PALM OIL CLINKER AS DRAINAGE LAYER IN GREEN ROOF SYSTEM UNDER MALAYSIA CLIMATIC CONDITIONS

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ABSTRACT

This paper reports on the potential of using palm oil clinker as drainage layer in green roof system as replacement of conventional materials (expanded clay, expanded shale, pumice, etc.). The ability for draining of palm oil clinker is studied since the purpose of drainage layer is to drain the excess water and to ensure aeration of substrate layer and root. This study used an experimental procedure in which hydraulic conductivity, infiltration rate and bulk densities were measured. Besides, the plant developments of selected green roof plants were also monitored to see any effect from the palm oil clinker replacement by means of experimental trays to simulate the real green roof system. It was found that palm oil clinker has a good ability of draining the excess water and there is no side effect in term of plant development. This indicates that there is a possibility of using palm oil clinker as drainage layer in green roof system.

KEYWORDS*: Green roof; drainage layer; palm oil clinker; hydraulic conductivity; infiltration rate*

1.0 INTRODUCTION

In recent years, the needs for design environmentally friendly building become a demand due to global warming which could leads to extreme and unpredictable weather condition. Since the beginning of educated life man was trying to alter the microclimate to be more "climate friendly", to avoid extreme climatic changes. These changes have a direct effect on the climate of urban spaces for example the central parts of cities, causing a rise of the urban temperature and other alteration named as the heat island effect which describes built up areas that are hotter than nearby rural areas. This can cause climatic unpleasant conditions.

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Nowadays, rising temperature and extreme changes in climate conditions made the developers to invent new technologies in order to reduce these changes. Green roof is one of the technologies that widely used these days especially in European countries. Green roof is an effective solution of the problems at the building and urban levels. It is not only gives pleasant environment but also offer several benefits that the normal roofs don't. They reduce air pollution and noise, improve storm water management, increase vegetation and animal biodiversity in cities and they also reduce the carbon dioxide through photosynthesis (Santamouris et al., 2007) . The green roofs can have great effect on the energy efficiency by reducing the heat transfer through the roof. In some normal roofs the temperature can reach high values in summer seasons. Green roofs on the other hand have a huge impact on this temperature because of (soil thermal resistance, evapotranspiration, foliage shading). The heat flux that going through the roof is affected and that can change the indoor thermal condition and the building energy demand (Palomo Del Barrio, 1997).

The government of Malaysia has taken an initiative through Kementerian Tenaga, Teknologi Hijau dan Air (KeTTHA) to increase awareness and culture on environment sustainability through activities which relates to green technology and environment (Asmat Ismail et al, 2012). To develop the culture, Persatuan Arkitek Malaysia (PAM) with collaboration with Association of Consulting Engineers Malaysia (ACEM) has played a role to launch the Green Building Index (GBI) which the main objective of GBI is to give certification to building for green status (Sheng et al., 2011). In the GBI rating assessment, installation of green roof is essential which led green roof technology to be part in construction industry in Malaysia (Fauzi et al., 2013).

The modern green roof design is formed by a few layers such as vegetation layer, substrate layer, root barrier, drainage layer and water proofing layer. Materials used for substrate layer is usually topsoil which has capacity retain water gives nutrient to the plant. As based on current design, material used for drainage layer is polymer modular panel which has the capability to drain water and gives good ventilation Other than that, porous stone materials such as expanded clay, expanded shale and pumice also used as drainage layer in green roof design. The function of drainage layer is primarily to get the optimum balance between air and water in green roof system (A. Vila et al., 2012).

Environmental sustainability becoming global issues recently. The need to used waste materials is essential to ensure the environmental sustainability. As mentioned before, porous materials are used as drainage layer which actually gives an impact to the environment. Thus it leads to environmental destruction in order to extract the materials. It is also leads to an increase in waste materials arise from later processing of the materials and those waste materials will increase the landfill area. Therefore, recycling is the best practice in order to minimize the waste product. Waste materials such as rubber crumbs can be used as a drainage layer in green roof system (G. Parez et al., 2012). Palm oil clinker is a by- product of palm oil industry which produced from burning of fibers and husk inside the boiler under high temperature. This process is actually to generate the steam engine for oil extracting process. As Malaysia among the world largest producer and manufacturer of palm oil product, they generate a large volume of palm oil clinker as a waste product. Nowadays, a few researchers have used the palm oil clinker as an aggregates replacement to produce lightweight concrete (Bashar, 2013). The utilization of these waste materials can avoid the undesired effects to environmental sustainability. In this research, the possibility of using palm oil clinker as drainage layer in green roof system is investigated. The palm oil clinker is used to replace the porous stone materials such as expanded clay, expanded shale and pumice which currently used as the drainage layer in green roof system. The fine aggregates produced from clinker are lightweight, porous and irregular in shape and thus having low values of bulk density and specific gravity (Basyar, 2013). In this research, experimental trays were used to simulate the real green roof system.

