EFFECT OF SOIL BURIED TO MECHANICAL PROPERTIES OF KENAF FIBRE REINFORCED THERMOPLASTIC POLYURETHANE COMPOSITES.

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***Abstract*—The aim of this research is to study the effect of soil buried to compressive strength properties of Kenaf fiber reinforced thermoplastic polyurethane (KFTPU) composite. Pulverized kenaf core particles was sieved into 3 sizes namely <123µm, 125-300µm and >300µm. Pulverized kenaf core particles reinforced TPU composite was prepared with 3 different percent of kenaf loading of 5wt%, 10wt% and 15wt%. The compressive strength of the composite was tested by using Compressive test machine. The samples were test to see which one have the highest compressive strength and low density. The results of compressive strength at 60% deformation show that sample 125-300µm and 10wt% kenaf loading have the best strength and low density. Thus, the composite with pulverized kenaf core particles size 125-300µm and 10wt% kenaf loading was buried into the soil. The buried sample was divided into two categories which at the presence of water and petrol oil. The compressive strength was determined after 1, 2, and 3 weeks. The weight gains by the samples after soil buried were recorded every on 1 week. The compressive strength of the buried composite during the presence of water increased from 2722.75 kPa to 4269.33 kPa for week 1 and week 3 respectively. While the compressive strength of the buried composite during the presence of petrol oil decreased from 3287.47 kPa to 1964.9 kPa for week 1 and week 3 respectively.**

***Keywords*— polyurethane, kenaf**

I. INTRODUCTION

Composite material is formed from combination of two different materials which have different properties. The two materials when combine together will be form the composite [1]. These combinations of two materials are form on purpose to obtain the new properties that only can be obtain through these combination of 2 material. The composite formed is not naturally happened [2]. The two materials usually use are polymers (matrix) and filler (reinforce material). As Verma et. al. (2012) [1] claimed, that the composite is actually consisting of discontinuous and continuous phase that combine together to from the composite material. The discontinuous is known as reinforce and continuous known as matrix. The combination of these two different phases was separate by a distinct interface [2].

Natural fiber reinforcement composite is deriving from the renewable resources. Nowadays, there are so many products that can give bad impact and cause problem to our environment. The product produce is not so environmental friendly. Thus, industry was asked to produce the product that more environmental friendly. So that the environmental problem causes by the product from the industry sector can be decrease. The uses of plastics are increasing in every sector from day to day. The plastics used are one of the products that can cause problem to the environment. That is why the research towards eco-composite or environmental friendly composite are getting expands.

Natural fibers have many advantages as compared to the synthetic fibers [4]. The most important advantage for the natural fiber reinforcement in composite is low cost and biodegradability. The cost of producing natural fiber reinforcement composite is cheaper than using synthetic fibers. The biodegradability characters of natural fiber give an advantage on solving the environmental problem.

Other advantage of the natural fiber is low density. The natural fiber reinforcement composite is lighter compared to the existing glass fiber composite [5]. That statement was supported with the density value of natural fiber which is around 1.2-1.6 g/cm3 and the glass fiber density value is around 2.4 g/cm3. This shows that the use of natural fiber as reinforcement for the new composite product is totally worth it.

There are many sectors in industry that used the natural fiber composite as their product. For example, natural fiber composites are being used for manufacturing many components in the automotive sector. The properties of natural fiber composites that consider in for market include elongation and ultimate breaking force, flexural properties, impact strength, acoustic absorption, suitability for processing and crash behavior. Plant fibers are mainly used in the part of car interior and truck cabins [6]. The natural fibers such as fiber from banana, coir, jute, pineapple and sisal also have been used in aerospace, building and packaging industries. The most attractive about the natural fiber is on their positive environmental impact. The natural fiber composite is also used in production of textiles, paper and fibers board [7]. The kenaf core is one of the natural fibers that use for reinforced thermoplastic polyurethane.

