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Optimum preparation and thermal conductivity of novel glossy paint prepared from waste of palm oil fly ash composite

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ABSTRACT

The optimum preparation and the thermal conductivity of environmental-friendly glossy paint that was prepared from the waste of Palm Oil Fly Ash (POFA) were investigated. For optimum pigment preparations, the aqueous precursor of 45 % wt POFA mixed with 25% wt sulphur, 20% wt calcium and 10% wt fine graphite was sintered at 900^{o}C to produce a complete crystalline product. The sintered product was milled to become a grayish fine powder pigment. From the SEM images, the grain size was approximately 0.404 µm. The pigments were mixed with a binder, solvent and additives and grinded to become a paint and was then tested (Glossy test, hardness test, adhesion test and thermal conductivity test). From the results, the optimum compositions of a paint are 22% wt POFA pigment, 29% wt alkyd binder, 39% wt polyurethane thinner and 10% wt mix additives (cobalt 10%, lead 32% and N.C Solution). It was also discovered that the paint is a good insulator with thermal conductivity of approximately 78.95 Wm^{-2}.

Keywords: POFA; paint; pigment; insulator.

INTRODUCTION

The production of palm oil will leave a huge number of solid waste materials. The solid waste material will be reused as fuel in the combustion process in order to generate electricity or heat. An ash known as palm oil fly ash (POFA) will be produced after the combustion process. Due the limited utilization of POFA, its quantity will increase annually. This unmanageable situation of POFA will lead to environmental problems [1-3]. However, there are researchers who have been using POFA as one of the pozzolanic materials in concrete production [4, 5]. Other than that, the study that conducted by [6] in respect of the construction product has found that POFA has potential for heat resistance. Table 1 shows the compositions of POFA [7]. Therefore, this study will involve the use of POFA as a pigment in paints. Developed paint is also expected to have a function as thermal insulation without affecting existing paint durability. The early stages of this research will involve the preparation of a pigment of POFA, followed by an optimum composition for the production of paint. The paint will then be tested using a method based on the current standard [8, 9]. The last stage is the thermal tests to determine the thermal resistance of the POFA paint.

Table 1. Compositions of POFA [5].

Chemical composition	(%)
Silicon Dioxide (SiO_2)	62.12
Al_2O_3	21.30
Fe_2O_3	5.55
TiO_2	1.38
MgO	1.58
CaO	0.53
K_2O	4.24
Loss on Ignition	3.30

METHODS AND MATERIALS

The experiments were divided into two stages. The first stage was the selection of the preparation and pigment composition while the second stage was the optimization of the composition and method of preparation of the paint. The microstructure of the pigments was observed using scanning electron microscope (JOEL JSM 6390LA) to reveal the grain sizes. Paint hardness was tested using pencil hardness (Thermimport Quality Control, TQC), ASTM D3363 standards. The adhesion strength was tested using Scratch Hardness tester Wolff Wolborn Dual Weight Thermimport Quality Control, TQC), ASTM D3359 standards. Meanwhile, the viscosity of the paint was tested using ASTM standard D1200 and glossy rate was measured at 60^{o} using Glossmeter Thermimport Quality Control, TQC).

Pigment preparations

POFA, sulfur powder, calcium hydroxide and graphite fine powder were weighed with six different ratios, as shown in Table 2, and mixed with distilled water at ambient temperature for 20 to 25 minutes under stirring. Finally, the samples were sintered at 900^{o}C for 6 hours in different conditions. After the sintering process, these samples underwent ball mill and sieving process. Finally, all samples became grayish fine powder.

Table 2. Mixing ratio/conditions of the raw material in pigment.

Sample	Sintering Condition	POFA (wt%)	Sulphur Powder (wt %)	Graphite Fine Powder (wt %)	Calcium Hydroxide (wt %)
1	In air	40	20	20	20
2	Closed	40	20	20	20
3	In air	45	25	10	20
4	Closed	45	25	10	20
5	In air	40	40	10	10
6	Closed	40	40	10	10

Paint preparations

The gloss paint was produced without Extender pigment [10]. Industry practices suggest that the best mixing ratio for produce gloss paint, which is alkyd paint, include 15-25% of pigment, 25-30% of the binder alkyd, 35-40% of solvent and 5-10 % of additives [11].

