Study of Mechanical and Physical Properties of Natural Hybrid Composites

I. K. Adi Atmika, I. D. G. Ary Subagia, I. W. Surata, and I. N. Sutantra

***Abstract*—Brake lining is one of the components in the braking system that directly rub against the rotating drum or disk. The ability of brake lining can be seen from several things including being able to absorb the amount of kinetic energy when braking, having good hardness, low water absorption. Previously, brake lining was made of asbestos material which has resistance to high temperatures reaching 800˚C, but asbestos material has a negative impact on the environment and human health. This research was developed to overcome these problems, namely finding alternative brake lining materials that have good impact strength, good hardness and do not interfere with the health of the driver of the vehicle and are environmentally friendly. This paper describes the mechanical and physical properties of the developed brake lining material. This brake lining material is made from basalt powder, shellfish powder, alumina powder and phenolic resin polymer as a binder with five variations of weight fraction. This material was made through a sintering process at a temperature of 150°C with a pressure of 2000 kg for 30 minutes, then each specimen was tested for impact strength using a Charpy impact test according to ASTM D 6110 standard, hardness was tested using Vickers test according to ASTM E384-99, and water absorption based on ASTM D 570-98 standards. The average impact strength of brake lining specimens was obtained at 0.0003327 J/mm^2, better than the average impact strength of brake linings from asbestos material. While the hardness obtained was the lowest 24.72 VHN and the highest was 26.55 VHN, still better than the asbestos brake lining of 24.75 VHN, and the highest water absorption of the brake lining specimens obtained was 0.041558 still lower than the water absorption of asbestos brake lining.**

***Index Terms*—Natural hybrid composite, hardness, impact strength, water absorption.**

I. Introduction

One component of the braking system is the brake lining, which this component serves to reduce speed or stop the vehicle. This component rubs directly against the rotating drum or disk [1]. In general, brake pads are asbestos, which have a high temperature resistance of 800°C [2], and they also have low water absorption [3]. However, asbestos brake linings have been discontinued because they have a negative impact on the environment and human health [4], [5].

Then other researchers also developed clamshell brake pads with a grit size of 600 µm which were tested at speeds below 100 km/h [6]. Morphological testing of shellfish granules is very possible to use as a friction plate for asbestos substitutes [7], and thermal test of shellfish material for friction material has also been carried out and has good properties [8]. However, the results achieved at this time have not been able to maintain mechanical properties, especially for wear resistance, temperature resistance, and high water absorption.

This paper discusses brake linings made from hybrid composites by mixing basalt powder, shellfish powder, alumina powder and phenolic polymer resin (PR-51510i) as a binder. Basalt is a rock from a volcanic eruption crushed into powder of a specific size. This material has heat resistance up to 1500˚C [9], has excellent corrosion resistance properties, low water absorption and is non-toxic [10]. Besides this material has excellent physical and mechanical properties, good ductility, high wear resistance [11], and this fiber can replace glass fibers [12]. Besides that, the main characteristic of this material is that it has low thermal conductivity.

II. Material and Method

A. Materials

This research was carried out by hybridizing three materials as reinforcement and one material as binding matrix in specific compositions. The reinforcing material consists of basalt powder, shellfish powder and alumina powder which are all in the form of solid particles with a size of 0.0074 millimeters, then as a matrix material is a phenolic resin (PR-51510i). Basalt characteristics are shown in Table I. Shellfish powder used consisted of several elements, namely 0.03% Fe_2O_3, 1.25% Al_2O_3, 7.88% SiO_2, 22.28% MgO, and 66.70% CaO.

TABLE I: Properties of Basalt Material

Properties of basalt	Value (unity)
Tensile strength	500k-550k (psi)
Density	2600-2630 (kg/m^3)
Operation temperature	-265 - 700 (ºC)
Sintering temperature	1050 (ºC)
Modulus of elastisitas	9100 - 1100 (kg/mm^3)
Elongation at break	3.15 (%)
Heat resistance	700-1000 (ºC)
Melting point	1170 (ºC)
Mohs Hardness @20ºC	5-9

B. Method

This brake lining material is made by mixing, compacting, and sintering at a temperature of 150°C. The sintering process of this brake lining material specimen was carried out with emphasis for approximately 30 minutes and a compressive load of 2000 N. The size and shape of the test specimen were made according to ASTM D 3171-09 standard, as shown in Fig. 1 and Fig. 2.

