RECYCLED GLASS AND CARBON FIBER BY MECHANICAL PROCESS FOR CONCRETE COMPOSITE

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This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

By

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DECLARATION

I hereby, declared this report entitled “Recycled Glass and Carbon Fiber by Mechanical Process for Concrete Composite” is the result of my own research except as cited in references.

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Date : 16 July 2021

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for the Degree of Bachelor Manufacturing Engineering (Hons). The member of the supervisory committee are as follow:

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(DR. SYAHRIZA BINTI ISMAIL)

ABSTRAK

Sisa polimer menghasilkan dan memakan banyak polimer bertetulang gentian karbon (CFRP) dan polimer bertetulang gentian kaca (GFRP) kerana ia digunakan dalam pelbagai bidang seperti industri pembinaan, penerbangan, minyak dan gas, sukan dan angin. Bahan-bahan ini sangat digunakan dalam pengeluaran di seluruh dunia. Selanjutnya, orang akhirnya membuang bahan komposit ini ke sungai, dan lain-lain, dan bahan komposit tidak hancur cukup cepat. Di samping itu, kos penghantaran sampah yang tinggi ke tempat pembuangan sampah dan caj kualiti semula jadi per kilogram, iaitu RM10/kg. Tujuan kajian ini adalah pertama, untuk mengkaji ukuran serat yang sesuai untuk pembuatan konkrit dari kaca kitar semula dan gentian karbon dengan menggunakan kaedah kitar semula mekanikal. Kedua, untuk menilai sifat mekanikal konkrit yang disediakan menggunakan gentian kaca dan karbon kitar semula. Ketiga, untuk melakukan analisis morfologi pada permukaan konkrit yang retak menggunakan mikroskopi elektron imbasan (SEM) dan struktur kristal menggunakan Difraksi Sinar-X (XRD). Ukuran gentian pada 50µm untuk pembuatan konkrit dilihat sesuai dengan kaedah kitar semula mekanikal ini. Kekuatan tegangan utama dan modulus konkrit Young dengan gentian kaca kitar semula adalah yang tertinggi di antara konkrit biasa dan konkrit dengan serat karbon kitar semula masing-masing adalah 9.06 MPa dan 6.92 MPa. Oleh itu, konkrit dengan kemasukan gentian kaca kitar semula telah menghasilkan peningkatan luar biasa sekitar 10.49% pada kekuatan tegangan dan 53.78% modulus Young berbanding dengan konkrit biasa. Terakhir, lakukan analisis morfologi pada permukaan konkrit yang retak menggunakan mikroskopi elektron imbasan (SEM) dan Difraksi Sinar-X (XRD). Dari mikrograf SEM, ini menunjukkan dengan jelas bahawa gentian kaca kitar semula mempunyai ikatan kuat dengan konkrit. Selain daripada itu, penyebaran gentian kaca kitar semula yang baik dalam konkrit dijumpai yang cenderung memberikan kekuatan tinggi dan ikatan yang baik. Dari analisis XRD, konkrit dengan konkrit gentian kaca, ia menghasilkan banyak puncak. Ini membuktikan bahawa adanya $Ca_3Si_2O_7$ dalam konkrit dengan gentian kaca kitar semula. Dengan cara demikian, ikatan antara $Ca_3Si_2O_7$ dalam konkrit dan SiO_2 dalam gentian kaca kitar semula adalah kekuatan yang kuat. Kajian ini menunjukkan dengan jelas pilihan yang layak untuk pengurusan sisa untuk gentian kaca kitar semula dan bahan serat karbon kitar semula melalui pengembangan aplikasi kitar semula akhir yang ekonomik yang akan menyumbang kepada industri komposit polimer yang diperkuat dengan gentian yang lebih lestari.

ABSTRACT

Polymer wastes produce and consume a lot of carbon fiber reinforced polymers (CFRP) and glass fiber reinforced polymers (GFRP) as they are used in various fields such as construction, aviation, oil and gas, sporting and wind industries. These materials are highly used in production throughout the world. Furthermore, people may end up throwing these composites materials into rivers, etc., and composite materials are not disintegrate fast enough. In addition, the high cost of sending waste to landfill and natural quality charge per kilogram, which is RM10/kg. The purposes of this study are firstly, to study the suitable fiber size for concrete fabrication of the recycled glass and carbon fibers by using mechanical recycling method. Secondly, to evaluate the mechanical properties of the concrete prepared using recycled glass and carbon fibers. Thirdly, to perform morphological analysis on the fractured surface of the concrete using scanning electron microscopy (SEM) and crystalline structure using X-Ray Diffraction (XRD). The fiber size at 50μm for concrete fabrication is seen to be suitable by using this mechanical recycling method. The ultimate tensile strength and Young's modulus of concrete with recycled glass fiber is the highest among normal concrete and concrete with recycled carbon fiber which is 9.06 MPa and 6.92 MPa respectively. Hence, the concrete with recycled glass fiber inclusion had yielded an extraordinary improvement of about 10.49% in the tensile strength and 53.78% of Young's modulus as compared to normal concrete. Lastly, perform morphological analysis on the fractured surface of the concrete using scanning electron microscopy (SEM) and X-Ray Diffraction (XRD). From the SEM micrograph, it shows clearly the recycled glass fiber had strong bonding with concrete. Other than that, a good dispersion of recycled glass fiber in concrete was found which tends to give high strength and good bonding. From the XRD analysis, concrete with glass fiber concrete, it produced many peaks. This proved that the present of $Ca_3Si_2O_7$ in concrete with recycled glass fiber. In such way, the bonding between $Ca_3Si_2O_7$ in concrete and the SiO_2 in recycled glass fiber were strong strength. This study

indicates clearly a viable option for waste management for recycled glass fiber and recycled carbon fiber materials through the development of an economical final recycling application that will contribute to a more sustainable fibre-reinforced polymer composite industry.

DEDICATION

Dedicated

To my beloved father, Jalaluddin Bin Muhiddin

To my beloved mother, Bousiya Begum

To my special supervisor, Dr Syahriza Binti Ismail

For giving me moral support, funding collaboration, encouragement and understanding.

Thank you so much and I love you all

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In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project successfully without difficulty.

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Other than that, I would like to thank my lovely friend Muhd Shiddiq Bin Sabuddin and NurHaliana Syazwani Binti Mohd Halim who always gave me much motivation and moral support to improve my work.

Last but not least, I would like to thank my parents and to my brothers for supporting me spiritually throughout my thesis writing.

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LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
CFRP	-	Carbon Fiber reinforced Polymer
EOL	-	End of Life
GFRP	-	Glass Fiber Reinforced Polymer
MIGHT	-	Malaysian Industry-Government Group for High Technology
SEM	-	Scanning Electron Microscope
PMCs	-	Polymer Matrix Composites
PAN	-	Polyacrylonitrile
UHTC	-	Ultrahigh Temperature Ceramic
C-SiC-UHTC	-	Silicon Carbide Composites
GF	-	Glass Fiber
CF	-	Carbon Fiber
FRP	-	Fiber Reinforced Polymer
rCF	-	Recycled Carbon Fiber
vCF	-	Virgin Carbon Fiber
RAC	-	Recycled Aggregate Concrete
NAC	-	Natural Aggregate Concrete
FA	-	Fly Ash
SOP	-	Standard Operation Procedure
XRD	-	X-Ray Diffraction

LIST OF SYMBOLS

C	-	Carbon
Ca	-	Calcium
Si	-	Silicon
S	-	Sulphur
O	-	Oxygen
mm	-	millimeter
min	-	minute
%	-	percentage
°	-	degree
µm	-	micrometes
nm	-	nanaometer
N	-	Newton
kN	-	kilo Newton
g	-	gram
kV	-	kilovolts
mA	-	milliAmpere
MPa	-	Mega Pascal

CHAPTER 1

INTRODUCTION

Composite materials are simply a mixture of two or more different kinds of materials used together to incorporate the best properties or to impart new features which none of the component materials alone can achieve.

1.1 Background of Study

Recycled of carbon and glass fiber by mechanical process for concrete composite is the industrial project during my internship at G7 Aerospace. In this company, they will inspect, restore, alter, re-engineering from manufacturing, technical services and repair and revision services for parts and structures. During repair the composite material, some of the project may have fault. So that, the composite material need to throw to the dustbin. After the end of life of composite material, usually people may end up throwing to the rivers, planted or sending waste to the landfill. So that, propose that to recycling/sustainable of composite materials which require all engineering composite materials to be properly recovered and recycled, from end-of-life (EOL).

Material composites include strengthening components such as glass fibre, carbon fibre, kevlar and a matrix such as polyester resin, epoxy resin, etc. The most used reinforcement materials are fibre glass. They have many qualities, including high strength, high resistance to chemical conditions and low weight (Sabău, 2018).

Polymer wastes are particularly high in production and consumption of carbon fiber reinforced polymers (CFRP) and glass fiber reinforced polymers (GFRP) as they are used in various fields such as construction, aviation, oil and gas, sporting and wind industry. The materials used are very high in production and in consumption throughout the world (S.R.Naqvi, 2018). Their use as high-performance light weight strengthens recently have seen a spike in applications of high added benefit (Loris G., December 2020). Among various fiber reinforced polymer composites, GFRP composite has a market share of 95% globally (M.M. Hiremath, March 2020). According to Naqvi *et al.* (2018), the GFRP composites industry is projected to reach a compound average increase rate of 9.18% over the projected years from 2018 to 2025 (Naqvi, et al., 2018).

Although synthetic composites like fibre carbon composites and composites provide structural advantages, they have put some limitations on synthetic composites, such as high cost of raw materials, and induced an end-of-life negative environmental impact, under which synthetic composites are non-recyclable or not degradable. (M.R.Mansor, 2019).

1.2 Problem Statement

In a wide variety of uses, composite materials are used such as transportation, aerospace, renewable energies. However, because of their intrinsic variability, they were not properly recycled. In Malaysia, the composite materials are usually planted or sold.

Different surveys have measured industry needs for new composites and the number of accumulated waste over recent decades in order to mitigate the possible negative effects. The main obstacles to the spread of carbon and glass fiber use are high cost and uncertainty about whether it can be recycled when composite products reach the end of their useful life.

Besides, due to the increase in the amount of carbon and glass fiber composites use. According to the Malaysian Industry-Government Group for High Technology (MIGHT) has revealed that in terms of volume, fiber glass has largely dominated (85%) composites, despite the significant rise in the utilisation of carbon and natural fibers. The matrix material for carbon fiber composites are largely (72%) epoxy. As for the Malaysia Composite industry turnover, it was estimated to be RM3.5 billion from a total of 70 fabricators.

Currently, the largest application was construction (43%), followed by aerospace (14%) and marine (14%) sectors (Malaysia, 2016). Growing industry and increasing fuel consumption levels would result in both manufacturing scrap and end-of-life (EOL) waste.

In addition, an increase in the amount of wastes are generated from the end of life components and manufacturing waste have become a problem because the waste products are cannot biodegradable. Even though there are some polymers which are degradable and eco-friendly, but those are not good enough for engineering applications. Until now, companies have used these composite materials easily without adequate knowledge of disposal procedures. For example, people may end up throwing these composites materials into rivers, etc., and composite materials are not disintegrate fast enough. Further redo, the high cost of sending waste to landfill and natural quality charge per kilogram, which is RM10/kg (Manager G7 Aerospace, 2020).

This study is important because it is able to reduce carbon and glass fiber waste at possible landfills detrimental to human health and the environment as well as encouraging consumption recycled carbon and glass fiber in industry instead to replace virgin carbon and glass fibers. In conclusion, composites are mixing two or more parts for thin solid and robust materials, are sustainable perfection but are a recycling challenge.

1.3 Objectives

The objectives of research are as follows:

1. To study the suitable fiber size for concrete fabrication of the recycled glass and carbon fibers prepared using mechanical recycling method.

