CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Composite is a mixture of two or more distinct constituents or phases. The second constituent is referred to as the reinforcing phase, or reinforcement, as it enhances or reinforces the mechanical properties of the matrix. In most cases the reinforcement is harder, stronger and stiffer that the matrix, although there are some exception. The geometry of the reinforcing phase is one of the major parameters in determining the effectiveness of the reinforcement, in the other words; the mechanical properties of composites are a function of the shape and dimensions of the reinforcement. Reinforcement usually describe as being fibrous or particulate. Here we will more focus on particulate reinforcement.

The functions and requirement of the matrix are to keep the reinforcement in place with the structure, carry interlaminar shear, control the electrical and chemical properties of the composite and the most important is to help distribute or transfer loads

The focus of attention on fiber reinforcements has usually blinded potential end users of composite materials to the many beneficial uses of particulate. However, industrial experts are now becoming more aware of these benefits and there will undoubtedly be increased particulate filler usage in future polymers, ceramics and metals. Particulate fillers can provide improved material, as compared with the unfilled matrix and can also be synergistic with a fiber reinforcement to further improve the system performance. Particulate reinforcement has dimensions that are approximately equal in all directions. The shape of the reinforcing particles may be spherical, cubic, platelet or any regular or irregular geometry. The arrangement of the particulate reinforcement may be random or with preferred orientation. In the majority of particulate reinforced composites the orientation of the particles is considered, for practical purposes, to be random.

The orientation of the reinforcement within the matrix affects the isotropy of the system. When the reinforcement is in the form of equaixed particles, the composite behaves essentially as an isotropic material whose elastic properties are independent of direction. When the dimensions of the reinforcement are unequal, the composite can behave as if isotropic, provided the reinforcement is randomly oriented. In other cases the manufacturing process may induce orientation of the reinforcement and hence loss of isotropy; the composite is then said to be anisotropic or to exhibit anisotropy.

Hence, this project is held because rarely studies regarding vermiculite as particulate reinforcement and hope will aim at achieving a unique result.

1.2 Problem Statement

Many composites reinforcement particles are in the form of sphere-like and rod-like but rarely in the form of plates. The mechanical property of rod-like particle reinforced composite is more or less established. Plate-like particles with its unique anisotropy might show unique mechanical properties that are interesting to study.

1.3 The Objective and Scope of Study

1.3.1 The Objective

To obtain data and results regarding the mechanical properties of plate-like epoxy matrix composite materials with vermiculite as the reinforcement.

Secondly is to study the effect of reinforcement composition and thirdly to study the effect of two most extreme different aspect ratios.

1.3.2 The Scope of Study

The scope of study is using Epoxy as the matrix and vermiculite particulate as the reinforcement. Follow ASTM D3039 standards for fabricating the tensile test specimen of composite. Mainly to study the mechanical properties by doing tensile test experiment at Mechanical Lab Block 17.

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1.4 Significance of Study

This study is significance because the behaviour of the composite is affected by the reinforcement shapes, content, types, and aspect ratios. Study about Vermiculite particulate as reinforcement is not many as fiber reinforcement. Therefore, in this study it will show unique result by manipulating the composition and aspect ratios of the Vermiculite.

CHAPTER 2

LITERATURE REVIEW

2.1 Review on Previous Researcher’s Works

In S.M.Sapuan ,M. Harimi, M.A Maleque (2003) journal presents the tensile and flexural properties of composites made from coconut shell filler particles and epoxy resin with three different filler contents that were 5%, 10% and 15% were carried out using universal tensile testing machine according to ASTM D 3039/D 3039 M-95 and ASTM D790-90. Several conclusions have made by them from the experiment that the tensile of the epoxy coconut filler composites were affected by the amount of filler in the composites. (1) The more filler content, the higher the strength. (2) Filler composites demonstrated linear behavior with sharp fracture. (3) The strain decrease with the increase in the filler contents due to the fact that the materials have become harder with the increase in filler contents. Mechanical properties of the natural fiber composites depend on several factors such as the stress-strain behaviors of fiber and matrix phases, the phase volume fractions, the fiber concentration, the distribution and orientation of the fiber or fillers relative to one another.

They use Epoxy Resin 3554A and hardener with the ratio 100:25. The open molds used were made from glass sheets and cement and the size and shapes as per ASTM D 638-90 tensile testing. The Epoxy and hardener were mixed in a container and stirred well for 5-7 minutes. The mold polished with release agent to prevent the composites from sticking onto the mold upon the removal. Finally the mixture was poured into the mold and left at room temperature for 24 hours until the mixture was hardened and later removed from the mold and placed inside an oven for 12 hours at 40°C for curing.

As for this project, the contents of the vermiculite that will study are 10%, 25% and 50%. Epoxy that will use is Epoxy Resin Clear and Epoxy Hardener Clear as the ratio prescribed by the manufacturer is 1:1. Open type mold will be used that made from zinc. The next procedure will be the same as in the journal.

2.2 Polymer Matrix Composite (PMC)

The most common matrix materials for composites are polymers. However, their strength and stiffness are low compared to that of metals and ceramics. This meant that there was a considerable benefit to be gained by reinforcing polymers and that the reinforcement, initially at least, do not have to have exceptional properties. The processing of polymer matrix composite does not involve high pressure or high temperature. The three classes, thermosets, thermoplastics and rubbers, are all important as far as matrices of PMCs are concerned.

2.3 Thermosetting

It has been estimated that over three-quarters of all matrices of PMCs are thermosetting polymers. Thermosetting polymers or thermosets are resins which readily cross-link during curing. Curing involves the application of heat and in the presence of a catalyst known as a curing agent or hardener.

These strong bonds of the cross-links have the effect of holding the chains together. This restricts the movement of the polymer chains and so increases the glass transition temperature to above room temperature. Consequently, thermosets are brittle at room temperature and have a low fracture toughness values.

2.4 Epoxy

Epoxy is a very versatile resin system, allowing for a broad range of properties and processing capabilities. Epoxies are the most widely used resin materials and are used in many applications from aerospace to sporting goods. Epoxy-based composites provide good performance at room temperature and elevated temperatures. Epoxies can operate well up to temperatures of 200 to 250°F.

Epoxies come in liquid, solid and semi-solid forms. Liquid epoxies are used in RTM, filament winding, pultrusion, hand lay-up and other processes with various reinforcing fibers such as glass. Semi-solid epoxies are used in prepreg for vacuum bagging and autoclave processes. Solid epoxy capsule are used for bonding purposes.

They are amorphous, highly cross-linked polymers as Figure 2.1 and this structure results in these materials processing various desirable properties such as high tensile strength and modulus, uncomplicated processing, good thermal and chemical resistance and dimensional stability as mention by Z.Zhikai (1997).

