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The development of paving block composite using high-density polyethylene plastic waste and palm kernel shell ash

C Nurhayati*, W Marthalia, N Susilawati and T Susanto

Palembang Institute for Industrial Research and Standardization, Ministry of Industry, Indonesia Perindustrian II street, 12 KM 9 Palembang, 30152, Indonesia

Email: chasrinurhayati@yahoo.com

Abstract. Palm kernel ash (PSA) waste by boiler heating in crumb rubber industry contents high silica, so it will influence the compressive strength of paving block. In addition to palm kernel ash waste, high density polyethylene (HDPE) plastic waste from human activities is very high so that it will affect environmental damage. The influence of various mixture composition of PSA and HDPE, by products from boiler heating in crumb rubber industry, on physical and mechanical properties of paving block have been studied. The Experimental model used variety of HDPE waste plastic concentration and palm shells ash waste that consisted of A0(100 : 0), A1(97,5 : 2,5), A2(95 : 5), A3(92,5 : 7,5), A4(90:10), and A5(87,5 : 12,5)%. Palm kernel ash and HDPE waste plastic were mixed and pressed at 180^oC, 200 kg.cm^2 use metal molding about 10x20x6 cm dimension. Plastic paving block result tested for physical, thickness, compressive strength, water absorption, and microscopic morphology using SEM. The result shows that palm kernel ash waste significantly influenced the compressive strength, water absorption, and microscopic morphology but no significant effect to physical property and thickness.

1. Introduction

Palm kernel ash can be used as a construction material, it is produced from palm shells that burned as boiler fuel in a crumb rubber factory. Generally, after the burning process, about 5% of palm kernel ash (based on the weight of solid waste) produced and palm shells contain ash 1,53%, Nitrogen (as N) 0,41% [1,2,3].

In general, palm kernel ash waste has varied in color, depending on the operating system in the factory. The utilization of palm kernel ash waste is not yet optimal, the amount is increasing and most of it is disposed of as waste, so it effects environmental problems. Research has been conducted to feasibility test of using ash as a substitute for cement [4]. In this study, palm kernel ash was obtained from burning palm shells. It was obtained from PT. Hevea MK. I Palembang, South Sumatra, it was sieved using a 150 mesh filter to separate the larger ash particles. Palm kernel ash contains Silicon dioxide (SiO_2) 43.60%, Aluminum oxide (Al_20_3) 11.40%, Ferric oxide (Fe_2O_3) 4.70%, Calcium oxide (CaO) 8.40%, Magnesium oxide (MgO) 4.80%, and Sulfur trioxide (SO_3) 2.80% [5].

Besides palm kernel ash, HDPE plastic waste is a potential waste that can pollute the environment. Human activities always produce waste, so dispose of it in a certain way so that waste management does not become a new problem. The use of plastic and composite materials is increasing, resulting in low costs and ease of use in manufacture. Therefore, the amount of accumulated plastic waste is high and it has potency as a big challenge to utilize the waste [6,7].

Disposal of plastic waste in the environment consider as a big problem because biodegradability is very low and its presence is in a large quantities [8,9]. The biggest components of plastic waste are polypropylene, polyethylene terephthalate, and polystyrene [8]. Types of HDPE plastic waste consist of milk bottles, shampoo bottles, detergent bottles, jerry cans of oil, and toys [10].

The chemical composition of HDPE such as (-CH2-CH2-) about 97%, carbon black about 2.25% and additive about 0.75%. (Source: Material Safety Data Sheet Polyethylene). HDPE can be recycled and it is good for products that require high flexibility but it must solid. The physical properties of HDPE such as Specific gravity about 0.941 - 0.965, Cristallinity (%) about 80-95, Melting temperature (^{o}C) about 127-135, Tensile strength (MPa) about 17.9-33.1, Tensile modulus (MPa) about 413-1034, Elongation at break (%) about 20-130, Impact strength (ft-lb/in) about 0.8-14 and Heat deflection temperature (C at 66 psi) about 60-88. HDPE is produced by free radical polymerization. HDPE is usually used for food and soft bottles such as honey, mustard, trash bags, agriculture and building construction. One of HDPE utilization waste is paving block material. Today, many consumers are interested in paving block rather than using other sidewalks such as concrete or asphalt because it is environmentally friendly materials, it helps with groundwater, it has a faster and easier installation and maintenance, and it has various forms and low budget [11].