2. To evaluate the mechanical properties of the concrete prepared using recycled glass and carbon fibers.

3. To perform morphological analysis on the fractured surface of the concrete using scanning electron microscopy (SEM) and crystalline structure using X-Ray Diffraction (XRD).

1.4 Scope

The research scopes are as follow:

1. Analyse the mechanical recycling method the suitable fiber size for concrete fabrication of the recycled glass and carbon fibers that include shredding at size of 100mm and grinding at size of 50µm to form concrete composites.

2. Characterize the mechanical properties of recycled glass and carbon fibers. The properties that will be evaluated is compressive testing.

3. Analyse the morphological fractured surface of particle size of recycled glass and carbon fibers concrete composite by using SEM observation.

4. Analyse the crystalline structure and phase of recycled glass and carbon fibers concrete composite by using XRD.

1.5 Significant/Important of Study

The significant/important are detailed as follows:

1. There are some potential benefits that can be gained by composite industry after the completion of this study.

2. To gain new knowledge application of recycled of carbon and glass fiber by mechanical process for concrete composite for sustainability.

3. The cost for dumping the waste into the landfill will decrease because this research will gain some ideas to recycle of carbon and glass fiber composite in structural application.

1.6 Thesis Organization

Chapter 1 starts with the thesis arrangement. Chapter 1 is all about the history of background, problem statement, objective, scope and important of study of research. Chapter 2 will come next. Chapter 2 is the literature review of related previous study on carbon and glass fibers, waste of composite material, and also application of recycled carbon fiber and glass fiber. All these requirements are sufficient to identify recycled glass and carbon fiber by mechanical process for concrete composite.

In addition, for Chapter 3 is methodology of recycled glass and carbon fiber by mechanical process for concrete composite. In this chapter starts with mechanical recycling process of carbon fiber and glass fiber, concrete composite. Then, have testing with compressive testing. After that, the entire data collected will be analysed and discussed. Then, analysis morphology surfaces with scanning electron microscope (SEM) and analysis crystalline structure with X-ray diffraction (XRD). Lastly, the conclusion is made based from the analysis and finally concrete with recycled glass fiber and concrete with recycled carbon fiber was produced and successfully characterized from this research work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The primary objective of this literature review is to collect information from reference books, magazines, journals, technical articles and websites for the project. In this chapter, the information obtained from variety sources will be discussed in this chapter. An overview of the recycling of carbon and glass fiber composite waste for sustainability is given in this chapter. Therefore, this chapter examines the properties and application of carbon and glass fiber. Other than that, the waste of composite materials which are carbon and glass fiber are also included. In addition, the basic view of sustainability of composite material is also clarified and explained. The recycling methods of composite material are also defined in the final section.

2.2 Composite Materials

Polymer matrix composites (PMCs) are widely used in a variety of high performance and weight sensitive applications. Many novel micro- and nano-composites have resulted in developments in the production of new resins and reinforcement. In addition, new composite architecture and analytical techniques have led to expanded uses of such materials in various fields, from aerospace, industrial, sports and consumer goods industries (Q. Guo, 2020).

From G.Koller, most polymers are known to have similar properties to plastics, which take a long time to degrade, and at the end of their life, it is difficult to eliminate waste. However, a composite material called FFU was manufactured by a Japanese firm called SEKISUI. To date, turnout, open steel girder system, and tunnels over 1300km (approximately 2 million sleepers) of track are commonly implemented (Koller, 2015).

Based on Timmis, fiber reinforced composite materials, such as carbon reinforced epoxy, are widely used in aeronautical and aerospace adaptations for challenging high-stiffness applications where their low structural weight capacity contributes to improved fuel efficiency and thus to lower usage phase costs and environmental benefits (A.J. Timmis, 2015). However, in composite manufacturing, carbon fiber reinforced plastic (CFRP) is a costly material method and material costs are substantial, representing between 20% and 60% of the overall cost of production, depending on the annual volume of production (M.K.Hagnell, 2019).

2.3 Carbon Fiber

In automotive, aerospace, and wind power industries, where weight reduction is an important factor, carbon fiber reinforced plastics (CFRPs) are usually used because such advanced materials have a high specific strength, high specific rigidity, lightweight and excellent resistance to corrosion (X. Sun, 2019). According to E.Witten, the significant demand for CFRP presents serious environmental problems, despite these overwhelming advantages. Globally, in 2010 annual demand for CFRP was 51,000 tonnes and rose to 114,000 tonnes in 2017 and is projected to rise to 199,000 tonnes in 2022 (E. Witten, 2018). According to Arslan Akbar, the world's highest demand is driven by the aerospace industry, which accounts for 36% of total demand, followed by 24% of the world's automotive industry, which consists primarily of high quality carbon fibers of polyacrylonitrile (PAN) (A. Akbar, 2020).

2.3.1 Properties of Carbon Fiber

Based on Sufang Tang, currently carbon fibres, with a high strength, high modulus, high rigidity and low thermal expansion coefficient, are the only acceptable insulation for use at high temperatures up to 3000°C. At the same time a suitably-shaped mandrel can be conveniently issued, knitted, tanged or rolled in the desired configuration. Therefore at high temperatures a carbon fibre composite can be expected to attain good oxidation and removal resistance properties as a matrix, as reinforcement, and ultrahigh temperature ceramic (UHTC) or silicon carbide composites (C-SiC-UHTC) matrix. (S. Tang, 2017).

Property/material	**C**	**SiC**	**HfC**	**ZrC**	**TaC**	**HfB_2**	**ZrB_2**
Molecular weight (g/mol)	12.01	40.10	190.54	103.23	192.96	200.11	112.84
Density (g/cm^3)	2.2	3.2	12.7	6.6	14.5	11.2	6.1
Melting point (°C)	3550 (sublimation)	2700	3890	3540	3880	3380	3245
Thermal expansion (ppm/°C)	2.5 (PyC)	4.3 (6H)	6.8	7.3	6.6	6.3	5.9
Thermal conductivity (W/(m°C))	150	125	22	20	22	104	85
Specific heat (J/(g°C))	0.84	0.58	0.20	0.37	0.19	0.25	0.43
Hardness (kg/mm^2)	20	2500	2300	2700	2500	2800	2300
Young Modulus (GPa)	-	448	350-510	350-440	285-560	480	489
Poisson's ratio	-	0.168	0.18	0.191	0.24	0.21	0.16
Oxidation temperature (°C)	~450	~1200	~800	~600	~750	~800	~700

Figure 2.1: Physical and Chemical Properties of Carbon (S. Tang, 2017)

According to Yingjun Liu, due to its high thermal stability, low density, superior stiffness and strength, carbon fiber has been considered one of the most effective toughening reinforcements. The carbon fiber by fiber pull-out, fiber debonding, fiber bridging, and crack deflection can have a beneficial impact on improving the fracture toughness (Yingjun Liu, 2020). Based on Yadvinder Singh, carbon fibers are extremely rigid, durable and efficient. There are similar properties of a carbon fiber component to steel and the weight is equal to that of plastic. The strength to weight the ratio of a part of carbon fiber and perhaps even the stiffness to weight ratio, is thus substantially greater than that of plastic or steel (Yadvinder S., 2020).

2.3.2 Application of Carbon Fiber

According to Sufang Tang *et al.* (2017), studies have devoted great attention to carbon fiber reinforced carbon matrix and silicon carbide matrix composites (C/C, C/SiC) because of their outstanding high temperature strength, high fracture strength, good thermal shock and ablation resistance, as well as high durability, based on the above requirements of ultra-high temperature aerospace applications (S. Tang, 2017). Besides, stiffness driven by most automotive applications such as body panels, floor, and roof and underbody structure is where carbon fiber can have major advantages (Nitilaksha Hiremath, 2020).

In addition, according to Lefeuvre *et al.* (2017), the Boeing 787 and Airbus A350 aircraft are one of the most representative CFRP applications, with CFRP contributing up to 50% by weight. By the way, based on Guermazi, high strength, rigidity, and load bearing/weight ratio, carbon fiber reinforced polymer composites have a wide variety of uses, such as in commercial and military aircraft (N. Guermazi, 2016).

2.4 Glass Fiber

In modern structures, glass fiber (GF) reinforced composites are among the most important materials (Jolie Frketic, 2017). Based on Shahid Iqbal, glass is used as a reinforcement fiber in most polymer matrix composites. Due to its full strength, cheaper material, often not impacted by chemicals and having strong insulating properties, it is highly valued in composite manufacturing (Shahid Iqbal, 2020).

According to Y.W. Lim *et al.* (2020), glass is used as a reinforcement fiber in most polymer matrix composites. Due to its full strength, cheaper material, often not impacted by chemicals and having strong insulating properties, it is highly valued in composite manufacturing. Based on W. Wildner, a transparent glass fiber reinforced polymers (GFRPs) can be obtained by matching the glass fiber refractive index (RI) and the polymer matrix, allowing refraction and dispersion reduction at the fiber matrix interface (Wolfgang Wildner, 2018).

2.4.1 Properties of Glass Fiber

Based on Dhanaraj R. *et al.* (2020), glass fibers are used as a reinforcing agent to form a very strong composite material called glass fiber reinforcement polymer (GFRP) relatively lightweight fiber reinforced polymer (FRP), also popularly known as fiber glass, for many polymer products (Dhanaraj R., 2020). According to K. Vijaya Kumar *et al.* (2020) experiment, a readily available natural fiber (bamboo) with a synthetic fiber (E-Glass fiber) was chosen for the preparation of hybrid composite structures to carry out this work. As the matrix medium, epoxy resin was chosen. The mechanical characteristics of the chosen fibres and resins are shown in the following table (K.Vijaya Kumar, 2020).

Properties	Bamboo Fiber	E-Glass Fiber	Epoxy Resin
Young's Modulus (GPa)	35 – 46	73	3
Poisson's Ratio	0.35	0.22	0.4

Figure 2.2: Mechanical properties of fiber and matrix materials (K.Vijaya Kumar, 2020)

Samples	Tensile Strength (MPa)	Tensile Modules (GPa)	Tensile Strain
Neat Epoxy	45	1.84	2.69
Carbon/Epoxy (40:60)	425	8.66	4.95
Carbon/Epoxy (50:50)	473	11.39	4.12
Carbon/Epoxy (60:40)	550	10.62	4.97
Glass/Epoxy (40:60)	111.5	2.89	3.95
Glass/Epoxy (50:50)	122	2.99	4.69
Glass/Epoxy (60:40)	134	3.49	3.54

Figure 2.3: Mechanical Properties of Carbon and Glass Fibers Laminated Composite (Z.I Khan, 2020)

There has been documentation of chemical corrosion of glass fiber. Based on Dan Xing *et al.* (2020), the corrosion of glass fiber (GF) has been studied in sulfuric acid solutions at various temperatures and concentrations. The findings showed that with increasing temperature, the corrosion rate increased significantly, regardless of sulfuric acid concentration. This has been due to calcium sulphate precipitation on the surface of the fabric (Dan Xing, 2020).

2.4.2 Application of Glass Fiber

Glass is used as a reinforcement fiber in most polymer matrix composites. Due to its maximum strength, cheaper material, mostly not affected by chemicals and having good insulating properties, it is highly appreciated in composite manufacturing (Shahid Iqbal, 2020). Based on H.E.Khaljiri, it has many uses and has been commonly used in aircraft, aerospace, construction, items that are corrosion resistant, and marine accessories. In grid systems and multi scale composites, the glass fiber has also been used (H.E.Khaljiri, 2019). Other than that, according to A.Thiagarajan *et al.* (2020), reinforced composites of glass fiber are currently under substantial and rapid improvement and are commonly used in automobile, aerospace, marine, and structural applications because of light weight and high strength (A.Thiagarajan, 2020).