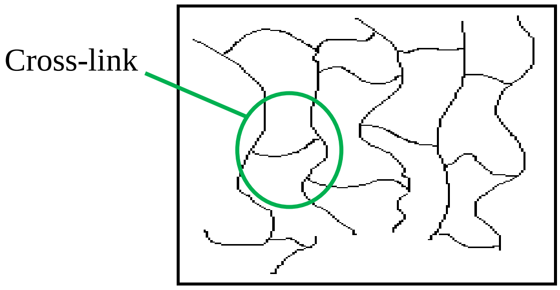

Figure 2.1: Cross-link of Epoxy (molecular chains of epoxy)

2.5 Vermiculite

Vermiculite is a hydrated magnesium-aluminum-iron silicate. Flakes of raw vermiculite concentrate are mica-like in appearance and contain water molecules within their internal structure. When flakes are heated rapidly at a temperature of 900ºC or higher, the water flashers into steam and the flakes expand into accordion like particles. The color, which can range from black and various shades of brown to yellow for the raw flakes, changes to gold, gold brown or bronze. This expansion process is called exfoliation and the resulting lightweight material is chemically inert, fire resistant and odorless. In lightweight plaster and concrete, vermiculite provides good thermal insulation. Vermiculite can absorb liquids such as fertilizers, herbicides, and insecticides, which can then be transported as free-flowing solids (Harben and Kuzvart, 1996, p. 432)

In fire protection, vermiculite-board products include factory-made boards and panels and premixed coatings that can be applied by mechanical spray or by hand; an example is hydrocarbon storage vessels fireproof with vermiculite cement.

Horticultural and related uses have been the largest U.S. end-use category of vermiculite in recent years. Alternative and competing products to vermiculite in this category include bark, peat, and perlite. One active market for vermiculite has been in the friction-lining industry (such as brake and clutch linings) as an alternative to asbestos. A fairly new market area for vermiculite has been in liquid vermiculite dispersions for use in flexible films for packaging, gaskets and other uses (Russell, 1999).

In refractory products, vermiculite is normally bonded with alumina cements, fire clays, and silicates to produce stable high-alumina concretes, high-alumina bonded bricks, slabs and special shapes, and silicate bonded insulating shapes and molded products (Russell, 1999). In this experiment, the vermiculite was collected from Block 5 Chemical Lab from the chemical container as the absorbent and fire protection. Figure 2.2 shows the exfoliated vermiculite.

Figure 2.2: Exfoliated Vermiculite

2.6 Mechanical Testing

Mechanical properties are among the most important properties for material selection and end-use applications. Mechanical behavior in general terms is concerned with the deformation that occurs under loading.

2.6.1 The Tensile Test (ASTM D3039, ISO 3268)

Tensile test are used for grading, selecting and design of material. The data is reported as Young`s modulus, tensile strength, yield strength, elongation at yield, ultimate tensile strength and elongation at break. Each value has specific meanings to the user.

The sample is placed in the grips of the testing machine, which pulls the sample apart at a prescribed rate. The force required to pull the sample apart and the amount of sample stretch are measured. These values along with the sample cross-sectional area in the gauge region are used to calculate tensile properties listed below

Young’s Modulus

A material constant taken from the slope of the stress strain curve in the linear portion. Stress is the measured force of displacement divided by the cross sectional area of the sample in the dog-bone region. The strain is generally measured by incorporation of a strain gage or an extensiometer. The strain must be localized to get a true measurement. The expression for calculating Young’s Modulus is:

$$\boxed{E = \frac{\sigma}{\gamma}} \qquad (1)$$

Where $\sigma = \frac{P}{A}$ and $\gamma = \frac{\Delta L}{L}$

Tensile Strength

The point where elongation of the sample increases without a corresponding increase in force is considered the yield point. This force divided by the cross sectional area is by definition the tensile strength at yield.

$$\boxed{TS = \frac{\text{Force at yield}}{\text{cross sectional area}}} \tag{2}$$

Elongation at yield

The quantity of stretch at the yield point. It is expressed in percent.

$$\boxed{EY = \frac{L - L_{\circ}}{L_{\circ}}.100} \tag{3}$$

Where $L_{\circ} =$ original sample length and L elongated sample length

Ultimate Tensile Strength

The quantity of force applied when sample breaks divided by cross sectional area is the ultimate tensile strength of tensile strength at break.

$$\boxed{UTS = \frac{\text{Force at break}}{\text{Cross sectional area}}} \tag{4}$$

Elongation at break

The quantity of stretch at the point of break expressed in percent. Figure 2.3 shows the tensile test curve.

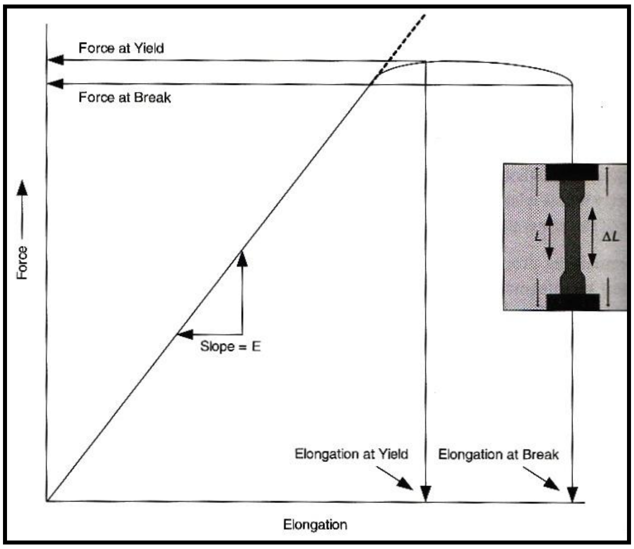

Figure 2.3: Tensile test curve, ASTM D3039

2.7 Rule of Mixture

Particles can have quite a variety of geometries, but they should be of approximately the same dimension in all directions. For effective reinforcement, the particle should be small and evenly distributed throughout the matrix. Furthermore, the volume fraction of the two phases influences the behavior; mechanical properties are enhanced with particulate content. Two mathematical expressions have been formulated for the dependence of the elastic modulus on the volume fraction of the constituent phases for a two-phase composite. These ‘rule of mixture’ equations predict the elastic modulus should fall between an upper bound represented by

$$\boxed{E_c(u) = E_m V_m + E_p V_p} \qquad (5)$$

and lower bound, or limit,

$$\boxed{E_c(l) = \frac{E_m V_m}{V_m E_p + V_p E_m}} \qquad (6)$$

In these expressions, E and V denote the elastic modulus and volume fraction, whereas the subscripts c, m and p represent composite, matrix and particulate phases. Figure 2.4 shows the modulus of elasticity versus volume percent tungsten for a composite of tungsten particles dispersed within copper matrix.Upper and lower bounds are according to equation (5) and (6) as stated in R.H. Krock, ASTM Proceedings, (Vol. 63, 1963).

