



**INFLUENCE OF CLAY CONTENT ON MECHANICAL  
PROPERTIES OF CLAY-POLYMER COMPOSITES FOR ROOF  
TILES APPLICATION**

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

by

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I hereby, declared this report entitled “Influence of Clay Content on Mechanical Properties of Clay-Polymer Composites for Roof Tiles Applications” is the results of my own research except as cited in reference.

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## **APPROVAL**

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering.

The members of the supervisory committee are as follow:

.....  
**(Dr. Toibah binti Abd Rahim)**

## ABSTRACT

Incorporation of clay as filler for epoxy has received considerable attention to improve the performance of the composites. In this study, clay-polymer composites for the roof tiles application were prepared by hand lay-up process. The effect of clay addition on the morphological and mechanical properties of the clay-polymer composites were investigated. The mechanical properties of the as-prepared composite were evaluated by the impact test, flexural test and tensile test. The results revealed that the impact strength, flexural strength and tensile strength of the composites were increased with the clay addition into the epoxy matrix. However, at higher amount of clay addition, 5 wt% of clay, reduction of mechanical properties was observed which is might due to the formation agglomerations of the clay particles and poor dispersion of clay in the epoxy resin. The SEM result shows that at 1 wt% of clay addition, the clay particles and fiber was well dispersed and stick together which is may cause the increment of the mechanical properties. Meanwhile at 3 wt% and 5 wt% of clay addition, the micro voids were formed and the huge lump of clay agglomerations were absence in the clay-polymer composites which lead to the reduction of the mechanical properties.

## ABSTRAK

Penggabungan tanah liat sebagai pengisi epoksi telah mendapat perhatian yang luar biasa dalam meningkatkan prestasi komposit itu. Dalam kajian ini, sebatian komposit polimer-tanah liat akan disediakan untuk aplikasi jubin atap rumah. Kesan penambahan tanah liat akan dikaji dengan mengubah peratusan berat tanah liat keatas polimer epoksi sebagai matriks sebanyak 0 wt%, 1 wt%, 3 wt% dan 5 wt% mengikut sifat mekanikal dan morfologi komposit polimer-tanah liat. Sifat mekanikal komposit yang disediakan diuji dari segi rintangan hentaman, kekuatan lenturan dan kekuatan tegangan komposit. Keputusan yang diperolehi dari ujian kekuatan lenturan, rintangan hentaman, dan kekuatan tegangan komposit menunjukkan sifat mekanikal komposit tersebut berlaku peningkatan dengan penambahan tanah liat. Dari keputusan SEM yang diperolehi, pada 1 wt% tanah liat menunjukkan bahawa zarah tanah liat terserak dengan baik antara satu sama lain dan mengakibatkan peningkatan pada sifat mekanikal komposit. Walaubagaimanapun, apabila amaun tanah liat tinggi, ia membentuk penggumpalan zarah tanah liat dan kelemahan pada penyebaran tanah liat terhadap epoksi resin seterusnya menyebabkan pengurangan pada sifat mekanikal komposit tersebut. Pada 3 wt% dan 5 wt%, lubang-lubang kecil bersaiz mikro terbentuk dan kehadiran penggumpalan tanah liat yang menjadi penyebab utama kepada pengurangan sifat mekanikal komposit tersebut dapat diperhatikan melalui keputusan imej SEM.

## **DEDICATION**

All the hard work is only for you:  
my beloved father, Mohd Azizi bin Ismail  
my appreciated mother, Noor Suzila binti Ali  
my adored brothers and sister,  
Ikhwan, Hazwani, Syahmi, Nabilah, Arif, Nasuha,  
And my dearest friend,  
Mawaddah & Izzati

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## LIST OF ABBREVIATIONS

SEM	-	Scanning Electron Microscopy
ASTM	-	American Society for Testing and Materials
RCF	-	Recycled Carbon Fiber
FVF	-	Fiber Volume Fraction
ISO	-	International Organization for Standardization
RTM	-	Resin Transfer Molding
XRD	-	X-Ray Diffraction
DGEBA	-	Bisphenol A Diglycidyl Ether
CP	-	Centipoise
Cu	-	Copper

