RESEARCH AND DEVELOPMENT OF FIRE RESISTANCE DOOR FROM KENAF CORE AND CEMENT SLURRY

NUR HAZIRAH IFFAH BINTI HASHIM

BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS AND TECHNOLOGY) WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this Choose an item. entitled " Research and Development of Fire Resistance Door from Kenaf Core and Cement Slurry" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : Nur Hazirah Iffah binti Hashim

Date : 18/01/2022

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

Signature : ………………………………………………………………

Supervisor Name : Prof. Madya Ir. Ts. Dr. Mohd Yuhazri bin Yaakob

Date : 18 January 2022

ASSOCIATE PROF. IR. TS. DR. MOHD YUHAZRI BIN YAAKOB
Deputy Dean (Research & Industrial Link)
Faculty of Mechanical and Manufacturing Engineering Technology
Universiti Teknikal Malaysia Melaka

DEDICATION

Dedicated to

My honourable father, Hashim bin Ali

My precious mother, Nor'Aini binti Giman

My beloved brothers, Muhammad Naquiddin bin Hashim,

Muhammad Naqib Najmi bin Hashim, Muhammad Nasr Nazran bin Hashim

My beloved sisters Nur Husna Izzati binti Hashim, Nur Haziqah Izzah binti Hashim,

Nur Hazimah Ismah binti Hashim, Nur Haqimah Irdina binti Hashim

Thank you so much

ABSTRACT

In recent years, natural fibres have been one of the most fibres used in many applications due to being available in abundance with lower cost, sustainability, and environmentally friendly compared to synthetic fibres. Thus, this study explored the kenaf core reinforced cement slurry composite for fire resistance door application. The sample of fire resistance doors using kenaf core reinforced cement slurry have been analyzed. The sample size of 360 mm x 250 mm x 40 mm for different sizes of kenaf core 30 mm, 20 mm, 10 mm and 20 mesh (0.84 mm) with varying kenaf core and cement slurry ratios were prepared. The preparation of the composite is by mixing the kenaf core and cement slurry starting with a ratio of 9:1 (cement slurry: kenaf core) and continuously increasing the amount of kenaf core until 7:3 (cement slurry: kenaf core). The composition was poured into a mould with 400 mm x 250 mm x 40 mm. Then, the samples were dried for 7 to 8 hours and proceeded with the curing process to stimulate the cement's maturity strength for 28 days by being immersed in water. All the samples were cut into standard size using an angle grinder by following the ASTM standard for each mechanical testing. The mechanical tests that will be carried out in this study are compression, three-point flexural, and fire resistance. Scanning electron microscope analysis was done to analyze the characterization of the samples. It was found that the best composition sample using kenaf core size 20 mesh had the potential to improve the mechanical performance of the cement and can withstand a long time in resistance to fire. Hence, using kenaf core reinforced cement slurry had proven to have better performance in fire resistance door application.

ABSTRAK

Kebelakangan ini, penggunaan gentian semulajadi telah menjadi salah satu serat yang banyak digunakan dalam banyak aplikasi kerana boleh didapati dengan kos yang lebih rendah, kemampanan dan mesra alam berbanding dengan serat sintetik. Oleh itu, kajian ini telah meneroka komposit simen yang diperkuatkan dengan teras kenaf untuk aplikasi pintu rintangan api. Sampel pintu rintangan kebakaran menggunakan simen yang diperkukuhkan dengan teras kenaf telah dianalisis. Sampel yang berukuran saiz 360 mm x 250 mm x 40 mm telah disediakan menggunakan teras kenaf yang berbeza saiz iaitu 30 mm, 20 mm, 10 mm dan 20 mesh (0.84 mm) dengan nisbah yang berbeza untuk teras kenaf dan simen. Penyediaan komposit adalah dengan mencampurkan teras kenaf dan simen bermula dengan nisbah 9:1 (simen:kenaf teras) dan jumlah teras kenaf meningkatkan secara berkala sehingga mencapai nisbah 7:3 (simen:kenaf teras). Komposisi dicurah kan ke dalam acuan yang bersaiz 250 mm x 350 mm x 500 mm. Selepas itu, sampel dikeringkan selama 7 hingga 8 jam dan proses pengabaian dilakukan untuk merangsang kekuatan kematangan simen selama 28 hari dalam rendaman air. Semua sampel dipotong menggunakan pemotong sudut dengan mengikuti saiz piawaian ASTM untuk setiap ujian mekanikal. Ujian mekanikal yang dijalankan dalam kajian ini adalah ujian mampatan, lenturan tiga titik dan rintangan api. Pengimbas analisis mikroskop electron telah dijalankan untuk menganalisis ciri-ciri setiap sampel. Hasil kajian mendapati bahawa sampel komposisi terbaik menggunakan saiz teras kenaf 20 mesh berpotensi untuk meningkatkan prestasi mekanikal simen dan dapat bertahan pada jangka masa yang lebih lama dalam ujian rintangan api. Justeru itu, menggunakan simen yang diperkukuhkan dengan teras kenaf telah terbukti mempunyai prestasi lebih baik dalam aplikasi pintu rintangan kebakaran.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	-	American Society for Testing and Material
mm	-	millimeter
ISO	-	International Organization for Standardization
^{o}C	-	Degree Celsius
kg	-	kilogram
KC	-	kenaf core
CS	-	cement slurry
SEM	-	Scanning Electron Microscope
Φ	-	diameter

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This chapter will explain and clarify about the background of the study, characteristics and behavior of kenaf core and cement slurry made for fire resistance door. This research is the concept that contains the fundamental theory in previous research, books and journals. Therefore, the information and problem are gathered to identify the development needed for this research.

1.1 Background

In recent years, the spread of fire in buildings endangers people's lives. Fire is the result of a chain reaction involving oxygen, fuel and heat (Tola et al., 2018). Most buildings have adequate oxygen and the availability of fuel determines the initial growth of a fire. According to Novak et al. (2018), to prevent the spread of a potential fire and minimize losses, one of the basic requirements, particularly for industrial buildings, is to divide the building into fire zones that are protected by fire structures such as installing the fire doors. The resistance of the doors to fire is critical for the overall fire safety of the building.

The ability of a material or combination of materials to resist the passage of fire from one distinct area to another is referred to as fire resistance. There are many materials that can be used in the manufacturing of fire door structures that give different mechanical properties when react to fire. Guobys et al. (2016) stated some structures use gas and polymer fillers, but these structures are expensive and complicated. Despite its good thermal insulation properties, wood has a limited fire resistance time due to its high combustion rate (about 2 mm/min). They also stated that the thermal insulation properties of gypsum and stone wool allow them to resist the spread of fire.

To test the fire door when react to fire, fire resistance is used. Because fire resistance tests are very expensive, the number of tests performed on each prototype of the structure is typically limited to one or two (Tabaddor and Jadhav, 2013). The furnace, along with the equipment that allows temperature control and monitoring of gas pressure in the furnace, is the main element in the fire resistance testing lab. According to Sulik and Kimbar (2017), the testing furnace can be powered by liquid or gas fuel. Interestingly, testing furnaces can be built in such a way that horizontal and vertical elements can be tested at the same time.

Over the last decade, natural fibres have been greatly used by human as a reinforcement material in exchange to synthetic fibres in concerning the environment issue. Natural fibre can be classified into plant fibre, animal fibres and mineral fibres. Sreenivas et al. (2020) stated that these fibres are preferrable compared to the synthetic fibres as it is lower in density, stiffness and hardness to the proportion of weight. It also is lighter when combine with other fibres. Based on journal by Ismail et al. (2019), the type of plant, extraction and manufacture process, fibre age or maturity process and the location of the plant's growth will affect the properties of the fibres.

Recently, natural fibres from plant are the most use in composites as the fibres are easily available in the market such as kenaf, jute and hemp. Composite materials are continuously used in many applications due to their flexibility and improved technologies especially from natural fibres that have higher potential than synthetic fibres. According to Hamidon et al. (2019), these natural fibres have received higher attention for the usage in composites as there are easy to be manufacture and give good benefits for the environment. The fibres gain higher demand in the industries such as transportation, building and construction materials as it can replace synthetic fibre in term of lower cost, eco-friendly and can be recycled (Mustaffa et al., 2018). However, the focus of this study is to use kenaf.

Based on research by Shahar et al. (2019), kenaf markets are rapidly expanding both locally and globally, particularly with the introduction of new technologies and applications that have the potential to improve kenaf fibres's mechanical and chemical properties and replace other materials in the future. Supported by Mahzabin et al. (2018), they stated that kenaf are produced all over the world, including Malaysia, where it contributes to the development of environmentally friendly assets. Kenaf has a high potential for use as an alternative raw material to replace synthetic fibre in the medium density fibre board and particle board manufacturing industries.

Due to the high demand for cement and concrete production around the world, the cement and concrete industries becoming more interested in finding alternative materials to replace the use of these resources with natural fibres (Jiang et al., 2018). There are many research primarily studied the properties of natural fibres that can be used to replace or mix with cement thus can lower the content of cement due to environmental issue. Since there are only few past studies related to kenaf core and cement slurry in fire resistance door, therefore this research will further focus on the study about the development of fire resistance door from kenaf core and cement slurry.

1.2 Problem Statement

Over the years, fire has been one of the most common and destructive disasters in the world, destroying lives, properties and businesses when it gets out of control. According to Suresh (2017), there are many fire disasters happened at the construction sites and buildings. In every building, structures such as fire resistance door is necessarily important to avoid from the spread of fire become larger and to protect the people in the building thus they can escape or evacuate out of the building safely (Guobys et al., 2016). Hence, this fire resistance door is a method of fire safety that highly getting attraction for the people to install in their building so that can reduce the damages. Fire resistance door need to withstand fire and heat at least for 30 to 180 minutes before damages to allow people evacuate safely (Seo et al., 2013). Fire resistance door usually made of cement or concrete as it has great strength compared to other material and easy to handle and manufacture.

According to Kang et al. (2017), although cement-based materials are widely used due to their high compressive strength, they are lack to bending and tensile forces. There are studies being conducted to investigate the mixing of various types of excellent mechanical performance fibre to overcome the shortcomings and improve the mechanical properties of cement- base material. Feng et al. (2019) stated that cement slurry emits a large amount of hydration heat during the cementing process, raising the temperature of the gas hydrate layer and causing gas hydrate decomposition, resulting in leakage. Therefore, to control and reduce the cementing risk and ensuring the cement quality, natural fibre will be added to the mixture.

Furthermore, to protect concrete structures from fire, cementitious fireproof material is widely used. However, there has recently been a surge of interest in developing more environmentally friendly structures with lower cement content, as cement manufacturing has a significant carbon footprint (Won et al., 2012). Other than that, when using cement-based material, weight of the fire door became heavier and not easily to be install. Hence, with the addition of natural fibres, it will reduce the weight of the fire door but still maintaining the performance of the fire door. Therefore, the use of composites based on agricultural residues found in nature is a new trend in material development.

Natural fibres as bio fillers have appealing properties such as low density, low cost, environmental friendliness, reduced tool wear, high specific mechanical performance, renewable and degradable properties (Verma and Shukla, 2018). Hence, many researchers have been gone through research in replacing synthetic fibres in fire resistance door due to environmental issue. The mechanical properties and the behavior of natural fibres will be further test and analysis to develop or improve the fire resistance door. Increasing in the fibre size and fibre percentage will increases the tensile strength of the fibre. However, not many manufacturing of fire resistance door is made from natural fibre. Therefore, this research will be focused on the research and development of fire resistance door from kenaf core and cement slurry.

1.3 Objectives

The objective of research are as follows:

a) To fabricate kenaf core reinforced cement slurry in various ratios for fire resistance door application.

b) To investigate the mechanical properties of kenaf core reinforced cement slurry in various ratios.

c) To recommend the best kenaf core reinforced cement slurry ratio for fire resistance door applications.

1.4 Scope of Research

The scopes of the research are as follows:

a) To study the potential of kenaf core and cement slurry used to produce fire resistance door.

b) This study will involve process of moulding and curing on kenaf core reinforced cement before proceeding with the testing.

c) This study will determine the best ratio composition of kenaf core reinforced cement slurry to produce fire resistance door.

d) To identify the strength of fire resistance door depending on the various ratios of kenaf core reinforced cement slurry.

e) To observe the performance of fire resistance door in the event of fire.

f) The mechanical properties included resistant to fire, compressive strength, and flexural strength of fire resistance door made from kenaf core reinforced cement slurry is examine and evaluate according to ASTM standard.

1.5 Rationale of Research

The rational of research are as follows:

a) Since kenaf plant can be easily grow in tropical climate and getting high demand around the world, therefore farmers can have the opportunity to grow the plant widely but at the same time will increase the social economy in Malaysia.

b) Since kenaf core have great advantages and easily accessible in Malaysia market as it is applicable natural fibres in many applications, therefore this study is conducted to identify the potential of using kenaf core mix with cement slurry in development of fire resistance door.

c) In recent past research, fire resistance door typically made from cement or concrete as this material easy to be produce but the disadvantages of using cement will lead to environmental issue. Thus, to reduce the release of carbon or other gases comes from cement in production of fire resistance door in the event of fire, kenaf core will be used by mixing with cement.

d) Developing and expose more information about kenaf core in order to produce a fire resistance door that are affordable, lightweight and high resistant to fire.

1.6 Thesis of Organization

The purpose of this study is about the research and development of fire resistance door from kenaf core and cement slurry. This report chapter consists of introduction, literature review, methodology, result, and discussion. PSM 1 will cover Chapter 1, Chapter 2, and Chapter 3 while PSM 2 will cover Chapter 4 and Chapter 5. The order sequence from Chapter 1 to Chapter 5 are structured accordingly. Chapter 1 is about the introduction of the research consists of background study, problem statement, objectives, scope of research and the rational of the research. Chapter 2 excites about the literature review of previous studies contains introduction to fire resistance door, testing of fire resistance, and type of material used in fire resistance door continued with kenaf core and its application while end with studies about cement. Then followed by Chapter 3 which describes the methodology in detail about the preparation of the raw materials which are kenaf core and cement slurry to produce fire resistance door. The method used includes preparation process, fabrication process and testing process using standard test such as flexural testing and fire resistance testing. After that, all the data and analysis obtained from the experiment testing will be evaluate in Chapter 4. Finally, all the discussion and findings were concluded in Chapter 5 where the improvement can be developed for further research or study.

CHAPTER 2

LITERATURE REVIEW

This chapter is an overview about the previous researcher in manufacturing of the fire resistance door. The standard specifications, testing and materials used for the fire door been studied to investigate the potential of using kenaf core as the natural fibre with cement slurry to produce an excellent quality of fire resistance door.

2.1 Introduction

Since the evolution of land plants more than 420 million years ago, fire has been an important component of Earth's ecosystems (Noss and Reed, 2021). Fire remains as a major hazard in our life. Fire has been classified into five groups based on its origin and how it can be contained within a structure building. These classes are shown in the Table 2.1 with their description for every classes. Gernay (2019) stated that in 2015 in the United States, over 2685 deaths and property damage of 10.3 billion dollars caused by structure fires. They said that exposure to fire hazard can be highly filtered by built environment at our homes, offices and commercial or public buildings.

Cooking, smoking, electrical appliances and other are the most common causes of building fires (Gaur et al., 2019). Figure 2.1 represents the causes of fires in various areas. These types of buildings or areas need to be built with fire resistance materials thus can become possible to evacuate safely in the event of fire or disaster. Fire resistance is an important feature of all building structures especially fire door, regardless of the materials used (Schmid et al., 2018). Every material or element have its own properties of fire resistance without considering the reaction to fire classification. Shah and Sharma (2017) stated that fire resistance can be defines as the property of materials or their assemblies that prevents or delays the passage of excessive heat, hot gases or flames. Even though there are many fires resistance building structures, this study will be focused on the research of fire resistance door.

Table 2.1 Categories of fire (Nimlyat et al., 2017)

Class	Description
A	Made up of common combustible materials. Can be extinguished by cooling, blanketing, or wetting the structure.
B	Made up of flammable liquids. Extinguished using carbon dioxide, dry chemical, and hydrogenated agent types.
C	Caused by flammable liquids. Carbon dioxide, dry chemical, and hydrogenated agent extinguishers may be used.
D	Caused by the combustion of metals. Special dry powder extinguishing agents are needed.
K	Started because of high-temperature oil combustion in appliances. Wet potassium acetate and a low pH-based agent are used to extinguish.

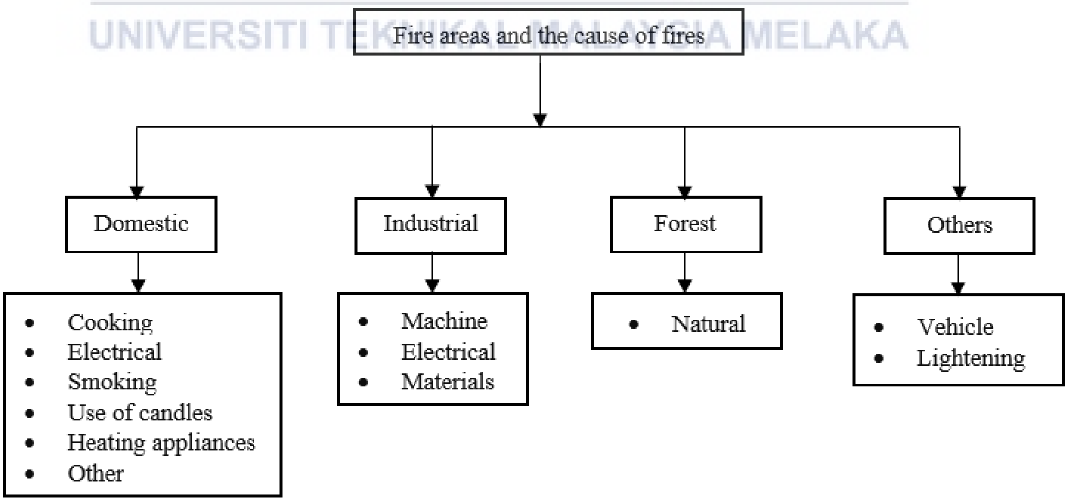


Figure 2.1 Figure Causes of fires in various areas (Gaur et al., 2019)

2.2 Introduction to Fire Resistance Door

The importance fire safety in the building is a door that resistance to fire. Fire resistance door are internal doors inside buildings (residential, industrial and commercial) that are installed to protect the fire from spreading in the event of fire (Seo et al., 2013). According to Tabaddor and Jadhav (2013), it stated that the presence of fire doors within a building is intended to prevent the spread of fire while also having a secondary effect on the smoke and heat exposures of the occupants. Supported by Wu et al. (2013), they said that fire door located in fire compartment, fire separation or evacuation passage where its one of active event in fire.

