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Fabrication of Porous Carbon Composite Material from Leaves Waste as Lightweight Expanded Carbon Aggregate (LECA)

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Abstract. Leaves waste has been used as Lightweight Expanded Carbon Aggregates (LECA) because of its high carbon material. LECA can be used as a water storage media. LECA is low in density so thatits massis very light. Due to its use as a water storage medium, it is important to find out the absorption which occurs in LECA.The LECA's absorption and evaporation rate is affected by the pores. The pores serves to increase water storage ability from LECA. LECA with PEG (pore-forming agent) mass percent variation of 5%, 10%, 15%, 20% and 25% is the focus of this study. LECA fabrication was conducted by mixing the carbon resulting from leaves waste pyrolysis and PEG and PVAc. The characterization of LECA was found out by calculating the porosity, the pore size distribution, absorption rate and evaporation rate. The result of the calculation shows that the higher PEG mass percentage, the higher LECA's porosity, the pore size distribution, absorption rate and evaporation rate. However, the porosity, the pore size distributionand absorption rate will be saturated by 25% PEG mass percent addition.

INTRODUCTION

Waste has become one of the problems for urban center which has not been resolved yet. The great number and variety of waste become an obstacle for the effectiveness of waste management. About 70% of the waste is organic waste [1]. The organic waste is largely derived from agricultural waste such as leaves. Many solutions have been offered in the completion of waste such as recycling leaves waste into composites [2]. In addition, waste is recycled into biomass, biodiesel and even into strong and lightweight composite materials [3].

Generally, the simple way which is done to reduce the leaves waste is by combustion process. This process stops after the waste is burnt completely and leaving no more utilization of the results from the process. The combustion process with low oxygen generates element which is dominated by the carbon material with a very distinctive characteristic of color, namely black [4,5]. Carbon has the properties of absorption and excellent thermal stability that is used for electrodes in electrochemical devices [6,7]. By the advantage of those physical properties, carbon also has been widely used as the filter medium for various types of pollutants [8].

The benefits of high absorption of carbon shed light on with a new function as a water storage media. Water storage media is known as Lightweight Expanded Clay Aggregate (LECA) [9]. Lightweight aggregate absorbs water much better than ordinary aggregate [10,11]. It is because the aggregate has so many pores as a place to store water. LECA is made of clay as the base material burnt at high temperature. This process makes the LECA has the characteristics such as small density, high porosity, light mass, strong and high thermal resistance [12,13,14].

The based-clayLECA has limitations, namelyextremely highcombustiontemperatures(~1000 ˚C) [14]. The reason of choosing carbon material from leaves waste instead of clay in making LECA is because of the carbon's low combustion temperatures, the formation of its pores which can be controlledand eco-friendly characteristic which can reduce excessive clay exploration. That's why this paper focuses on fabricating Lightweight Expanded Carbon Aggregate (LECA) using carbon from leaves waste as the base material and the PEG as pore controller.

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EXPERIMENT

Many kinds of leaves waste were collected and dried and then burned in a low oxygen condition to obtain charcoal. The obtained charcoal was pounded with mortar and pestle then it was sieved by using screen sablon T90. The sieving process was conducted to homogenize the size of carbon powder. After that, the homogeneous carbon powder was mixed with PEG as a pore-forming agent and PVAc as an adhesive. PEG mass percentage in LECA was varied from 5%, 10%, 15%, 20%, and 25%. The variations were made to form various pores. The mixed powder carbon was being molded round and heated by using Thermo Scientific brand furnace at the temperature of 120° C for 1 hour.

The characteristics of leaves waste-LECA were assessed by some measurements of basic units in physics.The pore size distribution was identifiedfrom cross section of LECA obtained from digital image of Moritex brand. To find out the percentage of empty space (pore) in the LECA, the porosity testing is done.The porosity of LECA was estimated by simple approach such as the difference in density [15]. LECA examination as the media of water storage was observed from its ability to absorb water and time to store water.

RESULT AND DISCUSSIONS

To find out LECA's physical characteristic with any kind of PEG mass percent variaton, it needs a basic quantity, so that the effect of PEG addition to LECA can be observed. Due to its role as a pore former activator, so that the pore size distribution becomes the parameter which is important to be studied. Fig. 1 shows the distribution of each PEG mass percent variation and the cross section of LECA obtained from digital image of Moritex brand.