2.0 METHODOLOGY

Palm oil clinker was collected at palm oil factory near Felda Lepar Hilir, Kuantan, Pahang. Then it was crushed and sieved into three different sizes namely 2 mm, 5 mm and 10 mm. The three samples were tested to see the drainage ability of the palm oil clinker and compared with conventional stone material (pumice). Two parameters were investigated namely saturated hydraulic conductivity and also an infiltration rate. These parameters can be determined through constant load permeameter test as shown in Figure 1(b).

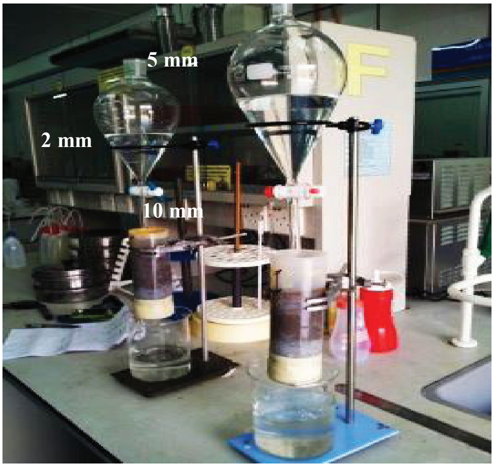

Figure 1. The constant load permeameter test setup

Bulk density was also calculated before the test. The experiments were done individually for every singles size of the palm oil clinker (drainage layer). Then, those samples were tested with adding substrate layer on top of them (substrate layer + drainage layer). The saturated hydraulic conductivity is calculated using Darcy's law with following expression:

$$Ks\left[\frac{cm}{h}\right] = \frac{V[cm^3] * L[cm]}{A[cm^2] * \Delta t[h] * h[cm]} \quad (1)$$

where K_s is the saturated hydraulic conductivity, V is the cumulative volume of percolated water, L is the length of sample in column, A is the cross-section area of the flow, Δt is the duration of the test and h is the hydraulic pressure difference.

The infiltration rate is calculated using the following formula:

$$v_i\left[\frac{cm}{min}\right] = \frac{V_1[\frac{cm^3}{cm^2}]}{t[min]} \quad (2)$$

where v_i is the infiltration rate, V_1 is the percolated water volume and t is the interval time.The bulk density is calculated using the following formula:

$$\rho_a\left[\frac{g}{cm^3}\right] = \frac{M_s[g]}{V_t[cm^3]} \quad (3)$$

where ρ_a is the bulk density, M_s is the mass of soil used and V_t is the total volume.

In order observed the behaviour of green roof system and the effects when replacing the drainage layer with palm oil clinker, a few experiment trays were installed. The experimental trays have 5 cm of substrate layer and 4 cm of drainage layer and the materials used for substrate and drainage layer is the same with the ones used in constant load permeameter test which are pumice and palm oil clinker in three different sizes. Two numbers of plants were studied namely Creeping Ox-Eye (Wedelia Trilobata) in Figure 2(a) and beach morning glory (*Ipomoea pes-caprae*) as shown in Figure 2(b). The Creeping Ox-Eye (Wedelia Trilobata) is chosen because it can make a dense cover by spreading like a mat while the beach morning glory (*Ipomoea pes-caprae*) is chosen due to its ability to tolerate with high ambient temperature which is required for green roof plants.

(a) (b)

Figure 2. (a) Creeping Ox-Eye (Wedelia Trilobata) and (b) beach morning glory (Ipomoea pes-caprae) in experimental tray

The parameter that was analyzed in this experiment is the plant development. Nine numbers of experimental trays were prepared taking into account the four drainage materials, two plant species and one reference trays which has no plant in it.

3.0 RESULT AND DISCUSSION

The general aim of research in this area is to investigate the ability of palm oil clinker to drain water so that to give enough aeration for substrate layer and root. Thus, parameters that should be look into are hydraulic conductivity and infiltration rate. Figure 3 shows saturated hydraulic conductivity for drainage layer materials (palm oil clinker) for three different sizes namely C-Small (2 mm), C-Medium (5 mm) and C-Big (10 mm) and pumice (3-10 mm) respectively. Based on the result, water can pass through the drainage layer (palm oil clinker) very quick. These indicated that palm oil clinker has the ability to drain the water fast. As can be seen in that figure, the hydraulic conductivity of the palm oil clinker is proportionate to the size of clinker. The bigger size of clinker will gives a higher value of hydraulic conductivity.