In addition, Sedlak et al. (2017) stated that fire doors are needed as a closure for openings in the event of fire that usually install in buildings, industries or special purpose structures such as tunnels. They are to form a barrier to fire, smoke and heat in fire conditions. Fire door must be the final door on an emergency exit route that will lead to a place of protection. In the study by Khalid et al. (2018), they describes that fire door need to have protection against spread of fire by delaying or stopping the transfer of thermal energy which is the heat is from one compartment to another.

Generally, the locations for the fire door can be estimated but it was not possible to determine fire door that will best fit the requirements of each potential places and the types of fire hazards in the surroundings. Previous studies have primarily concentrated on the capability or the function of the fire resistance door in the building. However, there is less reliable study that discussing about the specific locations for installing the fire door in the buildings. Figure 2.2 illustrate the location of fire resistance door installed in a commercial building located at Negeri Sembilan, Malaysia.

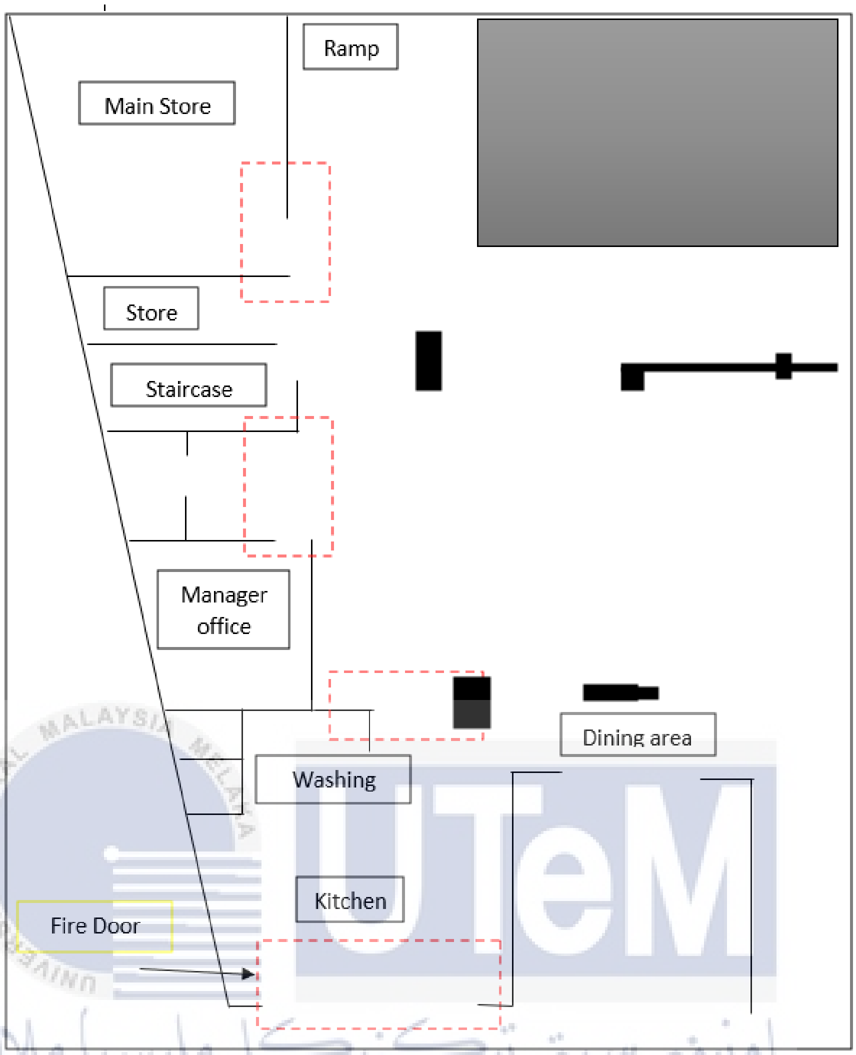


Figure 2.2 The location of fire resistance door in a commercial building located at Jalan Hutton, Negeri Sembilan, Malaysia

Worldwide, there are many manufacturing of fire resistance doors. Therefore, there is a wide range of products of this type. Even though every manufacturer has its own design solutions, some common uses can be found. Fire doors are designed based on the methodologies, aimed for optimizing the thermal behavior of the component. According to Moro et al. (2017), recently, industrially oriented research activities contributed to the development of innovative building materials capable of improving thermal performance in the event of fire. To ensure the safety of people and buildings, fire doors should be useful in normal operations while being safety in case of fire conditions.

Research by Khalid et al. (2018) observed that the fire door usually consists of a fire resistant core cover in a door shaped shell made of various materials that have the properties of fore retardant. Zhang et al. (2020) stated that fire door with fire-proof filler has good integrity performance and poor insulation performance. This is because the fire door mainly depends on high strength and low thermal conductivity filled insulating materials. According to Zhang et al. (2020), the construction of a large fire resistance door consists of a door frame, a door hinge, a door leaf, a driving mechanism and a locking mechanism. The door hinges secure the left and right door leaves to the door frame and the moving mechanism opens and closes them. Figure 2.3 shows the compartment for the large fire door for nuclear reactor.

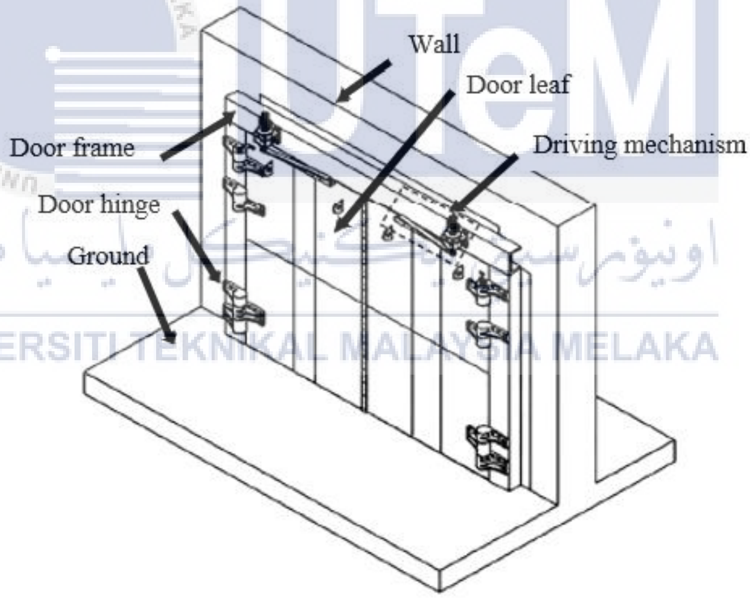


Figure 2.3 Large fire door for nuclear reactor (Zhang et al., 2020)

In contrast to the large fire door, the study by Wu et al. (2013) investigated the structure of a fire resistant steel double door. It stated that the door was assembled by two steel leaves, a steel door frame, eight hinges and a lock set. The dimensions of door frame were 2400 mm width x 2400 mm in height x 45 mm in thickness with no infill insulation material inside the leaves. Furthermore, the findings found by Izydorczyk et al. (2017) indicated that the fire door can be divided according to their method of opening such as hinged or the number of door leaves. They also mentioned that there is a special group of glazed closures with special fire glazing.

2.2.1 Testing and the specific standard of fire resistance

Generally, fire resistance doors must meet product certificate requirements, which typically include a fire test to determine the fire resistance rating. Schmid et al. (2018) mentioned that since 1900, the first fire resistance testing procedures have been developed by collecting and developing temperature-time curves and measurement systems. The graph shown in Figure 2.4 were originally recognized as Columbian curve.

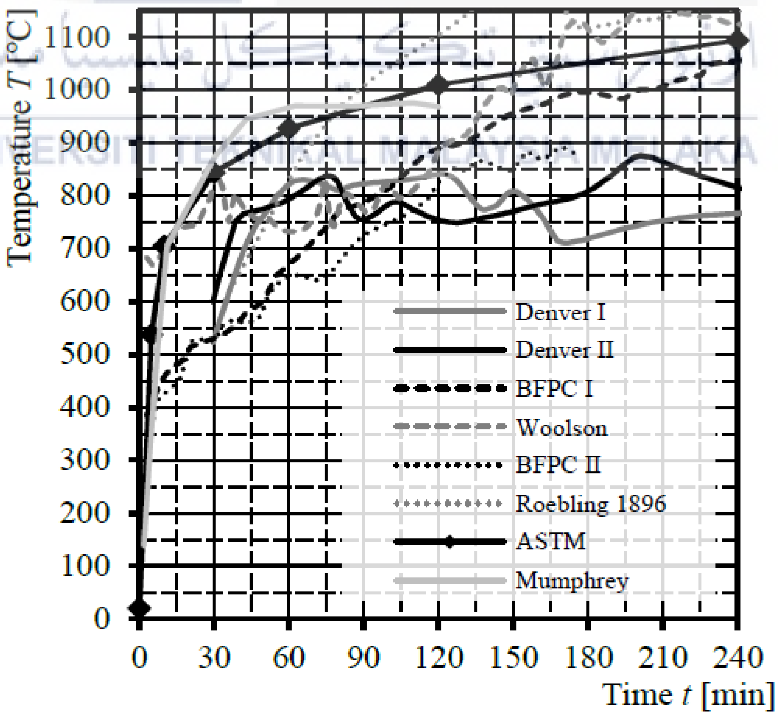


Figure 2.4 Standard fire curve from 1916 and earlier temperature curves (Schmid et al., 2018)

According to an investigation by Guobys et al. (2016), fire resistance test is defined as time (minutes) of fire exposure which will maintaining the fire resistance functions even though there are fire actions. It also stated that in the furnace test, the sample or specimen was exposed to the controlled temperature rise in the furnace thus it will vary with given limited time. Researched by Nassif et al. (2016) investigated that the minimum duration of exposure to the standard fire until the criterion to the fire failure is reached will determines the rating component or the assembly of fire resistance. Fire resistance can be derived through two testing which are physical and virtual testing. Some researchers stated that fire resistance test is expensive as it will destructive the specimen thus the number of tests for each specimen will limited to only two tests. Standard fire test set-up with the close view and deformed shape during the test were presented in Figure 2.5.

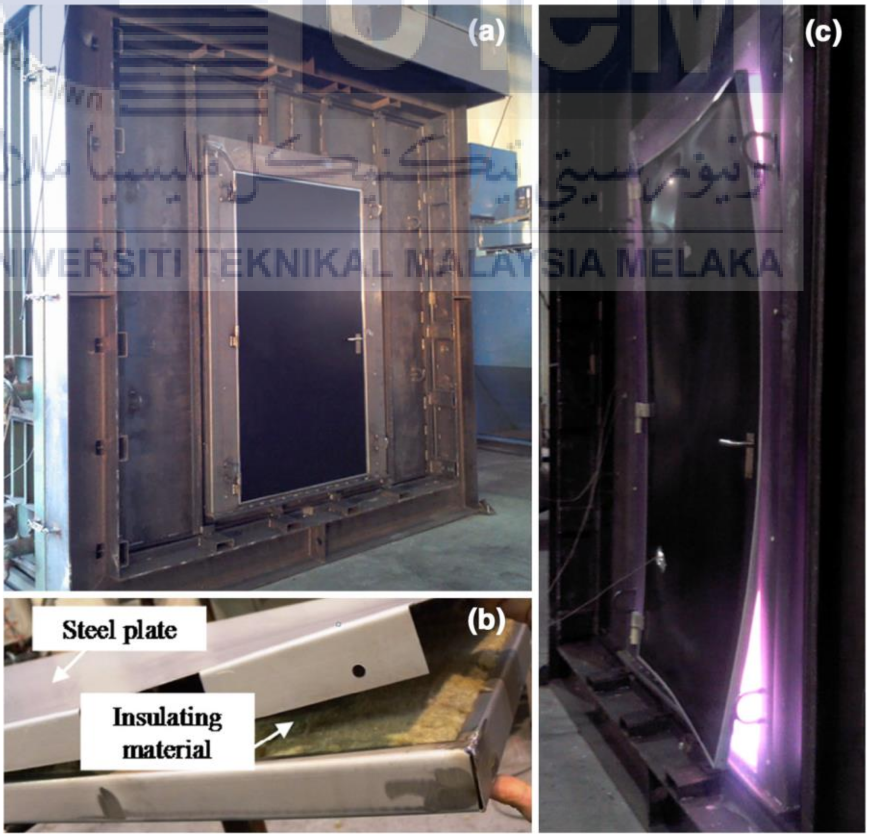
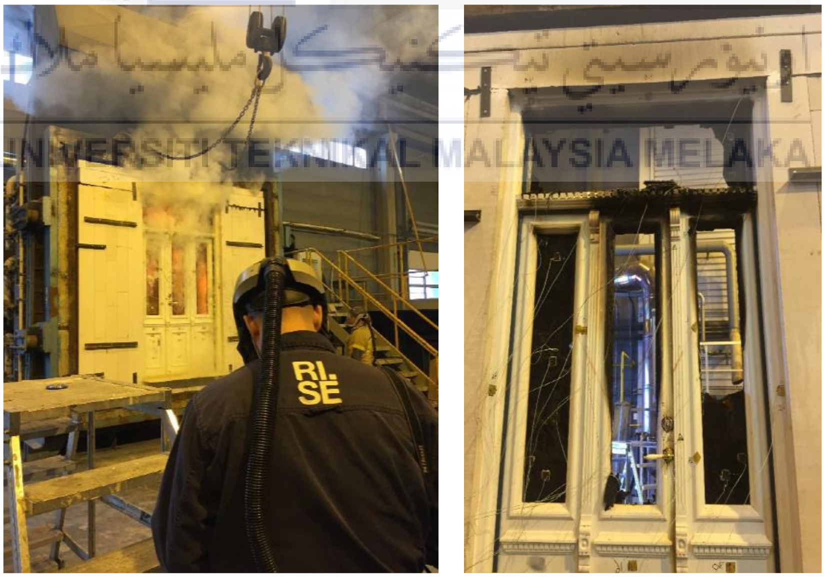


Figure 2.5 (a) Standard fire test set-up, (b) close view of fire door structure, and (c) deformed shape during the test (Moro et al., 2017)

Wang et al. (2017) studies that specific standard is indicate to specific building elements defined the detailed requirement for testing each kind of elements. It also stated by Sulik and Kimbar (2017) that describes the requirements set for the fire door depends on the type of elements, their composition and the measuring equipment that should be equipped with. Interestingly, they mentioned that the main element in fire resistance testing is using furnace together with the equipment enabling control of the temperature and monitoring the pressure of gas.

Other than using furnace test for testing the fire resistance of fire door, there are other existing standard tests such as ASTM E119 which is the standard test methods for fire tests of building construction and materials and ISO 834 that indicates the fire resistance tests for elements of building constructions. Standard fire resistance tests were introduced to compared building products. Figure 2.6 showed the fire resistance test in the furnace and the damage after testing.



(a) (b)

Figure 2.6 (a) Fire resistance test in the furnace and (b) after test ended (all glass panels are damage) (Storesund, 2020)

Besides having standard fire test, some studies also provided research about the classification of fire doors. Fire integrity (E) is defined as the ability of a structure element that acts as a partition to withstand fire applied at one side only without transferring to the unexposed side. Fire insulation (I_1 and I_2) is the ability of a structure element to withstand fire applied at only one side without transferring the fire to the unexposed side because of significant heat transfer from the heated side to the unheated side. While radiation (W) is the ability of the structure element to withstand action of fire applied at only one side to limit the possibility of transferring fire because of significant heat radiation by the element or by its unexposed surface to the nearby materials. Table 2.2 defines the fire resistance class. (Izydorczyk et al., 2017).

Table 2.2 Fire resistance classes of doors (Izydorczyk et al., 2017)

Class	Time (min)							
E	15	20	30	45	60	90	120	180
EI_1	15	20	30	45	60	90	120	180
EI_2	15	20	30	45	60	90	120	180
W		20	30		60			

Note: (*E is fire integrity, I is fire insulation, and W is radiation*)

Although fire resistance test and standard fire test method is important in research and development of fire door, the basic material used to make the door such as wooden and metal (most often aluminum or steel) are taken in consideration. In addition, there are a few studies that research regarding the type of materials used in fire resistance door besides using wood and metal.

2.2.2 Type of materials used in fire resistance door

In recent years, fire resistance door has been developed by many researchers with different materials used. Table 2.3 summarize several findings about the materials used in the application of fire resistance doors. Wu et al. (2013) studied about fire resistance performance of steel fire door. As a result, the findings are this no infill steel fire door has strong integrity performance, but it has low insulation performance due to its non-filled insulation material construction. This steel fire door performs in accordance with the fire endurance test criteria of exposure selected as three hours fire door. Mindeguia (2014) study on a thermo-mechanical model that has been developed to stimulate the thermal and mechanical behavior of cellulosic materials when subjected to a fire resistance test. There are two main difficulties that had been overcome which are the complexity of coupled phenomena and the lack of knowledge and data of the temperatures for the test.

In another study by Azieyanti et al. (2017), it stated that kapok fibre in composite discovered to influence the fire resistance thus should be considered as an insulated material in production of fire resistance doors. The research using kapok fibre and gypsum as the natural fibre to improve the fire resistance rating for the fire door. Towards the use of novel materials in shipbuilding that assessing thermal performances of fore doors by self-consistent numerical modelling was done by D'Amore et al. (2020). They analyzed that since the structure of fiberglass containing foam can be optimized for both thermal and acoustic efficiency as it is lighter than rock wool and better in mechanical properties while poor in thermal insulation. It also stated that the fiberglass is an incombustible material that is the most requirement for use in fore doors. There are a quite few research studies on fire resistance door. However, studies on different materials used in manufacturing of fire resistance door are rare to find in literature especially using natural fibre such as kenaf core.

Table 2.3 Listings on materials used in fire resistance door

Title	Finding/Description	Material	Author
Towards the use of novel materials in shipbuilding: assessing thermal performances of fire-doors by self-consistent numerical modelling	Fiberglass is found as an incombustible material that is the most requirement for use in fire doors as it is lighter compared to rock wool and have better mechanical properties but have poor capability in thermal insulation.	Fiberglass-containing foam	D'Amore et al. (2020)
Mixture of natural fibre with gypsum to improve the fire-resistance rating of a fire door: The effect of kapok fibre	Kapok fibre in composite discovered to influence the fire resistance thus should be considered as an insulated material in productions of fire-resistant doors.	Gypsum Kapok fibre	Azieyanti et al. (2017)
Thermomechanical behaviour of cellulose-based materials: application to a door under fire resistance test	A thermo-mechanical model has been developed to simulate the themal and mechanical behaviour of cellulosic materials when subjected to a fire resistance test.	Wood	Mindeguia. (2014)
Study of the fire resistance performance of a kind of steel fire door	Fire resistance test been carried out with the finding that this no infill steel fire door has strong integrity performance, but it has low insulation performance due to its non-filled insulation material construction.	Steel	Wu et al. (2013)

2.3 Kenaf Core

Kenaf which have scientifically named as Hibiscus Cannabinus L. has been existed around 4000 years ago that originally planted from Africa (Tharazi et al., 2017). According to Saba et al. (2015), "Kenaf" word comes from Persian defines as the plant that having short day and warm season. Kenaf is a sturdy plant that have viscous stalk which can resist insect damage and does not required any pesticides. It also requires minimum amount of chemical treatment and can be adjusted to any type of soils to grow beneficially. Originally, kenaf plant can adjusted to different type of weather of 22 °C and 30 °C (Azzmi and Yatim, 2018). It only needs a lower amount of water to growth on the grounds. Table 2.4 shows the climate condition needed for the growth of Kenaf plant.

