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Effect of Clay Composition and Human Haircut Waste on Mechanical Properties Mechanical Properties of Epoxy Resin Composites

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ABSTRACT

The impact of human haircut waste and the nature of clay soil on the mechanical characteristics of epoxy resin composites has been studied. This study utilizes clay sourced from Wonosari Village, Deli Serdang Regency. The clay was pulverized using a pestle and mortar until it reached a smooth consistency. It is then filtered through a 200 mesh screen and subjected to drying in an oven at a temperature of 105°C for around 3 h until the water content is completely evaporated. Finally, the dried clay stored in a desiccator. The clay powder was subjected to ball milling for 40 h at 350 rpm. The resulting particle size, determined by particle size analysis (PSA), was found at 0.764 µm. Next, the human haircut waste obtained from the surrounding campus of Universitas Sumatera Utara was prepared by separating the hair from fine hair and washing it clean. Clay soil powder and human hair cut waste are used as fillers, and some variations of epoxy resin mixtures are used. Morphological SEM analysis shows that clay and human haircut waste can be distributed evenly on epoxy resin composites. Testing of water absorption and mechanical properties of the board based on SNI 01-449-2006 standards include the test of dry bending strength (MoR) and the mode of flexural elasticity (MoE) obtained the optimum composition (50: 50: 1: 1) g against the epoxy resin mixture, waste human haircut, and clay soil obtained the water absorption test results of 1.64% with a value of MoE 36789.03 kgf /cm^2 and a value of MoR 664,41 kgf/cm^2. Test results of mechanical properties and water absorption have fulfilled the SNI 01-449-2006 quality standards for composite boards.

Keywords: Clay Soil, Hair, MoE, MoR, Water absorption

ABSTRAK

Pengaruh limbah potongan rambut manusia dan sifat tanah liat terhadap karakteristik mekanik komposit resin epoksi telah dipelajari. Penelitian ini memanfaatkan tanah liat yang bersumber dari Desa Wonosari Kabupaten Deli Serdang. Tanah liat tersebut selanjutnya dihaluskan menggunakan alu dan lesung hingga mencapai konsistensi yang halus. Kemudian disaring melalui ayakan 200 mesh dan dikeringkan dalam oven pada suhu 105°C selama kurang lebih 3 jam, hingga kandungan airnya menguap seluruhnya. Terakhir, tanah liat yang sudah kering disimpan dalam desikator. Serbuk tanah liat tersebut dilakukan ball milling dengan durasi 40 jam dengan kecepatan putar 350 putaran per menit (rpm). Ukuran partikel yang dihasilkan, sebagaimana ditentukan oleh analisis ukuran partikel (PSA), ditemukan sebesar 0,764 µm. Selanjutnya dilakukan preparasi limbah potong rambut manusia yang telah didapat dari sekitaran kampus Universitas Sumatera Utara dilakukan dengan memisahkan rambut dari rambut-rambut halus dan dicuci hingga bersih. Serbuk tanah lempung dan limbah potong rambut manusia digunakan sebagai bahan pengisi dengan beberapa variasi terhadap campuran epoksi resin. Analisa morfologi dengan menggunakan SEM dapat dilihat tanah lempung dan limbah potong rambut manusia dapat terdistribusi secara merata pada komposit epoksi resin. Pengujian daya serap air dan sifat mekanik papan komposit berdasrkan standar SNI 01-449-2006 meliputi uji keteguhan lentur kering (MoR) dan modulu elastisitas lentur (MoE) didapatkan komposisi optimum (50 : 50 : 1 : 1) g terhadap campuran epoksi resin, limbah potong rambut manusia, dan tanah lempung didapatkan hasil uji daya serap air sebesar 1,64 % dengan nilai sebesar MoE 36789.03 kgf/cm^2 dan nilai sebesar

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MoR 664,41 kgf/cm^2. Hasil uji sifat mekanik dan daya serap air telah memenuhi standar mutu SNI 01-449-2006 untuk papan komposit.