## LIST OF SYMBOLS

%	-	Percentage
Mpa	-	Mega Pascal
Gpa	-	Giga Pascal
E	-	Young's Modulus
$\sigma$	-	Stress
$\varepsilon$	-	Strain
mm	-	Millimetre
kN	-	Kilo Newton
N	-	Newton
g	-	Gram
°C	-	Degree Celsius
g	-	Gram
F	-	Force
A	-	Area
L	-	Length
L <sub>o</sub>	-	Original Length



# CHAPTER 1

## INTRODUCTION

### 1.1 Research Background

As the world changes, technologically and culturally, new-ages jobs and industries require us to take the initiative to lead with 21<sup>st</sup> century skills. People need to move beyond the common formulations of learning that the majority of us grew up with and it takes more than just computer and technological skills to face the increasingly competitive society. The genius problem solving should be implement for the real cases in the society.

These days, the current roofing tiles cannot give a good performance to the roofing frame. The genius problem solving is finding a good roofing material that can give a higher quality and money's worth to them. Rooftop tiles are the main protective shell of a house and it is functioned as to protect the building, house, and people living inside it also to keep out us from external influences such as rain, cold, heat, and storm. As an alternative, polymer roofing has been a popular choice for roofs.

Example of polymer roofing that widely used was epoxy. Alamri *et al.* (2012) has stated that epoxy has several good properties such as low shrinkage, high modulus, high chemical resistant and relatively high strength. However, epoxy also shows poor resistance to propagation of crack initiation, low impact strength and low fracture toughness which is it cannot directly take to use for the certain desired applications.

According to the Roslan *et al.* (2016) the highest usage of materials used for the rooftop applications in Malaysia were concrete, clay and metal deck which is 85%, 10% and 5% respectively. The reason why these types of materials have been used for ages and

popular among users in Malaysia is because of the life span of the roofing system can be prolonging and it only required minimal maintenance as compared to the other materials.

Even though the materials have been used for ages long, it also has its own weaknesses that can give the inappropriate behavior to the required applications; roofing applications. Qin, *et al.* (2017) also has stated that when concrete tiles are used for the rooftop application or house protection, the concrete tiles were colonized by dust and algae after many years due to the moist climate and rich rainfall in tropical regions in certain places and country.

Moreover, Krüger *et al.* (2019) also insisted that the current materials used was heavy in weight and difficult for the installation when it used for rooftop applications. The heavy weight materials lead to several bad causes to the users or workers. If the heavy weight materials still being used in construction site, it might contribute to longer installation times and caused the back pain complication to the workers if they keep using it in a long period. The workers also need to be more careful in handling the materials due to its heavy weight.

These two findings from the two different journal on the application of the rooftop tiles show that the materials that have been used in construction or in manufacturing field of the roof tile itself need to be improved in order to produce better tiles and brings out a perfect performance for the rooftop applications. From the problem stated, this study is more focusing on the clay addition onto the cured epoxy in fabricating the clay-polymer matrix to improve the mechanical properties of the clay-polymer composites for the rooftop application.

The different content of the clay was investigated and the improvement or negative impact of different properties was observed as the clay content added into the clay-polymer matrix composites. Hopefully, the finding of this study will bring benefits for the construction field and can produce the good material performance for more broad applications.

## 1.2 Problem Statement

Material that widely used to make the polymer roof is epoxy resin due to its excellent properties such as low viscosity, low shrinkage during curing, good chemical resistance, low manufacturing cost, and simplicity in processing. Yet, the use of epoxy has some limitation for structural applications due to low stiffness and strength. One effective way to overcome this problem is by incorporation of filler such as clay to the epoxy as the matrix in order to improve the physical and mechanical properties of the epoxy resins.

