Tensile Strength Of
Polyester/Woven Kenaf Composites

By

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CERTIFICATION OF APPROVAL

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Approved by,

(Dr. Mohamad Zaki B. Abdullah)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

This report presents the discussion on the mechanical properties of polyester/woven kenaf composites under the standard of ASTM. It consists of project's background, literature review, methodology, and all the relevant process and component related to this project. The usage of natural fiber in composites has been a huge breakthrough in Material Department. Natural fiber has very unique properties that can be used as a reinforcement of composites. Natural fiber has several advantages compare with glass fiber in terms of density, cost, renewability, abrasiveness, recyclability and biodegradability. With this, it can produce a better material that can be commercialized. In this study, the static mechanical properties of woven kenaf fiber reinforced with polyester composites was determined. By understanding the behavior of the kenaf fiber and also polyester, the static mechanical properties which was tensile properties was predicted. However, the study on polyester/woven kenaf composites tensile properties was very limited. Thus, the main objective of this study, to investigate about the tensile properties of polyester/knitted kenaf composites. The composites were fabricated using a hand lay-up method and the compositions that was tested are 80% of matrix and 20% for the reinforcement. In order to produce the composites, the kenaf were prepared by weaving it according to the desired size and then it was fused in a perspex mold using a roller to push the polyester into the woven kenaf. The results obtain was compared to pure polyester and it shows that the composites improved the tensile strength by 355% approximately. Based on the field emission scanning electron microscopy (FESEM) result, it showed that the interfacial bonding between the polyester and woven kenaf is good.

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Muhammad Al-Afiq Bin Abu Bakar

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CHAPTER 1:
INTRODUCTION

1.1 Background Study

Composite materials is a structural material that consists of two or more combined constituent materials which have different in mechanical properties. When they are combined a material with different mechanical properties are produced. There are two main components of composite material which are matrix and reinforcement. In this project the matrix was Polyester and the reinforcement was kenaf fiber which is a type of natural fiber.

Natural fiber can be subdivided based on their origin such as plant, animal, minerals and plant fiber. Kenaf falls into the plant fiber as it origin is from Hibiscus Cannabinus. Natural fiber like kenaf, sisal, jute, coir, and oil palm fiber have been proven to be good reinforcement with thermosets and thermoplastics matrices. Kenaf fiber as a natural fiber has several advantages compare to glass fiber in terms of low density, low cost, renewability, less abrasiveness, recyclability and biodegradability.

Polyester is a type of polymer which contains the ester functional group in the main chain. Polyester is a thermosets based on its structure. Thus it cannot be recycled. That is the main disadvantage of polyester. However, polyester has very robust properties. It is extremely strong, very durable, wrinkle resistance, and it is easily washed and dried. Thus for this project to make the composite material the polyester will be the matrix for the kenaf fiber. As the motivation for the project, by using kenaf which is environmental friendly can save the natural environment and by making polyester and kenaf composite can replace more cheaply and reasonable product that are available on the market for example car body parts and furnisher.

1.2 Problem Statement

Even though woven kenaf reinforced polyester composite has very good potential in enhancing mechanical properties as compared to neat polyester, very limited studies have been done on the composite especially on its tensile strength. Therefore, this project was proposed.

1.3 Objective

The objective of this project is to study tensile strength of polyester/woven kenaf composite.

1.4 Scope of Study

In this study, polyester was used as the matrix and kenaf was employed as the reinforcement. Kenaf was manually woven before it was reinforced with polyester. The specimens were fabricated using hand lay-up technique. Due to mold cavity limitation, only 80/20 (polyester/woven kenaf) composition was produced. The specimens were manually cut according to ASTM D638 standard.

CHAPTER 2:

LITERATURE REVIEW

2.1 Composite Materials

Composite material was used in many areas in this world. It is not a new discovery. A composite is a structural material which consists of combining two or more constituents. The constituents are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. Wood, straw and mud have been everyday composites. Composites have also been used to optimize the performance of some conventional weapons. Composite materials that obtained nowadays are very heterogeneous and very anisotropic which means the mechanical property of the material depends on the directions [1]. Many commercially produced composites use a polymer matrix material often called a resin solution.

There are many different polymers available depending upon the starting raw ingredients. There are several broad categories, each with numerous variations. The most common are known as polyester, vinyl ester, epoxy, phenolic, polyimide, polyamide, polypropylene, PEEK, and others. The reinforcement materials are often fibers but also commonly ground minerals. The various methods described below have been developed to reduce the resin content of the final product, or the fiber content is increased. As a rule of thumb, lay up results in a product containing 60% resin and 40% fiber, whereas vacuum infusion gives a final product with 40% resin and 60% fiber content. The strength of the product is greatly dependent on this ratio [2]. Reinforcing materials for polymer matrix composites are often referred to as fibres and they include E-glass, aramid(Kevlar), carbon, alumina, silicon carbide, and also boron. The properties of the fibers are shown in Figure 2.1. These fiber materials all have high specific strength and stiffness imparting high strength and stiffness to the composite [3].

