Penerbit Akademia Baru

Journal of Advanced Research in Materials Science
ISSN (online): 2289-7992 | Vol. 24, No.1. Pages 1-8, 2016

Grounding Enhancement Material Using Bentonite

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Abstract – *This paper discusses the effectiveness of bentonite as grounding enhancement material when it is mixed with different types of soil. The main objective is to study the characteristics of soil resistivity for 2 types of soil such as laterite and peat soil when bentonite is added to it and to investigate whether it can effectively reduce the soil resistivity. Based on the measurement result, it was found that the addition of bentonite to these soils can effectively reduce soil resistivity and grounding resistance.*

Keywords: Bentonite, grounding system, soil resistivity, ground resistance

1.0 INTRODUCTION

Grounding system is one of the important elements in electricity, where it is defined as a zero voltage point in electrical system in which the point is normally connected to ground or earth. It is a system that has form of grid of horizontally buried conductors, supplemented by a number of vertical rods connected to the grid [1]. In the electrical system, soil regularly utilized as the grounding system medium in light of its exceptionally poor power conduit. According to IEEE 81-2002 [2], soil has its own particular resistivity, known as soil resistivity, which strongly influences the execution of the grounding system. There are a few components that affect the development of grounding system. Those are soil resistivity, stratification, size and sort of electrode utilized, profundity which the terminal is covered and ultimately the dampness and substance of the soil [3]. A good and efficient grounding system should have 'zero impedance', however since nothing in this world is impeccable or perfect, it is difficult to get that value as soil is shaped by minerals, natural matter, water, air and living organic entity.

There are three main purposes of the grounding system [4]. The first one is for overvoltage protection. Lightning, line surges or unintentional contact with higher voltage lines can induce dangerous high voltages to the electrical distribution system wires. Grounding provides an alternative path around the electrical system of the building, thus minimizes damage from such occurrences. Secondly, grounding system is used for voltage stabilization. It is known that there are several voltage sources in electrical system. If there are no common reference point for all these voltage sources, hence it would be extremely difficult to calculate their relationships to each other. Further, earth is the most omnipresent conductive surface, and so it was adopted in the very beginnings of electrical distribution systems as a nearly universal standard for all electrical systems. The third purpose of grounding system is for current path in order to facilitate the operation of overcurrent devices. This is the most important purpose of grounding system because it provides certain level of safety to humans and properties in case of equipment damages.

Journal of Advanced Research in Materials Science
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In this cutting edge time and age, the grounding system has been truly examined all around the globe. So much change had been made with a specific end goal to accomplish the best grounding system, as it can forestall harm to hardware, human life and structures. In China, a study has been conducted to understand how safety in grounding system can be affected by weather [5]. From the study, they observed that during raining season, the low-resistivity soil layer was formed. In this circumstances, the touch voltage would expand, yet at the same time less than the real touch voltage. While in freezing season, high-resistivity soil layer was framed, bringing about expanding of step and touch voltage in the system. The increasing of step and touch voltage amid this season was over the breaking point of the step and touch voltage chose by surface granite layer.

There are several studies conducted related to the enhancement of grounding system for example those by Ramualdo-Torres [6] and Lee [7]. Both of them study about the improvement of the ground resistance of power systems. A considerable measure of study about the grounding system these days demonstrate how vital is the grounding system itself. Further, a study done by Yamani et al. [8], proposed new method to reduce grounding resistance by utilizing water absorbent polymer. The study came about that the water absorbent polymer can assimilate and keep water for a long stretch. The polymer additionally decreased the corrosion of grounding electrodes. In this way, the water absorbent polymer can be utilized as the backfill of the soil so as to increase the execution of grounding system and in addition bring down the grounding resistance. The polymer is utilized as diminishing material of grounding resistance on account of its strength in long term climate changes. The measure of polymer utilized is just 1/160 compared with bentonite, however it is as compelling as bentonite. Therefore, all in all, by utilizing water absorbent polymer, the grounding system performance can be increased by bringing down the ground resistance. Some other studies used palm oil ashes [9], rice straw ashes [10] and coconut husk ashes [3] as an additive to the soil and those studies proved that carbon produced from the ashes can reduce the soil resistivity.

