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Investigating Behaviour of Reinforced Concrete with Glass Fibre

Salahaldein Alsadey [a], Miftah Abdallateef [a], Muftah Mohamed [a] & Abdalrhman Milad [b]

[a]*Faculty of Engineering, Bani Waleed University, Libya*
[b] *Faculty of Engineering University of Azzaytuna (AZU). Tarhouna, Libya.*

**Corresponding author: lidcocompany@gmail.com*

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ABSTRACT

Concrete is the most commonly used building material. Nowadays, the world has seen the construction of engineering applications that has become difficult and complicated. Therefore, it is important to have high strength and adequate workability. Besides that, the glass fibre is highly beneficial as a construction material for reinforced concrete as it can be identified as one of the numerous compelling topics related to its benefits. This study contributes to the specification and classification of glass fibre reinforced concrete (GFRC). However, ordinary concrete has limited ductility, slight resistance to cracking, and insufficient tensile strength. Internal micro-cracks in the concrete are visible, and the proliferation of such micro-cracks caused its weak tensile strength. When a certain percentage of fibre is added to the concrete, it improves the properties of the strain, namely, resistance to cracking, ductility, toughness, and flexure strength. The current paper outlines the experimental study conducted on the usage of glass fibre with structural concrete. The parameters were used in percentages, which varied from 0.5% to 2% by weight of cement in concrete, and the properties of the FRC (fibre reinforced concrete), such as ultrasonic pulse velocity test, flexure strength, and compressive strength were examined. However, it refers to an increase in deformation before failure of the structural concrete, reinforced with a high ratio of GFR. The results show good performance of concretes containing glass fibre and increasing glass fibre content, increasing the compressive strength.

Keywords: Glass fibre reinforced concrete; glass fibre; ultrasonic pulse velocity test; flexure strength; compressive strength

INTRODUCTION

Since the beginnings of the 20th century, fibres have been used continuously in buildings. Since then, fibres were being manufactured using 39 various materials, including steel, polypropylene and glass, which have progressively spread to 40 different applications, especially fibre reinforced concrete (FRC) manufacturing (Simões et al. 2017). Generally, the quality of concrete primarily relies on the strength of the concrete. It is fair to identify that concrete is strong in compression and weak in tension. Since concrete is brittle, it has less capability to take tensile loads. In order to increase the ability of concrete to take more tensile loads, fibres are combined into the concrete. The fibres incorporated into the concrete, alter its mechanical properties, thereby differentiating it from standard conventional concrete (Sankeerthan et al. 2019). The concrete is one of the most versatile building materials as it can be cast to fit any structural shape such as a rectangular beam, a column in a high-rise building, or a cylindrical water storage tank. The usage of concrete can have more excellent fire resistance, higher water resistance, higher compressive strength, longer service life, and lower maintenance.

However, the content of the concrete influence its performance. Ordinary concrete is brittle and has weak tensile strength and strain capacity. Hence, the concrete needs to be reinforced to be widely utilised as a construction material. This reinforcement is conventionally done by placing steel bars in the concrete structure at suitable locations to bear the imposed shear and tensile stress. The usage of fibres, which are usually short, discontinuous, and randomly dispersed throughout the concrete, produces a composite construction material called fibre reinforced concrete (FRC).

FRC is a relatively new material that is presented nowadays to find out a better property of tensile strength in concrete. Due to a composite material containing a matrix that contains a random distribution or dispersion of small fibres, either natural or artificial, it has a high tensile strength (Swati et al. 2017). fibre-reinforced concrete (FRC) is concrete that includes fibrous material, which grows its structural safety. (Shetty & M 2012). Due to the presence of these uniformly dispersed fibres, the cracking strength of concrete is increased and the fibres acting as crack arresters (Chandramouli et al. 2010). The strength, resistance, and other characteristics of concrete consist of properties of its constituents on proportions of the mix.

Moreover, the method of compaction and other controls are through placing, compaction, and curing (Frederick & Paul 2009). Glass fibre, when utilised as a thermally insulating material, is mainly produced with a bonding factor to trap many small air cells, resulting in the peculiarly air-filled low density "glass wool" family of products (Somaiah et al. 2018). The mechanical properties of GRFC in the scope of structural utilisation, and they also reported that compressive strength decreased due to the low shearing strengths of glass fibres (Mise et al. 1982). fibre-reinforced concrete (FRC) is a Portland cement concrete that is reinforced with randomly dispersed fibres. In FRC, several small fibres are distributed and dispersed at random during mixing of the concrete, hence enhancing the particular properties thoroughly. Glass fibre reinforced concrete (GFRC) is a composite material that contains a mortar of hydraulic Portland cement and fine aggregate reinforced alkali-resistant glass fibres.