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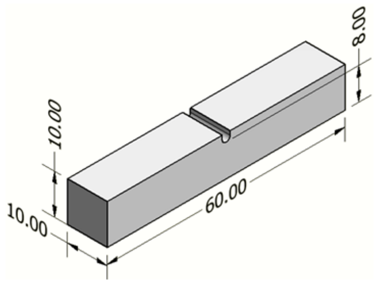

Fig. 1. Size of impact test specimens.

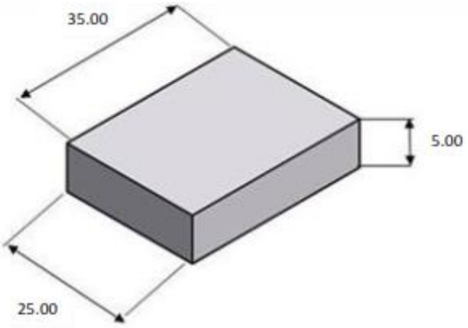

Fig. 2. Size of hardness test specimens.

Hybrid composite brake linings are made with a specific composition of five variations of weight fraction, as shown in Table II. The impact test specimens were made according to ASTM D 6110 standard, while the hardness of the specimens according to Vickers ASTM E384-99 test standard, and the water absorption test according ASTM D 570-98 standard. As a comparison, asbestos (X) brake lining was also tested according to each test standard.

TABLE II: FIVE VARIATION OF THE HYBRID COMPOSITE

Specimen	Phenolic Resin (%)	Alumina powder (%)	Basalt powder (%)	Shellfish powder (%)
I	40	10	45	5
II	40	10	40	10
III	40	10	35	15
IV	40	10	30	20
V	40	10	25	25

III. RESULTS AND DISCUSSION

Table III shows the results of the impact test and the hardness test then illustrated in the graph as shown in Fig. 3, Fig. 4, and Fig. 5. Then the water absorption test results are listed in Table IV and illustrated in the graph as shown in Fig. 6.

TABLE III: IMPACT STRENTH AND HARDNESS OF SPECIMENS

Variation of Composite	Is (J/mm^2)	VHN
X	0.000374867	24.75
I	0.000304851	24.18
II	0.000339547	25.11
III	0.000334516	26.34
IV	0.000325059	27.21
V	0.000332700	28.83

Fig. 3 and Fig. 4 show the impact strengths of the five variations of hybrid composite specimens and asbestos specimens. The highest impact strength is specimen II of 0.000339547 J/mm^2. This shows that hybrid composites with variations of 40% resin, 10% shellfish, 10% alumina, and 40% basalt have stronger and more perfect bonds between the matrix and basalt compared to other hybrid composites [13]. Then in general the impact strength of the developed hybrid composite material approaches the impact strength value of asbestos material (X) [14], [15].

TABLE IV: WATER ABSORPTION OF SPECIMENS

Variation of Composite	Water Absorption (%)				
	3 days	14 days	24 days	30 days	60 days
X	0.032136	0.041588	0.043478	0.043478	0.043478
I	0.038961	0.041558	0.041558	0.041558	0.041558
II	0.031414	0.036649	0.036649	0.036649	0.036649
III	0.028721	0.033943	0.036554	0.036554	0.036554
IV	0.026178	0.028796	0.031414	0.031414	0.031414
V	0.023499	0.026110	0.028721	0.028721	0.028721

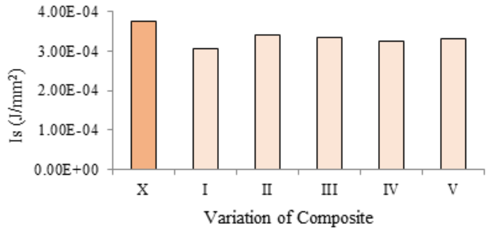

Fig. 3. Impact strength of the hybrid composite and asbestos.

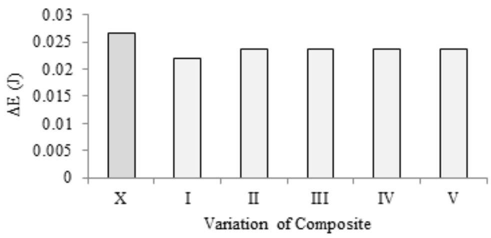

Fig. 4. Energy absorbed in the impact test.

The mechanical properties of hardness of hybrid composite specimens and asbestos specimens are shown in Fig. 5. Specimen I has a hardness of 24.72 VHN, then the hardness of specimen II is 25.40 VHN, specimen III is 25.67 VHN, specimen IV is 25.74 VHN, and specimen V is 26.55 VHN [15]. Thus the amount of basalt powder has a significant effect on the hardness of the brake lining material made [16]. It can also be seen that asbestos brake lining have a hardness value between composition I and composition II, so that the basalt powder and shellfish powder are natural alternative materials that can be used as alternative brake lining as a substitute for asbestos brake lining.