Similar research on the utilization of waste plastics in production of paver blocks has been conducted[12]. The process of paving block using 1.14 kg cement, 1.60 kg of dust/ mine dust, 2.08 kg of coarse/gravel aggregate, and 600 g of plastic waste, with melting process, the averages of compressive strengh is about 16.05 N / mm2. Another research about investigation of the Strength Properties of palm kernel shell ash concrete observed the mechanical properties of various percentages of cement, gravel oil palm kernel ash, shell aggregates and water, with 0% ash addition, 10 and 30% of palm kernel ash, and 0.5 water: cement ratio. The results of the product of compressive strength in 28 days for the addition of 10% ash from palm kernel ash (PSA) about 22.8 N/mm2 [3] .

In this research, HDPE plastic waste and palm kernel ash were melted in the reactor furnace, then pressed with hydraulic press to produce paving blocks. This research would contribute to road and pavement contruction. The result would contribute towards the solution for a safe disposal of waste plastic. The use of palm shell plastic waste intended to reduce environmental problems because of excessive waste plastic, production cost, and increase the quality of pavements.

2. Experimental method

Palm kernel shell ash (PSA) used in the study obtained from the boiler burning of a crumb rubber factory PT. Hevea MK 1 Palembang, South Sumatra. Other materials that used such as HDPE plastic, obtained from waste water disposal and water. The plastic waste was selected only for HDPE plastic, then it was washed with water to remove dirt, then it was dried. Furthermore, palm kernel shell ash waste was burned using a temperature of 180^{o}C, then sieved using a size of 150 mesh. Then HDPE plastic and palm kernel ash mixed following the research composition, then put the mixed into an injection machine with compressive strength in rate about 200 kg.cm^2 [13,14].

As a filter, a mixture of HDPE plastic waste and palm kernel shell ash (PSA) was prepared about 2000 g of total weight using reactor furnace and temperature at 180^{o}C for 15 minutes. After mixing, a hydraulis press was used about 210 kg.cm2 of compressive value and metal molding (length x width x thickness) about 10 x 20 x 6 cm for pressing at 5 minutes. Before testing, the mixture soaked in the water for 8 minutes. The research composition of HDPE and PSA was designed by varying the percentage weight/weight of (HDPE:PSA) such as A0(100: 0); A1(97.5: 2.5); A2(95: 5); A3 (92.5: 7.5); A4(90:10); and A5(87.5: 12.5)%. In addition, observations were made for the physical properties of the mixture such as visible properties, compressive strength, water absorption, and product thickness. A magnifying glass was used to observe the physical appearance on the surface of the composites, while a digital calliper was used to measure the

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thickness. Based on ASTM C 936, compressive strength was tested and utilizing ASTM D570-95 for the water absorption test. Those properties were conducted in three repetitions to obtain high accuracy data.

3.Results and discussion

3.1 Physical appearance

Physical appearance of paving blocks shown in table 1, physical appearance of the apparent nature of paving blocks for floors/roads was observed with a perfect shape criteria, no cracks and defects, part of the corners were not easily broken with the strength of the fingers.

Table 1. Physical-surface appearance of composites of HDPE/PSA.

