Performance of Galvanized – Steel and Copper Grounding Electrodes Using Bentonite and Coconut Husk Ashes as an Additives Material to Grounding System

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Abstract. Natural enhancement material often uses to improve performance of the soil resistivity in grounding system. Due to the different soil condition, focus for effective grounding go to the soil itself. Soil resistivity, moisture content and surrounding environment contribute to the impedance of the grounding. The usage of material to enhance the grounding can be considering important to maintain the grounding system performance. There are several techniques used to treat the soil using chemical substance known as grounding enhancement material. This technique produces low resistivity to the grounding electrode however the soil become contaminated. This paper will discuss about the performance of coconut husk ashes and bentonite as natural enhancement material and method being used to evaluate the results.

1. Introduction
Lightning phenomena occur all around the world and it is natural phenomena and consider impossible to avoid. To protect the structure and reduce the electrical fault impact from lightning, grounding being use as protection system. The system consists lightning air terminal, down conductor and grounding termination system. Lightning air terminal role is to capture lightning in its designated zone. Down conductor distributes the lightning current to the earth pit and the current dissipated to the earth mass. Grounding is a system design to provide a shortest path for current to flow when fault occurred in the electrical system. Usually under normal electrical operation, the grounding system will not carry any current. The system usually consists of electrode, equipotential bonding and grounding conductor. This protection mainly used at load side of power system. The objectives for the system are same, safety for human and equipment; regulations; and to provide shortest path to unwanted current flow.

According to IEC 62305, overall resistivity value for earth electrode must not exceed 10Ω [1]. The soil resistivity is varied due to weather conditions, moisture, temperature or hilly terrain. In order to reduce the resistivity, many techniques being applied to create shortest path route for current flow.

The modification of the electrode has been done before while it shows promising results, the cost to mass produce can be consider high [2] Corrosion is a main issue to overcome form the modification of electrode. Material with high moisture absorption produce the low ground impedance however it also can speed up the corrosion process. Modification of the electrode can be categorised as grounding enhancement material technique. To overcome the drawback, natural enhancement technique was introduced. Earth electrode being bonded together with [2] enhancement material before fuses with the earth. Natural enhancement material with high moisture absorption normally were choose. Industrial
waste also being research as natural enhancement material. This paper will use bentonite and coconut husk ashes as natural enhancement material. Bentonite has good moisture absorption characteristic. During dry condition, it is found that bentonite produces low resistivity and it achieve low breakdown voltage [3-5]. Bentonite slurry also being tested, and the first five months show 50% reduction of ground resistance [2]. Although the result promising, temperature and humidity plays a vital role of bentonite performance. The cost to produce also consider high.

Coconut husk contain chemical composition such as lignin, charcoal, tar tannin and potassium [6-14]. It normally uses in waste water treatment process to remove impurities. With high tensile strength, coconut husk will mix with bentonite as natural enhancing material for grounding system. Epoxidized oil can be used as a raw material for a various type of chemicals such as alcohols, alkanolamines, glycols, carbonyl compounds, olefinic compounds, and polymers [9]. Epoxidized oil has been widely used as polymer stabilizer and plasticizer in polyvinylchloride (PVC) [10]. These epoxidized oils are used as intermediate products to manufacture varies of end products that can be useful for industrial purposes. Hence, the economic value of the palm oil is increasing because of the conversion of palm oil into epoxidized palm oil [11]. Epoxidized oils are very important as intermediates in organic synthesis because of the high reactivity of oxirane rings can make them involve in some reactions [12]. By hydrolysis reaction of epoxidized palm olein, a high-value hydroxyl fatty acid called dihydroxystearic acid (DHSA) is produced. DHSA (C18H36O4) is also known as glycolic stearic acid that contains two alcohol groups and a carboxylic group in a long hydrocarbon chain [13]. DHSA is derived from in-situ epoxidation of the unsaturated fat in the palm oil with peracetic acid in the presence of catalyst followed with hydrolysis of the epoxide with hydrogen donor such as water. DHSA has been used widely in industry nowadays, as primary and secondary emulsifiers, pigments coating agents and oil gelling agent in cosmetic formulation [14-15].

2. Methodology

Two types of grounding electrode were chosen for the research purpose namely copper and galvanized steel electrode. Copper was widely use as ground electrode due to lower corrosion value [6]. Galvanized steel performance is better than electrode in lightning protection system [4]. The cost also cheaper and risk of being stolen lower. Selection of grounding electrical is essential since it was the final path for the unwanted current dissipated to the earth. The lower level of electrode will be put to natural enhancement material and not touching the soil. Comparison performance of these two types will be discuss in next topic. The electrodes mix with natural enhancement material were installed at field near Universiti Malaysia Perlis, Arau Malaysia (Figure 1). The topology of the sites considers unique as it consists of hilly terrain and flat terrace. The hilly terrain may impact soil performance of that area.