The method of manufacturing GRC products, component design and material properties are related to one another and depending on a wide variety of variables. These comprise manufacturing, mixture formulation, fibre product type, length, orientation, and admixture used. Studies done by (Chandramouli & Srinivasa 2010) noted an increase in the percentage of compressive strength of various quantity of glass fibre concrete mixtures from 20% to 25% in 28 days. Simultaneously, there was an increase from 15% to 20% in flexural strength and split tensile strength of various quantity of glass fibre concrete mixtures in 28 days. Experimental studies (Hemalatha & Rose 2016) revealed that adding glass fibre to ordinary concrete increased its durability and strength. Test results revealed that strength such as compressive, flexural and split tensile strength increased when glass fibres were added. (Chaitanya et al. 2016) have added cylinders and cubes with numerous portions of glass fibres, namely 0.5%, 1%, 2% and 3% to M-20 grade concrete and studied their flexural strength, split tensile strength, compressive strength and workability on the 7th and 28th day. Their findings revealed an optimum additional increase of 1% in strength properties. Besides, the concrete has a reduced number of cracks under different loading specifications. There was a 1% increase in the workability of the concrete when glass fibre was added.

EXPERIMENTAL PROCEDURE

An experimental investigation was conducted in the concrete laboratory of the Faculty of Engineering at Bani Waleed University, Libya. Thirty concrete specimens were cast with and without the addition of glass fibre. In this study, the specimens used were 15 in 100 mm side cubes with a compressive strength of 38.6 MPa and ten prisms 100x100x500 mm with a flexural strength of 11.96 MPa. The five specimens' slabs were prepared with a geometric size of 500 × 250 ×70 mm. (length × width × thickness). The nominal mixing proportion utilised for casting the specimens was 1:1:2 (cement: sand: coarse aggregate) by weight with a slump of (27±2) mm. The aggregate concrete was submerged 24 hours in water and later dried to obtain a wet-dry surface condition. Dry sand and cement were mixed before 0.45% of water was added. The mixture was mixed thoroughly for a minimum of 3 minutes to provide enough time for the glass fibre to be evenly distributed in the mixture. Before casting, the inner surfaces of the cast wood mould were smeared with oil. Three layers of concrete were poured into the mould and compacted thoroughly by using a standard compact vibrator. A trowel was used to smoothen the top layer. After 24 hours, the specimens were taken out from the mould and treated underwater for 28 days.

The specimens were taken out from the treatment tank 24 hours before conducting the test to dry in the open air. A compressive strength test was carried out by utilising a 2000 KN compression testing machine BS 1881:116. Next, the flexural strength test for beams and slabs were done using BS 1881:118. The tests were carried out according to relevant standard specifications. An ultrasonic pulse velocity test was done based on (ASTM C 597–2003). The path length between transducers, divide by time travel, will give the average velocity of wave propagation, V = L / T. Where V = Ultrasonic pulse velocity, km/sec, L = Path length, mm and T = transit time, sec. Direct transmission to 100×100×100 concrete cubes was conducted in this study.

FIGURE 1. Participant's posture

TABLE 1. Properties of glass fibre

Property	Description
Base	Glass fibre
Colour	Natural
Sika fibre (G)	Monofilament Fibber
fibre Length	18 mm
Diameter	13±10 microns nominal

TABLE 2. Mix proportion of concrete (kg/m³)

Mix No	Cemen Kg/m³	Fine Aggregate Kg/m³	Normal Coarse Aggregate Kg/m³	Glass fibre Kg/m³	Glass fibre %	Water Litter
M1	350	350	700	0	0	157.5
M2	350	350	700	1.75	0.5	157.5
M3	350	350	700	3.5	1	157.5
M4	350	350	700	5.25	1.5	157.5
M5	350	350	700	7	2	157.5