Table 2.4 The climate condition of kenaf plant (Azzmi and Yatim, 2018)

Plant	**Optimum Temperature (°C)**	**Minimum Moisture (mm)**	**Optimum Soil (pH)**	**Growing Cycles (day)**	**Fibre Yield (kg/ha)**
Kenaf	22 - 30	120	6.0 - 6.8	150 - 180	1700

Based on research by Tholibon et al. (2019), it said this plant is divided into some parts includes part that have long fibre which is the long stem. They also come with the research stated that the stem of the plant made of two type of fibres that are 35 % inner (bast) and the other 65 % is outer fibres (core). These two types of fibres are regard as two contrast types of raw material which can be differentiate based on their appearances. The appearances of the kenaf fibre and kenaf core can be seen in the Figure 2.7. The fabrication process of kenaf fibre and kenaf core are necessary to determine the quality of the extracted raw material. The importance of harvesting and extraction are dependable to the area located of the plant, processing procedure and the functionality of the output products.

(a) (b)

Figure 2.7 Kenaf (a) fibre and (b) core (Adole et al., 2019)

Since kenaf is made up of two different fibres, it is theoretically possible but not economically feasible to separate the kenaf core and bast. As stated by Shahar et al. (2019), after fibres been extracted and separated between fibre and inner fibre which is the core, the core will be machined and manufacture in different types of size of mesh or in the form of powder. The process to separate the bast fibre from core is done by two ways which are retting and decortating. Decortating is a process using decortator as an act to separate fibre and core while retting is a process using three different methods with the involvement of chemical process, mechanical process and water.

The research of mechanical properties of kenaf fibre reinforced concrete by Elsaid et al. (2011) claimed that the density of the core fibre is 0.09 to 0.11 gm/cm^3. The researchers also stated that the core particles performed well compared to other natural absorbent materials by a substantial margin. Absorption values up to 12 g were discovered for kenaf core particles. Water may be absorbed through the pores of the core particles or through the pores between the particles. Moreover, Radzuan et al. (2020) reported that kenaf core exhibit 20 to 230 MPa of tensile strength while the range length of fibre about 0.5 to 0.6 mm that is wider and shorter. However, far too little attention has been research about the properties of kenaf core reinforced cement for fire resistance door application.

2.3.1 Application of kenaf core

Kenaf market are rapidly growing both locally and globally, especially with the emergence of new technologies and applications that have the potential to enhance kenaf core mechanical and chemical properties and replace other materials in the future. Table 2.5 summarize several findings that show reported work on kenaf core as reinforcement in the research. In 2014, Batouli et al. studied about the environment performance of kenaf fibre reinforced polyurethane a life cycle assessment approach. Studies have found that kenaf core particles will reduces the porosity of polyurethane (PU) composites thus raising the density and shear resistance while retaining the thermal resistance. Another studies by Nar et al. (2015), they examined regarding rigid polyurethane and kenaf core composite foams. It stated that freely expanding foams lead to poor reinforcement when mixed while the expanding constrained on foams resulting in increasing the capability reinforcement of the kenaf core.

Furthermore, Kawahara et al. (2017) showed that the study on the application of kenaf core as a composite reinforcement: injection moulding of kenaf core/ Poly ($_{L}$-lactide) compounds lead to the findings of dry-distillation surface modification appears to be successful without the use of chemical coupling agents for improving the interfacial interaction and compatibility between kenaf core filler and poly ($_{L}$-lactide) matrix. Evaluation of the biodegradable for oil absorbed cassava starch film filled with kenaf core fibre was carried out by Walster et al. (2018). The authors observed that kenaf core fibre able to absorb more oil molecules compared to cassava starch film thus it improved the cassava starch film's oil absorption uptake when cassava starch films with kenaf core fibre.

In the study by Mustaffa et al. (2018), they observed that the tensile strength, elongation at break and Young's modulus of treated composites increased moderately compared to untreated composites. It also indicates that kenaf core powder filler treated with benzoyl chloride improved adhesion and provided tight interfacial bonding resulting in composites with high tensile strength. The study of Hussin et al. (2019) was the development and characterization novel bio-adhesive for wood using kenaf core (Hibiscus Cannabinus L.) lignin and glyoxal. They discovered that as compared to kraft lignin, soda lignin had a higher phenolic-OH content and a higher molecular weight. It also investigated that the kraft and soda lignin had the ability to partially replace phenol in the synthesis of lignin phenol glyoxal resins in terms of structural and thermal properties.

Wang et al. (2021) researched about hydrophobic kenaf straw core for biomass-based cement mortar with excellent mechanical properties. According to the studied, the coating successfully blocked the hydroxyl groups on the surface of the natural straw core. Endowing hydrophobic kenaf core with stable hydrophobic properties, reducing water consumption during cement mortar preparation, providing more room for calcium silicate hydrate (C-S-H) growth and improving cement mortar strength production.

In the year of 2021, Sabaruddin et al. studied the effects of unbleached and bleached nanocellulose on the thermal and flammability of polypropylene reinforced kenaf core hybrid polymer bio nanocomposites. Their analysis revealed that lignin aided in the late degradation process of nanocomposites to overcome the low thermal stability caused by sulfation and the amount of lignin content in nanocrystalline cellulose (NCC) both had an impact on the thermal stability and flammability of the kenaf core hybrid nanocomposites. Although kenaf core have been widely used as the reinforcement, however, there have been limited study that provided research about kenaf core reinforced cement slurry.

Table 2.5 Reported work on kenaf core

Author	Title	Findings	Method	Matrix
Sabaruddin et al. (2021)	The effects of unbleached and bleached nanocellulose on the thermal and flammability of polypropylene reinforced Kenaf core hybrid polymer bio nanocomposites	1. Lignin aided in the late degradation process of nanocomposites to overcome the low thermal stability caused by sulfation. 2. The amount of lignin content in NCC had an impact on the thermal stability and flammability of the kenaf core hybrid nanocomposites.	Melt mixing compounding	Polypropylene

Wang et al. (2021)	Hydrophobic kenaf straw core for biomass-based cement mortar with excellent mechanical properties	The coating successfully blocked the hydroxyl groups on the surface of the natural straw core, endowing hydrophobic kenaf core with stable hydrophobic properties, reducing water consumption during cement mortar preparation, providing more room for C–S–H growth, and improving cement mortar strength production.	N/A	N/A
Hussin et al. (2019)	Development and characterization novel bio-adhesive for wood using kenaf core (Hibiscus Cannabinus L.) lignin and glyoxal	1. As compared to Kraft lignin, Soda lignin had a higher phenolic-OH content and a higher molecular weight. 2. Kraft and soda lignin had the ability to partially replace phenol in the synthesis of lignin phenol glyoxal resins in terms of structural and thermal properties.	N/A	N/A
Mustaffa et al. (2018)	Thermoplastic Elastomer composite using Benzyl Chloride Treatment on Kenaf Core Powder Mixing with Polypropylene and Virgin Acrylonitrile Butadiene Rubber	Kenaf core powder filler treated with benzoyl chloride improved adhesion and provided tight interfacial bonding resulting in composites with high tensile strength.	N/A	Polypropylene
Walster et al. (2018)	Evaluation of the biodegradation for oil absorbed cassava starch film filled with kenaf core fibre	Kenaf core fibre able to absorb more oil molecules compared to cassava starch film thus it improved the casava starch film's oil absorption uptake and lower the amount of weight loss when cassava starch films with kenaf core fibre.	N/A	Glycerol
Kawahara et al. (2017)	Study on the application of kenaf core as a composite reinforcement: Injection moulding of Kenaf core/Poly(L-lactide) compounds	Dry-distillation surface modification appears to be successful for improving the interfacial interaction and compatibility between the kenaf core filler and poly (L-lactide) matrix without the use of chemical coupling agents.	Injection moulding	Poly (L-lactide)

Nar et al. (2015)	Rigid polyurethane and kenaf core composite foams	Freely expanding foams lead to poor reinforcement when mixed while the expanding constrained on foams resulting in increasing the capability reinforcement of the kenaf core.	N/A	Polyurethane foams
Batouli et al. (2014)	Environment performance of kenaf-fibre reinforced polyurethane a life cycle assessment approach	1. Kenaf core particles occupying the space in the PU that was previously occupied by air. 2. Kenaf core particles will reduces the porosity of PU composites thus raising the density and shear resistance while retaining the thermal resistance.	N/A	Polyurethane foams

2.4 Cement

Cement is a type of traditional and basic material used in borehole all protection and leakage plugging and its composite has a remarkable effect on improving cement performance (Wang et al., 2019). According to Liu et al. (2019), cement is essential in the construction industry. For example, it has been widely used in structural engineering mortars and concretes as well as cement-based stabilized soils in geotechnical engineering. In addition, the study by Wang et al. (2018) stated that majority of building and structures are built with cement and concrete which the structures are commonly have a lifespan of 50 to 100 years. Figure 2.8 represents fresh cement slurry in liquid state.

Figure 2.8 Fresh cement slurry in liquid state (Liu et al., 2019)

The technological process of producing cement is quite complicated, which is due to high demand of its properties includes proper grinding and specific area. In the study by Piklowska (2017), they highlights the step of manufacturing process of cement. There are two steps that been mentioned starting with the preparation of raw materials which having preliminary fragmentation by jaw or ball breaker and batches are prepared using dry method to obtain meal while sludge is obtained by wet method. The next process was mentioned by Tao et al. (2019) which are grinding clinker that inserted powdered mixture into a special rotary kin. They also stated that cement slurries are system that is reactive which changing their characteristics continuously.

However, during the cementing process, cement slurry generates a lot of hydration heat, which raises the temperature. The temperature of the gas hydrate layer and the gas hydrate decomposition, resulting in borehole collapse, well diameter expansion, well leakage, well surge and other factors cementing construction accidents (Feng et al., 2019). To ensure the quality of the cement is maintain and reduce cementing risk, strictly control the hydration heat release and hydration temperature rise of cement slurry system need to be controlled.

Nowadays cement strength classed of 32.5, 42.5 and 52.5 MPa have been widely applied in various types of construction with the same conditions of curing, testing and result in different values of compressive strength (Eskandari-Naddaf and Kazemi, 2017). Table 2.6 shows the physical and chemical properties of cements. In addition, they mentioned that due to its high mechanical strength, excellent durability and low cost, cement concrete have been widely used as the most significant engineering material (Wang et al., 2020). Furthermore, the study by Ma et al. (2021) observed that the fresh cementitious material can act as a solid under any applied shear stress below yield stress. The porosity of the fresh cement slurry is approximately 58.09 % and its pores size range from 100 mm to 850 mm (Liu et al., 2019).

Table 2.6 Properties of cement (Eskandari-Naddaf and Kazemi, 2017)

Cement strength class	Chemical analysis (%)												Physical analysis
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	LOI	F.CaO	C3A	C3S	Specific gravity (ton/m^3)
C 325	20.4	4.56	3.4	64.12	1.93	2.3	0.32	0.7	2.2	1.3	6.33	63.94	3.13
C 425	20.2	4.6	3.5	64	1.94	2.4	0.35	0.7	2.7	1.3	6.27	64.27	3.13
C 525	21	4.7	3.52	64.18	1.93	2.53	0.32	0.65	1.2	1.2	6.5	57.85	3.15

In another study, Wang et al. (2020) described that water to cement ratio is defines as the ratio of the weight of water to the weight of cement that play important role in the strength development and flow behavior of cement slurry. The effects of the water-cement ratio on flexural strength and compressive strength of the cement composites can be analyzed as the water-cement ratio increases, both strengths also increase. The water-cement ratio becomes the most basic parameters in mixing design and it shown that the static yield increases with the increasing of water-cement ratio.

Saleh and Teodoriu (2017) mentioned in their research that when mixing conditions change, typical cement slurry properties such as basic rheology, thickening time, compressive strength, free water and fluid loss can be directly influenced or modified. Cement being used mostly at the oil and gas industries as it can protect the concrete structures against fire. In the research by Levinskas et al. (2018), it stated that cement have compressive strength exceeding 42.5 MPa after being heated to temperature of 400 ^{0}C to 500 ^{0}C. However, some researchers argue that even tough cement has great properties and fireproof material, cement manufacturing generate large carbon footprint. It was supported by Jiang et al. (2018) that mentioned due to high demand for cement production, the industries have an increasing interest in finding alternative materials. Although there several researchers stated that cement is good in their properties and some is in contrast due to environmental issue, this study will be focused on the development of cement slurry as matrix in fire resistance door.

2.5 Summary

For the summary, many interesting information was found from previous research related to the fire resistance door. The findings form this literature review include theoretical aspect had been gone deep in the knowledge of fire resistance, type of materials used for fire door, kenaf core and cement slurry. The information collected and gathered will assist on the development of fire resistance door using kenaf core and cement slurry.

Generally, fire resistance or called as fire door are the important building structures that installed to ensure the safety of occupants and prevent the fire from spread widely in the event of fire. The fire door will act as the final door to evacuate the occupants in the building safely. Thus, this research will be focused on the fire resistance properties and materials that can withstand fire for at least 30 minutes to 1 hours (Khalid et al., 2018). In recent years, many materials had been used in manufacturing of fire door. Unfortunately, due to environmental issue such as harmful gases releases in the vent of fire, some researcher studied regarding natural material to replace existence materials for the fire door. The advantages of using natural materials are the price of the material is cheaper, sustainability, easy to produce and environmentally friendly.

Natural fibres come from either plant, animals or other natural resources. The highest demand natural fibres nowadays are from kenaf plant that consist of kenaf bast fibre and kenaf core fibre. According to previous journals, kenaf core have been a great potential of mechanical and chemical properties to replace other materials in the future in the application of new technologies. Table 2.7 summarized of previous research finding on the reported work on the application of kenaf core. Since Elsaid et al. (2011) stated that density of kenaf core is lighter and the absorption of the particles performed well than other materials, thus kenaf core is one of the materials that have the potential to be used as the insulator in fire resistance door in the event of fire to stop the spreading of fire.

While researching kenaf core as a reinforcement in composites, cement also been studies as the matrix substances. Cement or called cement slurry when mixing with water and sand is very important in the construction industry such as in structural engineering of concrete and mortars. It also found that building structures that built using cement have a lifespan up to 100 years and can withstand fire for a longer time. Although there are many studies regarding fire resistance door has been done, however it was found that the research of fire resistance door using kenaf core reinforcement and cement composite was not done yet. Therefore, this study will focus on the research and development of fire resistance door from kenaf core and cement slurry.

Table 2.7 Reported work on the application of kenaf core

Title	Application	Author
Effect of particle pre-treatments on the quality of kenaf core/HDPE plastic composites	The mechanical properties of 60/40 kenaf/HDPE mixture was improved with the pre-treatments of core particles with 1% sodium hydroxide for 1 hour and 1% hydrochloric acid for 30 min.	(Li et al., 2020)
Effects of kenaf core and bast fibre as dispersing phases on low density fibreboards (engineered wood)	The improvement of mechanical properties will increase the life services of the boards as the kenaf core and bast fibre have great potential.	(Anyanwu et al., 2019)
Effects of kenaf core fibre (Hibiscus cannabinus) as one of the dispersing phases in brake pad composite production	As the derived properties are comparable to those of standard commercial brake pads, kenaf core fibre can be used as a dispersing phase for brake pad composites.	(Anyanwu et al., 2019)
The effect of kenaf core fibre loading on properties of low-density polyethylene/thermoplastic sago starch/kenaf core fibre composites	With the addition of kenaf core fibre, the tensile strength and modulus of the low-density polyethylene/thermoplastic sago starch blend could be significantly improved.	(Sarifuddin et al., 2013)
Water absorption characteristics of kenaf core to use as animal bedding material	The evaluation comparison of the water absorption capacity of various kenaf core fractions with other commercial animal bedding materials such as straw and wood shavings	(Lips et al., 2009)

CHAPTER 3

METHODOLOGY

This chapter explained the proper process flow and methodology used in this research. The method used will be discussed to ensure the objectives of this research can be achieved successfully by following the proper planning of the methodology. This process flow included the preparation of material, fabrication process and related experimental testing. All procedures for the testing in this research will follow the American Society for Testing and Materials (ASTM) includes standard testing methods, tools, and technique.

3.1 Overview of the Methodology

The flowchart of overall process in this research is depicted in Figure 3.1. This research began with the preparation of raw material which are kenaf core and cement slurry that will be mix with different ratio of composition for each sample. After the preparation, moulding and curing technique is carried out. Moulding is a technique to produce samples of fire resistance door with the dimensions of 400 mm x 250 mm x 40 mm while allow the sample to be dried based on ASTM standard. If the quality of the samples is good, it will proceed with the testing but if the quality is not good, new sample need to be prepared. When the samples are ready, the samples were tested to observe the mechanical properties of the fire resistance door by compression test, three-point flexural test, and fire resistance test. Lastly, all the data are analyzed to conclude the research with the best composition ratio of kenaf core reinforced cement to produce fire resistance door.