2.5 Waste and Sustainability of Composite Material

Based on H.Nguyen *et al.* (2016), CFRP waste with a length of 3mm-6mm and a quantity of 2-3 percent weightage as reinforcement material for composite material has been investigated and huge changes in compressive strength and flexural bending strength of 5-13 percent and 12-20 percent have been recorded, together with improved fracture resistance (H. Nguyen, 2016).

According to N.Vijay *et al.* (2016), despite understanding the dangerous nature of the composite material ingredients, composite waste is often disposed of by combustion. The method of disposal produces harmful contaminants that can influence the living body as well as the environment. A great percentage of dangerous chemicals that are oxidised to particles produced during material combustion (N.Vijay, 2016). Even though in the face of the increasing amount of CFRP waste, the waste management of these materials is underequipped with regard to both technological and regulatory problems (A. Vo Dong, 2019). The most prevalent end routes for the end of life fiber reinforcement polymer (FRP) goods and scrap material have so far been land filling and decomposition.

Based on S. Kaewunruen, sustainability is a comprehensive term in the state of equilibrium that contains economic, social and environment variables. In addition, it is a complex idea that is difficult to explain in a short statement and in the figure below demonstrates the connection between social, economic and environmental influences, all of which are viewed from the perspective of sustainability (S. Kaewunruen, 2020).

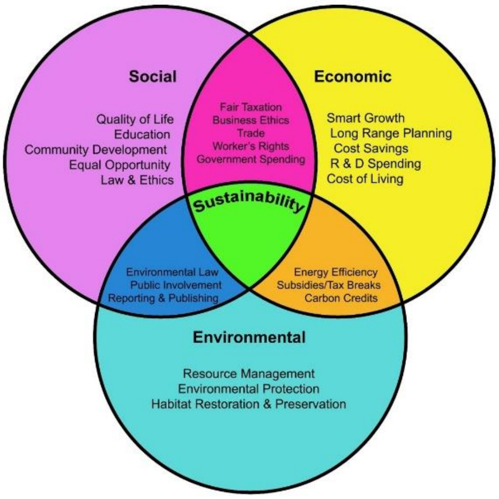

Figure 2.4: Sustainability of Composite Material

For many manufacturers, the sustainability of materials plays an important part. This point is one of the main points in the selection process, because it includes reliability and long term use. According to Maria Cristina *et al.* (2016), increased productivity and uses also lead to an increasing quantity of GFRP waste, end of life products (EOL) or production refuses, taking into account all advantages of more conventional materials from GFRP related products (Maria Cristina S. R., 2016).

2.6 Recycling of Composite Material

Recycling is the mechanism of recycling or refinement of waste materials into useful materials (J. Bowyer, 2015). Based on S. Kaewunruen *et al.* (2020), the recycling process seeks to increase the use value and lifespan of materials, yet at the same time reducing the environmental problems of waste material recycling. According to Lefeuvre A *et al.* (2017), a significant share of this is contributed by the aircraft and wind power industries. An approximate value of 23,360 tonnes per year EoL CFRP would be generated through the aviation sector if it is kept unrecycled by 2035. The combined quantities from the following countries worldwide are also expected to be eligible for recycling by 2050 due to advances in modern aviation: Asia will be 102,500 tonnes (Lefeuvre A, 2017).

According to F. Barnes stated that the word recycling describes the recycling and the remanufacture of parts from waste composites in usable components (Barnes, 2015). It then becomes more interesting to establish recyclable composites and methods for recycling them. Reclaimed carbon fibre (rCF) may be a fraction of virgin CF cost (vCF) and will lead to a decrease in the cost of the corresponding rCFRP.

Besides, the development of a two-phase recyclable technique (recovery and reconstruction), as illustrated in Figure 2. Based on J. Hazell, a method can be called closed-loop if no more materials are needed to spread until all the initiator material is applied. Composite production and recycling closing loop processes are in line with the theory of circular economics proposed by the Ellen MacArthur Foundation, and are endorsed by the UK Composite Strategy (2016) for new products (Hazell, 2017).

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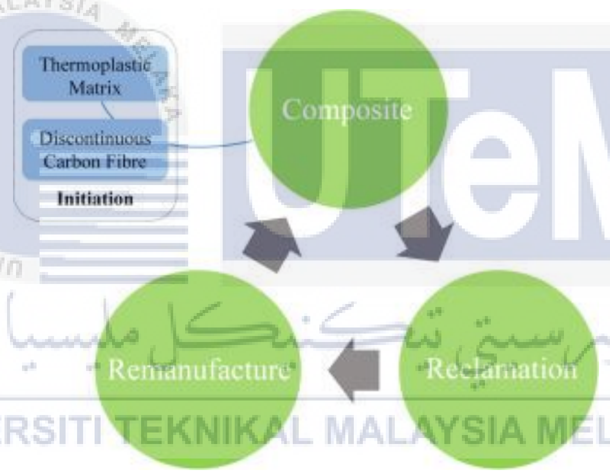

Figure 2.5: The technique of the closed loop in short; no further propagation material is needed after initiation of the cycle

Based on L. Zhang *et al.* (2018), during the process of sizing production, transport and manual handling a large amount of chunks and scrap waste composite panels were produced. The composite chunks have been incinerated or disposed of in a waste disposal in recent years as a thermosets material, resulting in a substantial amount of toxic gas and environmental contamination (L. Zhang, 2018). From experiment D.Simon *et al.* (2015), the system of recycling could essentially be divided into two groups with economic development: one mechanical grinding to minimise particle size in fillers, or components of composites. Besides, one was the thermal processing to break down the crushed aggregates into lower molecular organic (liquids and gases), which could be used as a raw material. Pyrolysis was nevertheless usually more difficult and required more treatment in order to purify and refinish the organic mixtures in successive processes, which were apparently relatively complex and likely to result in expensive finished goods (D. Simón, 2015).

2.7 Mechanical Recycling

Based on X.Li *et al.* (2016), the mechanical recycling of CFRP waste, that has been documented in many studies includes reducing the size and processing of fibers and powder recycling for reuse (X.Li, 2016). Although the mechanical method of recycling is capable both CFRP and GFRP, GFRP is the subject of most study (K.Wong, 2017). The approach is to use a main smash to transform the scrap components into useful pieces.

According to Pakdel *et al.* (2020), the mechanical approach is based primarily on the operation of grinding, moulding and milling the CFRCs into small bits or further ground into powders. While these techniques of recycling may be effective in minimising greenhouse gases pollution, utilising electricity and depleting capital, their financial feasibility is closely linked to the expense of the used energy and the valuation of the materials collected (Pakdel, 2020).

According to Vincent *et al.* (2019) experiment, equipment like shredding several shaft and cutting mills was used for this. The shaft shredding creates huge uniform elements, which are regulated by the gap between both the blades, the size of the sheet underneath and its speed of rotation (G.A. Vincent, 2019). When composite flocks are developed and metal components are discarded, the shredded components will then be mounted to powder which is then transformed into a composite.

2.8 Application for Recycled of Carbon Fiber and Glass Fiber

According to B. Ali *et al.* (2020), in the building industry, various kinds of fibers are commonly applied, depending on the type of substrate such as poly-propylene, steel, glass, carbon, basalt, etc., on scale such as macro and micro, and on the form (hooked, straight, ribbed), they have been widely used (B. Ali L. Q., 2020). In addition to the fiber beneficial impact on the mechanical efficiency of concrete, some of the resilience properties of the concrete greatly increase, including the tolerance against freezing hawing cycles and drying shrinkage.

Besides, improving the consistency of mix of fibers is the primary explanation for increased longevity. 3-dimensional strengthening avoids massive shifts in the concrete in drying shrinkage and freeze-thaw processes and prevents structural degradation (improved dimensional stability). Blocks that are fiber-reinforced have high longevity in hostile conditions for example, acidic mediums that allow binder matrix to be decalcified, and fibers keep the concrete in certain environments from being degraded suddenly (M. Koushkbaghi, 2019).

Mechanical strength of recycled aggregate concrete (RAC) is equal to that of a natural aggregate concrete (NAC). To address the poor efficiency of RAC, fly ash (FA) provides good opportunities to be used as mineral admissions due to its worldwide abundance at lower prices, using mineral or chemical admixtures (B. Ali L. Q., 2020). In different civil engineering schemes recycled aggregates from building and demolition waste can be deployed, which will lead to a long way in the country's economic and environmental sustainability. Recycled the aggregate concrete, the waste settlement and the use of naturally occurring aggregates have been focused on (Y. Jiang, 2019).

Based on Y. Wang *et al.* (2019), applications of recycled aggregate concrete containing broken bricks are seldom analysed on the grounds of these weak properties. In order to further facilitate its practical use on a broader scale in civil engineering projects the efficiency of recycled aggregate concrete using waste brick should be enhanced. Attempts have been made to enhance the mechanical properties and resilience of recycled concrete and the use of fiber as an efficient tool have been established. (Y. Wang, 2019)

This chapter have gathered all related information for this research. That information are some related theory and guidelines to mechanical recycling process of carbon fiber and glass fiber in concrete composite. From the comprehensive analysis, it was found that the recycling of composite materials for sustainability is competitively developed through this novel application that the analysis is focused. There are many researches from other countries are discuss about the recycling of carbon and glass fiber composite waste for sustainability. However, from the extensive review, it was clearly know that in Malaysia less focused on recycling of carbon and glass fiber composite waste for sustainability especially at the industrial area.

CHAPTER 3

METHODOLOGY

3.1 An Overview of Methodology

This chapter was clearly described the process flow of the research. The methodology of this research was included the principal of the method that was carried out to complete the research. The method that was discussed are mechanical recycling method as well as related experimental testing. The American Society for Testing and Materials (ASTM) Standard was closely referred as a guideline in performing the entire test. In addition, Standard Operation Procedure (SOP) for mechanical method was followed accordingly.

A flowchart was seen in Figure 3.1 summarising the complete flow of this study. Basically, there were three (3) major phases were involved in this study. The research was started with composite recycling materials. Later, the mechanical recycling method is used to reduce the size. Then the reduce carbon fiber and glass fiber is incorporate in concrete to produce the concrete composite. All the testing was done based to the ASTM standard and specific SOP of the testing machine.