Kata Kunci : Daya Serap Air, MoE, MoR, Rambut, Tanah Lempung

1. Introduction

The development of materials technology is currently accelerating. It is driven by the need for materials to meet certain desired characteristics. One of the results is polymer composite materials. Composite board is one of the promising products with special advantages, both in mechanical strength and economic value and corrosion resistance. In general, composite materials consist of two elements, namely filler (fiber) and binder(matrix). Fiber increases the material's strength, stiffness, and plasticity, while the matrix protects the reinforcement [1]. Epoxy resin belongs to a group of thermoset-type polymers widely used as a matrix in composite materials. The type of epoxy resin used in this research is bisphenol A- epichlorohydrin and polyaminoamide as hardener [2].

This resin is a viscous liquid or near-solid used for materials when they need to be hardened. This material is widely used in many automotive, aerospace, shipping, and electronic equipment applications. The advantages of this epoxy resin compared to other resins are high mechanical and thermal properties, resistance to water, long use time, heat resistance to temperatures up to 220°C, good chemical resistance and dimensional stability, strong adhesion to glass, and good metal [3]. However, epoxy resin is not a strong polymer because of its brittle structure, easy to crack, and low resistance to blows or pressure [4].

To improve the mechanical properties of this polymer, researchers are encouraged to research improving the mechanical properties of epoxy resins by adding fillers. Clay is one of the natural resources available on the earth's surface, with a SiO_2 content of 65.54% and Al_2O_3 of 18.78%. Minerals are one of the filler materials that have recently been widely used to reduce more expensive additives such as pigments, heat-resistant materials, and mechanical strength enhancers. The content of SiO_2 and Al_2O_3 in clay-composite epoxy resin can improve mechanical properties such as tensile strength and stiffness modulus [5].

In addition to natural minerals used as fillers, natural fibers can also be used as fillers in composite manufacturing. In this case, another natural filler material used is human haircut waste. Hair has high strength even though it has been discarded and buried in the ground; hair is not easily damaged and weathered. It is strong against acids, corrosive solutions, weather, and humidity. Based on research, hair fiber resin has mechanical properties that almost match the strength of glass fiber resin [6].

Human hair has about 65-95% protein by weight, more than 32% water, lipid pigments, and other components. Chemically, about 80% of human hair is formed by a protein known as keratin with high levels of sulfur derived from the amino acid type cysteine, which is characteristic to distinguish it from other proteins. Keratin is a layered complex formed by various structures, which gives hair strength, flexibility, durability, and functionality [7].

Therefore, the relationship between the two is due to the bond between the natural fiber and epoxy resin. Hair fibers contain amino acids and keratin as a filler material, while the thermosetting epoxy resin acts as a matrix, both of which have O-H functional groups. The presence of O-H groups in epoxy resins indicates that epoxy can interact with the O-H groups in the filler material [8]. From the results of the description above, the researchers are interested in researching the effect of the composition of clay mixing materials and haircut waste on the mechanical properties of dry flexural firmness (MoR), flexural modulus of elasticity (MoE), and water absorption tests. The selection of fillers for the manufacture of epoxy resin composites is based on their less-than-optimum utilization, so they can be used as additional materials to manufacture composite materials that have high mechanical properties following Indonesian National Standard SNI 01-499-2006 for composite boards.

2. Materials and Methods

2.1. Equipment

The tools used in this research include glassware, a 200 mesh sieve, an analytical balance, oven, desiccator, a ball mill, a hydraulic Press Test System, Universal Testing Machine, Particle Size Analyzer, and SEM Instrument.

2.2. Materials

The materials used in this research include clay, human haircut waste, wax glass of mirror no.8, resin a bisphenol A - epichlorohydrin, hardener B polyaminoamide, and aquadest.

2.3 Research Procedures

2.3.1 Preparation of Clay Soil Samples

500 g of clay soil was pounded using a pestle and mortar until smooth, then filtered with a 200 mesh sieve. Then in, dried in the oven at 105°C for ± 3 hours until the moisture content is lost and stored in a desiccator.

2.3.2 Preparation of Clay Soil Into Powder

100 g of clay soil was sieved using a 200 mesh sieve and seven metal balls(ball change) into a grinding jar. Then, it was placed into the grinding station. Close the engine cover, set the rotation speed to 350 rpm, set the playback time to 60 minutes, and press the start button. The playback was carried out for 40 hours. Furthermore, the clay powder obtained was then filtered using a 200-mesh sieve. Then, the clay powder that has passed the sieve is weighed. Moreover, it is characterized by PSA analysis.