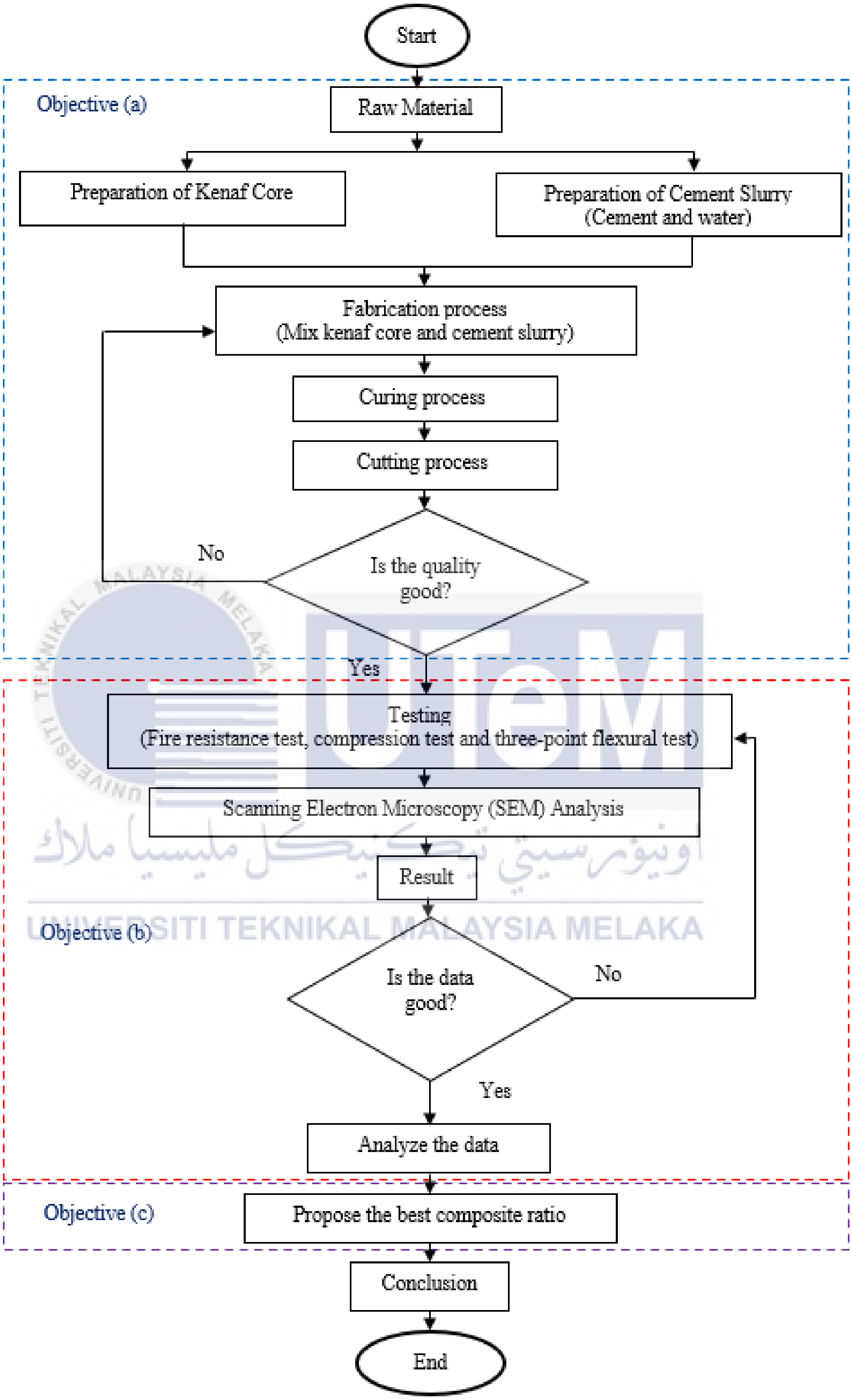


Figure 3.1 Flowchart of methodology

3.2 Raw Material Preparation

The preparation of raw material is very important and crucial step to produce the best quality product. The aim of this research is to prepare the appropriate amount of various ratios of kenaf core and cement slurry. There are two types of material which are kenaf core used as reinforcement while cement slurry was used as the matrix material. The details specifications and characteristics of each raw material will be explained more further in this research. The dimensions and quantity of the materials are measured accurately according to the requirements. The method of fabrication process used is based on the previous study and it is suggested in this research.

3.2.1 Kenaf core as reinforcing material

In this study, kenaf core (KC) is used as the reinforcing material. The properties of the KC are indicating in the Table 3.1. There are three types of KC will be used which are 30 mm, 20 mm, 10 mm and 20 mesh (0.84 mm) in size as shown in Figure 3.2. Different size of KC being used to determine which size of KC that will give the best result when mixing with cement in the production of fire resistance door. This is because size of KC will influence the interfacial bonding of the composites when contact with the surface area to the cement. The details price of each size of KC were provided in Table 3.2 and the KC was obtained from Lembaga Kenaf dan Tembakau Negara (LKTN).

(a) (b) (c) (d)

Figure 3.2 Different size of kenaf core, (a) 30 mm (b) 20 mm (c) 10 mm and (c) 20 mesh

Table 3.1 The properties of kenaf core

Density	Tensile strength	Absorption
0.09 – 0.11 g/cm^3	20 – 230 MPa	12 g

Table 3.2 Price of kenaf core based on mesh size

Mesh size	Quantity (kg)	Price (RM)
20 mesh	10.0	9.00
10 mm	10.0	4.50
20 mm	10.0	4.00
30 mm	10.0	3.50

3.2.2 Cement as matrix material

Cement is the matrix material used in this study as stated previously. Cement is a material that used in building structures and construction due to its high strength and have longer lifetime to damage. The production of cement is having higher demand in many applications as it easy to be produce. Since cement can withstand high impact when force exerted to its and resist high temperature in the event of fire, therefore, cement was chosen as the matrix material. In this study, cement in Figure 3.3 was purchased from Khem Mines Sdn. Bhd with the cost is RM 18.00 per bag which contain 50 kg for one bag of cement. Table 3.3 indicates the properties of the cement.

Figure 3.3 Raw materials for fire resistance door, cement

Table 3.3 Properties of cement

Material	Portland cement
Density, ρ	2240 – 2400 kg/m^3
Compressive strength	20 – 40 MPa
Tensile strength, σ	2 – 5 MPa
Drying shrinkage	4 – 8 x 10^{-4}
Shear strength, τ	6 – 17 MPa
Specific heat, c	0.75 kJ/kg.K

3.3 Preparation of the Composition

Before starting the testing, the preparation of raw materials is very important step in ensuring the quality of the finished product. Because of many samples need to be prepared, this early decision process will give impact to the research while affecting the accuracy of the results obtained. Therefore, ensuring all the samples are accurately measured and prepared with the same dimensions and parameters. In this study, the cement slurry (CS) will be prepared by mixing with water. Water is a major component of the cement. One of the most common types of water used in the manufacture of cement is tap water. The presence of water will cause the cement to hydrate. In the presence of water, the cement compound chemically combines with water to form new compound that serves as the hardened cement's infrastructure. The mix proportion for CS was 0.5:1 (water: cement).

The composition of KC and CS were provided in Table 3.4. The composition of the materials is different for each sample are because the purpose of this research is to propose the best ratio of KC and CS in producing fire resistance door. Therefore, the preparation of the composition started with the sample ratio of 9:1 (CS: KC) and continues with the percentage of KC increasing gradually until ratio of 3:7 (CS: KC) for each mesh size of KC. This is done to observe the performance of KC as the reinforcing material when combine with CS.

Table 3.4 Various ratios of kenaf core and cement with different size

Sample	Type A		Type B		Type C		Type D	
	CS (wt. %)	30 mm KC (wt. %)	CS (wt. %)	20 mm KC (wt. %)	CS (wt. %)	10 mm KC (wt. %)	CS (wt. %)	20 mesh KC (wt. %)
1	90	10	90	10	90	10	90	10
2	80	20	80	20	80	20	80	20
3	70	30	70	30	70	30	70	30

3.4 Fabrication Process of the Fire Resistance Sample

The fabrication process started with the moulding process of the kenaf core reinforced cement to produce the samples of fire resistance door with the dimension of 400 mm x 250 mm x 40 mm for each sample. Moulding is a process that involves shaping a raw material using a fixed frame known as mould for the sample. In this process, after the preparation of mixing KC and CS with different ratios, the composition was moulded using mould from plywood with the dimension of 360 mm x 250 mm x 40 mm as shown in Figure 3.4. The composition is poured into the mould until it is fully equipped the mould. To ensure no air bubble trapped inside the mould which can reduces the strength of fire resistance door, the mould is vibrated or shake. The samples were left to dry for 8 to 10 hours. Because of the cement slurry will begin to harden once the hydration process begins, the composition was used within an hour. After the samples were dried or harden, it will be removed from the mould and continue with the curing process.

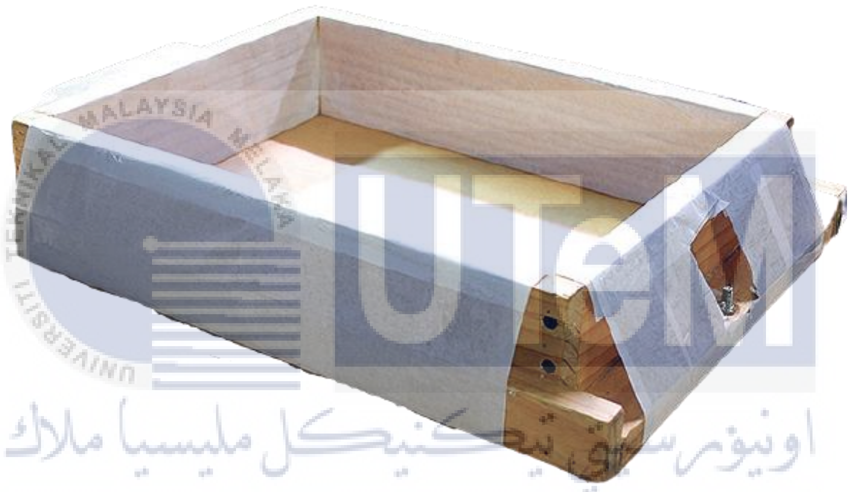


Figure 3.4 The mould for the fire resistance door

3.4.1 Curing process

Next, curing process for cement is the process of maintaining the moisture and temperature conditions of concrete for the hydration reaction to continue and help cement to develop hardened properties over time. This process helps cement to harden and bond with reinforcement material which is kenaf core while helps to prevent damages of vibration and impact to the bond of cement and kenaf core. Based on the ASTM standard for maturity of the cement, curing process is carried out by submerged the harden samples into the water for about 28 days until reach the maturity and stimulate optimum strength. The samples then will be examined to check the quality of the samples before proceeding further with the cutting process.

3.4.2 Cutting process

Cutting is a process that commonly done at the construction area to cut concrete floor, wall and concrete pavers. In this research, cutting process is done to cut the samples of fire resistance door into standard sample size for each testing. The cutting size will follow the requirement size for the testing. Even though many cements cutting saw is available, using an angle grinder is most convenient tool as it is suitable for small samples cutting work. The samples are cut using angle grinder as shown in Figure 3.5. The type of angle grinder will be used is GWS060 4’’ Angle Grinder which are brand from Bosch with power input of 670 watt and spindle thread of M10. The disc diameter and sanding plate diameter is 100 mm for both dimensions. The weight of the grinder without cable is 1.6 kg.

Figure 3.5 The cutting process

3.5 Mechanical Testing

There are three testing that will carried out to test the samples in this research which are compression test, three-point flexural test and fire resistance test. All the testing will be performed based on requirements of ASTM standard. The objective of these mechanical testing is to determine the mechanical properties of the samples. Table 3.5 indicates the ASTM standard for each type of tests.

Table 3.5 ASTM standard for mechanical testing

Testing	ASTM Standard
Compression Test	ASTM C39/C39M
Three-Point Flexural Test	ASTM D790
Fire Resistance Test	ASTM E119

3.5.1 Compression test

If the material does not have a lot of mechanical response in tensional load, compression test would be more appropriate since it will represent the material's properties better. Compression test is used to determine the behaviour of a material by crushing load and are typically performed by applying compressive pressure to a test specimen using specialised fixtures on a universal testing machine. The specimen will be subjected to compression load under the ASTM C39/C39M standard test method to analyze the qualities such as compressive strength, yield strength and elastic limit as illustrate in Figure 3.6. Five samples will be tested and the average result will be recorded.

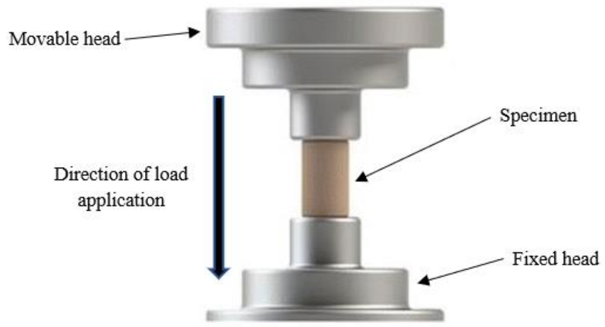


Figure 3.6 Standard of compression testing setup

3.5.2 Three-point flexural test

Three-point flexural test or known as bending test is to determine the flexural properties of a material under a bending strain or deflection. Bending action in beams is often referred as flexure is to tranverse loading of the beam. The deflection of the specimen is the displacement of a point at the neutral axis of beam from its original position due to applied loads. The mechanical properties of this testing are tangent modulus, flexural strength and flexural stress at break. This testing is performed using Instron 50 kN universal testing machine (UTM) with a three point bend fixture at a rate proportional to the specimes's depth as shown in Figure 3.7 by following standard of ASTM D790. Average result of five samples will be recorded.

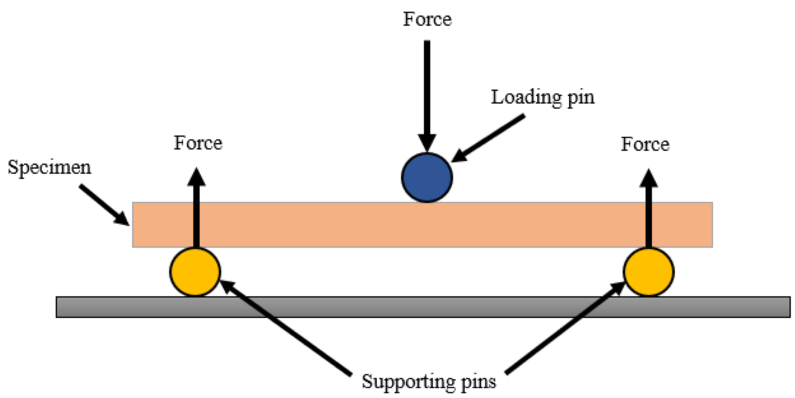
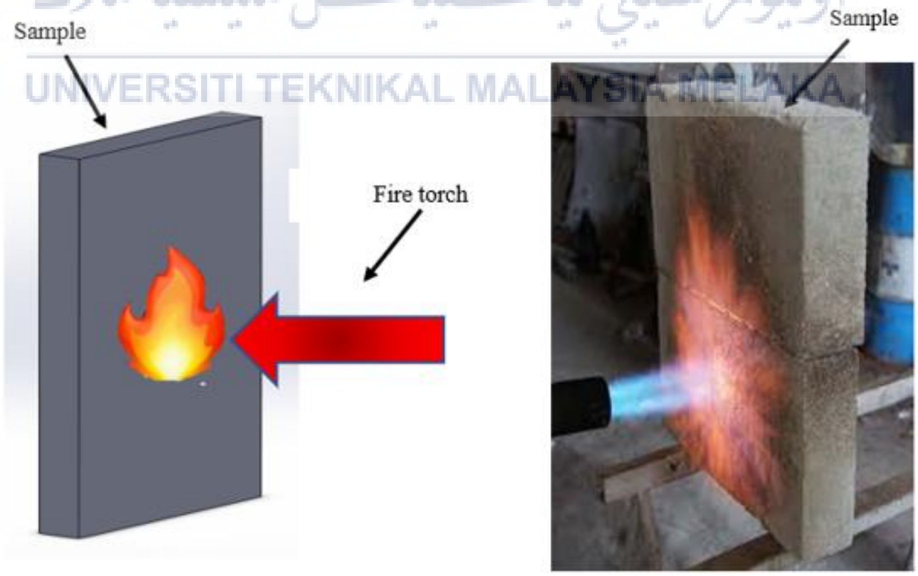


Figure 3.7 Standard setup for three-point flexural test

3.5.3 Fire resistance test

As stated previously, fire resistance test standards for fire resistance door are related to a structure's ability to prevent the spread of flame or smoke, allow time for occupants to evacuate form the buildings, maintain the structural stability of the tested specimen, and limit the fire damage in fully developed fires. Increase in temperature will result in the reduction of mechanical properties of the materials such as modulus elasticity. In this research, the samples are test using the basic method which is the standard setup and the fire torch used to test the samples shown in Figure 3.8. The fire resistance test will followed the standards of ASTM which is ASTM E119. During the fire test, it will focus on some aspects of fire behaviour such as ignitability, flame spread, heat release rate or toxicity of fire. After the test, the structural of the samples has been observed to see how the performance of the sample response of damage occurs. This fire resistance test will test five samples and the average result will be recorded.



(a) (b)

Figure 3.8 The standard setup for fire resistance test, (a) schematic diagram (b) an example of fire resistance door testing

3.6 Scanning Electron Microscope (SEM) Analysis

SEM is a process that scans the sample with an electron beam to generate a magnifies image for the analysis. The basic of SEM is the detection of high energy electrons emitted from the surface of a sample after being exposed to a highly focused beams of electrons from an electron gun as illustrate in Figure 3.9. This analyse is useful tool for characterization of test samples and failure analysis in materials. In this research, SEM analysis is used to detect the morphological view of the fire resistance door from kenaf core reinforced cement slurry. Using the SEM objective lens, this electron beam is focused on a small spot on the sample's surface. The SEM type and brand will be used in this study is ZIESS EVO 50. Five samples will be tested and the average result of the analysis will be recorded.

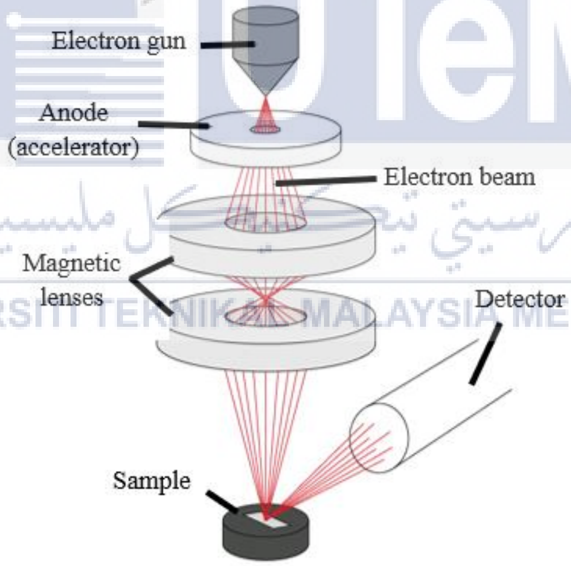


Figure 3.9 The standard setup for SEM analysis

3.7 Development of Fire Resistance Door Prototype

Prototyping is a fundamental process of creating new product by physically representing an idea. A prototype is a pre-production sample, model or release of a product designed to test a concept or process, The prototype created with basic sketches and rough materials, may be simple drawing or rough model that assists in determining what need to improve and fix. For this research, a prototype of single leaf fire resistance door is designed following the standard size of fire resistance door as shown in Figure 3.10. The dimensions of standard fire door are 2400 mm in length , 1220 mm in width and thickness of 50 mm. The raw material required to fabricate a single leaf fire resistance door in this project are based on the best properties obtained.

