Preliminary evaluation of physical and chemical characterization of waste palm oil shell as cool material replaced in asphaltic concrete as fine aggregate

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Preliminary evaluation of physical and chemical characterization of waste palm oil shell as cool material replaced in asphaltic concrete as fine aggregate

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Abstract. Malaysia is one of the biggest producer of palm oil product and currently as main source of economy for the country. During the production of crude palm oil, a large amount of waste material is generated, such as palm oil fibres, palm oil shells and empty fruit bunches. Palm oil shell aggregate (POSA) is identified as a material that shows good potential to be used as a fine aggregate replacement in asphaltic concrete. On other hand, the chemical compound that exist in the Palm Oil Shell (POS) have shown a good potential as reflective component in cool-material. The purpose of this study is to obtain the physical and chemical properties of palm oil shell. The result shows the apparent particle density of Palm Oil Shell is 1.6mg/m^3. The specific gravity of palm oil shell was obtained with the value 1.6 and the water absorption amount of palm oil shell recorded from this study was 25.1%. The X-Ray Fluorescence study shows that palm oil shell contains the highest amount of SiO_2 (46.412 wt%) and the second highest amount of Fe_2O_3 (34.016 wt%), both is the main output of relectivity compound. As a conclusion, waste palm oil shell has a potential to be used as alternative material for fine aggregate replacement. Besides that, the amount of chemical element that consist in palm oil shell which high in SiO_2 and Fe_2O_3, promising the benefit to mitigate urban heat island as a cooling material agent.

1. Introduction

The air temperature in the city is found warmer than rural region is called as Urban Heat Island (UHI) phenomenon. The properties of urban substantial are encourage more into solar heat absorption from solar energy through sun instead of influencing the reflectivity and emissivity [1,2]. Thus, the UHI can become worst due to application of this material. Pavement is one of the main contributors to the UHI phenomenon. About 20 - 39 % of the land surface in the city are covered by asphalt pavement[3,4].The heat generated by the pavement from the sunlight significantly increased the surrounding temperature in the city. Pavements with more reflective surface than traditional pavements, enable evaporative cooling, or other methods that allow the paved surface to remain cooler than traditional pavements [5,6]. This is because cool materials contain high solar reflectance and infrared emittance [7,8]. From the previous study the existence of near infrared reflective compound, such as SiO_2, Al_2O_3, Fe_2O_3 and TiO_2

is the main component that contributes to the cooling effects by study the chemical element of the material [9,10].

Oil palm industry refinement in Malaysia included 4.49 million hectares of land and producing 17.73 million tonnes of palm oil [11,12]. The industry becomes bigger , the fresh fruit bunch production is 75 million tons per annum and a significant amount of palm oil waste was generated problem of biomass waste overload, the problem was disposal difficulties and escalates the operating cost [13, 14]. Palm Oil Shell (POS) was partially a waste in 90s and early 2000 considering more than 350,000 tons were available for sale [15,16]. The waste material from oil palm production is also increases year by year [17,18]. Palm Oil shell is a by-product of palm oil processing, the properties of POS show that it can find useful application in light weight construction as material filler, as aggregate replacement and as sorbent material for industrial water treatment [17,19,20]. According to [21] POS can uses as an alternative material for more robust performance of asphalt mixes, specially tailored to the Malaysian condition.

Therefore, this research paper focuses mainly on the properties of waste POS sample to evaluate and investigate the physical and chemical characterization of the POS. Based on the study, the criteria of fine aggregate and cooling agent material for POS can be determined. The POS can be applied onto pavement as a cool material to develop cool pavement technology. On other hand, the utilization of POS waste can be varies and help to overcome the environmental problem.

2. Methodology

2.1. Material preparation

The POS waste materials utilized for this research work were collected from palm oil industry company which is Syarikat Perusahaan Kelapa Sawit Yong Peng Sdn. Bhd., where located in Yong Peng, Johor. A material was collected with sufficient amount from the factory and stored in the container. The waste POS were washed to remove dirt, dust or any impurities and free from deleterious material. Furthermore, the POS waste was air-dried naturally under the sunlight for 24 hours. Then, the material was oven dried for 24 hours in a lab-scale oven at 110°C. Once the drying process was completed, the waste POS material was crushed into fine grain size. After that, the crushed palm oil shell was re-cleaning by filtering and segregate the palm oil fibre where stick with POS. Finally, the fine size wasted POS material was sieved to obtain the grading particle size from 1.18mm to 0.075mm for the purpose of fine aggregate replacement.