HDPE/PSA (w/w) %	RESULTS
100/0	No cracks, smooth surface
97.5/2.5	No cracks, smooth surface
95/5	No cracks, smooth surface
92.5/7.5	No cracks, smooth surface
90/10	No cracks, smooth surface
87.5/12.5	No cracks, smooth surface

This situation was due to HDPE that had high elasticity so that the products produced with some addition of palm kernel shell ash had a good physical shape. The observation was made at the age of 0 days so that it had not been degraded by the presence of bacteria/ microorganisms and air/ozone attacks during the degradation process [15,16]. This condition was supported by the results of the research, if the plastic paving block was oxidized on the surface causing cracks and brittle due to the lack of antioxidants in the composite [17,18]. Physical-surface appearance paving block is in figure 1.

Figure 1. Physical-surface appearance paving block.

3.2 Water absorption

Testing of water absorption in specimens was done by the soaking process at room temperature for ±24 hours, removing and drying the remaining water for ±1 minute. Then, the surface of the product dried with a cloth in order to reduce the remaining water. Then, paving block weighing, drying in oven at 105^{o}C, cooling at room temperature.

Figure 2 illustrates that the greater percentage in addition of palm kernel shell ash, the higher the value of water absorption, the lowest average water absorption test results shown in treatment A0/100/0 (0.13%) and the highest average shown in treatment A5/87.5/12,5 (2,82%). Palm kernel shell ash (PSA) contained silica, the result of testing SiO_2 contained about 34.7%. It would increase the porosity and absorptive capacity [16], supported by another research that HDPE plastic had a small absorption (0.1%), the results of water absorption in plastic paving blocks were lower than cement paving blocks [19,16]. The increasing of water absorption with the addition of PSA suspected that the silica and hydroxyl groups of PSA allow water absorption through hydrogen bonds. The density of the test specimens greatly affected the water absorption value. The density of water absorption is inversely proportional [20]. The lower the density, the water absorption would be greater, and the higher the density of paving blocks, the bond between particles was more dense, so that the water cavity in the paving block decreased, and water was difficult to fill the cavity.

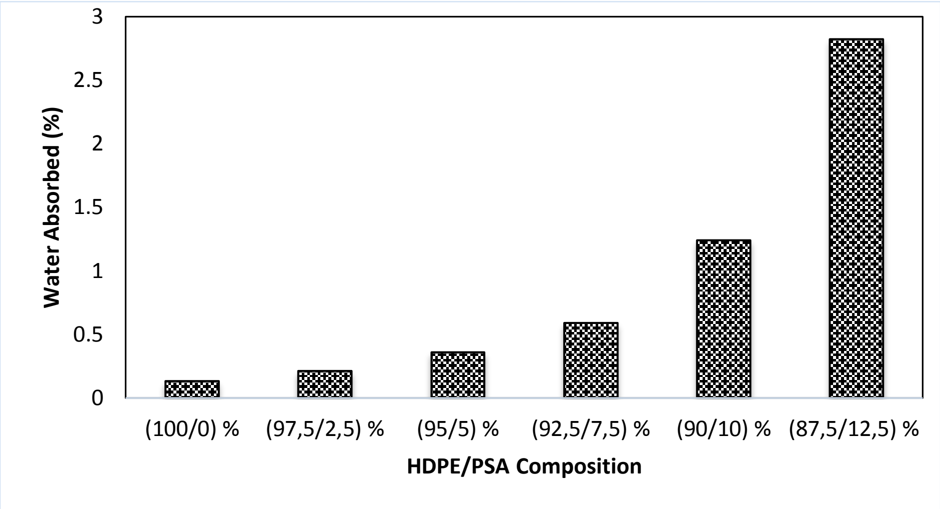

Figure 2. Water absorption of paving block with HDPE/PSA composites.

3.3 Compressive strength

The composite of paving block was made by mixing the HDPE and palm kernel shell ash, with melting in an injector with a temperature of around 180^{o}C, so that it would produce high compressive strength of the product, and the addition of palm kernel shell ash would reduce the compressive strength of the resulting product. The highest average compressive strength was in treatment A0/100/0 (127kg/cm^2) and the lowest average strength was in treatment A5/12.5 (75kg/cm^2).

