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Alternative Grounding Method Using Coconut Shell Charcoal as Media of Mesh Electrodes

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Abstract

The utilization of coconut charcoal as alternative media of grounding was investigated. The mesh-electrode was made of stainless steel of 8-mm diameter, whereas its lattice dimension was 50cmx50cm. Four variations of lattice number were considered, i.e. 1-, 2-, and 4-lattice structures. Dry and wet charcoal media were considered. Mesh location was fixed in the depth of 80cm under the ground, while the 10cm of medium thickness variation was chosen. The resistance obtained using 10-cm thickness of charcoal layer in a mesh consisting of 1-, 2-, and 4-lattices were 268, 131, and 78 ohms consecutively. The addition of layer up to 80-cm resulted in a resistance decrease of 48%, 33%, and 44%. Using wet charcoal, the 10-cm layer produced 26.5, 17.5, and 14.8 ohms of grounding resistance and a reduction of 25%, 10%, and 3.6% subsequently for 1-, 2-, and 4-lattice mesh structure if the layer thickness was 80 cm.

Keywords: *alternative media, coconut charcoal, mesh grounding*

1. Introduction

Coconut shell can be categorized as hardwood with chemical composition similar to wood which is composed of lignin, cellulose and hemicellulose. When subjected to heat treatment, its organic molecule content can produce carbon (C) in the form of charcoal (char) [1-2]. Characteristics of charcoal originating from natural substances depend strongly on its conditions during the carbonization process. Among them is the temperature, which will cause the increase of its electrical conductivity when it is increasing [1-2]. Results of another study indicated that the AC conductivity started to increase at the carbonization temperature of 400^{o}C [3-5].

Ground resistance is highly variable and greatly influenced by the climate and weather changes. It is a function of the content of electrolyte, water, mineral and salt in the soil [6-10]. A site location with high resistivity will generate high earthing resistance value. Grounding resistance could be lowered by adding coconut shell charcoal which had a relatively small resistivity [3-4,10]. Low grounding resistance could also be obtained using cocoa shell charcoal which also has low resistivity [3,11]. The use of rice husk was also proven to be useful to lower the grounding resistance of plate electrodes [12]. The number of lattices to be used in the mesh grounding influenced its resistance value [13-14]. Increasing the number of lattices of the same size would reduce grounding resistance. This paper presents the investigation results on the benefit of coconut shell charcoal as alternative media to reduce the grounding mesh resistance.

2. Research Method

2.1. Grounding Model

The model of mesh-electrode grounding resistance was derived by adopting that of rod-electrode grounding which was positioned horizontally, as shown in Figure 1. As seen, the charcoal media were placed around the electrodes because of its resistivity which is much lower than its surrounding soil [10, 15-17].

The mathematical model of the grounding resistance was determined based on the model of current distribution of the charcoal media. The current from the electrode was flowing radially through the charcoal media before going further through the soil. Each segment of the media was approximated as of tube-shape geometry. It was assumed that currents would penetrate radially through the tubular segment sheath and not through the circular sides of tube cover.

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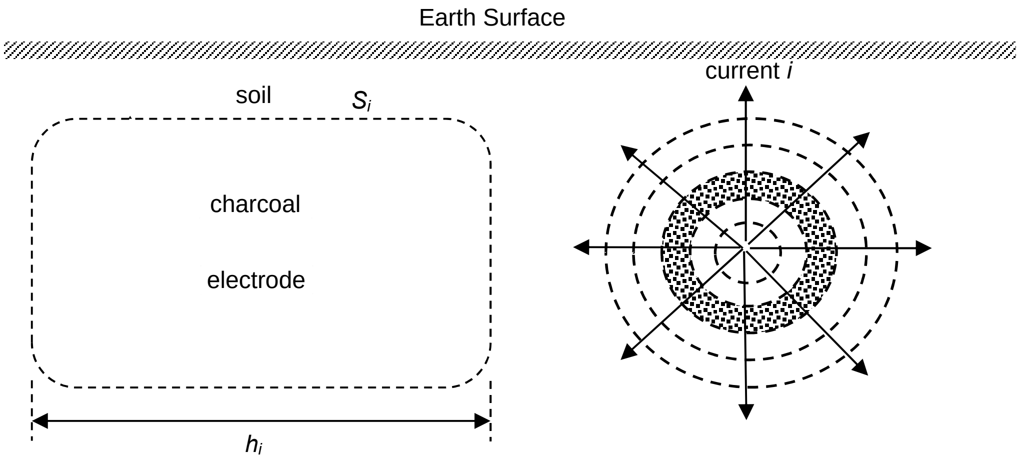

Figure 1. The adopted grounding model and the current distribution in the mesh electrodes

By using the current distribution model in Figure 1, the grounding electrode resistance can be expressed by the following equation [15],

$$R_E = R_e + R_i + R_c + R_s \tag{1}$$

with R_E is the grounding resistance, R_e is the metal electrodes resistance, R_i is the interface resistance between the electrode and charcoal media, R_c is the charcoal resistance, and R_s is the soil resistance.