To see the bond between the elements and the micro structure of the hybrid composite brake lining, observations were made using scanning electron microscopy (SEM). The observations are shown as in Fig. 6 to Fig. 11.

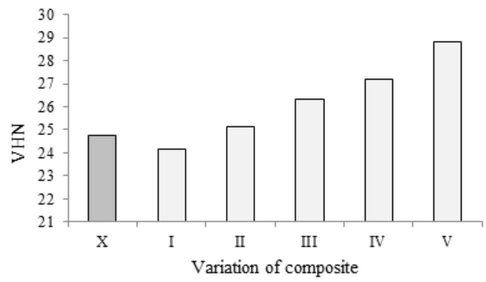

Fig. 5. Hardness of Vickers hybrid composite and asbestos materials.

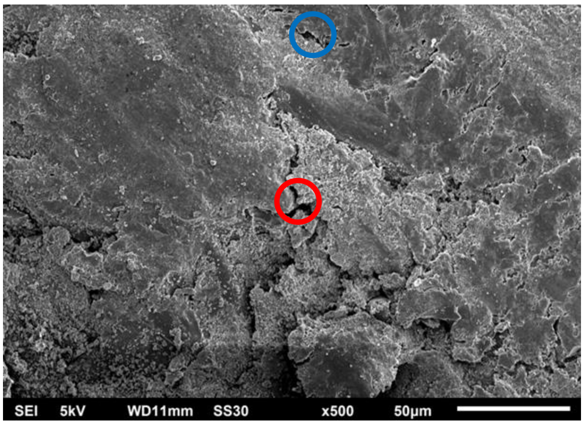

Fig. 6. SEM photo of bonding between particles of hybrid composite material.

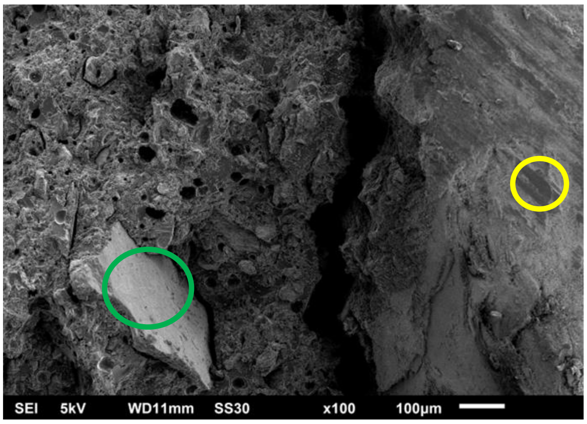

Fig. 7. SEM photo of 100x magnification of shellfish powder material.

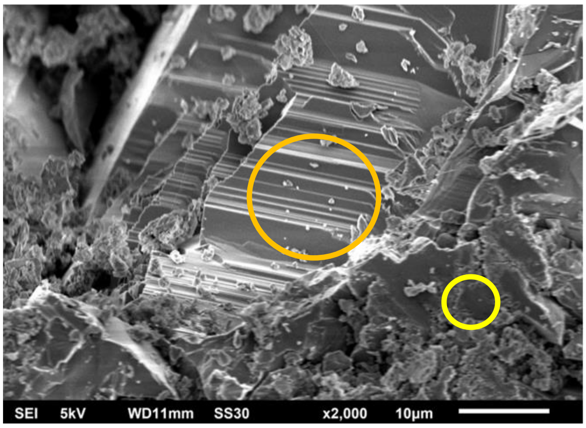

Fig. 8. SEM photo of 2000x magnification of alumina powder material.

Fig. 6 shows a SEM photo of specimen V with a magnification of 500x. It seems that there is still porosity (blue mark) and there are cracks (red marks), apparently due to the influence of water absorption [17]. The amount of porosity and crack is not so much, so that the hardness of the material is still good. Whereas Fig. 7 shows SEM photos on the same specimen with a magnification of 100x. It can be seen how the bond of particles between phenolic resin and basalt has a tight bond (yellow mark), whereas the bond with shellfish is still less dense or tenuous (green mark), but does not weaken the bond as a whole. Then Fig. 8 shows the SEM photo of the specimen, too, but with a magnification of 2000x. From this figure, it can be explained that the particle composition between phenolic resin and basalt has a strong bond (yellow mark) [9], while the bond with alumina granules is still less dense or tenuous (orange mark) [18]. Photo SEM of Fig. 9 and Fig. 10 show the position of specimen V through on EDS. Visible constituents of the shellfish material [19].