On the other hand, bentonite is a widely used ground enhancement material (GEM) available in the market. Its ability to absorb moisture makes it the best solution to a good grounding system for a high resistivity soil especially rocky soil such as in Greece [11]. Grounding system for lightning protection system consists of ground electrode and ground medium. The best ground electrode should be used to construct a good grounding system as it has a high conductivity so that the surge current can be grounded in a shorter time. Besides that, the electrode must be able to withstand the corrosion process in the soil so that the electrode last longer and also should be mechanically robust to withstand the repeated fault and surge current.

This study will focus on the ground resistance and soil resistivity measurement for different type of soils in Malaysia. Two types of soils are chosen for testing. They are laterite soil which was taken in vicinity of High Voltage and High Current (IVAT) and peat soil which was taken from Pontian, Johor. This study will use bentonite as grounding enhancement material to reduce the soil resistivity. The measurement of the soil resistivity was conducted using Wenner's arrangement method.

2.0 METHODOLOGY

The experiment that was conducted in this study is based on Wenner's Arrangement Four Pin method (Figure 1). The aim is to measure the soil resistivity and procedure for this experiment is according to the standard of Institute of Electrical and Electronics Engineers (IEEE) [2]. This is a suitable method for measuring apparent resistivity of large volume of undisturbed earth.

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This four-point method is divided to two arrangements, which are equally spaced arrangement and unequally spaced arrangement. Four probes of galvanised steel are installed in the earth, all at the depth of ‘b’ and separated by ‘a’, which is in straight line arrangement. Then, a test current between the two outer probes and potential difference between the two inner probes are measured using potentiometer or high-impedance voltmeter.

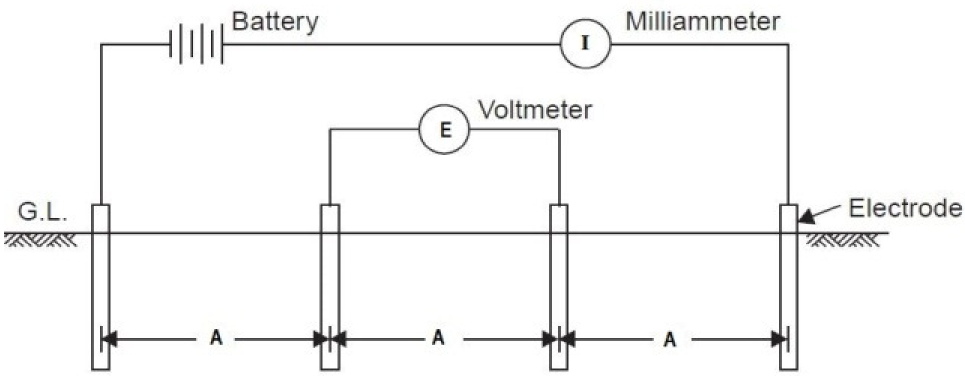

Figure 1: Wenner’s Four Pin Method Arrangement. Figure adapted from [12]

In the above figure, *a* represents the distance between two probes, while *b* is the depth of buried probes. The apparent resistivity, ρ in term of A, b and R is:

$$\rho = \frac{4\,\pi AR}{1+\frac{2A}{\sqrt{A^2+4b^2}}-\frac{A}{\sqrt{A^2+b^2}}} \tag{1}$$

where ‘R’ is the Wenner’s resistance measured as (V/I).

2.1 Physical Scale Model for Grounding System

The resistivity measurement was conducted in the vicinity of High Voltage and High Current Institute (IVAT). Four holes were prepared and each of them was filled with the mixture of soil and bentonite. Then a rod was placed at the center of each hole and buried in a depth of one meter as shown in Figure 2 and Figure 3. Two samples of the soil were used for the measurement. Each sample was labelled for easy identification. One of the samples is a reference/control for another sample. The samples that were tested in this experiment are:

i. Laterite (controlled sample)
ii. Peat soil (controlled sample)
ii. Mixture of soil and bentonite (tested sample)

The ground electrode used throughout the experiment is a 1-foot vertical copper ground rod. The size of the holes to backfill the rod with samples test is six-inch width and 1.6 ft. depth. Four holes are prepared for each sample. A total of four probes are installed in the soil with the depth of “*b*” and the probes are equally spaced by an interval of “*a*”. All probes are installed in a straight line. The two outer probes are then injected with a test current while the voltage drop is measured between the two inner probes using a potentiometer or high-impedance voltmeter. ABEM Terrameter SAS 300C was used as ground measuring instrument.