Wenner method (Figure 2) was used for measure soil resistivity since it was considering more accurate [1]. This method also considers common method used in industry. The test probe consists of four probe namely current and potential electrodes. Current probes will inject current into the soil then the voltage will measure voltage created. The calculation will be done automatically using the tester. Megger DET4TD were used for measuring soil resistivity. The probes spacing is equal and each probe shifted together for each measurement. However, for validation purpose, the soil resistivity was calculated using equation below [1]:

\[
\rho = 2\pi\alpha R
\]

Where:
- \(\rho\) = soil resistivity (\(\Omega m\))
- \(\alpha\) = earth resistance (\(\Omega\))
- \(R\) = distance between adjacent rod (m)
Coconut husk is available in tropical countries worldwide such as India, Philippines etc. Coconut particle reinforced composite was fabricated by reinforced shell particle (size between 200 – 800 μm) by wt % of 20, 30, 35, grinding in a machine. The coconut filler can be used on the broad range of applications, normally in the construction industry. Coconut husk also can be used as a fuel or charcoal. It will emit carbon dioxide and methane when burned. It also has huge amount of lignin and cellulose and the reason because of high calorific value of 18.62 MJ/Kg [7].

Bentonite could absorb moisture thus provide low resistivity for grounding system. With longer lifespan, bentonite use widely as grounding enhancement material. However, the cost to produce it is higher [3].

Three section was set up (Figures 3, 4 and 5) consists of copper electrode mix with bentonite and coconut husk, galvanizes steel mix with bentonite and coconut husk and copper electrode as control. Coconut husk ash and bentonite being compacted into PVC pipe before filling it with electrode. Theoretically when the electrode has contact with the material between soil, the resistivity should improve. The dimension of the PVC pipes is 0.5 meter height and 4 inches of diameter.
Figure 3. Electrode arrangement

Figure 4. Ground enhancement material mold

Figure 5. Electrode mix with enhancement material
3. Results and Discussion

3.1. Effect of different spacing to soil resistance
Before coconut husk being used, bentonite being evaluated with two different material of electrode. Effects of different spacing of the electrode being investigated. Wenner method were choose to determine the soil resistivity. The spacing varies for five different distance. However, the depth of the electrode being fix with 2 meter. Results from the table below shows that resistivity decrease when the spacing between electrode increased. The main factor is length between electrode affected the soil resistivity value.

| Spacing(m) | Resistance(Ω) | Soil Resistivity(Ωm) |
|------------|---------------|----------------------|
| 2          | 1.53          | 19.227               |
| 2.5        | 1.45          | 22.776               |
| 3          | 1.34          | 25.228               |
| 3.5        | 1.26          | 27.709               |
| 4          | 1.14          | 28.651               |

As of the Table 1, the resistance keeps decreasing when the spacing space being widen. The soil resistivity also increases proportionally with the spacing. The usage of pure copper is from Table 1, solely as controllable input factors. As copper being used widely as grounding electrode, other results will be compare with it.

| Spacing(m) | Resistance(Ω) | Soil Resistivity(Ωm) |
|------------|---------------|----------------------|
| 2          | 1.5           | 18.840               |
| 2.5        | 1.41          | 22.143               |
| 3          | 1.3           | 24.504               |
| 3.5        | 1.18          | 25.950               |
| 4          | 1.1           | 27.646               |

As per Table 2, copper electrode combines with bentonite backfill. Bentonite react as natural enhancement material to get lower resistivity. As per spacing between electrode get wide, the resistance getting low. However, soil resistivity getting higher. Performance of soil resistivity between Table 1 and Table 2 was comparable, although a slight decrease was observed when electrode mix with bentonite.

| Spacing(m) | Resistance(Ω) | Soil Resistivity(Ωm) |
|------------|---------------|----------------------|
| 2          | 1.67          | 20.986               |
| 2.5        | 1.61          | 25.289               |
| 3          | 1.55          | 29.217               |
| 3.5        | 1.48          | 32.547               |
| 4          | 1.4           | 35.186               |
Table 3 shows results of resistance and soil resistivity for galvanizes steel electrode with mix soil. The arrangement of the distance between the electrode also same as copper. It can be seen the resistance getting lower, however if compare with table 1, copper perform much better than galvanized. The soil resistivity of galvanized steel electrode mix with soil was higher than that of copper electrode. The performance of the galvanized suggest copper is a better material.

