated to appoint 5 mm from the bottom of the mould. Final setting time was determined when the needle with a hollowed metal attachment left a circular edge of 5 mm behind its tip.

Determination of compressive strength test

Compressive strength tests were carried out on the specimens, shown in Plate 5, using a Universal Tensile Testing Machine, model no. TQ SM 100.

Plate 1: The aggregate of materials used for casting

Plate 2: The casting

Plate 3: The Curing tank

Plate 4: Cement paste after consistence and final setting time

Plate 5: The removed cubes from the pallet according to different percentages of glass fibre

Consistency

For the determination of the initial and final setting time, neat cement paste was used inorder to have a standard of penetration consistence. Consistence was determined by the VicatApparatus (model no. ELE 63 – L0028) which was used to measure the depth of penetration of a 10 mm diameterplunger under its own weight. When the depth of penetration reached 40 mm, thewater contents required gave the standard consistence of 35 which was expressed as a percentageby mass of dry cement.

Shrinkage

Samples of the concrete /glass fibre aggregates with different cement ratios were investigated with respect to their ultimate drying shrinkage. The volumes of the samples in their fully wet conditions were determined. The volumes were again determined in fully dry conditions at 50^{o}C , the temperature that was attained within the curing tank.

$S_{ud} = V_i - V_f$ x 100% (1)

Where

S_{ud} = ultimate drying shrinkage

V_i = volume of fully we sample

V_f = volume of fully dry sample

Results and Discussion

Table 1 shows the test results of compressive strength after 7, 14, 21 and 28 days. Compressive strength in all the samples increased with increasing percentages of glass fibre. This can be explained by the fact that the glass fibres used in concrete might have suppressed the localization of micro cracks within the concrete. The durability of concrete can be increased by increasing its compressive strength [13].

Figures 1 and 2 show the test result of initial and final setting time for the different percentages of glass fibre within the concrete/glass fibre aggregates. It was observed that increase in percentage of glass fibre facilitated early initial and final setting times.

Figure 3 shows the effect of sand/cement ratio and the percentages of glass fibre on the ultimate drying shrinkage of the concrete/glass fibre aggregate. Ultimate drying shrinkage fell exponentially with increasing sand/cement ratio whilst increase in the percentage of glass fibre led to increase of the ultimate drying ratio.

Table 1: Compressive Strengths of The Concrete/Glass Fibre Aggregates

(%) Glass fibre	7 days (N/mm^2)	14 days (N/mm^2)	21 days (N/mm^2)	28 days (N/mm^2)	Average (N/mm^2)
0	2.0	2.1	2.1	2.8	2.3
5	2.7	2.8	3.0	2.9	2.9
10	3.6	3.5	3.6	3.6	3.6
15	4.5	4.7	4.8	4.9	4.7
20	5.2	6.0	6.1	6.3	5.9

