Australian Journal of Basic and Applied Sciences, 5(11): 291-296, 2011
ISSN 1991-8178

Fabrication and Mechanical Properties of Composite Palm ash Mixed With Phenolic Resins

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Abstract: Brake pad is one of the important engineering components in automobile and it is fabricated by combination of various materials. Asbestos is one of the components in brake pad that is harmful to the human. In this investigation, palm ash was used to replace asbestos. Characterization of palm ash was carried out by using XRF, Malvern Particle size and Scanning Electron Microscopy (SEM). The composite samples for brake pad application were developed by pre-mix the palm ash, $CaCO_3$, phenolic resins, Al_2O_3, graphite and steel fiber mill and then compacted at 15MPa. Samples were cured at a temperature of 150°C for 5 minutes. Study on microstructure, density, porosity, water absorption, compressive and impact test was carried out on the samples. The results showed that the compressive and impact strength were increased with increasing content of palm ash.

Key words: palm ash, $CaCO_3$, phenolic resins, Al_2O_3, graphite and steel fiber.

INTRODUCTION

Brake pad is one of the important engineering parts in all types of vehicle and it is used to slow down and stop moving any vehicle. Brake pad materials are generally considered as composites (Darius G. Solomon *et al.,* 2007). The amount of materials consumption to fabricate brake pads are consists of more than 8 different types of materials (A. Saffar *et al.,* 2010, Yousef and Saied, 2009). The types of materials for developing brake pad can generally be classified into five types of materials, depending on the specific functional requirement. These include fibers (Jie Fei *et. al.,* 2010*),* fillers (Mukesh Kumar *et. al.,* 2010), binders (G.M. Ingo *et al,.* 2004), friction modifier and lubricants (G.P. Ostermeyer. 2004). The performance (i.e. safety, durability and comfort) of various brake situations is mainly controlled by the composition and microstructure of the brake pad materials (M.M. Morshed *et al.,* 2004). The filler category is divided into various functions such as to reduce thermal conductivity, to resist fade and to improve the braked pad strength. This paper proposes the use of palm ash as filler materials in brake pad. It was reported that palm ash has been used as cement replacement material and as an absorbent for the removal of zinc from aqueous solution (N. Mohamed-Noor *et al.,*2004). As we know, palm oil industry is one of the biggest industries in Malaysia. Besides the production of crude palm oil, a large amount of solid waste is also an output from the palm oil industry. Because of economic reason, solid waste, such as palm kernel oil, beans and oil palm bunch are used as fuel to produce steam for electrical power. After burning, the palm ash is produced and this ash cannot be used for other processes. The problem is to dispose the palm ash because it requires a relatively large area to collect the ashes and affecting the surrounding environment (R.P. Singh *et all,.*2010, H. Ismail and S.M. Shaari. 2010, Weerachart Tangchirapat, Chai Jaturapitakkul. 2010). The use of waste materials in a brake pad is a potential alternative to reduce the palm ash waste and to reduce the costing of raw materials. This paper was aimed to fabricate and study the mechanical properties of the composite palms ash mixed with phenolic resin.

Eksperiments:

Six types of raw material such as palm ash, $CaCO_3$, phenolic resin, Al_2O_3, graphite and steel fiber were used to fabricate composite samples for brake pad. Palm ash was supplied by a local oil palm manufacturer Seberang Perai and used as filler. $CaCO_3$, phenolic resins, Al_2O_3 and steel fiber were purchased from local company. In this research, phenolic resin was selected as a binder, Al_2O_3 as an abrasive element, $CaCO_3$ as filler, steel fiber as fiber reinforcement. Finally, graphite was used as lubricant element. Palm ash was dried in oven at a temperature of 80 °C for 24 hours to release the moisture. An Endecotts sieve was used to obtain an average size of palm ash. The average size is in the range of 75- 150 μm. The particles size of palm ash, $CaCO_3$, Al_2O_3, phenolic resin, and graphite were determined by the Malvern Particle Analyzer Machine. The microstructures of the raw materials were characterized by scanning electron microscope (SEM)-EDX JEOL JSM-6460LA. All the raw materials were mixed together for 15 minutes to obtain the homogeneous mixed ingredients. The weight percentage used in the composite mixtures is shown in Table 1.