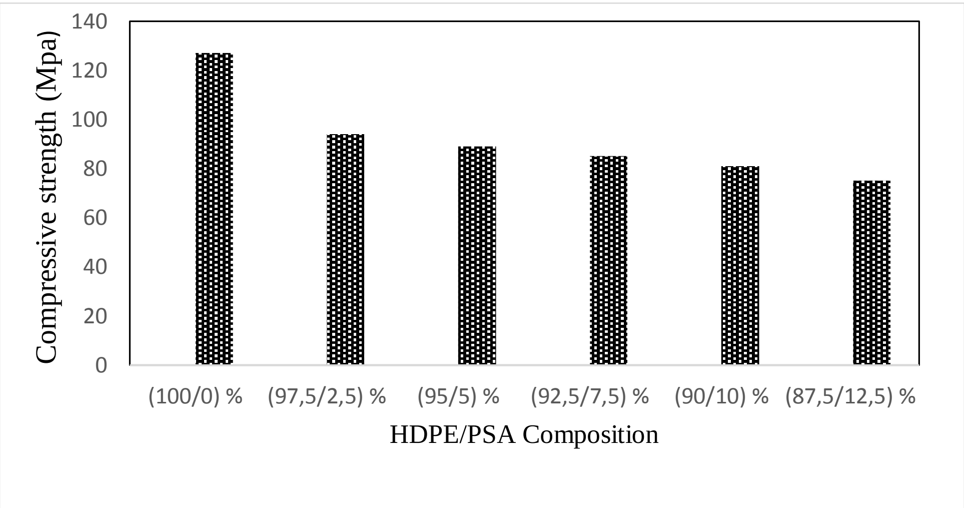

Figure 3. Compressive Strength of Paving block with HDPE/PSA composite.

Figure 3 illustrates the addition of palm kernel shell ash as a filler will reduce the compressive strength of paving blocks [13]. HDPE raw material from plastic bottle waste including

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polyethylene terephthalate (PET) group, is a polyester resin that is durable, strong, lightweight and easily formed when hot. The thickness is around 1.35-1.38 gram/ cc, makes its shape sturdy [14], then the addition of palm kernel shell ash will reduce the compressive strength.

The use of Palm Kernell Sell reduce the compressive strength and the use of palm kernel shell ash as a filler is not only intended to minimize environmental problems caused by excessive plastic waste but also to reduce the cost of producing composite plastics [16]. These silica contents will increase the compressive strength if a raw material used is a plastic powder without melting, cement and sand, because HDPE aggregate plastic has a low density of 0.945-0.962 (g/cc) [21].

3.4 Thickness

Figure 4 illustrates that product differences did not change significantly between combinations. The paving block product was replaced with a metal mold (length x width x thickness) about 10x20x6cm, hexagonal shape (hexagonal type with additional hexagonal engraving in the middle) and pressed with a 200 kg.cm^2 hydraulic press about 5 minutes. Then the product was soaked in water for 8 minutes before testing.