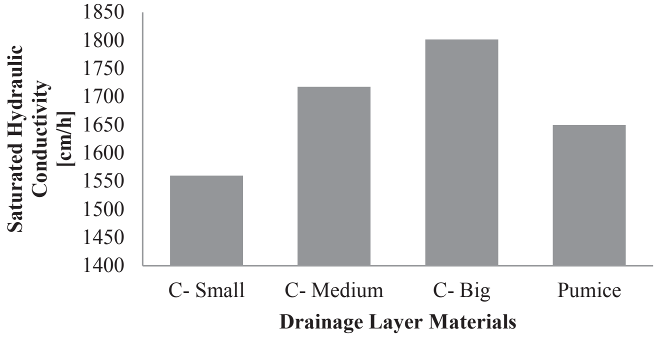

Figure 3. Saturated Hydraulic Conductivity of Drainage Layer Materials

Figure 4 shows saturated hydraulic conductivity for drainage layer material (clinker) and substrate layer material (soil). In the first case (Figure 3), only drainage layer is considered. Thus, water can easily pass through the medium. In the second case (Figure 4), substrate layer was added on top of drainage layer. As can be seen in figure 4, the hydraulic conductivity has been reduced about 2 times lower than the values in figure 3. This is due to effect of substrate layer that has an ability to retain water and also the effect when water brings down the soil particles to fill the pores in drainage layer. Thus, the hydraulic conductivity is reduced. Based on Figure 4, it can be observed that the two sizes of clinker which are the smallest size (C-Small) and the medium size (C-Medium) have a closer value to Pumice which indicates that both the two sizes can be used interchangeably in green roof system as drainage layer.

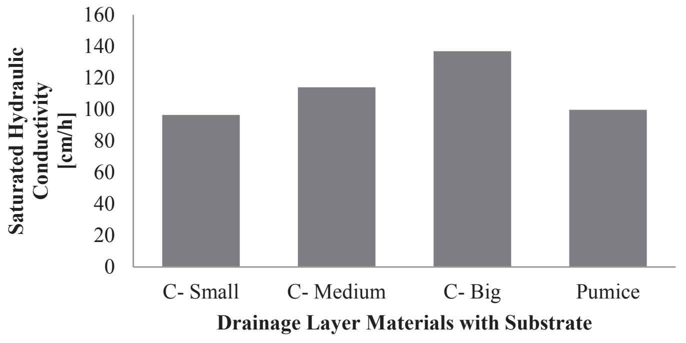

Figure 4. Saturated Hydraulic Conductivity of Drainage Layer Materials with Substrate

Figure 5 shows infiltration rate of drainage layer. The experiment was done at a given time (3 minutes) to see water flow through a medium. Based on the experimental result, the bigger size of clinker (C-Big) showed the highest infiltration rate followed by the medium size (C-Medium) and the smaller size (C- Small) respectively. Pumice showed an infiltration rate around 51 cm/min and it value is in between C- Medium and C-Small. This result is actually corresponding to hydraulic conductivity result shown in Figure 4.

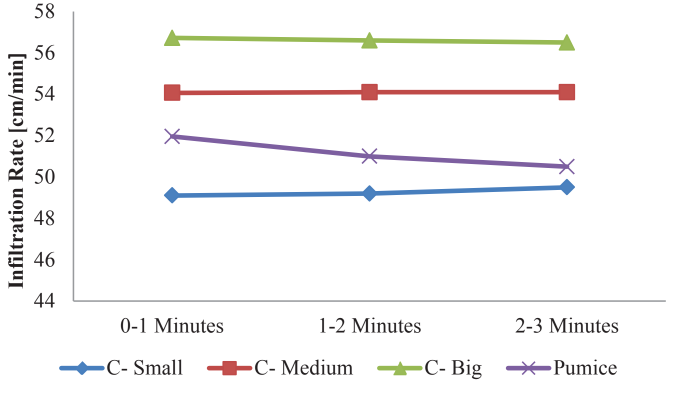

Figure 5. Infiltration rate of drainage layer

Figure 6 shows infiltration rate of substrate layer and drainage layer. The experiment was done at a given time (8 minutes). Based on the result, C- Big showed the highest value of infiltration rate followed by C- Medium, Pumice and C- Small respectively. This result also corresponds to hydraulic conductivity result shown in Figure 4. As can be seen in the Figure 6, C- Small has very similar values with Pumice and the other two samples shown only slight different values from

Pumice in term of infiltration rate. This is probably because of both clinker and pumice is porous materials and behaves in similar way.