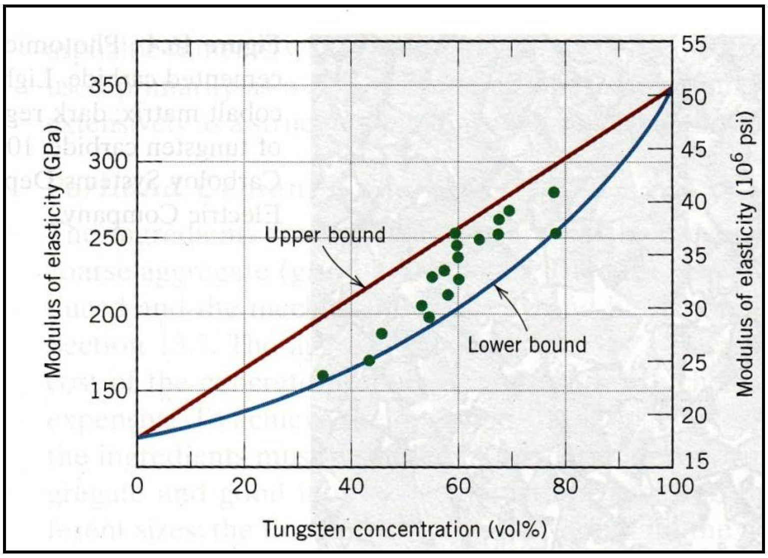

Figure 2.4: Modulus of elasticity versus volume percent of vermiculite

2.8 Hand Lay-Up Technique

The hand lay-up technique, also called wet lay-up, involves manual placement of dry reinforcements in the mold and subsequent application of the resin as Figure 2.5. Then the wet composite is rolled using hand rollers to facilitate uniform resin distribution and removal of air pockets. This process is repeated until the desired thickness is reached. The layered structure is then cured. The hand lay-up process may be divided into four basic steps: mold preparation, gel coating, lay-up and curing.

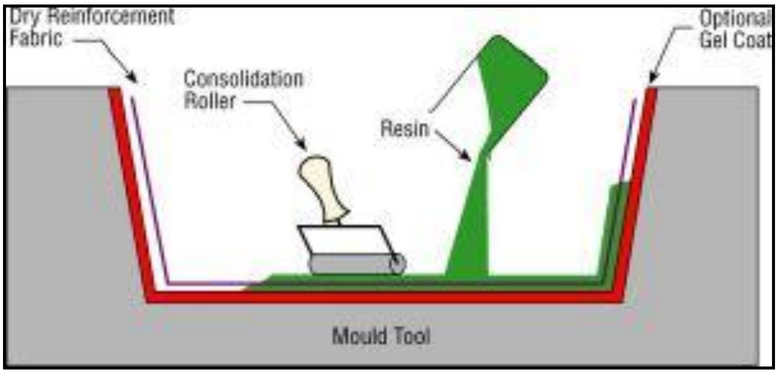

Figure 2.5: Hand Lay-up Process

2.9 Aspect Ratio

An important aspect of researches on composites has been the investigation of their mechanical properties and the parameters affecting the properties of the composites is the shape and distribution of the reinforcement throughout the matrix. It has been proven that composites reinforced with continuous fibers exhibit better properties than the one reinforced with discontinuous reinforcements.

The shape of reinforcements is determined by their aspect ratio that is defined as the ratio between the length and the diameter of the reinforcements. Fibers have the highest aspect ratio among different types of reinforcements. In this experiment, particles will be the shape of the reinforcement and it is the second highest of aspect ratio. Findings have proven that maximum tolerated load in these panels is less than that of the panels reinforced with discontinuous fibers and is about 578 kg but the absorbed energy, which is proportional to the area under diagram, is much higher (H. Elahi, A.S Motevasseli and J. Aghazadeh).

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

Beginning of this project is about researching and understanding regarding shapes and the reinforcement concept and epoxy matrix composites fundamentals. Thorough literature reviews are done through reference books, internet and journals for further understanding. All the works, effort and procedures used in this project are closely follow the provided Gantt chart. See **Appendix 1** regarding the process flow of fabricating the composite tensile specimen.

3.1.1 Grind Vermiculite

This is the first process in fabricating the composite specimen for tensile test. The Vermiculite was collected from Chemical Lab Block 15 as chemical packaging insulators. The Grind process was done at Mechanical Lab Block 17. They are two options, whether to use simple blender or grind machine. Blender was used in this process for about five minutes. Figure 3.1 shows the blender that was used in this experiment.

Figure 3.1: Blender

3.1.2 Sieving Process

The second step is the Sieving process. The sieving machine is located at Civil Lab Block 13.The purpose of this process is to sieve the vermiculite into several classes of meshes that are 1.18mm, 600µm, 425µm, 300µm, 212µm, 150µm, 75µm and less than 75µm. Clean the meshes first by using brush from any dirt or unwanted object that can interfere the result later. Set the sieving machine for about 15 minutes for the vermiculite to settle down. Then, place the sieved vermiculite in to several containers and label it. Figure 3.2 shows the sieving machine at Civil Lab 14.

Figure 3.2: Sieving machine

3.1.3 View Vermiculite in Scanning Electron Microscopy (SEM)

The third process is viewing the sieved vermiculite classes that are 1.18mm, 600µm, 425µm, 300µm, 212µm, 150µm, 75µm and less than 75µm in Scanning Electron Microscopy assisted by Mr.Anuar the Mechanical Technician with the purpose to determine the average aspect ratio (diameter divide by the thickness) of the particulate. The Scanning Electron Microscopy is located at Mechanical Lab Block 17 and this process must be accompanied by the technician because it is expensive and can be used only by train personnel only. Please refer to **Appendix 2** for clear view of vermiculite meshes.

3.1.4 Fabricate the mold

The forth steps is to fabricate the mold of the composite specimen based on the ASTM D3039.The perspex mold with dimension 25cm x 2.5cm x0.25cm was fabricated in block 21 Mechanical lab. Some of the tools were mold perpex cutter, steel measuring ruler, high adhesive glue and plasticine. Figure 3.3 shows the molds that were used.

Figure 3.3: Mold

3.1.5 Calculation of Weight Percent

Before the mixing process, some calculations have to be done first so that the mixture of epoxy, hardener and vermiculite is well mix. Please refer to **Appendix 2** for the calculation.

