

MARCH 2018

M.Sc. in Civil Engineering

ABDULLA AHMED MOHAMMED

**UNIVERSITY OF GAZIANTEP
GRADUATE SCHOOL OF
NATURAL & APPLIED SCIENCES**

**EXPERIMENTAL INVESTIGATION FOR FLEXURAL
BEHAVIOR OF RC BEAM CONTAINING GLASS FIBER**

**M. Sc. THESIS
IN
CIVIL ENGINEERING**

**BY
ABDULLA AHMED MOHAMMED**

MARCH 2018

**Experimental Investigation for Flexural Behavior of RC Beam Containing Glass
Fiber**

**M.Sc. Thesis
In
Civil Engineering
University of Gaziantep**

Supervisor

Assoc. Prof. Dr. Nildem TAYŞI

by

Abdulla Ahmed MOHAMMED

March 2018



© 2018 [Abdulla Ahmed MOHAMMED]

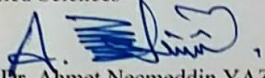
REPUBLIC OF TURKEY
UNIVERSITY OF GAZIANTEP
GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES
CIVIL ENGINEERING DEPARTMENT

Name of the thesis: Experimental investigation for flexural behavior of RC beam containing glass fiber

Name of the student: Abdulla Ahmed MOHAMMED

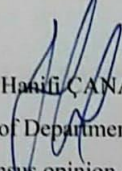
Exam date: 13.03.2018

Approval of the Graduate School of Natural and Applied Sciences


Prof. Dr. Ahmet Necmeddin YAZICI

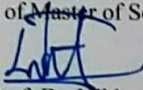
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.


Prof. Dr. Hasihi ÇANAKCI

Head of Department

This is to certify that we have read this thesis and that in our consensus opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.


Assoc. Prof. Dr. Nildem TAYŞI
Supervisor

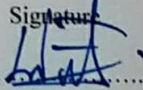
Examining Committee Members:

Assoc. Prof. Dr. Nildem TAYŞI

Asst. Prof. Dr. M. Tolga GÖĞÜŞ

Asst. Prof. Dr. Derya BAKBAK

Signature


.....


.....


.....

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Abdulla Ahmed MUHAMMED

ABSTRACT

EXPERIMENTAL INVESTIGATION FOR FLEXURAL BEHAVIOR OF REINFORCE CONCRETE BEAM CONTAINING GLASS FIBER

MOHAMMED, Abdulla Ahmed

M.Sc. in Civil Engineering

Supervisor: Assoc. Prof. Dr. Nildem TAYŞI

March 2018

48 pages

Concrete fails in a brittle manner, failure of Reinforced Concrete (RC) beams are brittle and suddenly occurs. These shortcomings are generally overcome by using several technics. One of them was the inclusion of fibers into the concrete such as steel, glass, basalt, carbon etc. By using Glass Fiber (GF) into the concrete reduces reinforcement congestion. This thesis presents the effect of GF and Hybrid Fiber (HF) on the compressive, tensile, flexural strength and weight of concrete M-30 grade.

In this investigation, ten different RC beams were cast and tested. All beams were tested over an effective span of 1300 mm up to the failure under 4-point flexural test loading. The beams were designed as a balance-section. All beams are the identical size of "1500 x 150 x 200 mm" and divided into three groups, Group A consist of three beams strengthened with different volumetric ratios (0.5, 1.0, and 1.5 %) of GF. Group B consists of three beams (0.25-0.75, 0.5-0.5, and 0.75-0.25 %) of glass and steel fiber and Group C consists of three beams (0.25-0.75, 0.5-0.5, and 0.75-0.25 %) of glass and basalt fiber. For each mix cast 3-cubes by dimensions "100 x 100 x 100 mm" and cylinders "Ø100 x 200mm" to obtain the compressive and tensile strength of samples. Addition of GF increase the compressive and tensile strength and decrease the weight of concrete.

Keywords: Glass fiber reinforced concrete beams, Flexural performance, Hybrid fiber.

ÖZET

CAM ELYAFI İÇEREN BETONARME KİRİŞİN EĞİLME DAVRANIŞININ DENEYSEL İNCELEMESİ

MUHAMMED, Abdulla Ahmed

Yüksek Lisans Tezi, İnşaat Mühendisliği

Danışman: Doç. Dr. Nildem TAYŞI

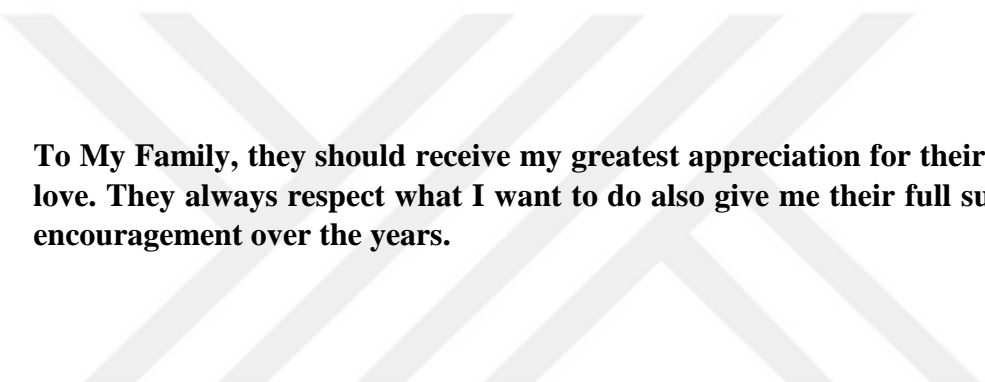
Mart 2018

48 sayfa

Beton kırılğan bir şekilde çöker. Betonarme (RC) kirişlerin kırılması gevrekçtir ve aniden olur. Bu sıkıntılar çeşitli teknikler kullanılarak aşılabilir. Bunlardan biri de beton içerisine, çelik, cam, bazalt, karbon vb. liflerin eklenmesidir. Cam Elyaf (GF) kullanılarak betondaki donatı azaltılabilir. Bu tezin amacı, GF ve Hibrid elyafın (HF) M-30 sınıfı betonun, basınç, gerilme, eğilme mukavemeti ve ağırlığı üzerindeki etkilerini göstermektir.

Bu araştırmada, on farklı RC kiriş dökülmüş ve test edilmiştir. Tüm kirişler 1300 mm'lik etkili aralıkta 4 noktalı eğilme testi yüklemesi altında göçene kadar test edilmiştir. Kirişler dengede olacak şekilde tasarlanmıştır. Tüm kirişler "1500 x 150 x 200 mm" lik eşit boyutlarda hazırlanmıştır ve kirişler üç grupta sınıflandırılabilir, Grup A, cam elyafı yüzde (0.5, 1.0 ve 1.5) hacim oranları ile güçlendirilmiş üç kirişten oluşmaktadır. Grup B cam ve çelik lifli (0.25-0.75, 0.5-0.5 ve 0.75-0.25) üç kirişten ve Grup C cam ve bazalt lifli (0.25-0.75, 0.5-0.5 ve 0.75-0.25) üç kirişten oluşmaktadır. Her bir karışım için "100 x 100 x 100 mm" ölçülerinde üçer küp ve "Ø100 x 200mm" ölçülerinde üçer silindirler numuneleri dökülerek basınç ve çekme mukavemetleri elde edilmiştir. Cam elyaf ilavesi basınç ve çekme mukavemetini arttırırken betonun ağırlığını azaltmaktadır.

Anahtar Kelimeler: Cam elyaf takviyeli betonarme kirişler, eğilme performansı, hibrid elyaf.



To My Family, they should receive my greatest appreciation for their enormous love. They always respect what I want to do also give me their full support and encouragement over the years.

ACKNOWLEDGEMENT

I would like to express my special appreciation and thanks to my supervisor Assoc. Prof. Dr. Nildem TAYŞI, for all her help, patience, valuable advice, always providing and guiding me in the right direction. I am very grateful and proud to work under her academic guidance, advice, encouragement, and suggestions during the preparation of this thesis. She consistently allowed this thesis to be my own work.

I would like to express truthful appreciation to my sister, Mrs. Wasilla Ahmed always helped and supported me every time. Special thanks to my family. Words cannot express how grateful I am to my father spirit that his words lead me to get certificates and my mother for all of the sacrifices that have made on my behalf.

I would like to express truthful appreciation to my friend Mr. Abbas and Mr.Saad for their patience, guidance, and support throughout this study, and tanks for Mrs. Duala Zuhairr that helped me as time in the laboratory job.

TABLE OF CONTENTS

	Page
ABSTRACT	v
ÖZET	vi
ACKNOWLEDGEMENT	viii
TABLE OF CONTENTS	ix
LIST OF FIGURES	xi
LIST OF TABLE	xiii
CHAPTER 1	1
INTRODUCTION	1
1.1 General.....	1
1.2 Advantages and Disadvantages of GF in Concrete	2
1.2.1 Advantages	2
1.2.2 Disadvantages.....	2
1.3 Research Objectives of the Investigation	3
1.4 Aim of Study	3
1.5 Thesis Layout.....	4
CHAPTER 2	5
LITERATURE REVIEW	5
2.1 General.....	5
2.2 Fiber Reinforced Concrete.....	5
2.3 Glass Fiber Reinforced Concrete.....	6
2.4 Hybrid Fibers Reinforce Concrete.....	9
2.5 Mechanical Behavior of Concrete	11
CHAPTER 3	12
EXPERIMENTAL PROGRAM	12
3.1 Introduction.....	12
3.2 Description of Test Specimen.....	12
3.3 Mix Design and Material Properties in the Experimental Investigation	14
3.4 Aggregates	15

3.5	Preparation of the Specimens	17
3.6	Setup and Testing Procedure of the Specimens.....	20
3.6.1	Compressive strength test.....	20
3.6.2	Splitting tensile strength test	21
3.6.3	Beam flexural strength test.....	22
CHAPTER 4	.....	24
RESULTS AND DISCUSSION	.....	24
4.1	General.....	24
4.2	Compressive Strength Test for the Cubes	25
4.3	Tensile Strength Test for the Cylinders	27
4.4	The Result of Flexural Test for the Beams.....	28
4.5	Response of Specimen for the Control Beam.....	29
4.6	The Result of the Flexural Beam Test for Group A	30
4.6.1	The result of flexural beam test for A1	30
4.6.2	The result of flexural beam test for A2	32
4.6.3	The result of flexural beam test for A3	33
4.7	The Result of Flexural Beam Test for Group B	35
4.8	The Result of Flexural Beam Test for Group C	38
CHAPTER 5	.....	40
CONCLUSION	.....	40
REFERENCES	.....	42

LIST OF FIGURES

	Page
Figure 2.1 Diffusion of crack in concrete during crush concrete consists of fibers	6
Figure 2.2 Steel and basalt fibers in the concrete.....	10
Figure 2.3 Effect, HF in the concrete during applied load in first and second phase.....	10
Figure 3.1 Compressive test machine for cubes and cylinders.....	13
Figure 3.2 Flexural test machine for beams	13
Figure 3.3 Beams geometry and reinforcement detail	13
Figure 3.4 Portland cement type 32.5 R.....	14
Figure 3.5 Drying process of the aggregates in furnace.....	17
Figure 3.6 Fabrication of reinforcement, greasy and formwork	18
Figure 3.7 Proportioning, mixing and casting of beam specimen.....	18
Figure 3.8 Casting concrete and using the vibrating machine	19
Figure 3.9 After casting and testing samples	19
Figure 3.10 Curing of Samples and beams by the pool and members curing method.....	20
Figure 3.11 Preparation beams for flexural test	20
Figure 3.12 Compressive machine test for compressive strength test	21
Figure 3.13 Compressive machine test for split tensile strength test	22
Figure 3.14 Flexural strength test machine for beams 4-point.....	23
Figure 4.1 Relation between % GF with compressive strength and weights	25
Figure 4.2 Result compressive strength and weight samples for the Group B (Maan Albiyate, 2017)	26
Figure 4.3 Result compressive strength and weight samples for the Group C (Maan Albiyate, 2017)	26
Figure 4.4 Result tensile strength and weight samples for the Group A.....	27

Figure 4.5 Result tensile strength and weight samples for the Group B (Maan Albiyate, 2017)	28
Figure 4.6 Result tensile strength and weight samples of Group C (Maan Albiyate, 2017).....	28
Figure 4.7 Control beam after the crush and indicate crack propagation	29
Figure 4.8 Load-displacement response of specimen control beam	30
Figure 4.9 Load-displacement response to specimen A1.....	31
Figure 4.10 Flexural tests for concrete beam A 1 GF	31
Figure 4.11 Beam A 2 GF after the crush and indicate crack propagation	32
Figure 4.12 Load-displacement response to specimen A2.....	32
Figure 4.13 Beam A 3 GF after the crush and indicate crack propagation	33
Figure 4.14 Load-displacement response to specimen A3.....	34
Figure 4.15 Relationship between load and deflection in various % GF for Group.....	35
Figure 4.16 Result ultimate load and maximum deflection Group A beams.....	35
Figure 4.17 Result of Flexural test for Group B beams	36
Figure 4.18 Flexural tests for Group B beams	36
Figure 4.19 Result ultimate load and maximum deflection for Group B beams (Maan Albiyate, 2017).....	37
Figure 4.20 Flexural tests of Group C beam	38
Figure 4.21 Flexural tests of Group C beam	38
Figure 4.22 Result ultimate load and maximum deflection Group C beams (Maan Albiyate, 2017).....	39