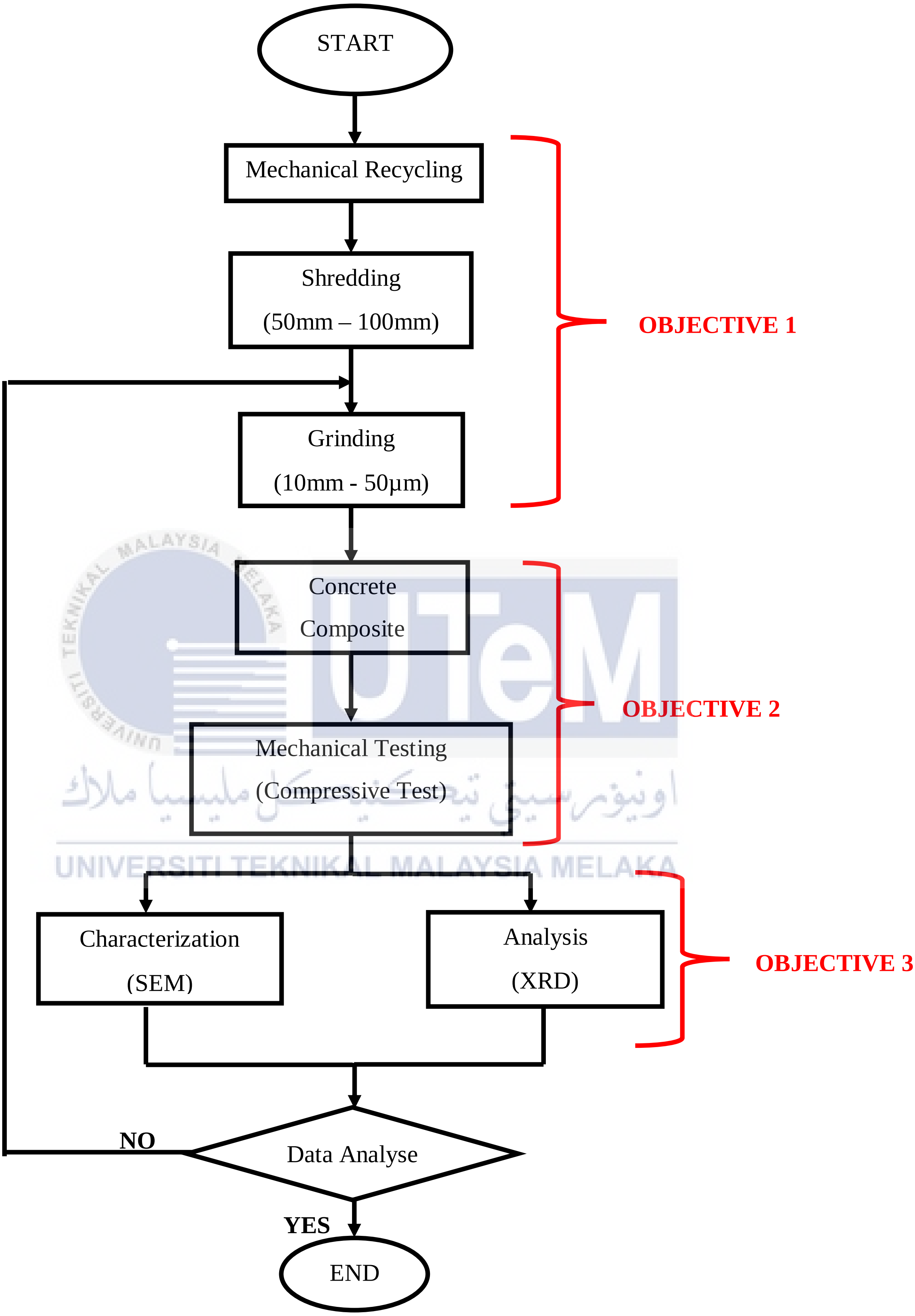

Figure 3.1: Flowchart of Methodology

For mechanical recycling, the filler particles consist of the fine granulation of all materials as the filling and fibrous particle, which could be reinforced by retained fiber thickness. In addition, the carbon fiber and glass fiber incorporate in concrete to produce concrete composite. Then, for mechanical testing, it consist of the compressive test. This testing is to test the stiffness of the concrete composite between concrete with carbon fiber and concrete with glass fiber. Next, the composite surface morphological observation through the scanning electron microscope (SEM) and analysis of X-Ray Diffraction (XRD). Toward the end, extra careful evaluation on all the experimental results with the extensive scientific discussion that lead into the conclusive statement was clearly justified.

3.2 Mechanical Recycling

In this study, for mechanical method, there was mechanical grinding method tested. The following parts were detailed out the method was used in mechanical recycling. The method used in this research is basically based from the previous work done by prior researchers and also some of it was invented and suggested from this study.

3.2.1 Grinding

Mechanical grinding involves breaking up composite scrap parts to make approximately different percentages of fibre and resin. Grinding is used to complete parts that need to display high surface consistency and high form and dimensional precision. The recycled glass fiber and recycled carbon fiber reinforced composites were tested for mechanical grinding. Figure 3.2 shows recycled carbon fiber and Figure 3.3 shows recycled glass fiber used in this research. In the mechanical grinding, there were two key steps identified, as shown in Table 3.1.

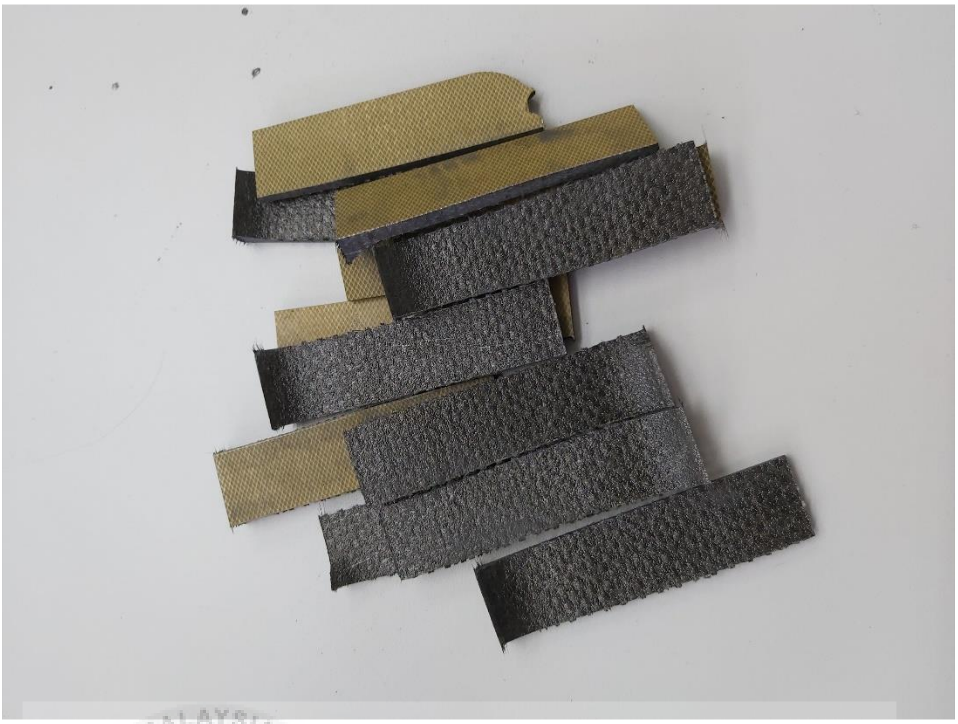

Figure 3.2: Recycled Carbon Fiber

Figure 3.3: Recycled Glass Fiber

Table 3.1: The Method of Mechanical Recycling (E.Pakdel, 2021)

	Particle Size	Process	Equipment
Shredding	50 – 100 mm	Reduce the waste materials into small pieces	Slow speed cutting or crushing mill
Grinding	10 mm – 50 µm	Grind the pieces into fragments	High speed cutting or hammer mill

The first step is shredded the recycled glass fiber and recycled carbon fiber composite material to 50 – 100 mm in small pieces using shredding machine as shows in Figure 3.4. This allows the replacement of metal inserts and facilities transport as used at the waste site. The size of waste fragment should be reduced to less than 100 mm utilizing low-speed crusher mills for successful mechanical processing of thermosetting polymer composites. At this step the metal pieces and other contaminants can be separated. The pieces of a high-speed hammer mill are further reduced by impact and shaving activities (R. Francis, 2017).

Figure 3.4: Shredding Machine

As shown in Figure 3.5 and Figure 3.6, the recycled carbon and glass fibers after shredding process in 100mm sizes. When mixed the recycled carbon fibers and recycled glass fibers with the sand, water and cement. The surface were rough and the recycled fibers are floating on the surface and did not well mixed with concrete when recycled fibers are in millimetre sizes as shown in Figure 3.7.

Then, using a grinding machine as shows in Figure 3.8, the pieces are then broken down into 10mm – 50 µm pieces. The result of this procedure is around < 50 µm in size. These may be divided into different sizes by the sieving process, creating pieces that are rich in resin and fiber. However, reuse applications are restricted and the market for these items is not presently developed. One potential application may be to fill composites, cement, asphalt or coatings, typically thought to be an economic down cycle. (E.Pakdel, 2021)

Figure 3.5: Recycled carbon fiber after shredding process

Figure 3.6: Recycled glass fiber after shredding process

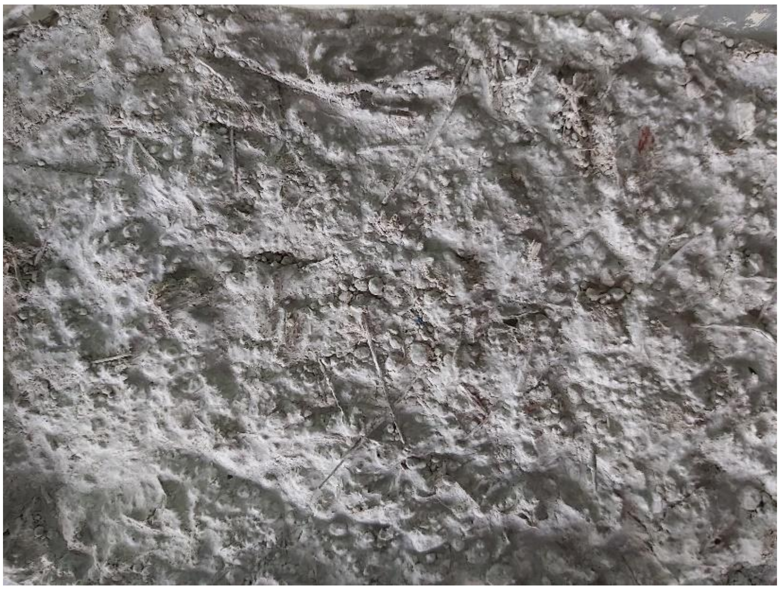

Figure 3.7: Concrete with recycled fibers in 100mm

Figure 3.8: Grinding Machine

3.3 Formation of Concrete Composite

In this study, for concrete preparation, there were 5 ingredients mixed together to form a concrete composite. The ingredients were Portland cement, sand, water, recycled carbon fiber and recycled glass fiber. In the presence of water, Portland cement chemistry comes to life. Cement and water are a mixture that replaces every piece of stone and sand that were aggregates. The cement paste is hardened by a chemical reaction called hydration and retains strength.

In addition, in this study also used concrete in comparison to cement weight, which incorporated 8% of recycled carbon fiber and 8% of glass fiber which was compared to cement mass percentage (%). This is because this was the proportion of the mechanical properties that facilitated the greatest improvement. The carbon fiber and glass fiber wastes which were produced from mechanical recycling after grinding process.

First of all prepare 3 containers to produce normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber. For normal concrete mixed water, cement and sand with the ratio of 1:2:3. Based from University of Illinois, the volume proportions of a simple concrete mixtures can be used of 1 water: 2 cement: 3 sand. The blend is not too stiffened or overwhelming. Good test specimens are hard to create if they are excessively rigid. Water might separate from the mix if it is too sloppy. Remember the main component is water. There is a weak concrete result in too much water. Too little water leads to unusable concrete (UIUC, 2020).

Besides, for concrete with carbon fiber and glass fiber mixed water, cement and sand with the same ratio of 1:2:3 and add 8% of carbon fiber and glass fiber. According A.C. Meira Castro *et al*, increasing the bending and compression strength of the resulting PMs (polymer mortars), whatever the grade of the GRF waste, is the partial substitution of sand add-ons with GFRP (glass fiber reinforced polymer) waste materials, which can be up to 8% in total weight content. An increase in GFRP recycled material is leading to a decreased mechanical characteristics of compound PMs and loading capacity tends to decline below that of unmodified PMs over 12% waste content. The effects of GFRP waste content are more evident in compression than bending, with 8% and 4% of waste content at turning points in the conduct trends of both materials. With an increased amount of GFRP recycled material, the compressive loading capacity of PMs rises by up to 8%. Average compressive force gains of 12.1% and 16.4% respectively, equivalent to an additional 4% and 8% of GFRP waste in weight in respect of unaltered PMs were found. More than 8% content in waste addition, flexural and compressive reactions decrease in PM formulations with reduced GFRP waste content (average drops of 1.8% and 4.3% in compressive and bending strength for GFRP waste over unmodified PMs for 12% content in waste supplements) (A.C. Meira Castro, 2013). So that, selected 8% of recycled glass fibers and recycled carbon fibers in relationship to cement mass compare to 4% and 12%. Then, 8% of carbon fibers and glass fibers in relationship to cement mass was added, as shown in Table 3.2.

