MECHANICAL-PHYSICAL PROPERTIES CHARACTERIZATION OF ALTERNATIVE MATERIALS FOR THE APPLICATION IN HIGHWAY GUARDRAIL

By:

AIDIL AZWADI BIN MOHD HAFNI

(Matrix no.: 141728)

Supervisor:

TS. DR. MUHAMMAD HAFIZ BIN HASSAN

July 2022

This dissertation is submitted to
Universiti Sains Malaysia
As partial fulfilment of the requirement to graduate with honors degree in
BACHELOR OF ENGINEERING (MANUFACTURING ENGINEERING)

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed…………………………… (AIDIL AZWADI BIN MOHD HAFNI)

Date………………………………

Statement 1: This journal is the result of my own investigation, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/ references are appended.

Signed…………………………… (AIDIL AZWADI BIN MOHD HAFNI)

Date………………………………

Statement 2: I hereby give consent for my journal, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available outside organizations.

Signed…………………………… (AIDIL AZWADI BIN MOHD HAFNI)

Date………………………………

ACKNOWLEDGEMENT

First and foremost, I would like to express my utmost gratitude to the School of Mechanical Engineering, Universiti Sains Malaysia for providing the assistance and required equipment together with the necessary materials to complete my Final Year Project. I would consider these four years in Manufacturing Engineering with Management as my golden opportunity for me to advance my knowledge in the engineering fields. Sincerely, very much appreciated. I believe that the university has prepared me to become a competent engineer in the future. Next, I would love to express my gratitude to my supervisor, Ts. Dr Muhammad Hafiz Bin Hassan whom has been very supportive with supervising and guiding me throughout the whole project. The skills he taught me will be carved inside, for me to become a better engineer. I would like to also acknowledge the Technical Staffs especially, Mr. Fakruruzi Fadzil, Mr. Mohd Ashamuddin Hashim, Mr. Mohd Idzuan Said, and Mr. Mohd Zalmi Yop who have been providing their expertise throughout this project. Besides that, a huge thanks to the course coordinator, Dr. Fauzi for his relentless efforts to guide the students for these final 2 semesters. Last but not least, I would like to thanks everyone that has indirectly involved with this project until this project reach success.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

EVA	Ethylene Vinyl Acetate
VA	Vinyl Acetate
TGA	Thermogravimetric Analysis
SEM	Scanned Electron Microscopy
JKR	Jabatan Kerja Raya

PENCIRIAN SIFAT MEKANIKAL-FIZIKAL UNTUK BAHAN ALTERNATIF BAGI APLIKASI PENGHADANG LEBUHRAYA

ABSTRAK

Penghadang lebuhraya telah menjadi sebuah aspek keselamatan yang penting bagi pengguna jalan raya. Walaubagaimanapun, terdapat beberapa isu yang dilaporkan mengenai bahan semasa yang digunaka pakai untuk aplikasi penghadang lebuh raya. Isu yang diketengahkan adalah mengenai prestasi jangka panjang bahan dan juga terdapat bahagian penting yang dicuri pada penghadang lebuhraya iaitu “packers”. Oleh itu, bahan alternatif menggantikan bahan keluli tergalvani semasa telah dikaji iaitu dua jenis polimer etilena vinil asetat, EVA (A) dan EVA (B) dan juga polimer bertetulang gentian kaca, B3WG6. Skop kajian adalah untuk mencirikan sifat fizikal dan mekanikal bahan-bahan ini. Terdapat 5 ujian yang telah dijalankan ke atas bahan-bahan ini iaitu ukuran ketumpatan, mikroskop elektron imbasan, analisis termogravimetri, ujian lekukan nano, dan juga ujian tegangan. Piawaian untuk ujian telah dikonfigurasikan melalui ulasan literatur. Keputusan daripada ujian menunjukkan bahawa EVA (B) mempunyai kebarangkalian tinggi untuk dipertimbangkan sebagai bahan alternatif untuk pembungkus pagar lebuh raya kerana sifat terikan tegangannya. Namun begitu, simulasi dan demonstrasi perlu dilakukan dengan prototaip yang sesuai pada masa hadapan untuk pembangunan kajian ini.

MECHANICAL-PHYSICAL PROPERTIES CHARACTERIZATION OF ALTERNATIVE MATERIALS FOR THE APPLICATION IN HIGHWAY GUARDRAIL

ABSTRACT

The highway guardrails have been the essence of safety for road users. However, there have been several issues reported regarding the current material used for the highway guardrail applications. The issues highlighted are regarding the long-time performance of the materials and also the stolen parts of the highway guardrails which is the packers. Therefore, alternatives material to replace the current galvanised steel material have been studied which are two types of ethylene vinyl acetate polymer, EVA (A) and EVA (B) and also a glass fibre reinforced polymer, B3WG6. The scope of study is to characterize the physical and mechanical properties of these materials. These materials are subjected to 5 tests which are density measure, scanned electron microscopy, thermogravimetric analysis, nanoindentation test, and also tensile test. The standards for the tests are configured through the literature reviews. The results from the test shows that EVA (B) has high probability to be considered as an alternative material for the highway guardrail packers due to its tensile strain property. However, simulation and demonstration needed to be done with a proper prototype in the future for the development of this study.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