LIST OF TABLE

	Page
Table 3.1 Cement ingredients.....	14
Table 3.2 The details of mix proportion for Group A in experimental investigation	14
Table 3.3 The details of mix proportion for Group B and C in experimental investigation (Maan Albiyate, 2017)	15
Table 3.4 Fibers specifications.....	15
Table 3.5 Sieve analysis and physical properties of the aggregate	16
Table 4.1 Result of compressive and tensile strength test for Group A	24
Table 4.2 Result of compressive and tensile strength Group B and C for cubs and cylinders (Maan Albiyate, 2017)	25
Table 4.3 The detail of result the flexural test for control beam.....	29
Table 4.4 The detail of result the flexural test for control beam.....	31
Table 4.5 Specimens A 2 details and key load stages.	33
Table 4.6 Specimen (GF 1.5 %) details and key load stages	34
Table 4.7 Result of flexural test for the Group-A beams	34
Table 4.8 Result of flexural test for the Group-B beams (Maan Albiyate, 2017).....	37
Table 4.9 Result of flexural test for the Group-C beams (Maan Albiyate, 2017).....	39

LIST OF SYMBOLS/ABBREVIATIONS

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
FRC	Fiber Reinforced Concrete
GF	Glass Fiber
GFRC	Glass Fiber Reinforced Concrete
HF	Hybrid Fiber
HFRC	Hybrid Fiber Reinforced Concrete
LVDT	Linear Variable Differential Transformer
P_r	First Cracking Load
P_u	Ultimate Load
RC	Reinforce Concrete
σ	Compressive Strength

CHAPTER 1

INTRODUCTION

1.1 General

Today concrete is one of the most renowned for construction materials in the world (Naik, 2008). It is broadly adopted as an essential of construction in the reality that it is neither as strong as steel because of its relatively low cost (Page, 2007). Therefore, concrete has been widely used in many large structures, such as multistory buildings, high-rise buildings, dams, bridges, marine structures and nuclear preservation structures (Spennemann, 1999). Concrete construction materials are widely used, with desired properties such as high pressure, strength, hardness and durability in natural environmental factors (Chandramouli et al., 2010).

Nevertheless, it has few disadvantages such as brittle and weak in tension, the tensile strength of the concrete is approximately 10-15 % of the compressive strength (Gilstrap and Dolan, 1998). These shortcomings are generally overcome by using several techniques one of them was the inclusion of a small amount of short randomly distributed fibers (Lusti et al., 2002).

The mechanical characteristics may be enhanced through the introduction of reinforcing fibers that have high tensile strength and ductility (Faruk et al., 2012). Scientists and researchers have performed extensive experimental studies to better understand the behavior of concrete and to improve upon the concrete failure model from brittle to ductile (Coronelli and Gambarova, 2004). In addition, Fiber Reinforced Concrete (FRC) can be used as a composite material made up of fibers suitable for concrete and symmetrical, discrete and uniformly dispersed (Foster, 2009). FRC is a new structural material which is gaining increasing importance (Wafa, 1990).

The addition of fiber reinforcement in discrete form improves many mechanical properties of the concrete such as compressive, tensile, and flexural strength (Holschemacher and Ribakov, 2010). All of the there consequences can be studied by the addition of fibers into concrete mass, which reduces reinforcement congestion (Nehdi and Ladanchuk, 2004). Today's reinforcement fiber is mainly used in applications such as industrial floors, coatings, and concrete sprays, although there are other application areas (Zheng and Feldman, 1995). In general, fibers are the principal load-carrying members, while the surrounding matrix keeps them in the desired locations and orientation, acting as a load transfer medium between them, and protects them from environmental damage (Alawsi et al., 2009). RC with fibers is less expensive than hand-tied rebar, while still increasing the tensile strength (Avinash et al., 2012). There are several types of fiber with different specific physical, chemical, and geometrical properties of the fiber.

1.2 Advantages and Disadvantages of GF in Concrete

For advantage and disadvantage of GF as explained by (Kima and Waldron, 2008).

1.2.1 Advantages

- GFRC is lightweight and is about 75 % lighter than traditional concrete.
- GF is a great material for the restoration of old buildings and is used for the exterior of the buildings it is also being used extensively for walls and ceilings.
- It is very adaptable in that it can be poured or sprayed.
- High flexural strength, high strength to weight ratio.
- Improved durability of the structure.
- Increased tensile and flexural strengths.
- Higher resistance to later cracking.
- Improved crack distribution.
- Reduced shrinkage of early age concrete.

1.2.2 Disadvantages

- Greater reduction of workability.
- The cost of GFRC is higher than traditional concrete.

1.3 Research Objectives of the Investigation

The purpose of this thesis is studying the structural behavior of beam specimens by an experimental study on the GFRC and HFRC, and compared to control beam. The proposed of this research is to develop a general confined suitable for GF. The GFRC and HFRC beams were tested in the laboratory. The load-deflection curve and mechanical properties were obtained. At last, the experimental GFRC test results are compared with control beam.

The main objectives of the thesis are as follows

- To study the ultimate strength and load-deformation characteristics of concrete beams reinforced with GF and steel reinforcement.
- To conduct tests on full-scale beams utilizing reinforcement bars and fibers.
- To compare the crack control properties in the beam that mixed with and without GF.
- To predicate the failure type of GFRC beams.
- Investigate the influence of behavior mechanism in different percentage of GF that has been tested in Structural Lab.

1.4 Aim of Study

The aims of this study are to understand and evaluate the shear behavior of discrete GFRC and HFRC beams, for a given aspect ratio (It is defined as the ratio of the length of fiber to its diameter L/d) and were carried out on M-30 grade concrete. The size of GF used to be 12 mm all beams are divided into three groups.

Group A consists of three beams strengthened with different volumetric ratios (0.5, 1.0, and 1.5) % of GF. Group B consists of three beams (0.25-0.75, 0.5-0.5, and 0.75-0.25) % of glass and steel fiber and Group C consists of three beams (0.25-0.75, 0.5-0.5, and 0.75-0.25) % of glass and basalt fibers. The studies on compressive, tensile, and flexural strength are done compared with control beam; that have pure concrete without any fiber.

1.5 Thesis Layout

The thesis was planned to provide additional knowledge on the structural behavior of beams under 4-point flexural test and with and without GF and HF reinforcement, by carrying out suitable series of tests. In Chapter 2, the literature review for GFRC and HFRC was presented.

In chapter 3, details of materials and their properties were presented, which were used in this experimental investigation. The mix proportions used and details of the experimental program are also given in the same chapter. Chapter 4 gives the experimental results, shows the response of the tested beams, and discusses the cracking patterns and the effect of GF addition to concrete beams. In Chapter 5, conclusions are presented with recommendations for further studies.

CHAPTER 2

LITERATURE REVIEW

1.6 General

Presently concrete is mainly used in construction work because it has several advantages as investigated by (Spoelstra and Monti, 1999). The mechanical properties of the RC depend on access to various parameters like the production method (Salvetat and Rubio, 2002). The concrete has a very good compressive strength, but weak in the tension and flexibility as explained by (Boulekbache et al., 2010).

1.7 Fiber Reinforced Concrete

The FRC suitable utilized in the precast application; they have involved manhole covers, pipes made of concrete, machine foundation, and structures (Meškėnas, 2011). Developed flexural and influence strengths may be permitted the applying of fibers, concrete components in rough handling situations (Meier, 1995).

The term FRC is defined by AC1 544.2R. Over the past few years, many natural fibers have been used to improve the properties of concrete as discussed by (Chen and Liu, 2005). The use of FRC has evolved and durability of the concrete till now under investigation to obtain the positive result for durability of the concrete as studied by (Hanseth and Lyytinen, 2010). Usage the fibers not a new idea, for the first time used by the Egyptians.

They have used animal hairs, straw to mud bricks and walls in houses, around 1500 B.C as explained by (Jain, 2015). Using the different way of the production methods as well different types of fiber, size, orientation and distribution as the study by (Buratti et al., 2011). Presently many types of fibers are used in civil engineering projects, utilized according to the mechanical properties of fiber needs. FRC widely uses due to high corrosion resistance, high flexibility, and durability as the study by (Li 2003). Other recruitments FRC are utilized in structured fields, especially in the military and naval fields, for example, in the fortified structures, the explosion-proof

structure, offshore platforms, undersea underground oil exploitation as expanded by (Sharqui et al., 2002). The added fiber to the concrete can improve the characteristics of the concrete, such as the tensile, flexural, impact, fatigue, abrasion strength, deformation capability, toughness, and load-bearing capacity after cracking as investigated by (Jiang and Chen, 2014). There are several types of fiber used in cement and concrete composites such as steel, carbon, and glass (Naaman, 2003).

1.8 Glass Fiber Reinforced Concrete

The reason utilizes GF are relatively inexpensive, lightweight and has higher tensile strength (Harish et al., 2009). The GF has been developed primarily for the production of thin sheet components as explained by (Butler et al., 2010). In addition, GF into the RC, there are many benefits such as the production of thin concrete sheet and increasing its shear strength as investigated by (Lopez and Karbhari, 2000). The role of GF in the concrete very important prevents of diffusion the crack in the concrete, as shown in Figure 2.1.



Figure 0.1 Diffusion of crack in concrete during crush concrete consists of fibers

As well as exposure to natural moisture and the cycle of temperature will occur periodically dimensional variation as explained by (Blaga, 1980). They aimed to investigate different the compressive strength and flexural strength by making the test using beams of size "1500x200x150 mm", the cubes "100x100x100 mm" were used and the cylinders "Ø100x200 mm" they found that when using 1.5 % of GF, the concrete compressive strength reached the maximum as the study by (Shakor and Pimplikar, 2011), in their investigation results of the test showed the compatibility between GF and pure concrete.

The bending test also showed that primary material's resistance which coincided with the transmission point in response to the shift load around (13.1 MPa), 8.8 % of the compressive strength was unlimited as explained by (Roth et al., 2010). The results of this experimental study are illustrated by the addition of GF the alloy mixture has significantly improved bending and tensile strength of the cement mixture as investigated by (Mobasher and Li, 1996).

The performance of this composite as age increases, it depends on the matrix mixer (Lee and Choi, 2017). In their studied shown effects, adding GF on tensile strength and compressive strength in the RC, the fiber content of 1.0 % and 1.5 % mixed concrete has been used, they have made 18 cylinders of each mix for compression and segmentation testing experiments were performed at 7, 28 and 90 days. The results of the experiment indicate that the addition of GF to concrete increases the tensile strength of concrete. About 20-50 % and tensile strength as explained by (Kliazovich and Granelli, 2006).

They related with compressive strength and flexural strength of GFRC, the test samples are $150 \times 150 \times 150$ mm with a cylinder size of $\text{Ø}150 \times 300$ mm and $100 \times 100 \times 500$ mm. GFRC compressive strength increased 5% and flexural tensile strength was 11 % increased as explained by (Kizilkanat et al., 2015).

The comparative experimental study of GF as a fiber reinforcement in high strength concrete was carried out. In their study, it has been reported that the concrete workability was reduced by adding GF into the concrete mixture. The results of the experiments showed that the addition of the GF content of more than 0.25 % causes a slight increase in compressive strength as explained by (Zhang et al., 2017). In their investigation based on result, they noted that the addition of fiber has no direct effect on the RC elastic modulus.

The modulus elasticity of concrete, slightly reduced when the dosage of GF was increased and fatigue performances of GFRC concrete in flexure as investigated by (Lv et al., 2012). In their investigation, they utilized GFRC beam sample of "100 × 100 × 400" mm was tested under four points load porosity fatigue by using the flexural machine test to get the fatigue of GFRC at different stress levels. Samples were 0.6 %, 0.8 % and 1 % GF of the fractional volume. The results showed that the statistical distribution of GFRC fatigue life was in agreement with two parameters.

The coefficients of the fatigue equation are determined given the probability of different variable survival to predict GFRC fatigue strength expected the level of survival probability as explained by (Hua et al., 2012). GF strengthening effects on flexural strength and ductility of the concrete and GF strengthening depended on shrinkage cracking factor and lightweight concrete temperature resistance as investigated by (Çağlar and Aydın, 2002). In their investigation, all of these lightweight concrete properties benefited from its introduction fraction of mercury fiber from 0.5 % to 0 % (volumetric percentages 0.25-0.75 %) were examined mass fraction of fiber 1.0-2.0 % (volume fraction 0.25-0.5 %). It was enough to control the constricted cracking cracks and increase the flexural strength and light resistance of light concrete.

(Ferreira et al., 2011) studied the mechanical properties of GFRC for structural applications. The results showed the presence of fibers, it might be the loss of compressive strength of the material. In addition, the presence of GF in the matrix improves the hard pressure and cracks the properties of the arrest.

(Avinash et al., 2012) has observed that the workability of concrete decreases with the addition of GF that investigated by (Abdullah and Jallo, 2012). When there was a sudden increase in the crushed cylinder sample in the final strength of the GFRC tensile strength compared to pure concrete. (Murthy and Jain, 2012) in their experimental investigation includes water to cement ratio 0.45 and concrete samples with 0.0, 0.5, 0.7, 0.9, 1.2, and 1.5 % of GF. Based on the results the authors conclude that there is an increase of 30 % in flexural strength in comparison with pure concrete. (Babu and Seshu, 2008), in their article focused on FRC behavior with M-30 concrete strength and a different percentage of fiber additives (0.5, 1, and 1.5 %). Increased compressive strength 24.7 % by adding 0.5 % fiber to the concrete, increased compressive strength the rate 47.3 % by adding 1 % and increased compressive strength the rate 16.4 % by adding 1.5 % GF to concrete M-30.