Table 3.2: The formation of concrete composite

Concrete	**Water (g)**	**Cement (g)**	**Sand (g)**	**Glass fiber waste (Cement mass %)**	**Carbon fiber waste (Cement mass %)**
	250	500	750	8.00	8.00
Ratio	1	2	3		

Initially, measured the empty container and took the reading mass of empty container because to avoid reading measure of water, cement and sand from the ratio. First of all, begun to make normal concrete which mixed with water, cement and sand with mass ratio from table 3.2, which was 250g of water, 500g of cement and 750g of sand. Then, pour the normal concrete into a mould of shape cylinder which measuring at diameter of 100mm and height of 150mm to keep the concrete in place until it has been set and pushed it so that it filled the space.

Besides, for concrete with recycled glass fiber, mixed 250g of water, 500g of cement, 750g of sand and 40g of recycled glass fiber which it was grinded in micro size. Then, pour the concrete with recycled glass fiber into a mould of shape cylinder which measuring at diameter of 100mm and height of 150mm to keep the concrete in placed until it has been set and pushed it so that it filled the space. Lastly, repeated the same steps for concrete with recycled carbon fiber.

The word cure is used to characterise concrete chemical hardening. Only when the concrete is kept humid and the temperature checked will it be completely achieved. Usually enough water is applied for the mix to curing, as long as no water is lost during a drying period and the mixture's temperature cannot increase too high. As soon as the concrete is hardens and lasts for at least seven days, cure should be begun. So that, the concrete protected by leaving the shuttering in a place for two weeks.

3.4 Mechanical Testing of Concrete Composites

There was one mechanical testing that was carried out in this research, which was compressive testing. The experiment undertaken in this analysis adhere to the ASTM requirements as set out in Table 3.3.

Table 3.3: ASTM standard of mechanical testing

Testing	**Standard**
Compressive Testing	ASTM C39

3.4.1 Compressive Testing

The compressive strength of concrete decides whether the concrete in a building may carry the weight of what is above it or if it splits into one million pieces and collapses the building. In order to create cylindrical samples of the same concrete that is poured, it is very crucial for engineers how strong concrete is and therefore construction materials testers deploy the field experts to different building plants. In this research, the sample made in a cylinder shape at diameter of 100mm and height of 150mm according to ASTM C39 standard. Figure 3.9 shows the compressive testing machine, which maximum stress at 100kN.

Figure 3.9: Compressive Testing Machine

For the testing, take the cylinders out of the moisture chamber and cover them with wet moisture to maintain moisture. Check the cylinders for faults (hole, crack, and crumbliness), use your right edge and nail to check for fluidity, and put the ones with ends that are not flat to be cut off. Then, measure each cylinder diameter twice at 90 degree angles in the middle of each cylinder. Ensure you have a clean and debris-free bearing area on your machine and verify the cleanliness of your neoprene caps if you use unbonded caps.

After that, put on your cylinder ends neoprene caps and verify that the caps fit correctly and are plane and level. Set the specimen on the lower bearing block to center with the rings on the bottom block of the higher bearing block. The cylinders may now be loaded. The suggested rate of around 4-5 kN / second is permitted to be increased.

Do not interfere with the rate of load following the midway point as the cylinder approaches the peak load. The cylinder hits a peak and falls down. The weight can begin to climb again if somewhat lowering, so let go until the weight decreases constantly, and there are visible proofs of a fracture pattern forming, and then turn the lever away. Lastly, remove the cylinder and remove the caps then from the machine. Carry it over and remove the wrap, allowing the pieces to fall into the wheelbarrow. Determine the fracture type and then enter the load and fracture type.

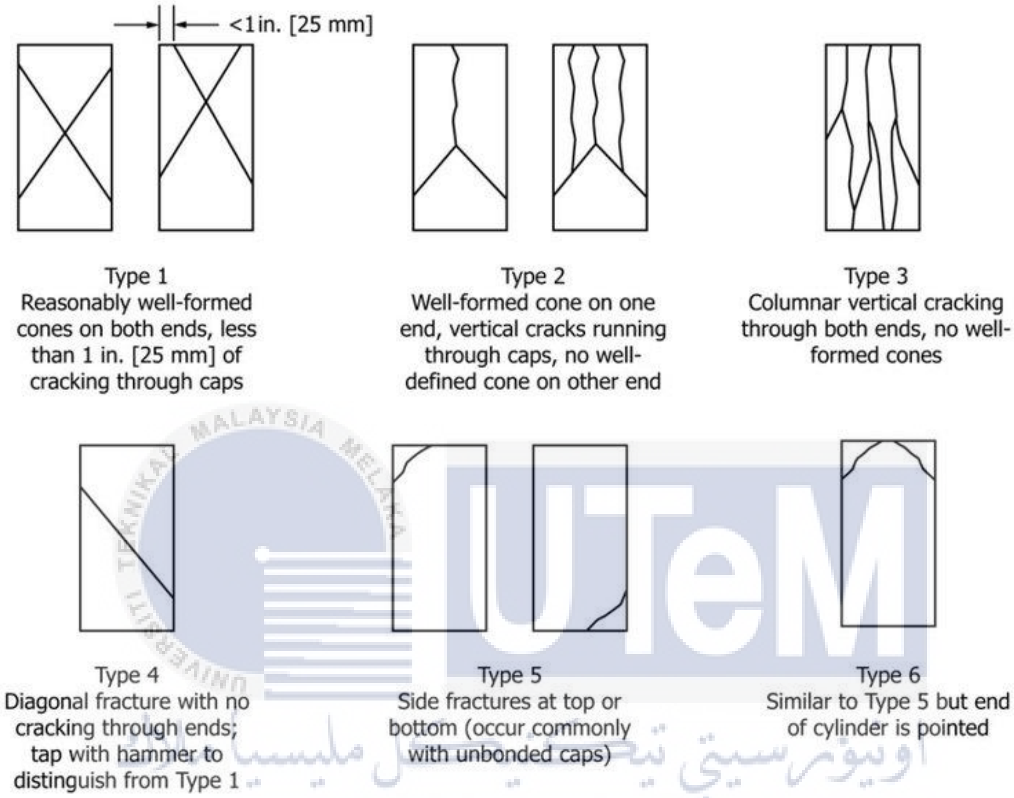

Figure 3.10: Cylinder fracture types

3.5 Characterization using SEM

Scanning electron microscope (SEM) is typically used to analyse fiber-concrete interface morphological surface characteristic by mechanical samples testing. By using SEM, can be observed the surface of concrete with carbon fibers and concrete with glass fibers. The fractured surface were cut and mounted on the stub with carbon tape before being gold coated to eliminate the charging and to protect the samples from electron damage during the observation. Furthermore, by using SEM, the surface failure can be observed and was further analysed.

3.6 Analysis of X-Ray Diffraction (XRD)

The normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber were examined with the XRD technique, which is the morphological structure. XRD operates through the x-ray radiation of a material and measures the intensities and dispersion angles of the x-rays which leave the substance. It was carried out using the Pan Analytical Diffract Meter, which worked at 40kV and 30mA with Cu K5-007 radiation (5-007 = 0.154 nm). Scans were carried out in the range of 10° - 90° at a scan rate of 0.50° per second with a continuous scan phase size of 0.0170. A thin layer of composite film or sample will be analysed for normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber as it are. Figure 3.11 below shows the X-Ray diffraction (XRD) test unit used in this analysis.

Figure 3.11: X-Ray Diffraction (XRD) Machine

CHAPTER 4

RESULT AND DISCUSSION

4.1 An Overview of Result and Discussion

This chapter will present the experimental results obtained in this research work. This chapter mainly explained the data collected after completed the sample and mechanical testing experiment. All the hypothesis and statement given were supported by the previous similar research with further justification and consideration after careful observation. The visual observation of the normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber after formation was discussed. Furthermore, the mechanical testing of compressive test was discussed and fracture types were determined after compressive test. Finally, the morphological surface of the normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber were observed under the Scanning Electron Microscope (SEM) observation and the crystal structure of the synthesized nanoparticles was determined by the X-Ray diffraction (XRD).

4.2 Visual Observation

Due to the grinding process which were conducted to recycled glass fiber and recycled carbon fiber to change it in to microscale sized, this is because it can easily combined with the water, cement and sand to make concrete. Figure 4.1 and figure 4.2 showed the recycled glass fiber and recycled carbon fiber in microscale sizes after the grinding process. Besides, after the grinding process, the recycled glass fiber and recycled carbon fiber in microscale sized mixed together with water, cement and sand to make the concrete.

Figure 4.1: Microscale of recycled glass fiber

Figure 4.2: Microscale of recycled carbon fiber

Figure 4.3, Figure 4.4 and Figure 4.5 below showed the normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber successfully formed in good surfaces and good condition. Based on the observations, the three samples had a diameter of 100mm and height of 150mm but the surface of normal concrete had a good surfaces while the surface of concrete with recycled glass fiber and concrete with recycled carbon fiber had a slightly pore on the surfaces. This is because due to do not pressed correctly the concrete in the mould to make it smooth surfaces. Higher adherence and strength are achieved by the rough surface between the cement paste and the aggregates, and better concrete functionality during casting is achieved by a smooth area (K.Ninčević, 2019).

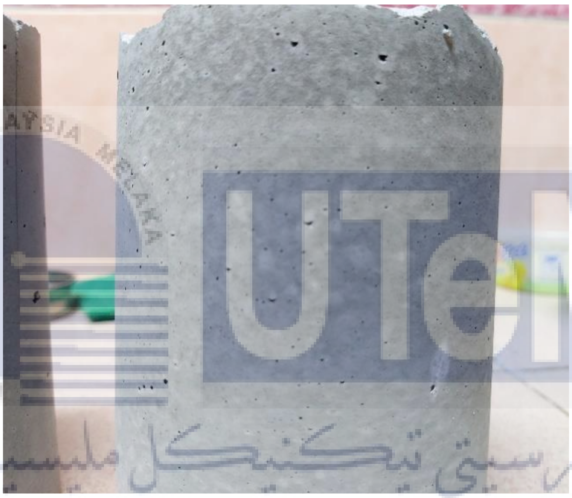

Figure 4.3: Normal Concrete

Figure 4.4: Concrete with Recycled Glass Fiber

Figure 4.5: Concrete with Recycled Carbon Fiber

4.3 Evaluation on Compressive Properties of Normal Concrete, Concrete with Recycled Glass Fiber and Concrete with Recycled Carbon Fiber

Compressive test is used to examine the mechanical strength properties of produced concrete composites. There are two (2) important responses were highlighted for the compressive properties evaluation, which are the ultimate tensile strength and tensile modulus. The result of the compressive test were directly inter-related with the interfacial bonding established between the concrete and the recycled glass fiber or recycled carbon fiber composites.

4.3.1 Analysis of the compressive properties

The purposes of compressive testing to evaluate the interaction between the concrete and the recycled glass fiber or recycled carbon fiber composites. From the testing, the ultimate tensile strength and Young's modulus of the normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber can be measured. Figure 4.6,

Figure 4.7, and Figure 4.8 shows the stress versus strain of normal concrete, concrete with recycled carbon fiber and concrete with recycled glass fiber. From the graphs stress versus strain, the ultimate tensile strength and Young's modulus of each concrete calculated.