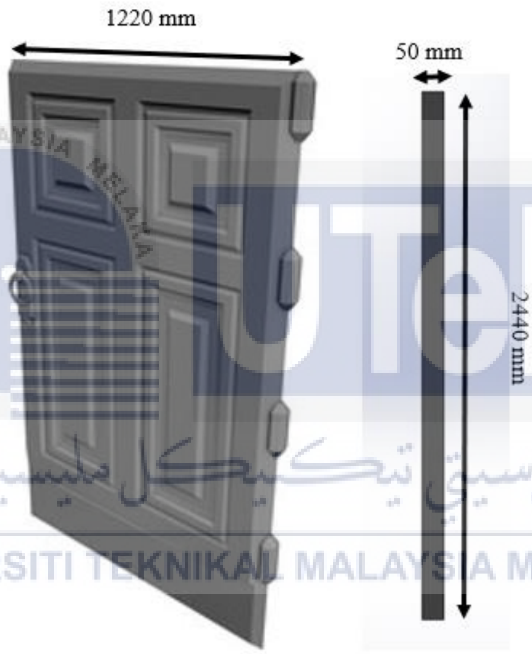


Figure 3.10 Example prototype of fire resistance door

CHAPTER 4

RESULTS AND DISCUSSION

This chapter will present discuss the analysis of the experimental results following by the production of sample and various testing experiments. The discussion will be discussed accordingly to the objectives. Firstly, the fabrication of kenaf core reinforced cement slurry in various ratios for fire resistance door application. Secondly, the mechanical properties of kenaf core reinforced cement slurry in various ratios. Lastly, to propose the best kenaf core reinforced cement slurry ratio that suitable for the application of fire resistance door.

4.1 Fabrication of Fire Resistance Door from Kenaf Core and Cement Slurry

This research is conducted to observe and study the application of kenaf core as reinforcement material and cement slurry as matrix to fabricate the fire resistance door. The size of the kenaf core used in this research is 20 mesh, 10 mm, 20 mm and 30 mm. Firstly, the sample needed for this research is 75 samples which each size of kenaf core will have three compositions with an additional of 5 samples coming from industry as a benchmark in this study. To fabricate the sample in time, 25 moulds with dimensions of 400 mm x 250 mm x 40 mm were built with the measurement of each sample size should be 360 mm x 250 mm x 40 mm. After drying samples for 8 to 10 hours, all the samples would be submerged into the water to undergo the curing process for 28 days. Then, the samples will be cut into five pieces for each testing with the dimension were based on the standard measurement.

Before preparing a suitable sample for the testing, an experimental sample is prepared to determine which method is convenient for mixing cement and kenaf core to ensure that the mixture is well blended to be more robust and more stable. Figure 4.1 shows the process of making the trial sample with different mixing methods. Then, all the trial samples were dried out under sunlight for a few hours until thoroughly dried. This step was done to know the composition of kenaf core that will be used for each size of kenaf core when mixed with cement slurry. The results of this trial sample showed in Figure 4.2(a), where the suitable method will give good strength and not easily crack when broken. Unfortunately, if wrong method is used and not thoroughly dried the sample, it will break easily and cannot be used for further process as illustrated in Figure 4.2(b).

Figure 4.1 Trial sample of mixing kenaf core and cement slurry

(a) (b)

Figure 4.2 (a) Good sample and (b) rejected sample

After confirming the suitable method where kenaf core will be mixed equally together with cement, the kenaf core will be thoroughly covered. Then, water is added thus the mixture will have a good bonding with each other as shown in Figure 4.3. The mixture will be poured into the mold and compress well to ensure the sample get an excellent flat surface and avoids any bubbles trapped. Figure 4.4 illustrates the molding process of the samples and will be dried out under sunlight for 8 to 10 hours.

(a) (b) (c)

Figure 4.3 The fabrication process (a) kenaf core added in the cement (b) mixing process and (c) final mixture after water added

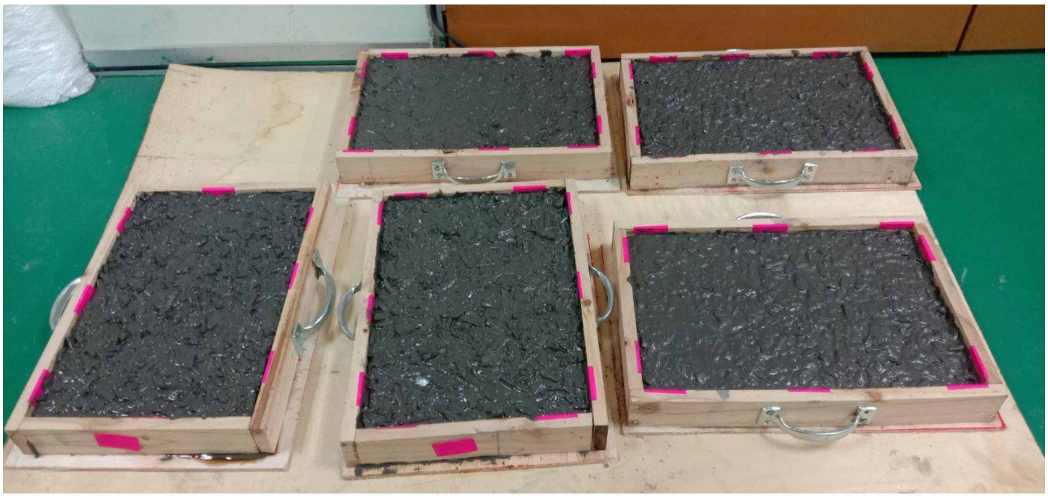


Figure 4.4 The molding process of the samples

After the drying process, the samples will be removed from the mold gently to avoid any vibration that will lead to the sample breaking or cracking easily. Figure 4.5 and Figure 4.6 show samples' examples after undergoing the drying process. Most of the samples give better results with smooth and flat surfaces while some are not which the samples cannot be used for the following process. Broken or fully cracked becomes rejected samples and needs to replace it with new sample because if still want to use it, it will become more crack during the cutting process because vibration occurs from the cutting tool. After that, the good quality samples will be weight to measure the mass before and after the curing process.

(a) (b)

Figure 4.5 The example of samples after drying process (a) cement not fully covered KC and (b) good samples that mix well

(a) (b)

Figure 4.6 The example of rejected samples (a) crack happen at the edge and (b) broken sample that cannot be used for testing

Lastly, the curing process gains strength's maturity for the cement properties. The samples were submerged in the water for 28 days and the condition of the samples will be observed frequently to ensure water is enough throughout the process. Figure 4.7 shows the curing process of the samples before and after 28 days. After 28 days, the samples will be removed from the water and dried out for one day so that the samples are thoroughly dried as shown in Figure 4.8. This drying method is vital for the samples because any water trapped inside the samples will negatively impact the next process. Although some samples happen to be cracked during the process, they still can be used for testing as it does not affect the condition of the samples.

Figure 4.7 The curing process (a) before and (b) submerged in water for 28 days

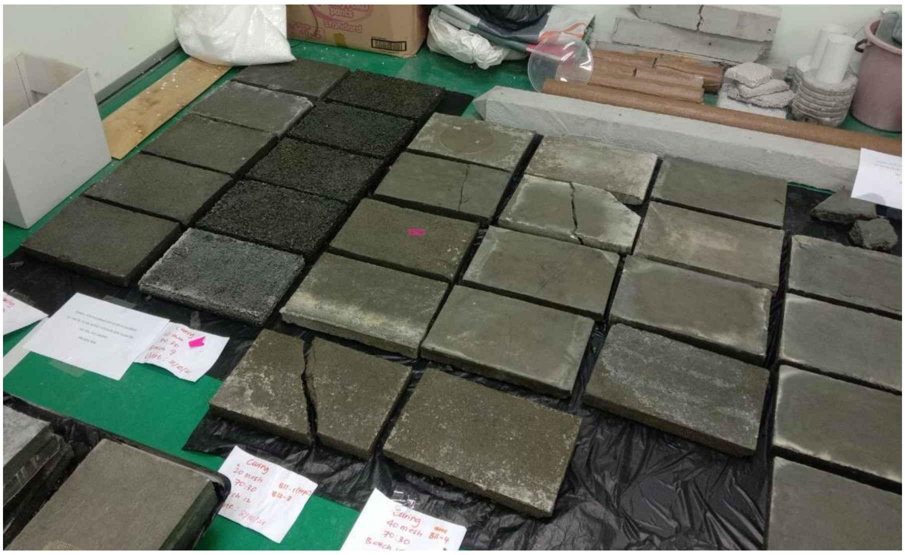


Figure 4.8 The sample been dried before proceeding next process

4.2 Mechanical Properties of Fire Resistance Door Sample

The performance of the applied study and experiment is reviewed to determine the mechanical properties of the sample from numerous tests, including the 3-point flexural test, compression test, and fire resistance test according to ASTM standards. Each testing will measure the average of 5 samples for each composition of samples. Hence, these tests will determine the best performance of a sample of kenaf core reinforced cement slurry for fire resistance door applications. In this research, sample from industry which made of cement, coconut fiber and polystyrene foam was used as the benchmark.

4.2.1 Flexural Performance

In this section, flexural performance was conducted by testing the samples using Universal Testing Machine (UTM) Instron 100kN as shown in Figure 4.9. The size of sample for the testing is 360 mm x 50 mm x 40 mm. The data is recorded thus the graphs were generated to comes out with the analysis and comparison of flexural performance for each composition with different size of kenaf core. Figure 4.10 illustrates the mode of failure occurs after the testing.

Figure 4.9 The example of 3-point bending test

Figure 4.10 The condition of sample after the testing

4.2.1.1 Flexural Strength of 20 mesh of Kenaf Core

Based on the Figure 4.11, the samples of 20 mesh KC linearly increase from 30 % to 10 %. Sample of 20 % KC and 10 % KC have major variance which is 0.498 MPa and 5.772 MPa. It increases to 91.37 % where its impact a lot in flexural strength. While 30 % of KC indicates the lowest flexural strength with the value 0.154 MPa. From the Figure 4.12, there is a small crack line appears where it can be concluded that 10 % KC is strong enough making it less susceptible to cracks while in Figure 4.13, there are large amount of porosity can be seen as the amount of matrix decreases. This is because bonding between the cement and kenaf core is lower. The result is supported with the study by Rossi et al. (2020) that stated the bond strength is required not only to ensure the safety in concrete action but also need to control the structural behavior and ensure the adequate ductibility. It can say that reducing the reinforcement material in the sample will increasing the flexural strength. Higher performance with smaller size KC will gives good impact and better mechanical strength.

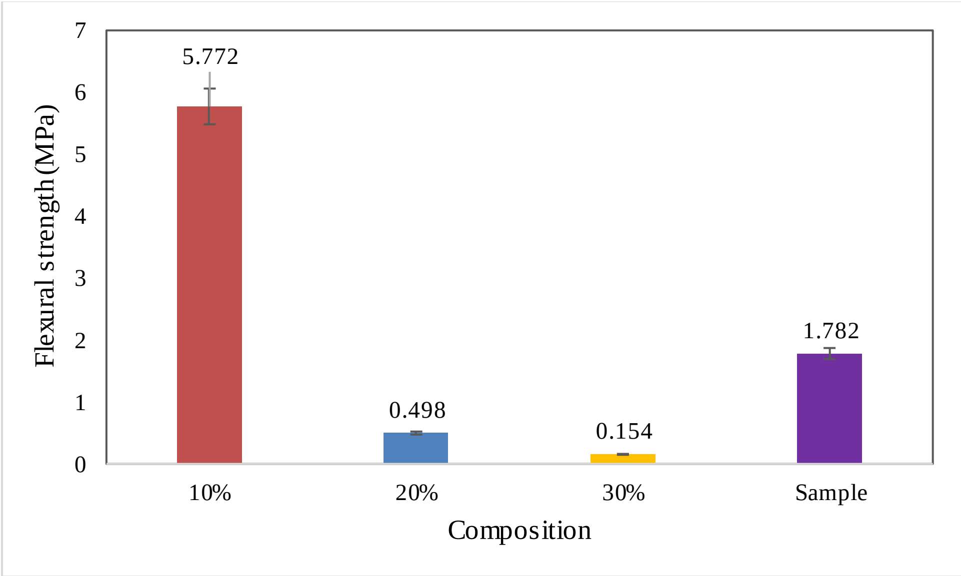


Figure 4.11 Comparison of flexural strength for 20 mesh composition

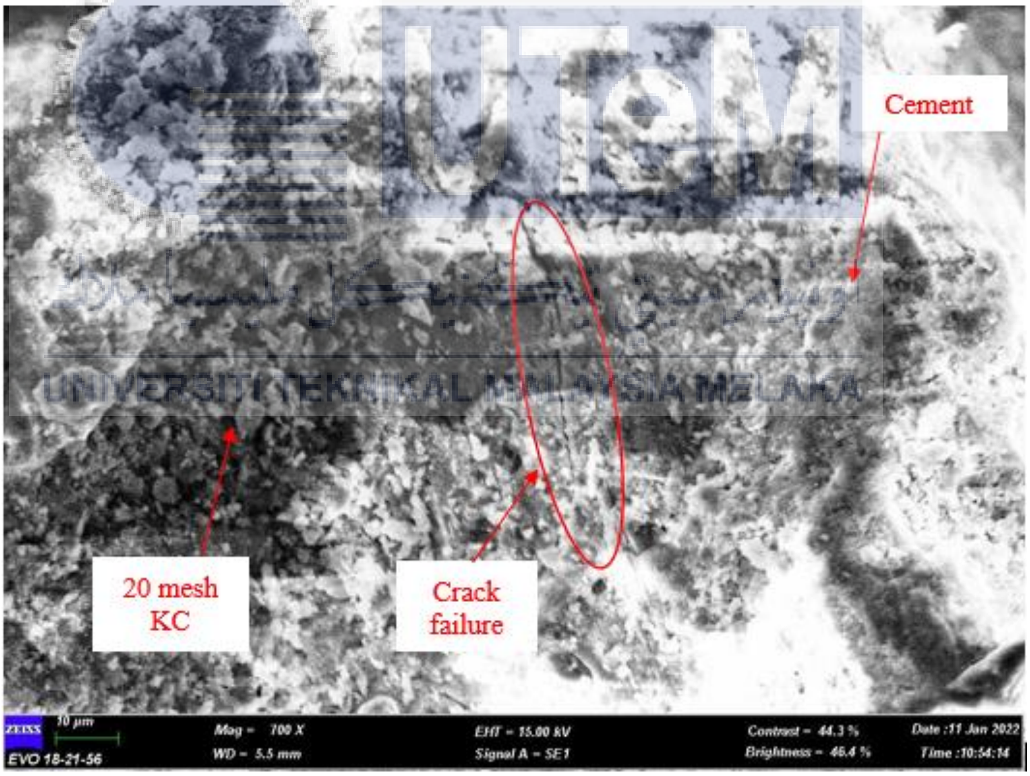


Figure 4.12 The small crack propagation line after flexural test of 10 % KC

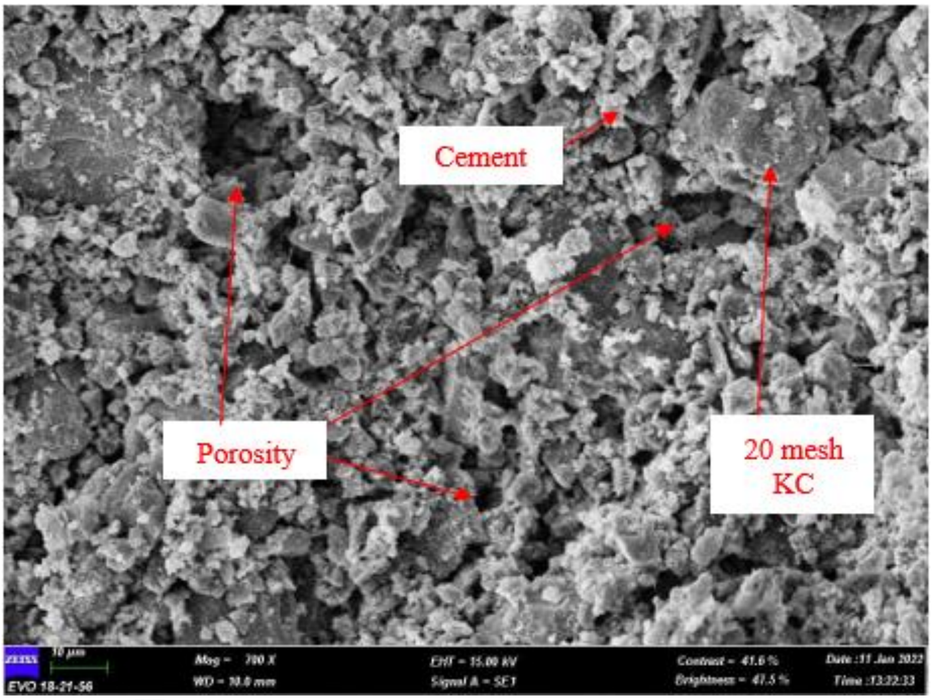


Figure 4.13 SEM analysis for 30 % KC

4.2.1.2 Flexural Strength of 10 mm of Kenaf Core

Figure 4.14 demonstrated the data of flexural performance for the composition of 10 mm in size of kenaf core had a downward trend. The discussion results begin with the highest performance of 1.872 MPa by 10 % of KC with 90 % of CS and the lowest performance of 0.73872 MPa by 20 % KC. This analysis highlights that sample of 10% composition showed and amazing improvement of 60.86 % as compared with the lowest performance. But, surprisingly the strength for 30 % composition is measured as 0.814 MPa which is slightly higher than the 20 % of KC. This explains that the higher the composition of KC, the lower the performance of the compression. Furthermore, curing process strongly influence the increasing of the flexural strength. To compare with the performance of 20 mesh, this size is slightly lower for the composition of 10 % but higher in 20% and 30 %. This is shown in Figure 4.15 that marks the reason where this size is lower in flexural strength.