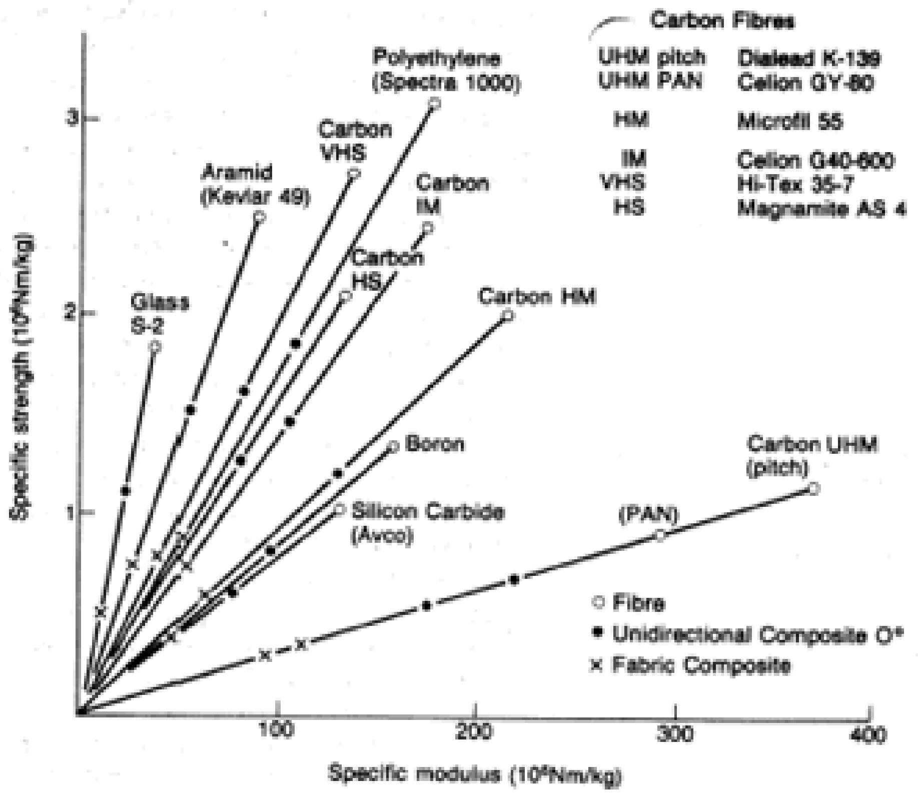

Figure 2.1: Properties of common reinforcing fibers [3].

2.2 Natural Fiber

There are many types of fiber that available on this world. These fibers have many types of application. Steel fiber, Glass fiber, Polypropylene Fiber, Asbestos fiber, Organic fiber, Vegetable fiber, Carbon fiber, Polyester fiber etc. are various types of fiber available in world. Fiber technology is one of the fastest updating technologies today. There are currently 2,00,000 metric tons of fibers used for concrete reinforcement [4].

Natural fiber has become attractive to researcher, engineers and scientist as an alternative reinforcement for fiber reinforcement polymer composites. This is because they have low cost, fairly good mechanical properties, high specific strength, non-abrasive, eco-friendly, and have bio-degradable characteristic. They can be an alternative in order to replace the conventional fiber, such as carbon and glass [5].

Besides that these are some of the advantages and disadvantages of natural fiber. They are renewable, can be thermally recycled, give less problem concerning health and safety of workers, less abrasive, good specific properties, good thermal and acoustic properties and also excellent price-performance. They also have disadvantages such as moisture adsorption, fluctuation in quality, price, and availability, dimension instability, susceptibility to rotting, swelling leads to micro-cracking, restricted processing temperature, low strength, and the smell of natural fiber when process at high temperature [1] and [6]-[12].

Unlike the traditional engineering fibers, e.g. glass and carbon fibers, and mineral fillers, these lignocellulosic fibers are able to impart the composite certain benefits such as low density, less machine wear during processing than that produced by mineral reinforcements, no health hazards, and a high degree of flexibility. The later is especially true because these fibers, unlike glass fibers, will bend rather than fracture during processing.

Whole natural fibers undergo some breakage while being intensively mixed with the polymeric matrix, but this is not as notorious as with brittle or mineral fibers. Also, natural fibers impart the composite high specific stiffness and strength, a desirable fiber aspect ratio, biodegradability, they are readily available from natural sources and most important, have a low cost per unit volume basis. It should also be mentioned that the hollow nature of vegetable fibers may impart acoustic insulation or damping properties to certain types of matrices [6]-[12]. Figure 2.2 shows the example of natural fibers.

Figure 2.2: Example of natural fibers [6].