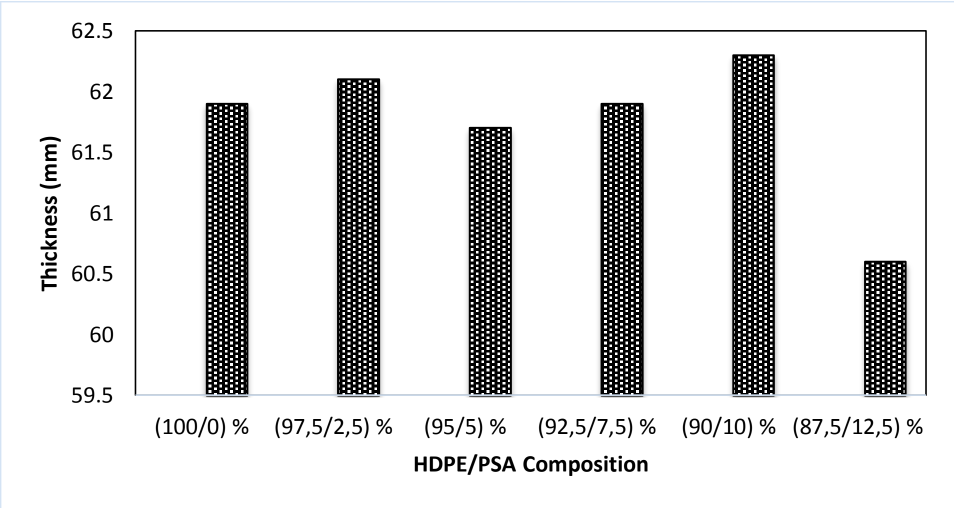

Figure 4. The thickness of paving block with HDPE/PSA composite.

There was no difference in thickness between the printed paving blocks and the metal mold (length x width x thickness) around 10x20x6 cm so it would have an insignificant thickness.

3.5 Major element testing based on SEM test

The results of carbon element testing and oxygen Scanning Electron Microscope (SEM) in table 2.

Table 2. Results test of major elements based on SEM test.

Major element	Treatment					
	100/0	97.5/2.5	95/5	92.5/7.5	90/10	87.5/12.5
Mass C (%)	67.26	59.74	52.55	37.64	37.55	35.64
Mass O (%)	1.22	9.11	17.56	24.55	24.65	24.55

The highest carbon element test results obtained at treatment A0/100/0 of 67.26% while the lowest test results at treatment of A5/87.5/12.5 amounted to 35.64%. These results indicated that the higher percentage of HDPE, the higher the element C while the addition of palm kernel shell ash would reduce the carbon content in paving block products. The element carbon was a non-metallic element with 4 valence, there were 4 electrons which could be used to form covalent bonds, not with the appearance of clear (diamond) and black (graphite). The addition of elements

C in the increasing amount of HDPE plastic was due to the chemical reaction of HDPE with content of palm kernel shell ash consisting of silicates (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) and small elements in the form of carbon, calcium, magnesium, and moderate sulfur palm shell containing 1.53% ash, nitrogen (as N) 0.41% [1].

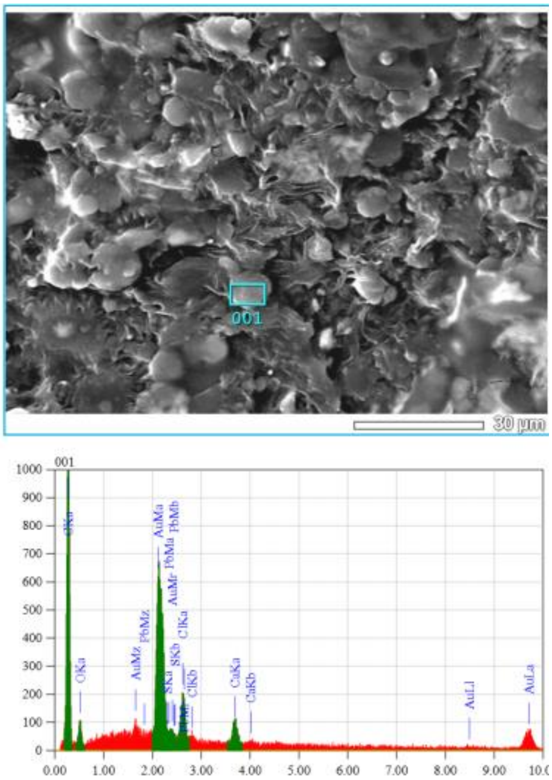

Figure 4. SEM EDX Results, paving block sample A1/97.5/2.5, Magnification 250X, position 1 (coating). Observe the element composition in the composite sampel A1 that contains Carbon (C) 37.34%, Oxygen (O) 5.99%, Sulfur (S) 1.303% , Clorida (Cl) 4.62%, Calsium (Ca) 3.08%, Aurum (A) 43.29% and Plumbum (Pb) 4.38%.