3.1.6 Mix the Vermiculite with The Epoxy Resin

Mix the vermiculite and epoxy resin according to the calculated mass and manually stir it. Slowly stir to prevent from bubble to appear as shown in Figure 3.4.

Figure 3.4: Mixing process

3.1.7 Put Hardener into the Mixture

Put the hardener into the mixture with the ratio of 1:1 based on the manufacturer. Stir it again until the mixture is well dissolve.

3.1.8 Spray Release Agent On to the Surface of the Mold

Spray release agent on to the surface of the mold thoroughly so that easy to remove the specimen from the mold after curing. Release agent that was used is F28 heavy duty silicone lubricant that suitable for lubricates, anti-rust, releases, protects and food grade as Figure 3.7.

3.1.9 Pour the Mixture into the Mold

Pour the mixture into the mold slowly as Figure 3.5 and monitor if there is bubble, if does, try to remove it by drag the bubble to the wall of the mold and break it. Leave it in room temperature within 24 hours for the curing process to take place. Break the mold to release the specimen and lastly do tensile test.

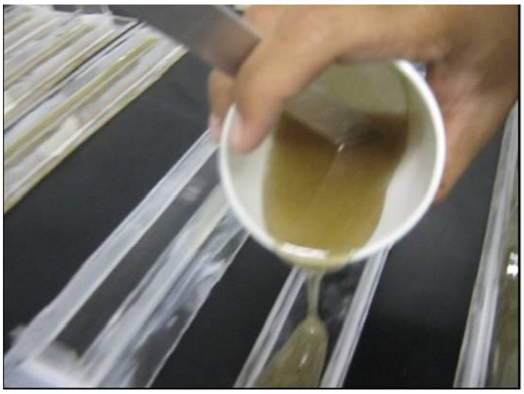

Figure 3.5: Pouring process

3.1.10 Do Tensile Test

After cool in room temperature for 24 hours, do tensile test by using Ultimate tensile machine as Figure 3.9 in Mechanical Lab 17. Several specimens were tested, 0% of composition of vermiculite, 10% and 25%. For 10% and 25%, it is divided by 150m and 75m, see **Appendix 4** for more details. For each category, three samples were tested to get the average data.

3.2 Project Activities

Project activity is mainly the process of fabricating the specimen based on the standard starting from grinding the vermiculite until leave the specimen in room temperature. After that, tensile test process and the data and results were collected and are discuss in chapter 4: Result and Discussion.

Besides that, a purchased ordered Epoxy Resin Clear 3kg and Epoxy Hardener Clear 3kg from Euro Chemo-Pharma Sdn.Bhd at Penang, Malaysia for RM 276.50. The ratio prescribed by the manufacturer is 1:1 as Figure 3.6 shows the Epoxy and Hardener.

Figure 3.6: Epoxy and Hardener

3.3 Project Gantt Chart

A Gantt chart is constructed to plan and organize all works so that the project can be completed as scheduled. Gantt chart shows the activities which are arranged according to the specific dates. The tasks and its specific date are shown clearly in Table 3.1.

Table 3.1: Gantt chart for progress monitoring

NO.	DETAILS/WEEK	1	2	3	4	5	6	7	8	9	10		11	12	13	14	15	16
1	Project Work Continue	🟪	🟪	🟪								🟩						
		🟧	🟧	🟧								🟩						
2	Submission of Progress Report 1				🟪							🟩						
					🟧							🟩						
3	Project Work Continue				🟪	🟪	🟪	🟪				🟩						
					🟧	🟧	🟧	🟧	🟧	🟧		🟩						
4	Submission of Progress Report 2								🟪			🟩						
									🟧			🟩						
5	Seminar (compulsary)										🟪	🟩						
											🟧	🟩						
6	Project Work Continue								🟪	🟪	🟪	🟩						
									🟧	🟧	🟧	🟩						
7	Poster Submission										🟪	🟩						
											🟧	🟩						
8	Submission of Dissertation (soft bound)											🟩					🟪	
												🟩					🟧	
9	Oral Presentation											🟩						🟪
												🟩						🟧
10	Submission of Porject Dissertation (hard bound)											🟩						🟪
												🟩						

🟪 plan
🟧 actual
🟩 mid sem break

3.4 Tools

3.4.1 Release Agent

In this project, release agent is use just before the mixture is pour into the mold. The purpose of the release agent is to ease the release of the specimen from the mold surface and prevent the specimen from sticking onto the mold. Figure 3.7 shows the release agent that being use in this project.

Figure 3.7: Release Agent

3.4.2 Ultimate Tensile Machine

For the tensile, compression, bend and shear test of various metal material, or plastic, concrete, cement and other non-metal material. Figure 3.8 shows the Ultimate Tensile Machine in mechanical lab. The main aspect is to do test on tensile and record the data of the mechanical properties.

Figure 3.8: Ultimate Tensile Machine

3.4.3 Scanning Electron Microscope (SEM)

The scanning electron microscope (SEM) is a type of electron microscope that images the sample surface by scanning it with a high-energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition and other properties such as electrical conductivity. In this experiment, the use of SEM is to identify the average aspect ratio of vermiculite particles. The SEM machine is located at mechanical lab Block 17. It must be accompanied by the technician.

3.4.4 Sieving Machine

In this experiment, sieving machine as in Figure 3.3 is used in second steps of fabricating the composite specimen. Sieve in several classes of meshes that are 1.18mm, 600µm, 425µm, 300µm, 212µm, 150µm, 75µm and less than 75µm.

3.4.5 Weigh Machine

Weigh machine were used in several occasion in this project such as, weigh the vermiculite, epoxy, hardener before mixing and also weigh the tracing paper. The weigh machine is limited to 500g only and it is located at Mechanical Lab 17 as Figure 3.9.

Figure 3.9: Weigh Machine

CHAPTER 4
RESULT AND DISCUSSION

4.1 Aspect Ratio

From the observation of Vermiculite in SEM, eight average aspect ratios were established. For 1.18 mm the average diameter is 3843 µm and the average thickness is 254.4 µm hence the aspect ratio is 15.11. For 600µm, the average diameter is 1518.89 µm and the average thickness is 222.2 µm hence the aspect ratio is 6.84.For 425 µm the average diameter is 793.88 µm and the average thickness is 68.71 µm hence the aspect ratio is 11.55 . For 300 µm, the average diameter is 605.28 µm and the average thickness is 52.29 µm hence the aspect ratio is 11.57.For 212 µm, the average diameter is 380.24 µm and the average thickness is 35.49 µm hence the aspect ratio is 10.71. For 75 µm, the average diameter is 187.74 µm and the average thickness is 32.73 µm hence the aspect ratio is 5.74. For vermiculite less than 75 µm, the average diameter is 81.07µm and the average thickness is 8.01µm hence the aspect ratio is 10.12. Table 4.1 shows the data for the aspect ratio.