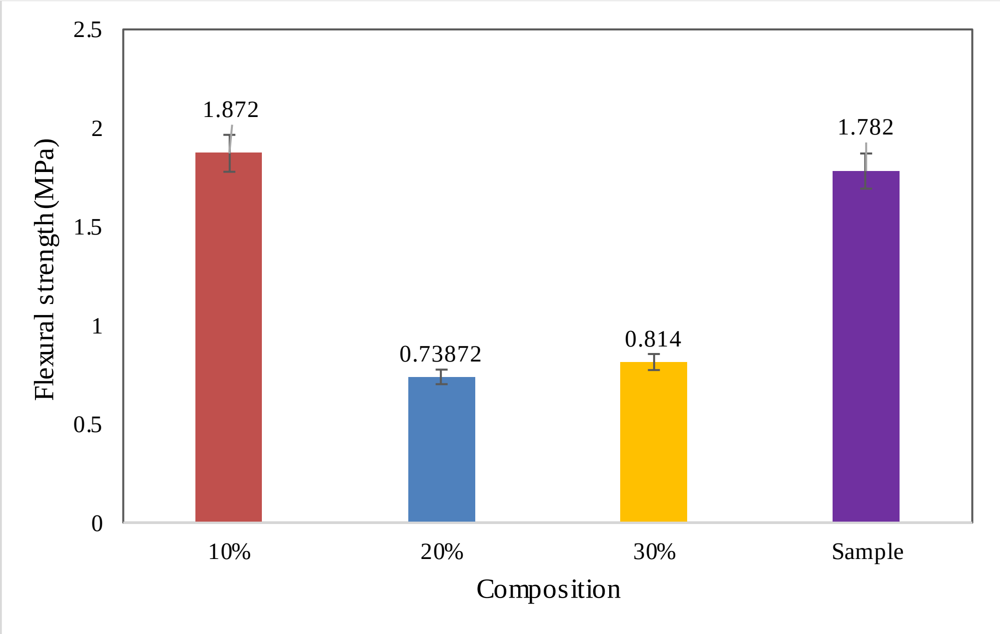


Figure 4.14 Comparison of flexural strength for 10 mm composition

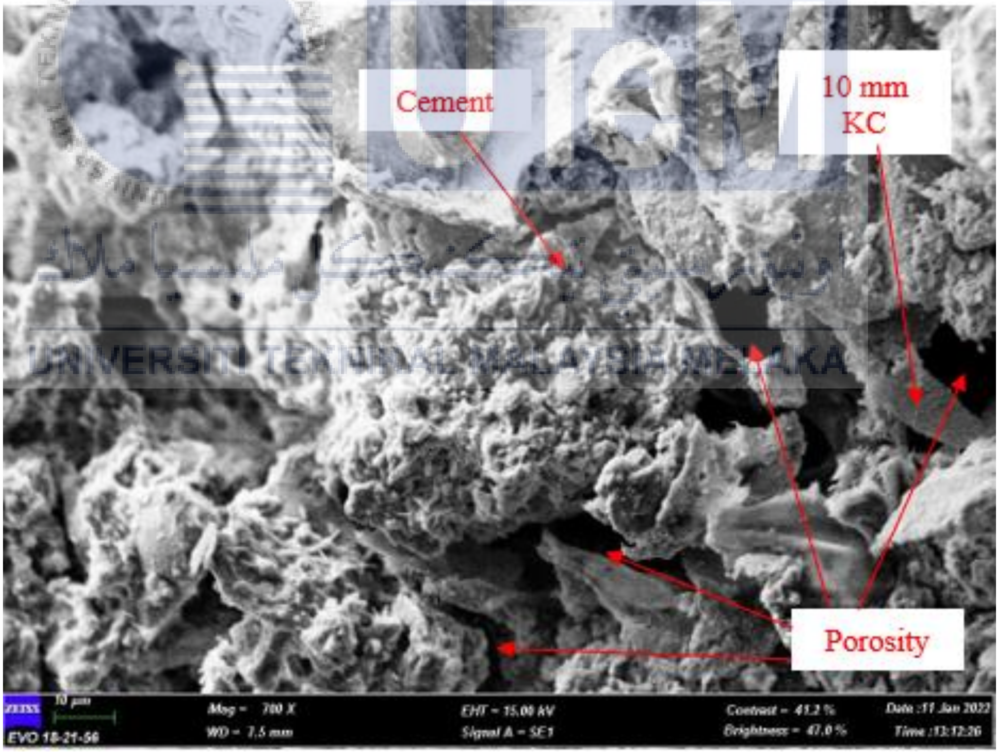


Figure 4.15 SEM analysis for 10 mm KC

4.2.1.3 Flexural Strength of 20 mm of Kenaf Core

Figure 4.16 indicated the flexural strength of 20 mm composition of 10 %, 20 % and 30 % with 3.037 MPa, 0.757 MPa and 0.429 MPa respectively. The trend of the chart shows that it is linearly decreasing in strength when more kenaf core is used in the sample. The result is in lines of earlier study by Zheng et al. (2018) that found when the fibre content is lower than 1%, the flexural strentgth rate growth slowly increasing while the fiber content more than 1% is increasing rapidly in terms of flexural strength rate. 10 % of KC indicates a surprisingly difference of 75.07 % in strength compared to the 20 % of kenaf core used in the sample when mix with cement slurry. It also slightly decreases in difference between 20 % and 30 % with 43.33 %. Figure 4.17 shows that there is a major crack in the sample were resulting to the lower value in flexural strength. In line with the recent study, Soltangharaei et al. (2021) stated that cracks in cementitious materials have been shown to affect the durability of concrete structures. Because of their low tensile strength and brittleness, cementitious materials are prone to cracking.

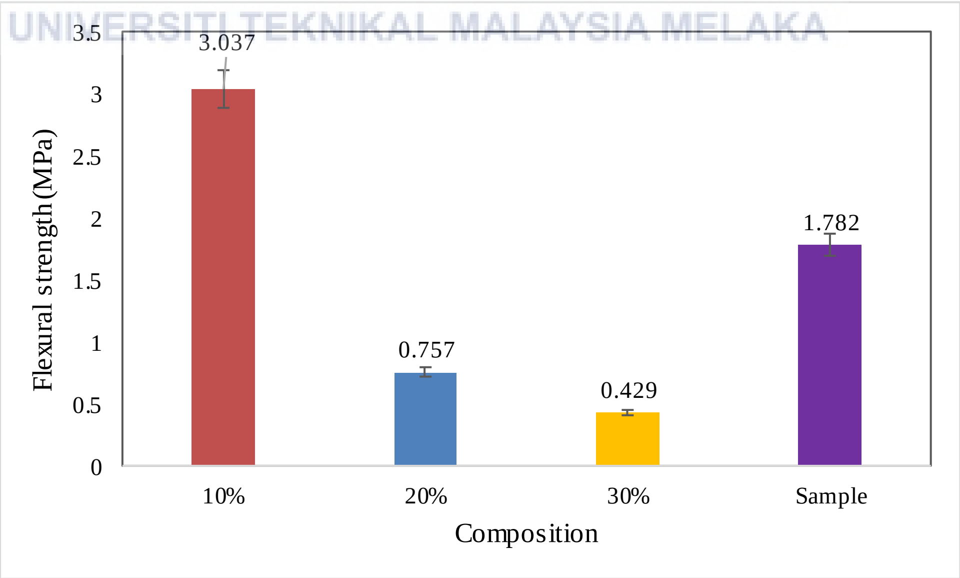


Figure 4.16 Comparison of flexural strength for 20 mm composition

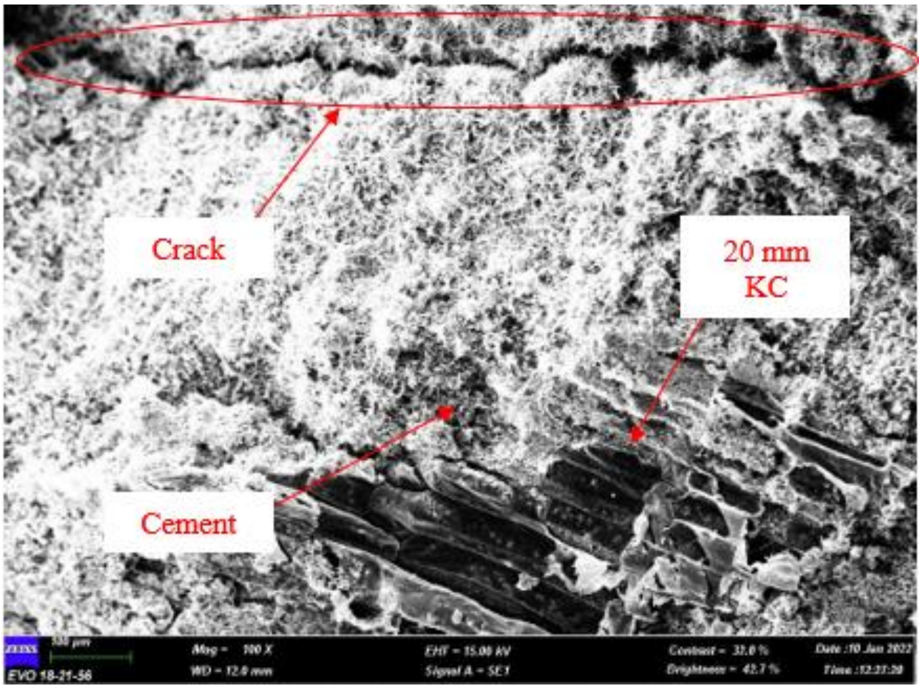


Figure 4.17 SEM analysis for 20 mm KC

4.2.1.4 Flexural Strength of 30 mm of Kenaf Core

Figure 4.18 shows the employment of 30 mm KC that have a linearly downward performance from 10 % then 20 % and 30 %. The flexural strength of 20 % KC shows 68.58 % differences compared to the 30 % KC with the strength of 1.55 MPa and 0.487 MPa respectively. Furthermore, 10 % KC indicates higher performance for 30 mm with 2.671 MPa. This is because using more reinforcement material will lower down the flexural strength of the sample where less amount of matrix material will give more porosity to the sample. This can generate lower bonding between kenaf core and cement slurry where it cannot generate higher flexural strength. Hence, as the content of kenaf core increases, cracking moments are significantly reduced as shown in Figure 4.19. This finding is consistent with the past research by Sabarish et al. (2020) that stated where the fibres' main roles in cement-based composites are to improve the toughness and post-cracking performance of the matrices.

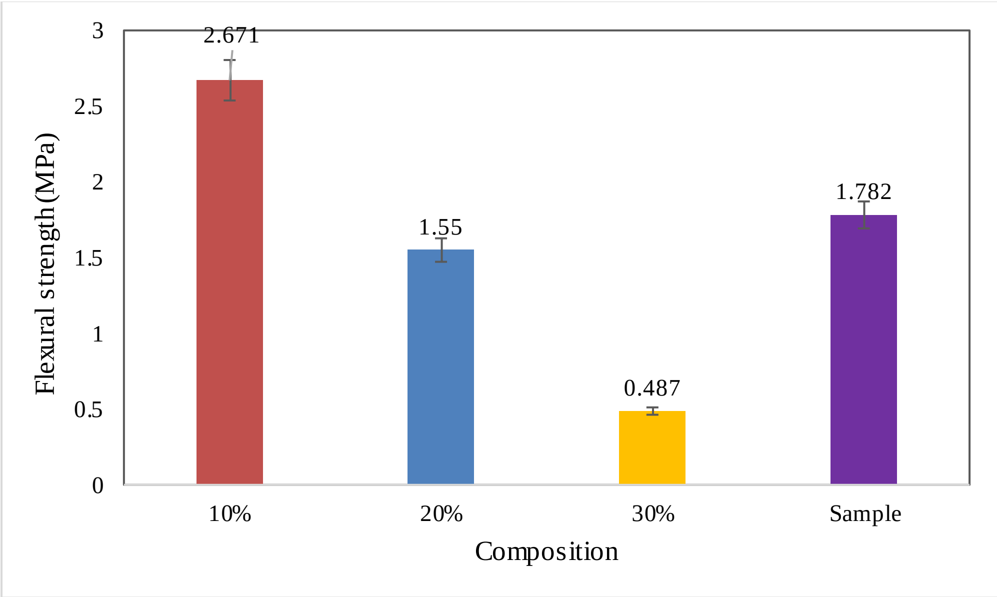


Figure 4.18 Comparison of flexural strength for 30 mm composition

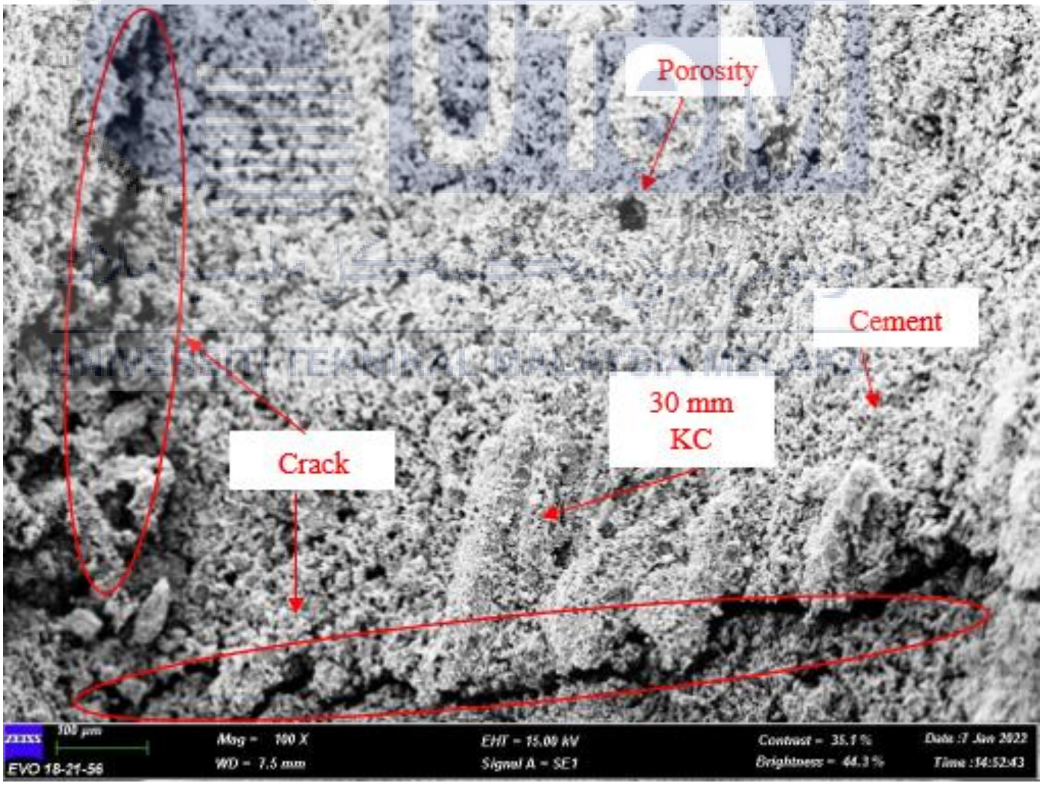


Figure 4.19 SEM analysis for 30 mm KC

To summarize all the results obtained for flexural strength, using larger size of kenaf core gives an impact to the matrix material which is cement slurry. This is proven by calculating the differences between 30 mm KC and 20 mesh KC where it shows significant distinctions with 53 % higher. As shown in Figure 4.20, when comparing 20 mesh KC where it can perform well during the flexural strength with 5.722 MPa than the sample from industry with 1.782 MPa. This huge differences of 68.3 % can be justified that smaller size of kenaf core have better potential in replacing other material such as polystyrene foam in the application of fire resistance door. The above finding is consistent with finding of past studies by Falliano et al. (2019) which stated that additonal of fibre content increase the flexural strength of the cement compared to cement without reinforcement. The scanning electron microscope images revealed that the kenaf core adheres well to the matrix, which is cement. The bonding of the fibres to the cement matrix is an important factor in determining the performance of reinforced composites.

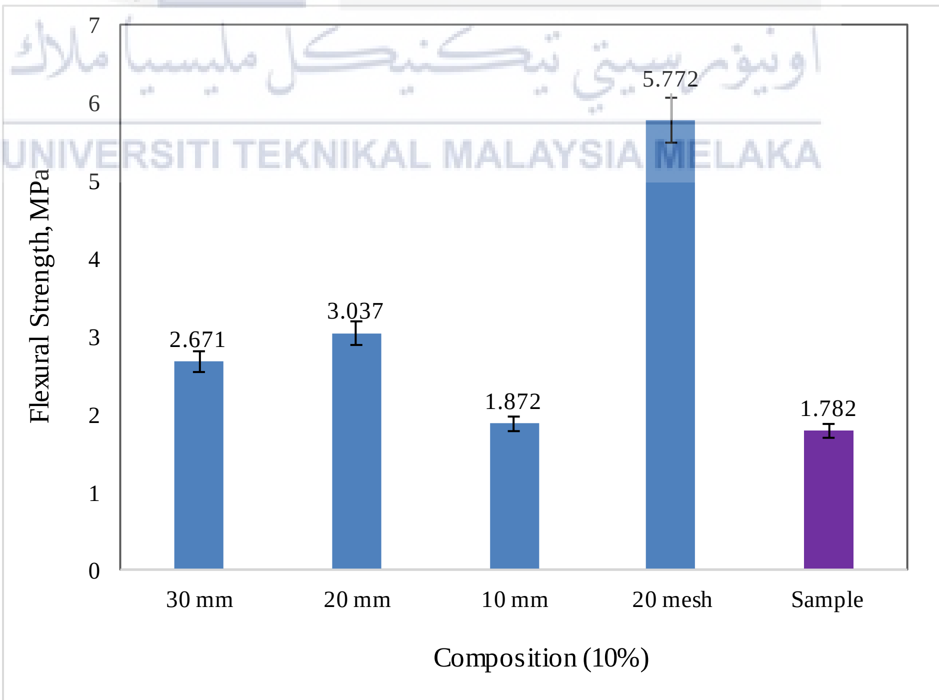


Figure 4.20 Comparison of flexural strength of the best for each size of composition