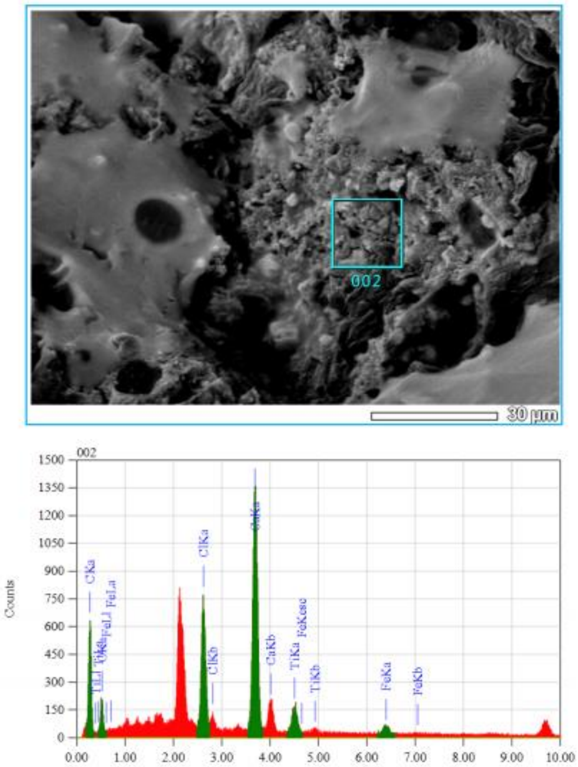

Figure 5. SEM EDX Results, paving block sample A4/ 90/10, magnification 250X, position 2 (no coating). Observe the element composition in the composite sampel A4 that contains Carbon (C) 16.63%, Oxigen (O) 11.36%, Clorida (Cl) 16.03%, Calsium (Ca) 46.11%, Titanium (Ti) 5.89% and Ferrum (Fe) 3.96%.

The lowest oxygen element (O) results in test obtained at A0/100/0 treatment of 1.22%, increased in line with the addition of palm kernel shell ash. These results indicated that the higher percentage of HDPE, the lower the element O while the addition of palm kernel shell ash would increase the oxygen content of the paving block products. Element O was easy to react with almost other elements. The increasing element of oxygen in each addition of palm kernel ash was caused by water from palm kernel shell ash (20.70%) that would be trapped when HDPE plastic melting so that it became an oxygen element in the product. The presence of this oxygen element caused a high porosity and a decrease in compressive strength of the product [1,13]. The decrease in oxygen test results in treatment A5 /87.5/12.5 was likely due to a less homogeneous stirring, thereby increasing the oxygen content to 24.55%. The result from A1 and A4 is in figure 4 and 5.

SEM testing demonstrated the increase of oxygen levels and the reduction of carbon levels in the product. The compressive strength of paving blocks tended to decrease with higher PSA addition but still within the range of paving quality requirements, and the use of palm kernel ash a filler was not only intended to minimize environmental problems caused by excessive plastic waste but also to reduce production costs. On the contrary, The HDPE/PSA composite water absorption capacity increased slightly due to the addition of palm kernel ash.

4. Conclusion

Recycled plastic composites consisting of HDPE using palm kernel shell ash have been successfully carried out. The addition of palm kernel shell ash to paving block products is physically insignificant, but by recycled plastic composites consisting of HDPE using palm kernel ash have been successfully carried out, but by SEM testing will increase oxygen levels and reduce carbon levels in the product. The compressive strength of paving blocks tended to decrease with higher PSA addition but still within the range of quality requirements of paving block, and the use of palm kernel shell ash as a filler was not only intended to minimize environmental problems caused by excessive plastic waste but also to reduce production costs. On the contrary, the HDPE/PSA composite water absorption capacity increased slightly due to the addition of palm kernel shell ash.

Further research is recommended to study the modifier/plasticizer and coupling agent, anti-oxidants to increase the dispersion of recycled HDPE and PSA fillers to determine the nature of biology degradation and thermal aging.

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