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Article

Preparation of heat-adsorbing materials from coconut shell-tar

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Abstract

Asphalt can be used as a good and safe heat-adsorbing material (HAM), however the asphalt consumption for road reconstruction process is increasing nowadays. Therefore, synthesis of HAM from bio-asphalt is needed. In this study, tar that obtained from the pyrolysis of coconut shell was used as bio-asphalt. It has physical and chemical properties similar to the asphalt. Heat-adsorbing material was composed from the mixing of powder coconut shell (PCS), coconut shell charcoal powder (CSCP), bio-asphalt and latex compound. The composition of CSCP and PCS used in this study were 30 : 0, 25 : 5, 20 : 10, 15:15, 10: 20, 5: 25 and 0: 30 % with coconut shell tar 55%, and latex 15% of the total mass, respectively. Characterizations of HAM including thermal conductivity test, penetration and surface morphology using *Scanning Electron Microscopy* (SEM) were investigated. The results showed that HAM with 0 : 30 composition of CSCP : PCS has the best heat-adsorbing properties. Its thermal conductivity numbers were from 0.045 to 0.0997 W/mK. Its thermal resistance up to 115 ° C, penetration value of 57.6 pen and density of 1.0534 g/cm^3.

Keywords : *coconut shell charcoal powder, coconut shell powder, coconut shell tar, heat-adsorbing, thermal conductivity*

Introduction

Indonesia is a tropical country that has warm or slightly hot weathered. Hot weather caused a person feel uncomfortable being in the room. Thus air conditioner is commonly used to overcome this situation. However, this utilization can break the ozone because it contains freon as refrigerant which has negative effect on the environment. The alternative solutions to maintain temperature in the building is by installing a heat-adsorbing material (insulator) in the walls or roof.

Asphalts have been reported having the ability as a heat-adsorbing materials. Generally, asphalt is used in the form of tiles, paving or roof tile. Research in producing polymer tile-based asphalt has been conducted (Milawarni, 2012; Suryati, 2012). However, the use of asphalt for road reconstruction process is intensive resulting low availability of asphalt. Therefore, it is necessary to do research on the manufacture of heat-adsorbing material (HAM) made from bio-asphalt.

Tar from coconut shell pyrolysis process can be referred as bio-asphalt because its major constituent is bitumen which has same component with asphalt (Nuryanto, 2008). Tar also has physical properties similar to asphalt, which has black or dark brown liquid due to the main constituent is carbon, pungent, adhesive and thermoplastic material (in liquid form when heated and in pasta form at room temperature) (Kamulyan, 2008).

Tar which is used as HAM should be improved by the addition of filler in order to increase the hardness so fulfill the criteria of a good HAM. Filler that used to increase hardness tar such as coconut shell charcoal powder (CSCP) (Mashuri and Manicar, 2006) or latex (Karacasua and Okur, 2006). Criteria of good HAM are has low value of thermal conductivity, high thermal resistance and compressive strength, low water absorption and density, non-flammable and environmentally friendly (Suwardiyono and Awwaludin, 2011).

The low value of thermal conductivity and low density can be achieved by adding a fibrous or porous material in the manufacture of HAM. A high porosity or fibrous materials are able to absorb the heat and reduce the rate of heat transfer by conduction. Porous or fibrous materials were used for heat-absorbing such as rice husk ash (Sunendar, Handoko and Subari, 2008), rice husks (Mulyadi, Adril and Apriono, 2010), pineapple leaves (Tangjuank, 2011), fiber papyrus (Tangjuank and Kumfu, 2011), and the durians skin fibers (Jintakososl and Kumfu, 2012). Furthermore, fibrous or porous materials attached with an elastomeric materials, such as natural rubber (latex) or synthetic rubber that can improve the performance of insulation (Ford et al., 2009).