MATERIALS USED

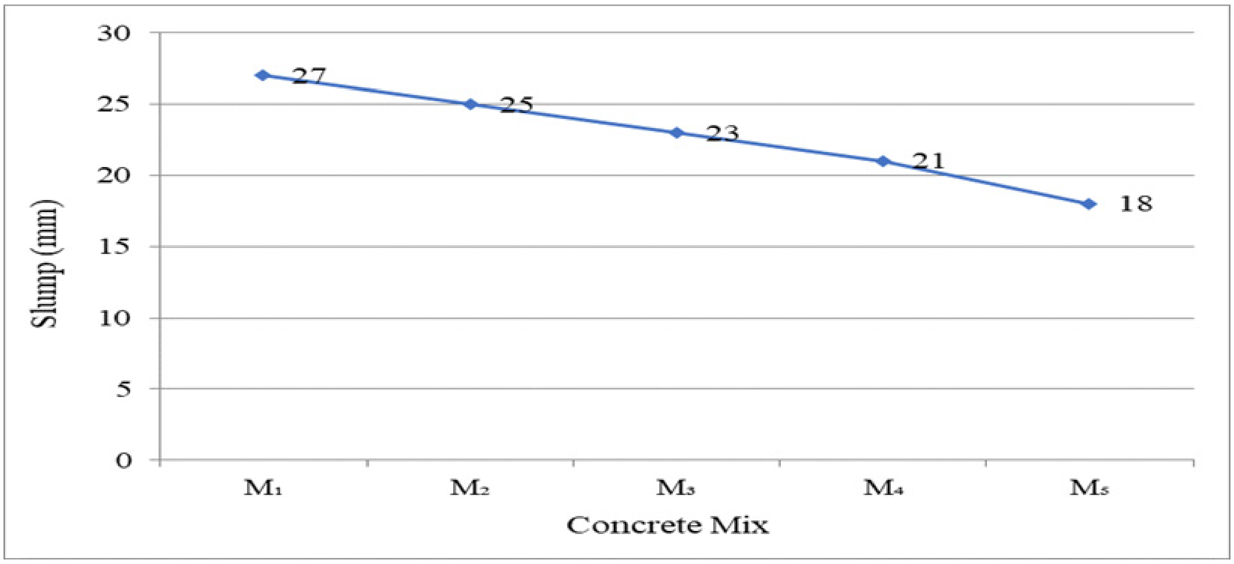
In this study, Ordinary Portland Cement (OPC) confirmed by ASTM C150-99a, was used to cast all the concrete. Sea sand was used as fine aggregate; the specific gravity was 2.66. Its grading was within BS 882-19992. Crushed stones from a local source was used as coarse aggregate. The specific gravity was 2.65, and were size-screened to a maximum of 14mm. Sieve analysis of coarse aggregate was also done under ASTM C33-03. Table 1 displayed the fibrillated glass fibre properties utilised in this study. Moreover, the raw sea sand is used as a fine aggregate due to an increase in the utilisation of concrete in the construction sector in Libya. However, the need for sea sand has been increased enormously. Limitations have been laid on the large-scale mining of sea sand from other types.

MIX DESIGN

The arbitrary method was utilised to mix proportions. The sand, cement, and coarse aggregate was weighed according to mix portion 1:1:2. Table 2 displays the mix proportion and properties of concrete.

TABLE 3. Results obtained from the slump test

Specimen	Slump (mm)
M_1	27
M_2	25
M_3	23
M_4	21
M_5	18



RESULTS AND DISCUSSION

EFFECT OF GLASS FIBRE ON WORKABILITY OF CONCRETE

A slump cone test was carried out to ascertain the slump of the concrete mixture. Table 3 and Figure 1 displayed the slump values of various mixtures. The findings displayed in the figure revealed that as the percentage of glass fibre content increased, the slump values decreased slightly. The reduction in the slump as the fibre increased was caused by fibre, which obstructed the free flow of concrete.

EFFECT OF GLASS FIBRE ON HARDENED PROPERTIES OF CONCRETE

Hardened characteristics, namely compressive strength and flexural strength, are examined for 28 days for a various ratio of glass fibre on concrete mixtures.

COMPRESSIVE STRENGTH OF CONCRETE CUBES

Table 4 illustrates the value of the compressive strength of the cube specimens on the 28-day period. Figure 2 illustrates the test results which revealed the compressive strength of concrete cubes with glass fibre that was 0.5%, 1%, 1.5% and 2% higher than the cubes without glass fibre at 39.9 MPa, 44.7 MPa, 43.7 MPa and 41.5 MPa, respectively compared with the control mixture without glass fibre whose compressive strength was 38.6 MPa.