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Table 1: Ingredients used in composites.

Sample / Material	A	B	C	D	E	F	G
Palm Ash (%)	5	10	15	20	25	30	35
$CaCO_3$ (%)	35	30	25	20	15	10	5
Phenolic (%)	20	20	20	20	20	20	20
Al_2O_3 (%)	10	10	10	10	10	10	10
Graphite (%)	10	10	10	10	10	10	10
Steel fiber (%)	20	20	20	20	20	20	20

The mixtures were then compacted with the pressure of 15MPa using unaxial hydraulic hand press machine. The compacted samples were cured at 150°C for 5 minutes. Porosity value for each sample was obtained by using the JIS D 4417: 1996 standard. Oil was used as the liquid for the measurements. The percentage of apparent porosity was calculated using the following formula:

$$\rho = \left(\frac{m_2 - m_1}{\rho_2}\right) \times \left(\frac{1}{V}\right) \times 100$$

where:

ρ = porosity (%)
m_1 = mass of test piece (g)
m_2 = mass of test piece after absorption water (g)
ρ_2 = density of oil (g/cm^3)
V = volume of test piece (cm^3)

Izod impact test value for each sample was obtained by using the ASTM 256-06. The suggested configuration and dimensions of the specimens are based on American Standard Testing Method (ASTM) as shown in Fig. 1.

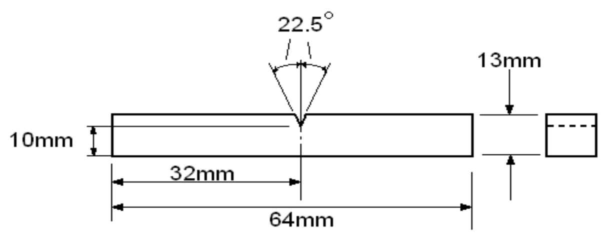


Fig. 1: Standard dimension for izod impact test.

The fracture surface of the composite samples after impact test was studied under SEM.

RESULTS AND DISCUSSION

3.1 Raw Material Characterization:

Table 2 shows the listed of raw materials and average particle size of CaO_3, phenolic resins, Al_2O_3 and graphite respectively. The average particle size of palm ash is 150 µm and sieved by using Endecotts sieve

Table 2: Raw material used in this study.

Raw Material	Average size (µm)	Average Length (mm)
Palm Ash	150	-
$CaCO_3$	10	-
Phenolic resin	15	-
Al_2O_3	80	-
Graphite	8.7	-
Steel fiber	-	2-4

Fig. 2 shows the particle shape of the raw materials including palm ash, $CaCO_3$, phenolic resin, Al_2O_3, graphite and steel fiber observed under SEM. Fig. 2(a-d) shows irregular shape of palm ash, which had been sieved in the range of 150 µm, $CaCO_3$ having irregular shape, particle phenolic resin in agglomerated form, irregular shape of particle Al_2O_3 respectively. Fig. 2(e) shows particle graphite in the form of agglomerates irregular shape and finally Fig. (f) show morphology of steel fiber.