The grounding resistance is obtained from the total series resistances comprising the electrode resistance, the interface resistance, the whole resistance of all segments of the charcoal and soil media. As electrode is an excellent conductor and the thickness of interface between the electrode and the charcoal media is very small, the values of R_e and R_i are also very small and can be ignored so that the equation (1) can be simplified into the following equation,

$$R_E = R_c + R_s \tag{2}$$

R_c and R_s can be determined using Ohm's Law given in the following equations,

$$R_c = \sum_{i=1}^{m} R_{ci} \tag{3}$$

$$R_{ci} = \frac{\rho_c\, t}{S_i} = \rho_c\, t \frac{1}{S_i} = f(S_i)\ \ ;i : 1,...,m \tag{4}$$

$$R_s = \sum_{i=m+1}^{n} R_{ci} \tag{5}$$

$$R_{si} = \frac{\rho_s\, t}{S_i} = \rho_s\, t \frac{1}{S_i} = f(S_i)\ \ ;i : m+1,...,n \tag{6}$$

$$S_i = 2\pi\, (\frac{2i-1}{2} t)(h_i + 2i\,t) \tag{7}$$

where

R_{ci} : resistance of i-th segment of charcoal media
R_{si} : resistance of i-th segment of soil media
S_i : the average tube area of i-th segment of any media
i : i-th segment of any media
ρ_c : resistivity charcoal media
ρ_s : soil resistivity
t : the thickness of segment of any media
m : the amount of segments of charcoal media
n : the amount of segments of soil media
h_i : the tube length

As the radius of metal electrode is much smaller than the segment thickness *t* of any media, it can be ignored.

As can be observed in the equations (3)-(7), R_{ci} and R_{si} are functions of the average tube area of each segment *i*. The greater the value of *i* is, the greater the value of S_i and the smaller the value of R_{ci} and R_{si}. So, the most influencing factor on the grounding resistance is the closest media to the electrode, or the segment with the smallest *i*. Consequently, the media with resistivity lower than that of its surrounding soil should be chosen.

2.2. Experiment Layout

The testing object of this research was the grounding mesh [10,15]. The considered number of lattices and dimension of each mesh-electrode as shown in Figure 2. Three variations of lattice number were taken to be 1-, 2-, and 4-lattice, with each lattice was of 50cmx50cm dimension.

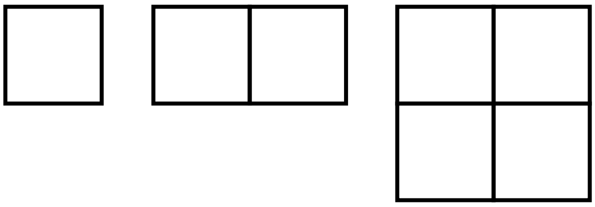

Figure 2. The shape and lattice-number variations of mesh electrodes: 1-, 2-, and 4-lattice

The field site of experiment is shown in Figure 3. As seen, the mesh electrodes were laid in a pit of 120cmx120cm of size. The height of the pit was 100cm. The mesh-electrodes were placed directly over a layer of charcoal of 20cm thickness, meaning that the position of the mesh was at a depth of 80cm under the earth surface. The mesh electrodes were made of stainless steel of 8mm diameter. Around the mesh-electrodes was also covered with the charcoal layer of 10cm thickness. Three variables of treatment were considered, which were the number of lattices, the placement depth of the electrodes, the thickness and water content of charcoal media. There have been considered two variations of water level content in the charcoal, i.e. the dry charcoal and the charcoal with 50% wetting treatment. The wet charcoal condition has been obtained by immersing the charcoal powder using water during 1 hour and then drying it. The resulted wet charcoal would have 1.5 times its original weight.

Figure 3. The pits for experiments

The placement layout of mesh electrodes and the addition of charcoal in the pits were given in Figure 4. As seen, a 20cm-layer of charcoal media was first spread over the base of the pit. A 4-lattice mesh electrode was then placed over the layer of powdered coconut shell charcoal. Additional layers of 10cm of thickness were furthermore given until reaching the earth surface while performing ground resistance measurement using the three-point method at each layer addition.