2.2. Physical properties of palm oil shell

2.2.1. Particle density and water absorption. All the measurement is significant to presume the performance of asphaltic concrete when the waste POS replaced with fine aggregate. The determination of particle density and water absorption for fine aggregate were conducted and calculated accordance with the procedure [22–24] standard, which used small pycnometer method.

2.2.2. Soundness of aggregate by using magnesium sulfate. Soundness of aggregate by use magnesium sulfate test was performed and calculated based on ASSHTO Part 1: T 104-99 [25] standard. The soundness test determines an aggregate's resistance to disintegration by weathering and freeze-thaw cycles. Aggregates that are durable (resistant to weathering) are less likely to degrade in the field and cause premature hot mix asphalt (HMA) pavement distress and potentially failure.

2.3. Chemical properties of palm oil shell

Chemical analyse was carried out to determine the major chemical component or minerals that are present in the experimental of palm oil shell. The chemical characteristic element of palm oil shell samples was determined by using X-Ray Fluorescence (XRF) analyser (X-Supreme Oxford Instrument). It is a non-destructive analytical technique that used the interaction of x-ray with a material to determine

accurately the elemental composition and it has become widely used tool in the laboratory because of its diverse range of application. The rhodium X-ray tube with power as low as 3kW and voltage from 40 to 60kV was equipped in the XRF analyser [26]. Furthermore, to measure the main and trace element that present in the test sample, the sample of palm oil shell were crushed into fine powder form after sieve 63µm in size approximately. The pellet or thin disk with diameter 2.7cm and thickness 4mm were performed and compressed by using 10g the fine powder of palm oil shell sample [10]. The sample was sent to Kolej Kemahiran Tinggi Mara Masjid Tanah, Melaka, for XRF analysis. Figure 1 shows the crushed POS with 1.18 mm and 0.063 mm.

Figure 1. Crushed POS.

3. Results and Discussions

3.1. Particle density and water absorption determination.

The result of particle density, water absorption and specific gravity of waste POS material obtained from the experimental works are shown in table 1.

Table 1. Particle density, water absorption and specific gravity of waste POS material.

Physical Properties	POS Test Value	Comparison with Previous Studies			
		[27]	[28]	[29]	[30]
Particle Density on oven dried basis	1.2	-	-	-	-
Particle Density on a saturated and surface dried basis (mg/m^3)	1.4	-	-	-	-
Apparent Particle Density, ρ_s (mg/m^3)	1.6	0.65	1.6	-	-
Water Absorption (%)	22.5	14	23.30	24.39	23.8
Specific Gravity	1.6	1.62	1.17	1.4	1.3

As seen in table 1, the result shows from the particle density and water absorption test of palm oil shell, from the table the value of the specific gravity of palm oil shell obtained is 1.6. Specific gravity of the palm oil shell is not in the category of common rock but its showed the same porosity as granite and limestones [27]. Other than that POS specific gravity is pass the standard of asphalt properties which the specific gravity value need to be exceed 1.0 [24]. As a result, by comparing with previous studies, the range of POS specific gravity value is 1.17 – 1.6. The apparent particle density recorded are much higher than particle density on saturated and surface dried basis and particle density on oven dried basis, which is 1.6mg/m^3, 1.4mg/m^3 and 1.2mg/m^3. From the result, the POS has a great number of pores so the density was changed due to condition applied. Besides that, based on the experimental conducted, the palm oil shell has an amount of water absorption which is 22.5%. Referring the previous study by depending on type of trees of POS obtained, it can be described the value of water absorption varies between range 14% – 25%. Thus, it shows palm oil shell absorbed more water to be compared with normal fine aggregate. This is because of POS is a high in fibre, so the presence of pores is great in that

material, hence the material absorbed more water. Meanwhile, the studies indicate pumice aggregate absorbed more than 37% of water, pumice are categories as lightweight aggregate [27, 31].

3.2. Soundness of aggregate by use magnesium sulfate

The result of the soundness value of waste POS material obtained from the experimental works is shown in figure 2.

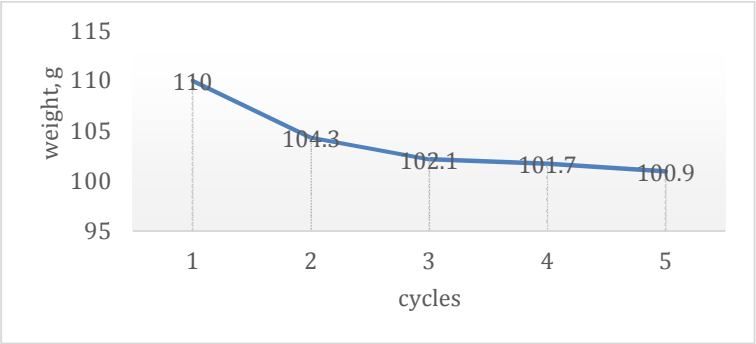

Figure 2. Soundness aggregate value (The erosion of POS).