The glass fibre effectively supports the micro-cracks that happened in the concrete mass. The increasing ratio in the compressive strength for cubes with glass fibre 0.5%, 1%, 1.5% and 2% compared to the cubes without glass fibre are 3.36%, 15.80%, 13.21% and 7.51%, respectively. The test result showed that the maximum ratio increase in compressive strength could be obtained from cubes with glass fibre 1%. Hence, a glass fibre of 1% is recommended to obtain the maximum benefit in enhancing compressive strength. It is perceived that the usage of glass fibre is useful to enhance the compressive strength of concrete. If more glass fibre is utilised, it will cause workability issues, and air cavities will be left in the system. Hence, adding more fibre will cause its strength to decrease gradually (Retnakar et al. 2017; Alam et al. 2015).

FLEXURAL STRENGTH OF CONCRETE BEAMS

The concrete specimens displayed the maximum flexural strength for specimens prepared with all percentages of glass fibre. At a fibre content of 0.5%, 1%, 1.5%, and 2%, the flexural strength of the concrete increased by 16.80%, 20.98%, 3.42%, and 2.50%. Figure 3 illustrates that a slight increase in the fibre content can increase the flexural strength of concrete compared to the ordinary concrete specimen. Maximum strength was achieved by M3 specimen with 1% glass fibre compared to concrete without glass fibre. Thus, the

M3 concrete denoted 20.98% strength higher than the control of concrete specimens. It is noted that the glass fibre disclosed greater strength under flexural loading. The glass fibre can repel the spread of cracks and reduce the sudden failure of the structure of concrete. Thus, the load-carrying capacity of concrete was increased (Kene et al. 2012; Löber & Holschemacher 2014; Kiran et al. 2016).

STRENGTH OF CONCRETE SLABS

Figure 4 displayed the reinforced concrete tested slab with 0.5%, 1%, 1.5%, and 2% glass fibre. The failure mode and properties of the slab without glass fibre are compared. The conventional concrete slab specimen showed a strength of 17.70 MPa. The glass fibrous concrete slab specimens revealed their strength as 18.84 MPa, 19.72 MPa, 17.45 MPa and 17.01 MPa, respectively, with 0.5%,1%, 1.5%, 2% glass fibre content. It revealed that when the fibre content was less than 1%, the strength increased rapidly,

TABLE 4. Compressive strength for different cubes

Specimen	Compressive Strength MPa
M_1	38.6
M_2	39.9
M_3	44.7
M_4	43.7
M_5	41.5

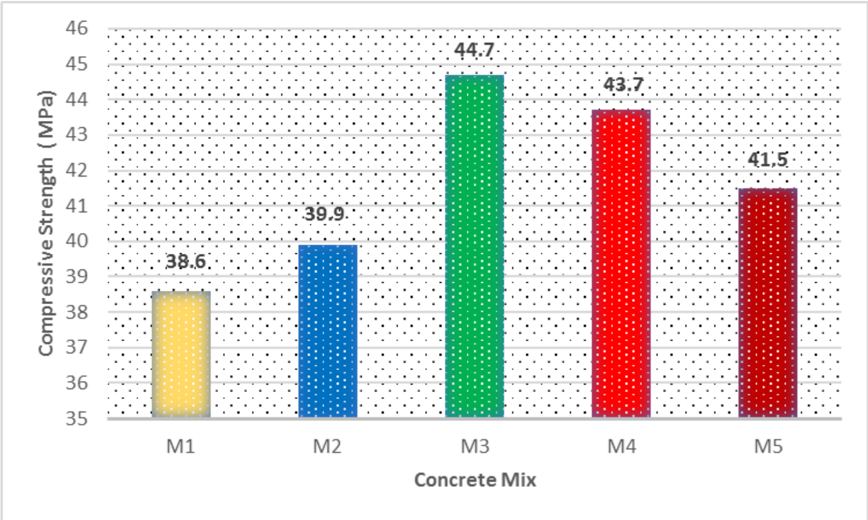


FIGURE 2. Compressive strength variation with a ratio of glass fibre

TABLE 6. Strength of different slabs

Specimen	Flexural Strength MPa
M_1	11.96
M_2	13.97
M_3	14.47
M_4	12.37
M_5	12.26

but when the glass fibre content was more than 1% (for example, 1.5% and 2.0%), there was a slow and slight decrease in strength.