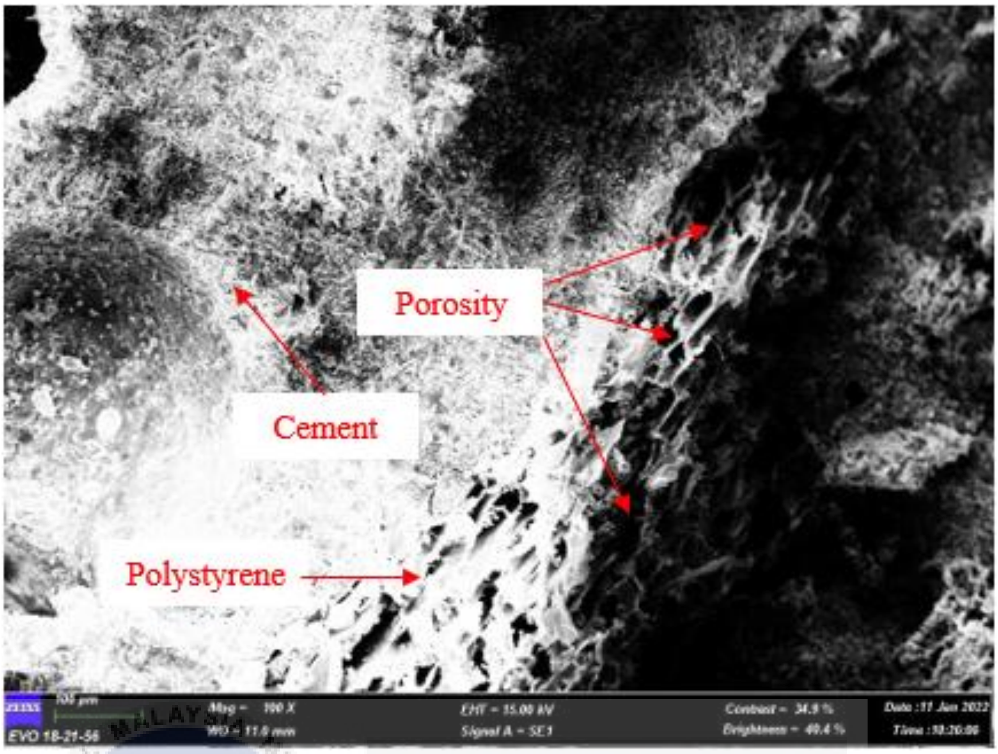


Figure 4.21 SEM analysis for sample industry

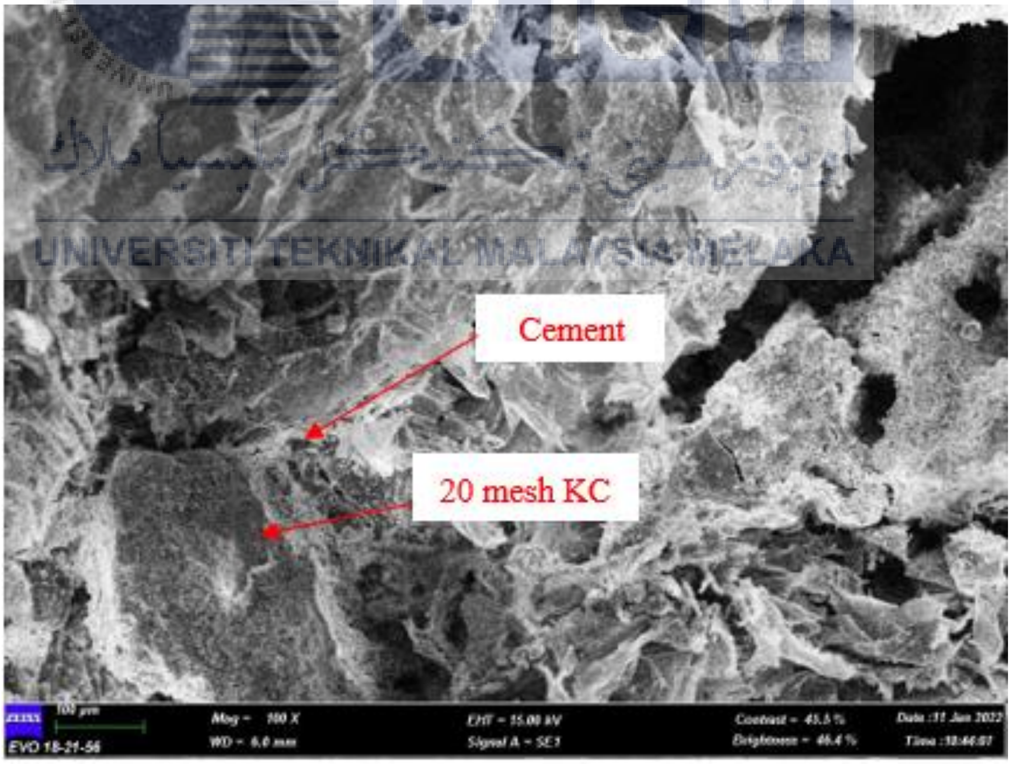


Figure 4.22 The bonding between cement and kenaf core

4.2.2 Compression Performance

In this part, compression test is test accordance with ASTM C39/C39M to determine the performance of the samples. The sample from industry was being tested first to observe the compression strength thus used as the benchmark to compare the performance from each composition.

4.2.2.1 Compression Test of 20 mesh of Kenaf Core

Figure 4.23 demonstrated that data of compression performance for the composition of 20 mesh in size of kenaf core had a downward trend when the composition increases from 10% to 30 %. The discussion results begin with the highest performance of 14.178 kN by 10 % of KC with 90 % of CS and the lowest performance of 0.170 kN by 30 % KC. This analysis highlights that sample of 10% composition showed and amazing improvement of 98.8 % as compared with the lowest performance. The force for 20 % composition is measured as 0.424 kN which is slightly higher than the 30 % of KC. Figure 4.24 illustrates the small crack failure occurs after the testing which indicates the reason behind the performance value of the compression. Research finding by Abdelmonem et al. (2019) also points towards the study that this weak interfacial zone may act as a micro-crack, causing cracks to form at the interface between the materials and hastening the breakdown of the concrete matrix, which may explain the trend of losses and reductions in strengths. This explains that the higher the composition of KC, the lower the performance of the compression. This is because lower amount percentage of cement was used that generally will lower the ability for the samples to withstand higher force.

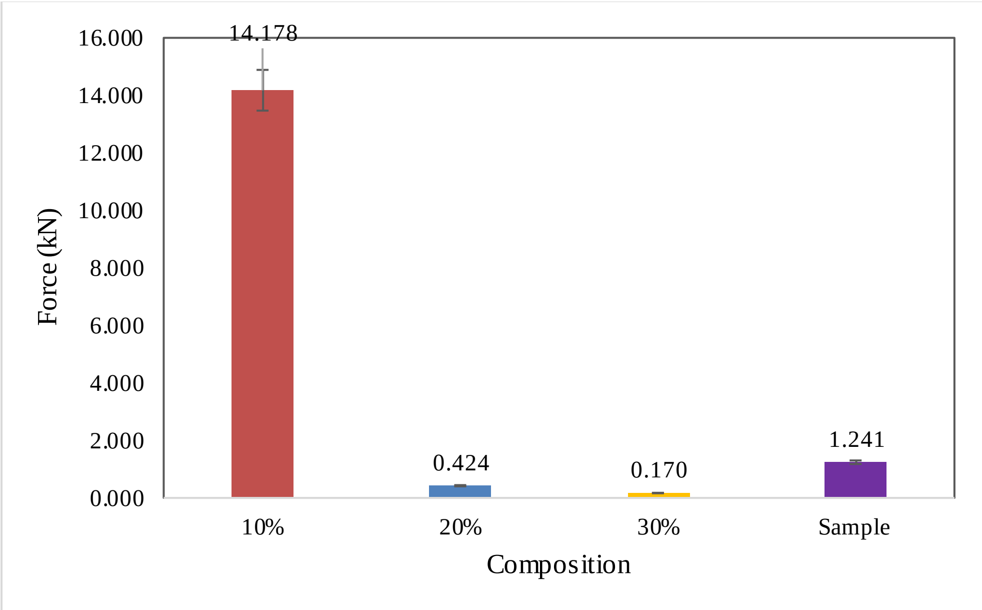


Figure 4.23 Comparison of compression strength for 20 mesh composition

Figure 4.24 Condition of 20 mesh KC after testing

4.2.2.2 Compression Test of 10 mm of Kenaf Core

Figure 4.25 shows that data of compression performance for the composition of 10 mm in size of kenaf core not having any trend. Based on the result obtained, sample of 20 % and 30 % of KC generated the value of 0.478 kN and 0.606 kN respectively. The value compression performance of 30 % KC was increasing by 21.1 % compared to 20 % KC. The sample of 10 % KC have highest performance of 25.74 % with the force of 0.762 kN compared with the 30 % KC. The force for each composition is slightly different between each other. Even though, the compressive strength will reduce when the fibre is content is higher and the size is larger, but it can increase in force when the size of the kenaf core is smaller just like illustrates in Figure 4.26 where crack occurs after the testing conducted but still can withstand higher load. This study can be supported with the research by Zheng et al. (2018) stated that if the fibre content is lower than 1%, the compressive strength rate can be increasing faster rather than the fiber content more than 1% as it rate of compressive strength become slower.

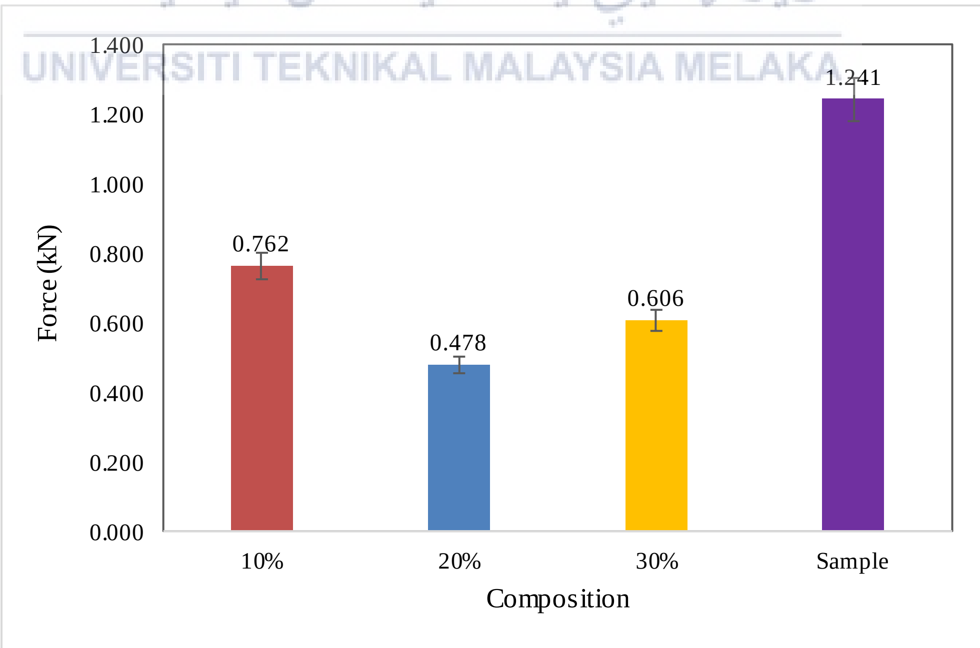


Figure 4.25 Comparison of compression strength for 10 mm composition

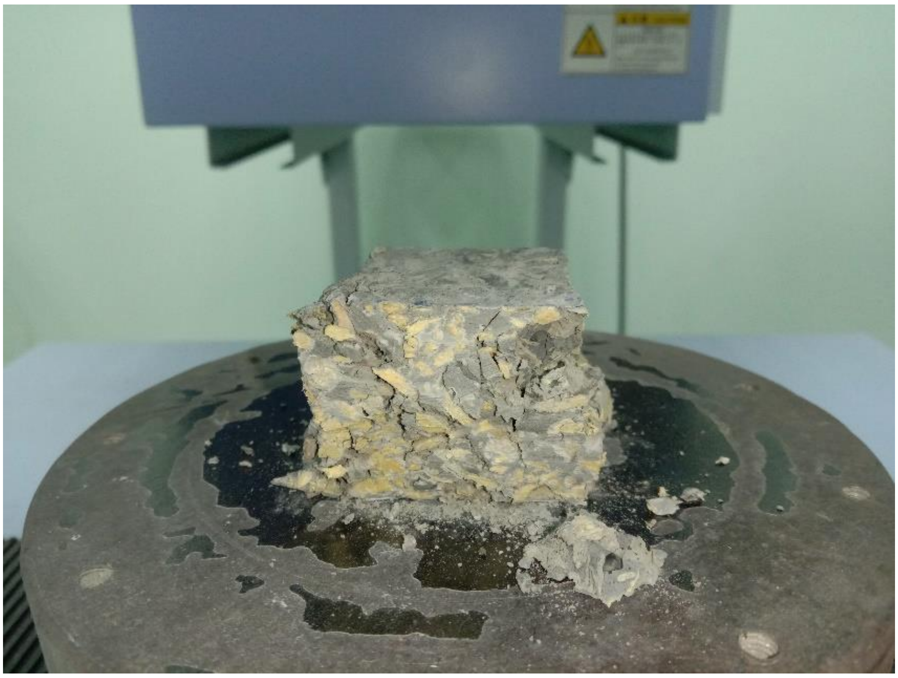


Figure 4.26 The condition of 10 mm KC after testing

4.2.2.3 Compression Test of 20 mm of Kenaf Core

Figure 4.27 shows the result for 20 mm composition where the trend of chart is decreasing gradually. The highest value of compression performance started with 1.83 kN which is 10 % of KC then continue decrease to 0.086 kN for 20 % and drop to the lowest is 30 % with the value is 0.123 kN. The characteristic of 20 mm KC is like 10 mm where the sizing is big but still smaller in size compared to 30 mm KC. This is consistent with the finding of Hilles and Ziara (2019) which showed that the fiber's ability to control micro cracking growth is primarily determined by the number of fibers. As a result, a greater number of fibers in the matrix increases the likelihood of a micro crack being intercepted by a fiber, resulting in higher compressive strength. Furthermore, the failure was sudden, brittle and destructive with loud sound without a compact sample like shows in Figure 4.28.

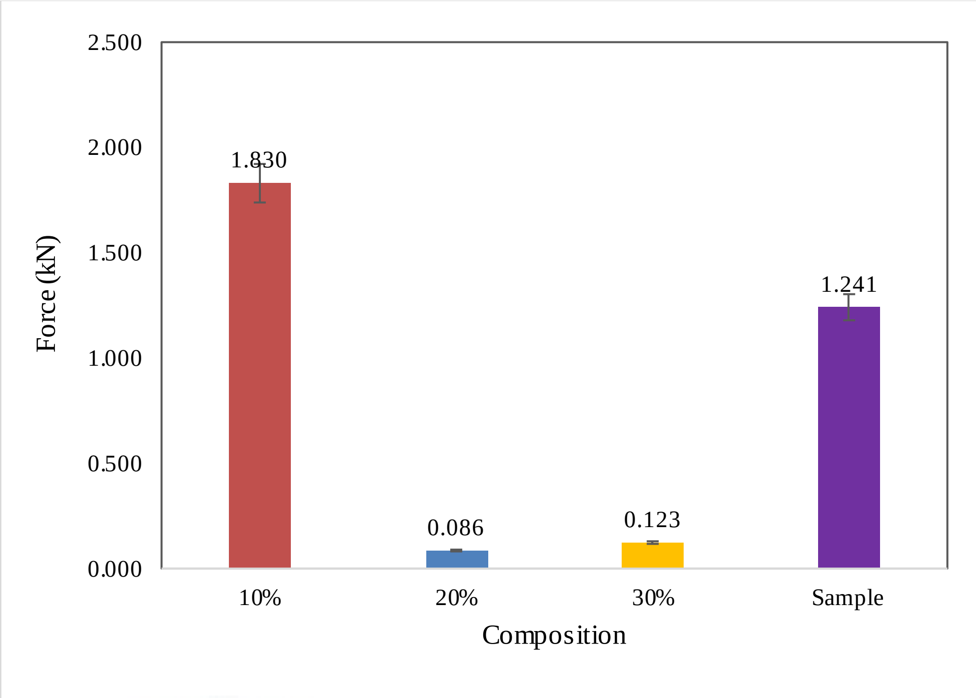


Figure 4.27 Comparison of compression strength for 20 mm composition

Figure 4.28 The condition of 20 mm KC after testing

4.2.2.4 Compression Test of 30 mm of Kenaf Core

Figure 4.29 demonstrated that data of compression performance for the composition of 30 mm in size of kenaf core had a downward trend when the composition increases from 10% to 30 %. The discussion results begin with the highest performance of 1.922 kN by 10 % of KC with 90 % of CS and the lowest performance of 0.265 kN by 30 % KC. This analysis highlights that sample of 10% composition showed improvement of 86.21 % as compared with the lowest performance. The force for 20 % composition is measured as 0.372 kN which is slightly higher than the 30 % of KC. This explains that the higher the composition of KC, the lower the performance of the compression. However, interestingly, this is contrary to a study conducted by Solahuddin (2022). The author comes out with the finding that the additional of kenaf fiber will reduced the compressive strength of the cement. This is because the cement was not completely dry and hardened before and after curing process.

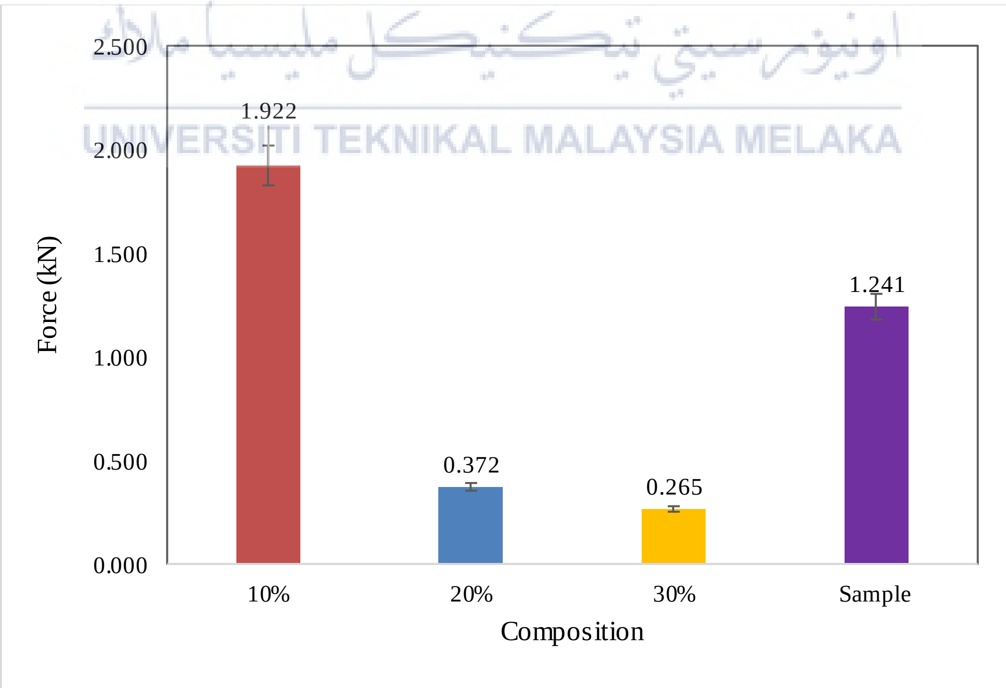


Figure 4.29 Comparison of compression strength for 30 mm composition

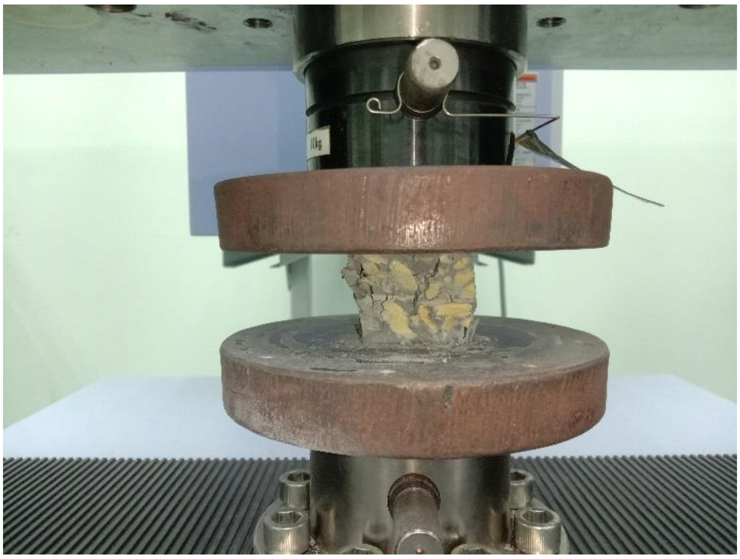


Figure 4.30 The condition of 30 mm KC after testing

To summarize all the findings for compression performance, Figure 4.31 indicates the comparison of compression strength for each size of composition. The smaller the size of kenaf core will give the best compression strength compared to the larger size. It showed that 20 mesh KC in size gives amazingly higher performance than other sizes. 20 mesh have huge potential to be withstand larger force as it differences between sample is 91.25 % which the sample only can withstand force of 1.241 kN compared to the 20 mesh KC with 14.178 kN. When comparing sample as benchmark with 30 mm, 20 mm and 10 mm, there are slightly differences in performance but still manage to have higher performance than the sample. The addition of kenaf core to cement can give it ductility, making it less susceptible to cracks, increasing its strength, and making it suitable for use in large scale structures that are constantly subjected to high forces. Hence, it can be concluded that this proves kenaf core as reinforcement material does enhance the performance of the sample.