2.3.3 Preparation of Haircut Waste Human

Haircut waste was collected from barbers around the campus of the Universitas Sumatera Utara, and it was then filtered from fine hair washed with water until clean and dried and cut into small pieces of ± 1 cm.

2.3.4 Preparation of Haircut Waste Human

Clay powder was mixed into resin A-type bisphenol A-epichlorohydrin while stirring using mechanical stirring techniques until homogeneous, after which hardener B-type polyaminoamide was added while stirring again until homogeneous. Then the mixture was placed into a molded specimen with a size of 12 cm x 2 cm x 1 cm, which was coated using wax, and after that, it was hot pressed with a hydraulic forge for 30 minutes with a temperature of700Cat a pressure of 125 Psi. The composites were stored for 2 days at room temperature. The same procedure was carried out for different variations in mixing resin with human haircut waste and resin with clay powder and fiber and human haircut waste. The composition of the composite materials can be seen in Table 1. The composites were then characterized by testing their mechanical properties with dry flexural strength (MoE) and flexural modulus of elasticity (MoR) according to Indonesian National Standard SNI-01-499 2006, water absorption and surface morphology analysis with SEM.

Table 1. Composition of Epoxy Resin Composite with Clay Soil

Sample	Resin (g)	Hardener (g)	Tanah Lempung (g)
1	50	50	1
2	50	50	2

Table 2: Composition of epoxy resin composites with human haircut waste

Sample	Resin (g)	Hardener (g)	human haircut waste (g)
1	50	50	1
2	50	50	2

Table 3. Composition of epoxy resin composite blend with clay and human haircut waste

Sample	Resin (g)	Hardener (g)	human haircut waste (g)	Clay Soil (g)
1	50	50	0	0
2	50	50	1	1
3	50	50	1	1
4	50	50	2	1
5	50	50	2	1

2.3.5. Characterization of Material Analysis Composites

2.3.5.1 Water Absorbency Test

Water absorption is the ability of a material to absorb water up to the maximum limit. The more water it absorbs, the more pores there are in the material. This test determines the percentage of water absorbed by samples soaked with immersion for 24 h [9].

Water Absorbency Equation:

$$DSA = \frac{B2-B1}{B1} \times 100\%$$

Where:
B2 = Final weight after soaking (g)
B1 = Initial weight before soaking (g)

2.3.5.2 Dry Flexural Firmness Test (MoR) and Flexural Elastic Modulus (MoE)

The test sample's length, width, and thickness were measured and then placed flat on the support. The load was applied to the center of the test sample at a rate of approximately 10 mm/min, and the deflection and load were recorded until the maximum load B.

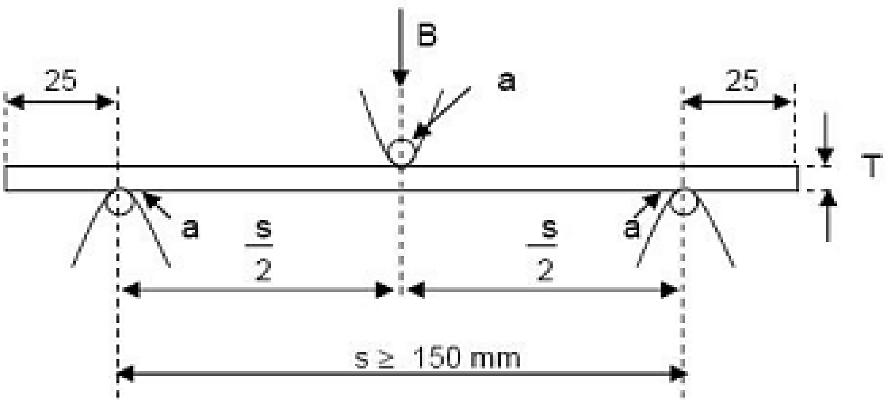

Figure 1. Dry flexural strength test and flexural modulus of elasticity

Figure description :
B is load (kg)
a is diameter ± 10 (cm)
S is the support distance (cm)
T is particle board thickness