The main purpose of this project is to characterize the mechanical and physical properties ethylene vinyl acetate (EVA) and glass fibre reinforced, B3WG6. The aim is to identify whether the engineered rubber or the glass fibre reinforced could become suitable alternatives for replacing the current material used for the packer component in highway guardrails. The foundation of this project is based on two main problems found throughout the earlier research of this project. From these problems, an idea has emerged from Selia-Tek Holdings Sdn. Bhd. which was to find an alternative material to replace the current material used for highway guardrail packers. The suggested material is ethylene vinyl acetate, an engineered rubber, that is assumed to have the capabilities and acceptable criteria to replace galvanized steel as the new material for highway guardrail packers. Another material that has also been suggested for research is the glass fibre reinforced that is currently being used by Selia-Tek Holdings Sdn Bhd for fabrication of railway pads. There are several problems related to the current material applied in the highway guardrail specifically a component in the guardrail which is called as packer.

1.1.1 Current Application

Basically, packers are used on the highway guardrails to hold and uplift the guardrails along the roads. Hence, it is considered as a very important component for the highway guardrails and without it, the highway guardrails would not serve its purposes. Figure 1 shows the example application of packers on the highway guardrail.

Note that there are various types packers according to the regulations instructed by Jabatan Kerja Raya Malaysia (JKR) (Jalan & Jkr, n.d.).

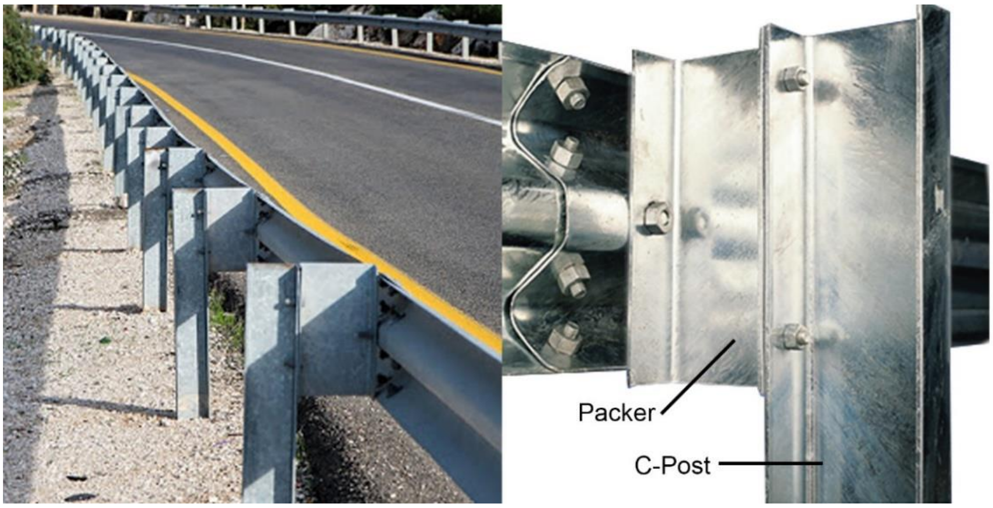

Figure 1-1: Highway guardrail and packers

In Malaysia, it is acknowledged that the most common material used for packers are made of galvanised steel. This material is known for their good mechanical properties and therefore considered as the most suitable material for application in highway guardrails. However, some issues have aroused regarding the application of this material in highway guardrail packers as the time went by.

1.1.2 Problems with current material

First and foremost, one of the most concerning issues related to the use of galvanised steel as packers' material is the metal theft. Note that this issue is based on actual occurrences and evidences in Malaysia. Based on the infamous local newspaper, 'The Star' has reported about metal theft that happened in Malaysia which involved stealing of highway guardrail and other related components. Basically, there are 3 main components of a highway guardrail which are the 'W' beam, vertical or C post, and packers. These components are usually made up of the same material, galvanised steel. There are reported cases in Malaysian highways and roadsides where these components are being stolen. The thieves either take the whole part or only the packers.

One of the many cases reported from ‘The Star’ newspaper was in Seberang Prai, Pulau Pinang (*PressReader.Com - Digital Newspaper & Magazine Subscriptions*, n.d.). It was reported that thieves have been stealing metal packers that hold guardrails along the busy streets. According to the paper, thieves are preying for the guardrail packers as they are said to be able to fetch up to RM50 per set in the scrap yard market. Hence, one of the flaws of using galvanised steel guardrail packers have been identified. It is fair to deduce that the current material used for packers in the highway guardrail application has high scrap values. According to the Malaysia Steel Institute (MSI), the scrap value of steel could range between RM 2,054 – RM 2,105 per metric tonne (as of November 2021) (*MSI | Malaysia Steel Institute*, n.d.). As a result, these thefts could cause risky dangers to the road users especially when unintended crash occurs. As the packers are removed from the guardrail, the guardrail can no longer serve its purposes.

