INVESTIGATION OF LOCAL EMPTY FRUIT BUNCH PERFORMANCE WITH ADDING CEMENT BONDED FIBER

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FACULTY OF ENGINEERING

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DECLARATION

I hereby declare that this thesis was submitted to Universiti Malaysia Sabah as partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering. This thesis has not been submitted to any other university for any degree. I also certify that the work described herein is entirely my own, except for quotations and summaries sources of which have been duly acknowledged.

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26 July 2022

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ABSTRACT

The largest producers of agricultural waste came from the palm oil industry, particularly the oil palm empty fruit bunch (OPEFB). In Malaysia, palm oil mills have been reported to generate 2.4 million tons of OPDEFB annually, where most of it ditched as waste due to its bulky form and poor economic value. Improper disposal of the empty fruit bunches (EFB) leads to negative implication to the environment. Thus, integrating the local empty fruit bunch fiber into the cement will produced Fiber Reinforced Cement Composite (FRCC) which is enhanced in the mechanical properties. This study was carried out to investigate the performance of local empty fruit bunch with adding cement bonded fiber. The mechanical properties such as compressive strength and water absorption was evaluated through compression test and water absorption test. The percentage of fiber 1%, 2%, 3%, 4% and 5% were replaced with the sand weight in the 215mm x 96mm x 70mm brick specimens. The cement-sand mix ratio used was 1:4 and the cement-water ratio of 0.47. The result reveal that the optimum amount of EFB fiber content was 3% that yielded up to 50% of increased in strength development when it is compared to the control specimen. Besides, the study found out that excessive amount of EFB fiber content added in the cement composite will decrease the compressive strength and continue to increase water absorption.

ABSTRAK

SIASATAN PRESTASI TANDAN BUAH KOSONG TEMPATAN DENGAN MENAMBAH SIMEN FIBER TERIKAT

Pengeluar terbesar sisa pertanian adalah daripada industri minyak sawit, khususnya tandan kosong kelapa sawit (OPEFB). Di Malaysia, kilang kelapa sawit telah dilaporkan menjana 2.4 juta tan OPDEFB setiap tahun, di mana kebanyakannya dibuang sebagai sisa kerana bentuknya yang besar dan nilai ekonomi yang rendah. Pelupusan tandan kosong (EFB) yang tidak betul membawa kepada implikasi negatif kepada alam sekitar. Oleh itu, penyepaduan serat tandan buah kosong tempatan ke dalam simen akan menghasilkan Komposit Simen Bertetulang Serat (FRCC) yang dipertingkatkan dalam sifat mekanikal. Kajian ini dijalankan untuk menyiasat prestasi tandan buah kosong tempatan dengan penambahan gantian terikat simen. Sifat mekanikal seperti kekuatan mampatan dan penyerapan air dinilai melalui ujian mampatan dan ujian penyerapan air. Peratusan gentian 1%, 2%, 3%, 4% dan 5% telah digantikan dengan berat pasir dalam spesimen bata 215mm x 96mm x 70mm. Nisbah campuran simen-pasir yang digunakan ialah 1: 4 dan nisbah simen-air 0.47. Keputusan menunjukkan bahawa jumlah optimum kandungan gantian EFB ialah 3% yang menghasilkan sehingga 50% peningkatan dalam pembangunan kekuatan apabila dibandingkan dengan spesimen kawalan. Selain itu, kajian mendapati jumlah kandungan gantian EFB yang berlebihan ditambah dalam komposit simen akan mengurangkan kekuatan mampatan dan terus meningkatkan penyerapan air.

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LIST OF ABBREVIATION

OPEFB	Oil Palm Empty Fruit Bunch
EFB	Empty Fruit Bunch
FRCC	Fiber Reinforced Cement Composite

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Cement, in general, adhesive substances of all kinds, which are finely ground powders that, when mixed with water, set to a hard mass result from hydration (Britannica, n.d.). The application of cement usually in building construction mostly required the composite material that must be good in bending, compression strength and internal bonding. Therefore, integrating the cement with a natural cellulosic fiber strengthen the structural vulnerabilities which is called Fiber-Reinforced Cement Composites (FRCCs). There are two types of fibers that can be extracted from the empty fruit bunches by retting beating process which are the stalk and the spikelet (Musa *et al.*, 2017). The empty fruit bunches consist about 20-25% stalk and 75-80% spikelet (Xiang *et al.*, 2015).