The formula calculates flexural toughness:

$$MoR = \frac{3\ BS}{2\ LT^2}\ (kgf/cm^2)$$

Where :
B = maximum load (kgf)
S = support distance (cm)
L = width (cm)
T = thickness (cm)

The formula calculates the flexural modulus of elasticity:

$$MoE = \frac{S^3 \Delta B}{4\ LT^3\ \Delta D}\ (kgf/cm^2)$$

Where :
S = support distance (cm)
L = width (cm)
T = thickness (cm)
ΔB = load difference (kgf)
D = deflection (cm)

2.3.5.3 Surface Morphology Analysis with SEM

Observing samples with scanning electron microscopy (SEM) starts by affixing the sample to a Stab of aged specimen metal. After cleaning the sample using a blower, it is coated with gold and palladium using a dionspater machine at a pressure of 1492 $x10^{-2}$ atm. The sample is placed in a designated chamber and exposed to a 10-kilovolt electron beam, resulting in secondary and rebounding electron emission. These particles can be detected using a sensor detector, and their signals are amplified by an electric circuit, leading to an image's appearance on the CRT (Cathode Ray Tube). Capturing photographs involves carefully choosing a specific portion of the object (sample) and determining the appropriate level of magnification in order to achieve a high-quality and sharp image [10].

3. Results and Discussion

3.1 Characterization of Clay Powder with Ball Mill

The clay utilized in this investigation was sourced from Wonosari Village, Tanjung Subdistrict, Morawa, Deli Serdang Regency. The clay chunks were fragmented into smaller pieces of dirt, pulverized using a pestle and mortar until they had a smooth consistency, and filtered using a 200 mesh screen. Subsequently, the sample was dried in an oven at 105°C for approximately 3 h until water content was removed. The dried sample was then kept in a desiccator.

The clay powder was sieved using a planetary ball mill (PBM) by adding seven metal balls into the grinding jar and then inserted into the grinding station. Securely fasten the engine cover and adjust the rotation speed to 350 rpm. Set the playback time to 60 minutes and activate the start button. Allow the ball mill process to continue for 40 h. In addition, the clay powder was analyzed using a particle size analyzer.

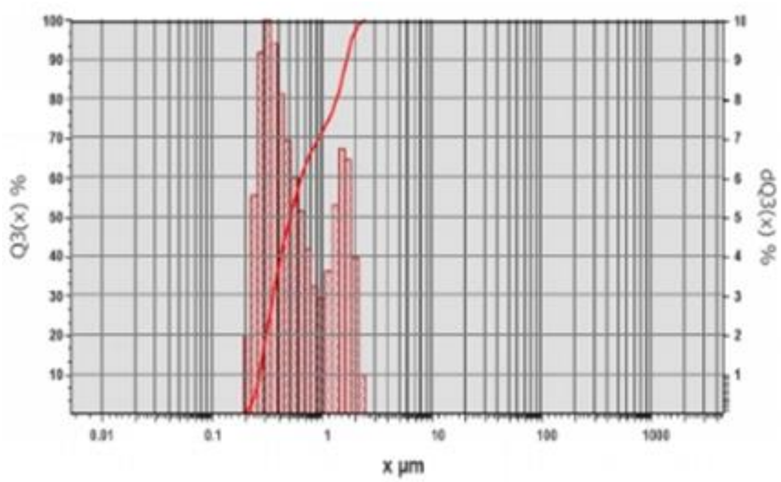

Figure 2. PSA Measurement Results

From the results of grinding using a planetary ball mill with a variation of grinding time of 40 hours, the distribution number was obtained with an average clay particle size of 0.764 μm.

3.2 Preparation of Human Haircut Waste

The preparation of human haircut waste aims to remove dust and dirt attached to the hair, and the haircut waste collected from barbers around the Universitas Sumatera Utara campus was then filtered from fine hair.