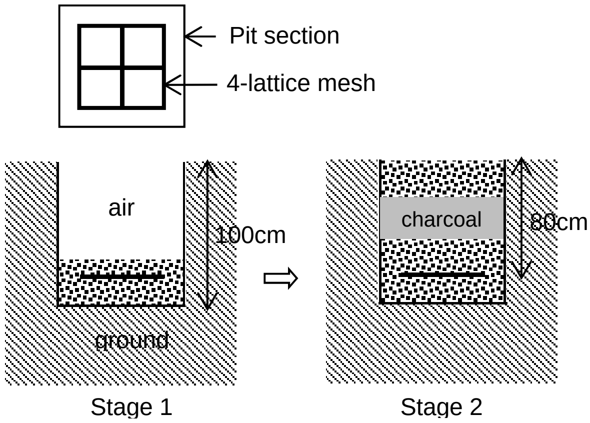

Figure 4. The placement layout of mesh electrodes and the addition of charcoal in the pits

3. Results and Analysis

Calculation of grounding resistance based on Equation (3-7) being applied to a horizontal-electrode structure of 1-m long in a soil media of 300-Ωm resistivity resulted in a resistance of 154.8Ω. Insertion of dry coconut-shell charcoal of 15-Ωm resistivity could reduce the grounding resistance value by 78% to 34Ω. The use of wet charcoal condition giving resistivity of 5-Ωm decreased more the resistance by 81% to the value of 29.75Ω, as illustrated in Figure 5. Figure 5 indicates the influence of each segment addition to the total grounding resistance. It also shows that the saturation condition was reached approximately after the 20th segment addition, indicating no significant further contribution to the total grounding resistance value. It was depending on the surrounding resistance closest to the electrodes, i.e. being determined by the media resistivity closest to the metal electrodes.

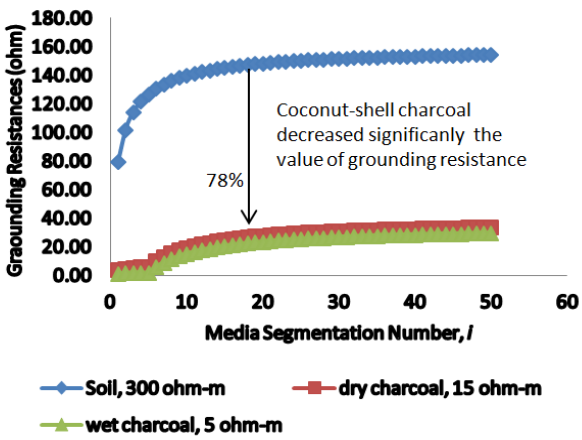

Figure 5. The addition of coconut-shell charcoal to reduce grounding resistance

Some variables have been observed: the number of lattices in the mesh, the thickness of charcoal media, the placement depth of the electrodes, the water content of charcoal media. Two variations of water level content in the charcoal have been considered, i.e. the dry and wet charcoal conditions. The wet charcoal has been obtained with 50% wetting treatment. It has been obtained by immersing the charcoal powder using water during 1 hour and then drying it, to obtained the wet charcoal with 1.5 times of its original weight.

Table 1 indicates the obtained grounding resistances using just the soil media. The resistance values for various lattice-numbers have been obtained as a function of the thickness of media layer. Thickness variation from 30 cm to 100 cm have been considered, with three variations of lattice-number which are 1-, 2-, and 4-lattice structures. It also shows that increasing the number of lattices can reduce the grounding resistance value. Addition of the layer up to the height of 100cm for the mesh-electrodes composed of 1-, 2-, and 4-lattices resulted in the grounding resistance values of 748Ω, 368Ω, and 239Ω respectively.

Table 2 indicates the obtained grounding resistances using dry charcoal media. The same procedure has been performed as to obtain the results of Table 1. The resistance values for various lattice-numbers have been obtained as a function of the thickness of charcoal layer. Media thickness variation from 30cm to 100 cm have been considered, with three variations of lattice-number which are 1-, 2-, and 4-lattice structures. The lattice size was 50cmx50cm. As Table 1, increasing the number of lattices can reduce the grounding resistance value. Addition of the layer up to the height of 100cm for the mesh-electrodes composed of 1-, 2-, and 4-lattices resulted in the grounding resistance values of 139Ω, 88Ω, and 43.8Ω respectively. Table 2 proved that addition of coconut-shell charcoal media reduced drastically the grounding resistance in general.

Table 1. Grounding resistance as functions of lattice-number and media layer-thickness in a grounding system using soil media

No	Ground soil layer thickness (cm)	Grounding resistance (ohm)		
		1-lattice	2-lattice	4-lattice
1	30	1022	497	342
2	40	908	444	305
3	50	837	419	286
4	60	800	398	264
5	70	799	386	255
6	80	776	377	246
7	90	754	370	241
8	100	748	368	239

Table 2. Grounding resistance as functions of lattice-number and media layer-thickness in a grounding system using dry charcoal media

No	Dry charcoal layer thickness (cm)	Grounding resistance (ohm)		
		1-lattice	2-lattice	4-lattice
1	30	268	131	78
2	40	226	117	66
3	50	193	105	57
4	60	168	97	50
5	70	151	91	46
6	80	142	89	44.8
7	90	140	89	44.3
8	100	139	88	43.8

