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A study on copper and galvanized grounding performance using palm oil fuel ash as new additive material

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Abstract: This paper aimed to study the improvement of grounding performance by reducing the grounding electrode resistance using palm oil fuel ash as the backfill. This is achieved by mixing the soil with a specific portion of palm oil fuel ash and obtains the grounding electrode resistance value by using Three Pin Method. In order to obtain the grounding electrode resistance, the mixture of palm oil fuel ash and soil were compacted and installed with electrodes. Two types of electrodes were connected to measuring device which is Kyoritsu Digital Earth Tester Model 4105A and grounding electrode resistance values were displayed. The two types of electrodes used in this study were copper and galvanized steel electrodes. It was found that by adding palm oil fuel ash to the soil, the grounding performance can be improved to at least 90% and above for both copper and galvanized steel electrodes. The palm oil fuel ash is very effective in improving the grounding performance at low cost and environmentally friendly.

1. Introduction

One of the important parts in electrical engineering is the grounding system. Electrical grounding is a safety measure to prevent people from the risk of electrical hazard. Electrical grounding can be defined as an electrical circuit connected to the ground [1]. The purpose is to protect the consumers or consumers' device from electrical shocks by providing an alternative path for current from faulted electrical part or lightning strike to the ground. Electrical grounding helps to protect electrical equipment by discharging any static charge produced in live conductor [2]. The grounding system formed by burying conductors or electrode in a grid that connected to other electrical equipment or appliances. Besides that, grounding becomes more important in the electrical system as electronics and electrical field is developing rapidly. Moreover, most electrical devices produce disturbing noise and cause other electrical devices to operate in low efficiency. Electrical grounding is necessary to remove the unwanted noises by sending them to ground [3].

A good grounding system in the electrical system consists of a low impedance path for current from the grounding system to the ground with low soil resistivity value [4]. The ideal ground resistance is zero ohm resistance [5]. However, it is hard to find the ground with zero ohm resistance as the content of moisture, the compactness of soil and temperature give impact to the resistivity of the soil [6]. Moreover, each type of soil has the value of resistivity called soil resistivity [7-8]. Soil resistivity is the measure of resistance to the flow of electricity in the soil. The value recommended by the National Fire Protection Association and Institute of Electrical and Electronics Engineers for the ground resistance is less than 25 Ω and for facilities with sensitive equipment should be 5 Ω and below [5].
There are many ways to reduce soil resistivity. The first way is by increasing the moisture of the soil.

Increasing the soil's moisture content helps the chemicals in the soil around the grounding electrode to carry the electrical current. The increase of soil's moisture from 5% to 10% would reduce topsoil resistivity by 800 Ω-m. But in most cases, increasing soil moisture is not a practical option as the moisture can dried up throughout the time. The second method is by treating the soil with a salt such as copper sulphate, magnesium sulphate, or sodium chloride. The added salts to the moisturised soil would reduce the earth resistivity. However, the problem of this method is that salts may become corrosive to the grounding electrodes. Moreover, soil would turn back to its initial condition or untreated condition if the salts washed away. To counter this problem, the salt must be recharged periodically [9].

Another way to reduce the resistivity of the soil is by using ground enhancement material. Ground enhancement materials can be applied to the soils with high resistivities such as rock soil or stony soil where the ground is hard for the electrode to be driven or area with limited spaces that make the grounding with conventional methods more difficult. Some of the grounding enhancement materials are bentonite clay, coke powder, and specially engineered substances [9].

An experiment conducted by a group of students from UNIKL MSI, Kulim showed that, the soil resistivity was successfully reduced when palm oil ashes was added to the soil as enhancement material while copper, aluminium and galvanized steel was used as grounding grid. The soil resistivity value without the additive material is 19.3 Ω, and the soil resistivity value with the additive material is 17.3 Ω. From this experiment, it can be said that the resistivity of soil was improved after palm oil ashes were added as backfill [10]. The results show an improvement of 9%-12% only, may be the studies did not include much palm oil ashes. This paper proposed to include more palm oil ashes in order to further reduce the soil resistance.