2.3 Research about Mechanical Properties of Natural Fiber Composites

There are many studies that have been done over a past few years mainly about natural fibers and composites. Composites spread so widely during short period of time due to their high mechanical properties and their low weight. They have been used for a variety of applications although they were born originally in the aerospace industry where light weight plays an important role in selecting the appropriate materials.

All parts made of composites are designed to sustain long life. This advantage has become disadvantage due to the fact that composites are not easy to dispose off after their proposed life. There are many method to dispose the composites, however the methods really expensive and have potential to polute the world. Referring to this facts, the research about composites and natural fiber increase.

Many researcher are trying to develope a very good quality of natural fiber. There are many ways that can be used. Alkalization, acetylation, cyanoethylation, the use of silane coupling agent, and heating have carried out in order to modify the fiber surface and its internal structure. Also indicated by infrared spectroscopy, X-ray diffraction and tensile tests, variations in composition, structure, dimensions, morphology and mechanical properties of the sisal fibers can be induced by means of different modification methods [13].

The volume of the fiber in composites also main an important role as a study shows that the higher the percentage of the fiber, the mechanical properties will be increase also. But this factor excludes the bonding between the composites which means the bonding between the composites can affect the mechanical properties.

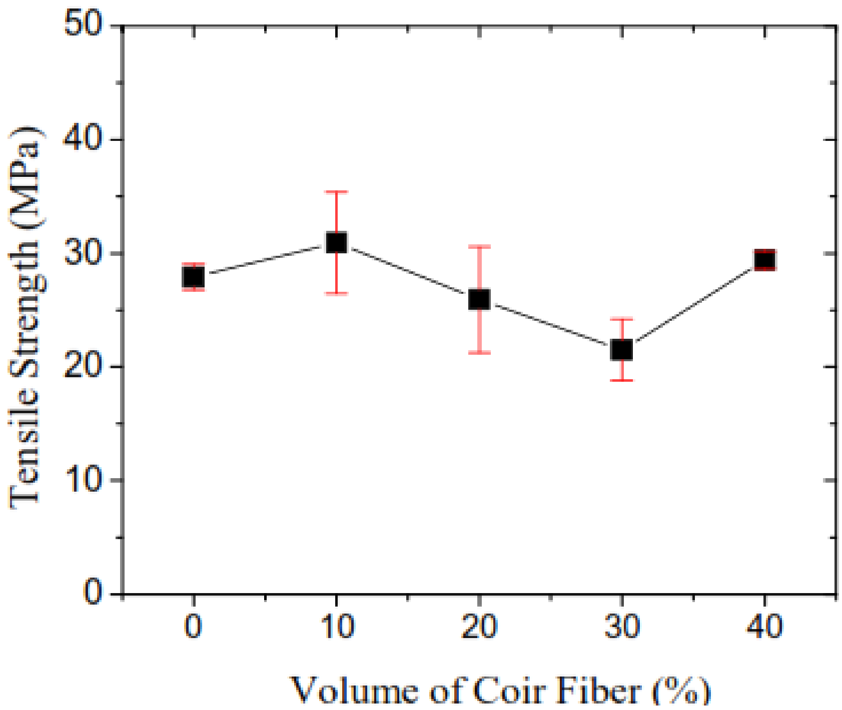

Figure 2.3.1: Variation of tensile strength with the volume fraction of coir fiber [13].

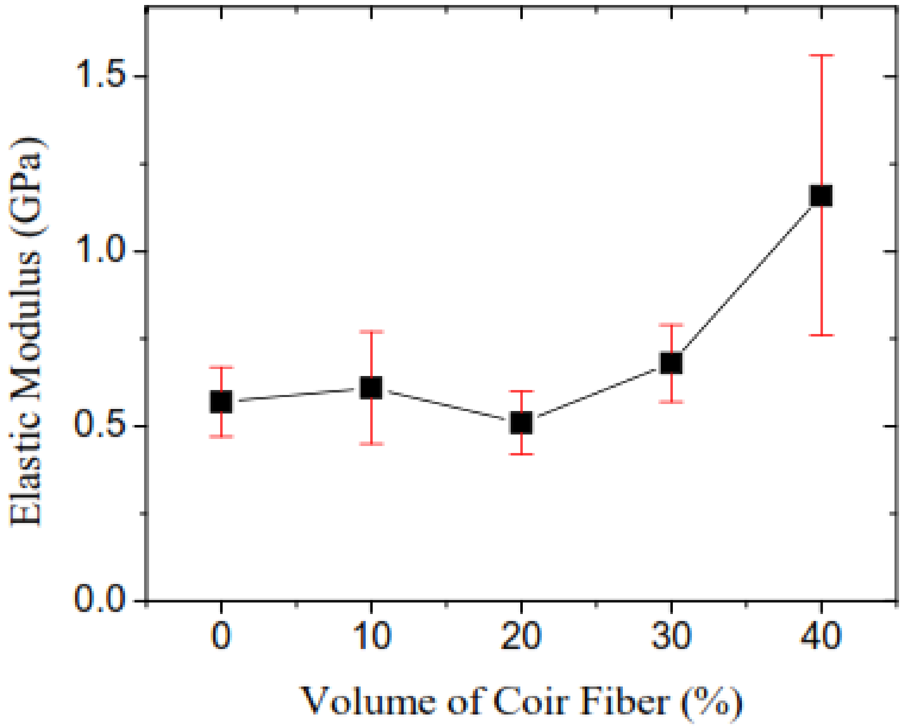

Figure 2.3.2: Variation of elastic modulus with the volume fraction of coir fiber [13].