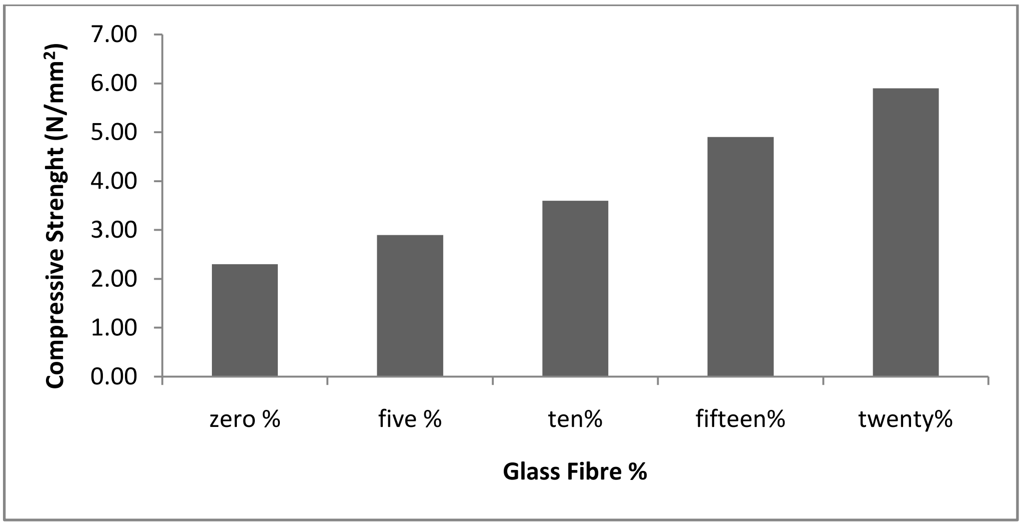

Figure 1: The Effect of the Glass Fibre Content on the Compressive Strength of the Concrete

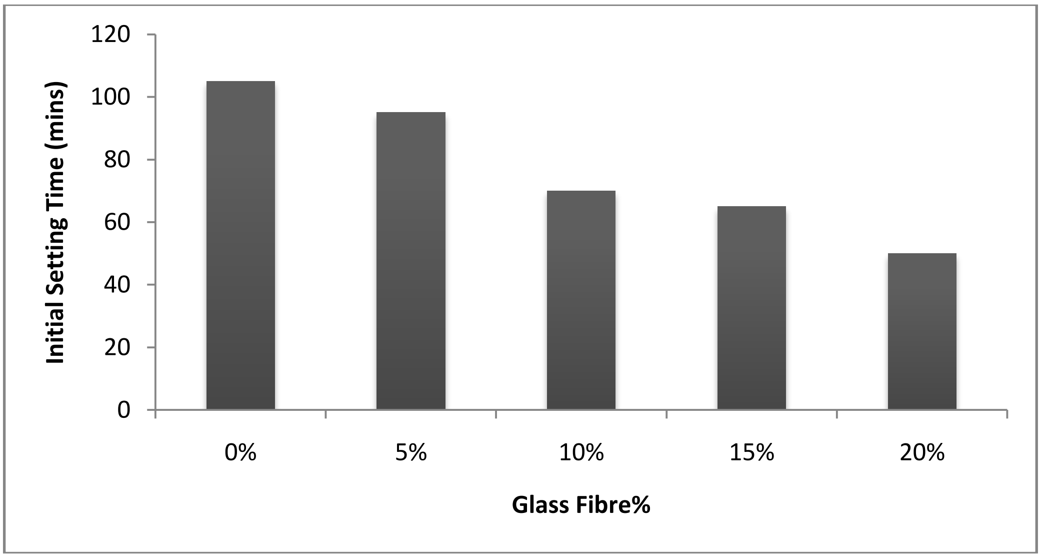

Figure 2: Effect of the Glass Fibre Content on the Initial Setting time of the Concrete