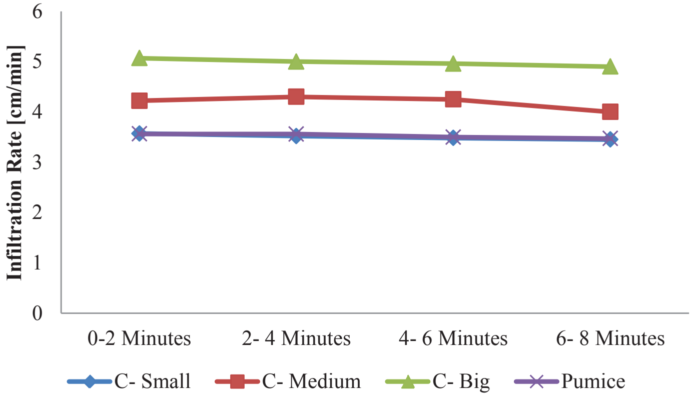

Figure 6. Infiltration rate of substrate and drainage layer

Based on the result for hydraulic conductivity and infiltration rate, it is shown that Pumice can be replaced by palm oil clinker since both materials are porous materials. Palm oil clinker has shown almost similar result for hydraulic conductivity and infiltration rate. The medium size of clinker (C-Medium) is the best to replace pumice since it can slightly increase the capacity to drain water.

Figure 7 shows the bulk density of drainage materials and substrate used in this study. Substrate showed the highest value with 1.205 g/cm^3 followed by pumice with 1.103 g/cm^3. The three sizes of clinker showed lower values compared to substrate and pumice. Among the three clinker sizes, C- Small showed the highest value of bulk density with 1.030 g/cm^3, followed by C- Medium with 0.925 g/cm^3 and C- Big showed the lowest value with 0.819 g/cm^3 respectively. Low bulk density is an indicator of low porosity which means there is more pore space in a material. Thus, low bulk density provides a good aeration system and also a good ability to drain water. The low bulk density material is a good selection of material in construction of green roof since it gives reduction in weight if compared to pumice or any other conventional materials used in green roof system.

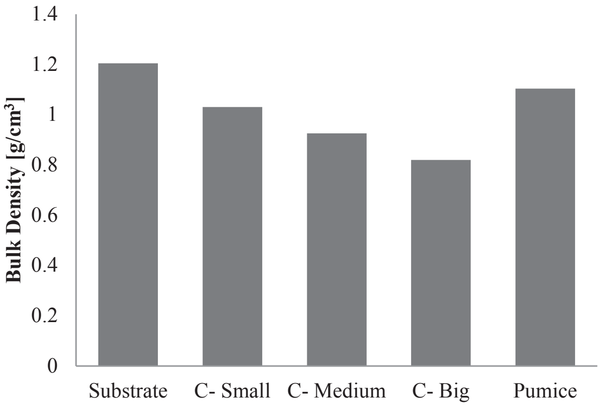

Figure 7. Bulk density of drainage materials and substrate

As mentioned earlier, apart from investigating the ability of palm oil clinker to drain water, it is also essential to study the behaviour of the plant by means of experimental green roof trays. In general, the newly planted plant needs enough water and sunlight to survive with new environment if there is no effect on toxicities from substrate or drainage layer. As can be observed from this study, Creeping Ox-Eye (*Wedelia Trilobata*) showed some symptom of stress due to dryness during the first week. This is probably because of Malaysia has a very hot and humid climate. Thus, the plant was watered about 1 L every day. After a week later, the plant had shown no stress symptom. Similar to beach morning glory (Ipomoea pes-caprae), it has shown a symptom of stress due to dryness for the first week. The frequency of watering is increase, then the plant become normal and adapt with new environment.

In term of plant development, both plants have shown no sign of disease for intoxication from palm oil clinker. It is evident that palm oil clinker is exceptionally good as a replacement for pumice.

4.0 CONCLUSIONS

The lab experiment by means of constant load permeameter test and field experiment through experimental tray were carried out to investigate the use of palm oil clinker as drainage layer in green roof system. Based on the analysis of the result, it can be concluded that:

1. The constant load permeameter test, it was found that palm oil clinker has a good ability of draining the excess water based on its performance on hydraulic conductivity and infiltration rate. C- Big has showed the highest value for both hydraulic

conductivity and infiltration rate. In general, all sizes of clinker used as drainage layer are suitable to replace the pumice or any other conventional materials used in green roof system.

2. All of clinker sizes used in this study shown lower bulk density if compared to pumice. Low bulk density provides a good aeration system and also a good ability to drain water. Since the palm oil clinker has low bulk density, it is a good material to be used in green roof system because its gives a lighter system or weight reduction if compared to conventional material.
3. The field test on experimental tray, it was found that there is no effect in term of plant development when the palm oil clinker is used as drainage layer. This indicates that there is a possibility of replacing the conventional stone materials with palm oil clinker.

In general, it can be conclude that the palm oil clinker is suitable to replace pumice as drainage layer in green roof system and since it is a waste material, it can help in term of environment sustainability.

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