Another important issue worth to be highlighted is the performance of the guardrail over time. It is fair to say that the performance of the galvanised steel is exceptional and choosing it as the material for guardrail packers was right. Adding to that, galvanising the steel was a good resort to improve the performance of the packers. However, the performance of the packers still deteriorates over time due to corrosion. Note that the packers are continuously exposed towards changing of temperatures and weather conditions (Jewell, 2016). As a result, the performance of the packers deteriorates in terms of flexural and also causing harm to the road users as the guardrail are not able to absorb the impact and probably rebound the vehicle back to the road and minimizes the crash effects when accident happens. Figure 2 below is the reference for the statement above (*Four Killed in Gruesome Crash on East Coast Expressway*, n.d.).

Figure 1-2: Car crashing highway guardrail

1.2 Problem statement

Packers is a component of highway guardrails which holds and uplifts the guardrails. The material of the today's packers is mostly galvanized steel. This material has high scrap value hence became the target for metal thieves. The material also corrodes over time hence reducing the performance of the packers. Ethylene Vinyl-Acetate (EVA) and glass fibre reinforced are considered as suitable alternatives for replacement. However, the properties of these materials need to be characterized in the first place so that it could exhibit similar or better properties to the galvanized steel. The characterization should include material behavioural, hardness, tensile properties and physical properties.

1.3 Scope of Research

This project is an experimental-based with the aim to characterize the properties of EVA as supplied from the supplier, Selia-Tek Holdings Sdn Bhd. It is an innovative idea to find the alternative for replacing the current material applied for highway guardrail packers. In this project, the properties of EVA, galvanised steel and the glass fibre reinforced (B3WG6) would be compare. The comparison will provide the idea for suitability of the materials studied to replace the current material.

The aim of this project is to identify the physical and mechanical properties of the EVA (A), EVA (B), and B3WG6 for the application in highway guardrail packers. The properties needed to be identified were suggested and agreed with the provider of materials, Selia-Tek Holdings Sdn Bhd and explained throughout the content of this report. The properties identified are also compared with the current material used in highway guardrail packers which is galvanized steel. Ultimately, these knowledges can be used for further development of producing highway guardrail packers with these alternative materials. The objectives of this research are as listed below.

1.4 Research objectives

The general objective of this study is to characterize the mechanical and physical properties of 3 materials which are ATEVA 1075A, ATEVA 1070, and B3WG6. The aim is to gather the information regarding the properties of these materials for the development of an alternative material for highway guardrail application. In order to achieve this aim, the research objectives have been defined as follows.

i. To identify the density, elemental composition, material behavioural with temperature, hardness, and tensile properties of the 3 materials.

ii. To compare the mechanical and physical properties of EVA (A), EVA (B), B3WG6, and galvanized steel.

iii. To study the suitability of the materials as an alternative material for replacing current material used in highway guardrail application.

1.5 Overview and structure of project

This project is intended to do research on characterizing the physical and mechanical properties of an engineered rubber namely Ethylene Vinyl-acetate. This research is suggested for a foreseeable outcome in replacing the current material applied for the highway guardrail packers. However, it needs to be proven analytically whether this material will perform as good as the current material in order to be considered as an alternative.

Briefly, this project will consist of multiple tests. The purpose of these tests is to basically identify the mechanical and physical properties of the material EVA. Adding to that, another material has also been brought into this research to compare with the properties of EVA. The material is glass fibre reinforced B3WG6. After all the tests are done for both of these materials, the next step will be to deduce the information regarding the materials and the suitability of the materials to replace the current galvanized steel guardrail packers in the market.

The company, Selia-Tek Holdings Sdn Bhd has provided 3 different types of materials together with the Material Technical Data Sheets as reference for comparisons. Firstly, is the ATEVA 1075A which is a type of polymer (engineered rubber) which consists of 9.0 weight % of Vinyl-Acetate (VA). Next, is the B3WG6 which is a type of glass fibre reinforced that is currently used by the company to produce railway pads. Lastly, a material which is also similar with the first material (engineered rubber) but it is called ATEVA 1070. For the purpose of distinction, ATEVA 1075A has been identified as EVA (A) while ATEVA 1070 has been identified as EVA (B).

In order to characterize the materials, it is better to first understand the type or grade of these materials. To help with that, Selia-Tek Holdings Sdn Bhd has provided the Technical Data Sheet and Material Safety Data Sheet. These papers will become the guidance for the tests to be done. Meanwhile, the reference for this research will be based on the research journals available. Extracting the information from both of these sources, the structure of this project is created and the milestones for this project is clear.

1.6 Organization of thesis

This thesis is divided into five chapters. The introduction of this project is elaborated in chapter one with a brief elaboration regarding the current issues with the application of galvanized steel in highway guardrails which focuses on the highway guardrail packers. In chapter two, the literature review on the proposed tests to characterize the mechanical and physical properties of the materials are presented. In chapter three, the methodology of the tests that were done are elaborated in detail. In chapter four, the results from the tests done are discussed and then compared to the properties of current material used in highway guardrail packers which is galvanized steel. Last but not least, the conclusions and foreseeable future works of this project are presented in chapter five.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature reviews will be focusing on understanding the 2 different types of materials that are being researched within this project. The foundation knowledges for the EVA and B3WG6 are utterly important for choosing the tests that should be done to characterize the materials. Besides that, other journals will also be reviewed with respect to tests that have been chosen. The reason being is to understand the methodology, standards, and procedures to be taken to execute the tests hence obtaining good results.