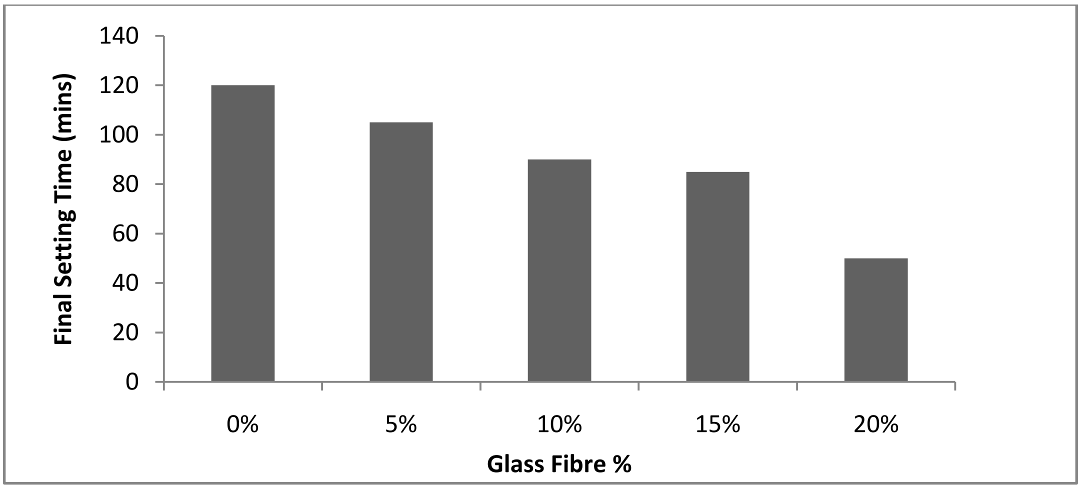

Figure 3: Effect of the Glass Fibre Content on the Final Setting time of the Concrete

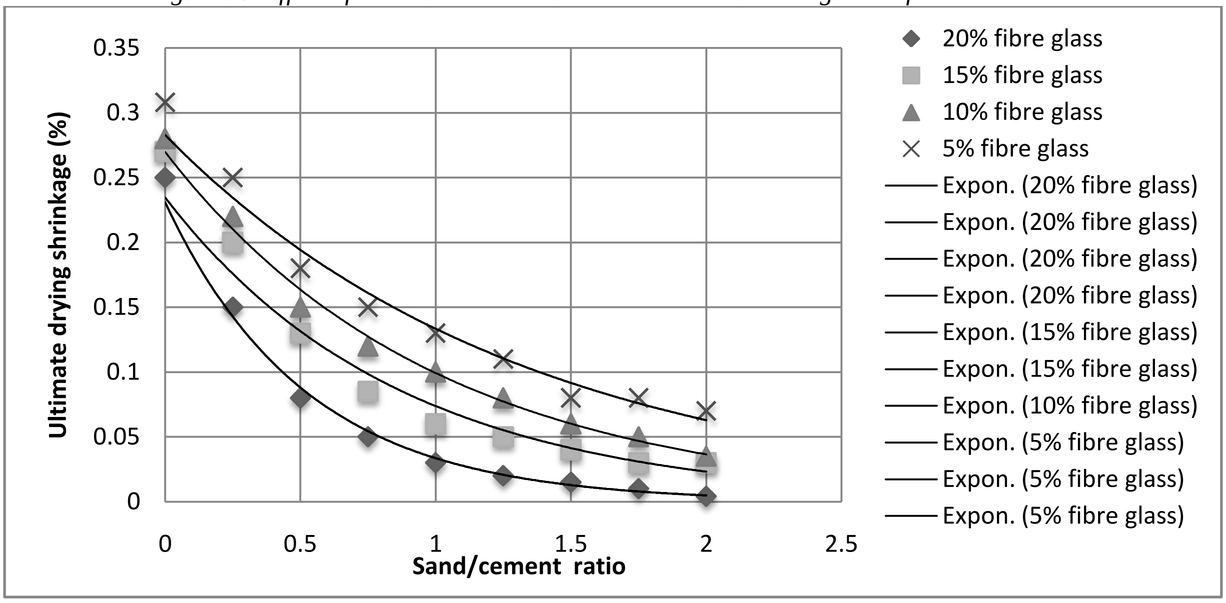

Figure 4: Effect of silica sand on the shrinkage of the Concrete

Conclusion

The addition of glass fibre into the concrete mixture improved compressive strength after 28 days of curing. The addition of 20% of glass fibre to the concrete gave the best result in mechanical properties and durability of the concrete/glass fibre aggregate. Increase in the percentage of glass fibre in concrete/glass fibre aggregates enhancedearly initial and final setting of the aggregates. Ultimate drying shrinkage decreased as the sand/cement ratio increased whilst Increasing the glass fibres percentage assisted tremendously in reducing the drying shrinkage of the concrete-glass fibre aggregate

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