Figure 2.3.1 and 2.3.3 shows that the variation of tensile strength and elastic modulus with the volume fraction of coir fiber reinforcing polyester composites [13]. It is shown that at 40% of volume fraction the modulus elasticity is high and the tensile strength also high. This shows that the composition of the composite can really influence the tensile strength.

Natural fibers, when used as reinforcement, compete with such technical fibers as glass fiber. The advantages of technical fibers are good mechanical properties; which vary only little. Several natural fiber composites reach the mechanical properties of glass fiber composites, and they are already applied, e.g., in automobile and furniture industries. Natural Fibers are renewable raw materials and they are recyclable [13].

The study of kenaf composite is mainly to investigate the mechanical properties of the composites. Figure 2.3.3 shows that the TPNR-kenaf-MAPP composites have the best mechanical properties compared to others.

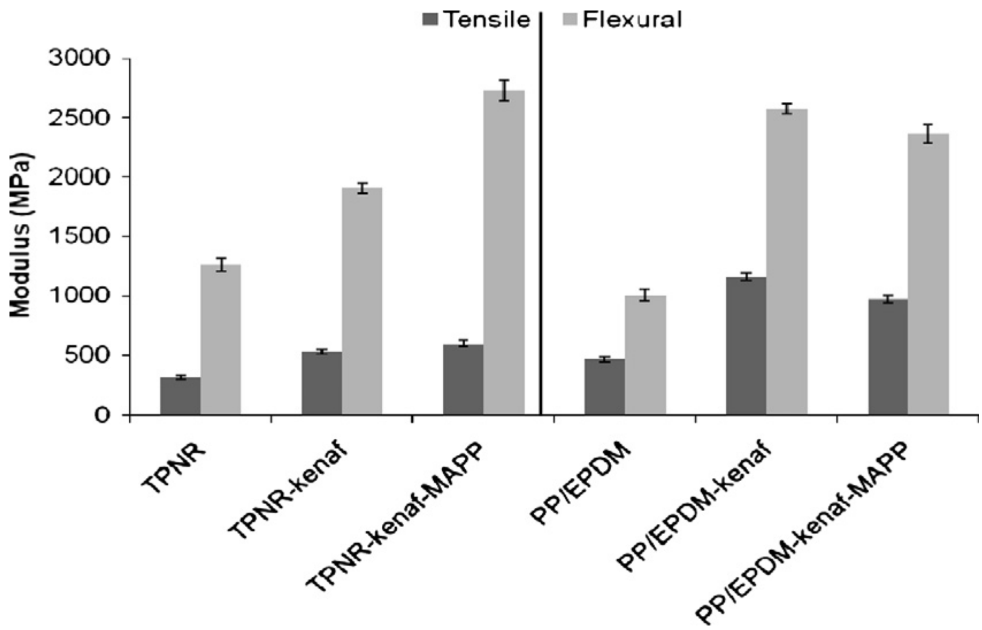

Figure 2.3.3: Tensile modulus and flexural modulus of TPNR composite and PP/EPDM composites [14].

The study to inestigate about the kenaf fiber properties also have been done. It was shown that thermal analysis of kenaf fibers revealed that tensile strength of kenaf fibers decreased when kept at 180 degree celsius for 60 min. Therefore, biodegradable composites were fabricated at a molding temperature of 160 degree celsius.

The unidirectional fiber-reinforced composites showed tensile and flexural strengths of 223 MPa and 254 MPa, respectively [15]. It is shown that at 160 degree celsius is the highest temperature that will not effect the properties of kenaf fiber. Dynamic mechanical properties of pultruded kenaf fiber reinforced polyester composites are greatly dependent on the volume fraction of the fiber [16].

CHAPTER 3:

METHODOLOGY

3.1 Procedure

The procedure for this project can be divided into two stages. The first stage was test sample preparation and for the second stage was tensile strength testing.