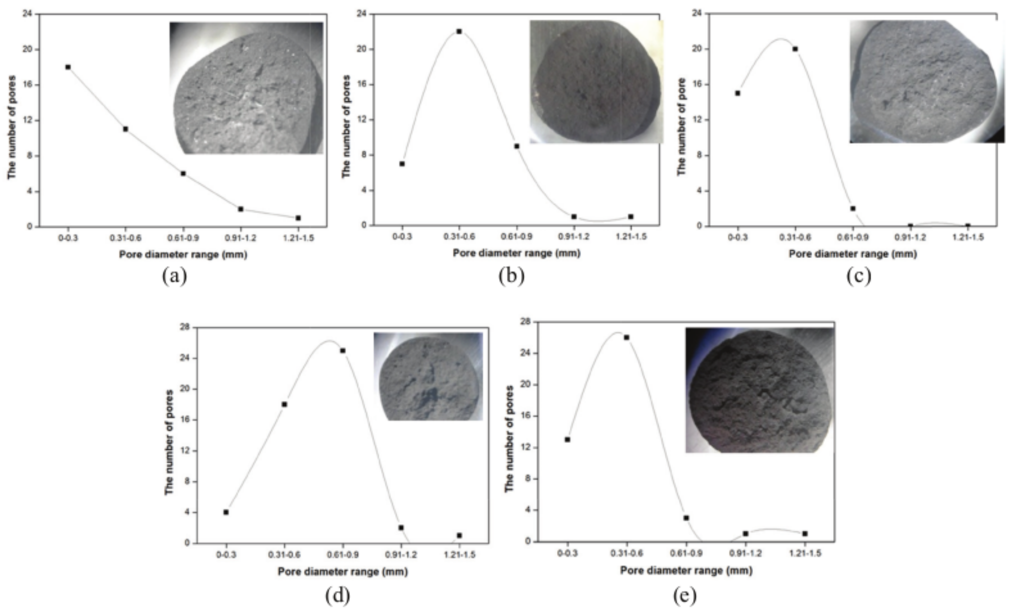

FIGURE 1. The Distribution of LECA's pore size with PEG mass percent of (a) 5%, (b) 10%, (c) 15%, (d) 20%, (e) 25%.

Generally, the pores in a material are not equal in size. To find them out, it needs an analysis of dominant pore size distribution. LECA with PEG mass percent of 5% had 18 dominant pores, whose diameter size in the 0 – 0.3 mm range was 0.18 mm, while the pores were 11 in the 0.31-0.60 mm range, 6 pores in the 0.61 – 0.90 mm range, 2 pores in the 0.91 – 1.2 mm range, and 1 pore in the 1.2 – 1.5 mm range. For LECA with 10% PEG mass percent, it had 22 dominant pores in the 0.31 – 0.60 range, and for LECA with 15%, 20% and 25% PEG mass percent, there were 20 dominant pores in 0.31 – 0.60 mm range, 20 pores dominant pores in the 0.61- 0.90 mm range, and 25 dominant pores in the 0.31 -0.60 range. It shows that the more PEG mass percent addition causes the shift of the graphic of pore size distribution.

LECA's examination performance as the water storage is shown at the Fig. 2 The figure shows that LECA has asmall density so thatits massis very light. In the examination process at t_0 LECA, will float but after a while LECAwill sink. This indicates that the LECA has been thoroughly fulfilled by water. The water can be observed by LECA within the span of time $t_0 + \Delta t$ due to the empty space. The empty space which has been fulfilled by the water creates the greater LECA mass and finally the LECA is able to sink. This empty space which is filled with the water will be the interesting assessment about porosity.

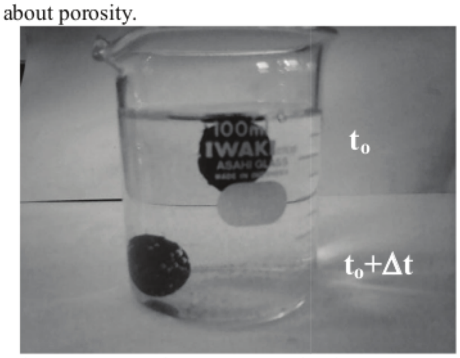

FIGURE 2. The LECA's performance examination as water storage media.