(Kovler and Roussel , 2011), in their article explained the effect of GF on concrete strength properties with different percentages of GF cement weight in the fixed mixture and water-cement ratio. Their results show that the workability of concrete reduction with increasing GF content. The significant increase in the GFRC tensile and flexural strength in the GF content was 1.5% compared to conventional concrete.

(Deshmukh and Zende, 2012) in their experimental investigation explained the effect of adding GF into RC. They used different percentages of GF 0 to 0.1 % and studied on the mechanical properties of concrete by using compressive strength test, flexural strength test and split tensile strength test. The results showed improvement in mechanical properties and durability with the addition of GF.

(Kwan et.al., 014), in their studied showed that the efficiency of GFRC would be reduced by increasing the percentage of GF into concrete. And (Banthia et al., 2012), the was planned to explore the effects of using different percentages of GF on the properties of hardened concrete like workability, compressive strength, tensile strength, flexural strength and ultrasonic pulse velocity. In their article describes four specific programs.

(Mobasher, 2011) in his investigations to measure, the density and impact of GFRC behavior composites using a third influence blow and bending tool and tools. The specimens were subjected to two-way stresses, third-dimensional flexibility, and instrumental impact. The results of experiments showed 25 performances better than sample GFRC when compared to healthy samples. The impact test was the first crack and the tear rupture modulus was approximately twice as high as the flexural test. (Dehghan et al., 2017) in their experimental study results observed the tensile strength increased the rate 40 % by adding 1.0 % basalt fiber into the concrete. The low modulus, strength fibers such as polypropylene, basalt, and GF are more useful in ductility improvement and reduce cracking (Pakravan et al., 2017). Therefore, to obtain cementations composite with both improved strength and ductility, combining fibers with different chemical/mechanical properties is necessary.

1.9 Hybrid Fibers Reinforce Concrete

Adding more than one type of fiber to concrete is known as Hybrid Fiber Reinforced Concrete (HFRC). Single fibers can be activated only in the limited range of cracking and crack opening. Some high modulus fibers and high strength, such as carbon, polyvinyl alcohol, steel, and asbestos fibers can effectively increase the strength of concrete. Therefore, to obtain cementations composite with both improved strength and ductility, combining fibers. Because two or more combinations of fibers are in use they provide cement composites different responses to cracking process during different download stages.

In construction projects, utilize several types of fibers same of them are shown in Figure 2.2.



Figure 0.2 Steel and basalt fibers in the concrete

Applications of HFRC in the field of civil engineering

- Hybrid Fiber Reinforcement in Concrete Pavements.
- Rehabilitation of Bridge Deck Using Hybrid Fiber Reinforced Concrete.
- Construction of machine foundation.
- Tunnel Linings.

The HFRC can protect the concrete in the propagation of the cracks as shown in Figure 2.3.

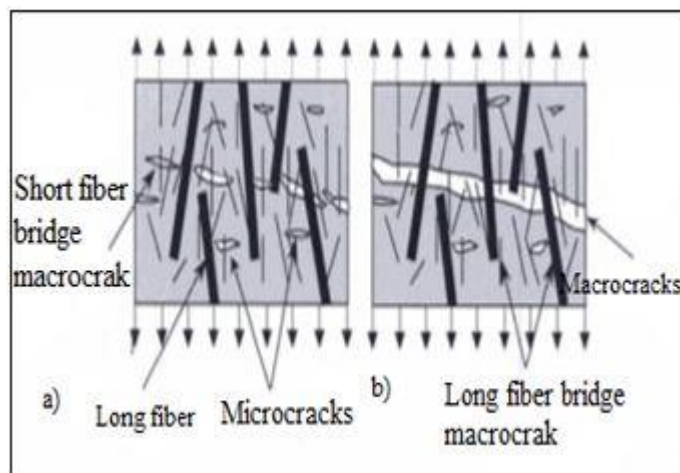


Figure 0.3 Effect, HF in the concrete during applied load in first and second phase

1.10 Mechanical Behavior of Concrete

The analysis of the evolution of stress-strain states into reinforced concrete structures due to humidity and temperature changes and physical attacks to the concrete (Saetta and Vitaliani, 1998). Humidity and temperature affect both the process of cement hydration and the physical attack's effect on the mechanical properties of concrete (Saetta et al., 1998). The concrete is composite material and consist of different material such as a mixture of cement paste and fine grains, and they have special mechanical properties as explained in their article by (Tam et al., 2005). Due to shrinkage contraction and thermal imbalance between derivatives and matrices also observes stress and tension stress as explained by (Hsu et al., 1963).

The mechanical behavior of concrete depends on the development of micro-crack as clarify by (Ferreira et al., 2011) in their investigation results showed that the presence of fibers might result in the loss of this concept compressive strength of materials and the presence of GF in the matrix have improved strain and crack retrofit properties also the tensile strength of concrete can be increased by add fiber to the concrete mix.

During their research (Choi, 2017), they're found that GFRC had a tensile strength of 20-50 percent higher than pure concrete. (Lee and Choi, 2017) studied on effect GF on the concrete and based on their results they concluded that tensile strength is divided from this composite into time intervals between 9-13 % of their compressive strength. The GF use in the structural field and in the aerospace industry GF are working to build thermal insulations, body heals, light weight car parts, and rubber tires. One of the mainly disadvantages of the GF their relatively modest modules are compared to other types of fiber such as carbon and SF.

CHAPTER 3

EXPERIMENTAL PROGRAM

1.11 Introduction

This chapter presents the experimental investigation of concrete beams reinforced with GF that consists of three Groups A, B, and C beams. Group A consists of various percentages of GF (0.5, 1.0, and 1.5) % and control beams and but Group B was HF; that mixed are GF and SF with different ratio are (GF 0.25 % SF 0.75 %, GF 0.5 % SF 0.5 % and GF0.75 %, SF0.25 %). And the other group was Group C that was HF and mixed two different fibers GF and BF with various ratio of them are (GF0.25 % BF0.75 %, GF0.5 % BF0.5 % and GF0.75 % BF0.25%). For any mix cast three cubes and cylinders, to obtain compressive and tensile strength results.

1.12 Description of Test Specimen

The test for cubes and cylinders were carried out by compression test machine in the Gaziantep University laboratory as shown in Figure 3.1. And so on ten beams were constructed and divided into three groups, Group A, B and C. The tests for beams were carried out by the flexural machine (INSTRON) in the Gaziantep University laboratory as shown in Figure 3.2. The reinforcement details and dimensions for all of the beams are same.

The beams were reinforced with four horizontal bars 2 \varnothing 10 mm for tension (bottom) and 2 \varnothing 8 mm for compression (top) and stirrup \varnothing 5.5 mm @ 100 mm. The dimensions of the beams are (1500 x 200 x 150) mm as shown in Figure 3.3.



Figure 3.1 Compressive test machine for cubes and cylinders

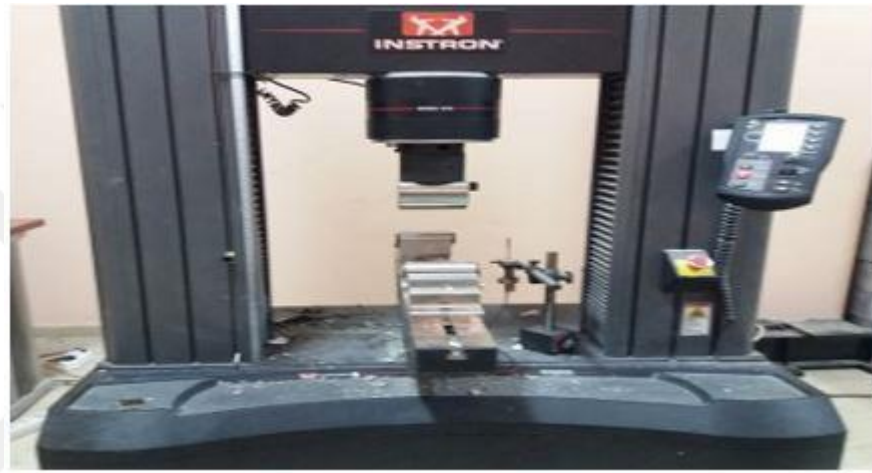


Figure 3.2 Flexural test machine for beams

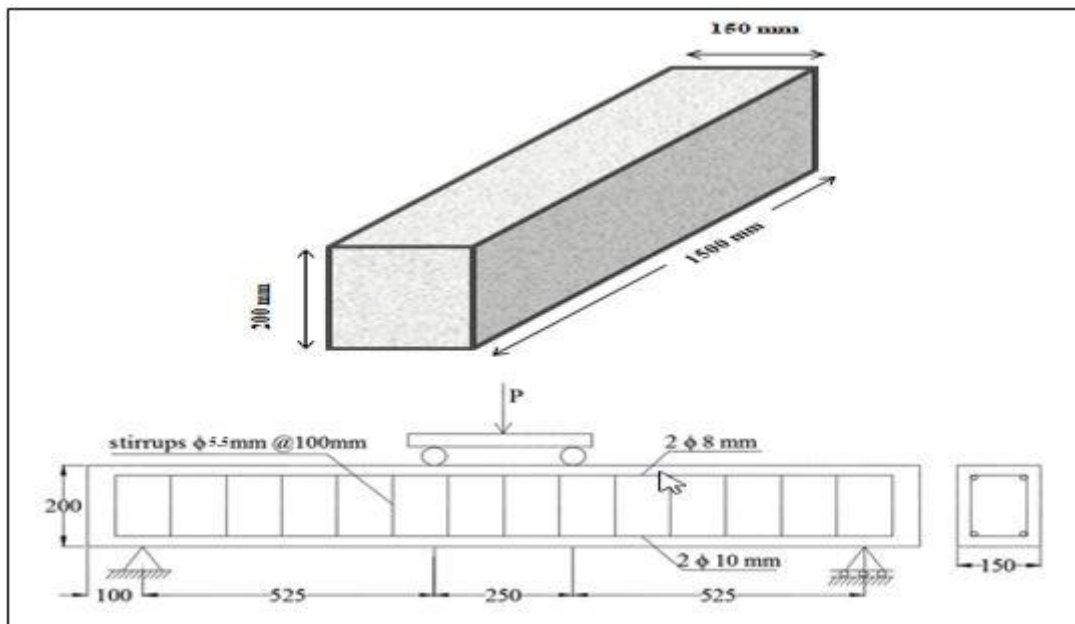


Figure 3.3 Beams geometry and reinforcement detail

1.13 Mix Design and Material Properties in the Experimental Investigation

Cement was used 32.5 R type and ingredients of cement are given in Table 3.1 and shown in Figure 3.4.

Table 3.1 Cement ingredients

Cement component	Calcium Oxide (CaO)	Silica (SiO ₂)	Alumina Dioxide (Al ₂ O ₂)	Iron Dioxide (Fe ₂ O ₂)	Other
Percentage of component	63	22	7.7	3.3	4



Figure 3.4 Portland cement type 32.5 R

By adding fibers into the concrete reduce the workability of the concrete, to overcome this shortcoming added super-plasticizer into the mixture. The Table 3.2 and 3.3 showed the amount of utilized material.

Table 3.2 The details of mix proportion for Group A in experimental investigation

Group	Mix Concrete	Cement (Kg)	Water (Liter)	Coarse aggregate (Kg)	Fine aggregate (Kg)	Super Plasticizer (Lt.)	Fiber content by Kg			
							GF	SF	BF	
CB	Control Beam	400	192	1110	600	0.126				
A	A1					GF 0.5 %	0.217	0.91		
	A2					GF 1.0 %	0.294	1.82		
	A3					GF 1.5 %	0.371	2.73		

Table 3.3 The details of mix proportion for Group B and C in experimental investigation (Maan Albiyate, 2017)

Group	Mix Concrete	Cement (Kg)	Water (Litter)	Coarse aggregate (Kg)	Fine aggregate (Kg)	Super Plasticizer (Litter)	Fiber content by (Kg)		
							GF	SF	BF
B	GF 0.25%, SF 0.75 %	400	192	1110	600	0.294	0.45	4.12	
	GF 0.5%, SF 0.5 %						0.91	2.74	
	GF 0.75%, SF 0.25 %						1.36	1.37	
C	GF 0.25%, BF 0.75 %						0.45		1.41
	GF 0.5%, BF 0.5 %						0.91		0.94
	GF 0.75%, BF 0.25 %						1.36		0.47

The mechanical properties of the fibers that used in this investigation see Table 3.4

Table 3.4 Fibers specifications

Fibers Types	Diameter (μm)	Length (mm)	Aspect ratio (L/D)	Modulus of Elasticity (GPa)	Specific Gravity	Tensile Strength (Mpa)	Density (Kg/m^3)
Glass Fiber	55	12	220	77	2.6	3400	2600
Steel Fiber	540	30	55	210	7.85	1200	7850
Basalt Fiber	50	12	240	89	2.8	4100-4800	2800

1.14 Aggregates

The coarse aggregate used was river gravel with a nominal maximum size of 16 mm.