**Table 4. Galvanized steel electrode mix with bentonite**

| Spacing(m) | Resistance(Ω) | Soil Resistivity(Ωm) |
|------------|---------------|----------------------|
| 2          | 1.63          | 20.483               |
| 2.5        | 1.58          | 24.819               |
| 3          | 1.5           | 28.274               |
| 3.5        | 1.46          | 32.107               |
| 4          | 1.36          | 34.181               |

As can be seen from Table 4, resistance value is increase when compare with copper electrode mix with bentonite. The soil resistivity gradually increases with longer spacing between electrode. There was little difference of soil resistivity between galvanized steel electrode mix with soil and galvanized steel electrode mix with bentonite.

### 3.2. Effect of different grounding material

For this experiment, the measurement takes 100 days to assure that grounding enhancement material effectively mix with electrode and soil. Wenner method were used and all the electrode buried vertically. Using Megger DET4TD tester, the soil resistivity was measured (Figure 6 and Table 5).

**Figure 6. Soil resistance copper electrode vs copper mix with bentonite**

**Table 5. Pure copper vs bentonite+copper**

| Soil Resistance-Copper electrode | Pure copper(Ωm) | Bentonite+copper(Ωm) |
|----------------------------------|-----------------|----------------------|
| Mean                             | 4.995           | 3.526                |
| Median                           | 4.765           | 3.495                |
| Minimum                          | 3.94            | 2.54                 |
| Maximum                          | 6.24            | 4.79                 |
In terms of soil resistivity, the performance of copper electrode shows in Figure 7. Pure copper means no enhancement material were mix. Then the bentonite mixes with copper. Bentonite mix with copper shows lower resistivity achieved (Table 6).

![Figure 7. Soil resistance galvanized electrode vs galvanized mix with bentonite](image)

**Table 6. Galvanized vs galvanized+bentonite**

| Soil Resistance-Galvanized electrode | Pure copper(Ωm) | Bentonite+copper(Ωm) |
|-------------------------------------|------------------|----------------------|
| Mean                                | 4.66             | 4.268                |
| Median                              | 4.43             | 4.205                |
| Minimum                             | 3.89             | 3.27                 |
| Maximum                             | 5.91             | 5.9                  |

Figure 8 shows the performance of galvanized steel performance as grounding electrode. Although bentonite mix with galvanized shows lowest resistivity in some point, it cannot be concluded that the enhancement material performs flawlessly. The results still show copper electrode mix with bentonite achieve lower soil resistance compare to galvanized iron mix with bentonite (Table 7).

![Figure 8. Soil resistivity with coconut husk mix with different electrodes](image)
Table 7. Soil resistance with coconut husk

| Soil resistance – Galvanized electrode | Pure galvanized | Galvanized + Husk coconut | Pure Copper | Copper + Husk Coconut |
|---------------------------------------|----------------|---------------------------|-------------|----------------------|
| Mean                                  | 52.84          | 45.22                     | 38.515      | 32.14                |
| Median                                | 53.42          | 43.98                     | 38.325      | 32.05                |
| Minimum                               | 45.24          | 36.57                     | 31.92       | 28.9                 |
| Maximum                               | 57.18          | 54.41                     | 46.49       | 35.81                |

Figure 9 shows result for soil resistivity when coconut husk being add as natural enhancement material. The performance between pure copper and galvanized steel electrode can be seen from Figure 9. Galvanized steel electrode achieves higher soil resistivity compare to copper. There was minimal influence of coconut husk on galvanized electrode compare to copper electrode (Table 8).

Table 8. Earth resistance with coconut husk

| Soil resistance – Galvanized electrode | Pure galvanized | Galvanized + Husk coconut | Pure Copper | Copper + Husk Coconut |
|---------------------------------------|----------------|---------------------------|-------------|----------------------|
| Mean                                  | 52.84          | 45.22                     | 38.515      | 32.14                |
| Median                                | 53.42          | 43.98                     | 38.325      | 32.05                |
| Minimum                               | 45.24          | 36.57                     | 31.92       | 28.9                 |
| Maximum                               | 57.18          | 54.41                     | 46.49       | 35.81                |

Figure 9 shows the result of earth resistance when coconut husk mix with copper and galvanized electrode. Cooper electrode combine with coconut husk produce lower resistivity compare with galvanized iron. Lower resistivity has been observed from coconut husk when compare with bentonite

4. Conclusion
From the results, it is found that the copper electrode is better than galvanized steel electrode. Major reason is the galvanized steel electrode has less corrosion resistance than copper electrode. In term of lifespan, copper electrode is preferable since the performance was better. Coconut husk and galvanized steel are not suitable combination for grounding system. This can be seen from higher soil resistivity
when those two perform. Highest value of resistivity can be seen when galvanized steel act as ground electrode.

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