Another experiment in Universiti Teknologi Malaysia was conducted on grounding enhancement materials by using bentonite. From the result, the using of bentonite as grounding enhancement materials can reduce resistivity and reduce the grounding resistance. However, the moisture, surrounding temperature, humidity of the soil and the amount of rainfall can influence the performance of bentonite [4]. Furthermore, the observation from the experiment found that the peat soil has high resistivity than the laterite soil. The reason is that laterite soil consists of the higher content of clay. Clays' water holding capacity is higher compared to peat soil. Higher water content helps the laterite soil to reduce the resistivity [4].

A study done by Arfah et al. [2] discovered that the size of electrodes or the electrode diameter affects the resistivity value. The bigger the electrode size, the lower the resistivity value measured. This is because of the bigger diameter of the electrode, the lower electrical resistance [2]. This study also found that galvanized iron rod shows better performance by giving out a lower resistivity value, even though copper is most commonly used for grounding electrodes. Since galvanized iron is more affordable compared to copper, therefore it is a good idea to use lower cost material but good in performance [2].

This study will focus on the effect of palm oil fuel ash towards the grounding electrode resistance value when it is mixed with the soil and measurement was conducted in a vicinity of Universiti Malaysia Perlis. Type of soil used in this location is laterite which contains sand and clay with a soil resistivity value of about 150 Ω-m [11]. Two types of electrodes used in this study were copper rod and galvanized steel. The measurement of the grounding electrode resistance was conducted by using Three Pin Method. Compared to previous study by Roshidi A that used grounding grid, this study used grounding electrodes for the grounding systems [10]. Besides that, the palm oil fuel ash in this study were varied ascendingly with specific amount from 0 g to 3000 g in order to observe any effect of added amount palm oil fuel ash to the grounding electrode resistance. The soil humidity in this also emphasized as the factor that can affect the grounding performance where in previous study it is not concerned.

2. Methodology

This study method using Three Pin Method to measure the grounding electrode resistance, while the measuring device used in collecting the grounding electrode resistance value was Kyoritsu Digital Earth Tester Model 4105A. The holes were dug and filled with a specified amount of palm oil fuel ash. Then the soil and palm oil fuel ash mixture were compacted and installed with the electrode. The electrode then connected with the measuring device and the grounding electrode resistance was measured. Three Pin Method was chosen to complete this project as this method is suitable to be used to obtain the grounding electrode resistance compared to Wenner Array Method that is suitable so measure soil resistivity value.

The sequences in the steps of the study are shown below:
i) Preparation of grounding electrode.
ii) Site Installations.
iii) Measuring with testing equipment.

Three Pin Method
The first step involves the preparation of electrodes. The copper rod was selected because in most cases, copper is widely used for grounding rod and it is an excellent conductor, good mechanical properties and excellent resistance to corrosion [12]. The copper rod used in this study is 0.6 m long with 12 mm diameter. A 12 mm diameter is the standard minimum specification required for copper grounding rod [13]. The other type of electrode used in this study was galvanized steel. The purpose of using galvanized steel in this study is to observe whether this material has the same capability with copper or much better in improving the grounding performance as the galvanized steel has a protective layer of zinc. The specification of the galvanized is the same as the copper rod, which is 0.6 m in length and 12 mm in diameter.

Site Installations
The grounding electrodes were installed on a field near the School of Electrical Systems Engineering, Universiti Malaysia Perlis. Hole with a depth of 0.5 m and 0.15 m (6 inches) wide as shown in figure 1 was dug using a hoe. A total of 10 holes were dug in arrangements of 5×5 as shown in figure 2. For the first row of holes 200 g, 400 g, 600 g, 1.5 kg and 3 kg full-filled of palm oil fuel ashes were filled with the copper rod installed in five holes respectively. As reference, there was one copper rod buried 0.5 m deep into the soil without any palm oil fuel ash added to it. For the second row of holes all the palm oil ashes and soil mixture portion are the same but the copper rod was changed to galvanized steel. For the variable of 0 g of palm oil fuel ash, the galvanized steel rod was buried into the soil without any palm oil fuel ash added with the 0.5 m depth.