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ISSN (online): 2289-7992 I Vol. 24, No.1. Pages 1-8, 2016

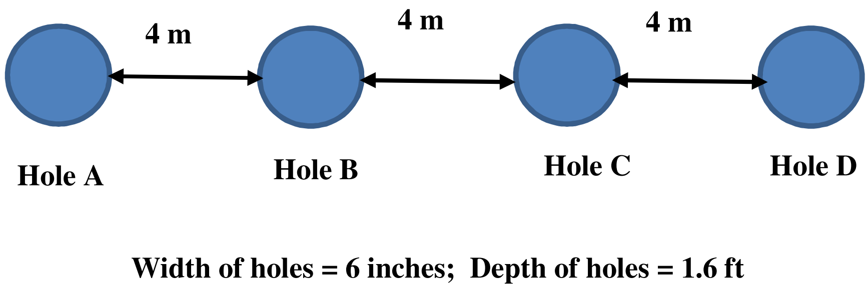

Figure 2: Grounding system scale model design.

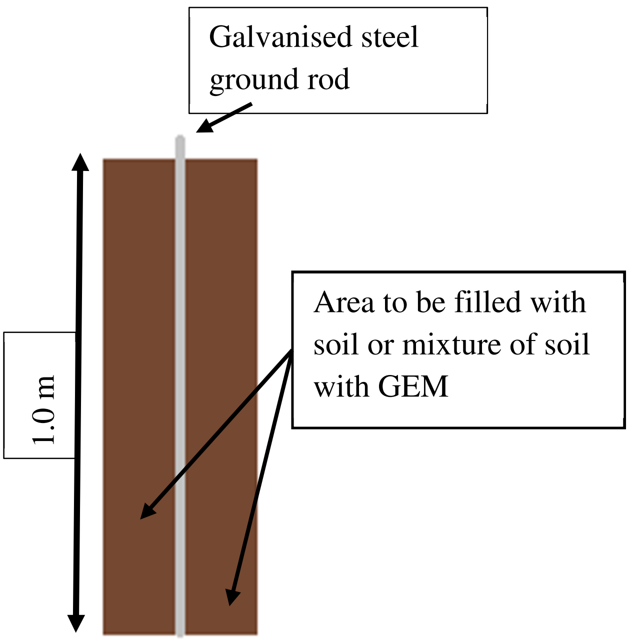

Figure 3: Ground Electrode Model

The experiment is monitored for one month. If raining, the data would be collected after the rain. Four sets of data were collected from each sample and the average reading was calculated for a more accurate result. The ground resistance reading was taken every day. Each sample was tested for one week.

3.0 RESULTS AND DISCUSSION

The measurement was conducted from 16th March 2016 until 22th March 2016. The measurement was performed for a week and a set of 4 readings were taken daily. Two scale model of grounding systems according to Wenner's arrangement method were constructed. The first grounding system was constructed using laterite soil as grounding medium while the second grounding system was constructed using peat soil. After one week, both controlled samples were mixed with different amount of bentonite that was 50g, 150g, and 250g. The value of grounding resistance was measured using ABEM Terrameter SAS 300C. The tests

Journal of Advanced Research in Materials Science
ISSN (online): 2289-7992 I Vol. 24, No.1. Pages 1-8, 2016

result for each constructed grounding system with bentonite was then compared to the result of controlled sample as tabulated in Table 1 and 2, respectively.

Table 1: Average ground resistance for laterite soil grounding system scale model

Day	Average ground resistance of laterite soil (Ω)	Average ground resistance of laterite soil + bentonite (Ω)		
		50g	150g	250g
1	2.95	2.83	2.83	2.87
2	2.94	5.36	2.82	2.88
3	2.94	2.74	2.79	2.89
4	2.92	2.72	2.82	2.86
5	5.47	2.80	2.81	2.66
6	2.82	2.74	2.82	2.86
7	2.84	2.81	2.80	2.87
Mean	3.26	3.14	2.81	2.84

The ground resistance value of controlled laterite soil is found to be 3.26 Ω and it is further reduced when bentonite was added to it. The ground resistance decrease to 3.14 Ω when 50 g bentonite was added while 2.81 Ω and 2.84 Ω, respectively when 150g and 250g bentonite was added. Note that the ground resistance of 150 g and 250 g bentonite is almost similar and not much difference is observed between those two readings. Meanwhile, the ground resistance of controlled peat soil is 5.21 Ω, which is considerably higher than ground resistance of laterite soil. As tabulated in Table 2, one can clearly see that in general, the ground resistance is decreasing from 4.62 Ω to 4.60 Ω when the quantity of bentonite is increasing (50g to 250 g).