And fine aggregate, a natural river sand was used with a maximum size of 5 mm.

The coarse aggregate had a specific gravity of 2.72 and its water absorption was 1.0 % the specific gravity and water absorptions of natural river sand was 2.66 g/cm³, and 1.5 %. The particle size gradation obtained through the sieve analysis and physical properties of the fine and coarse aggregates are presented in Table 3.5.

Table 3.5 Sieve analysis and physical properties of the aggregate

Properties of aggregate		Fine aggregate	Coarse aggregate
Sieve size (mm)	16	100	100
	8	100	31.5
	4	86.6	1
	2	56.7	0.5
	1	37.7	0.5
	0.5	25.7	0.5
	0.3	6.7	0.4
Fineness Modules		2.87	5.66
Specific Gravity		2.66	2.72
Absorption		1.5 %	1 %

The process to find the water absorption for aggregate put the aggregate in the water for 24 hours to be fully saturate then take out of the water and dry the surface of aggregate then balance the aggregate before and after putting out from the furnace. For this process put aggregate into the furnace for 24 hours in the 100 to 110 °C to be dry. For determining the water absorption in the aggregate using the equation 3.1

$$\frac{M_1 - M_2}{M_2} * 100 \quad (3.1)$$

Where M_1 is the mass of the saturated aggregate in Kg and M_2 is the mass of the furnace-dried aggregate.



Figure 3.5 Drying process of the aggregates in furnace

1.15 Preparation of the Specimens

To performed the mold utilized the wood template and connected templates by bolts and nut. And performed the reinforcement by using the rebars to the connect and tie the bars used thin wire. Before the casting process cleaned up and greasy all mold as shown in Figure 3.7.

The concrete was mixed in a vertical mixer by 150-liter capacity see Figure 3.8. At the start in mix in first add the dray material such as coarse and fine aggregate, cement and fiber put in the mixer was mixed for 5 minutes clockwise and counter clockwise to be homogeneous material. And then added water, and super-plasticizer for 5-10 minutes into the mixed concrete and the concrete ready for casting. The concrete was placed in layers and each layer was compacted by vibrating machine as shown in Figure 3.8 and 3.9. Prepared three cubes and cylinders specimen for each beams as shown in Figure 3.7.



Figure 3.6 Fabrication of reinforcement, greasy and formwork



Figure 3.7 Proportioning, mixing and casting of beam specimen

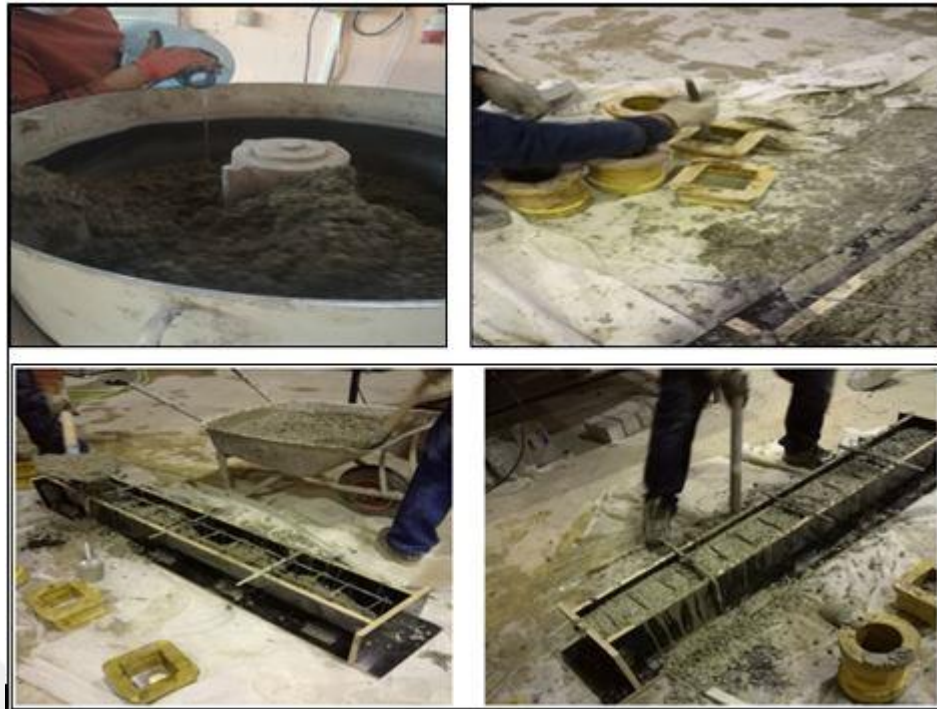


Figure 3.8 Casting concrete and using the vibrating machine

Three-cylinders samples by dimensions (100 × 200) mm and three cube samples by dimension (100 x 100 x 100) mm were prepared with every concrete batch see Figure 3.7 and 3.9. The cylinders were used to evaluate the tensile strength of the concrete and cubes were made to evaluate the compressive strength of the concrete. In last cast the samples and after finish the curing process sample ready for test as shown in Figure 3.10.



Figure 3.9 After casting and testing samples

The sample was de-molded after one day of casting and then placed in a curing pool with 23 °C for 28 days of curing. For the beam carried out members curing method see Figure 3.11. After the curing process for beams, the carried out paint and line up for the beams as shown in Figure 3.12.



Figure 3.10 Curing of Samples and beams by the pool and members curing method



Figure 3.11 Preparation beams for flexural test

1.16 Setup and Testing Procedure of the Specimens

1.16.1 Compressive strength test

Concrete mixtures can be designed to provide a wide range of mechanical and durability properties to meet the design requirements of a structure. Concrete is mostly used in construction. The compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, and quality control during production of concrete...etc. For compressive strength test casted cubes. For test process utilized (BESMAK) digital series compression

machine, the applied load by kN/sec and output results by Mpa as shown in Figure 3.14.



Figure 3.12 Compressive machine test for compressive strength test

1.16.2 Splitting tensile strength test

The concrete subjected to tension in very rare cases and is never designed to resist direct tension. For splitting tensile strength test used, cylinders for test process utilized (BESMAK) digital series compression machine. The rate of loading was 1.5 kN/sec and output results by Mpa. And cylinder was laid in a horizontal position, and vertically applied to the cylinder. To determine the value of splitting tensile strength results using equation (3.2).

$$T = 2P/\pi ld \quad (3.2)$$

Where; T is the splitting tensile strength in MPa and P is maximum applied load in N also the d symbols the diameter of a cylinder in mm and l is the height of the cylinder in mm.



Figure 3.13 Compressive machine test for split tensile strength test

1.16.3 Beam flexural strength test

The flexural strength of concrete can determine by use simple support beam test and have two types three-point loading and four-point loading in this investigation used four-point loading. For test process utilized (INSTRON) hydraulic actuator with 250 kN load capacity and at an average rate of displacement 0.2 mm/sec as shown in Figure 3.15. To find out the mid-span deflection used Linear Variable Differential Transformer (LVDT). The beam was rested on the supports with a clear span of 1300 mm and distance between two-point load are 250mm.

To determine the flexural strength used following equation (3.3).

$$f = \frac{PL}{bd^2} \quad (3.3)$$

Where,

f is the strength of the beam in MPa, and P is the load that act on the beam in kN then L is the length span in mm and b is the average width of the beam at the fracture, as oriented for testing, in mm and d is the average depth of the specimen at the fracture, as oriented for testing in mm.



Figure 3.14 Flexural strength test machine for beams 4-point

CHAPTER 4

RESULTS AND DISCUSSION

1.17 General

The addition of fiber into the concrete can improve several characteristics of the concrete such as the tensile, flexural, impact, fatigue and abrasion strength, deformation capability, toughness and load-bearing capacity after cracking. There are several types of fiber can be used in the concrete composite, such as steel, carbon, basalt, glass...etc.

For the beams were divided into three groups are A, B, and C. The Table 4.1 and 4.2 shown the output result of the compressive and tensile strength test.

Table 4.1 Result of compressive and tensile strength test for Group A

Group	Concrete mix	Compressive strength (MPa)	Tensile strength (Mpa)	Weight of sample (Kg)	
				Cub	Cylinder
A	CB	Control Beam	63.66	11.39	
	A1	GF 0.5	60.82	16.32	
	A2	GF 1	62.74	18.57	
	A3	GF 1.5	58.18	17.34	

Table 4.2 Result of compressive and tensile strength Group B and C for cubs and cylinders (Maan Albiyate, 2017)

Group	Concrete mix	Compressive strength (MPa)	Tensile strength (Mpa)	Weight of sample (Kg)	
				Cube	Cylinder
B	GF 0.25 , SF 0.75	58.82	22.22	2.39	38
	GF 0.5 , SF 0.5	61.09	26	2.37	3.79
	GF 0.75 , SF 0.25	55.42	18.44	2.36	3.75
C	GF 0.25 , BF 0.75	57.8	16.64	2.4	3.79
	GF 0.5 , BF 0.5	57.41	15.83	2.39	3.76
	GF 0.75 , BF 0.25	55	20.22	2.38	3.7

1.18 Compressive Strength Test for the Cubes

The compressive strength of concrete is the capacity of a material. To clarify and obtain the result of the compressive strength concrete utilized cube sample and tested by compression machine. The compression machine records the ultimate stress by MPa. In Group A, the compressive strength slightly decreases by adding 0.5 % GF, by adding 1 % GF the compressive strength increase and in last by adding 1.5 % GF the compressive strength decrease. So, according to the out put result the positively result for compressive strength was 1 % G.F. The relation between the weight of concrete and percentage of GF are proportional as shown in Figure 4.1 and Table 4.1.

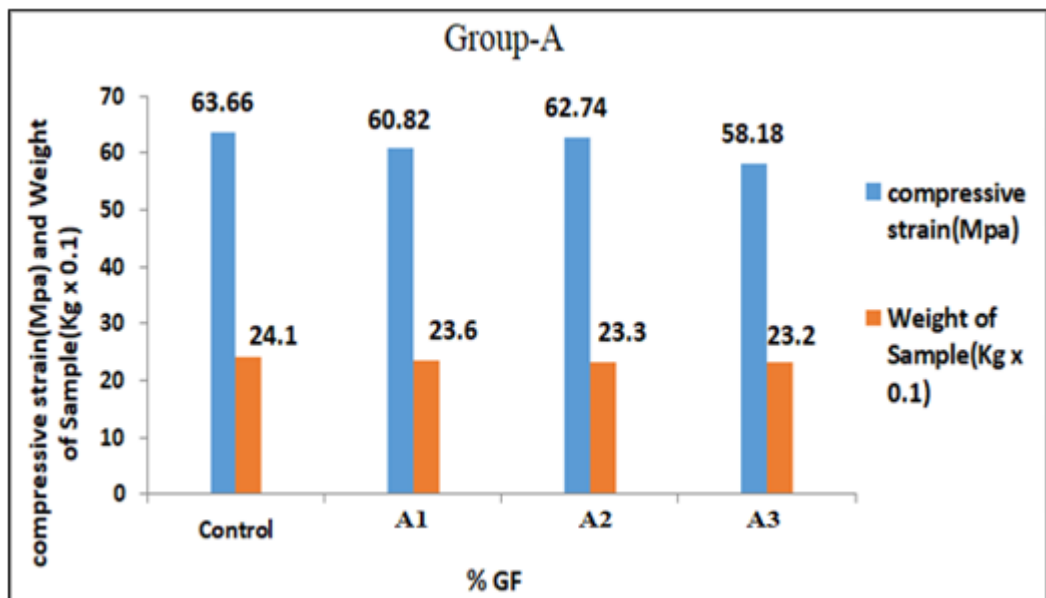


Figure 4.1 Relation between % GF with compressive strength and weights

For the HF; consist of Group B and C in all of the ratio the weight of concrete sample decrease by adding more fiber into the concrete and for compressive strength in all of the ratio have negatively output results in compare with the control cube sample. In both groups by adding more GF the weight of a concrete decrease because the specific gravity GF less than specific gravity SF and BF as shown in Table 3.4.