The ultimate tensile strength is it shows the maximum amount of stress a material can bear before failure. The ultimate tensile strength for normal concrete is about 8.20 MPa while the ultimate tensile strength for concrete with recycled carbon fiber is about 4.62 MPa. Besides, the ultimate tensile strength for concrete with recycled glass fiber is about 9.06 MPa. The largest increase of ultimate tensile strength is about 10.49% at concrete with recycled glass fiber addition compared with normal concrete. It has been found that a greater adhesion between the concrete and the recycled glass fiber. In addition, the nanoscale size of recycled glass fiber had good bonding with concrete when a stress is being applied. Hence, the tensile modulus and strength are greatly improved due to this beneficial interaction (Z.I Khan, 2020). Furthermore, there is a sharp decreased in the ultimate tensile strength when normal concrete compared with normal concrete with carbon fiber, which is about 56.34%. This is because the nanoscale size recycled carbon fiber did not had a good bonding with concrete. Even though, carbon fiber had high thermal stability, low density, superior stiffness and strength, and had been considered one of the most effective toughening reinforcements but it is cannot bonding with concrete well (Yingjun Liu, 2020).

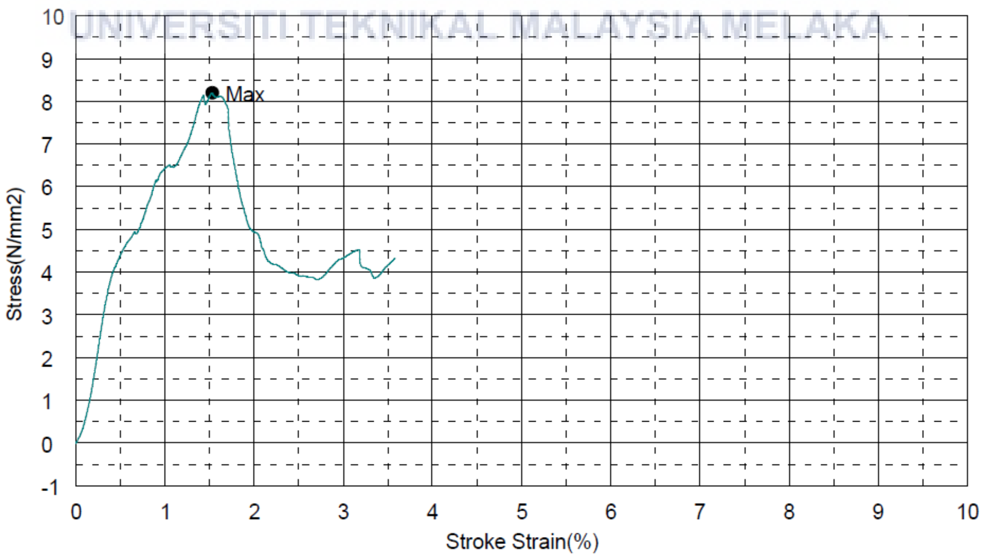

Figure 4.6: Stress-Strain Curve of Normal Concrete

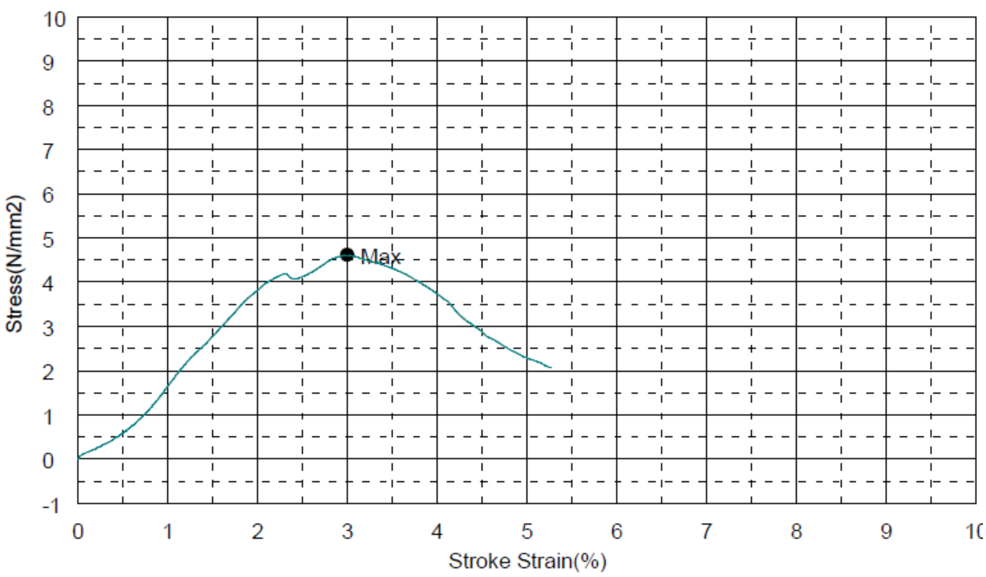

Figure 4.7: Stress-Strain Curve of Concrete with Recycled Carbon Fiber

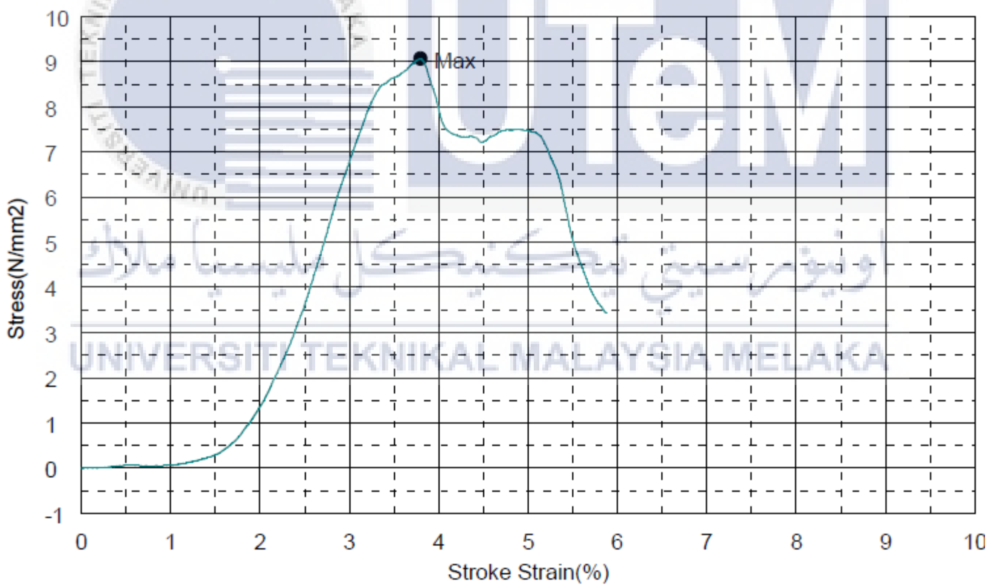

Figure 4.8: Stress-Strain Curve of Concrete with Recycled Glass Fiber

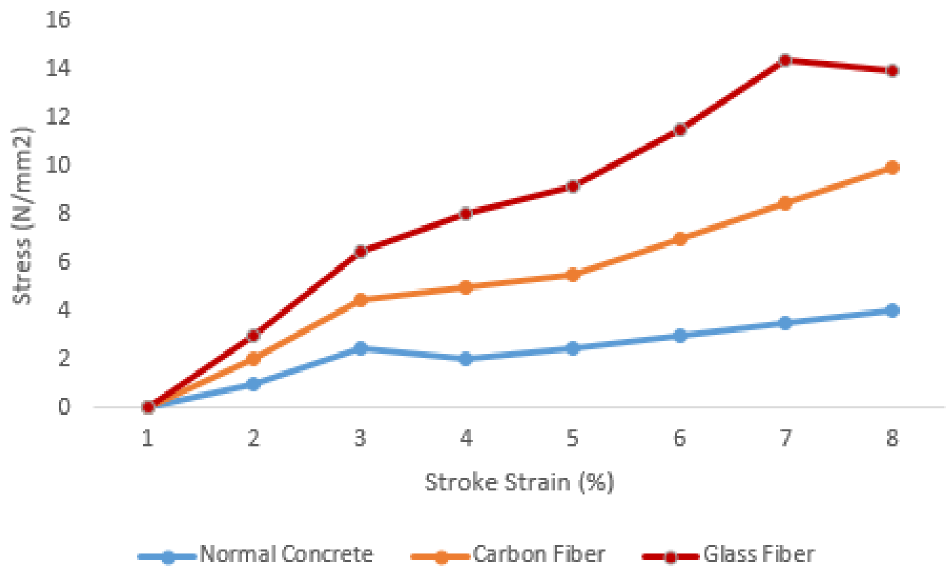

Figure 4.9: Stress-Strain Curve between Concrete Composites

The Young's modulus of an engineering materials reacts to the rigidity of the samples generated. The higher the Young's modulus, the samples are tightened and the greater the strength resulting. Therefore, the Young's modulus is linked to the strength of the sample. The Young's modulus for normal concrete about 4.50MPa. The addition of concrete with recycled glass fiber results an increased in the Young's modulus, before decreased afterwards with addition of concrete with recycled carbon fiber. The trend was similar with the ultimate tensile strength attribute. The highest Young's modulus was found at about 6.92 MPa which belongs to the concrete with glass fiber. The favourable improvement value was increased at about 53.78% compared than the normal concrete. This is because the present of silica in recycled glass fiber very strong bonding with the silicon dioxide which was present in the concrete. The lowest Young's modulus was detected from the sample concrete with carbon fiber which is 3.80MPa. There are almost 15.56% reduction as compared to the normal concrete. The properties dropped might due to the improper bonding with the concrete. In addition, carbon atom in recycled carbon fiber did not adhesives with the silicon dioxide in the concrete. However, these fibre agglomerates not only impair the working ability of the concrete mixture and make it hard to vibrate, but also create stress concentration after hardening when it is exposed to stress, forms a weak spot in the concrete matrix and reduces concrete strength (S.Lu, 2021).

4.3.2 Analysis Cylinder Fracture Type

After done the compressive test, analysed and recorded the cylinder fracture type. This is because to know the concrete was formed strong or not. From Figure 4.9 shows the fracture of normal concrete after compressive test. For normal concrete it shows type 2 which is well formed cone on one end. There are some vertical cracks running through caps and no well-defined cone on other end. Besides, Figure 4.10 shows the fracture of concrete with recycled glass fiber after compressive test. Fracture type for concrete with recycled glass fiber shows type 1. The concrete with recycled glass fiber is reasonably well formed cones on both ends. There is less than 25mm of cracking through caps. In addition, Figure 4.11 shows the fracture of concrete with recycled carbon fiber after compressive test. For concrete with recycled carbon fiber shows fracture type 5. This type defines side fractures at top because it occur commonly with unbonded caps.

Figure 4.10: Fracture of Normal Concrete

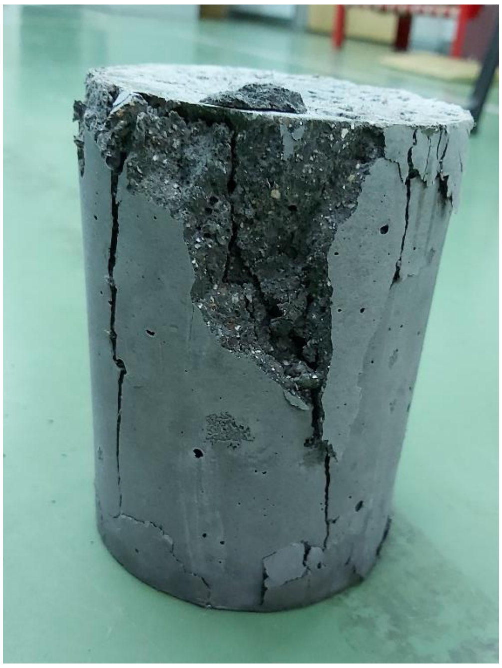

Figure 4.11: Fracture of Concrete with Recycled Glass Fiber

Figure 4.12: Fracture of Concrete with Recycled Carbon Fiber

4.4 Analysis of Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy (SEM) will study the morphology of normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber. In scanning electrons Model JSM-7100 F, the morphological characteristics of the produced nanoparticles were analysed. Micrograph at Figure 4.12, Figure 4.13 and Figure 4.14 shows the bonding surface of the fractured samples with normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber. According to W.Wilson *et al.*, a qualitative description of the microstructure of the pastes is provided by the examination of polished concrete surfaces under the optical and scanning electron microscopes (W.Wilson, 2017).