2.2 Ethylene Vinyl Acetate, EVA

Ethylene vinyl-acetate or commonly called as EVA is an engineered rubber. It is a copolymer which resulted from the polymerization of ethylene and vinyl-acetate. This material has a variety of applications depending on the properties of the EVA materials themselves. Generally, there are 3 different types of EVA copolymer which varies in terms of the weight percent of the vinyl-acetate content. The content of vinyl-acetate usually ranging between 10% to 40% within the EVA (*EVA*, n.d.).

A. Types of EVA copolymer.

1. Low proportion of vinyl-acetate.

Vinyl acetate modified polyethylene is a term used to describe an EVA copolymer with a low concentration of vinyl acetate which is approximately up to 4% of the EVA material. It is a copolymer that is used to make thermoplastics and similar to low-density polyethylene. It has some of the qualities of a low-density polyethylene, but with added gloss, softness, and flexibility which is important for film. The substance is typically regarded as non-toxic.

2. Medium proportion of vinyl-acetate.

The thermoplastic ethylene-vinyl acetate copolymer (EVA copolymer) is a thermoplastic elastomer material that is based on a medium proportion of vinyl acetate, about 4% to 30% of the EVA material. It is not vulcanised, but it has some rubber or plasticized polyvinyl chloride qualities, especially at the higher end of the range. Both filled and unfilled EVA polymers are robust and have good low temperature characteristics.

3. High proportion of vinyl-acetate.

The higher proportion of EVA copolymer which is usually greater than 60% is referred as ethylene vinyl-acetate rubber. This material exhibits the same physical properties of rubber in terms of flexibility.

B. Polymerization.

The EVA material is made through polymerization of ethylene monomers and vinyl-acetate monomers into copolymers and it is called a copolymerization (Shrivastava, 2018). In general, there are 2 main mechanisms of polymerisation which are chain-growth polymerisation and step-growth polymerisation. As for EVA fabrication, the mechanism used for copolymerisation is the chain-growth polymerization (Zarrouki et al., 2017). Within this mechanism, there are several types of polymerization process and the one that is commonly used for EVA fabrication is the Free Radical Polymerisation.

There are 3 general steps involved within the free radical polymerisation process (Sisanth et al., 2017).

1. Chain Initiation

In this step, the polymerization reaction is initiated usually by means of an external radical initiator which creates a reactive site. For instance, the initiator could be tetrahydrofuran (THF) or dimethyl carbonate (DMC).

2. Chain Propagation

In this strep, the monomers or repeating units attach to the molecular chain, propagating the chain length.

3. Chain Termination

In this step, the chain growth is terminated through neutralization of the reactive center. A clean environment is crucial to avoid termination due to impurities.

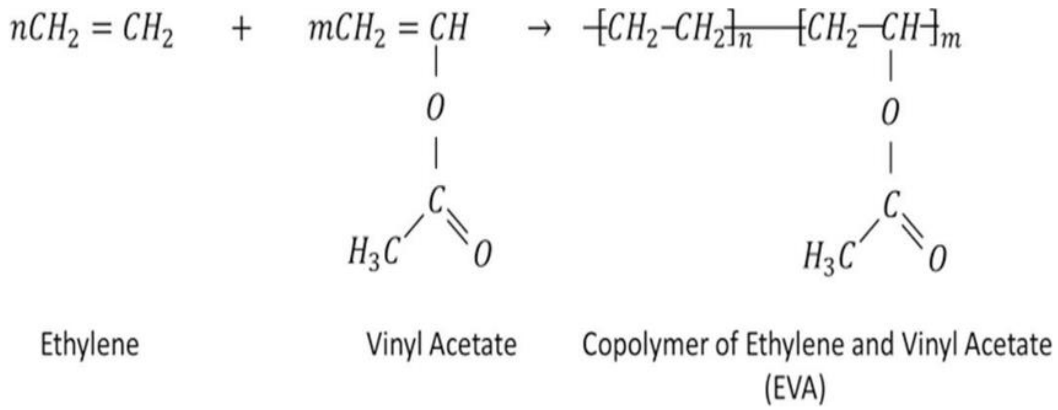

Figure 2-1: Polymerization of EVA polymers

2.3 Properties characterization

Currently, there has been yet implied the application of EVA or glass fiber reinforced in highway guardrail applications. In general, most of the research journals have showed that the application of EVA as an additive material to enhance the performance of the main materials. Adding to that, the modified materials and EVA materials are subjected to various testing to characterize the mechanical and physical properties. Note that this research is made for the application of highway guardrail packers. Henceforth, the material characterization will be focusing on the requirements solely for the application and also other possible experiments to enhance the understanding for this engineered rubber, EVA.