In recent times, clay has been used to improve the property of the polymer due to its small particle size and low cost. However, study about the optimum amount of clay loading into the epoxy matrix in composite using glass fiber as the reinforcement is very limited. Therefore, it is very important to study what is the optimum amount of the clay that can be added as filler into the epoxy as the property of the as-prepared composites also depends on the clay that have been used.

In this study, influence of clay content on mechanical properties of clay-polymer composites were studied. The clay content was varied ranging from 0 wt% up to 5 wt%. Then, the mechanical properties of the composites were investigated through impact, flexural and tensile strength. The morphology of the fracture surfaces was also conducted.

## 1.3 Objectives

The objectives are as follows:

- (a) To evaluate the effect of the clay contents onto the mechanical properties of glass fibre reinforced epoxy composite
- (b) To correlate the influence of clay contents onto the fracture behaviour of glass fibre reinforced epoxy composite

## **1.4 Scopes of The Research**

This project has been focused on the variation of clay addition, 0wt%, 1wt%, 3wt%, and 5wt% into the glass fiber reinforced epoxy composites to turn out a better performance layer of composites. The hand lay-up process was used to produce the clay-polymer composite materials. The mixture of the epoxy resin and clay at different wt% were prepared by mechanical stirrer. Then, hardener was added into the mixture and poured into the mold with layers of fiber mats. In order to study the effects of clay addition, a fixed of 30% fiber volume fraction ( $V_f$ ) will be used. The samples will be cured in oven. The properties of the as-prepared composites were examined on the flexural strength, tensile strength and impact strength.

## **1.5 Significance of Study**

This study is significant for rooftop tiles application in order to produce low brittle tiles and lightweight tiles for roofing material. This study also beneficial for the workers that work in the construction field and for the instalment of the roof tiles. By understanding the problems of current rooftop tiles and the benefits of the quality of the tiles, the workers will get the benefits by a reformulation of the composites. Moreover, this study also can improve the quality in the construction sector and manufacturing industry towards the better performance of the composites due to the excellent properties. This study also can serve as a future reference for the researcher hybrid matrix composites.

## **1.6 Chapter Overview**

The flows of this report is as follows; Chapter 1 that presents the introduction, research background, problem statement, objectives, scopes and report organization. Chapter 2 shows the comprise of the literature review of previous research finding on the application of the clay-polymer matrix composites for rooftop application and deep understanding of that application. Chapter 3 covers the methodology of the research which includes the flowchart, raw materials, sample preparations, characterization, and testing. Meanwhile, chapter 4 is regarding the result and discussion that explains and discusses the report outcome and result of data from the project and lastly, the full conclusion throughout the report and about the result observation and the recommendation for further study also has been included into final chapter, chapter 5.

## **CHAPTER 2**

### **LITERATURE REVIEW**

This chapter basically reviews the study relating to the past findings that are executed by other researchers and theory involving the clay-polymer hybrid composites. There are used several sources to search out information regarding clay-polymer composites and related subject. The sources used in order to support the detail in this chapter are journal, books, online and etc.

#### **2.1 Introduction**

The accelerating pace of change through technologically, culturally, new-age jobs and industries require people to take the initiative to lead in 21<sup>st</sup> century world. The 21<sup>st</sup> century world included the achievement in Industry 4.0. In essence Industry 4.0 is a type of connection for the Industry with IoT, Internet of Things. In order to push the current state industry into Industry 4.0, the inefficiencies must be cut and the supply chain must be in order system because this industry can restructuring the entire production systems by transforming the analog and centralizing the workflows into digital and decentralized production process (Raj *et al.*, 2019) .

As the industry level is moving forward, the urge to increase the efficiency also should be expanding. Each of the industry compete to serve the better quality and performance to the customer and make sure the customer experience the A-level quality. So,

most of the industry has been thinking about increasing the efficiency and one of the ways by having a low-cost material and excellence performance for certain applications.