The expanded polystyrene (EPS) for road embankment has been used for over 40 years. EPS provides a viable alternative to lengthy preloading of soft soils for control of settlements and widening of embankments to achieve settlement compatibility. However, the EPS material has several vulnerabilities on hydrocarbon, fire or combustion, physical damage, durability and buoyancy. Therefore, the new composite product has to be created to replace the EPS. The new composite should be able to overcome the weakness of the EPS and should have a good strength better than EPS. Thus this research was conducted to evaluate and investigate the properties of the kenaf fiber reinforced thermoplastic polyurethane composites that may have a better property than EPS.

II. METHODOLOGY

A. Materials and apparatus.

To make the sample of the composite, the main material is Kenaf Fiber and polyurethane (PU). The Kenaf core was supplied by Kefi Sdn. Bhd. The Kenaf fiber was stored in a closed container to avoid from contamination. PU was formed by mixing the polyol and diphenylmethane 4,4’-Diisocyanate.Pentane,polyethylene glycol, and triethylamine were mixed with polyol which were acted as blowing agent, surfactant, and catalyst respectively. Peat soil was used to bury the composite for 3weeks. For the buried test, water and petrol oil were used by pouring it on the soil. For the composite preparation, the materials use is aluminum foil. The aluminum foil will be cut, fold and seal to form rectangular shape according to ASTM D1621 size (5cm×5cm×2.5cm) for compression test. The composite sample will be buried in the peat soil place in poly-bag. To test the strength, the compression machine Instron 3382 is used.

B. Pulverized Kenaf core particles preparation.

The pulverized kenaf core particles was sieved into 3 size ranges namely less than 125 µm (<125µm), 125-300µm and greater than 300µm (>300µm). Sieve process was conducted using sieve shaker machine. The sieved kenaf was placed in a closed container.

C. Composite preparation.

One drop of pentane, polyethylene glycerol, and triethylamine were dropped into the 20g of polyol using dropper. The mixture was strried for 15 seconds.
5 wt% (2g) of pulverized kenaf core particles was placed inside the aluminum container first. The polyol mixture will be mixed with the pulverized kenaf core particles first. Then, 20g of diphenylmethane 4,4’-Diisocyanate was added into the mixture using the measuring cylinder. The mixture was stirred to ensure the polyol and diphenylmethane 4,4’-Diisocyanate were mixed well. The mixing process was stirred manually using glass rod for 15 second. The mixture was left until the rising foam formed a rigid body.

D. Buried sample.

The peat soil was filled into the poly bag. The composite sample of a dimension of 5cm×5cm×2.5cm was buried in the soil. Each sample was buried in different poly bag. The sample was divided into 2 groups which were poured by using water and petrol oil. 50ml of water was poured 1 times every 2 days. 50 ml petrol oil was poured for the same duration. Every one week, the samples were taken out for compressive strength measurement..

E. Mechanical characterization.

The compressive tests of the Kenaf reinforced PU composite were conducted using compressive Instron 3382 machine. The test followed the ASTM D1621 and ISO 844 at the Lab Strength, Mechanical Engineering. The sample of compressive test measurement was cut in to rectangular shape by using coping saw and flat file. The dimension of the sample is 50×50×25 mm. The samples were tested with crosshead speed of 2.5mm/min. The samples were compress to 60% from original size.

Figure 1 : Compressive machine Instron 3382

F. Density measurement

The density of the sample was determined according to ISO 845 Standard. The samples were weighted by using electronic precisions balance. The volume of each sample was calculated. The density was calculated by using this formula (mass of sample/volume of sample).

G. Image Analysis.

The image analysis was conducted by using Image J software. This software was used to count the pore and pore size formed on the cross sectional surface area of the sample. The area of the sample’s surface or region of interest (ROI) used for the pore count was 4cm×4cm.