Table 3 indicates the obtained grounding resistances using the 50% wet coconut-shell charcoal media. The same procedure has been performed as to obtain the results of Table 1 and Table 2. The resistance values for various lattice-numbers have been obtained as a function of the thickness of charcoal layer. Media thickness variation from 30cm to 100 cm have been considered, with three variations of lattice-number which are 1-, 2-, and 4-lattice structures. The lattice size was 50cmx50cm. As obtained in Table 1 and Table 2, increasing the number of lattices can reduce the grounding resistance value. Addition of the layer up to the height of 100cm for the mesh-electrodes composed of 1-, 2-, and 4-lattices resulted in the grounding resistance values of 19.9Ω, 15.8Ω, and 14.3Ω respectively.

The relationship between the grounding resistance and media type is shown in a form of graphic in Figure 6. It shows respectively the grounding resistances as a function of lattice-number for soil media, dry charcoal, and wet charcoal for the same electrode placement depth of 80cm. It was done by placing the electrodes in the depth of 80 cm. The layer of the media was added 10 cm at each time, making the height variations of 30cm to 100cm, as also shown in Table 3.

Table 3. Grounding resistance as functions of media type and media layer-thickness

No	Media height (cm)	Grounding resistance (ohm)		
		Soil media	Dry charcoal media	Wet charcoal media
1	30	342	78	14.8
2	40	305	66	14.5
3	50	286	57	14.5
4	60	264	50	14.4
5	70	255	46	14.3
6	80	246	44.8	14.3
7	90	241	44.3	14.3
8	100	239	43.8	14.3

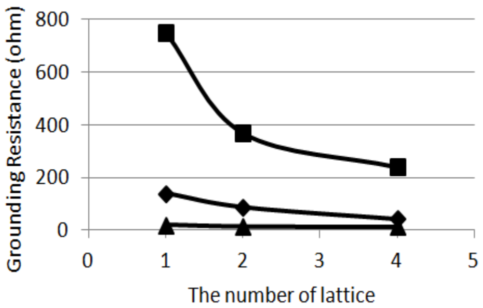

Figure 6. The influence of the lattice-number on the resulted grounding resistance at 80cm media layer height for three different media types (soil media, dry charcoal media, wet charcoal media)

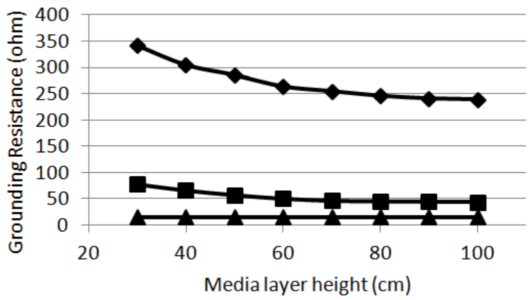

Figure 7. The influence of the media layer height on the resulted grounding resistance of 4-lattice mesh for three different media types (soil media, dry charcoal media, wet charcoal media,)

Table 3 shows that higher the media layer, lower will be the resistance value of the grounding mesh. The resistance decrease started to change insignificantly at about the ground height of 60cm. The table also indicates that the type of filling media used greatly affects the value of grounding resistance. At the same media laer height of 100cm, the grounding resistance values of 4-lattice mesh were 239 ohms in soil media, 43.8 ohm in dry charcoal media, and 14.3 ohm in wet charcoal media respectively, as also shown in Figure 7. Figure 6 shows that in the media with high resistivity values (soil and dry charcoal) increase in lattice number will decrease the grounding resistance value, whereas Figure 6 indicates that the decrease in resistance value was not significant when using wet charcoal media.

4. Conclusions

The mesh-electrode grounding system using charcoal media is designed in this research. Addition of charcoal media can be considered to lower the grounding resistance value. The wet charcoal media resulted in lower grounding resistance value than dry charcoal media. Comparing the resistivity of media types considered in this research (soil, dry charcoal, wet charcoal) showed that the soil media has the biggest resistivity, being followed with dry charcoal media, and then wet charcoal media. Lower the resistivity of media, lower will be the grounding resistance to be obtained. The number of lattices of the mesh-electrode determines the grounding resistance value. Higher the number of lattices used, lower will be the grounding resistance to be obtained. The values of resistance obtained using 10cm thickness of charcoal layer in a mesh consisting of 1-, 2-, and 4-lattices were 268, 131, and 78 ohms consecutively. The height of media layer used determines the grounding resistance value. Higher the media layer, lower will be the grounding resistance to be obtained. Using wet charcoal, the 10cm layer produced 26.5, 17.5, and 14.8 ohms and a resistance decrease of 25%, 10%, and 3.6% subsequently for 1-, 2-, and 4-lattices mesh structure if the layer thickness became 80cm.

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