Therefore, in this study, the composition ratio in Table 3 was suggested. The pigments were mixed with a binder, solvent and additives and grinded to become paint and then tested.

Table 3. Mixing ratio of paint components.

Sample	Pigment(wt%) (Table 2)	Binder(wt%) (alkyd)	Solvent(wt%) (Polyurethane)	Additives (wt%) (Cobalt 10%, lead 32% and N.C Solution).
1	22	29	39	10
2	20	30	40	10
3	18	31	41	10
4	16	32	42	10

RESULTS AND DISCUSSION

The images observed by SEM as shown in Figure 1 were used to determine the grain size. The ASTM E112 standard was applied in order to calculate the average size of the grain. The results (Table 4) indicate that the specimens sintered in closed condition have a smaller grain size. The reason for this phenomenon is due to sintering at the atmospheric condition, which allowed the oxidation that increased densification rate. From the observations, the smaller grain sizes of POFA pigment were easier to stick and dilute during the grinding process of paint making. The coarsest pigment particle will react as extender pigment that is not suitable for gloss paint [10]; therefore, sample 4 (Table 3) that consists of 45% POFA, 25% S, 10% G, 20% CH that was sintered in closed conditions with the average grain size of 0.404 μm was chosen. Vehicle (continuous phase) was prepared before the discontinuous phase. In the continuous phase, POFA pigment, alkyd binder and polyurethane solvent were grinded with 50g of ball without additive. After the Vehicle was produced, all paint components (Table 3) were re-grinded with higher speed and mixed with additives (cobalt 10%, lead 32% and N.C Solution) and discontinuous phase was achieved. According to [10], gloss of more than 85 GU, (Gloss Unit) at 60° is considered high gloss (Gloss level 7). The paint prepared with fine grains of POFA pigment that is mixed with alkyd binder contributes to the high gloss paint. Table 5 shows all paint samples that are classified as high-gloss finish paint. In this study, the mixing ratio of paint component is an important parameter for producing high quality paint. Thus, it is found that the relation between mixing ratio of paint component and value of glossy range, which is the value gloss range, increased with decrease in percentages of pigment and increase in percentages of binder and solvent.

Table 4. Average grain size for the pigment of sample 1-6.

Pigment, Sample	Average Grain Size (μm)
1	0.682
2	0.471
3	0.709
4	**0.404**
5	0.786
6	0.517

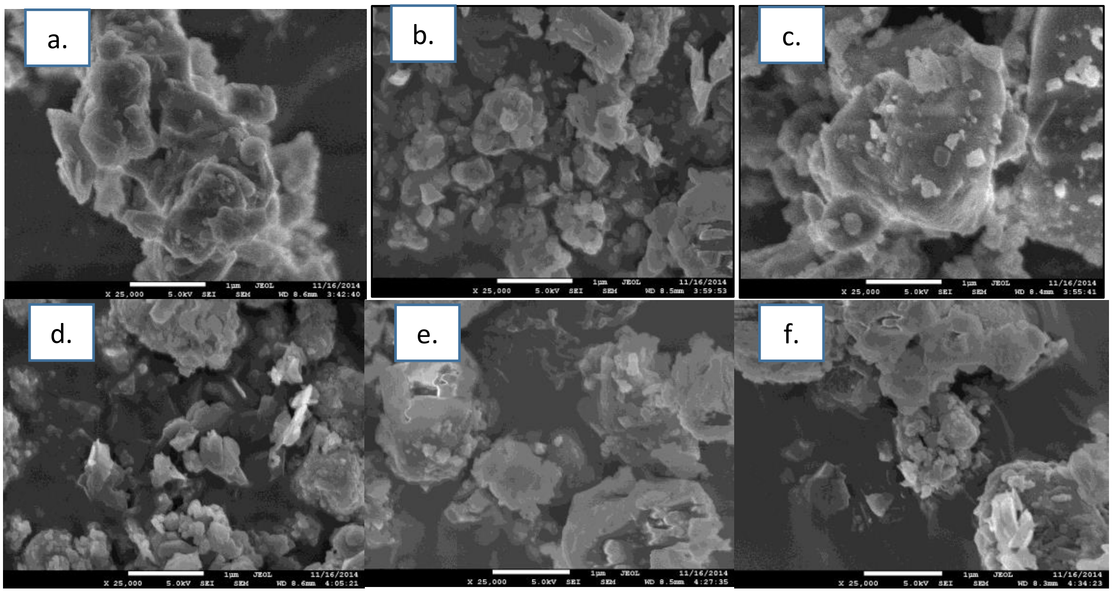


Figure 1. SEM images of pigments for - a. Sample 1 – Open, b. Sample 2 - Closed, c. Sample 3 – Open, d. Sample 4 – Closed, e. Sample 5 – Open, f. Sample 6 – Closed.