Coconut shell is a fibrous material containing lignocellulose that has been widely used as reinforcement in the manufacture of composite particles. In this study, coconut shell powder (PCS) is used in the manufacture of HAM together with tar, CSCP and latex compound. The function of each ingredient is PCS as a porous material and reinforcement particles, CSCP as adsorbent and reinforcing particles, latex compound as elastomeric, and tar (bio-asphalt) as an adhesive for the three other components. The advantages of HAM that made from natural materials are renewable, biodegradable and environmentally friendly (Lee and Choi, 2007).

Materials and Methods

Preparation and Characterization HAM

The materials used for the preparation of heat-adsorbing materials are weighed according to variations of percent composition, ratio of CSCP 200 mesh and PCS 100 mesh are (30:00, 25:05, 20:10, 15:15, 10: 20, 05:25, and 00:30) %, tar 55%, and 15% of the latex compound total mass. That samples coded PP-3000, PP 2505, PP-2010, PP-1515, PP-1020, PP-0525, and PP-0030. Each material (except latex compound) was heated at 110 °C for 30 minutes before it's mixed by stirring, after that the mixture was pressed into mold. For thermal conductivity test, the dimension of the mold is 4 cm in diameter and two various thicknesses that are 4 mm and 6 mm. For penetration test (hardness) sample was pressed or poured into the penetration cup. Finally samples were stored at room temperature until the sample dried and hard. For density test performed by using Archimedes method.

Results and Discussion

Characterization of Heat-Adsorbing Materials

1. *Penetration tests*

Penetration test (hardness) of HAM based on RSNI 06-2456-1991. The results in Fig. 1 shows that the hardness increase as increasing PCS and decreasing CSCP in the sample, evidenced by the lower penetration value.

The hardness of HAM caused by high content of lignocellulose in PCS. Lignin is poly-aromatics compound that amorphous shaped, so it has many π bond in the double bonds. The molecule becomes more rigid when it has many phi bonds. Sp^2 hybridization at some atoms that have double bond can make a flat triangular molecular shape then the molecules can be rigid and tight. Therefore, increasing PCS in the sample can increase the hardness too. Beside lignin, PCS also contains cellulose and hemicelluloses that can make HAM become elastic. Oxygen atoms in -OH group can form single bond with other atoms. Atom that form single bond or sigma bond (σ) can spin (rotation) then the overall shape of a molecule always change sustainably (Ford et al., 2009). Thus, the addition of PCS will make HAM becomes hard and elastic.

Addition CSCP into the sample cannot generate a harder HAM than the addition of PCS because CSCP is an adsorbent. If the amount of adsorbent (CSCP) is not proportional with the amount of adsorbate (tar) so the increase of hardness will not become maximum.

2. *The density test*

The density test performed by using Archimedes method as shown in Figure.2. The density of samples decreases with increasing percentage of PCS and decreasing percentage of CSCP in composition of HAM. Density influences the weight of the HAM, the lower density value the sample getting lighter. There is no specific connection between lighter and SEM or hardness test result with the density test.