Table 4.1: Aspect Ratio Data

MESH (μm)	Diameter (μm)	thickness(μm)	Aspect ratio $= \frac{\text{diameter}}{\text{thickness}}$
1180	3843	254.4	15.11
600	1518.89	222.2	6.84
425	793.88	68.71	11.55
300	605.28	52.29	11.57
212	380.24	35.49	10.71
150	350.65	15.45	22.69
75	187.74	32.73	5.74
<75	81.07	8.01	10.12

From table, two aspect ratios were selected 22.69 from 150 μm and 5.74 from 75 μm meshes because they have the most extreme different in aspect ratio.

4.2 Final Cross Section Area

Final cross section area will be use later to calculate the Tensile Strength, Stress at Break and Stress at Yield. To determine the final cross section area, two variables that were consider, that is the area of the tracing paper and the weight of the tracing paper. Three different squared area tracing papers were cut and weigh to set the setting line where graph of area (cm^2) versus mass (mg) were plotted. The three squared setting area were 2cm x 2cm, 4cm x 4cm and 10cm x 10cm where their weigh are 44mg, 178.75 mg and 1125.65mg as figure 4.1.

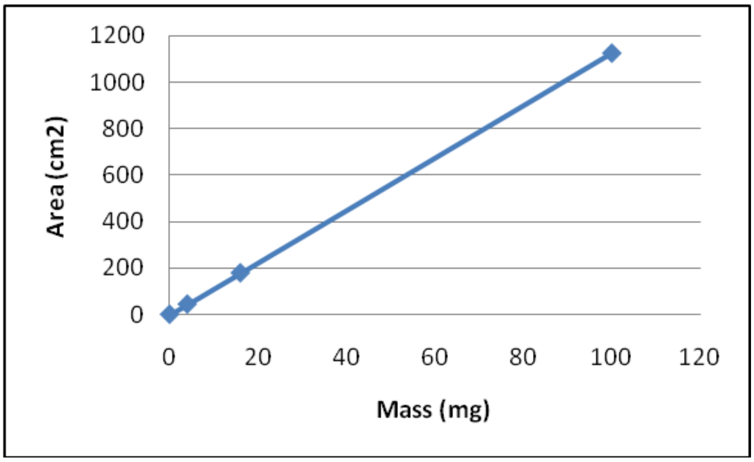

Figure 4.1: Area versus mass

After the tensile test, cut the specimens near the breaking part of the specimen. Trace the area of the cut specimen on the tracing paper, cut it and weigh it. Figure 4.2 shows the cut and tracing of the specimen.

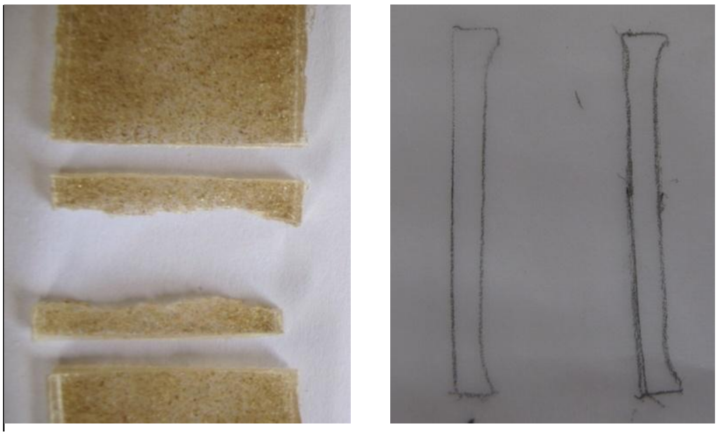

Figure 4.2 : Cut and trace

From the graph, we can determine the mass (mg) of each specimen. Table 4.2 shows the data of weight for each specimen.

Table 4.2: Weight of Specimens

	epoxy	75m 10%	75m 25%	150 m 10%	150 m 25%
Mass (mg)	8.7	8.6	7.8	7.85	6.75
Tracing paper (cm^2)	0.7909	0.7818	0.7091	0.7136	0.6136

4.3 Stress-strain Curve and Data Obtained

From the tensile test, several mechanical properties such as Stiffness, Young’s Modulus, Load at Maximum ,Load at Break , Load at Yield ,Tensile Strength, Stress at Break, Work to Break and Stress at yield were obtained from the stress-strain curve, see **Appendix 5** for details clear view of the each stress-strain curves . The tensile test speed was set to 50 mm/min. See **Appendix 6** regarding raw data obtained from the stress-strain curve of the composite specimens. See **Appendix 7** regarding calculated data of Final Tensile Strength, Final Stress at Break and Final Stress at yield.

4.4 Mechanical Properties of Vermiculite in Epoxy Matrix Composite

From the calculated data, several final mechanical properties such as Tensile Strength, Stress at break and Stress at yield were obtained and tabulated in Table 4.3.

Table 4.3: Data of Mechanical properties

Composition	Epoxy (100%)	Vermiculite : Epoxy 25% : 75%		Vermiculite : Epoxy 10% : 90%	
Vermiculite Mesh (µm)	-	150	75	150	75
Stiffness (N/m)	1182802.815	1300159.043	5734258.63	2666434.144	2124053.545
Young's Modulus(MPa)	2838.7268	3120.3817	13762.2205	6399.4419	5097.7285
Tensile Strength,$_f$ (MPa)	15.2074	16.3486	14.7984	25.4388	18.6219
Stress at Break,$_f$ (MPa)	10.074	11.0448	10.2114	19.9375	12.2507
Work to Break (J)	54.248	13.9078	12.3817	8.0438	23.5055
Stress at Yield,$_f$ (MPa)	15.2074	16.3486	14.7984	21.7354	18.6219

From table 4.3, the data are represented in the form of two different curve lines, in **Section 4.4.1** until **4.4.6.**

4.4.1 Stiffness Versus Composition of Vermiculite

Stiffness is a measure of the resistance offered by an elastic body to deformation. From Figure 4.3, the stiffness for 150µm (2666434.114 N/m) is slightly higher than 75µm (2124053.55 N/m) in 10% composition while in 25% composition, 75µm (1300159.04 N/m) is far higher than 150µm (5734258.63 N/m). Stiffness for 150µm is higher in 10% composition but lower in 25% composition maybe because the 10% composition is the highest composition that 150µm can achieved in the maximum stiffness , after that the slope is decreasing for 25% composition. While for 75µm the stiffness slope is increasing as the composition is increase. Hence, it is better to choose low aspect ratio that is 5.74 and also high in percent composition of vermiculite, in this case 75µm of mesh and 25% composition for higher stiffness properties in composite material.