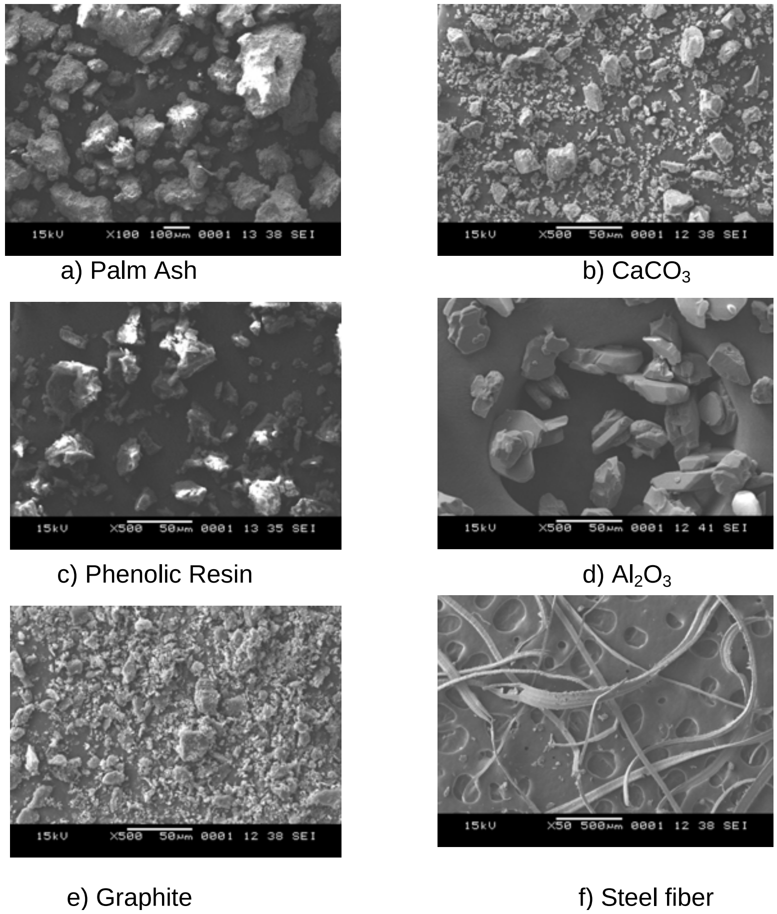


Fig. 2: Scanning electron micrograph of raw materials of a)Palm Ash b)Ca_2O_3 c)Phenolic resin d)Al_2O_3 e)Graphite f) Steel fiber

X-Ray Fluorescence (XRF):

Chemical compositions palm ash was analyzed based on the point analysis by using XRF. Chemical composition of palm ash is presented in Table 3. The main chemical composition of palm ash is potassium oxide, silica and calcium oxide.

Table 3: Chemical compositions in palm ash.

Chemical composition	Weight (%)
K_2O	52.7
SiO_2	22.1
CaO	13.2
P_2O_5	4.9
SO_3	4.0
Fe_2O_3	1.65
TiO_2	0.33
Rb_2O	0.25
MnO	0.23
CuO	0.22
ZnO	0.15
NiO	0.072
SrO	0.088
Y_2O_3	0.02
Yb_2O_3	0.02
Re_2O_7	0.05

3.2 Porosity Testing:

Fig. 3 shows the graph trend indicating the porosity decreases with increasing the palm ash content. Composite with 5wt.% palm ash has the highest value of porosity and composite with 35 wt.% palm ash has the lowest value of porosity. It is expected that the irregular shape and 150μm size of palm ash have reduced the porosity.