THE ULTRASONIC PULSE VELOCITY TEST RESULTS

The ultrasonic pulse velocity test is a useful tool to provide information about the interior of concrete. However, the test is utilised to calculate the uniformity of concrete besides detecting the voids and cracks. It provides valuable information about the interior structure of the concrete, the size of micro-cracks zones, and crack formation. Table 7 displays the values of ultrasonic pulse velocity for different types of concrete mixtures with several percentages of glass fibre, and Figure 5 shows the ultrasonic pulse velocity for all mixtures ranging between 4.55 km/s and 4.67 km/s. By utilising the proposed classification method by (Jones & Gatfield 1963), all the concrete produced in this study is of excellent quality, according to ASTM C597.

The results obtained by all specimens showed an increase in Ultrasonic Pulse Velocity values with an increase in percentages of glass fibre. The increase in UPV for 0.5%, 1%, 1.5% and 2% of glass fibre in concrete mixture were 4.61%, 4.67%, 4.67%, 4.67%. Moreover, the findings revealed that concrete mixtures containing glass fibre noted a significant increase in UPV than ordinary concrete. This behavior is due to the increase in the ratio of glass fibre that causes a rise in wave speed as the velocity of ultrasonic through materials is greater if it is transferred through space. Hence, the rise in the glass fibre ratio increases the ultrasonic pulse velocity.

CONCLUSION

From the investigational study, it is clear that the adding of fibres to the conventional concrete has improved the compressive, flexural properties of the concrete to a great extent. Thus, experiments were carried out in the laboratory to examine the influence of glass fibre on the strength of

TABLE 6. Strength of different slabs

Specimen	Strength MPa
M_1	17.70
M_2	18.84
M_3	19.72
M_4	17.45
M_5	17.01

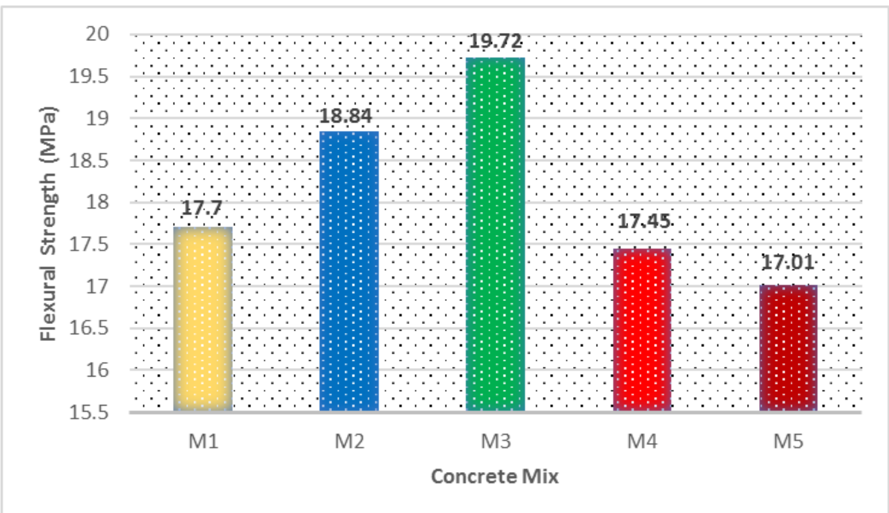


FIGURE 4. Flexural strength variation with the ratio of glass fibre

TABLE 7. The results of ultrasonic pulse velocity

Mixture code	Ultrasonic Pulse Velocity (km/s)
M_1	4.55
M_2	4.61
M_3	4.67
M_4	4.67
M5	4.67

concrete. The following conclusion was drawn based on the experiments performed on the specimens with several percentages of glass fibre:

• There was a reduction of a slump if the content of glass fibre was raised significantly when its 2%, and the resulting mixture became fibrous and difficult to handle.

• The compressive strength of the glass fibre concrete mixture has an increase of 15.80% compared to the mixture without fibre. The specimens with 1% glass fibre content produced optimum results compared with other specimens utilised in this investigation. Thus, adding glass fibres to the concrete would improve its mechanical properties.

1. The maximum flexural strength of 1% glass fibre was 14.47 MPa compared to the flexural strength of concrete with no fibre. When other portions of glass fibre were utilised, a small drop in flexural strength was observed.

2. For the remaining fibres, the increase in fibre addition increases both toughness index and energy absorption capacity.