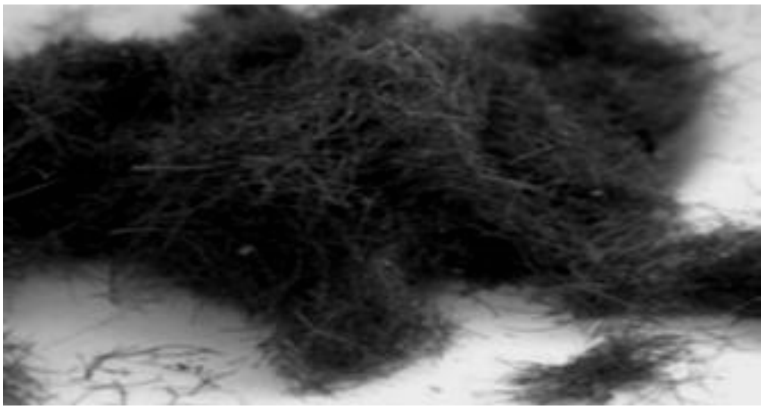

Figure 3. Human Haircut Waste

After the hair has been separated from fine hair, it is washed with distilled water until clean and dried. Then, cut into small pieces of ± 1 cm in size, which aims to improve the mechanical properties of the hair so that it can be spread evenly. It was based on research conducted by Purboputro et al (2006) [11], which explains that the longer the fiber, the mechanical properties will decrease because the bond between the matrix and the fiber is stronger so that the fiber will break at the fracture line. So, this study chose a hair size of ± 1 cm.

3.3 Water Absorption Test

Water absorption testing aims to determine the percentage of water absorbed by samples soaked with distilled water for 24 hours at room temperature. This property shows whether a composite can be damaged when used outdoors. When the composite is submerged in water, water molecules will permeate into the composite by diffusion. Avoiding water is necessary since it can cause internal damage to the composite structure, decreasing its mechanical qualities. Based on the measurements of the composite's dry mass and wet mass.

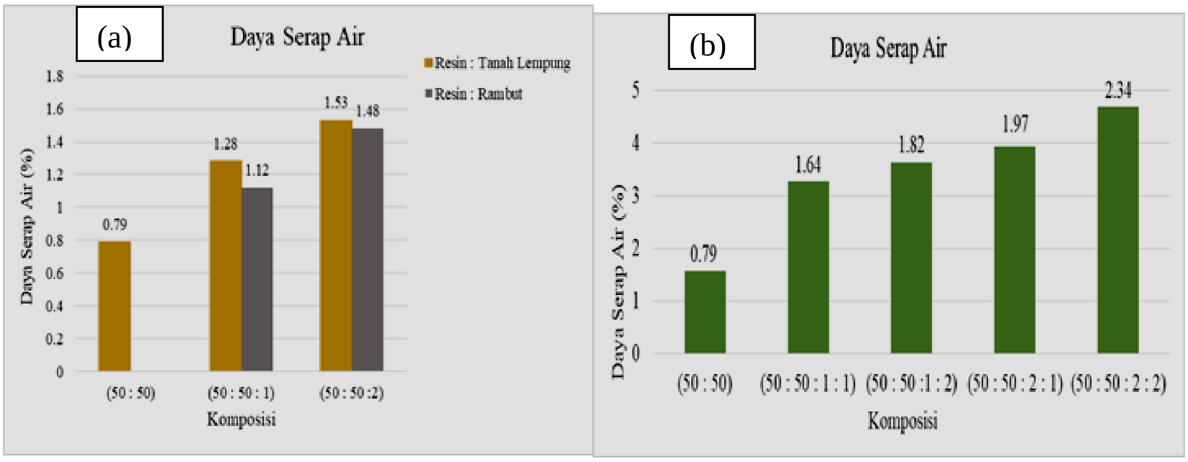

Figure 4. Relationship between absorption and the composition of human haircut waste with (a) clay soil and (b) loamy soil

Based on Figures 4a and 4b, it can be seen that the relationship between the composition of the filler material and the water absorption is that the water absorption of the composite will be higher with increasing amounts of filler material. In this study, the absorption of composites with the largest filler material is in the composition (50: 50: 2) for human haircut waste and clay soil, with a percentage of 1.48% and 1,53%. As for the composition of the mixture of epoxy resin, human haircut waste, and clay, the greatest water absorption is in the composition (50: 50: 2: 2) with a percentage of 2.39%, and the lowest water absorption is in the pure composition with a percentage of 0.79%. The presence of voids formed in the process of providing composites can cause increased water absorption in the composite because *voids* can cause the formation of pathways for water to be absorbed into the composite. This causes the water absorption with the largest filler material to be higher than that of pure resin, which has a high density [12].