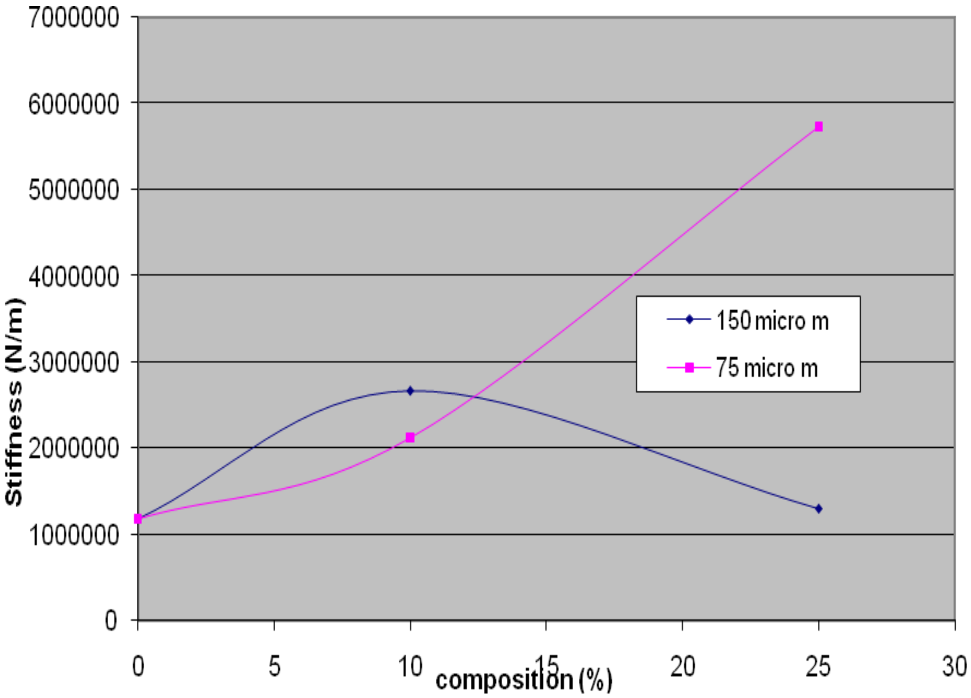

Figure 4.3: 150µm and 75µm trend of slopes for Stiffness versus composition of vermiculite

4.4.2 Young’s Modulus Versus Composition of Vermiculite

Young’s Modulus , E or also known as modulus of elasticity is a constant of proportionality in the Hooke’s Law where it represent by the formula $\sigma = E\varepsilon$. Hooke’s Law is a relationship between engineering stress and engineering strain for elastic deformation. From Figure 4.4, Young’s Modulus of 150µm (6399.44MPa) is slightly higher than 75µm (5097.73MPa) in 10% composition while in 25% composition, 75µm (13762.22MPa) is higher than 150µm (3120.38MPa). Young’s Modulus for 150µm is higher in 10% composition but lower in 25% composition maybe because the 10% composition is the highest composition that 150µm can achieved, after that the slope is decreasing for 25% composition. While for 75µm the Young’s Modulus slope is increasing as the composition is increase. Hence, it is better to choose low aspect ratio that is 5.74 and also high in percent composition of vermiculite, in this case 75µm of mesh and 25% composition for higher Young`s Modulus properties in composite material.

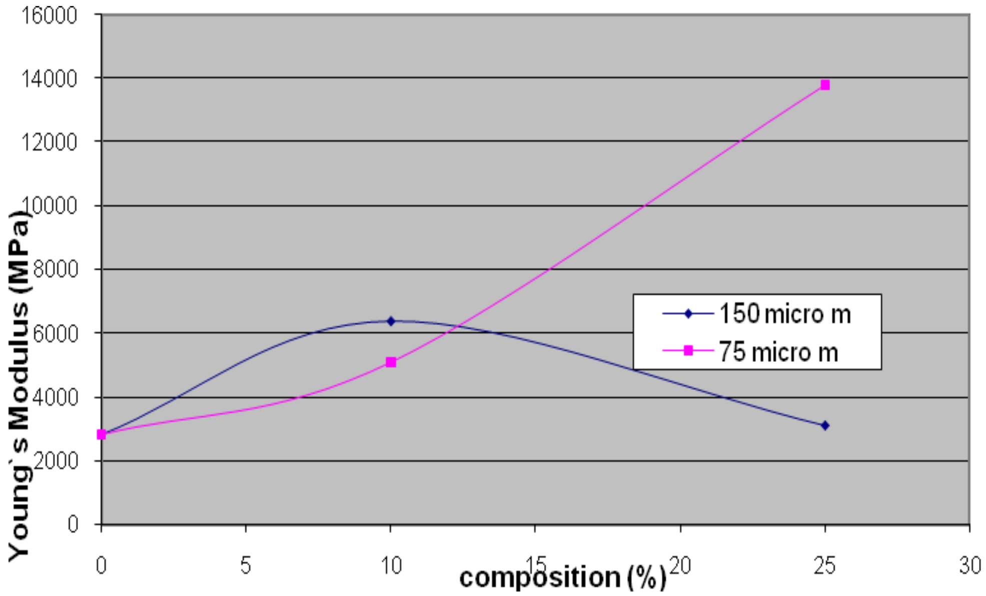

Figure 4.4: 150µm and 75µm trend of slopes for Young’s Modulus versus composition of vermiculite

4.4.3 Tensile Strength Versus Composition of Vermiculite

The tensile strength is the stress at the maximum on the engineering stress-strain curve . This corresponds to the maximum stress that can be sustained by a structure in tension. From Figure 4.5, 150µm (25.44 MPa) is higher than 75µm (18.62 MPa) in 10% composition , same as 25% composition, where 150µm (16.35 MPa) is slightly higher than 75µm (14.80 MPa). Tensile strength for 150µm is higher at 10% composition but lower in 25% composition. While for 75µm, the trend of tensile strength slope is the same as 150µm but lower. The slope is increase at 10% composition because the 10% composition is the optimum value. The 150µm is higher than 75µm because of the strengthening effect from the reinforcement elongation. Hence, for higher tensile strength properties, it is better to choose high aspect ratio and less percent composition, which are 22.69 from 150µm of mesh and 10% composition of vermiculite for composite material.