Table 2: Average ground resistance for laterite soil grounding system scale model

	Soil Resistivity (Ωm)			
	Laterite	Laterite + 50g bentonite	Laterite +150g bentonite	Laterite + 250g bentonite
	74.14	71.08	71.08	72.21
	73.76	134.71	70.82	72.33
	73.84	68.81	70.12	72.58
	73.46	68.31	70.95	71.83
	137.35	70.37	70.50	66.93
	70.87	68.94	70.82	71.88
	71.38	70.50	70.32	72.21
Mean	82.1	78.9	70.7	71.4

Based on the collected data for ground resistance, the value of soil resistivity was calculated based on formula (1) above. During the experiment, the four rods are placed in a straight line at interval *a* (*a*=4m), and driven to a depth not exceeding 0.1a which is 0.4 m, then *b* is assumed to be equal to zero and the following equation is yield.

$$\rho=2\pi aR \tag{2}$$

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Table 3: Laterite soil resistivity

Day	Average ground resistance of peat soil (Ω)	Average ground resistance of peat soil + bentonite (Ω)		
		50g	150g	250g
1	4.76	3.84	4.81	4.59
2	4.76	5.74	4.71	4.62
3	4.76	4.42	4.66	4.62
4	4.81	4.55	4.70	4.62
5	4.84	4.57	4.70	4.61
6	4.63	4.62	4.80	4.59
7	7.93	4.66	4.69	4.58
Mean	5.21	4.62	4.72	4.60

Table 3 shows that the mean of laterite soil resistivity without bentonite is 82.1Ωm. When 50g of bentonite was added to the soil, the resistivity decrease slightly to 78.9 Ωm. The value is further decreased to 70.7 Ωm when 150g of bentonite was added to the ground medium. However, the average value increases a bit when to 71.4 Ωm when 250g of bentonite added to the laterite soil.

Table 4: Peat soil resistivity

	Soil Resistivity (Ω m)			
	Peat	Peat + 50g bentonite	Peat +150g bentonite	Peat +250g bentonite
	119.7	96.5	120.9	115.4
	119.7	247.9	118.3	115.9
	119.5	111.0	116.9	115.9
	120.9	114.4	118.1	116.2
	121.5	114.7	118.1	115.8
	116.3	116.2	120.6	115.2
	199.2	117.1	117.7	115.2
Mean	130.9	131.1	118.6	115.6

On the other hand, as tabulated in Table 4 it can be observed that the resistivity of peat soil is higher compared to laterite. This is because laterite soil has a high clay content which means higher water-holding capacity than peat soil. The existence of high water content (moisture) in laterite soil contributes largely to the lower value of resistivity. It can be observed that the mean value of resistivity for controlled peat soil is 130.9 Ωm but the value increase slightly when 50g of bentonite was added to it. The increment may be due to hot and dry weather, when bentonite shrunk forming a large air gap in the soil between the ground electrode and the ground medium. However, when the amount of bentonite is increased to 150g and 250 g 118.6 Ωm and 115.6 Ωm, respectively.

4.0 CONCLUSION

The performance of bentonite is strongly depending on the amount of rainfall, soil humidity, moisture and temperature of the surrounding. Even though in general the soil resistivity for both types of soils were reduced when bentonite was added to it, the reduction is not extensive.

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This could be due largely to the effect of hot weather in Malaysia during the measurement where the highest temperature of 36˚C was recorded. This has contributed to the dryness of tested soil thus affecting the resistivity value of the soil. However, based on the measurement result, it can be concluded that bentonite can be used as GEM to reduce soil resistivity and thus reducing grounding resistance.

ACKNOWLEDGEMENT

This project was fully supported by Universiti Teknologi Malaysia, GUP grant no. 07H13 and 13H96 as well as financial supported by MOHE from grant no 4F672.

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