In addition to the presence of voids, another factor is the filler material in this study is clay. Clay is a material from soil with a colloidal size that expands when wet and is absorbent to water. Therefore, it is called hydrophilic; there is a bond between ions due to the Van der Walls force, which is so weak that it causes water molecules to enter the clay [13].

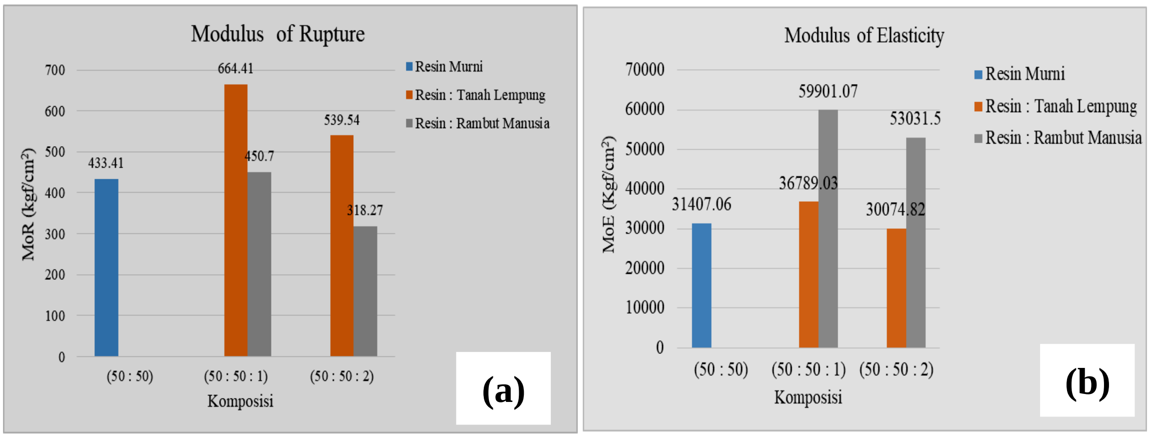

Figure 5. graphs of the composition of human haircut waste with clay soil and loamy soil (a) MoE and (b) MoR

From the test results obtained that the maximum MoR value obtained in the composition (50: 50: 1) g with resin variations with clay fillers and resin variations with human haircut waste fillers obtained MoR values of 664.41 Kgf/cm^2 and 539.54 Kgf/cm^2. While the maximum Modulus of Elasticity (MoE) value in the composition (50: 50: 1) g with resin variations with human haircut waste fillers and with clay fillers obtained MoE values of 36789.03 Kgf/cm^2 and 59901.07 Kgf/cm^2. This has met the SNI 01-4449-2006 standard of a minimum of 255 Kgf/cm^2 for MoR, while for MoE, the SNI 01-4449-2006 standard is a minimum of 20400 Kgf/cm^2.