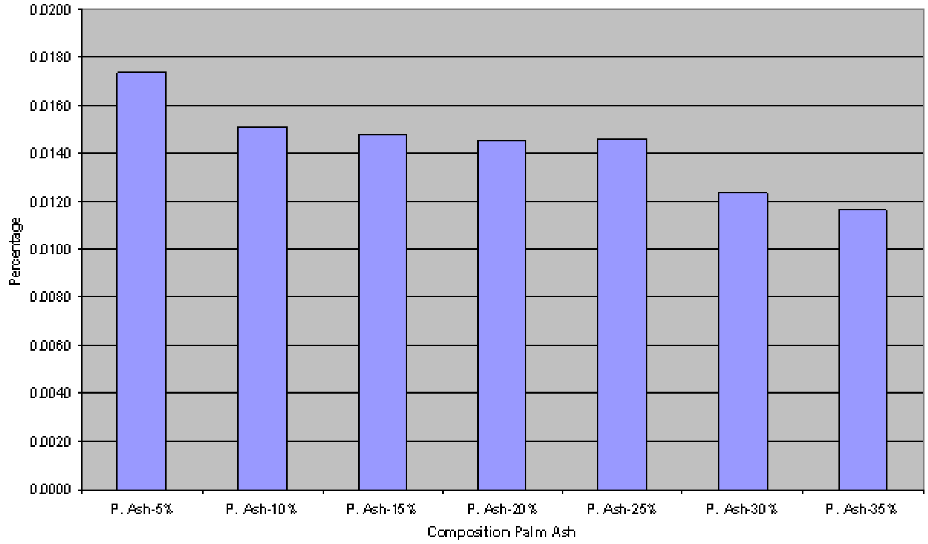


Fig. 3: Correlation of porosity with palm ash addition.

3.3 Izod Impact Test:

Fig. 4 shows the impact strength of the composites increases with increasing the palm ash content. Composite with 35wt.% of palm ash give the highest impact strength whereas PA-5% has the lowest value of impact strength.

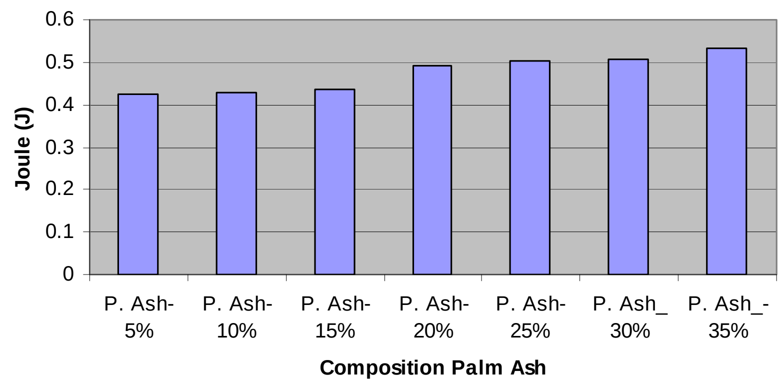


Fig. 4: Impact strength versus palm ash addition.

3.4 Compressive Test:

Fig. 5 shows the compressive strength increases with increasing the content of palm ash. The result shows, that, composite with 35wt. % of palm ash has the highest value whereas composite with 5wt.% has the lowest value of compressive strength. This can be attributed to the fact that palm ash reduced the porosity and improving the strength.

3.5 Fracture Analysis:

Microstructure analysis of fracture surface of composite samples after Izod test was done by SEM at 100X magnification. Figs. 6 (a-d) show more pores are found in the composites with 5, 10, 15 and 20wt. % of palm ash. On the other hand, composites with 25, 30 and 35wt. % of palm ash are having less pores on the fracture surface and this result is in agreement with porosity test. It is indicated that the presence of pores is controlled by the content of palm ash. The pores decreased with increasing content of palm ash.