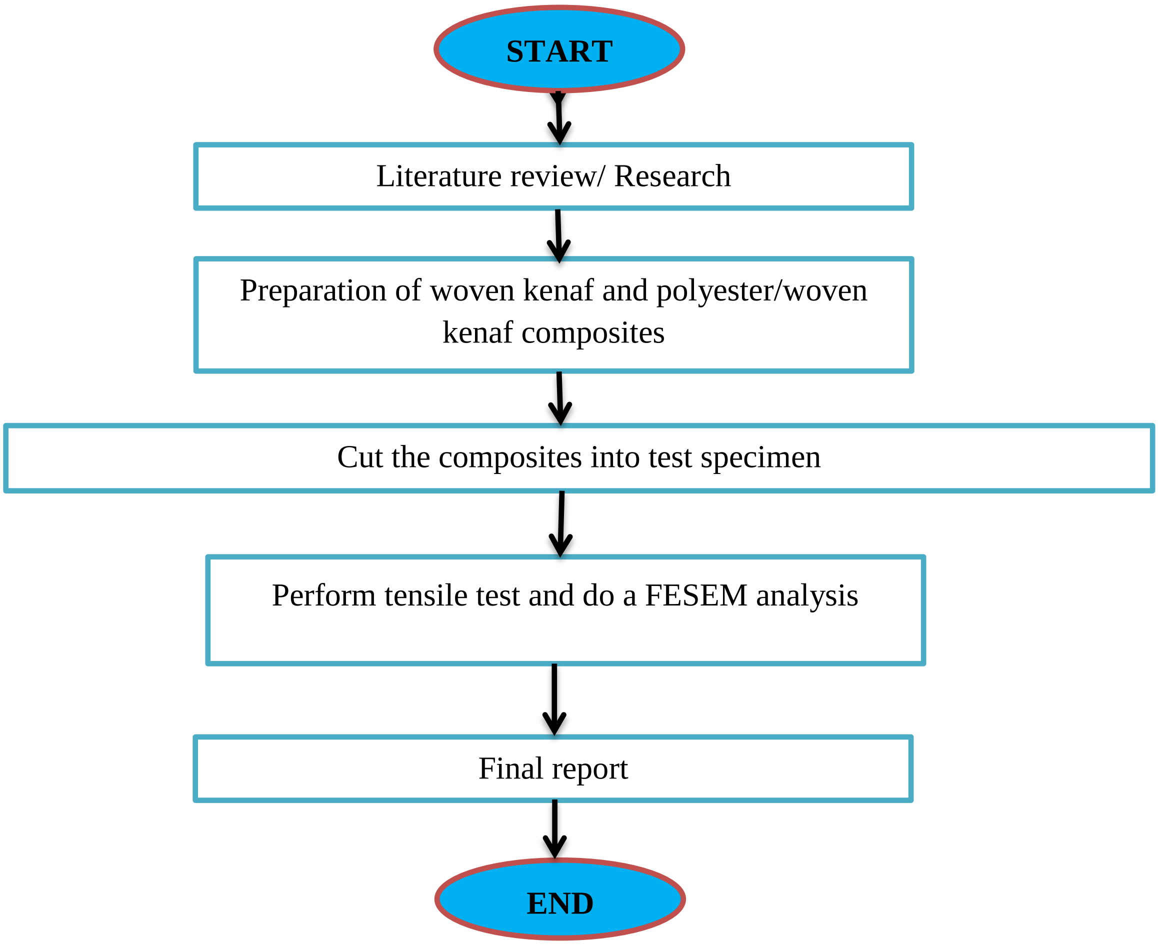

Figure 3.1: Shows the flow chart of the project activities.

3.1.1 Preparing the apparatus for this project.

Most of the apparatus needed for this project were available in the lab. The weaving kenaf frame was one of the apparatus that was limited in the lab. In order to save the time a new weaving frame were fabricated.

The weaving frame can produce a 40 cm both for the length and width woven kenaf. The hand lay-up mold also needs to be prepared and the lab cannot provide the mold. The new mold was design with 35cm for the width and length and it also have a depth 8 mm to produce 6-8mm composites sheets. Because of limited time allocated, the mold was built outside. Figure 3.1.1 below shows the weaving kenaf frame.

