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Analysis of Grounding Resistance Performance for Various Bio Fillers Medium Effect

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Abstract

Electrical grounding, crucially known as earthing, safeguards against electric shocks by redirecting current during short circuits. This study investigates enhancing grounding systems economically using bio-fillers in peat soil to mitigate high soil resistivity. The research aims to improve grounding efficiency by incorporating bio-based materials such as seashells and banana peels. Four configurations—standard copper with peat soil, with banana peel, with seashell, and with a combination of peat soil, seashell, and banana peel—were tested over 30 days to measure grounding resistance. Results reveal that standard copper with peat soil alone demonstrated the most efficient performance with the lowest and most stable resistance (7.5 to 8.4 ohms). The combination of peat soil, seashells, and banana peels showed intermediate resistance (7.7 to 8.8 ohms), while adding banana peels slightly increased resistance (8.5 to 9 ohms). In conclusion, peat soil emerges as the optimal grounding medium due to its effectiveness in achieving low and consistent resistance values.

1. Introduction

Electrical grounding, sometimes referred to as earthing, serves as a safety line to reroute electric current in the event of short circuits, which essentially offers some protection from electric shocks. This is achieved for domestic equipment using a three-pronged electrical socket that has a separate grounding prong [1].

Bio-based materials are created using renewable biomass sources. Typically, these sources consist of marine, forestry, plant, and animal components. Algae and effluent from sugar refineries and biofuel manufacturing are two more potential sources [2]. The possible applications of bio-based filler materials in electrical systems have drawn attention to banana and seashell trash. Seashell waste contains calcium carbonate, which can act as a dielectric, while waste from bananas has been shown to contain cellulose and lignin, which are recognized for their insulating qualities [3].

The degree to which soil resists the flow of electricity is known as soil resistivity. Low resistivity is favored since low ground resistance is required or preferred in most applications. The ground resistance by itself is not as important in many applications as the grounding configuration. A high soil resistivity, however, still poses difficulties for these designs and can exacerbate flaws or under design [4]. In earthing systems, soil resistivity is crucial because it directly affects the performance and security of electrical installations. Creating a secure route for electrical fault currents to dissipate into the ground is the main goal of an earthing system in electrical installations [5].

Soil resistance is most important when designing a grounding system for new installations (green field applications) to meet ground resistance requirements. Soil resistivity is affected by temperature, moisture content, and composition of the soil. Rarely is soil homogenous, and the resistivity of the soil varies with soil depth and location [6].

Research conducted at Durban University of Technology (DUT) on soil resistivity and its impact on grounding systems design [7] has highlighted the significant influence of soil depth and moisture content on resistivity. Utilizing the Wenner method, researchers found that soil resistivity decreases with increased moisture content and varies with depth and spacing. The results provide essential insights for designing effective earthing protection schemes, emphasizing the need to consider soil moisture and type to minimize voltage elevation, ensure a steady power supply, and protect personnel and equipment. Wet soil consistently showed lower resistivity compared to dry soil, reinforcing the importance of moisture in achieving optimal grounding system performance.

Other than that, prior study by the researchers [8] indicates that moisture is an essential requirement for low resistance. When defining the evaluation of an earthing system, the two-layer model is appropriate to utilize. Compared to high soil resistivity, low soil resistivity has the advantage of requiring fewer electrodes to achieve the desired earth resistance.

2. Materials and Methods

2.1 Grounding Rod

A standard copper rod's shape that was comparable to that of a nail that can pierce through soil with ease was used in this project. Researchers from Universiti Tun Hussein Onn in Malaysia [9] have demonstrated that copper rods exhibit superior soil resistivity values compared to other materials like iron, making them highly suitable for grounding systems. The study, which used the Wenner Four Point method to measure soil resistivity in clay soil, found that new rod designs with branches were not effective replacements for standard rods due to significantly higher measured resistivity. Copper's high conductivity and durability, as it effectively transfers electrical discharge to the ground without rusting even after long-term burial, make it an ideal choice for earthing. Therefore, copper rods were used in this project for their proven efficiency, reliability, and long-term performance in grounding applications.

In this grounding system project, a single vertical grounding electrode was used due to its ability in dispersing lightning currents and its simplicity in design and implementation [10]. Vertical grounding electrodes are commonly utilized in lightning protection systems because they provide a direct path for the lightning current to flow into the earth, minimizing the risk of high voltage buildup that could damage infrastructure or pose a danger to people. The primary function of the grounding electrode is to effectively disperse the lightning current to the earth, and vertical electrodes have been shown to perform this task efficiently.

Furthermore, research has indicated that the grounding resistance decreases with increasing vertical ground distance from the lightning current injection point [11]. This suggests that longer vertical electrodes can improve the grounding system's performance by reducing the minimum impulse grounding resistance. In this project, using a single vertical grounding electrode allows for a straightforward and reliable method to achieve low grounding resistance, essential for ensuring the safe operation of the system. By adopting this configuration, the project leverages the proven benefits of vertical grounding electrodes in effectively managing and dispersing fault and lightning currents, providing a dependable grounding solution. The standard copper rod used was shown in Fig. 1.

Fig. 1 *Standard copper rod*

2.2 Bio Fillers

The bio fillers chosen to aid in this grounding system project were seashell and banana peel. In this project, a ratio of 20% bio filler to 80% peat soil was used. To ensure accurate and consistent measurements, the same container was utilized to measure both the bio filler and the peat soil. This method allowed for precise volumetric ratios, ensuring that 20% of the container's volume was filled with the bio filler mixture (comprising seashell and banana peel), while the remaining 80% was filled with peat soil.