III. RESULTS AND DISCUSSION

A. Effect of kenaf reinforcement to composite compressive stress.

Figure 2 shows the compressive stress at 60% deformation for all samples. The compressive stress of the composite that consisted of kenaf with 125-300µm with 15wt% of kenaf loading are 6438.313 kPa. However, the strength of the same size range of kenaf particles in the composite reduce to 6151.974 and 2444.431 kPa when the kenaf loading decrease to 10 wt% and 5wt% respectively.

These results showed that the size pulverized kenaf core particles 125-300µm has better bonding and wettability [8] compare to others.

For the compressive stress of the composite that consisted of pulverized kenaf core particles with <125µm in the figure 1, it shows that the compressive strength decrease from 3045 to 1732 kPa for 5wt% and 10wt% kenaf loading respectively. But for 15wt% kenaf loading, it increase back from 1732 to 2416 kPa. Figure 1 also shows that the sample with kenaf particles size of <125µm had the lowest compressive stress compared to others 2 samples with kenaf particles size range 125-300µm and 300µm. Based on the research by Yousuf Ali El-Shekeil, the reason why low strength for the small Kenaf particles size probably relate to the surface area. Smaller the kenaf particles size possessed the larger surface area that nonreactive to the matrix. Thus, more stress point were created that make the result of the compressive stress is low [8].

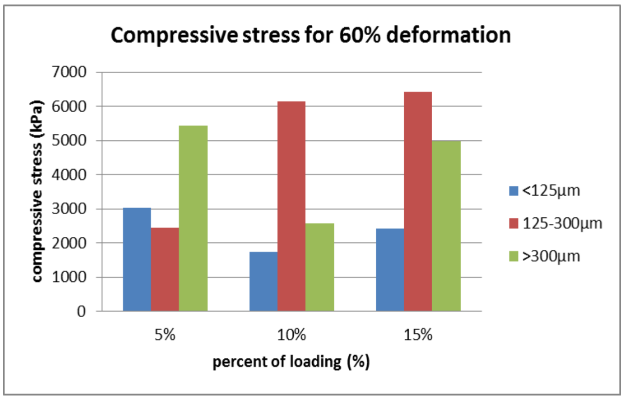

Fig. 2: Compressive stress of 60% deformation result for Polyurethane Reinforce Kenaf fiber.

B. Image analysis.

The image analysis had been done by using Image J software. Figure 3 was shown the result of number of pore on sample by using the Image J software.

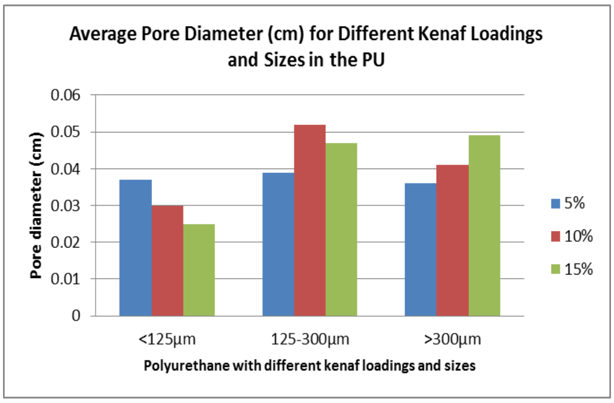

Figure 3 : Average diameter size of pore on samples.

Based on figure 3, the average diameter size of the pore on samples label <125µm is decrease as the percent loading increase from 5wt% to 15wt% kenaf loading. That means, the size of pore is decrease as the percent loading is increase. However, the samples with kenaf particles size range 125-300µm in figure 3 show the different trend compare to samples with kenaf particles size range <125µm. The average diameter size of pore is increase as percent loading increase from 5wt% to 10wt% kenaf loading. But for 15wt% loading, the average pore size decreases. The average pore diameter size for the sample >300µm is increase as the percent loading increase from 5wt% to 15wt%. Generally, the addition of the fibers will cause an increase of the cell size (pore/void), due to the increasing number of nucleating sites induced by the kenaf surfaces [9]. The sample <125µm fail to show the increasing trend on pore size maybe due to the blowing agent is not evaporate well. The blowing agent is the volatile liquids that evaporate and make the foam expand [10]. The evaporation of the blowing agent may not evaporate well because of the environment.