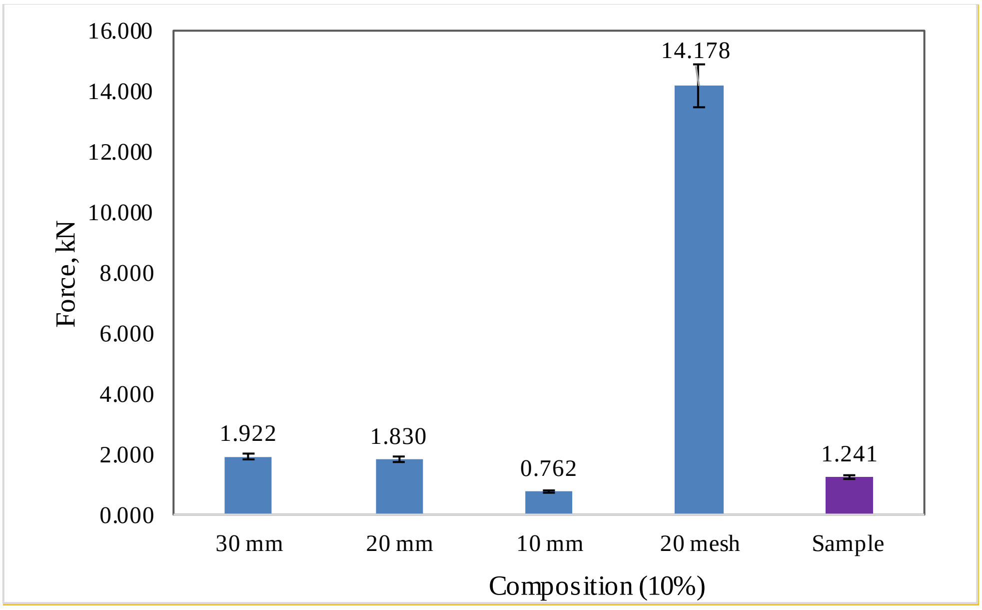


Figure 4.31 Comparison of compression strength of the best for each size composition

4.2.3 Fire Resistance Performance

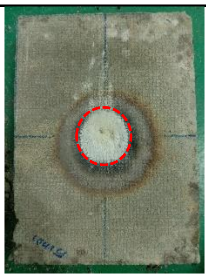
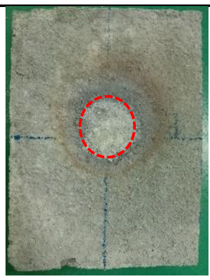
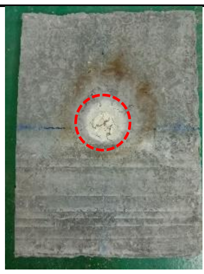
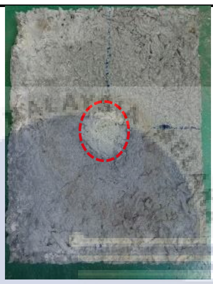
Fire resistance test is done in this research by carried out according to the ASTM E119 which is the standard test method for determining the ability for the building material to withstand fire in longer time. The reaction of the sample towards the fire source will be observed for 15 minutes, 30 minutes, 45 minutes and 1 hour to measure the spread of fire and it burnt until penetrate to the backside of the sample or not. Each composition of different size of kenaf core will be tested once.

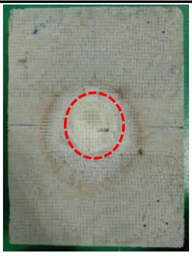
The performance of each composition after fire resistance test were shown in Table 4.1. This table illustrates the dimension area of burning and spread of fire. After the testing, it can be observed that larger size with higher composition of kenaf core was burnt easily with the formed of wood ash. Figure 4.32 indicates the comparison between 20 mesh, 20 mm and 30 mm in dimension area of burning and the condition after the area been dig up to see the depth of the burning after going through 45 minutes of fire resistance test. Size of 20 mm and 30 mm showed that the sample area of fire was burnt completely until it can penetrate to the backside of the sample while 20 mesh remain the same with just a little form of crack appear.

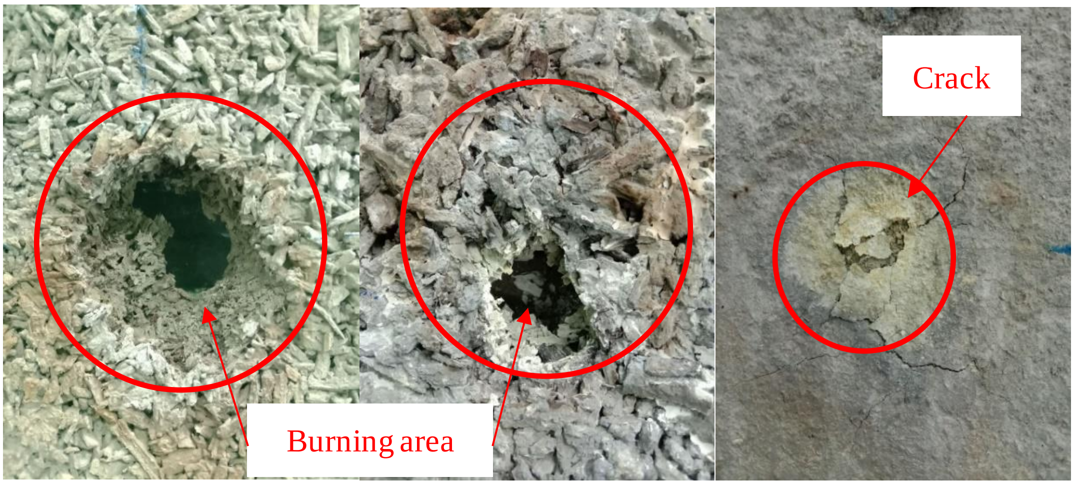
The results show that the smallest kenaf core size produces good performance. this is because the small size of kenaf core can fill any available empty space when mixed with cement. This can produce a good result and can be seen from Figure 4.33. This figure illustrates that after the 60 minutes of firing process, the sample remains intact and produces only a few dusts and does not burn completely. Thus, revealing fewer surface cracks, resulting in a reduction in temperature and a lower potential for fire spread. The result corresponding with the study by Yin et al. (2019) where it stated that both prototypes passed the 2-hour fire resistance test with no integrity failures or significant leakage. Hence, numerous cracks on the surface of the prototypes allowing for higher rates of heat transfer to the prototype's backside.

Table 4.1 The performance of char formed on the samples after test

Sample		**Time (min)**			
		15	**30**	**45**	**60**
20 mesh	**10%**	 Φ = 40 mm	 Φ = 40 mm	 Φ = 40 mm	 Φ = 50 mm
	20%	 Φ = 50 mm	 Φ = 50 mm	 Φ = 60 mm	 Φ = 60 mm

	30%	 Φ = 45 mm	 Φ = 55 mm	 Φ = 60 mm	 Φ = 60 mm
10 mm	**10%**	 Φ = 50 mm	 Φ = 50 mm	 Φ = 70 mm	 Φ = 40 mm
	20%	 Φ = 50 mm	 Φ = 60 mm	 Φ = 50 mm	 Φ = 40 mm
	30%	 Φ = 60 mm	 Φ = 65 mm	 Φ = 40 mm	 Φ = 50 mm
20 mm	**10%**	 Φ = 50 mm	 Φ = 70 mm	 Φ = 60 mm	 Φ = 40 mm
	20%	 Φ = 40 mm	 Φ = 60 mm	 Φ = 75 mm	 Φ = 50 mm

	30%	 Φ = 60 mm	 Φ = 60 mm	 Φ = 60 mm	 Φ = 40 mm
30 mm	**10%**	 Φ = 70 mm	 Φ = 80 mm	 Φ = 70 mm	 Φ = 60 mm
	20%	 Φ = 50 mm	 Φ = 70 mm	 Φ = 70 mm	 Φ = 60 mm
	30%	 Φ = 50 mm	 Φ = 80 mm	 Φ = 70 mm	 Φ = 60 mm
Sample industry		 Φ = 50 mm	 Φ = 60 mm	 Φ = 60 mm	 Φ = 30 mm



(a) (b) (c)

Figure 4.32 Comparison after 45 minutes of fire resistance test (a) 20 mm (b) 30 mm and (c) 20 mesh

(a) (b)

Figure 4.33 Comparison after 60 minutes of fire resistance test of (a) sample industry and 20 mesh

4.3 The best composition of fire resistance door

The present findings show the overall best composition that gives well performance towards each testing is sample of 20 mesh with 10 % composition mix with cement. This is because smaller size of kenaf core will gives more interfacial bonding of the composites when having mixing with the cement. Furthermore, when compared with the sample from industry, this composition considered as a potential application in fire resistance door in replacing other materials because of the high resistance in fire and high performance in flexural and compression strength.

Moreover, small size of kenaf core can be a medium to transfer the heat or storage heat as illustrates in Figure 4.34 thus, advantages of adding kenaf core as the reinforcement material will lead to reduce the release of carbon and other gases to the environment. Abbas et al. (2022) found that the addition of fibres will increase the compressive and flexural strength of the cement-based composite which is in good agreement with the results of the present study. It stated that composites reinforced with kenaf fibres can achieved highest mechanical properties when compared to other fibres. Hence, using kenaf core can developed new application of fire resistance door in terms of lightweight, high resistant to fire and affordable in price.

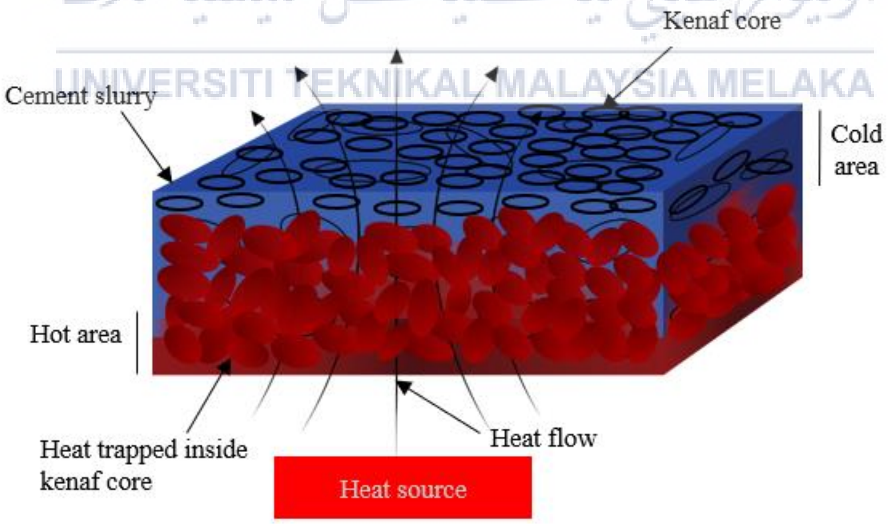


Figure 4.34 Illustration of heat moves along the fire resistance door

CHAPTER 5

CONCLUSION

5.1 Conclusion

The purpose of this study is to fabricate the fire resistance door application using kenaf core reinforced cement slurry. The samples for this study were made of different ratios with different size of kenaf core. The results of this study indicate that;

a) Successfully made the fabrication of fire resistance door using kenaf core mix with cement slurry.
b) Each samples have different ratios of kenaf core and cement slurry with different sizing of kenaf core.

The second objective of this study is to investigate the mechanical properties of kenaf core reinforced cement slurry in various ratios. The significant conclusion for this objective as below;

a) From the overall flexural performance analysis, the sample of kenaf core size 20 mesh with 10% composition is proven has the ability to withstand force better than other size of kenaf core and composition. The best performance which shown by sample sizing of 20 mesh with the highest flexural strength of 5.772 MPa which increase 69 % compared to the sample from industry with 1.782 MPa.

b) From the overall compression test analysis, it can be concluded that the sample of kenaf core size 20 mesh with 10% composition achieve the highest compression strength with the value of compression force is 14.178 kN. This result shows that 91 % improvement achieved compared to the sample from industry with the value of 1.241 kN.

c) From the overall observation when analysis the fire test, it can be concluded that most of samples can withstand longer time during the fire test which is from 15 minutes to 1 hour. The size kenaf core of 20 mesh with 10 % composition showed significant result which the sample does not burn out easily and only slightly crack occurs.

Lastly, the third objectives is to recommend the best kenaf core reinforced cement slurry ratio for fire resistance door applications. After the analysis was carried out, the result obtained is shown below;

a) Size kenaf core of 20 mesh (0.84 mm) with 10 % of composition mix with 90 % of cement slurry is recommended to be the best composition.

b) Size kenaf core of 20 mesh had a good bonding with cement slurry with best performance for flexural strength, compression strength and fire resistance test.

c) The evidence from this study suggests that kenaf core can be added to the cement slurry to improve the performance of fire resistance door.

5.2 Recommendations

This research has thrown up many questions in need for further investigation related to this field of study. Hence, there are few recommendation suggestions for upcoming research. The following are recommendations proposed;

a) The fabrication process, which is the development of the sample, needs to be improved by changing the method of mixing the cement and kenaf core, drying method, curing process for further investigation.

b) The experimental testing for fire resistance test was suggested for further studies.

c) Study on the behavior of different temperature towards the performance of fire resistane door.

5.3 Green Element

Green product is one that is designed to have green element and have as little environmental impact as possible throughout its entire life cycle and even after it is no longer useful. It is critical to always strive for green technology in order to keep the earth from causing additional pollution and environmental issues. Using natural fibre instead of synthetic fibre will protect our environment and human being. Therefore, this research is using kenaf core in production of fire resistance door instead of using other materials. Using kenaf core are expected can withstand fire and decreasing the weight of fire resistance door subsequently make it easier for the installation of fire resistance door as it it light and easy to handle. Addition, kenaf core also expected can reduce the usage of cement in the production of fire resistance door thus will reduce the releasing of carbon to the environment. This is because cement is not environmentally firendly, this results in waste in the economy and pollution of the environment and to manufacture cement, higher energy consumption needed compared to kenaf core. Kenaf core has high potential to solve the problem since its low in toxicity. With the kenaf core used as reinforcement for the composite of fire resistance door, the amount of cement used as a matrix for manufacturing the fire door can be reduced, as can the amount of waste produced for the environment and landfill.

5.4 Sustainability

Sustainability is the capacity to meet current demands thus is critical in ensuring that the ecosytem is continously implemented and maintained so that future generations can maintain current technology. It is also necessary to keep our surroundings in order while meeting our human needs and desires in life. By using natural fibre which is kenaf core are compatible as kenaf is sustain because only needed four to six months to be harvested. Kenaf plant also very suitable to be planted in Malaysia. One factor to consider is that the manufacturing material was easily accessible. Since kenaf plant became a commercial plant promoted by the Malaysian governemnt to replace tobacco plantations, the kenaf core has been easily accessible. As a result of its accessibility, the kenaf core used as reinforcement has completely fulfilled the principle of sustainability. Therefore, kenaf core can reduce the amount of cement in production of fire resistance door due to its high strength but low in cost and lead to produce an eco friendly product to the environment.

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APPENDICES

APPENDIX A Gantt chart for PSM 1

Gantt chart for PSM 1																
No	**Task project**	**Plan/Actual**	**Week**													
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Registration of PSM title	Plan														
		Actual														
2	Briefing of PSM and project explanation by supervisor	Plan														
		Actual														
3	Drafting and writing of Chapter 2 Literature Review	Plan														
		Actual														
4	Presentation of draft Chapter 2 with supervisor	Plan														
		Actual														
5	Submission of Chapter 2	Plan														
		Actual														
6	Briefing of Chapter 1 with supervisor	Plan														
		Actual														
7	Writing of Chapter 1	Plan														
		Actual														
8	Submission of Chapter 1	Plan														
		Actual														
9	Discussion of Chapter 3 with supervisor	Plan														
		Actual														
10	Draft and writing of Chapter 3	Plan														
		Actual														
11	Submission of Chapter 3	Plan														
		Actual														
12	Writing Chapter 4 and Chapter 5, expected outcome and conclusion, abstract	Plan														
		Actual														
	Submission of report PSM 1 first draft	Plan														

13		Actual														
14	Last correction of the report	Plan														
		Actual														
15	Submission of report to supervisor and panels	Plan														
		Actual														
16	Preparation slide and presentation PSM 1	Plan														
		Actual														

APPENDIX B Gantt chart for PSM 2

Gantt chart for PSM 1																	
No	**Task project**	**Plan/Actual**	**Week**														
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Discussion planning task with supervisor	Plan														
		Actual														
2	Raw material preparation and equipments	Plan														
		Actual														
3	Fabrication process	Plan														
		Actual														
4	Testing	Plan														
		Actual														
5	Analysis of the data	Plan														
		Actual														
6	Writing of Chapter 4	Plan														
		Actual														
7	Submission of Chapter 4	Plan														
		Actual														
8	Writing of Chapter 5	Plan														
		Actual														
9	Submission of Chapter 5	Plan														
		Actual														
10	Submission first draft report PSM 2	Plan														
		Actual														
11	Submission second draft report PSM 2	Plan														
		Actual														
12	Preparation for presentation of PSM 2	Plan														
		Actual														

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: **RESEARCH AND DEVELOPMENT OF FIRE RESISTANCE DOOR FROM KENAF CORE AND CEMENT SLURRY**

SESI PENGAJIAN: **2021/22 Semester 1**

Saya **NUR HAZIRAH IFFAH BINTI HASHIM**

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☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☑	TIDAK TERHAD	

Disahkan oleh:

Alamat Tetap:

793, JLN S2 K21/3 VISION HOMES,

70300 SEREMBAN,

NEGERI SEMBILAN

Tarikh: 17/01/2022

Cop Rasmi:

ASSOCIATE PROF. IR. TS. DR. MOHD YUHAZRI BIN YAAKOB
Deputy Dean (Research & Industrial Link)
Faculty of Mechanical and Manufacturing Engineering Technology
Universiti Teknikal Malaysia Melaka

Tarikh: 18 January 2022

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.