First and foremost, EVA is widely used as an additive in various fields. The reason being is because of the capability of EVA to enhance the performance and functionality of the material. One of the applications is the modification of asphalt with EVA copolymer. Asphalt is the material used for pavement construction. According to (Liang et al., 2017), the modification of asphalt with EVA are able to enhance the mechanical and stability performance. The experiment concluded that modification of asphalt with moderate vinyl acetate content, 18wt%, is the pivotal value to acquire the ideal performance at high and low temperature. Besides that, the fabrication of exfoliated polymer/clay composites are also involved with the incorporation of EVA copolymer as matrix and organically modified montmorillonite (O-MMT) as nanofiller (Abdul Hamid et al., 2020). The result of the experiment has shown that EVA has improved the performance of the nanocomposite in terms tensile and toughness. These claims are not blatant claims but they are tested with various experiments. Hence, providing the necessary experiments or tests required for this research in order to characterize the properties of EVA copolymer.

There are various tests mentioned and explained in the journals. However, only those which are necessary or relevant for this research purpose will be reviewed in order for the properties' characterization.

2.3.1 Tensile Test

The tensile toughness values indicate the maximum energy being absorbed before the materials fails (break). The values will be obtained by measuring the are under the stress-strain curve of the tested materials (Abdul Hamid et al., 2020). According to (Paiva Junior et al., 2021), the tensile strength is the force per unit are applied to the specimen in accordance with the ASTM standards. From the available material Technical Data Sheet (TDS) of EVA, the tensile properties are as follows. The material should have at least tensile strength of 15 MPa with the elongation at 500% (*HDPE EVA Rubber Rail Pad for Different Size Steel Rails*, n.d.). This data is comparable to the specimen provided from Selia-Tek which is the EVA rail pad. Hence, there are few other journals that share the same idea and understanding on tensile test for EVA materials and it is fair to deduce from the journals that there are specific standards to execute the test in accordance to the ASTM Tensile Test Machine.

2.3.2 Scanned Elcetron Microscopy

The Scanned Electron Microscopy (SEM) is used to study the phase morphology of the material (Zhang et al., 2020). The result from (Zhang et al., 2020) has shown the different phases on the surface of EVA/PLA blends hence providing knowledge regarding the material composition. Basically, the SEM works by producing images of the sample by scanning it with a beam of electrons. Thereby, the electrons interact with the different atoms presented at the surface of EVA which will result with various signals that reveal the information on the surface morphology and composition of the EVA material (Pinto et al., 2018).

2.3.3 Thermogravimetric Analysis

Thermogravimetric Analysis (TGA) is an analytical technique used to determine a material’s thermal stability and its fraction of volatile components by monitoring the weight change that occurs as the sample of the material is heated at a constant rate (Rajisha et al., 2017). It is found that the TGA can be conducted on EVA sample specimen about 10±1 mg with a temperature ranging 25°C up to 650°C with a constant heating rate at 20°C per minute under nitrogen atmosphere which was pumped into the system at a flow rate of 30 ml per minute (Alakrach et al., 2016). This test will provide an understanding on the material behaviour by analysing the material behaviour until end of the degradation.

2.3.4 Hardness Test

According to (Paiva Junior et al., 2021), the hardness for EVA composite mixed with EVA waste can be determined through 'The Asker C' hardness in which the sample is shaped like a rectangle. The measurements are then taken in the diagonal direction of the rectangle. Basically, a hardness test will provide the knowledge of strength, ductility and wear resistance of the material. As for this research purpose, the hardness test will be done through Nano Indentation. The nanoindentation method allows the measurement of mechanical properties of EVA material with the application of extremely low load and also exhibited a favourable test-retest reliability (Mansour et al., 2021).

2.3.5 Vinyl Acetate content

It is acknowledged that the EVA consists of ethylene and vinyl acetate. However, the vinyl acetate (VA) content plays a very important factor which influence the properties of EVA material as a whole. Comparing the surface morphology between two mixtures with different VA content was done (12wt% and 28wt%) has shown a significant difference through SEM (Ercan & Korkmaz, 2021). Different type of EVA will exhibit different mechanical properties. Higher VA content will exhibit rubbery-like texture while lower VA content will exhibit more stiff texture (Abdul Hamid et al., 2020). Therefore, it is important to characterize the EVA specimen provided by Selia-Tek in order to identify whether the type of EVA with the VA content is a suitable alternative for replacing the current material applied in guardrail packers.

2.4 Summary

To summarize the literature reviews, it can be said that drawing a conclusion from the journals are a bit indecisive. Mostly, every journal presented different use of materials which are used to incorporate or mixed with the material of focus, EVA. Moreover, there are few to none journal that depicts the application of EVA nor glass fibre reinforced in highway guardrails. This research can be considered as the pioneer research regarding the highway guardrail packers' application. Therefore, the focus of the literature reviews has been toward the tests done to characterize the mechanical and physical properties of the materials. However, these journals have provided a vast idea on structuring this research. Throughout these reviews, the foundation knowledge on the required tests and methodologies for carrying out the tests has been acknowledged.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter is mainly representing the overall methodology practiced in this research project. In total, five tests have been carried out for the material properties characterization. The various testing carries their own respective purposes to study on the properties of the three materials involved within this research. The materials are provided by Selia-Tek Holdings Sdn Bhd.