As a result, the concrete strengthened with short fibers significantly increases its efficiency and negates its drawbacks, such as low tensile strength, poor ductility and low absorption ability (Akbar & Liew, 2021). The natural fibers reduce the weight of the composite, improves the strength in addition it is easy to handle and processing (Danso, 2017). The usage of natural fibers also improves the cracking resistance and also improves post cracking behavior (Kriker *et al.*, 2008). The natural fibers become the sustainable building material due to its salient features such as low cost, environmental friendly in production and handling (Ramakrishna & Sundararajan, 2005). Therefore, this shows a great interest developed towards the natural fibers due to high specific modulus, lower weight and better mechanical properties (Norul Izani *et al.*, 2013). The FRCCs have a wide range of applications such as sewer pipes, thin concrete shell roofs and tunnel linings.

The largest producers of agricultural waste came from the palm oil industry, particularly the oil palm empty fruit bunch (OPEFB). The extraction of palm oil from the fresh fruit bunches generates the major solid waste due to the extraction process. In Malaysia, palm oil mills have been reported to generate 2.4 million tons of OPDEFB annually, where some of it was used as fuel to generate electricity and producing steam, while most of it ditched as waste. Every fruit bunch produces nearly around 6-7% of kernel, 21% palm oil, 14-15% fiber, 6-7% shell and 23% empty fruit bunch (Rama Rao & Ramakrishna, 2021). Thus, every 1 to of palm oil production results 1.1 tons of fiber waste (Raut & Gomez, 2016). Due to its bulky form, EFB has a poor economic value and creates a disposal difficulty. Conventionally, it is burnt, disposed of in landfills, or composted to organic fertilizer (Isroi *et al.*, 2012). However, EFB is no longer advised for burning since it pollutes the air. As a result, optimizing the use of EFB as a feedstock is a must in the chemical, energy and biomaterials sectors is necessary to address these issues and improve its judicious use as feedstock for valuable products (Reneta Nafu *et al.*, 2015).

In order to investigate the structure for fiber-reinforced cement composite, the compression test can be conducted. The compression tests are essential for determining the elastic and compressive fracture properties of brittle and low-ductility materials. For each increase of load, the maximum fiber stress and strain are computed. In this test, a graph of stress-strain can be generated. Flexural test findings may generally be used to estimate the specimen's modulus of elasticity, compressive yield point, compressive yield strength and compressive strength. The greatest stress in the outermost fiber is known as compressive strength. Young modulus measurement can be determined from the slope of the stress-strain curve.

Once done collecting all the research for literature review, the objective of this research project is to investigate the performance of local empty fruit bunch when the cement bonded fiber was added. This project will further the study on the mechanical properties and behavior of the fiber reinforced cement composite. To achieve the objective of this experiment, the compression test along with the density and water absorption test will be conducted to examine the mechanical properties of the fiber reinforced cement composite.

1.2 Problem Statement

In construction, bricks are the most important things that used to construct walls. It also used as filler in the foundation of the building, noise insulation, thermal insulation and divided the space into various room. However, the common concrete bricks are less strong and durable as it is more vulnerable to seismic damage due to its low resistance to tension and torsion loads. The concrete bricks will easily crack when its tensile capacity is exceeded. Thus, producing a concrete brick that enhanced in strength is needed to overcome this problem in the construction industry.

The main reason for incorporating fibers into the cement matrix is to provide reinforcement for concrete products, increase tensile strength by delaying crack growth, and increase strength by transmitting stress across a cracked section. Other benefits of adding fiber to concrete include higher fracture toughness, modified elastic modulus qualities, and decreased the density. Increased the fiber content in concrete is not feasible since it will induce 'balling' during mixing, affecting the characteristics of concrete products.