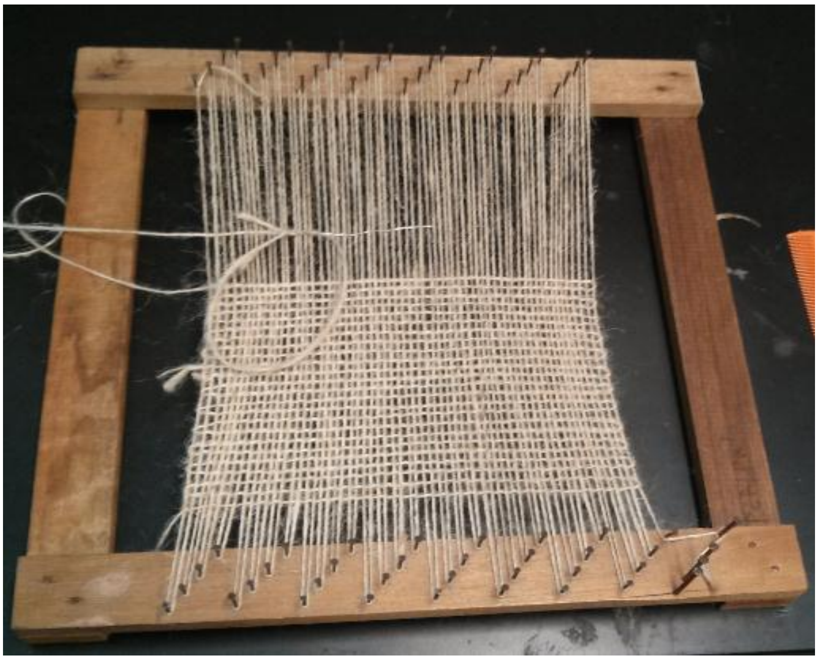

Figure 3.1.1: Woven kenaf on weaving tool.

3.1.2 The polyester sheets and polyester/knitted kenaf composites production.

There are several techniques to produce a thermosets composite, and hand lay-up method was chosen for this project. Hand lay-up method was chosen because it is easy to fabricate and simple to prepared. This procedure will be done in a room temperature and the composites will be prepared by using a roller to push the kenaf fiber into the molten polyester.

The roller is needed to ensure that the molten polyester is perfectly combined with the kenaf fiber. To obtain 80 wt% matrix and 20 wt% of fiber composites the weight of the kenaf fiber and the polyester need to be measured. Approximately there will be five plates of composites that will be prepared for this project. All the plates of composites will be having 6-8 mm thickness approximately. Figure 3.1.2 below shows that the author fabricated a composite using hand lay-up technique.

Figure 3.1.2: Author making composites using hand lay-up method.

3.1.3 Test samples production.

All the fabricated composites sheets will be cut manually using a metal saw. The metal saw used because it have a small cutting eye that can penetrate the composites. Then in order to get a finer finish, it was finally finish using a milling machine. The composites will be cut according to the test standards. The specimens will be tested on the second stages of this project.

The tests that will be conducted are tensile test. The tensile test standard used is ASTM D638. The test was done by using Instron Universal Tester. The result will be recorded and analyzed for further analysis. For each test there will be 5 specimens will take the tests. All the data gathered then will be compared and discussed. Finally, after finish all the analyzing the documentation for this project needs to be done. All the process that take place, the preparation, testing and result and the discussion need to be include into the documentation for this project. Figure 3.1.3 below shows the tensile test machine used.

Figure 3.1.3: Instron Universal Tester.

3.1.4 Gantt Chart

Activities			FYP II													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	To produce polyester/knitted kenaf specimen															
	1.1	Built a kenaf knitting frame														
	1.2	Knitting the kenaf fiber														
	1.3	Prepare a perspex hand lay-up mold														
	1.4	Produce polyester sheets														
	1.5	Produce the composites														
	1.6	Cutting the samples according to respective test method														
	1.7	Prepared the test sample										* (20/11/2013)				
2	Mechanical testing															
	2.1	Tensile testing											* (28/11/2013)			
3	Analyze the data obtain															
	3.1	Analyze the recorded data														
	3.2	Comparing the results obtained													* (19/12/2013	
	3.3	Finish Analyzation														* (3/1/2014)

(*) Key Milestone

CHAPTER 4:

RESULTS AND DISCUSSION

4.1 Composition calculation

In order to achieve the desired composition of the polyester/woven kenaf composites which was 80% of the polyester and 20% of the woven kenaf in terms of weightage matrix, a simple calculation was needed. An exact composition that are desired in this project can be achieved. The formula used to get desired composition was

$$\frac{x}{y} = wt.\%$$

Where *x* is the mass of woven kenaf used in a composites. The knitted kenaf is weight to get the mass in order to find the value of y which is the total mass of the composites. An example of calculation is shown below.

$$\frac{13.776\ g}{y} = \frac{20}{100}$$

$$y = 68.88\ g$$

$$68.88\ g - 13.776\ g = 55.104\ g$$

From the calculation we know the mass of the polyester needed to do the composites which is 55.104 *g*. Other than using the formula, there also other method which is try and error method. This method is really time consuming as the composites takes long time to undergo complete hardening process which is 24 hours with the hardener. By doing simple calculation the time can be save and also the usage of the polyester can be save.

4.2 Tensile test result

Tensile strength test was carried out and the result are shown in the Table 4.2.1 below.

Table 4.2.1: Tensile test result of the specimen.

Area (mm^2)	Max. Load (N)	Elongation@break (%)	Tensile Strength (N/mm^2)
17.648	2782.346	2.00	157.655
17.120	3681.493	2.00	215.044

From the table above it shown the tensile strength that was obtained from the test and the result was very pleasing as the tensile strength obtained was very high. From the tensile strength above, the mean of the tensile strength result was 186.4MPa. The result obtained was compared to the tensile strength of the neat kenaf where it was shown in the Table 4.2.2 below.