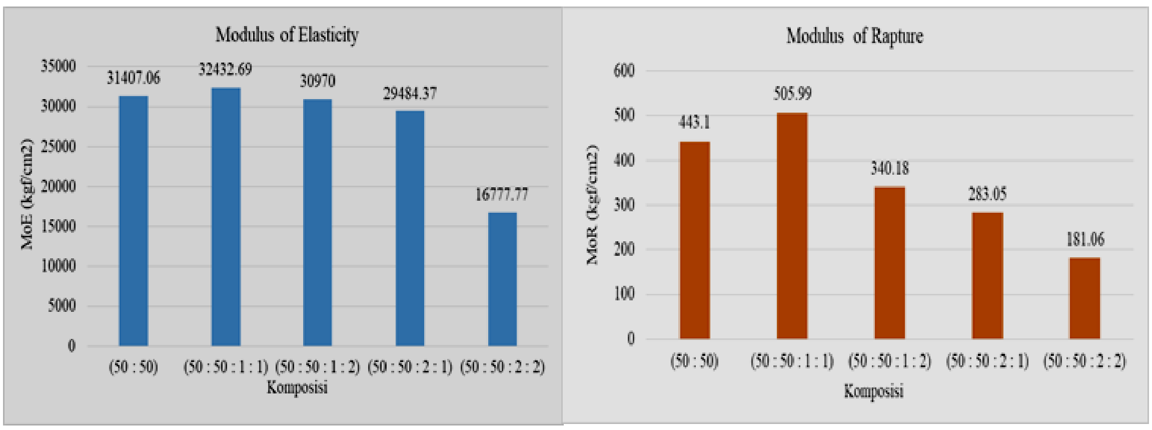

Figure 6. MoE and MoR graphs against mixing the composition of human haircut waste and clay soil

From the test results for the variation of epoxy resin mixture with clay and human haircut waste, it is obtained that the maximum MoR value is obtained in the composition (50: 50: 1: 1) g with a variation of resin with human haircut waste filler and with clay filler, the MoR value is 505.99 kgf/cm^2. While for the maximum

MoE value obtained in the composition (50: 50: 1: 1) g with a variation of resin with human haircut waste filler and with clay filler, the MoE value is 32432.69 kgf/cm^2. This has met the SNI 01-4449-2006 standard of a minimum of 255 Kgf/cm^2 for MoR, while for MoE, the SNI 01-4449-2006 standard is a minimum of 20400 Kgf/cm^2. From the graph above, the effect of composition on mechanical properties will decrease with the increase in filler material. Hasbi, et al (2016), which states that polymer composites reinforced with clay particles show that the hardness value decreases with the increase in clay composition. The matrix may have inserted the clay structure where one or more epoxy matrix molecules insert the silicate layer. The dispersed clay particles are inhibitors of stress propagation. The more clay dispersed in the matrix, the more it will weaken its mechanical properties [14].

Increasing the clay weight composition causes a decrease in the fracture toughness of the epoxy/clay/glass fiber composite. This is possible due to the agglomeration and uneven clay dispersion in the epoxy matrix, which can cause stress concentration. This stress concentration is the beginning of cracking, which decreases the fracture toughness of the epoxy/clay/glass fiber hybrid composite [15]. Likewise, the hair dispersed in the matrix will further weaken its mechanical properties in hair with more hair composition. This is due to the aggregation and uneven hair dispersion to reduce its mechanical properties with increasing weight composition.

3.4 Morphological Analysis with Scanning Electron Microscopy (SEM)

The SEM technique essentially examines and analyzes the surface. The data or display obtained is data from the surface, or a layer about 20 μm thick from the surface obtained is a topographic image with all protrusions, indentations, and surface holes [16]. The morphological results of epoxy resin composites with the addition of clay fillers and areca nut fiber are shown in Figure 7.