On the other hand, palm oil industry is one of the largest producers for agricultural waste in Malaysia. Empty fruit bunch has a poor economic value and creates a difficulty during disposal due to its bulky form. Furthermore, the EFB are not only underutilized, but they are also typically pollutant sources. Therefore, the fiber-reinforced composite cement is the best way to overcome these problems due to its eco-friendly, low cost and sustainable aspects along with its improvement in strength, high specific modulus, lower weight and better mechanical properties. As a summary, the statement of problems observed are the low compressive strength of brick and large numbers of oil palm empty fruit bunch as an agriculture waste.

1.3 Research Objective

The aim of this research project is to investigate the local empty fruit bunch performance with adding cement bonded fiber. This aim can be achieved by the objectives below.

1. To produce the Fiber Reinforced Cement Composite (FRCC) brick and conduct the compression test and water absorption test.
2. To carry out the modelling of Fiber Reinforced Cement Composite (FRCC) using Finite Element Analysis (FEA).
3. To determine the optimum fiber content that yield the maximum compressive strength.

1.4 Scope of Work

The scope of this project covers the following:

a) Research related to fiber reinforced composite cement conducted through literature review.

Literature reviews are conducted to gain background knowledge in the fiber reinforced composite cement, compression test for Fiber Reinforced Cement Composite (FRCC) and any relevant information related to this topic. All the information was extracted from many sources such as articles, eBooks and lecture notes. More focus given to the previous research that related to the FRCC mechanical properties and compression test performed on the FRCC.

b) Performing numerical analysis.

Numerical analysis using ABAQUS will be performed on the compression performance of fiber reinforced composite cement. It used a numerical approximation with mathematical analysis to obtain the compressive strength of the FRCC.

c) Performing the compression test to obtain the mechanical properties of FRCC.

Compression performance test will be done to investigate the performance and mechanical properties of the FRCC. It usually used to determine the compressive strength and modulus of the specimen.

d) Comparing the compression performance of the FRCC between the numerical analysis and compression performance result.

The result from both compression test and numerical analysis will be compared to see the difference or approximation between the results for both analyses.

1.5 Research Methodology

A lot of literature review required for this project because it will provide necessary theoretical information about the fiber reinforced composite cement and also the numerical analysis on the performance of FRCC that will be verified through the compression test.

a) Numerical Analysis

Numerical analysis will be performed on the compression performance of fiber reinforced composite cement using ABAQUS. It used a numerical approximation with mathematical analysis to obtain the compressive strength of the FRCC. After that, the results obtained through the numerical analysis are presented with the Finite Element Model. The Finite Element model analysis are used to validate the compression result and give us a better view about the FRCC performance (K P *et al.*, 2020).

b) Experimental

To confirm the FRCC meet the requirement and expectation, an experiment will be conducted in accordance with ASTM C39 standard for the compression test by varying the downwards load to understand the behaviour of the compressive strength and young modulus (Mehndiratta *et al.*, 2018). Since the standard of ASTM C39 was used in this experiment, the top-load compression test will be used for this experiment using the Universal Testing Machine (UTM).

1.6 Research Flow Chart

Based on the Figure 1.1 below, the research flow chart started by identifying the problem followed by the background study through literature review. The literature review contributes to the preparation of the samples. The project was divided into two method which are experimental work and numerical analysis. The experimental work consists of compression test and water absorption test. While the numerical analysis consists of the simulation of compressive strength through Finite Element Analysis (FEA) using Abaqus. The result for simulation was used to validate the result for experimental analysis. If the outcome result meets the objective, it will be proceeded to documentation. If not, it will be repeated from the experimental work.