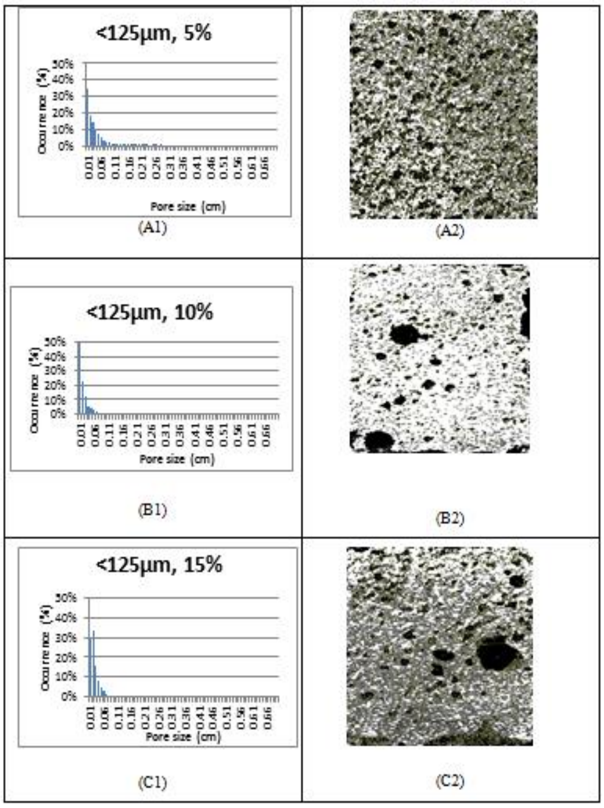

Figure 4: Size of pore comparisons for different kenaf fiber loading sample for kenaf core particles size size <125µm.

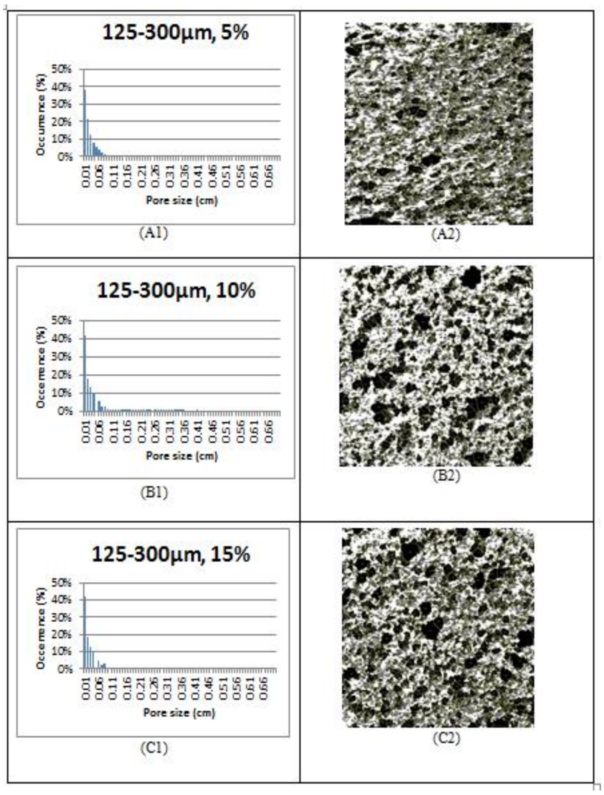

Figure 5: Size of pore comparisons for different kenaf fiber loading sample for kenaf core particles size size 125-300µm