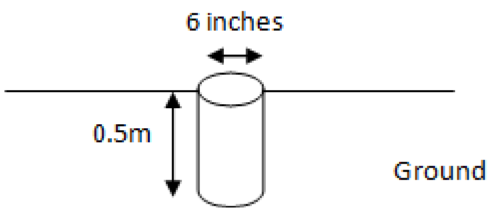

Figure 1. Depth of hole

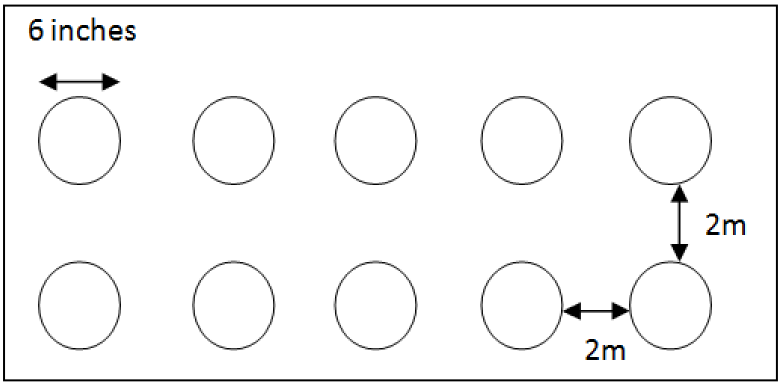

Figure 2. Hole Arrangement

Electrodes were buried at the centre of compacted mixtures. For full-filled palm oil fuel ash variable, there is no any mixture with soil. The arrangements are shown in figure 3 and figure 4.