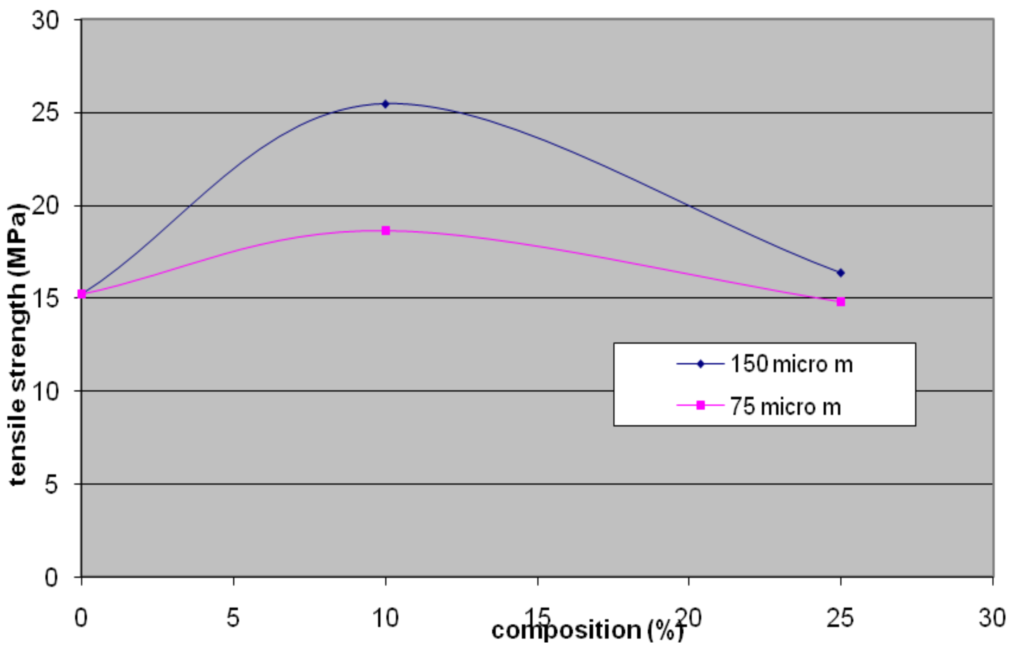

Figure 4.5: 150µm and 75µm trend of slopes for tensile strength versus composition of vermiculite

4.4.4 Stress at Break Versus Composition of Vermiculite

Stress at break (MPa) is formulated from Load at break (N) divided by final cross section area (m^2). From Figure 4.6, 150µm (19.94 MPa) is far higher than 75µm (12.25 MPa) in 10% composition, while in 25%, the 150µm (11.04 MPa) is slightly higher than 75µm (10.21 MPa). Stress at break for 150µm is higher in 10% composition but lower in 25% composition. While for 75µm the trend of stress at break slope is as same as 150µm but lower. See section 4.3.3 for explanation. The slope is increase at 10% composition because the 10% composition is the optimum value. The 150µm is higher than 75µm because of the strengthening effect from the reinforcement elongation. Hence, for higher stress at break properties, it is better to choose high aspect ratio that is 22.69 and less percent composition, which is from 150µm of mesh and 10% composition of vermiculite for composite material.

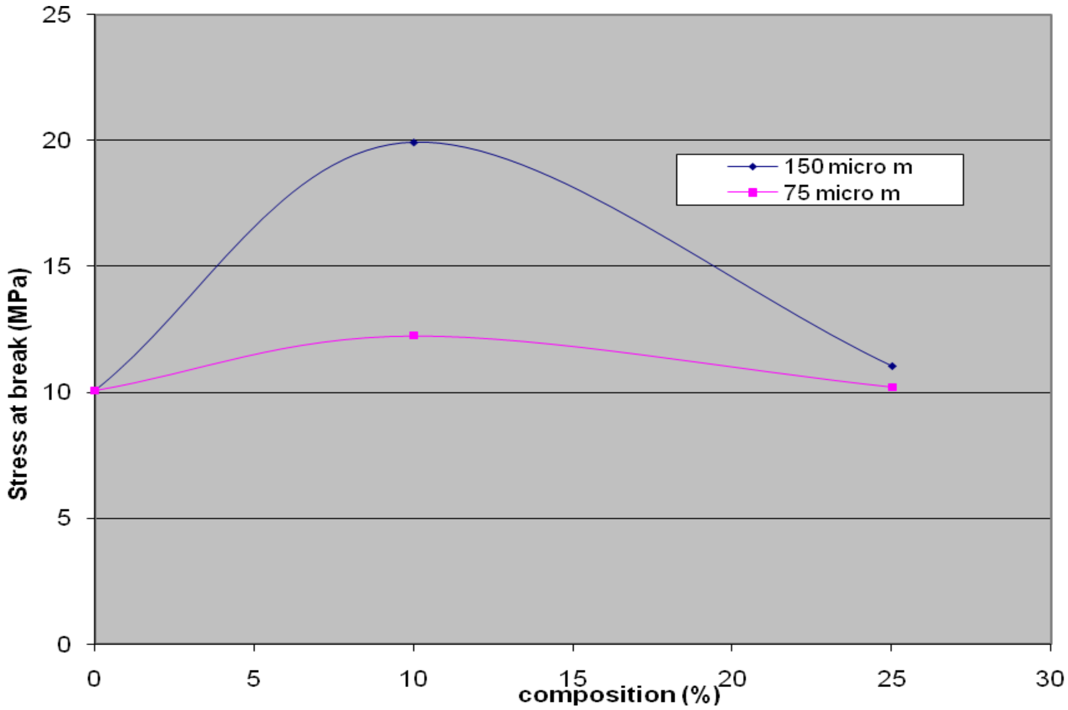

Figure 4.6: 150µm and 75µm trend of slopes for stress at break versus composition of vermiculite

4.4.5 Toughness Versus Composition of Vermiculite

Toughness is a mechanical term that is used in several contexts, loosely speaking , it is a measure of the ability of a material to absorb energy up to fracture. From Figure 4.7 above, the work to break or energy to break is higher for 75µm (23.51 J) than 150µm (8.04 J) in 10% composition of vermiculite but at 25% composition, 150µm (13.91 J) is slightly higher than 75µm (12.38 J). Toughness for 150µm is decrease from 0% composition of vermiculite to 10% but increase in small amount in 25%, while for 75µm, the toughness slope is decrease from 0% composition to 25%. The trend of slope is decrease because of the incompatibility surface properties, where epoxy is non-polar while vermiculite is highly polar. As the vermiculite is increase, the toughness will decrease. The toughness of 75µm is higher than 150 µm because the 75 µm have less extensive of interface hence less surface incompatibility Hence, for toughness properties, it is better to choose low aspect ratio that is 5.74 and less percent composition, which is from 75µm of mesh and 10% composition of vermiculite for composite material.