Table 5. Results of gloss rate (60°) and the hardness for paint for sample 1-4.

Paint Sample	Glossy Range (GU) - 60◦	Hardness level
1	90.5 – 85.5	2H
2	92.3 – 87.0	2H
3	93.1 – 91.9	H
4	95.2 – 92.7	H

Hardness Test

The results of the hardness level are also shown in Table 5. Sample 3 and 4 were slightly soft compared to sample 1 and 2. This is because the POFA content of pigment in the paint was characterized as high-strength component. The percentages of pigment in mixing ratio increase with the increase in hardness level. According to ASTM D3363 (Figure 2), these paints are considered hard.

$6B-5B-4B-3B-2B-B-HB-F-H-2H-3H-4H-5H-6H$

Softer   Harder

Figure 2. Scale of hardness (ASTM D3363).

Tape Adhesive Test

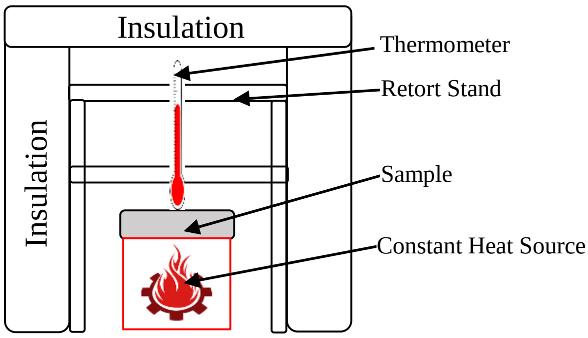
The remarkable results (Table 6) obtained for adhesiveness of sample 1 and 2, which is that none of the area was removed. Meanwhile, for sample 3 and 4, less than 5% was removed due to the effect of solid contents that increase the performance of additives (N.C Solution with lead) that contributed to the brittleness of the paints.

Table 6. Results of tape adhesive test.

Paint Sample	Percentages of Removal Area	Classification
1	**None**	**5B**
2	**None**	**5B**
3	Less than 5 %	4B
4	Less than 5 %	4B

Thermal Conductivity

For thermal conductivity, the experiment combined with established theory of heat transfer [12] was conducted. Figure 3 shows the schematic of the experimental set-up for the test. The obtained results were calculated using equation 1. During the experiment, all specimens were subjected to the same atmosphere of measurement.



$$\dot{Q} = -kA\frac{T_1 - T_2}{L} \quad (1)$$

Where $k = Thermal\ Conductivity$
$A = Cross - Sectional\ Area$
$T_1 - T_2 = Temperature\ Diffrent$
$L = Thickness$
$\dot{Q} = Rate\ of\ Heat\ Transfer$

Figure 3. Schematic of thermal conductivity experiment.