Figure 2 shows the soundness test value of palm oil shell to analyse physical characteristic of the material. As shown, the palm oil shell was experience the erosion when the test was carried out. Initial weight of the sample before tested are 110g and after 5 cycles of immersion the POS in the magnesium sulphate, the result shows POS has loss 8.27% of the weight. Based on the specification by Public Road Department of Malaysia, the requirement of weighted average loss for fine aggregate that used in asphaltic concrete must not more than 20%, hence the POS are acceptable to be used as fine aggregate for replacement.

3.3. Chemical properties of waste palm oil shell

This section discusses the major pure element which is present in POS aggregate. The result of XRF analysis for the chemical compound for the waste POS is shown in table 2.

Table 2. Chemical composition of wasted palm oil shell.

Compound	Concentration Wt %				
	POS Concentration Value	Comparison with Previous Studies			
		[32]	[14]	[33]	[29]
MgO	0.662	6.11	4.8	3.19	3.7
Al_2O_3	7.739	11.4	11.4	2.47	5.5
SiO_2	46.412	54.81	43.6	63.72	63.4
P_2O_5	2.448	-	-	-	-
SO_3	2.276	-	2.8	0.77	0.9
Cl	0.767	-	-	-	-
K_2O	1.928	6.25	0.87	6.20	6.3
CaO	3.027	8.79	3.5	7.16	4.3
TiO_2	0.219	-	-	-	-
Cr_2O_3	0.258	-	-	-	-
Mn_2O_3	0.085	-	-	-	-
Fe_2O_3	34.016	0.36	4.7	1.39	4.2
ZnO	0.165	-	-	-	-

The result XRF analysis for major chemical composition element that present in palm oil shell is presented in table 2. As can be seen, the test result generally show silica oxide (SiO_2) was most abundant in the samples followed by iron oxide (Fe_2O_3). The composition of SiO_2 and Fe_2O_3 which present in POS material are more than 40% and 30% each element and the weight percentage are dominantly higher than other elements. Other than that, Aluminium oxide (Al_2O_3) has a possibility to contribute to NIR solar reflectance although the element compound present in palm oil shell material nearly 10 wt% of its present**.** Based on previous study, Silica Dioxide, SiO_2 acquire a high reflectivity tint where it is suitable to become material for cool pavement [34]. Appreciable amount of CaO, P_2O_5, SO_3 and K_2O were also present with traces less than 1% of each oxide is MgO, Cl, TiO_2, Cr_2O_3, Mn_2O_3 and ZnO. The value of MgO is different compared to previous studied because of the the type of palm oil trees and the presence of impurities inside POS samples. As a result, by comparing with previous studies and considered different species of palm oil trees, POS material contain high Silica dioxide with range 46wt% to 63wt%. Hence, these pure element are considered high NIR reflective agent, based on NIR reflectance value stated by previous study[9]. There are three type solar reflectance, ultraviolet (UV), visible region (VIS), and near infrared region (NIR). In addition, 50% of solar energy occurs in the VIS and 45% from NIR [6]. Thus, the higher VIS reflectivity the more effective to reduce heat penetration and surface temperature. However, it will affect human vision which cause by glare effect when the VIS reflectivity is high. Hence, higher NIR reflectivity can be considered to reduce the heat. Subsequently, palm oil shell has the potential as a reflective agent to perform solar reflectance due to the presence of high quantity of SiO_2 and Fe_2O_3. The increasing reflectance of pavement is important to reflect the solar radiation onto pavement to mitigate UHI, thus the surface temperature will reduce. The reflectivity characteristic in POS when used in pavement can be a combating technology of this problem.

4. Conclusion

This study has been carried out to evaluate the physical and chemical properties of waste palm oil shell. Palm oil shell as partial replacement of fine aggregate in asphaltic concrete has been used because of its possibility to reduce surface temperature of pavement. Finding show that palm oil shell specific gravity value exceeds the value of asphalt properties. The palm oil shell absorbed more water than normal aggregate which is the 22.5%. Moreover, the result also shows the amount of major chemical element existed in palm oil shell. The present of SiO_2 element in a palm oil shell waste material encourages the high amount of solar reflectance of NIR part in the solar spectrum. Other element including SiO_2, Fe_2O_3, Al_2O_3 and T_iO_2 are also possible for NIR reflectance contribution. In addition, based on finding, palm oil shell waste as fine aggregate in general have the potential as UHI mitigation when replaced with fine aggregate in asphaltic concrete.

5. References

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