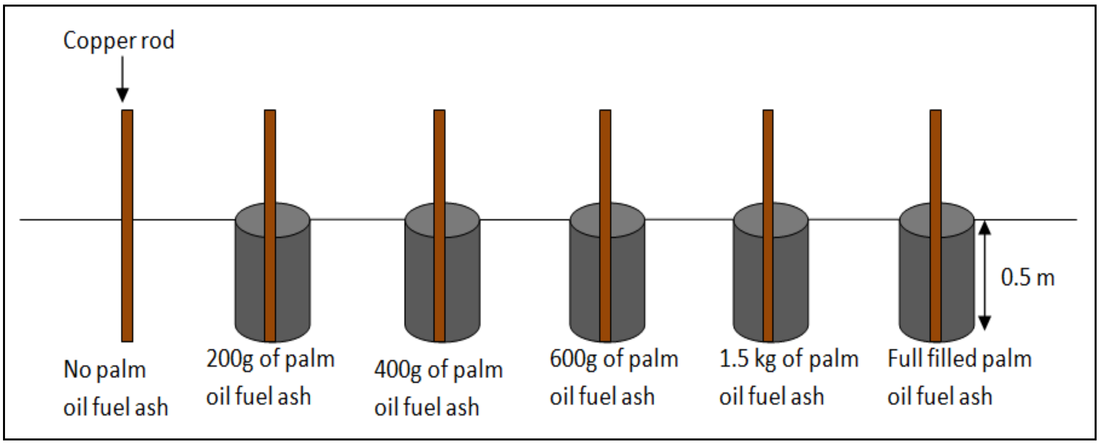

Figure 3. Electrode Arrangement for Copper

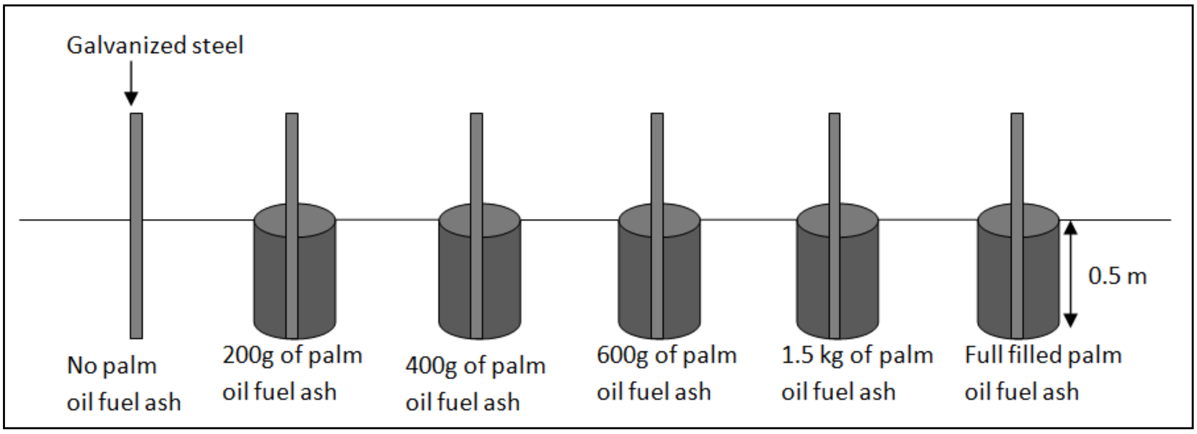

Figure 4. Electrode Arrangement for Galvanized Steel

Measuring With Testing Equipment

During the measurement, the electrode was connected to the resistivity measuring equipment by using cables. Another two spikes were buried in series with a separation distance of each spike is 3 m away as shown in figure 5. The equipment used to measure the grounding electrode resistance is Kyoritsu Digital Earth Tester Model 4105A. The monitor on the equipment displayed the value of resistance. All values were recorded in table 1.

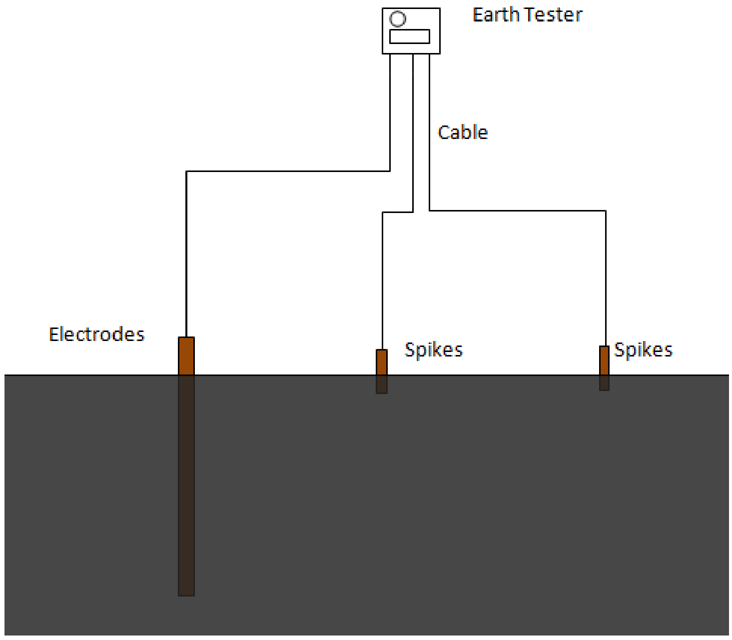

Figure 5. Arrangement for Three Pin Method

On the testing instrument, Kyoritsu Digital Earth Tester Model 4105A the selector's switch was set to "2000 Ω" as the range of reading value. The TEST button was pressed and turned to obtain continuous reading. The measurement value then displayed on the LCD monitor. The soil humidity and temperature were taken by using 4 In 1 Soil Survey Instrument. By inserting the instrument's probe to the soil, this instrument displays the temperature reading and humidity level of the soil. The humidity levels displayed are DRY+, DRY, NORMAL, WET and WET+ which mean humidity less than 30%, 30-40%, 40-50%, 50-60% and more than 60% respectively. After that, the resistance measured values were recorded in Table 1. These steps were repeated for each type of electrodes and each amount of palm oil fuel ash. Figure 6 shows the step taken in measurement.