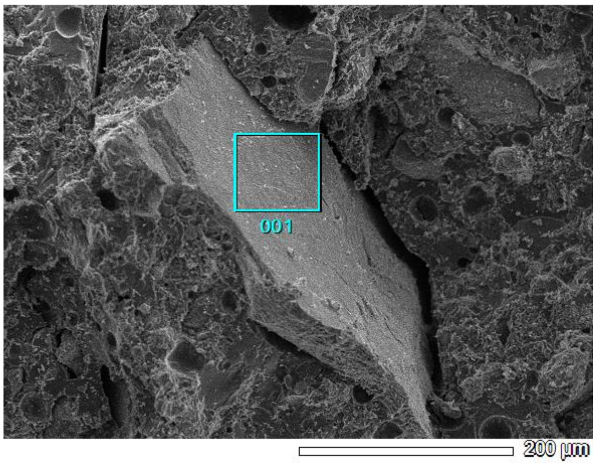

Fig. 9. photo of EDS shellfish powder material.

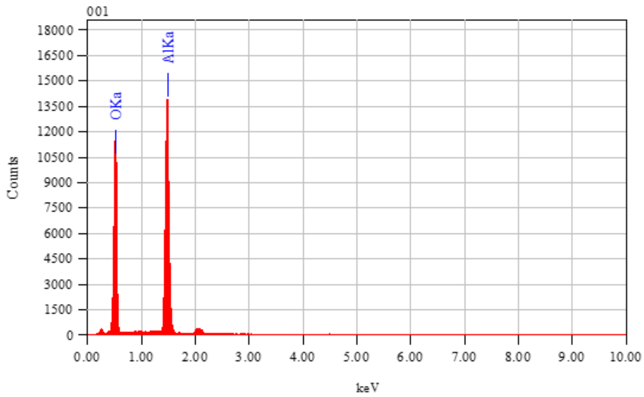

Fig. 10. EDS chart shellfish powder material.

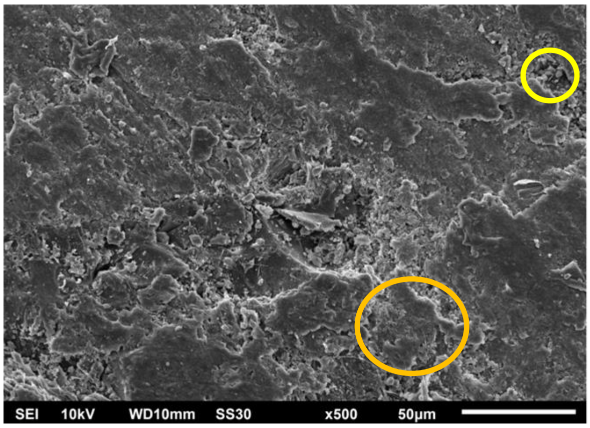

Fig. 11. SEM photo of bonding between particles of asbestos material (500x).

Meanwhile, to see the bond between the constituent elements and microstructure of asbestos brake lining specimens, an electron microscope (SEM) was also observed. Then the results are shown as in Fig. 11 to Fig. 14.

Fig. 11 shows SEM photos on asbestos brake linings with a magnification of 500x where it can be seen that in the process of casting asbestos shoes there are still porosity (yellow mark) and cracks (orange mark) [20]. Fig. 12 and Fig. 13 show SEM photos on asbestos brake lining pads at 1500x magnification and 2000x magnification, explaining how the bond between material particles in asbestos brake linings is quite tight (orange mark), and is seen to be bound by both material (yellow mark) [3].

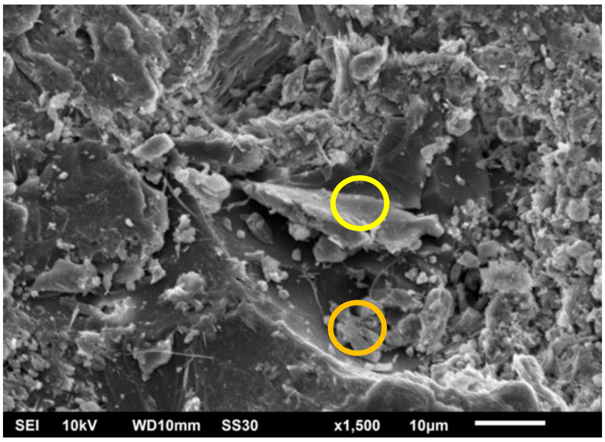

Fig. 12. SEM photo of bonding between particles of asbestos material (1500x).