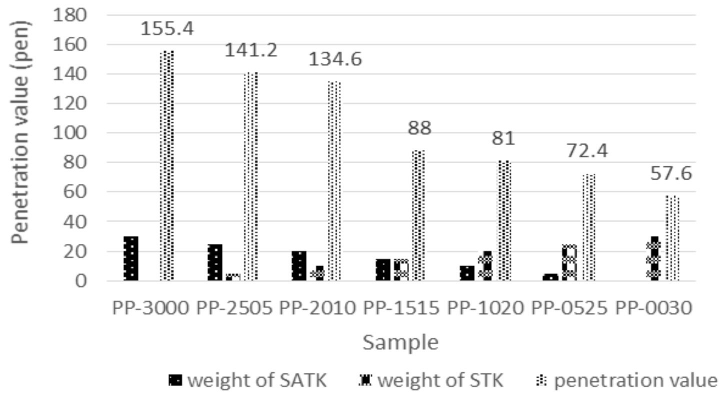

Figure 1. Penetration test of the hat-adsorbing materials

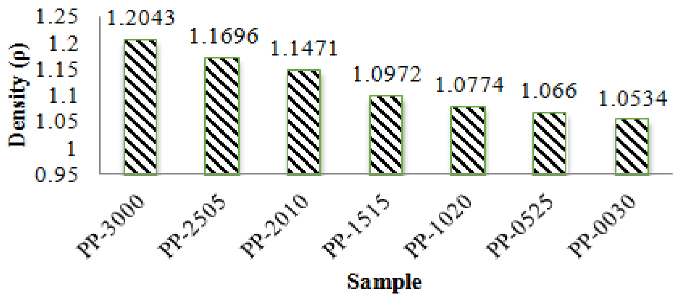

Figure 2. Penetration test of the hat-adsorbing materials

3. *The thermal conductivity test*

The purpose of thermal conductivity test is to determine a material's ability to conduct heat (thermal). Decreasing of thermal conductivity number (k) in material means the thermal energy will be more difficult to passed the materials, and otherwise. Testing on each sample was carried out at temperature 40, 60 and 80°C. Generally, the temperature has a linear connection with thermal conductivity. Table 1 shows that increasing PCS and decreasing CSCP in HAM will give smaller thermal conductivity number. Good insulating ability generated by PP 1515, PP-1020, PP-0525 and PP-0030.

The thermal absorption ability on sample is influenced by the PCS quantity in the mixture. PCS is filler that has lignocelluloses as the major component.

Table 1. The thermal conductivity test

Sample	Thermal conductivity value (W/mK)		
	40 °C	60 °C	80 °C
PP -3000	0.0668	0.0518	0.1162
PP -2505	0.0638	0.0247	0.0995
PP -2010	0.0917	0.1635	0.0185
PP -1515	0.0828	0.154	0.2024
PP -1020	0.0740	0.1374	0.1550
PP -0525	0.0658	0.0899	0.1318
PP -0030	0.0450	0.0520	0.0997

The amorphous structures of lignin and hemicelluloses along with many -OH groups contained in lignocelluloses caused PCS able to absorb the heat treatment. Tetrahedral molecule that formed by the bond between carbon atoms with oxygen atoms in the -OH groups can form three-dimensional structure that allows air entering it so the heat absorption can occur.

Addition CSCP in the sample caused the sample tighter because CSCP is absorbent which can absorb tar or latex compound to the pores. However, addition CSCP in the sample caused decreasing heat absorption because CSCP that absorbed into the tar or latex compound pores will close the pores.

Besides the heat isolation ability, the thermal resistance ability on the sample is also need to be considered. Thermal resistance of HAM is influenced by the presence of inter-molecular bond that is formed from the addition of PCS and CSCP. PCS composed of lignin, cellulose and hemicelluloses which have many -OH groups that have high potential to form intra molecular and intermolecular hydrogen bonds. In addition, many phi bond and intra molecular or intermolecular Van der Waals forces can be formed between PCS and tar or latex compound. However, addition CSCP on samples only donated intra molecular or intermolecular Van der Waals forces between CSCP and tar or latex compound. Based on the comparison of the binding energy between atoms, hydrogen bond has a binding energy of about 5-10 kcal/mol, while the Van der Waals forces have less than 5 kcal/mol bond energy (Ford et al., 2009). Thus, the thermal resistance of HAM will increase along with the increasing hydrogen bonds formed in PCS.

Based on the results of thermal conductivity test, the lowest thermal conductivity value obtained from PP-0030. Therefore, thermal conductivity measurement should do at higher temperatures to determine the thermal resistance. The results can be seen in Fig. 3 that show PP-0030 has a thermal resistance up to 115 °C. At temperatures of 40-115 °C, PP-0030 has thermal conductivity numbers of 0.0552-0.1544 W/mK. The PP-0030's thermal conductivity is lower than asphalt which has thermal conductivity of 0.5 W/mK. Thus, this sample is potential to be alternative material to substitute asphalt as heat absorber.