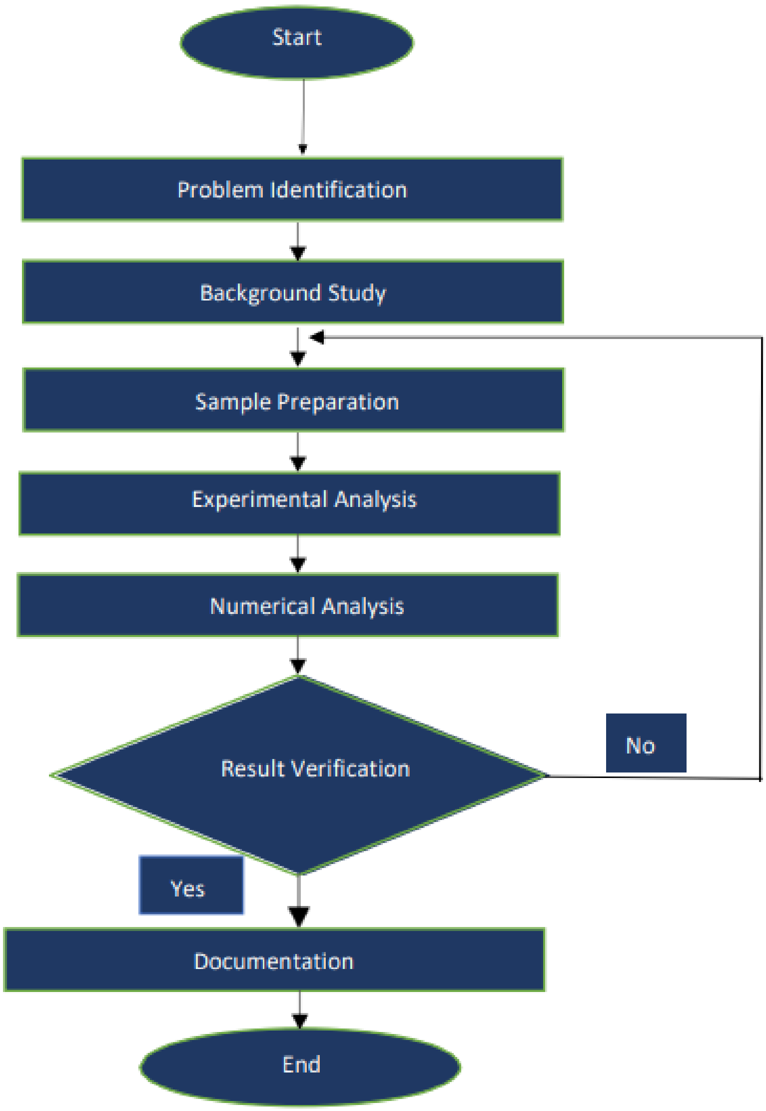

Figure 1.1: Project flowchart.

1.7 Material and Equipment

a) Material

Ordinary Portland Cement (OPC) (ASTM type II) and Urea-formaldehyde (UF) were used as binder materials. Natural river sand with a fineness modulus of 2.5 was used as fine aggregate (FA). Drinking water was used during the mixing of dry ingredients. The fibers were extracted from the palm oil empty fruit bunch which are the stalk and spikelet to develop the FRCC. The advantages of using empty fruit bunch fiber itself are easily to obtain, cheap price, good mechanical properties and environmentally friendly.

b) Equipment

The compression performance test will be carried out using the universal testing machine in accordance with the standard of ASTM C39. This machine is used to perform compression and tensile test to measure the mechanical properties of the specimen. The mechanical properties that will be evaluated are including the modulus of elasticity, compressive yield point, compressive yield strength and compressive strength.

1.8 Research Contribution

The objective of this project is to investigate the performance of local empty fruit bunch with added cement bonded fiber. The outcome of this project will profit the construction industries as the fiber reinforced composite cement have a better mechanical property, good in strength and lower in weight. On the other hand, this project also one of a sustainable development act along with its low cost of manufacturing.

