Development of brake lining based on mountain stone and shellfish waste

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Abstract. In general, brake pads made from asbestos, when used asbestos brake lining have a negative impact on health and the environment. In this research, a hybrid composite brake lining was developed with reinforcement of mountain stone powder, shellfish powder, and alumina with a certain composition. This paper describes the compression strength and water absorption ability of hybrid composite brake linings developed, as an alternative to brake pads that have good mechanical properties and are environmentally friendly. Hybrid composite brake lining material is made in seven weight fraction compositions through a sintering process. The test method is carried out by an experimental method based on ASTM E 9-89a for compression strength testing and based on ASTM D 570-98 for water absorption. The results showed that there was an influence of weight fraction on each composite variation on the compression strength of the brake lining. Reduction of percentage of mountain stone in each composition resulted in varying compression strength values, with the highest compressive strength value in specimen A of 0.1350 kN/mm² and the lowest in specimen G of 0.0883 kN/mm². Then the highest water absorption of the brake pad specimen made is 0.041558%, still lower than the asbestos brake lining pads.

1. Introduction
Brake lining is one component of a motorized vehicle that serves to slow down or stop the vehicle's speed. While high-speed vehicles brake linings have a very important role, on the other hand motorized vehicles in each year are growing from all aspects including the speed of the vehicle, so it must be balanced with high security. Currently active safety concerns are focused on the ability of the braking system, where most accidents occur due to poor performance of the brake function. In this case brake lining is one of the important components in braking performance. Brake lining is arranged in a brake system made of asbestos material [1], and other additional elements such as SiC, Mn or Co and is attached together with various organic resins, rubber, and others[2, 3].

Previously, the brake lining was made from the main material, namely asbestos, this material does have resistance to high temperatures reaching 800 °C [4] and this material has low water absorption but has good sound absorption [5]. However, asbestos is discontinued because it has a negative impact on the environment and health[6]. For this reason brake lining pads began to be replaced by other materials such as aramid fibers, kevlar, twaron, rock wool, fiberglass, potassiumtate, BaSO4, resins, nitrile butadiene rubber, carbon fiber, graphite, cellulose, vermiculate, and steel fibers. Several asbestos-free brake lining patents have been issued such as WS-08 type brake lining, WS-45 type brake lining, WS-65 type semi-metal brake lining, WS-85 type and WS 156 type[7, 8].

Currently with the issue of environmentally friendly and the use of natural materials, a lot of brake lining are developed that use natural materials. To make it happen, in this research developed the
material of brake lining with mountain stone waste, hereinafter referred to as basalt and combined with shellfish and alumina. In mechanical strength such as tensile and flexural stress and elastic modulus, basalt fiber has a better advantage than glass fiber. Basalt fiber is very resistant to water absorption, low thermal conductivity [9], low density, has good resistance to high temperatures and is non-toxic [10].

Many researchers developed asbestos-free brake linings. In 2014, C. O. Mgbemena et al. developing non-asbestos based on palm kernel shell (VFD), this non-asbestos friction plate is produced containing fibrous reinforcing agents plus elastomeric additives, as well as thermosetting resins. The results showed that the Palm kernel friction plate material was obtained at a temperature of 53.84°C to a temperature of 634.87°C and a weight reduction percentage of 86% [11]. Then other researchers also developed a shell-based brake pad material with a grit size of 600 µm. The material was tested still at speeds below 100 km/h [12], but the results achieved at this time have not been able to maintain mechanical properties, especially against the strength of compression and water absorption is still quite high.

This paper presents the characteristics of the compressive strength of brake lining material and the water absorption ability of hybrid composites developed with basalt, shellfish, alumina and bonded using a phenolic resin matrix polymer (PR-51510i). Basalt is one of the volcanic eruption material which has heat resistance up to 1500°C [13], resistant to corrosion, low in water absorption and resistant to chemical and non-toxic treatment [14]. Properties of basalt have excellent physical and mechanical properties, high tenacity [15], and high wear resistance [16], and can replace glass fibers [17]. Then the most important characteristic of this material is that it has low thermal conductivity.

### 2. Materials and Methods

This research was carried out by mixing or hybridizing three types of material as reinforcement and one material as matrix. The reinforcing material is basalt powder, shell powder and alumina powder in the form of solid particles with a size of 60 mesh, then as a composite matrix material used phenolic resin (PR-51510i). Element of basalt are shown in table 1. The powdered shellfish material is produced from burning the crushed shells and the percentage element are shown in table 2.

| Table 1. Elemental basalt content |
|----------------------------------|
| **Element**         | **Percentage**          |
| SiO₂                | 48.59 – 60.49          |
| TiO₂                | 0.48 – 1.00            |
| Al₂O₃               | 16.47 – 21.76          |
| Fe₂O₃               | 5.83 – 10.61           |
| MnO                 | 0.11 - 0.19            |
| MgO                 | 2.37 – 8.84            |
| CaO                 | 5.57 – 11.47           |
| Na₂O                | 1.83 – 3.32            |
| K₂O                 | 0.31 – 1.67            |
| P₂O₅                | 0.14 – 1.21            |

| Table 2. Element of shellfish |
|-----------------------------|
| **Element** | **Percentage** |
| CaO          | 66.70          |
| SiO₂         | 7.88           |
| Fe₂O₃        | 0.03           |
| MgO          | 22.28          |
| Al₂O₃        | 1.25           |