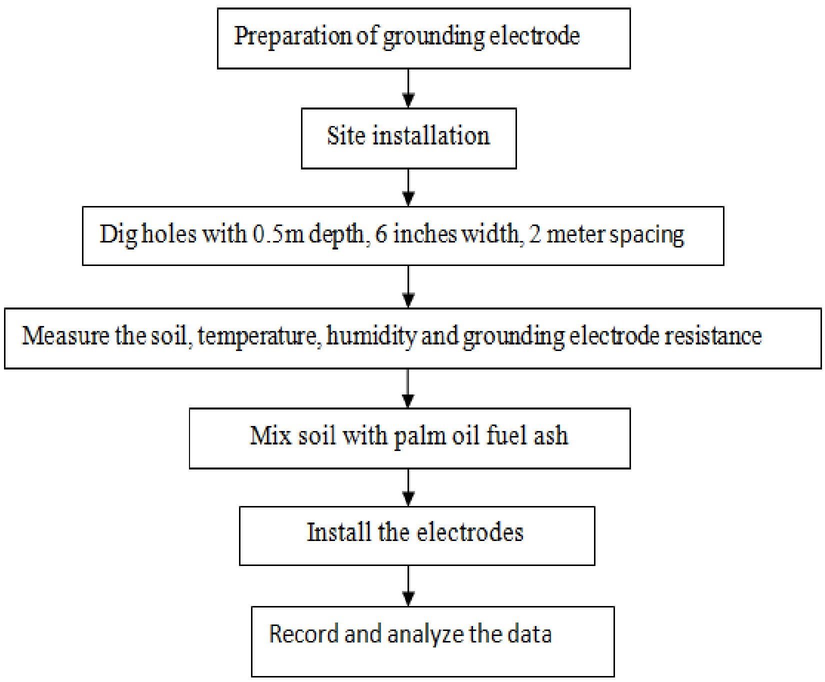

Figure 6. Grounding Electrode Resistance Measuring Steps

3. Results and Discussions

The measurement taking conducted on 12th, 13th, 14th, 16th and 17th March 2019. The measurement was performed by taking a set of reading daily. This was done by varying the types of electrodes which are copper rod and galvanized steel and by varying the amount of palm oil fuel ashes which were 200 g, 400 g, 600 g, 1500g and 3000 g (without mixing with soil). The grounding electrode resistance obtained during the measurement was recorded in table 1.

Table 1. Measured Grounding Electrode Resistance Value

Day	Soil Tempe rature (˚C)	Soil Humidity	Material	Grounding Electrode Resistance (Ω) Based On Palm Oil Fuel Ash Amount (G)					
				0 g	200 g	400 g	600 g	1500 g	3000 g (No soil)
1	32	50-60%	Copper	171	37.7	31.9	23.7	34.5	15.0
			Galvanized Steel	141	27.0	24.0	18.0	32.0	7.0
2	31	>60%	Copper	145	38.0	33.0	23.0	35.0	15.0
			Galvanized Steel	138	28.0	25.0	19.0	33.0	7.0
3	32	30-40%	Copper	181	41.0	35.0	24.0	37.0	16.0
			Galvanized Steel	134	29.0	26.0	19.0	35.0	9.0
4	30	<30%	Copper	184	48.0	41.0	27.0	44.0	19.0
			Galvanized Steel	138	33.0	29.0	22.0	57.0	13.0
5	31	<30%	Copper	191	54.0	45.0	29.0	49.0	21.0
			Galvanized Steel	149	35.0	32.0	23.0	85.0	16.0

The values recorded in Table 1 are interpreted in the form of graphs in figure 7 and figure 8 so that any changes in trends can be easily understood.