1.9 Research Commercialization

The goal of commercialization is to make a profit from this project research and the construction sector will clearly benefit from it. Technological advancements have expanded the usage of natural fiber reinforced composites in industries such as industrial, automotive and construction with an emphasis on sustainability and renewable fiber reinforced composites cement. In advanced, due to the awareness of environmental sustainability which had be taken seriously in this past few decades will make this product accepted on the marketplace. Growing demands for lightweight and fuel-efficient vehicles will further propel the growth of FRCCs in the market (Taiwo *et al.*, 2019). Therefore, the commercialization of FRCCs is auspicious on the marketplace in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Cement Bonded Fiber is the integration of cement with a natural cellulosic fiber or also known as Fiber-Reinforced Cement Composites (FRCC). The FRCC is a composite which consist of fiber and matrix. The fiber used in this research is from the oil palm empty fruit bunch (OPEFB) where two types of fibers can be extracted from the empty fruit bunches by beating and retting process which are the stalk and the spikelet (Musa *et al.*, 2017). The result from the integration of cement with a composite material shows positive feedback to the construction industries as it strengthened and improved the mechanical properties of the cement. On the other hand, the natural fibers become the sustainable building material due to its salient features such as low cost, environmentally friendly in production and handling (Ramakrishna & Sundararajan, 2005).

There are many studies on the effect of fiber's application in cement brick were conducted lately. However, there still lack of information on the strength and durability of cement brick when the palm oil fiber was added. Thus, further research on the application of fiber from the empty fruit bunch to the concrete should be carried out. The conventional cement brick has a fragile nature and vulnerable to stress. Meanwhile, the mixture of fiber in cement brick able to improve the strength also increase the cracking resistance and post cracking behavior. Thus, analyzing the literature summary of Fiber Reinforced Cement Composite able to provide more knowledge of the properties of cement brick and the fiber. The literature review of Fiber Reinforced Cement Composite is presented as following section.

2.2 Composite Material

When compared to the individual components, a composite material is made up of two or more materials that have various superior material qualities physically and chemically. Composite materials can improve the strength and stiffness of a material. A composite material is made up of the matrix, which is a continuous bulk phase, and the dispersion phase (Gibson *et al.*, 2016). A scattered or contiguous phase, which is seen as a tougher and stronger component, is one of the most common properties of composite materials. Particle-reinforced composites, structural composites, and fiber-reinforced composites are the three types of composite materials. A composite material has various advantages over bulk materials, including great strength and stiffness mixed with low density, which allows the finished item to be lighter. During the reinforcing process, strength and stiffness are given.

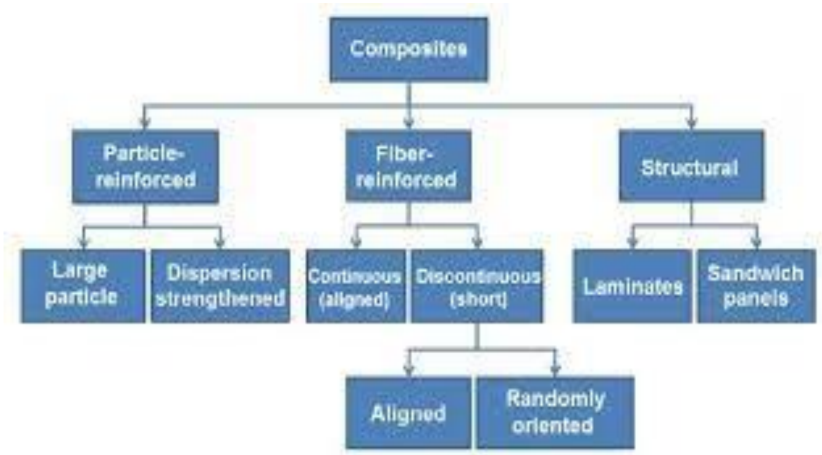

Figure 2.1: List of composites materials
Source: (Otani *et al.*, 2014).

2.3 Type of Composite Materials

Basically, the type of composite materials is divided into five basic type which consist of fiber composite, particle composite, flake composite and filled composite. Each type of composite has different material orientation and has its own advantages and disadvantages.