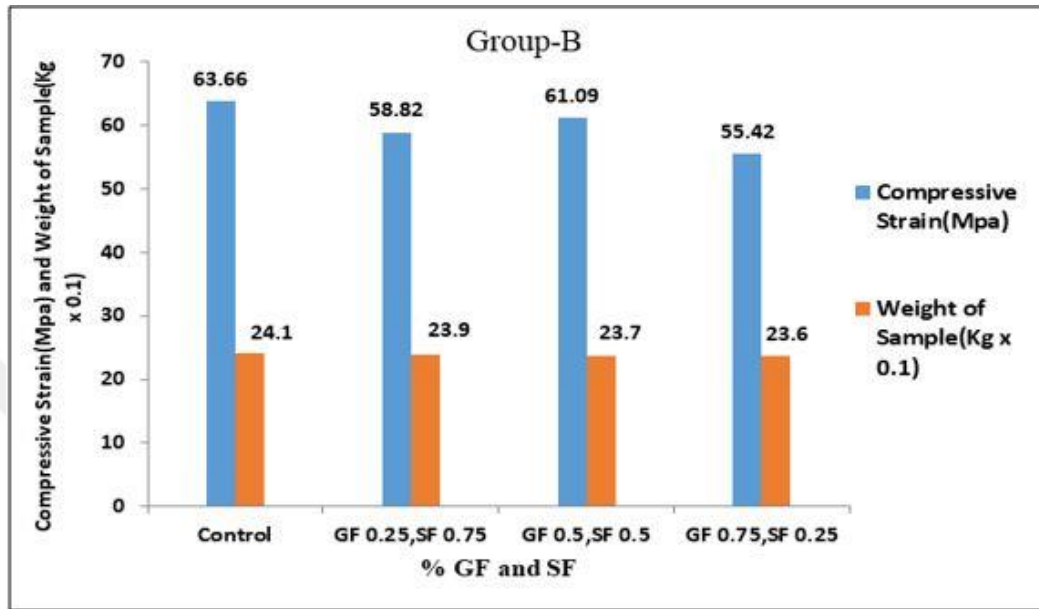


Figure 4.2 Result compressive strength and weight samples for the Group B (Maan Albiyate, 2017)

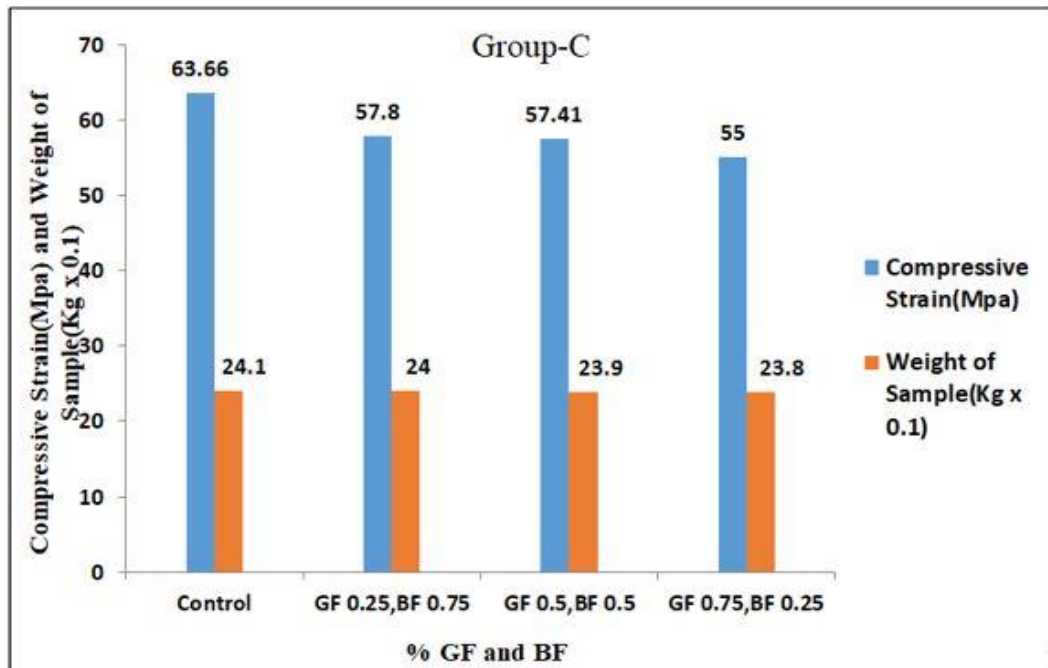


Figure 4.3 Result compressive strength and weight samples for the Group C (Maan Albiyate, 2017)

1.19 Tensile Strength Test for the Cylinders

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension (Nagalakshmi, 2013). During this investigation, by adding a variable percentage of GF and HF the tensile strength to change. For this test, the compression machine was utilized. By increasing the load with time on the sample, hairline cracks were observed on the face of the cylinder. Finally, the cylinder concrete sample was crushed. The output results record by test machine in kN. In the all percentage ratio the tensile strength of concrete has a positively result because. For the weight of sample also disproportional with added fiber to the concrete, especially GF because lighter than SF and BF. For the HF in Group B, the positively result was (% 0.5 GF, % 0.5 SF) in compared with the control sample and other ratios in Group B and for the Group C, the positively result the ratio was (% 0.75GF, % 0.25 BF) in comparison with a control sample and other ratios in Group C as shown in 4.4, 4.5 and 4.6 also Table 4.1 and 4.2

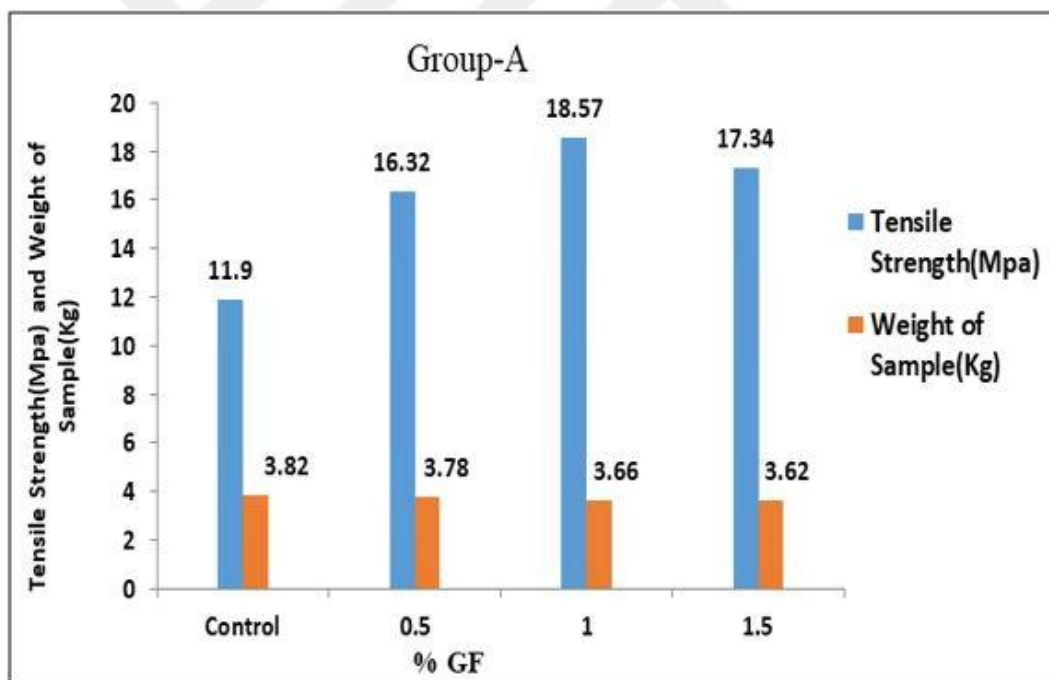


Figure 4.4 Result tensile strength and weight samples for the Group A

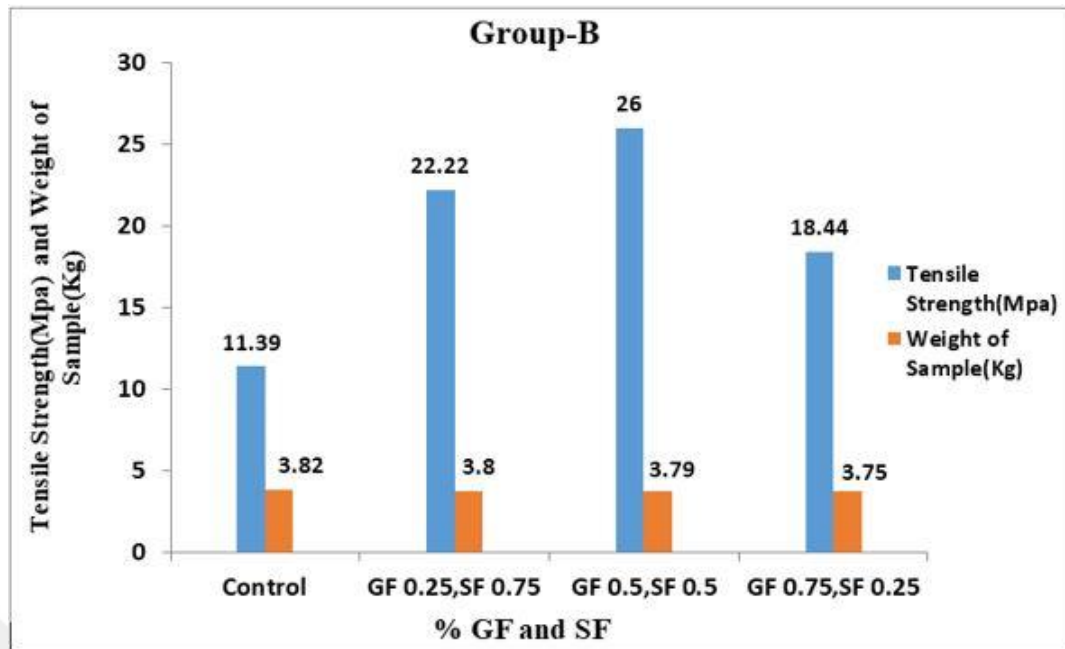


Figure 4.5 Result tensile strength and weight samples for the Group B (Maan Albiyate, 2017)

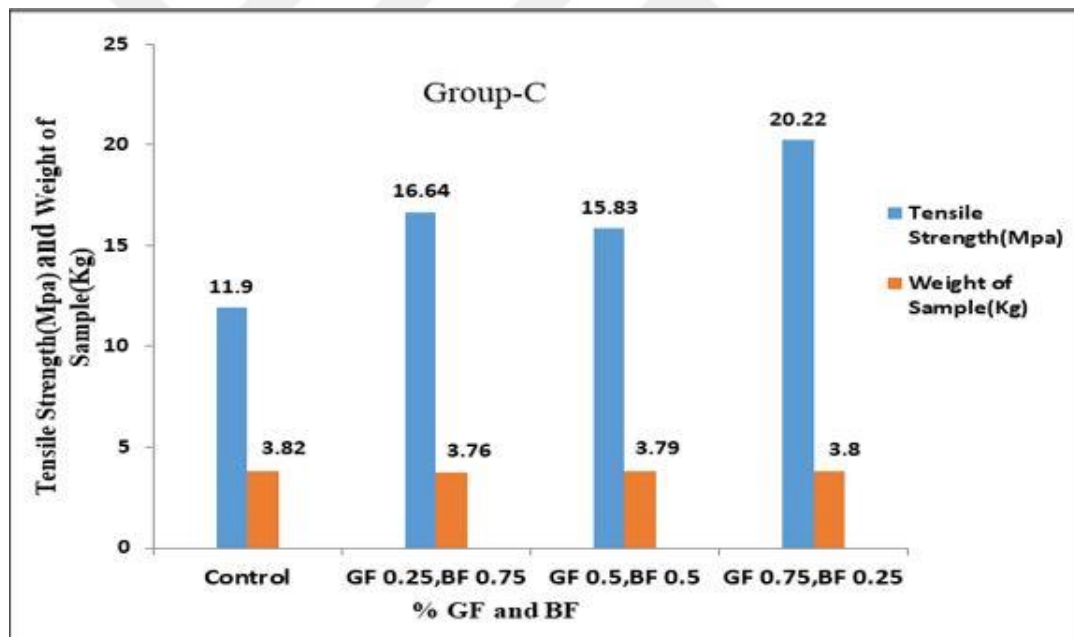


Figure 4.6 Result tensile strength and weight samples of Group C (Maan Albiyate, 2017)

1.20 The Result of Flexural Test for the Beams

All of them have same dimensional and components only are differences in percentage of fiber. The total beams that used are ten that divided into three groups with control beam. To observe the mechanical properties of the beams the out put results of beams compared with out put result of the control beam.

The tested beams are painted with white emulsion and a grid of line made with a distance of 50 x 50 mm. The crack initiation is shown in alphabetical order (i.e. A, B, C, D, and E respectively). The propagation of these cracks is marked with multi-color pen and load is denoted on each stage of crack propagation as shown in Figure 4.7.

1.21 Response of Specimen for the Control Beam

The beam detail and process of preparing indicated in the previous chapter. After the casting process, curing, painting, and line up the beams ready to test by flexural test machine. By increasing apply load hairline cracks observed on the side of the beam at load, 28.9 kN on time 191.9 second (3.19 minute). This crack followed by another crack on the right and left side at a load and those cracks grew and extended until ultimate load 54.941 kN on time 754.7 second (12.57 minute), also failure occurred of load 49.138. The maximum displacement in mid-span was 47.971 mm as shwnTable 4.3.