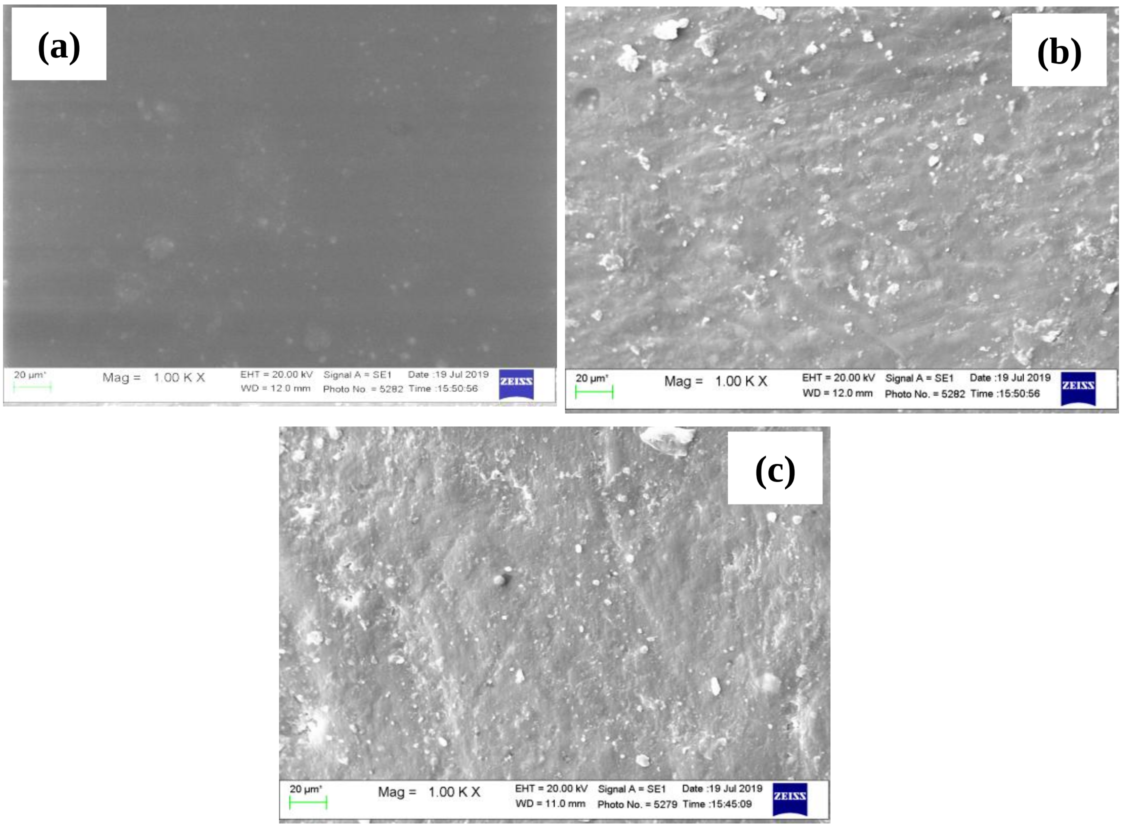

Figure 7. a) SEM morphology results of pure resin (50:50) g, b) SEM morphology results of RE composite: TL: RM (50:50:1:1) g, and c) SEM morphology of RE composite: TL: RM (50:50:1:2) g

The results of the surface morphology of SEM photos in Figure (a), with a magnification of 1000 times, show that the mixture of resin A and hardener without adding clay or human haircut waste shows a flatter surface and few voids. This is due to homogeneous mixing. Whereas in Figure (b), with a magnification of 1000 times, the effect of the composition of clay and human haircut waste in the ratio (50: 50: 1: 1) g can be seen in clay powder and human haircut waste that has been evenly distributed in the epoxy matrix.

This is due to the filler's short fiber size and small particle size, allowing clay and human haircut waste to combine with epoxy resin. Whereas in Figure (c), with a magnification of 1000 times the effect of the composition of clay and human haircut waste in the ratio (50: 50: 2: 2) g as the composition increases, the spread of fillers is very unevenly distributed or only stacked (agglomeration) on one side only while on the other side there is no filler. There are empty spaces in the epoxy matrix, which causes lower mechanical properties.

4. Conclusion

In conclusion, the optimum composition obtained from epoxy resin composites in mixing clay and human haircut waste with composition variations (50: 50: 1: 1) g is seen from the MoR and MoE values and the water absorption test obtained. Next, the results of the characterization of the mechanical properties of epoxy resin composite materials found mixing the two fillers between clay and human haircut waste with the optimum composition variation (50: 50: 1: 1) g obtained a MoR value of 505.99 kgf/cm^{2}and MoE of 32432.69 kgf/cm^2. In the water absorption test, the results obtained are directly proportional to the increase in composition, the greater the water absorption where the composition of the lowest water absorption in the composition (50: 50) g is 0.79%, and the highest water absorption in the mixing variation (50: 50: 2: 2) g is 2.34%. The optimum absorption in the mixing variation (50: 50: 1: 1) g is 1.64%. Subsequently, the results of the SEM morphology test show that the composition of clay fillers and human haircut waste in the composition (50: 50: 1: 1) g is more evenly distributed and has few voids compared to the composition (50: 50: 2: 2) g which is not evenly distributed and there is agglomeration which can reduce the mechanical properties of the composite.

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6. Conflict of Interest

Authors declare no conflicts of interest

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