3. The compressive strength of the GFR tends to increase with the increase of fibres addition. Results also show that the compressive strength growths according to the tensile strength and stiffness of the fibre.

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DECLARATION OF COMPETING INTEREST

None.

REFERENCES

Md. Alam, A., Ahmad, I. & Rahman, F. 2015. Experimental study on properties of glass fibre reinforced concrete. *IJETT* 24(6): 297–301.

American Society for Testing and Materials. 2015. (ASTM), Standard specification for Portland cement, ASTM C150/C150M, ASTM International, West Conshohocken, PA.

ASTM C 192/C 192M. 2002. ―Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory‖. ASTM International.

ASTM C597-2003, .Standard test method for pulse velocity through concrete. *Annual Book of ASTM Standard American Society for Testing and Materials* 4(2).

British Standard Institution. 1983. 1881: Part 102 (1983). Methods for Determination of Slump.

British Standard Institution. 1983. 1881: Part 116 (1983). Methods for Determination of Compressive Strength of Concrete Cube.

British Standard Institution. 1983. 1881: Part 118. Testing concrete Methods for Determination of flexural Strength.

Chandramouli, K. & Srinivasa Rao, P. 2010. Strength properties of glass fibre concrete. *ARPN Journal of Engineering and Applied Sciences* 5(4).

Chandramouli, K., Srinivasa Rao, P., Pannirselvam, N., Seshadri Sekhar, T. & Sravana, P. 2010. Strength Properties of Glass Fibre Concrete. *ARPN Journal of Engineering and Applied Sciences* 5(4).

Frederick, T., Wallenberger, & Bingham P.A. 2009. Fibreglass and Glass Technology: *Energy Friendly Compositions and Applications*. Springer.

Chaitanya Kumar, J. D., Abhilash, G.V.S., Khan, P.K., Manikanta, S.G. & Ram, V. T. 2016. Experimental Studies on glass fibre concrete. American Journal of Engineering Research (AJER) 5(5): 100104.

Jones, R. & Gatfield, E. 1963. Testing Concrete by Ultrasonic pulse Technique. London: Her Majesty's stationary Office.

Reddy, K.B.S., Prasad, J.S.R. & Venu, M. 2019. Durability and physical properties of glass fibre reinforced concrete subjected to elevated temperatures. International *Journal of Innovative Technology and Exploring Engineering* (IJITEE) 8(11).

Kene, K.S., Vairagade, V.S. & Sathawane, S. 2012. Experimental study on behavior of steel and glass fibre reinforced concrete composites. *Bonfring International Journal of Industrial Engineering and Management Science* 2(4): 125–130.

Kiran, S.T. & Srinivasa, R.K. 2016. Comparison of compressive and flexural strength of glass fibre reinforced concrete with conventional concrete. *International Journal of Applied Engineering Research 11*(6): 4304–4308.

Löber, P. & Holschemacher, K. 2014. Structural glass fibre reinforced concrete for slabs on ground. *World Journal of Engineering and Technology* 2: 48–54.

Mise, T., Mashima, M. & Yukawa, K. 1982. Shearing behavior of glass fibre reinforced concrete. In the Cement Association of Japan. The 36th General meeting, Technical Session, pp. 204–205.

Retnakar, A., Aswin, S., Hussain, S.S.K., Shilpa, T.S., Varun, V. & Kumar, M.D.S. 2017. Performance evaluation of glass fibre reinforced concrete. *IRJET* 4(3): 950–954.

Hemalatha, S., Dr. Rose, A.L. 2016. An experimental study on glass fibre reinforced concrete. International Research *Journal of Engineering and Technology* (IRJET) e-3(4): 2285.

Shetty, M.S. 2012. ―Concrete Technology.

Sika Company, "Technical data sheet catalogue" polypropylene, glass, carbon fibres, January, 2006.

Simões, T., Costa, H., Dias-da-Costa, D. & Júlio, E. 2017. Influence of fibres on the mechanical behaviour of fibre reinforced concrete matrixes. *Construction and Building Materials* 137: 548–556. doi:10.1016/j.conbuildmat.2017.01.104

Somaiah, G. M. & Kumar, A. A. 2018. Fabrication and evaluation of properties of glass fibre reinforced polymer composites. 5(5).

Swati, J.S. & Gunjan P.D. 2017 Study of Conventional Concrete, fibre Reinforced Concrete and self-curing concrete. *IJRTI* 2(5).