Table 4.3 The detail of result the flexural test for control beam

Control beam	GF ratio: 0%		
Mechanical properties	Time (sec)	Load (kN)	Displacement (mm)
Initial seating	0.4	0.016302	0.089
The first hairline cracking	191.9	28.9	15
Ultimate bearing capacity	754.7	54.941	12.66
Failure	2878.32	49.138	47.971



Figure 4.7 Control beam after the crush and indicate crack propagation

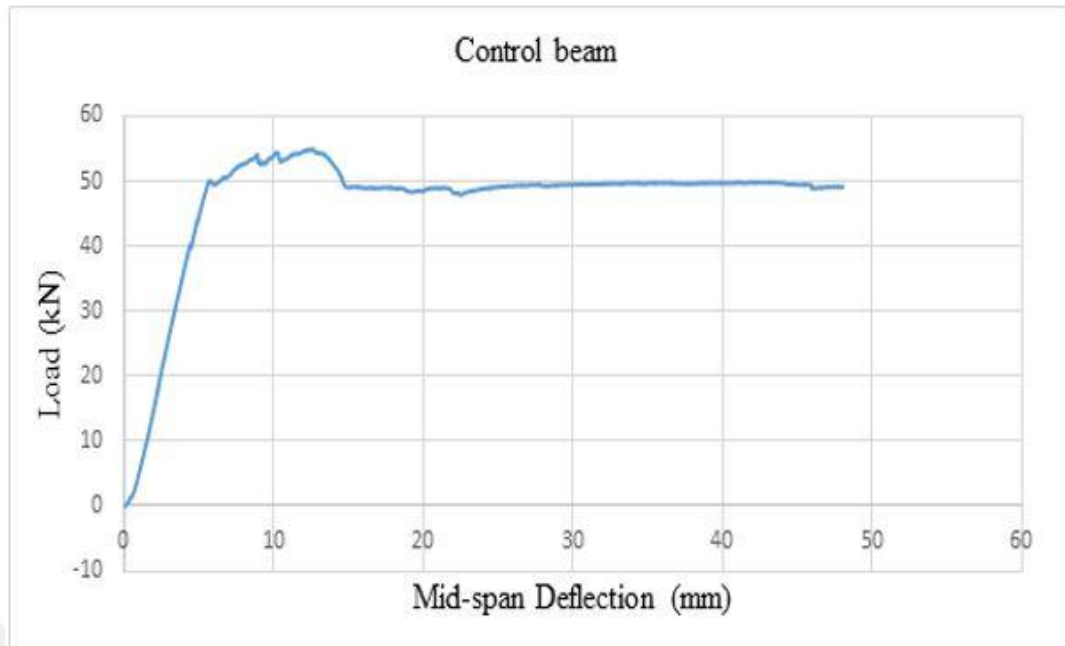


Figure 4.8 Load-displacement response of specimen control beam

1.22 The Result of the Flexural Beam Test for Group A

1.22.1 The result of flexural beam test for A1

The first hairline cracks observed on the side of the beam at load, 29.6 kN on time 248.3 second (4.13 Minute). This crack followed by another crack on the right and left side by passing of more time at the ultimate load of 46.19 kN on time 3267.47 second (54.46 Minute), and cracks grew. At last, the failure load 23.86 kN on time 3632.24 second (60.65 Minute). The maximum displacement in mid-span was 60.47 mm as shown in Figure 4.9 and 4.10 and Table 4.4.

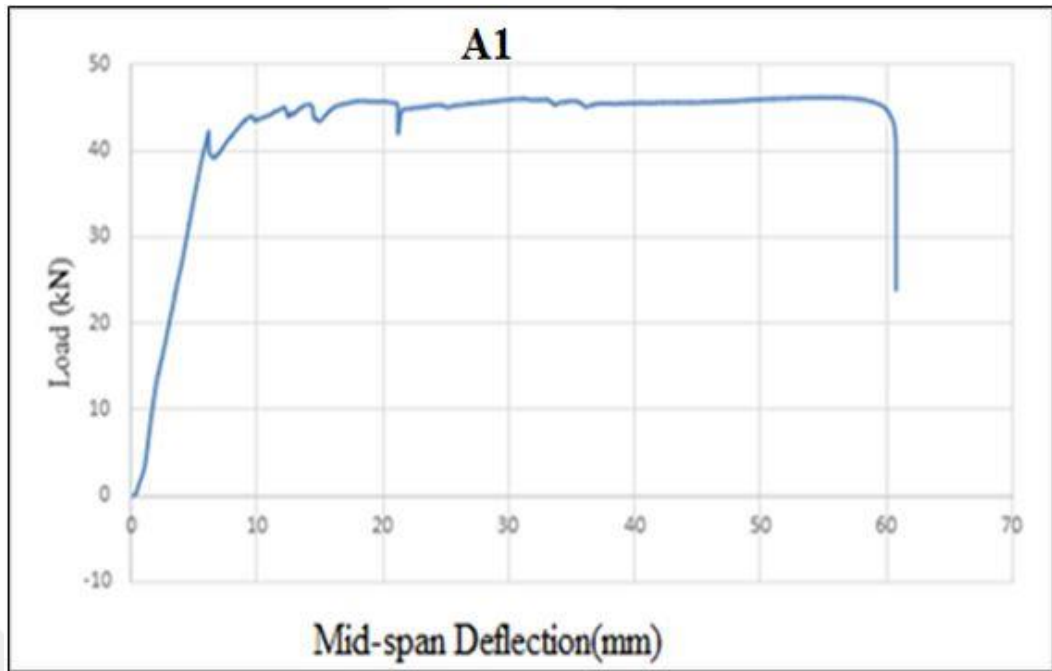


Figure 4.9 Load-displacement response to specimen A1

Table 4.4 The detail of result the flexural test for control beam

A 1 GF beam	GF ratio: A1		
Mechanical properties	Time (s)	Load (kN)	Displacement (mm)
Initial seating	0.4	0.016302	0.089
The first hairline cracking	248.3	29.6	21
Ultimate bearing capacity	3267.47	46.195	54.66
Load failure	3632.24	23.86	60.746



Figure 4.10 Flexural tests for concrete beam A 1 GF

1.22.2 The result of flexural beam test for A2

The first hairline crack observed on the side of the beam at the load 30.12 kN on time 217.6 second (3.62 Minute). And cracks followed by another crack on both sides of the crack at the ultimate load 58.66 kN on time 1104 second (18.4 Minute).

Diffusion of crack continuous until at final, failure occurs at the load 27.31 kN on time 3896.58 second (64.94 Minute). The maximum displacement in mid-span was 60.47 mm was 65.252 mm as shown in Figure 4.11 and 4.12 also Table 4.5.



Figure 4.11 Beam A 2 GF after the crush and indicate crack propagation

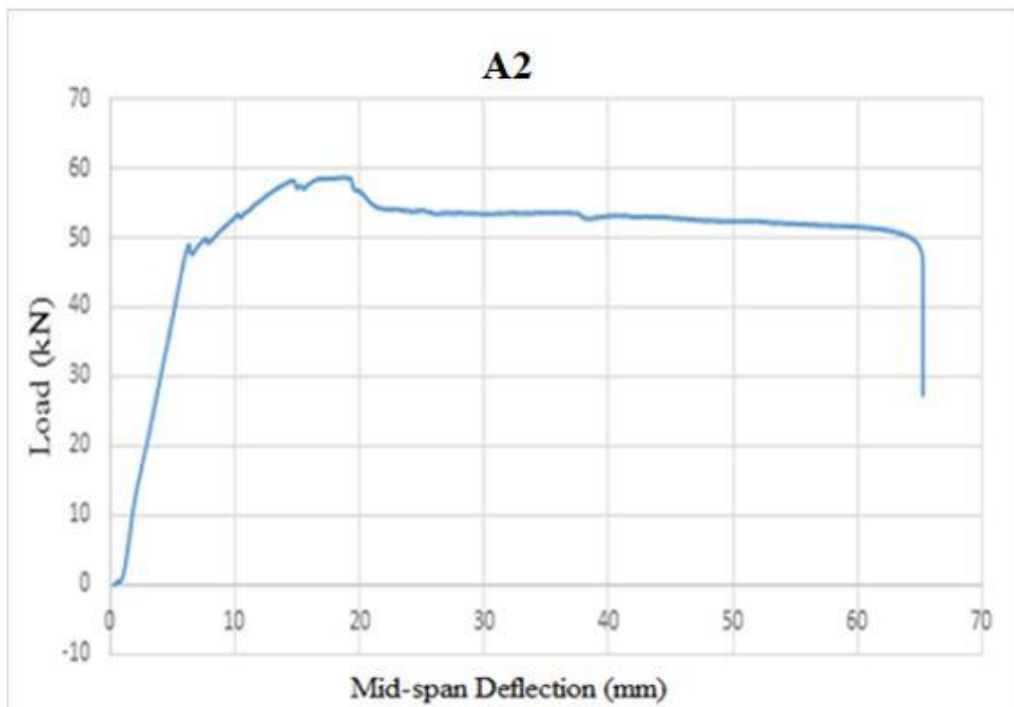


Figure 4.12 Load-displacement response to specimen A2

Table 4.5 Specimens A 2 details and key load stages.

A 2 GF beam	GF ratio: A 2		
Mechanical properties	Time (s)	Load (kN)	Displacement (mm)
Initial seating	0.4	0.016302	0.089
The first hairline cracking	217.6	30.12	3.93
Ultimate bearing capacity	1104	58.664	18.704
Load failure	3896.58	27.312	65.252

1.22.3 The result of flexural beam test for A3

The first hairline crack observed on the side face of the beam at load, 28.011 kN on time 248.3 second (4.13 Minute). This crack followed by another crack on the right and left side until the ultimate load 49.2 kN on time 1177.3 second (19.62 Minute). The cracks grew and extended the diffusion of crack continuous until failure occurred on the beam at the load 24.85 kN on time 3907.51 second (65.125 Minute).

The maximum displacement in mid-span was 65.169 mm as shown in Figure 4.13 and 4.14 also Table 4.6.



Figure 4.13 Beam A 3 GF after the crush and indicate crack propagation

Table 4.6 Specimen (GF 1.5 %) details and key load stages

A 3 GF beam	GF ratio: A 3		
Mechanical properties	Time (sec)	Load (kN)	Displacement (mm)
Initial seating	0.4	0.016302	0.089
The first hairline cracking	248.3	28.011	4.17
Ultimate bearing capacity	1177.30	49.200297	19.66243
Load failure	3907.51	24.859	65.169

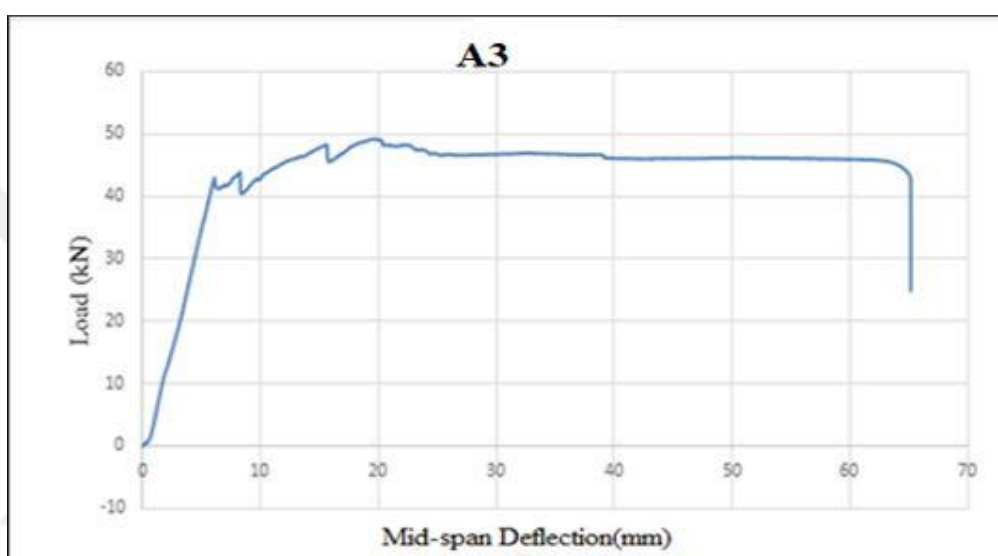


Figure 4.14 Load-displacement response to specimen A3

In the last according to the out put results conclude the by increasing the percentage of GF into the concrete beam the failure time occure delay. The relations between thpercentages of GF and displacement are proportional. The ultimate load of the beam in % 1 GF has positively result.