Figure 3-1: Material specimens according to ATSM D638 Type IV

For the purpose of this research, Selia-Tek Holdings Sdn Bhd has provided the materials in a dumbbell shaped as shown in the figure. The material is prepared according to ASTM D638 Type IV standard.

All of the materials were prepared through hot injection moulding. The materials were not sent in their granule resin form because the aim is to characterize the properties of the materials after they went through the fabrication process which is the injection moulding process. The reason being is because the properties of the material might differ from the Technical Data Sheet provided to the company as the fabrication process might have influence in the alteration of mechanical and physical properties of the materials. The injection moulding process parameters used for the material preparation are the same to their production process parameters.

In this chapter, the detailed methodology of density measure, scanned electron microscopy, thermogravimetric analysis, nano indentation, and tensile test are represented and followed by the results in the next chapter.

3.2 Density Measure

The density measure is carried out at School of Materials & Mineral Resources Engineering. The method used for measuring the density of each material was through densimeter by using XB 220A Analytical Balance. The concept applied by using this densimeter is based on the Archimedes' Principle. The understanding is that the buoyant force of the submerged materials is equal to weight of the fluid displaced. The purpose of measuring the density for the three materials is that it will provide the idea for estimating the amount of material required for the fabrication of highway guardrail packers.

For the measurement, three samples of each material are prepared and every sample is measured for three times. Then, the average density for each material is recorded and compared with the density values form the Technical Data Sheet provided by Selia-Tek Holdings Sdn Bhd.

3.2.1

The samples for density measurement are prepared from the dumbbell shaped materials provided. The samples are cut to approximately 10 mm by 10 mm in dimension using cutter. Figure below shows three samples for density measurement for EVA (A).

Figure 3-2: Samples for density measure

3.2.2 Measuring the density

Firstly, the densimeter was set up on the XB 220A Analytical Balance as shown in the figure. The solution used is distilled water which have the density of 1g/cm 3 and the test is carried out at 25°C of temperature.

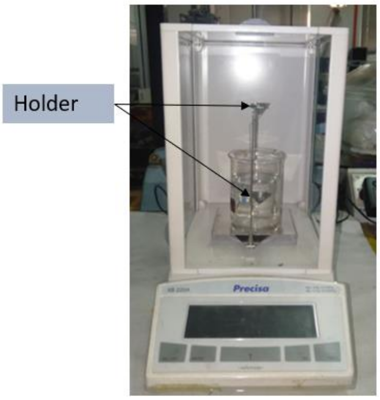

Figure 3-3: Densimeter setup

Then, one sample is placed in the top holder to measure the weight in air and then placed onto the bottom holder to measure the weight in liquid. The balance will then generate the density of the material. These steps are repeated for three times for each sample for every material. The density values are recorded and the average density of the materials are calculated together with the standard deviations.

3.3 Scanned electron microscopy

The purpose of carrying out SEM in this research is to identify the element contents of the materials by the aids of Energy Dispersive X-ray Spectroscopy (EDX). The knowledge from this analysis will provide useful reasonings on the mechanical and physical properties of the three materials researched in this project. For this project, the magnification set for SEM is at 100 magnification which observes the surface of the materials at 500 µm

Figure 3-4: SEM machine

3.3.1 Sample preparation

The samples are prepared with the dimension of approximately 20 mm in length by cutting the materials provided using specimen cutter. Then, the samples are mounted with resin through could mounting process in which the samples are left for 24 hours in the molted resin to let them hardens. This is done while the cross-sectional areas of the materials are facing upwards. Once the mount is prepared, the samples are grinded and polished until the surface of the cross-sectional areas reach satisfaction for SEM.

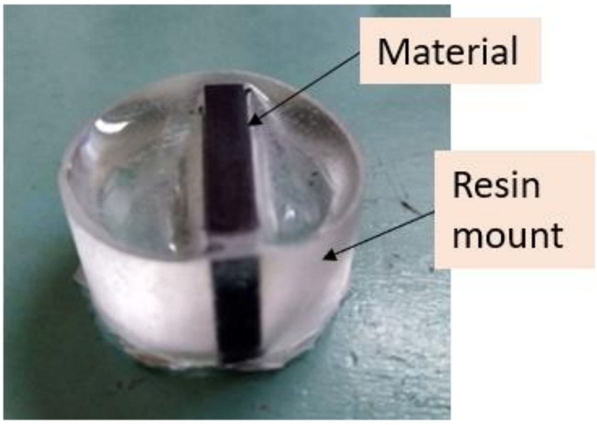

Figure 3-5: Cold mounting resin

3.3.2 SEM test

For the scanning, one sample is placed inside the machine's chamber and then the parameter is set such as the magnification at 100 times. Then, the scanning is done and the EDX data for the samples are recorded. At least, three spots are chosen on the surface for each sample for the EDX analysis. These procedures are repeated for the other two samples as well. From the EDX results, the elements within the materials can be classified with the approximate wight percent of the elements within materials.