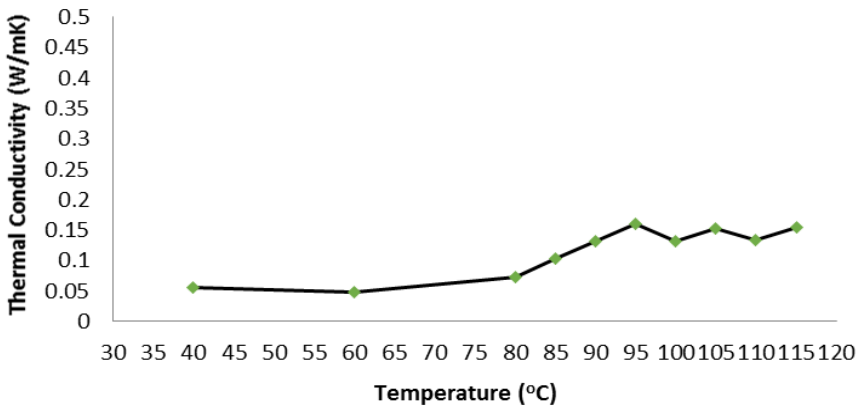

Figure 3. The thermal stability test of PP-0030

4. *The surface morphology test*

CSCP can absorb tar or latex compound into their pores (Fessenden and Fessenden, 1982), so the more addition CSCP on HAM, the sample's surface morphology is smoother and spread evenly. Eventhough, PCS is not an absorbent so the interactions between PCS with other components such as tar, CSCP and latex compound are surface interactions. Increasing the percentage of PCS in the sample caused more PCS particles attached to tar surface, then the sample's surface morphology rougher. In other words increasing PCS and decreasing CSCP into the mixture of HAM will lower the compatibility of material. Fig. 4 shows that the sequence of the samples surface morphology ruggedness are PP-0030 > PP-0525 > PP-1020.

The presence of pores between PCS particles that wrapped by tar and latex compound can be shown at Fig. 4c. The pore is formed because PCS patch on the tar surface. This pore is not visible on the PP-1020 that has 10% of CSCP and start to seem at PP-0525 which has pore less than PP-0030. This happen because PP-0525 also contains of 5% CSCP which allows CSCP to adsorb tar.

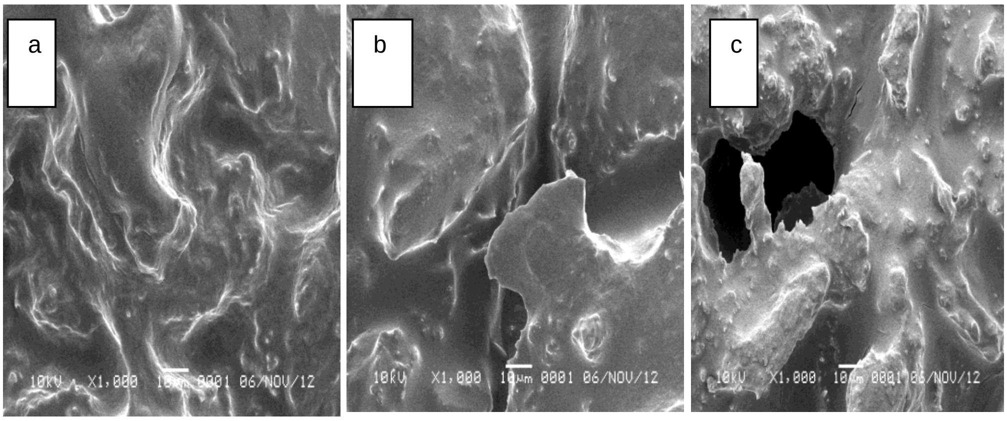

Figure 4. Morphology of the heat-insulator materials: a. PP-1020 b. PP-0525 c. PP-0030

Conclusion

Sample with high PCS is potential to become as alternative material to substitute asphalt as heat absorber. PCS is fibrous material that can increase the hardness of HAM based on coconut shell-tar.

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