Figure 4.12 shows the micrograph of normal concrete sample. From the micrograph, it was clearly shown that there were not any foreign objects present in the mixture. In the normal concrete only had mixed with water, cement and sand. Besides, it was poor and not strong enough between interfaces within them. The weak interface was resulting lower strength of the concrete. Other than that, there are some poor bonding which that becoming a weak point when applied a stress. The tension of the normal concrete is quite weak and its compressive strength in most situations is less than 12%. It therefore readily fractures under tensile pressures and provides extremely poor bending or tensile strength resistance (H.Iqrar, 2020).

Micrograph Figure 4.13 shows that the concrete with recycled glass fiber. This proves that the present of $Ca_3Si_2O_7$ in concrete and the recycled glass fiber interface are stronger which promoting a better resulted strength. Other than that, a good dispersion of recycled glass fiber in concrete was found which tends to give high strength and good bonding. In addition, the present of $Ca_3Si_2O_7$ in concrete and also the present of silicon dioxide (SiO_2) in glass fiber give them strong strength composites. Similarly, the compression strength and bending strength of glass fibers were increased by 3-7% and 25-28% correspondingly (B. Ali L. Q., 2019).

Figure 4.14 shows the concrete with recycled carbon fiber. This figure proves that the present of $Ca_3Si_2O_7$ in concrete and the recycled carbon fiber interface are not strong enough. This totally reduced the strength of produced composites of concrete with recycled carbon fiber. According to Khaleel *et al.* (2021), he highlighted that most research showed that increased carbon content leads to lower compressive strength, due to the functionality of the mixtures which are not effectively performed and create more empty spaces (O.R.Khaleel, 2021).

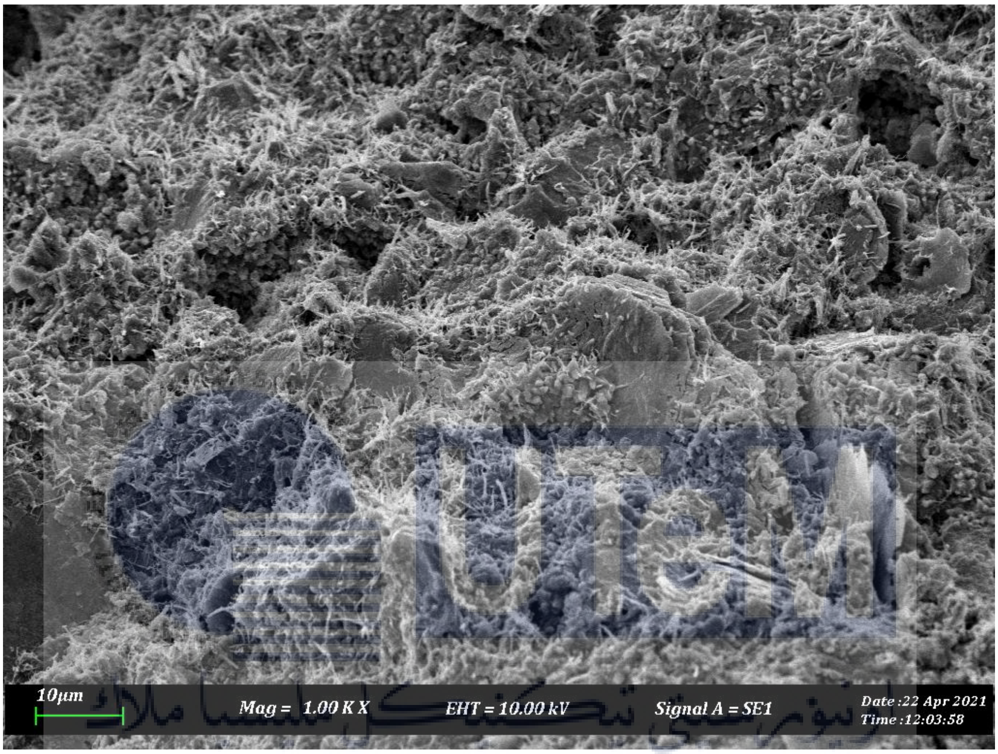

Figure 4.13: Micrograph of Normal Concrete

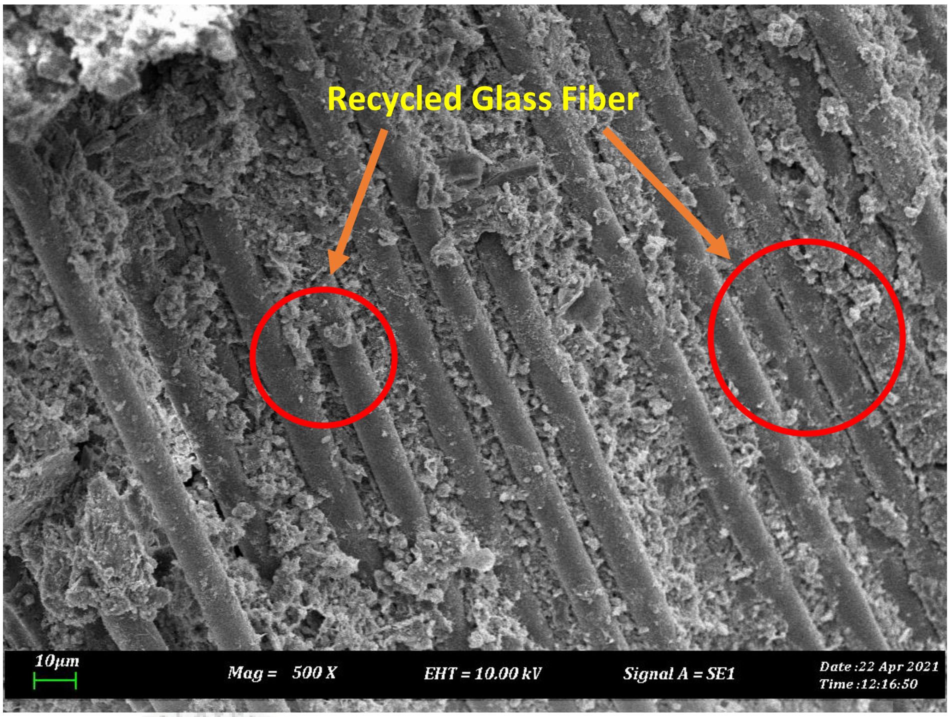

Figure 4.14: Micrograph of Concrete with Recycled Glass Fiber

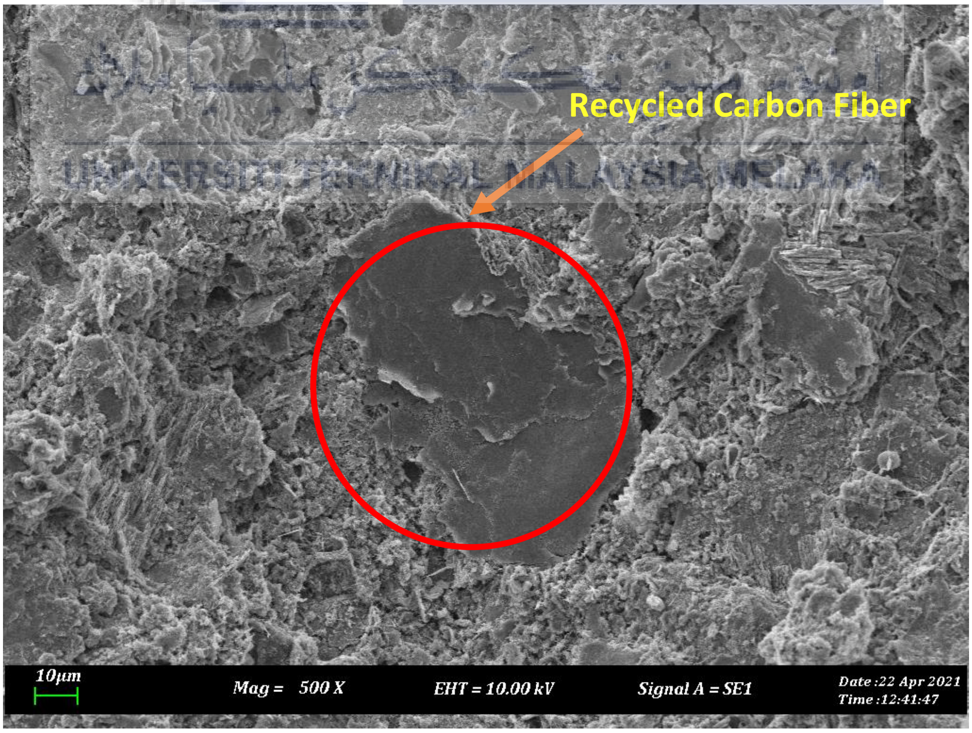

Figure 4.15: Micrograph of Concrete with Recycled Carbon Fiber

4.5 Analysis of X-Ray Diffraction (XRD)

X-Ray diffraction analysis (XRD) will determine the crystallographic structure of a normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber. The peaks were recorded in the 2θ start position from 10 to end position 90. It using copper as anode material, 40kV, 30mA and at a scanning speed of 4°/min.

Based on M. Parisatto *et al,* in line with the XRD composition analysis, the initial hydration, the cement components $3CaOSiO_2$ (C_3S: alite), $2CaOSiO_2$ (C_2S: belite) and CaO are highly reactive anhydrate compounds, and thus, the hydrates and calcium hydroxide develop as follows when they react with water:

$$2Ca_3SiO_5+6H_2O \rightarrow Ca_3Si_2O_7 \cdot 3H_2O+3Ca(OH)_2$$

$$2Ca_2SiO_4+4H_2O \rightarrow Ca_3Si_2O_7 \cdot 3H_2O+Ca(OH)_2$$

$$CaO+H_2O \rightarrow Ca(OH)_2$$

Figure 4.15 shows the XRD spectrum of normal concrete. For normal concrete, the crystalline structure at the near to 47.45°. In normal concrete, $Ca_3Si_2O_7$ present in concrete were little. So that, it was not strong bond enough interfaces between them. Besides, Figure 4.16 shows the XRD spectrum of concrete with recycled carbon fiber. XRD patterns of $Ca_3Si_2O_7$ had two peaks at 2θ = 36.12° and 47.63° due to 2 degree plane. In concrete with recycled carbon fiber, there were a few present of $Ca_3Si_2O_7$. So that is why carbon atom in recycled carbon fiber did not adhesives with the $Ca_3Si_2O_7$ in the concrete.

In addition, Figure 4.17 shows the XRD spectrum of concrete with recycled glass fiber. It produced many peaks which was located at 28.93°, 39.46°, 48.55°, 57.34°, 65.65° and 83.67°. This proved that the present of $Ca_3Si_2O_7$ in concrete with recycled glass fiber. In such way, the bonding between $Ca_3Si_2O_7$ and the present of SiO_2 in recycled glass fiber and concrete were strong and therefore it had a strong strength.