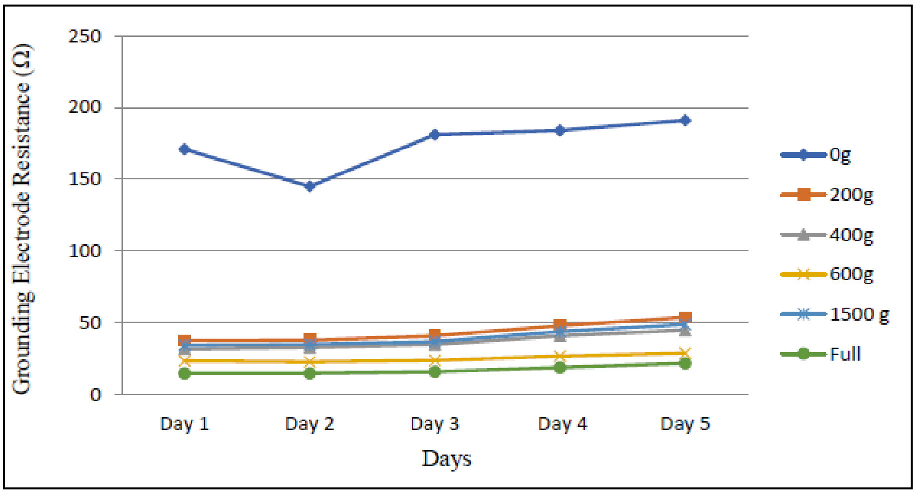

Figure 7. Grounding Electrode Resistance Taken for 5 Days Using Copper Rod

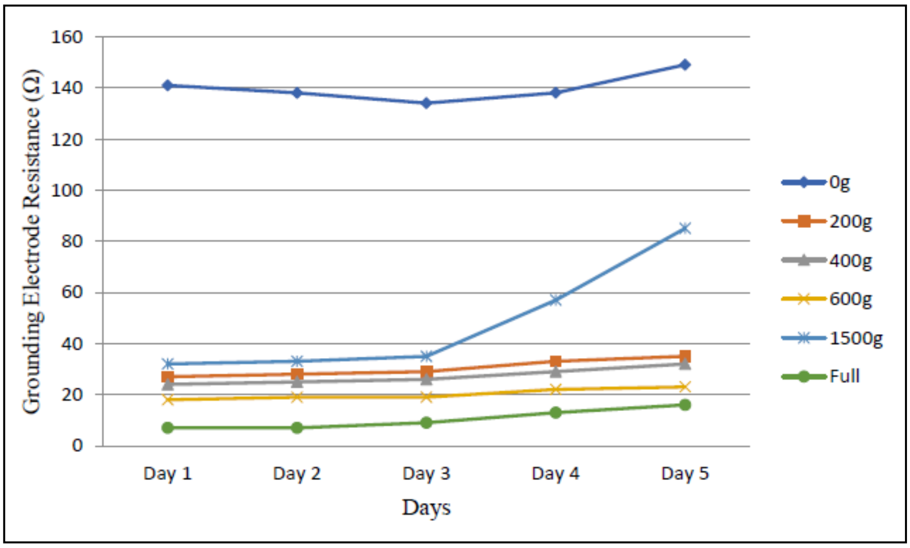

Figure 8. Grounding Electrode Resistance Taken for 5 Days Using Galvanized Steel

Based on the graph trend from figure 7 and figure 8, the changes in grounding rod resistance value are influenced by many factors. The first factor that influences the changes of grounding rod resistance is the amount of palm oil fuel ash added to the soil. From the first day until the fifth day, most of the cases the grounding electrode resistance decreased as the palm oil fuel ash added increase from 0 g, 200g, 400g and 600g. However, when the 1500g of palm oil fuel ash is added, the grounding electrode resistance increased. This increment should not happen. This is due to the soil structure around the holes that is slightly stony and rocky. The stones and rocks are capable to affect the soil resistivity by reducing the compactness of the soil hence affect the grounding electrode resistance. For full-filled palm oil fuel ash, the grounding electrode resistance decreased and achieved the lower value of grounding electrode resistance compared to others. From these observations, it can be concluded that the larger amount of palm oil fuel ash added, the lower the value of grounding electrode resistance obtained. This might be due to the reason that the palm oil fuel ash has lots of ions content such as Na2+, K2+, Ca2+ and Mg2+ [14]. The high number of ions helps to conduct electricity from electrode to the ground hence lowering the grounding electrode resistance value.