Porosity is the percentage of voids or the measure of the pore amount contained in a material. The distribution of LECA porosity value with the PEG variation is showed in Fig. 3. The leaves waste-LECA's porosity value increased with the increase of PEG mass percent**.** It is because the higher LECA's mass percent addition, the more empty spaces formed [16]. The empty spaces were formed as the result of PEG which evaporated in heating process at t=120°C. These empty spaces are called pores, so that the more PEG added, the more pores formed and the higher porosity [14]. It allows the water to be absorbed maximally. The result shows that PEG, as a pore activator in LECA, is effective. The heating process at sufficient low temperature and within relatively short time, has successfully evaporated the PEG in LECA.

Pores are considered as groups of ducts where liquid can flow. The effective width of the pores also varies. Pore is the relatively wide part, while the neck of the pore is the relatively narrow part. Broadly speaking, the increase of the porosity on 5%, 10% and 15% PEG mass percent addition is not too high. It is because the pore itself is still individual pore which has may pore necks. Suspected that on that PEG composition, it was difficult for the water absorbed to move from one pore to another pore because it must go through many pores which were relatively narrow [15].

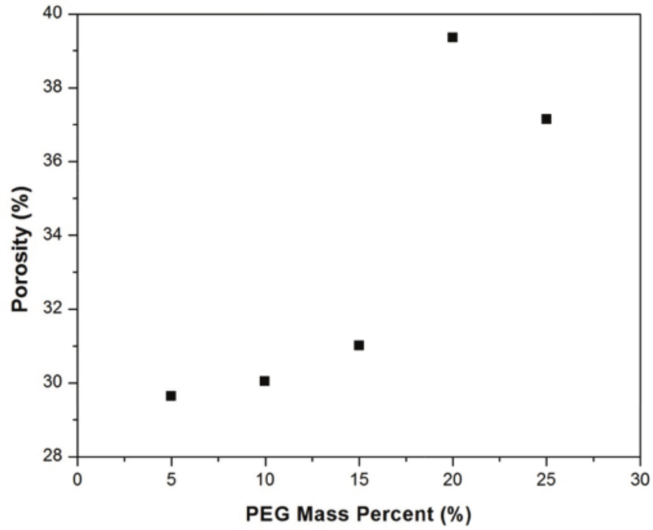

FIGURE 3. LECA's porosity distribution with PEG mass per cent variation of 5%,10%, 15%, 20% and 25%.

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Another phenomenon was observed on LECA with 20% PEG mass percent. On this composition, there was a surge of significant porosity value. Presumed that the pore formation on this composition made the pores interconnected, so that water can be easily absorbed from one pore to another pores. The Illustration of pore formation due to PEG mass percent is shown in Fig 4. The pores interconnected due to the more PEG mass percent addition definitely will form wider pores which will make water easy to move.

The LECA's porosity with 25% PEG mass percent decreased. Suspected that pore formation in this composition was saturated. It's because many pore on LECA formed by PEG of 25% is not much different from pores formed by PEG of 20%.Besides, another factor supporting porosity was the uneven PEG distribution. As the result, the pore distribution also became uneven within LECA. The pore distribution was presumed not wholly being within LECA, but on the LECA's surface, so that water could not fill the pores maximally. It is because the porosity phenomena in a material is influenced by pore structure, including pore size distribution, geometric shape, broken grains percentage and pore interconnection [14,17].

The illustration of pore formation above has been commonly used to describe porous material, such as illustrating the ions movement in the porous electrodes and modelling the composition effects and pore structure of the electrodes in electrochemical capacitors [18,19].Fig 4 shows the pore formation process in LECA due to the evaporated PEG.The higher PEG mass percent addition makes the more pore formation.The illustration on Fig.4 is used to explain pore size distribution which will result the consequences to the porosity of LECA. The pore size distribution in a material is divided into two, polydisperse and monodisperse. Polydisperse is interpreted as the varied pore size in a material, while monodisperse is the almost homogeneous size of pore. A material which has varied size form (Polydisperse) which will result a large porosity, while the homogeneous one tends to have a small porosity. It is shown on pore formation with 20% PEG mass percent addition. The pore formation on that composition has made LECA have varied pore size. Therefore, the value of porosity increase rapidly.