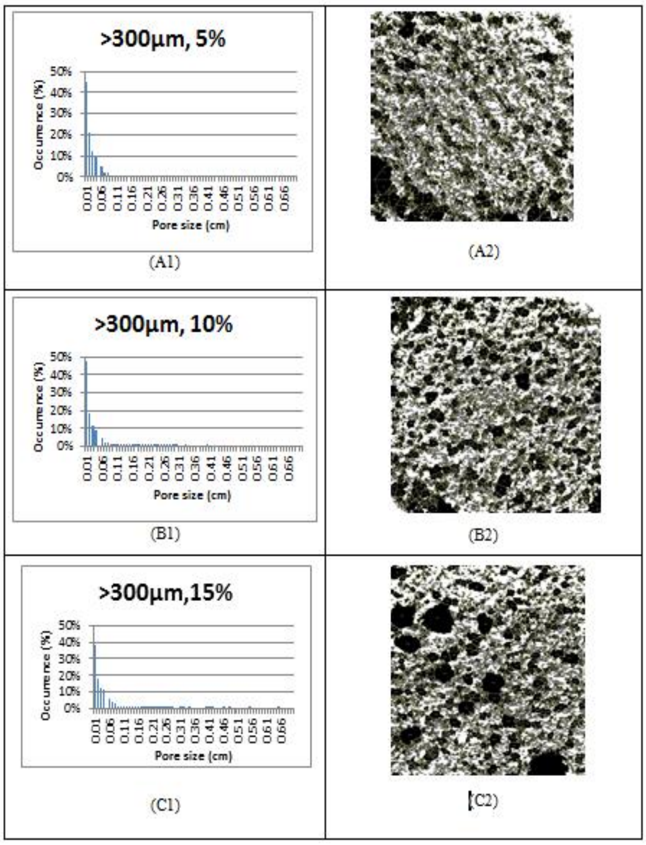

Figure 6: Size of pore comparisons for different kenaf loading sample for kenaf core particles size >300µm.

Figure 4 until 6 is shows the size of pore comparisons for different percent of pulverized kenaf loading for sample with pulverized kenaf particles size <125µm, 125-300µm, and 300µm.

Based on result of image analysis in figure 4, it can be said that 30% to 50% of the pore on the sample is in size range between 0 to 0.01 cm diameter sizes for samples contain pulverized kenaf particles size <125µm. The number of occurrence is decrease as the size increase. That means, most of the pore have small size and only several pore is form in large size. The size of pore on sample surface area does not uniform. There are many size of pore appear on the surface area of sample. One of reason why the pore size form is not uniform is because of the formulation of surfactant maybe not suitable. The surfactant is play role as to control the foam. So, the formulation use for surfactant maybe is not good enough to control the void.

Figure 5 shows the pore size that appears on the cross section area of the sample that contains kenaf particles size 125-300µm. The highest percent of pore occurrence is at pose size 0.01cm for all samples that contains kenaf particles size 125-300µm. The percent of pore occurrence at pore size 0.01cm is 38.42%, 41.51%, and 41.85% for kenaf loading 5wt%, 10wt%, and 15wt% respectively.

Figure 6 shows the pore size that appears on the cross section area of the sample that contains kenaf particles size >300µm. All samples that contain kenaf particles size 125-300µm also shows that pore size 0.01cm has highest percent of occurrence on the cross section area of the sample.

All samples have the highest number of pore with the size between 0-0.01 cm diameters. However, the percent occurrence of pore with size 0.01cm is not exceeding 50% of occurrence for all samples. The size of the pore is not uniform for every specimen. In all foams of polymer, the pore structure is not specific uniform unit [10]. The sizes cells of the polyurethane foam are controlled by the addition of the surfactant on the mixture [11]. The additions of the kenaf core into the polyurethane also cause the form of irregular foam cell size on polyurethane foam [12].

C. Effect Kenaf Fiber reincorced to density of the composite.

The density of the sample was determined according to ISO 845 Standard. Figure 5 shows the density of the composite.