The process of making a specimen is done by mixing reinforcing material and matrix material in the dry phase. The variation of weight fraction of brake lining material studied is shown in table 3.
Table 3. Element of shellfish

| Variation of Composite | Basalt powder | Shellfish powder | Alumina powder | Phenolic Resin |
|------------------------|---------------|------------------|----------------|---------------|
| A                      | 45            | 5                | 10             | 40            |
| B                      | 40            | 10               | 10             | 40            |
| C                      | 35            | 15               | 10             | 40            |
| D                      | 30            | 20               | 10             | 40            |
| E                      | 25            | 25               | 10             | 40            |
| F                      | 50            | -                | 10             | 40            |
| G                      | 50            | 10               | -              | 40            |

The stages of systematic composite material manufacturing are shown as in Figure 1. Figure 1 (a) shows the equalization and measurement of mountain stone powder, shellfish powder and alumina powder. Then the three powders were mixed with the composition in Table 3, by mixing the reinforcement and phenolic resin matrix in Figure 2 (b). Then, the mixture is done using a hot press machine with a constant temperature of 1500°C for 30 minutes and a pressure of 2 tons. Then, dry the brake pad composite at room temperature for 24 hours, after it is completely dry, separate the composite from the mold slowly.

![Figure 1](image)

**Figure 1.** The process of manufacturing hybrid composite materials; a. measurement and alignment process, b. mixing process, c. sintering process

This test method includes the capacity of the specimen to withstand loads which will reduce its size. This test method includes equipment, specimens and procedures for testing axial compression loads at room temperature. Compression strength testing refers to ASTM E 9-89a, while the ability of water absorption is tested based on ASTM D 570-98.

3. Results and discussion

The results of the compression strength test are shown in table 4, while the results of the water absorption test are shown in table 5. Then a comparison picture of the magnitude of the compression strength and the water absorption distribution of the seven variations of hybrid composite developed with comparative brake pad material (X) is shown in Figure 2 and Figure 3.
Table 4. Compression strength of hybrid composite and asbestos specimens

| Variation of Composite | Compression Strength (kN/mm²) |
|------------------------|-------------------------------|
| X                      | 0.0950                        |
| A                      | 0.1350                        |
| B                      | 0.1333                        |
| C                      | 0.1333                        |
| D                      | 0.1316                        |
| E                      | 0.1300                        |
| F                      | 0.1216                        |
| G                      | 0.0883                        |

Table 5. Water absorption hybrid composite and asbestos specimens

| Variation of Composite | Fluid Absorption (%) |
|------------------------|-----------------------|
|                        | 3 days                | 14 days | 24 days | 30 days | 60 days |
| X                      | 0.032136              | 0.041588 | 0.043478 | 0.043478 | 0.043478 |
| A                      | 0.038961              | 0.041558 | 0.041558 | 0.041558 | 0.041558 |
| B                      | 0.031414              | 0.036649 | 0.036649 | 0.036649 | 0.036649 |
| C                      | 0.028721              | 0.033943 | 0.036554 | 0.036554 | 0.036554 |
| D                      | 0.026178              | 0.028796 | 0.031414 | 0.031414 | 0.031414 |
| E                      | 0.023499              | 0.02611  | 0.028721 | 0.028721 | 0.028721 |
| F                      | 0.040909              | 0.043636 | 0.044467 | 0.044467 | 0.044467 |
| G                      | 0.040286              | 0.042992 | 0.043831 | 0.043831 | 0.043831 |

Figure 2. Compression strength of the hybrid composite and asbestos specimens
Figure 2 shows a picture of the compression strength of the seven variations of hybrid composites, where the highest value of compression strength obtained from the composition of hybrid composites A is 0.1350 kN/mm². This shows a hybrid composite with a variation of 45% basalt, 5% shell, 10% alumina, and 40% resin has a stronger and more perfect bond between the matrix and basalt compared to other hybrid composites. Then in general the compression strength of the developed hybrid composite material is greater than the compression strength value of asbestos material (X) of 0.0950 kN/mm² [16].

Figure 3 shows the water absorption by the hybrid composite material being developed as well as the asbestos brake lining material. It can be seen that the trend after 24 days immersion has begun to be constant for each specimen variation [18]. The lowest water absorption is specimen E of 0.028721% compared to the other six specimens and water absorption is all still below the water absorbency of asbestos brake lining material.

4. Conclusions
Increasing the percentage of basalt powder and reducing the percentage of powder shellfish, the percentage of alumina constant produces a value of compression strength that is almost the same and on average is still higher than the compressive strength value of asbestos brake lining. Then the reduction in the percentage of basalt in each composition results in a decrease in water absorption and is still lower than the water absorbency of asbestos brake linings. Therefore, the hybrid composite brake lining material developed has potential as a substitute for asbestos for environmentally friendly brake lining material.

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