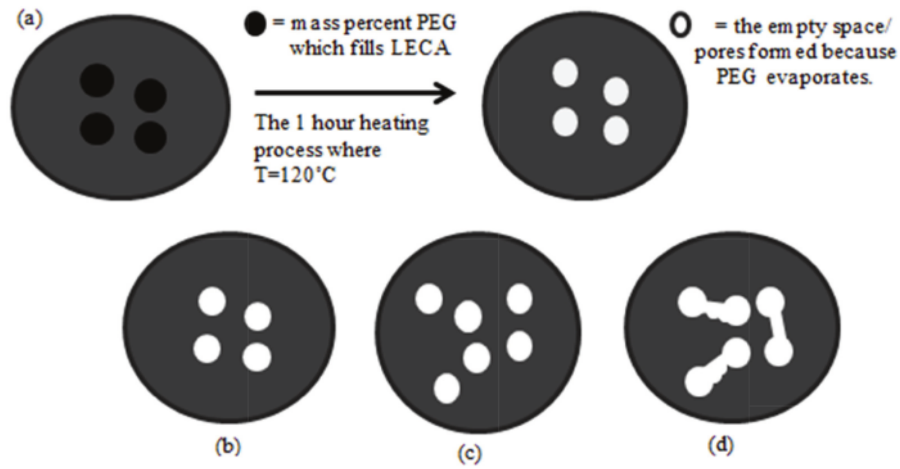

FIGURE 4. Pores formation illustration on LECA (a) as the result of heating with PEG mass percent, (b) 10%, (c) 15% and 20%.

The ability to store water on storage media is very important. Water storage media which is capable to store water efficiently in long period will minimalize water use for particular function so that the parameters which is important to be observed in LECA examination performance are absorption and evaporation rate.

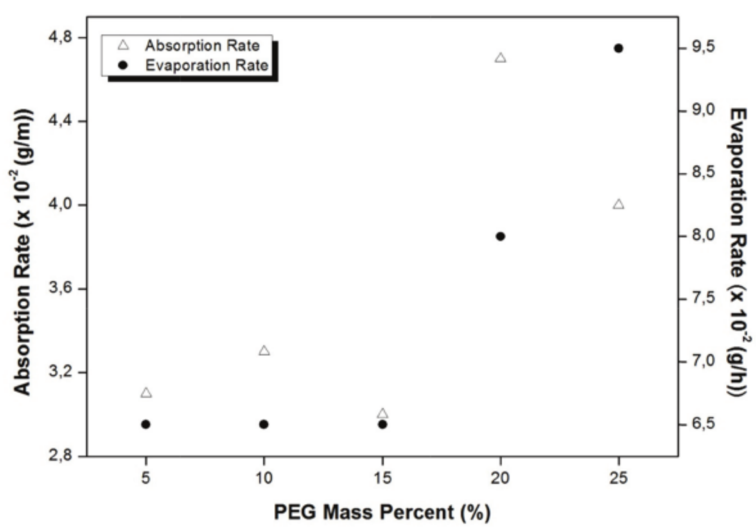

FIGURE 5.LECA's absorption rate with PEG mass percent variation of 5%, 10%, 15%, 20% and 25%.

Fig. 5 shows the absorption rate of LECA. As a water storage media, the high porosity will make LECA become high absorbent. It's because the more pores formed, the more water which can fill LECA. The absorption examination was conducted by calculating the density difference after soaking LECA for 30 minutes. The examination was conducted in order to find out how much water which filled LECA's pores in certain time. The three variations of the earlier PEG mass percent which were 5%, 10% dan 15%, gave absorption rate inalmost the samerange3-3,3x10^{-2} gram/minute. It shows that the PEG addition was not effective to the composition because it was still hard for the water to move from one pore to another pores. Another phenomenon was identified on the absorption rate with 20% PEG addition. On that composition, the absorption rate increased significantly. This interconnection between pores in this composition is still used as an excuse to explain the phenomena.

Besides the absorption rate, it is also important to find out the evaporation rate of LECA. The evaporation rate was identified from the LECA's mass reduction after being stood for 2 hours at room temperature. Based on the data obtained, the highest evaporation rate is LECA with 25% mass percent PEG. Suspected that on the PEG mass percent addition, there are more pores for air to evaporate water.

CONCLUSION

Leaves waste can be used as a base material in fabricating Lightweight Expanded Carbon Aggregate (LECA). LECA has been known as a material which can be used as water storage media. As a water storage media, LECA has high porosity, absorption rate and evaporation rate. However, the porosity and absorption rate saturates on the 25% PEG mass percent addition. That characteristic of LECA is influenced so much by the pore size distribution.

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