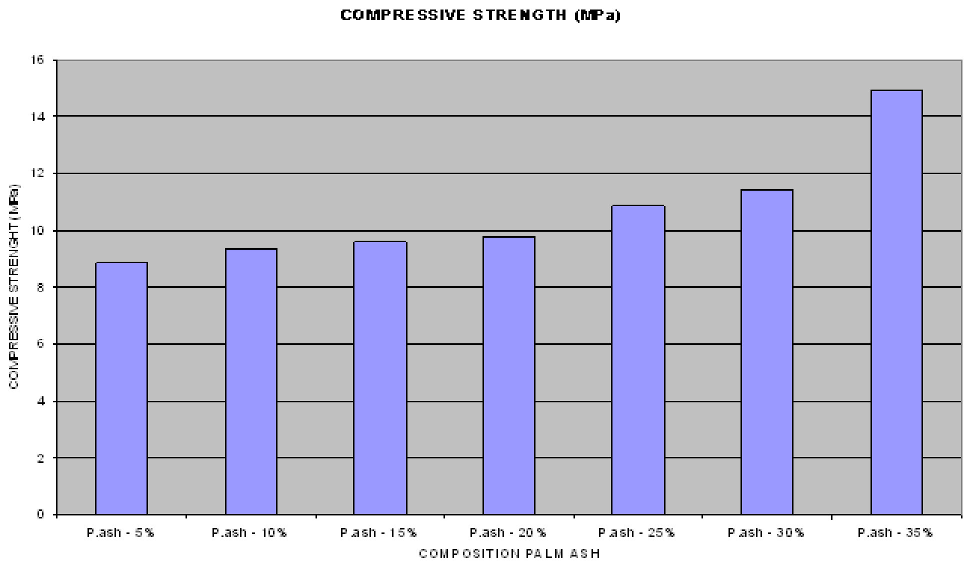
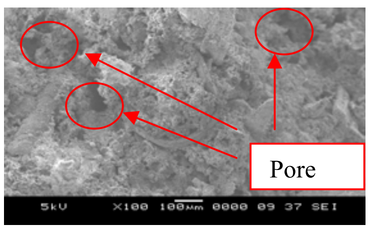
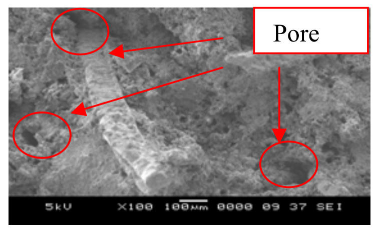
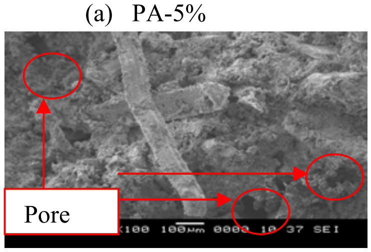


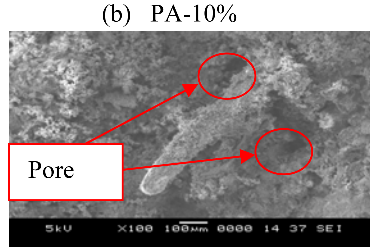
Fig. 5: Compressive strength of composites versus palm ash content.



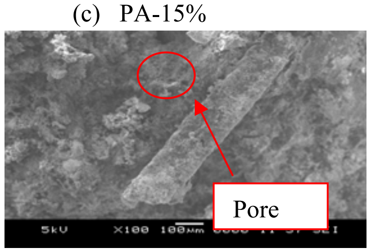


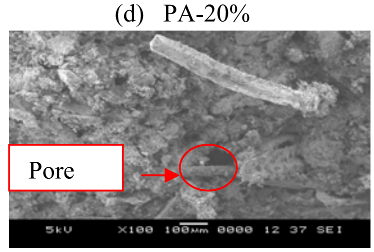
(a) PA-5% (b) PA-10%



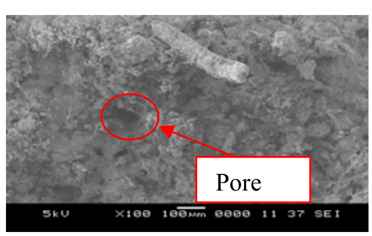


(c) PA-15% (d) PA-20%





(e) PA-25% (f) PA-30%



(g) PA-35%

Fig. 6: SEM micrograph of brake pad samples with different percentage of palm ash after Izod impact testing.

Conclusions:

In conclusions, fabrication of composite palm ash mixed phenolic is possible for making brake pad. The addition of palm ash has improved the compressive and impact strength of the composites. Composite strength was improved due the less pores in the composites.

ACKNOWLEDGEMENT

The authors thank to MOSTI for providing the Science Fund Research Grant

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