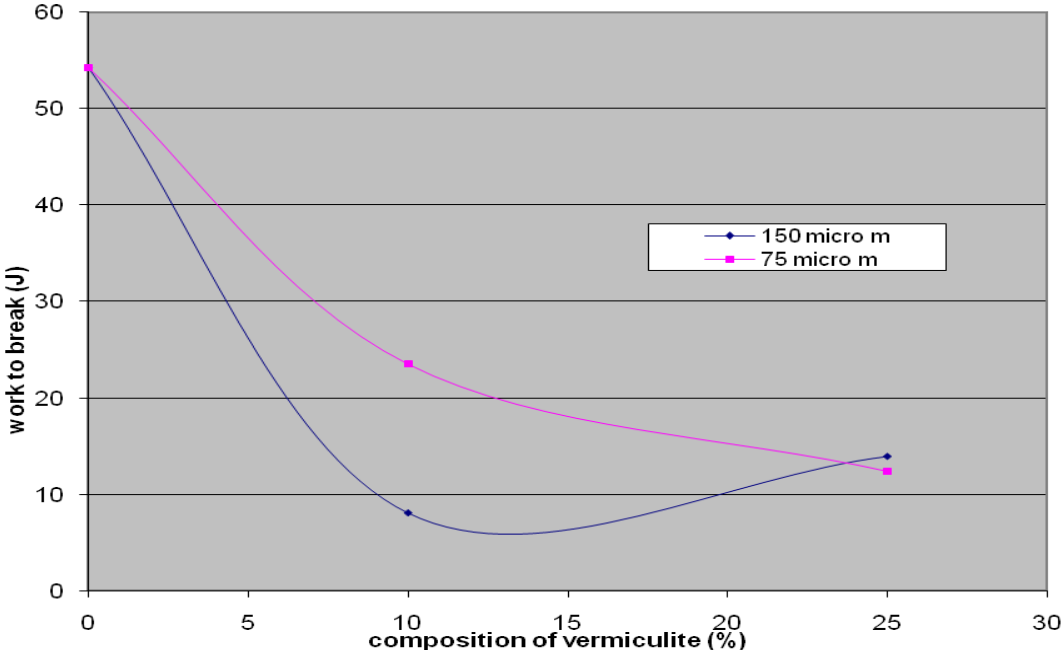

Figure 4.7: 150µm and 75µm trend of slopes for work to break versus composition of vermiculite

4.4.6 Stress at Yield Versus Composition of Vermiculite

Stress at yield (MPa) is formulated by load at yield (N) divided by final cross section area (m^2).From Figure 4.8, stress at yield for 150µm (21.74 MPa) is higher than 75µm (18.62 MPa) in 10% composition, same as 25% composition, where 150µm (16.34 MPa) is higher than 75µm (14.80 MPa). Stress at yield for 150µm is higher in 10% composition but lower in 25% composition. While for 75µm the trend of stress at yield slope is as same as the 150µm but lower. The slope is increase at 10% composition because the 10% composition is the optimum value. The 150µm is higher than 75µm because of the strengthening effect from the reinforcement elongation. Hence, for higher stress at yield properties, it is better to choose high aspect ratio and less percent composition, which are 22.69 from 150µm of mesh and 10% composition of vermiculite for composite material.

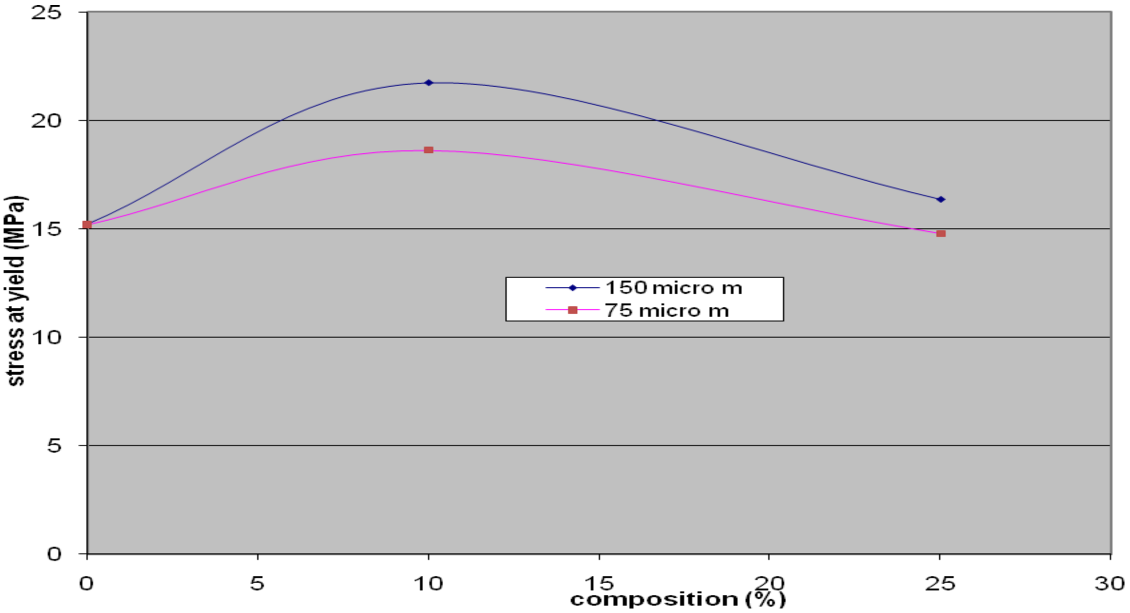

Figure 4.8: 150µm and 75µm trend of slopes for stress at yield versus composition of vermiculite.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The mechanical properties achieved from tensile testing of vermiculite as reinforcement in epoxy matrix composite materials have been studied and discussed. The following conclusion can be drawn from the present study. First conclusion is that the reinforcing effect is better for high aspect ratio 22.69 rather than small 5.74 represents by the tensile strength because of the elongation effect. Second conclusion, for stiffness criteria, it is better to choose the lower aspect ratio 5.74 rather than 22.69. Third conclusion, for Young’s Modulus or elasticity criteria, the lower aspect ratio 5.74 is better, additionally in higher percent composition that is 25%. Forth conclusion, the toughness is affected by the incompatibility surface properties criteria, hence it is better to choose the lower aspect ratio 5.74 to maintain its toughness.

5.2 Recommendation

Some recommendation for this project is to add several more percent composition of Vermiculite in the epoxy matrix composite, so that further understanding of the slope trend can be achieved. To add some test on the specimens such as flexural test for further understanding of the reinforcing effect of Vermiculite in Epoxy matrix composite. Lastly, to use surfactant to increase surface compatibility in future studies.