Table 4.2.2: Mechanical properties of neat kenaf.

Property[2] of cured casting[4] at 25°C (77°F)	Value (SI)	Value (US)	Method
Barcol Hardness	40	40	ASTM D2583
Tensile Strength	41 MPa	6000 psi	ASTM D638
Tensile Modulus	3585 MPa	5.2×10^5 psi	ASTM D638
Tensile Elongation	1.3%	1.3%	ASTM D638
Flexural Strength	79 MPa	11,500 psi	ASTM D790
Flexural Modulus	3720 MPa	5.4×10^5 psi	ASTM D790
Heat Distortion Temperature	140°C	284°F	ASTM D648

From the table 4.2.2 it shown that the tensile strength of the neat polyester was 41MPa and the tensile strength of the composites specimen was higher which was 186.4MPa. The improvement of the tensile strength was summarized in Figure 4.2.1 below.

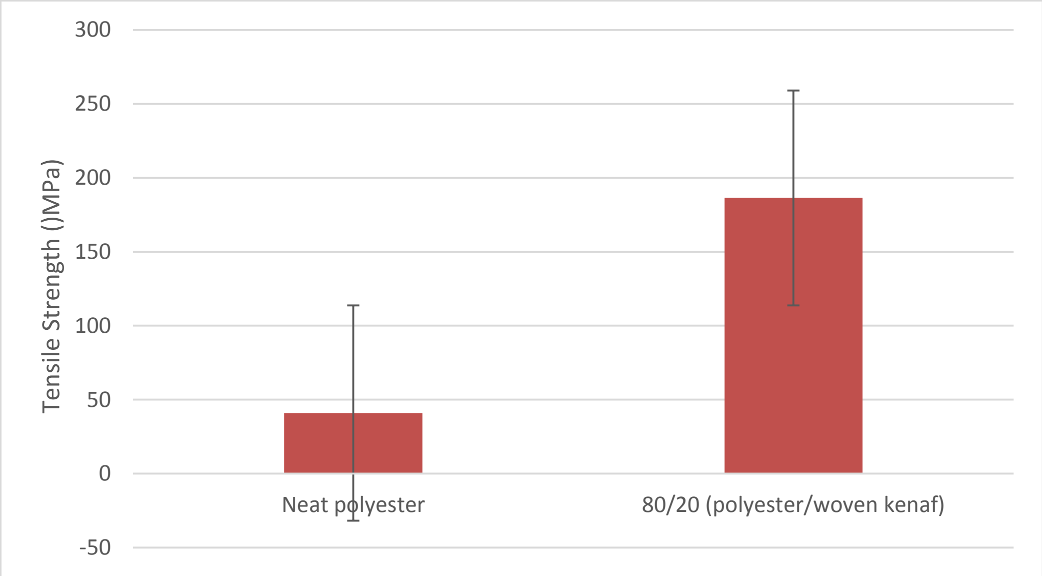

Figure 4.2.1: Comparison between neat polyester and 80/20 composite.

The improvement of tensile strength in polyester/woven kenaf composite was approximately 355% compared to neat polyester. As expected woven kenaf has strengthened the composite. Figures 4.2.2, 4.2.3, and 4.2.4 shows FESEM micrograph of fractured 80/20 sample of polyester/woven kenaf composite.