Table 4.7 Result of flexural test for the Group-A beams

% GF	Control Beam	0.5 % GF	1 % GF	1.5 % GF
Ultimate Load kN	54.94	46.19	58.66	49.2
Deflection mm	47.97	60.74	65.16	65.25
Failure Load	49.13	23.86	27.312	24.85
Failure Time (mint)	47.97	60.53	64.94	65.12

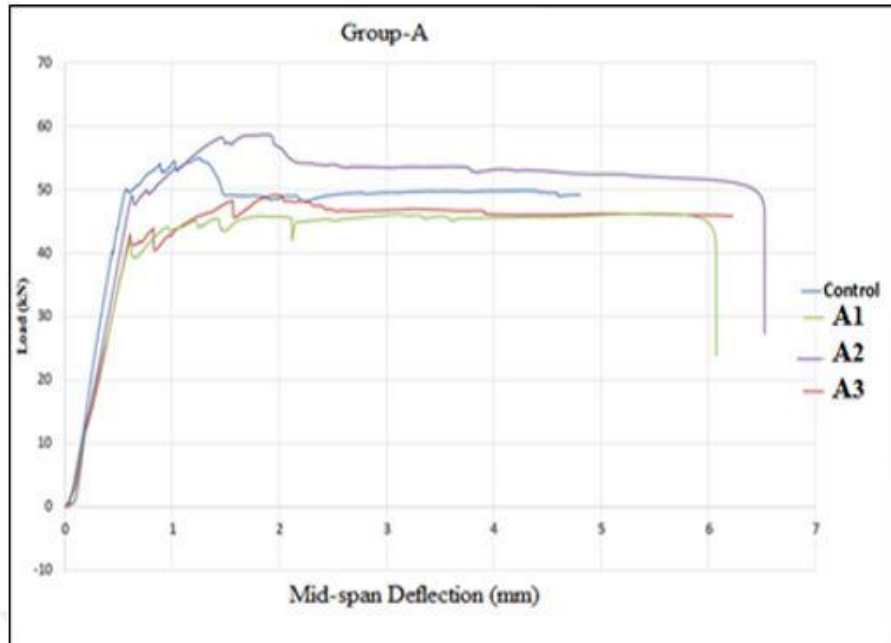


Figure 4.15 Relationship between load and deflection in various % GF for Group A

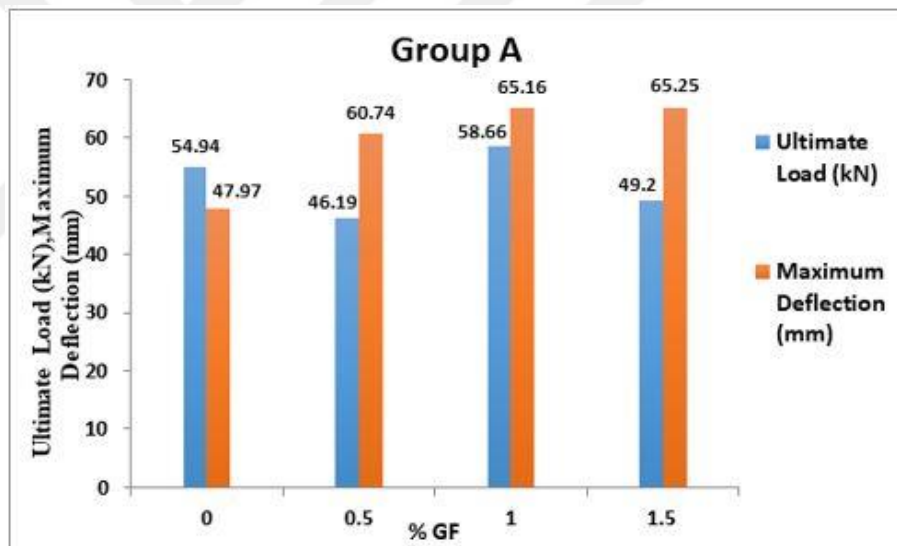


Figure 4.16 Result ultimate load and maximum deflection Group A beams

1.23 The Result of Flexural Beam Test for Group B

In this group, according to the out put results the ultimate load has positively result at the ratio % 0.5 GF, % 0.5 SF in compared with other ratios in the group. For the maximum displacement, the positively ratio was % 0.25 GF, % 0.75 SF in compared with control and other ratios as shown in Figure 4.18 and 4.19.



Figure 4.17 Result of Flexural test for Group B beams

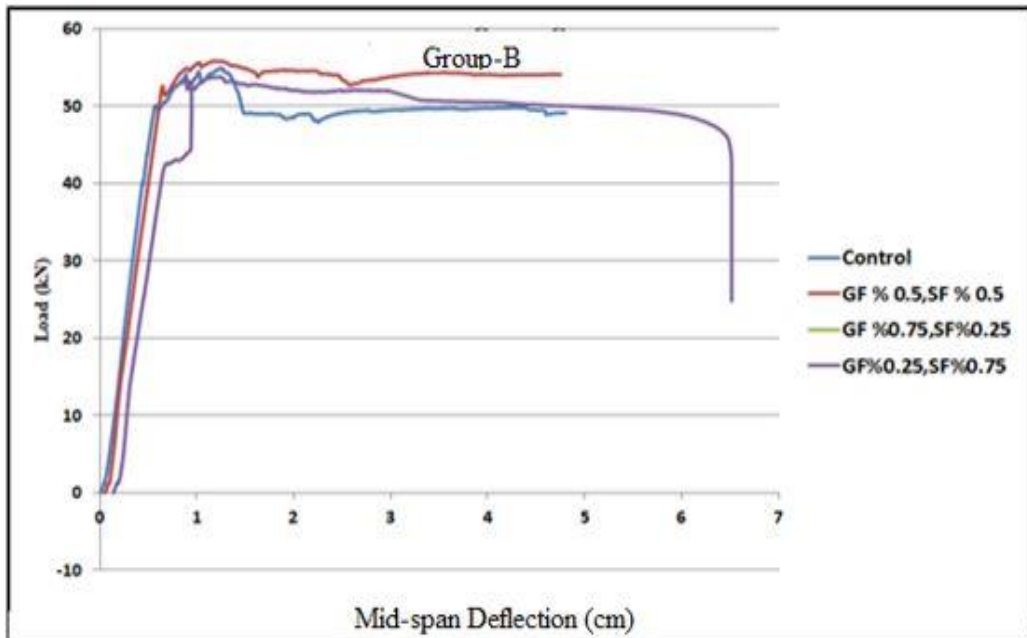


Figure 4.18 Flexural tests for Group B beams

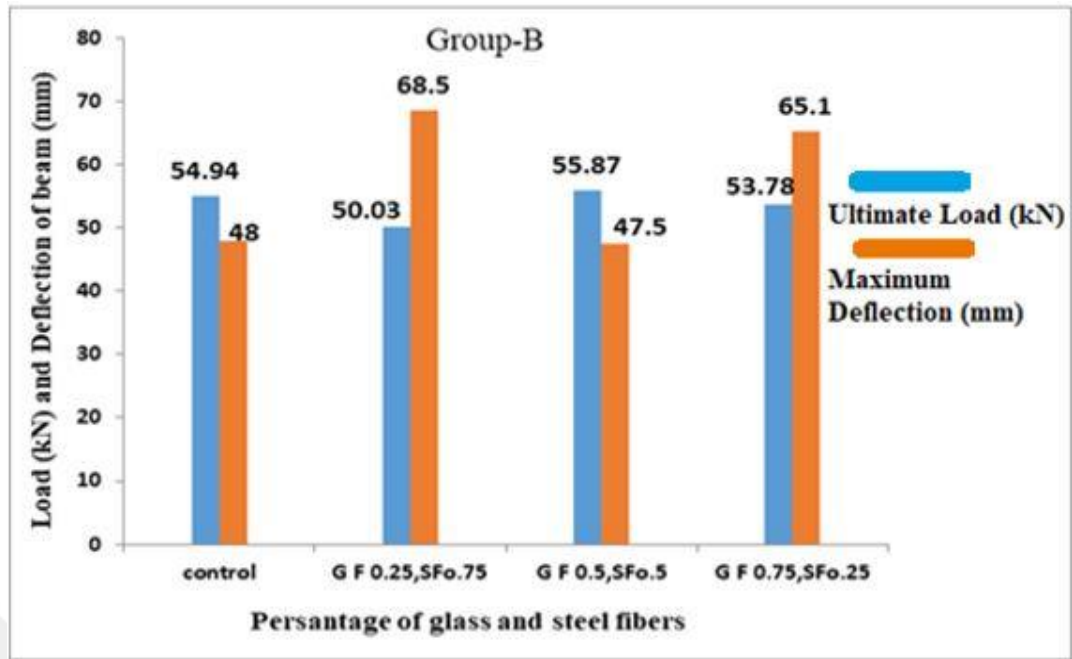


Figure 4.19 Result ultimate load and maximum deflection for Group B beams (Maan Albiyate, 2017)

Table 4.8 Result of flexural test for the Group-B beams (Maan Albiyate, 2017)

% HF	Control Beam	0.25 % GF + 0.75 % SF	0.5 % GF + 0.5 % SF	0.75 % GF + 0.25 % SF
Ultimate Load kN	54.94	50.03	55.87	53.78
Deflection mm	48	68.5	47.5	65.1
Failure Load	49.13	53.82	54.08	23.64
Failure Time (mint)	47.97	67.15	40.05	67.15

1.24 The Result of Flexural Beam Test for Group C

In the Group C according to the out put results the ultimate load has positively result at the ratio % 0.75 GF, % 0.25 BF in compared with other ratios in the group. For the maximum displacement, the positively ratio was % 0.75 GF, % 0.25 BF in compared with control and other ratios as shown in Figure 4.18 and 4.19.



Figure 4.20 Flexural tests of Group C beam

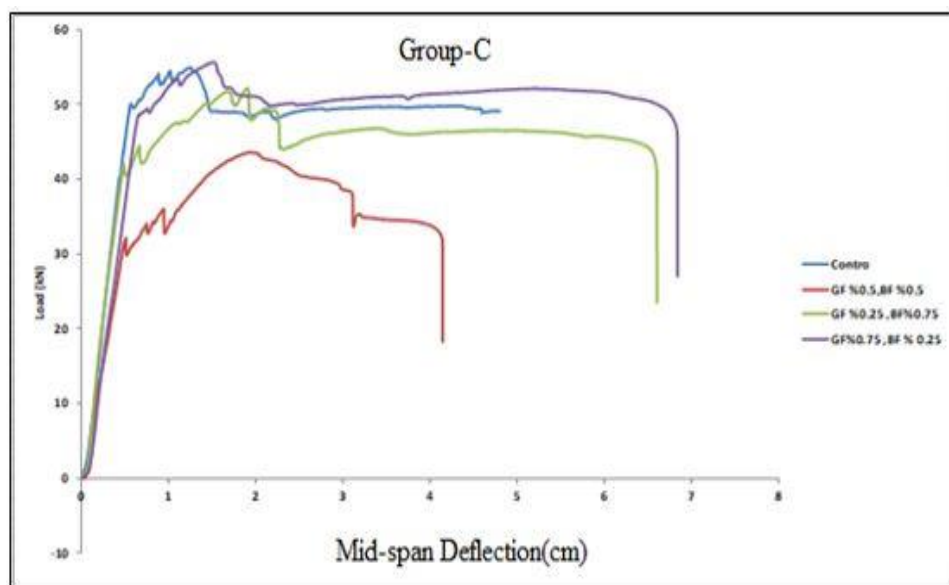


Figure 4.21 Flexural tests of Group C beam

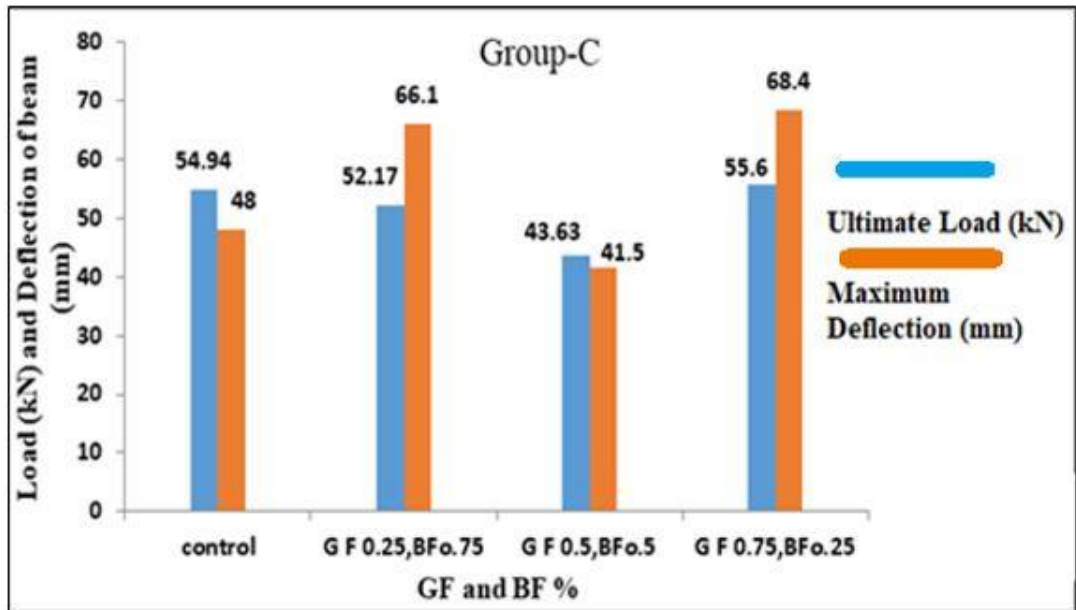


Figure 4.22 Result ultimate load and maximum deflection Group C beams (Maan Albiyate, 2017)

Table 4.9 Result of flexural test for the Group-C beams (Maan Albiyate, 2017)

% HF	Control Beam	0.25 % GF + 0.75 % BF	0.5 % GF + 0.5 % BF	0.75 % GF + 0.25 % BF
Ultimate Load kN	54.94	52.17	43.63	55.6
Deflection mm	48	66.1	41.5	68.4
Failure Load	49.13	23.5	18.29	27.05
Failure Time (mint)	47.97	66.07	41.12	68.31

CHAPTER 5

CONCLUSION

In this study, the effect of GF and HF on the mechanical properties and flexural test on steel reinforced concretes was investigated. Based on the results of the present experiments, the following conclusions may be drawn out.

- Generally, there is a decrease in workability when fibers were added to the concrete production especially for GF, it has been shown decrease more than the other fibers.
- A systematic decrease in compressive strength of the concretes was observed with increasing the percentage of GF in Group A, the results showed that the reduction in the compression strength range between (4.46 – 8.60) % but the 1.0 % percentage approved the best result therefor this percentage was depended in the other groups.
- Group B and C proved the same behaviour, the results showed also decrease in compressive strength more than Group A
- Group A was observed that increasing the percentage ratio of GF resulted in a gradual increase in the tensile strength of concrete mixes. The increasing range was (43.28 – 63.04) %. Moreover, the 1.0 % percentage also has the best value if its comparison with the other mixes.
- The HF has a positive effect on the tensile strength of the concrete, Group B has the highest rate of increase in the tensile strength, especially at (0.5 % GF, 0.5 % SF) if compared with the control sample and other ratios in the group.