3.4 Thermogravimetric analysis

A The purpose of TGA in this project research is to identify the material behaviour and thermal stability of the materials when heated at a constant rate. The parameters considered for this test are the heating rate, heating range, and the gas flow rate. Among these three parameters, only the heating rate is varied while the other two were kept constant in which the heating range is set at 30°C to 650°C and the nitrogen gas flow at 20 mL per minute. The heating rates were 5°C, 10°C, 20°C, 30°C, and 40°C per minute.


Figure 3-6: TGA machine

3.4.1 Sample preparation

The sample is prepared by cutting the materials into very small pieces that it would fit the sample pan. The weight of the sample are approximately 5 to 7 milligrams. Then, the TGA machine is preheated so that it is well prepared for the heating process. The warm should take at least 30 minutes for efficient heating while running the TGA test. To start the test, the sample pan is firstly hung gently onto the hanger and was let to rest for 3 minutes to allow for stabilization before setting the tare weight. Then, a piece of sample is placed inside the sample pan very carefully and also been let to rest for 3 minutes. The initial weight of the sample is obtained and recorded. Then, the furnace is brought up and parameters are set for the heating process. After the test is done, the data are collected and TGA graphs are plotted.

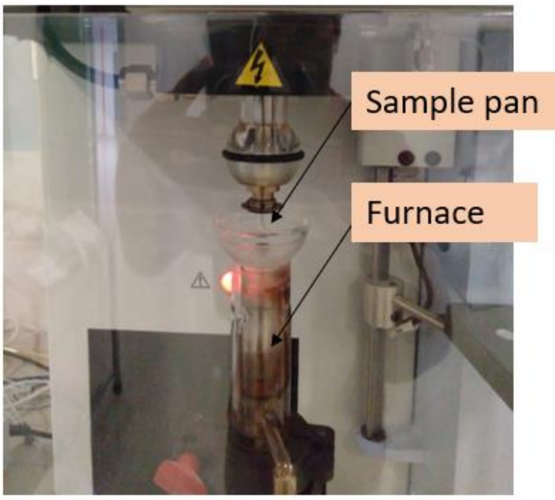

Figure 3-7: Sample on heating

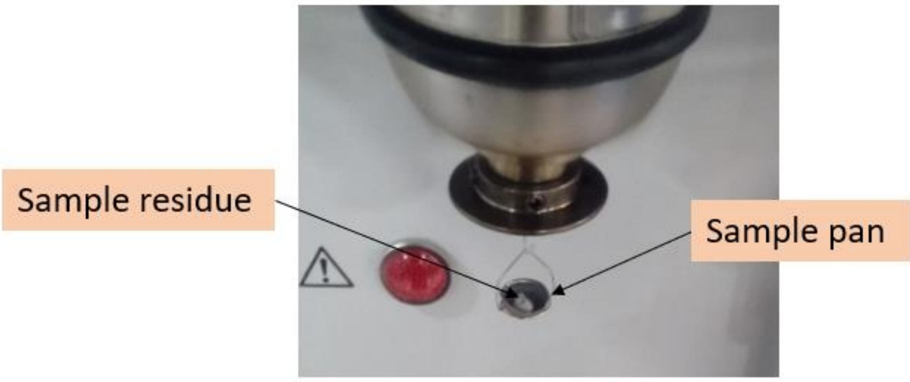

Figure 3-8: Loaded sample pan

3.5 Nanoindentation test

The purpose of nanoindentation is mainly to characterize the hardness of the materials. In comparison to the conventional hardness test, nanoindentation applied smaller amount of load and uses a different type of indenter. As for this project, nanoindentation is selected compared to the conventional hardness tests in order to acknowledge the hardness at localized areas on the materials whereas the conventional hardness tests would only provide the average hardness over the large areas. Typically, nanoindentation tests can be described as an indenter penetrating the surface of a material with a specified load. The load applied upon the surface is defined as the function of penetration depth. As a result, the test will produce load-penetration curve in which will provide the analysis on the maximum displacement, maximum load, the contact stiffness, and the hardness of the material (Chegdani et al., n.d.).

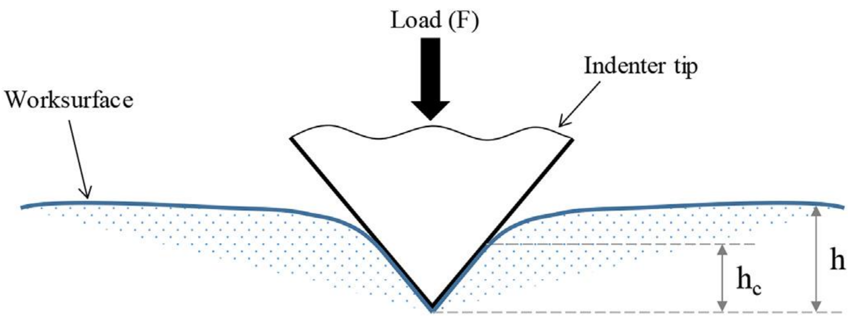

Figure 3-9:Illustration of nanoindentation

3.5.1 Sample preparation

The samples for the indentation tests are prepared with the dimension of approximately 10 mm by 10 mm in dimensions. The samples are then glued onto a mount to be fixed onto the stage during the nano indentation test.