4.3 FESEM Result

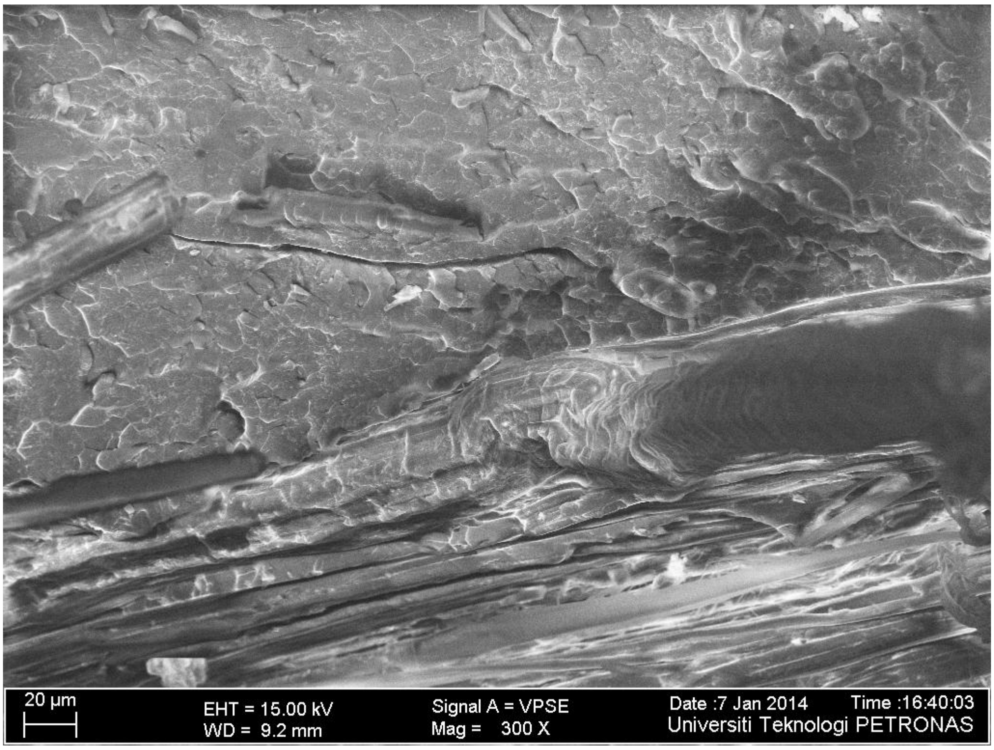

Figure 4.2.2: FESEM micrograph of 20 µm magnification.

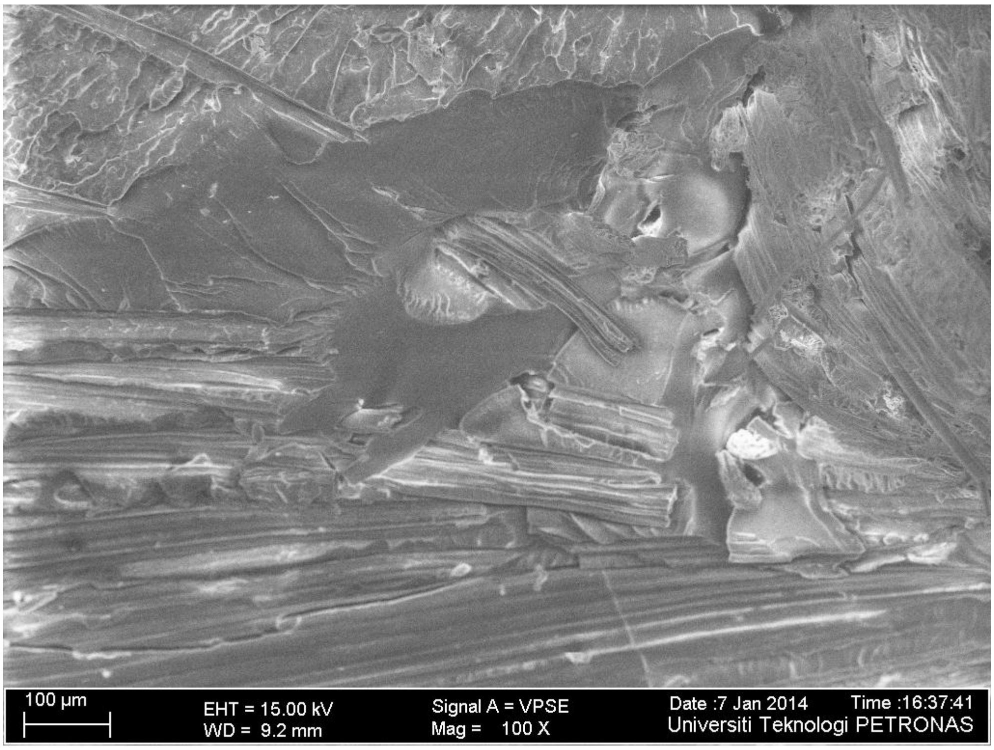

Figure 4.2.3: FESEM micrograph of 100 µm magnification.

Figure 4.2.4: FESEM micrograph of 200 µm magnification.

Based on the FESEM micrograph shown on the Figure 4.2.2, 4.2.3, and 4.2.3, it can be seen that the interfacial bonding between fiber and matrix is very good. It can be observed in the figures that the failure was due to fiber ruptured, suggesting that the load was being absorbed by the fiber.

CHAPTER 5:

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Improvement of 355% in tensile strength of polyester/woven kenaf was achieved compared to the neat polyester. Compared to the tensile strength of the neat polyester which was 41MPa and the mean tensile strength from the specimen which was 186.4MPa, it can clearly see that there was a really high improvement in the tensile properties for the polyester/woven kenaf composite. This also can be seen from the FESEM result shown that the interfacial bonding between the polyester and the kenaf is really good. Thus, for this project the objective was achieved since the improvement of the tensile strength can be seen.

5.2 Recommendations

For further work, the composite compositions should be varied. The effect of polyester/woven kenaf compositions on mechanical properties should be studied. The mechanical properties should cover flexural and also impact properties as well. The orientation and number of layer of woven kenaf should also be varied as it may also effect the mechanical properties of the composites.

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APPENDIXES