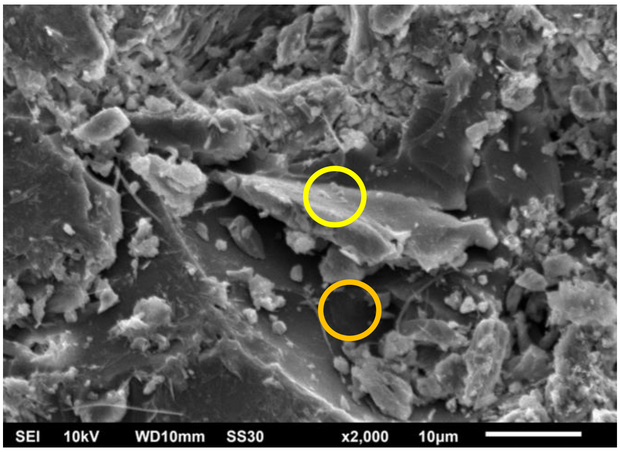

Fig. 13. SEM photo of bonding between particles of asbestos material (2000x).

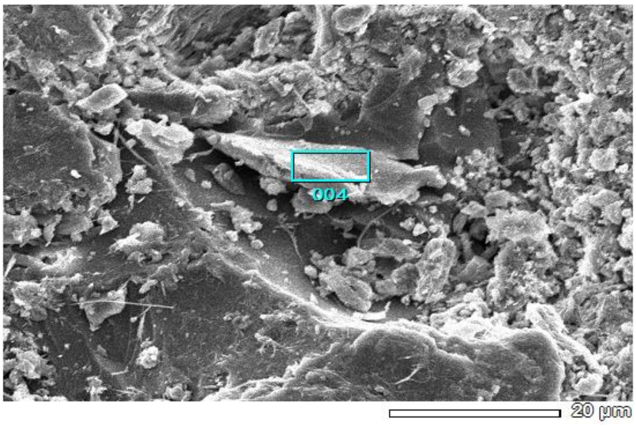

Fig. 14. photo of EDS asbestos material.

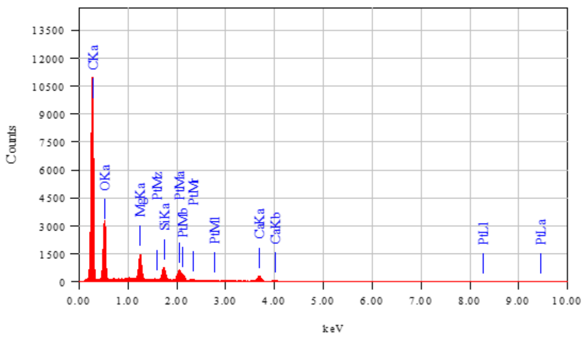

Fig. 15. EDS chart asbestos material.

Photo SEM of Fig. 14 and Fig. 15 show the position of specimen asbestos through on EDS. Visible constituents of the asbestos materials [21].

Then the characteristics of the water absorption of hybrid composite brake lining pads and asbestos brake linings are shown in Fig. 16.

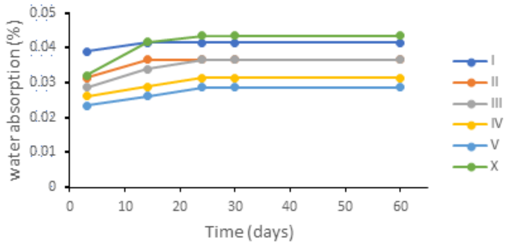

Fig. 16. Water absorption of the hybrid composite and asbestos materials.

Fig. 16 shows an overview of trends in water absorption by hybrid composite materials being developed as well as asbestos brake lining material [3]. It is seen that the trend after 24 days of immersion began to be constant for each specimen variation [13]. The lowest water absorption of specimens V was 0.028721% compared to the other four specimens and all of them were still below the water absorption capacity of the asbestos brake lining material (X) [22], [23].

IV. Conclusion

Increasing the percentage of basalt powder and reducing the percentage of shellfish powder at a constant alumina percentage results in almost the same impact strength and not much different from the impact strength of asbestos brake lining. Then reducing the percentage of basalt powder and adding the percentage of shellfish powder at a constant alumina get a higher hardness value. Furthermore, the reduction in the percentage of basalt in each composition produces a brake lining with better water absorption and is still lower than asbestos brake lining. The illustration provides a strong basis that the developed hybrid composite material has good mechanical and physical properties as brake linings, which we call environmentally friendly brake linings.

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