3.5.2 Nanoindentation test procedure

The first step after sample is prepared is to fix the mount onto the stage. Then, the stage is brought closer to the microscopes to identify the most appropriate surface for the penetration. After that, the stage is then brought to the indenter to continue with the penetration. There are two different loads tested on the three materials which are 5 mN and 10 mN. Each sample is subjected to five penetrations for an identified area on the surface of the samples. Meanwhile, each sample is marked with four areas for the indentation. From these tests, the hardness values for each material are obtained and plotted into a bar graph.

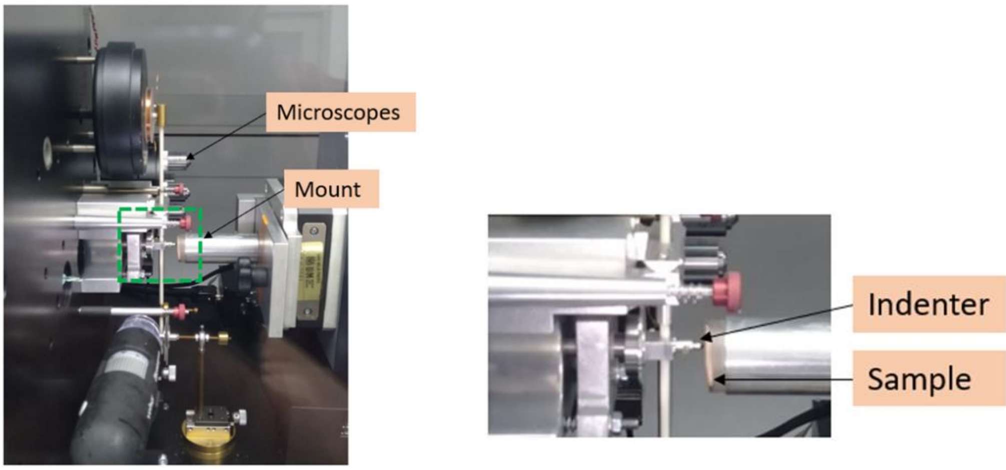

Figure 3-10: Sample under nanoindentation

The process of nanoindentation was carried out in a very gentle manner. During the testing, very minimal vibrations is required to avoid any disturbance during indentation.

3.6 Tensile test

The purpose of tensile test in this research is utterly important as the knowledge on the tensile properties of the materials are very useful for further development of this research as alternative materials for the application of highway guardrail packers. The tensile test is carried out with Universal Testing Machine with a maximum load of 30kN load.

3.6.1 Sample preparation

For the tensile test, the samples used are based to the ASTM D638 Type IV standards. The dimensions of the samples are as according.

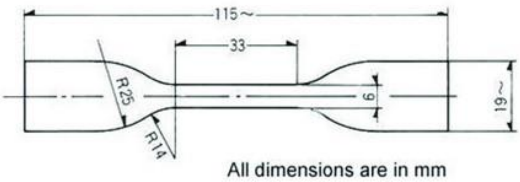

Figure 3-11: ASTM D638 Type IV

3.6.2 Tensile testing procedure

For the testing, five samples for each material are used. The samples are fixed onto the jig of the table mounted UTM. Then, the initial extension is calibrated to zero so that the elongation of the samples can be obtained. As for this experiment, extensometer was not required as the nature of the EVA material is known to be rubbery and would have a long elongation. Therefore, the elongation of the samples is directly measured form the setup of the jig. Then, the parameter which is the crosshead speed is configured through the software and set at 50 mm/min. The test is then run and result is recorded. From the results, stress vs strain results are plotted using SigmaPlot software. Adding to that, the other values obtained are also plotted into bar graphs for a better observation and clear comparison.

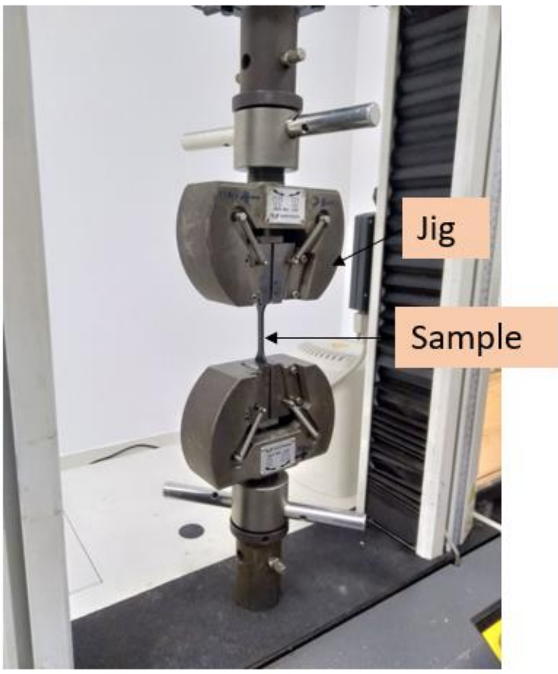

Figure 3-12: Tensile test setup