- In general, by adding fibers into the concrete the weight of the concrete decrease in all groups and the rate of decrease depending on the specific gravity of the fiber that added to the concrete.
- The most important advantage from the GF appears on the beams test, the results for Group A showed that by adding 0.5 % GF the deflection of the beam increases until 26.62 % in comparison with control beam. And for 1 % GF, the deflection of the beam dramatically increases the rate 35.83 %. But when 1.5 % GF was added the deflection of the beam increases to 36 % in comparison with control beam.
- Also another important positive effect, the failure time was increased with the increasing of FG at the beginning when 0.5 % GF was added the increasing rate 26.18 % in comparison with control beam. And for 1 % GF the ratio was 35.37 %. then it will reach 35.75 % when 1.5 % GF was added in comparison with control beam.
- A similar trend was also observed in the Groups (B and C), where shown the same positive effect but on a different level.

REFERENCES

- Abdullah, M. M., & Jallo, E. K. (2012). Mechanical Properties of Glass Fiber Reinforced Concrete. *Al-Rafadain Engineering Journal*, **20**(5).
- Alawsi, G., Aldajah, S., & Rahmaan, S. A. (2009). Impact of humidity on the durability of E-glass/polymer composites. *Materials & Design*, **30**(7), 2506-2512.
- Alsalihi, M. A. J. (2014). Mechanical Properties of Glass Fiber Reinforced Polymer Bars After Exposure to Elevated Temperatures.
- Avinash, G., Quadri, S. I., Quadri, S. M., Ali, S. M. A., & Hussaini, S. S. (2012). Strength aspects of glass fibre reinforced concrete. *Materials Science: An Indian Journal*, **8** (12).
- Babu, T. S., Rao, M. S., & Seshu, D. R. (2008). Mechanical properties and stress-strain behavior of self-compacting concrete with and without glass fibers. *Asian Journal of Civil Engineering (building and housing)*, **9** (5), 457-472.
- Banthia, N., Bindiganavile, V., Jones, J., & Novak, J. (2012). Fiber-reinforced concrete in precast concrete applications: Research leads to innovative products. *PCI journal*, **57**(3).
- Blaga, A. (1980). Deterioration mechanisms in weathering of plastic materials. In *Durability of Building Materials and Components*. ASTM International.
- Boulekbache, B., Hamrat, M., Chemrouk, M., & Amziane, S. (2010). Flowability of fibre-reinforced concrete and its effect on the mechanical properties of the material. *Construction and Building Materials*, **24**(9), 1664-1671.

- Buratti, N., Mazzotti, C., & Savoia, M. (2011). The post-cracking behaviour of steel and macro-synthetic fibre-reinforced concrete. *Construction and Building Materials*, **25**(5), 2713-2722.
- Butler, M., Mechtcherine, V., & Hempel, S. (2010). The durability of textile reinforced concrete made with AR glass fibre: effect of the matrix composition. *Materials and structures*, **43**(10), 1351-1368
- Çağlar, A., Yilmaz, H., & Aydin, C. (2002). Effect of glass fiber reinforcement on the flexural strength of different denture base resins. *Quintessence international*, **33**(6).
- Chandramouli, K., Srinivasa Rao, P., Pannirselvam, N., Seshadri Sekhar, T., & Chen, B., & Liu, J. (2005). The contribution of hybrid fibers on the properties of the high-strength lightweight concrete having good workability. *Cement and Concrete Research*, **35**(5), 913-917.
- Coronelli, D., & Gambarova, P. (2004). Structural assessment of corroded reinforced concrete beams: modeling guidelines. *Journal of Structural*
- Dehghan, A., Peterson, K., & Shvarzman, A. (2017). Recycled glass fiber reinforced polymer additions to Portland cement concrete. *Construction and Building Materials*, **146**, 238-250.
- Deshmukh, S. H., Bhusari, J. P., & Zende, A. M. (2012). Effect of glass fibers on ordinary Portland cement concrete. *IOSR Journal of Engineering*, **2**(6), 1308-1312.
- Deshmukh, S. H., Bhusari, J. P., & Zende, A. M. (2012). Effect of glass fibers on ordinary Portland cement concrete. *IOSR journal of engineering*, **2**(6), 1308-1312.
- Engineering*, **130**(8), 1214-1224.
- Faruk, O., Bledzki, A. K., Fink, H. P., & Sain, M. (2012). Biocomposites reinforced with natural fibers: 2000–2010. *Progress in polymer science*, **37**(11), 1552-1596.

- Ferreira, P. J., Zhu, Y., Murali, S., Stoller, M. D., Ganesh, K. J., Cai, W., ... & Su, D. (2011). Carbon-based supercapacitors produced by activation of graphene. *science*, **332**(6037), 1537-1541.
- Foster, S. J. (2009). The application of steel-fibres as concrete reinforcement in Australia: *from material to structure*. *Materials and Structures*, **42**(9), 1209.
- Gilstrap, J. M., & Dolan, C. W. (1998). Out-of-plane bending of FRP-reinforced masonry walls. *Composites science and technology*, **58**(8), 1277-1284.
- Hanseth, O., & Lyytinen, K. (2010). Design theory for dynamic complexity in information infrastructures: the case of building the internet. *Journal of information technology*, **25**(1), 1-19.
- Harish, S., Michael, D. P., Bensely, A., Lal, D. M., & Rajadurai, A. (2009). Mechanical property evaluation of natural fiber coir composite. *Materials characterization*, **60**(1), 44-49.
- Henriksen, T., Lo, S., & Knaack, U. (2015). Advances in the application of thin-walled glass fiber reinforced concrete elements. *Advances in Civil Engineering Materials*, **4**(1), 115-130.
- Holschemacher, K., Mueller, T., & Ribakov, Y. (2010). Effect of steel fibres on mechanical properties of high-strength concrete. *Materials & Design (1980-2015)*, **31**(5), 2604-2615.
- Hsu, T. T., Slate, F. O., Sturman, G. M., & Winter, G. (1963, February). Microcracking of plain concrete and the shape of the stress-strain curve. In *Journal Proceedings*, **60**(2), 209-224.
- Hua, M., Zhang, S., Pan, B., Zhang, W., Lv, L., & Zhang, Q. (2012). Heavy metal removal from water/wastewater by nanosized metal oxides: a review. *Journal of Hazardous Materials*, **211**, 317-331.
- Jain, J. K. (2015). *Effect of Chopped Glass Fibres on the Strength of Concrete Tiles* (Doctoral dissertation).

- Jiang, C., Fan, K., Wu, F., & Chen, D. (2014). Experimental study on the mechanical properties and microstructure of chopped basalt fibre reinforced concrete. *Materials & Design*, **58**, 187-193.
- Kim, G. B., Pilakoutas, K., & Waldron, P. (2008). Thin FRP/GFRC structural elements. *Cement and Concrete Composites*, **30**(2), 122-137.
- Kizilkanat, A. B., Kabay, N., Akyüncü, V., Chowdhury, S., & Akça, A. H. (2015). Mechanical properties and fracture behavior of basalt and glass fiber reinforced concrete: An experimental study. *Construction and Building Materials*, **100**, 218-224.
- Kliazovich, D., & Granelli, F. (2006). Cross-layer congestion control in ad hoc wireless networks. *Ad Hoc Networks*, **4**(6), 687-708.
- Kovler, K., & Roussel, N. (2011). Properties of fresh and hardened concrete. *Cement and Concrete Research*, **41**(7), 775-792.
- Kwan, W. H., Ramli, M., & Cheah, C. B. (2014). Flexural strength and impact resistance study of fibre reinforced concrete in simulated aggressive environment. *Construction and Building Materials*, **63**, 62-71.
- Lee, J. H., Cho, B., & Choi, E. (2017). Flexural capacity of fiber reinforced concrete with a consideration of concrete strength and fiber content. *Construction and Building Materials*, **138**, 222-231.
- Lopez-Anido, R., & Karbhari, V. M. (2000). Fiber reinforced composites in civil infrastructure. *Emerging materials for civil infrastructure, state-of-the-art*. Reston, VA: ASCE, 41-78.
- Lusti, H. R., Hine, P. J., & Gusev, A. A. (2002). Direct numerical predictions for the elastic and thermoelastic properties of short fibre composites. *Composites Science and Technology*, **62**(15), 1927-1934.
- Lv, L., Hua, M., Zhang, S., Pan, B., Zhang, W., & Zhang, Q. (2012). Heavy metal removal from water/wastewater by nanosized metal oxides: a review. *Journal of Hazardous Materials*, **211**, 317-331.
- Maan Abdelhakeam Albayati, (2017). Experimental Study For Flexural Behaviour Of High Strength Rc Beams With Hybrid Fibers, MSc Thesis.

- Meier, U. (1995). Strengthening of structures using carbon fibre/epoxy composites. *Construction and Building Materials*, **9**(6), 341-351.
- Meškėnas, A. (2011). Stress strain analysis of steel fibre reinforced concrete members (Doctoral dissertation, Vilnius Gediminas Technical University).
- Mobasher, B. (2011). Mechanics of fiber and textile reinforced cement composites. CRC press.
- Mobasher, B., & Li, C. Y. (1996). Mechanical properties of hybrid cement-based composites. *ACI Materials Journal*, **93**, 284-292.
- Murthy, Y. I., Sharda, A., & Jain, G. (2012). Performance of glass fiber reinforced concrete. *International journal of engineering and innovative technology*, **1**(6).
- Naaman, A. E. (2003). Engineered steel fibers with optimal properties for reinforcement of cement composites. *Journal of advanced concrete technology*, **1**(3), 241-252.
- Nagalakshmi, R. (2013). Experimental study on strength characteristics on M25 concrete with partial replacement of cement with fly ash and coarse aggregate with coconut shell. *International Journal of Science & Engineering Research*, **4**(1).
- Naik, T. R. (2008). Sustainability of concrete construction. *Practice Periodical on Structural Design and Construction*, **13**(2), 98-103.
- Nehdi, M., & Ladanchuk, J. D. (2004). Fiber synergy in fiber-reinforced self-consolidating concrete. *Materials Journal*, **101**(6), 508-517.
- Page, C. L. (2007). Corrosion and protection of reinforcing steel in concrete. *Durability of concrete and cement composites*, 136-186.
- Pakravan, H. R., Latifi, M., & Jamshidi, M. (2017). Hybrid short fiber reinforcement system in concrete: A review. *Construction and Building Materials*, **142**, 280-294.

- Pakravan, H. R., Latifi, M., & Jamshidi, M. (2017). Hybrid short fiber reinforcement system in concrete: A review. *Construction and Building Materials*, **142**, 280-294.
- Rossi, P., Acker, P., Malier, Y. (1987). Effect of steel fibres at two different stages: the material and the structure, *Materials, and Structures*, **20**, 436-439.
- Roth, M. J., Eamon, C. D., Slawson, T. R., Tonyan, T. D., & Dubey, A. (2010). Ultra-High-Strength, Glass Fiber-Reinforced Concrete: Mechanical Behavior and Numerical Modeling. *ACI Materials Journal*, **107**(2).
- Saetta, A., Scotta, R., & Vitaliani, R. (1998). Mechanical behavior of concrete under physical-chemical attacks. *Journal of engineering mechanics*, **124**(10), 1100-1109.
- Saetta, A., Scotta, R., & Vitaliani, R. (1998). Mechanical behavior of concrete under physical-chemical attacks. *Journal of engineering mechanics*, **124**(10), 1100-1109.
- Salvetat-Delmotte, J. P., & Rubio, A. (2002). Mechanical properties of carbon nanotubes: a fiber digest for beginners, carbon, *International Journal of Public Administration*, **40**(10), 1729-1734.
- Shakor, P. N., & Pimplikar, S. S. (2011). Glass fibre reinforced concrete use in construction. *International Journal of Technology and Engineering System*, **2**(2), 632-634.
- Sharquie, K. E., Najim, R. A., & Abu-Raghif, A. R. (2002). Dapsone in Behçet's Disease: A Double-Blind, Placebo-Controlled, Cross-Over Study. *The Journal of dermatology*, **29**(5), 267-279.
- Singh, V. K., & Kumar, D. (2014). Effect of Fiber on Properties of Concrete. *International journal of engineering science and research technology*, **3**, 312-317.
- Singha, K. (2012). A short review on basalt fiber. *International Journal of Textile Science*, **1**(4), 19-28.

- Spennemann, D. H. (1999). Cultural heritage conservation during emergency management: luxury or necessity?. *International Journal of Public Administration*, **22**(5), 745-804.
- Spoelstra, M. R., & Monti, G. (1999). FRP-confined concrete model. *Journal of composites for construction*, **3**(3), 143-150.
- Tam, V. W., Gao, X. F., & Tam, C. M. (2005). Microstructural analysis of recycled aggregate concrete produced from two-stage mixing approach. *Cement and concrete research*, **35**(6), 1195-1203.
- Wafa, F. F. (1990). Properties & applications of fiber reinforce concrete. *Engineering Sciences*, **2**(1).
- Zhang, W., Wang, Q., Ye, J., & Zhou, J. (2017). Fracture development and fluid pathways in shales during granite intrusion. *International Journal of Coal Geology*, **183**, 25-37.
- Zheng, Z., & Feldman, D. (1995). Synthetic fibre-reinforced concrete. *Progress in Polymer Science*, **20**(2), 185-210.