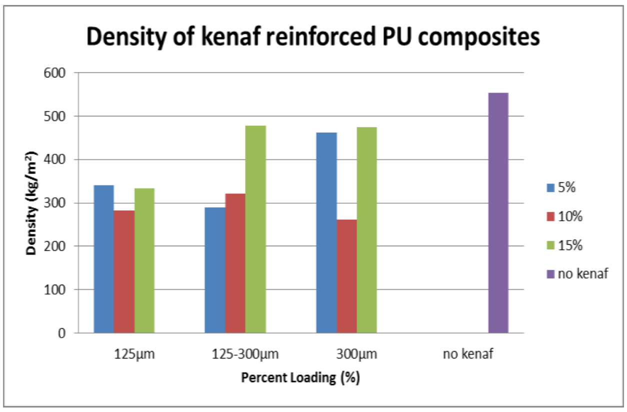

Figure 7: Density of kenaf reinforced PU composites

From figure 7, it can be seen that the density of the kenaf reinforced PU composites for pulverized kenaf particles size <125µm and >300µm is decrease. However the density decrement was limited to 10wt% only, since the density increase with 15wt% of kenaf loading. As stated in one of research journal of coconut coir fiber reinforced polyurethane, the research found that the addition of the coir fiber produced lighter polyurethane but it limit to 15wt% fiber loading [13]. Based on the result obtained in figure 7, the statement by the journal is the same like the result obtain where the addition of pulverized kenaf core particles produce lighter polyurethane composite. However for the pulverized kenaf core loading, it limited to 10wt% loading only compare to coir fiber loading which limited to 15wt%. These differences may due to the type of fiber loading, which means different fiber will give different result of density.

The density of the kenaf reinforced PU composite is less than pure PU. The density of the pure PU base on the figure 7 is 553 kg/m^2. While the all kenaf reinforced PU composite samples have density less than 500 kg/m^2. This is due to the regular cell structure and smaller cell size of the pure polyurethane foam [12].

Thus is can be said that the natural fiber reinforced improve the density of the TPU to become more light. Generally, polymer foam can be dividing into two categories of foam which is closed-cell or open-cell structure. The closed-cell foam structure is rigid, while open-cell foam structure is usually flexible [10]. For this TPU, it is categorize as rigid foam. Thus it pores or void is form close-cell. There is a journal had approved that the addition of the fiber into the polyurethane foam give result of irregular foam cell size and the cell size may increase slightly by varies the percent of pulverized kenaf loading up to 7wt%. [12]. This can be relating to the result of density of composite in figure 7. When the cell size increase, the density should be decrease since the air space inside the composite is increase as cell size increase. The density increase as the fiber content increase [17].

D. Effect of soil buried to compressive stress of the sample.

The samples that had been buried are sample that contain pulverized kenaf particles size 125-300µm and 10wt% pulverized kenaf loading. The samples were divided into 2 groups which are water presence group, and petrol oil presence group. The figure 5 is the result of compressive stress at 60% of deformation after 3 weeks.

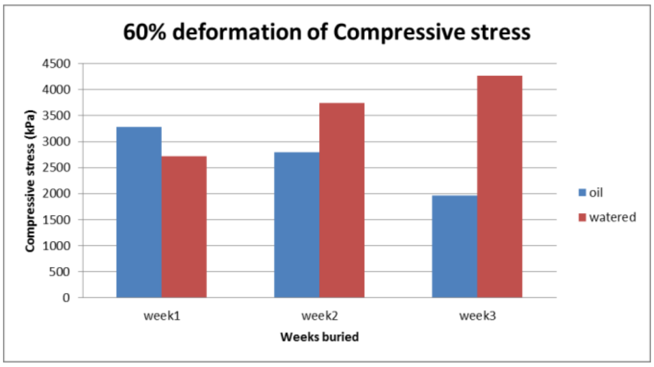

Figure 8: Compressive stress of soil buried kenaf reinforced PU composites

Figure 8 shows the effect of water and petrol oil on the compressive strength of buried sample for 3 week. As shown in the figure 8, the compressive stress buried sample that presence of water shows the increasing trend, while the buried sample presence of petrol oil shows decreasing trend from week 1 to week 3. Based on the result obtained in figure 8, it can be describe that the Petrol oil may affect the strength of the kenaf reinforced PU composites since the compressive stress was decrease as the week of buried increase. When PU is exposed to hydrocarbon, it may make the PU expand slightly. This expansion can lead to reduction in PU's tear resistance [13]. Thus the strength would be decrease. The PU can block or reduce the water penetration into the interface of the composite [14].