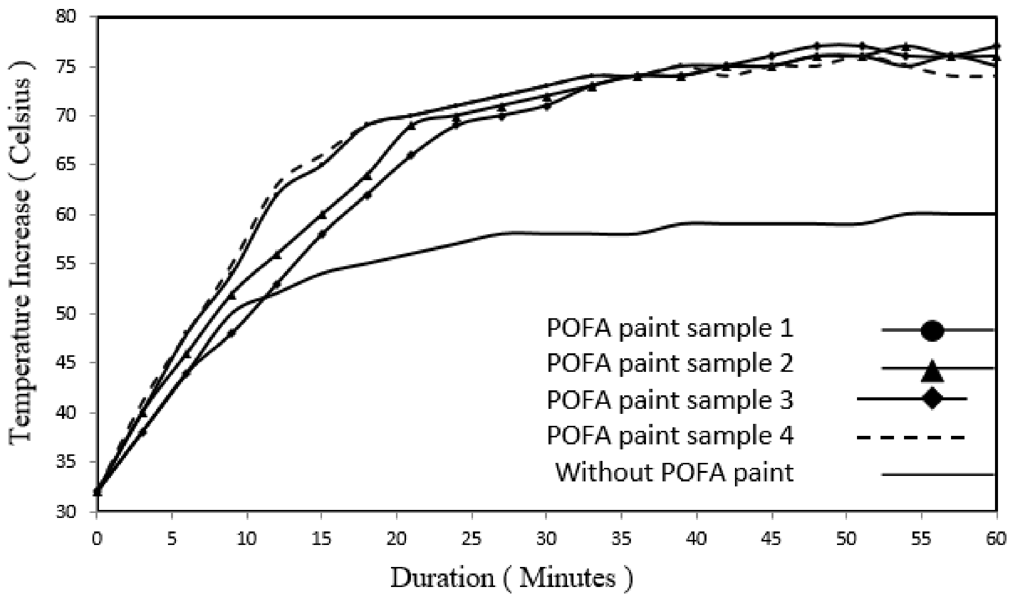


Figure 4. The temperature profile of plat with constant heat coated with POFA paint Sample 1-4 and without POFA paint.

Figure 4 shows the heat evolution for each paint sample. The approximate value of thermal conductivity of each paint sample is shown in Figure 5. Based on the calculations, Sample 1 had the lowest thermal conductivity, 78.95 W/m^2. Among all of the POFA paint samples, the highest thermal conductivity was obtained from paint sample 4 with the value of 81.97 W/m^2. Thus, the thermal conductivity varied between 78.95 W/m^2 and 81.97 W/m^2. It is found that the value of thermal conductivity decreases with the increase in the POFA pigment in the paint composition. Based on the results, it is found that the percentage weight of POFA pigment in paint is inverse proportion to the total temperature rise of paint. This characteristic is similar to the characteristic of the POFA as reported by [13]. As the percentage weight of POFA is higher, the total temperature rise of paint decreases. The results of the thermal conductivity show that the lowest thermal conductivity is obtained from paint sample 1. This is probably related to the increase of percentage weight of pigment due to the ingredient of POFA in the pigment. Additionally, [6] also reported that the thermal conductivity decreases due to the increase of pigment POFA content. The paint sample with a high percentage weight of POFA pigment offers a good way for making environmentally friendly heat insulation paint.

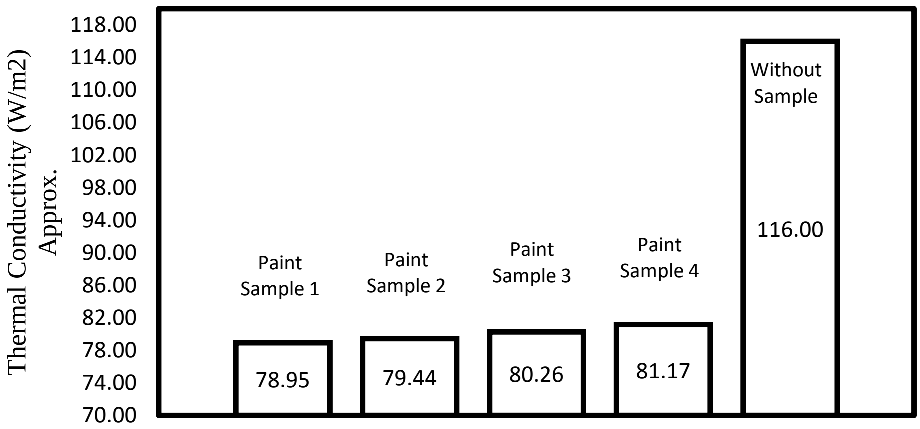


Figure 5. Approximations of Thermal conductivity (W/m^2) for POFA paint sample 1 -4 and without POFA paint.

CONCLUSIONS

This study successfully revealed the compositions and the ratios of ceramic based POFA pigment in making paint. The POFA as waste was utilized. After various tests, we found that ceramic-based POFA pigment is able to create the pigment phase (discontinue phase) with alkyd binder and polyurethane solvent. The additive was added to improve the curing capability. Finally, the high gloss black paint with good thermal insulation was produced. From the standard paint test, we found that the performance of the paint is equivalent or better than available paints in the market.

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