There are a number of products in various industries, as well as automotive, workplace and home furnishings, construction and others that using composite materials. The global composites demand in three key markets industrial fields as well as automotive, consumer goods and aerospace for the year between 2013 and 2020. (Nottingham & User, 2017).

## **2.2 Polymer-clay composites**

Polymer-clay composites often used in various applications in academic field or industry sector. It was claimed by Vo *et al.* (2018) that the polymer clay composites has been used due to its superior properties such as rigidity, flame retardant and stability. While still maintaining the lightweight of polymeric materials, this type of composite can give a high performance to the product without losing of it optical clarity and recycling.

The performance of the polymer-clay usually related to the clay volume fraction that inserted and dispersion state of the clay platelets. These two parameters need to be aware because from the research of Alamri & Low (2013), Rafiq & Merah (2019) and Rafiq *et al.* (2014) the different clay content will gives different properties, usually physical and mechanical properties.

According to the Johec Mošková *et al.* (2018), insertion of clay will created two types of clay dispersion in the polymer matrix. One is intercalated and the other one is exfoliated. Intercalated is where the filler penetrated well between the galleries and it not destroying the regular structure of the filler particles. Meanwhile, exfoliated is where the individual particles in form of thin sheets. Figure 2.1 below shows the scattering model of different clay dispersion.

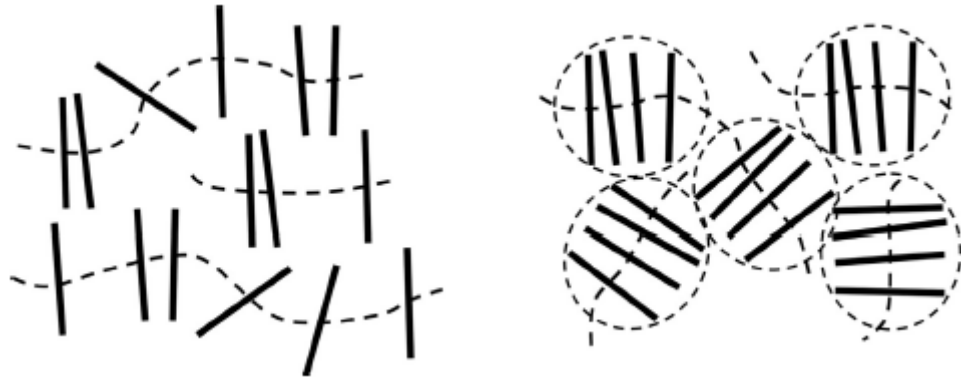


Figure 2.1: Sketches of interconnections scattering model with thermodynamic model (Frielinghaus *et al.*, 2019)

Comparing exfoliated and intercalated structure, exfoliated structure better than intercalated that improve rigidity at high volume fraction of clays. Addition of the filler may create the exfoliated and intercalated structure depending on the clay content inserted into the polymer matrix.

### 2.3 Clay

Clay available abundantly and inexpensive. Due to the character of clay that is easy to get and inexpensive, people usually used clay as in their research. Clay is used as inorganic fillers to overcome the weak interaction between the polymer matrix and the fillers as mentioned by Shin *et al.* (2019).

The dispersion of the layered clay has a high aspect ratio, high surface areas and high strengths into epoxy-based matrices and improved the properties over neat epoxy at low clay loading. Due to the good enhancement that the clay has served, it often used as the filler in order to increase the desired mechanical properties.

According to the Jean Serge *et al.* (2019), The degree dispersion of the clay holds the major role in determining the final properties of the composites. The efficacy of the clay is evaluated by its ability to disperse in polymer matrix. Moreover, the dispersion of the clay also depending on the particle size of the clay.

According to the Al-Qadhi *et al.* (2013) the addition of 1 wt% until 5 wt% increased the mechanical properties such as water uptake and tensile strength. Any addition of clay content above 5 wt% decreased the properties of composites itself and initiated the crack.