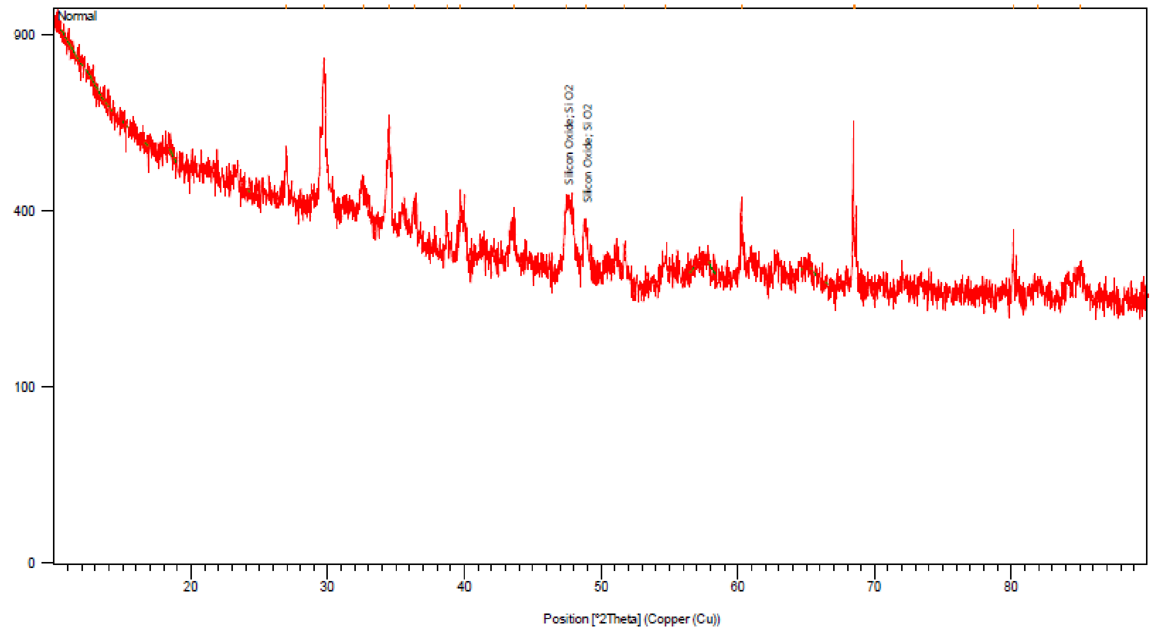

Figure 4.16: XRD Spectrum of Normal Concrete

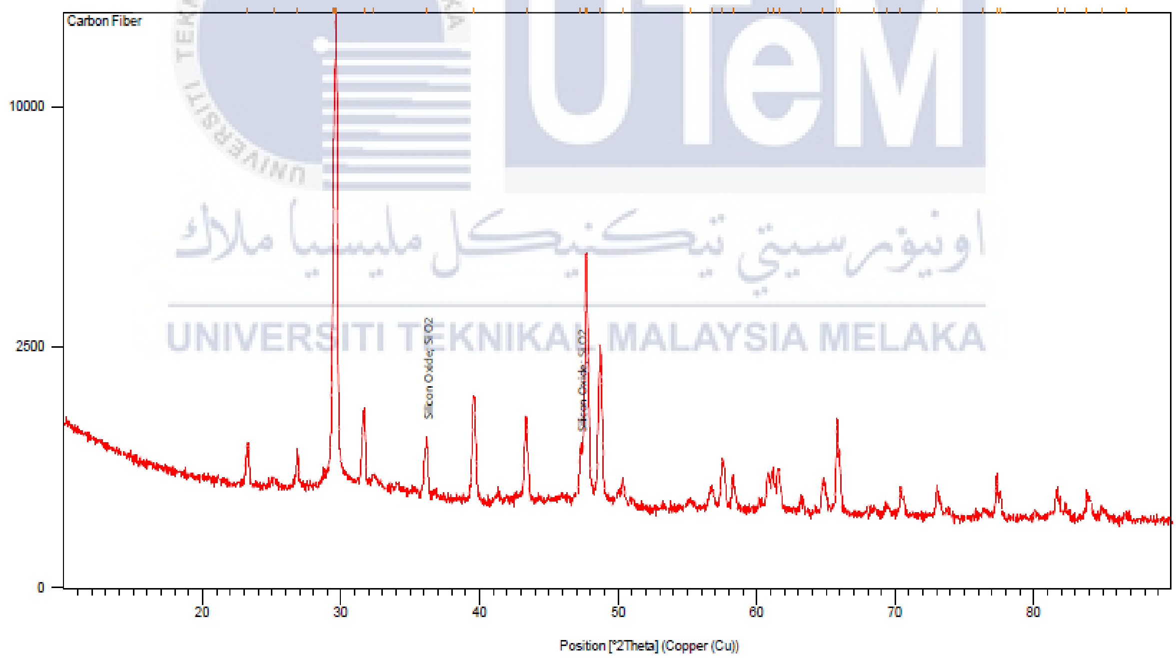

Figure 4.17: XRD Spectrum of Concrete with Recycled Carbon Fiber

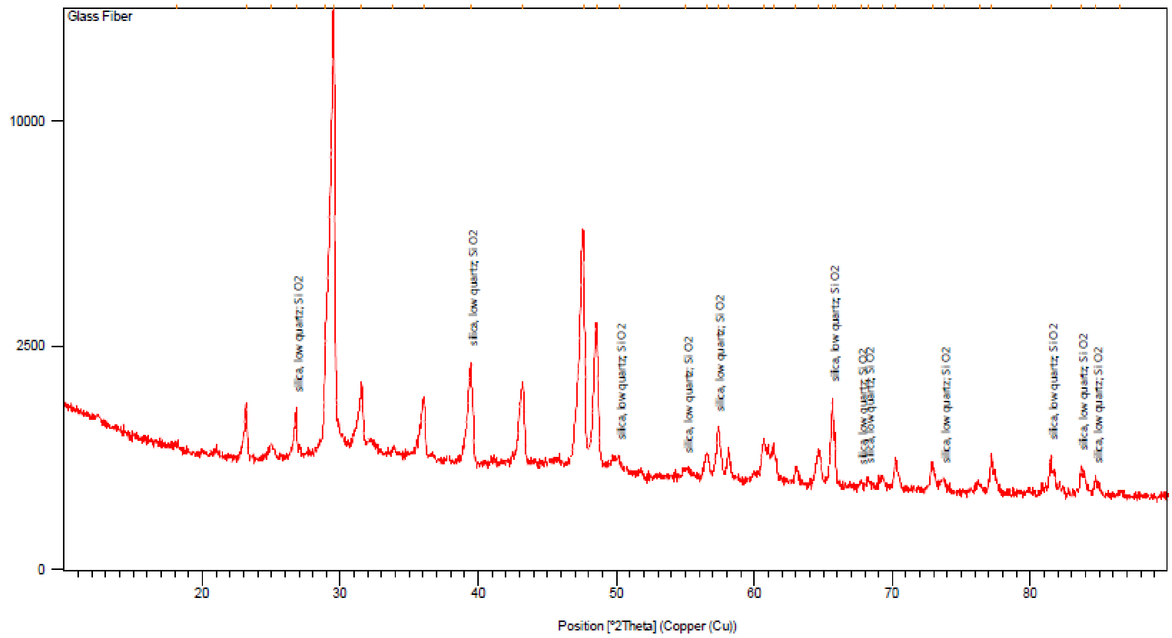

Figure 4.18: XRD Spectrum of Concrete with Recycled Glass Fiber

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

In conclusion, concrete with recycled glass fiber and concrete with recycled carbon fiber were successfully produced by using mechanical process. The reason for this research was that can recycling glass fiber and carbon fiber for progressive hybrid composites with lightweight and low price materials.

The first objective of this research is to study the suitable fiber size for concrete fabrication of the recycled glass and carbon fibers prepared using mechanical recycling method.is successfully achieved with highlight as the following:

i. Recycled glass fiber and recycled carbon fiber are the raw materials that were used in this research. The mechanical recycling were successfully suggested by shredding and grinding the recycled glass fiber and recycled carbon fiber in microscale size at 50µm.

The second objective of this research is to evaluate the mechanical properties of the concrete prepared using recycled glass and carbon fibers are successfully achieved. Significant results indicating the attainment of the second objective are summarized below.

i There are three samples were produced with same ratio at 1:2:3 of sand, cement and sand, which are normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber. The mass were 250g of water, 500g of cement and 750g of sand. Then, poured the concrete into a mould of shape cylinder which measuring at diameter of 100mm and height of 150mm.

ii While for the concrete with recycled glass fiber and carbon fiber added which incorporated 8% of recycled carbon fiber and 8% of glass fiber which was compared to cement mass percentage (%).

iii The ultimate tensile strength and Young's modulus of concrete with recycled glass fiber is the highest among normal concrete and concrete with recycled carbon fiber which is 9.06 MPa and 6.92 MPa respectively.

iv Hence, the concrete with recycled glass fiber inclusion had yielded an extraordinary improvement of about 10.49% in the tensile strength and 53.78% of Young's modulus as compared to normal concrete.

v In addition, the cylinder fracture types for normal concrete it shows type 2 which is well formed cone on one end. Fracture type for concrete with recycled glass fiber shows type 1. The concrete with recycled glass fiber is reasonably well formed cones on both ends. For concrete with recycled carbon fiber shows fracture type 5. This type defines side fractures at top because it occur commonly with unbonded caps.

The bonding surface morphology and the crystallographic structure of normal concrete, concrete with recycled glass fiber and concrete with recycled carbon fiber, were observed through scanning electron microscopy and X-Ray diffraction respectively to meet the last objective stated for this study. The following findings are interesting for the success of this research to be underlined.

i From the SEM micrograph, it shows clearly the recycled glass fiber had strong bonding with concrete. Other than that, a good dispersion of recycled glass fiber in concrete was found which tends to give high strength and good bonding. Besides, recycled carbon fiber shows does not bonding together with concrete. So that, it proves that the present of sand in concrete and the recycled carbon fiber interface are not strong enough. This totally reduced the strength of produced composites of concrete with recycled carbon fiber.

ii From the XRD analysis, the normal concrete, the crystalline structure at the near to 47.45°. It shows there were a little present of $Ca_3Si_2O_7$. So that, it was not strong bond enough interfaces between them. Besides, concrete with recycled carbon fiber. XRD patterns of SiO_2 had two peaks at $2\theta = 36.12°$ and 47.63°. The carbon atom in recycled carbon fiber did not adhesives with the $Ca_3Si_2O_7$ in the concrete. Lastly, for concrete with glass fiber concrete, it produced many peaks which was located at 28.93°, 39.46°, 48.55°, 57.34°, 65.65° and 83.67°. This proved that the present of $Ca_3Si_2O_7$ in concrete with recycled glass fiber. In such way, the bonding between $Ca_3Si_2O_7$ in concrete and the SiO_2 in recycled glass fiber were strong strength.

5.2 Recommendations

There are several further recommendations that could be suggested to further improvise this research. Among all are as follows:

i In the future, use recycled glass and carbon fiber by chemical process for concrete composite.

ii To ensure that this composite is appropriate for the building sector, it must be studied further to test certain durability qualities including permeability of water and permeability of gas.

iii More research will also be required in the future in relation to the long-term reliance on concrete containing recycled fibers such as shrinkage and cracking.

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Gantt Chart For PSM I															
No	Task	Weeks													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of PSM title														
2	PSM title selected and filled the synopsis of title														
3	Research study and understand the synopsis of title														
4	Find the related information, journal and book														
5	Implement and review of chapter 2 by supervisor														
6	Meet and discuss the progress of chapter 2 by supervisor														
7	Make correction of chapter 2														
8	Implement and review of chapter 1 by supervisor														
9	Make correction of chapter 1														
10	Implement and review of chapter 3 by supervisor														
11	Meet and discuss the progress of chapter 3 by supervisor														
12	Make correction of chapter 3														
13	Preparation of poster presentation														
14	Complete the report and submit to supervisor and panel														

PLANING

ACTUAL

Gantt Chart of PSM II																				
No	Task	March (2021)				April - July 2021 (Weeks)														
		1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Seek for raw material																			
2	Meet and discuss the progress of PSM by supervisor																			
4	Raw material preparation																			
5	Samples preparation																			
9	Curing Samples																			
6	Compressive test																			
7	SEM Characterization																			
8	XRD Analysis																			
10	Data Analysis																			
11	Report writing for chapter 4																			
12	Report writing for chapter 5																			
13	PSM II presentation																			
14	Correction for Report PSM II																			
15	Report Submission																			