The second factor is the soil humidity. As can be seen from the results, the soil humidity is changing from day 1 to day 5. Day 1 the soil humidity is about 50-60 %. Take copper rod with no palm oil fuel ash added as a reference. The grounding electrode resistance on day 1 is 171Ω. Then the soil humidity rose to more than 60 % on day 2. The grounding electrode resistance on day 2 dropped to 145Ω. Then on day 3 the grounding electrode resistance varies between 30- 40% and the grounding electrode resistance increased to 18 Ω. On day 4, the soil humidity dropped again to below than 30% and the grounding electrode resistance increased to 184 Ω. Same goes to day 5 where the grounding electrode resistance increased to 191Ω as the soil humidity is below than 30%. The grounding electrode resistance value increased as the soil humidity decreased. Higher moisture content means a higher number of ions that may help to conduct electricity from electrode to the ground hence low in resistance value.

Another factor that changed the grounding electrode resistance value is the material used as electrodes. In this study, the grounding electrode resistance value for galvanized steel electrodes is lower compared to the copper rod. The performance in the grounding of galvanized steel is better than the copper rod as the galvanized steel serve a low impedance path for current from rod to ground. Moreover, galvanized steel has a protective layer of zinc to prevent any corrosion from occurred. The comparison between the average of grounding electrode resistance in 5 days against the amount of palm oil fuel ash for copper rod and galvanized steel is shown in figure 9.

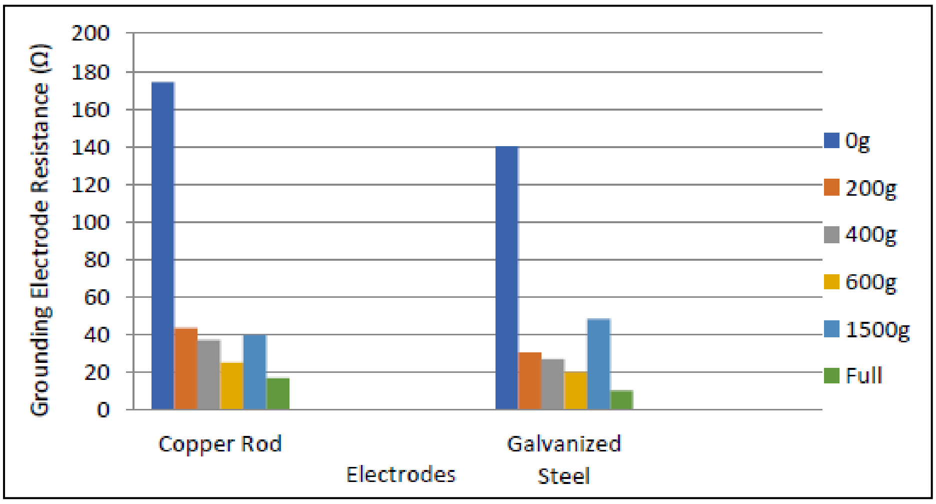

Figure 9. Comparison of Average of Grounding Electrode Resistance between Copper Rod and Galvanized Steel

4. Conclusion and Recommendation

As a conclusion, adding the palm oil fuel ash as an additive material to the soil can improve the grounding performance for at least 90% for both galvanized steel and copper rod. The grounding electrode resistance decreased as the amount of the palm oil fuel ash added increase, except for 1500 g case. Comparing both copper rod and galvanized steel electrodes, the galvanized steel shows better results than copper rod. Based on this study, the galvanized steel seems to serve better than the copper rod as a grounding rod as the galvanized steel has a lower impedance for current to flow to the ground for discharge purpose.

The palm oil fuel ash can be obtained easily in any palm oil factory in Malaysia and with minimum cost. Using the palm oil fuel ash as an additive material, it also helps to reduce the waste from palm oil factory, and thus this could help the environment protection by reducing the demand of landfill for disposal purpose.

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