The buried samples with presence of water in figure 8 shows the increment of compressive strength. The reason that could be relate with the increment result is the fact that high amount of water cause the swelling of the fibers in the polyurethane foam which it can fill the space between the fiber and the polymer-matrix. These phenomena can lead the increment in the mechanical properties of the composite [15]. This result can relate to the research that reported for jute fiber reinforced polymer composite show the increasing of flexural strength after immersed in water [15].

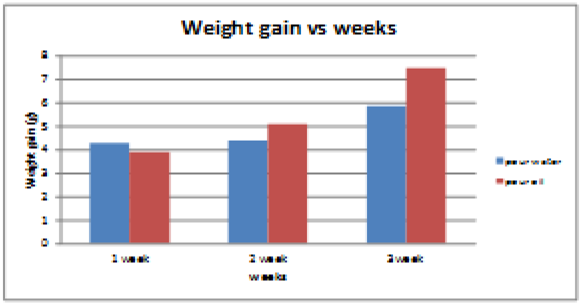

Figure 9: Graph of weight gain by the sample after buried.

The weight gains by the buried samples obtained from the research were drawn in figure 9. For the figure 9, it can be described that the water and oil were absorbed by the sample. But not 100% of the weight gain is water and petrol oil absorbed by the samples since some of the water and petrol oil was absorbed into the soil.

E. Immersion result.

The samples were immersed in the water and petrol oil to see how much the water and petrol oil have being absorbed by the samples in 24h. The results as in table 1.

Table 1: The weight gain by the specimen after immerse for 24h.

Sample	Weight gain (g)	
	Immerse in water for 24h	Immerse in petrol oil for 24h
125-300µm, 10%	2.47g	12.95g
125-300µm, 15%	4.4g	18.27g

Table 1 shows that the samples can absorb water and petrol oil. For the immersion in water, the result in table 1 shows that samples with 15wt% pulverized kenaf core loading weight gain is higher than 10wt% pulverized kenaf core loading. The absorption of water is due to hygroscopic nature of fiber. As the kenaf core particles loading increase, water expected to be increased [16]. In 24h, the samples of kenaf fiber reinforced thermoplastic polyurethane composites were absorbing petrol oil more than absorbs the water. When TPU is exposed to hydrocarbon, it may make the TPU expand slightly. This expansion can lead to reduction in TPU's tear resistance [13].

IV. Conclusion

In conclusion the the best compressive strength for kenaf fiber reinforced thermoplastic polyurethane composites (KFTPU) is the composite with pulverized kenaf core particles size range 125-300µm and 15% kenaf loading. However, composite with kenaf pulverized kenaf core particles size range 125-300µm and 10% kenaf loading is choosen as sample use for buried test is because the density of sample 10 wt% kenaf loading is less than sample with 15 wt% kenaf loading. The effect of the soil buried with the presence of petrol oil cause the compressive strength of the sample decrease from 3287.47 kPa to 1964.9 kPa as number of weeks in increase from 1week to 3 weeks. While the effect of the soil buried with the present of water cause the compressive strength of the sample increase from 2722.75 kPa to 4269.33 kPa as number of weeks in increase from 1week to 3 weeks. Besides that, the compressive strength of the buried sample for both present water and present petrol oil has lower reading of the compressive strength compare to the unburied sample composite. However, effect of the petrol oil does not change the physical form of the kenaf fiber reinforced thermoplastic polyurethane composites.

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