Seashells were chosen as a bio filler for this grounding system project due to their intriguing hierarchical structure, which spans from the nanoscale to the macroscopic scale. Composed of macromolecules and calcium carbonate (CaCO3), seashells possess remarkable properties that can be advantageous for enhancing electrical conductivity. A study published in the International Journal of Molecular Sciences [12] reported the synthesis of polypyrrole using waste seashell powder, producing a composite material with electrical conductivity. This suggests that seashells can be converted into particles that conduct electricity, making them a potentially useful material for grounding systems. The crushed seashells that were used in this project were shown in Fig. 2.

Fig. 2 *Crushed seashells*

Banana peels were selected as the second bio filler due to their abundance and high moisture content, making them a significant component of food waste in Malaysia. Research indicates that banana peels in Malaysia contain approximately 88% moisture [13], which is advantageous for grounding systems as moisture can lower soil resistivity and enhance conductivity. The high moisture content and availability of banana peels make them a practical and effective choice for improving the grounding resistance performance of the system. By utilizing banana peels, the project aims to leverage their natural properties to achieve a more efficient and sustainable grounding solution. The banana peels that were used in this project were shown in Fig. 3.

Fig. 3 *Banana Peels*

2.3 Fall of Potential Method

The Fall of Potential method was chosen to measure the grounding rod resistance in this project due to its accuracy and reliability. By applying Ohm's law [14] and measuring the voltage drop between a movable electrode and the electrode being tested, this method provides a precise resistance measurement of the grounding electrode. Its ability to accurately determine the total resistance value, regardless of whether the ground electrode is in parallel or series with other rods, makes it a widely accepted and trusted technique.

Furthermore, the versatility of the Fall of Potential method allows it to be effective in various soil conditions, which is essential for evaluating the impact of different bio fillers. Its simplicity, proven effectiveness, and consistent results ensure a comprehensive and dependable assessment of the grounding system's performance. This makes it the ideal choice for accurately measuring and analyzing the grounding rod resistance in this project. Fig. 4 illustrates the fall of potential method used in this project.

Fig. 4 *Fall of potential method*

2.4 Digital Earth Tester

The digital earth resistance tester used to measure the earth resistance accurately and safely was shown in Fig. 5. The choice of this instrument is due to its user-friendly design and precise instructions, ensuring that reliable readings can be obtained. The procedure begins by checking the battery symbol to ensure that the device has sufficient power, as a low battery can lead to inaccurate results. The tester is then connected to the test leads using the supplied earth spikes, and the switch is flipped to check the earth voltage. Ensuring that the earth voltage is 10V or less is crucial to prevent erroneous resistance readings.

The digital earth tester offers a step-by-step approach to ensure accurate measurements. After verifying the earth spikes and adjusting the switch to 2000 ohms, the "PRESS TO TEST" button is used to check for high resistance readings, indicated by a blinking symbol. If necessary, adjustments can be made to the connections, spike positions, or by applying water to reduce resistance. The tester allows for selecting the appropriate range for measurement and provides precise readings by pressing "PRESS TO TEST". Additionally, a two-wire system can be used with an existing earth electrode for simplified measurements when auxiliary earth spikes are not feasible. By following these detailed procedures, the digital earth resistance tester ensures methodical and trustworthy measurements of grounding rod resistance, which is essential for evaluating the performance of different bio fillers in the grounding system.

Fig. 5 *Digital Earth Tester*

3. Result and Discussion

3.1 Soil Composition

The project successfully achieved its objective of enhancing peat soil with bio-fillers to create new soil compositions for grounding systems. By utilizing natural materials such as banana peels and seashells, the project developed innovative soil mixtures that demonstrated improved conductivity and overall performance. The first notable outcome was the formulation of a new soil composition using banana peel and peat soil. This mixture leveraged the high moisture content and organic matter of banana peels, resulting in a practical and effective grounding medium. The banana peel and peat soil composition improved soil structure and moisture retention, providing a sustainable solution that repurposes organic waste and enhances soil conductivity for optimal grounding system performance. The banana peel and peat soil composition were shown in Fig. 6.

In fig. 6, the banana peel composition has water, unlike the seashell composition and the combination of seashell, banana peel, and peat soil, which appear dry. This difference is due to the conditions during the project. While the soil used was the same for all samples, it rained when the hole was dug to bury the sample with the banana peel composition, resulting in a wetter mixture. The rainwater contributed to the higher moisture content observed in the banana peel composition, while the other samples remained dry.

Fig. 6 *Banana peel and peat soil composition*

In addition to the banana peel mixture, a second soil composition was created using peat soil and seashells. The seashells, primarily composed of calcium carbonate, were crushed and mixed with peat soil, enhancing the soil's alkalinity and structural integrity. Although the seashell composition did not significantly increase the grounding system's efficacy, it demonstrated the potential of marine bio-fillers to improve specific soil properties, such as nutrient availability and reduced compaction. Fig. 7 shows the seashell and peat soil composition.

Fig. 7 *Seashell and peat soil composition*

The final achievement was the successful creation of a composite soil made of peat soil, banana peel, and seashell. This three-component blend combined the structural benefits of seashells with the moisture-retentive qualities of banana peels, resulting in a well-balanced medium that offered promising conductivity and nutrient availability. The project effectively demonstrated the potential of combining various bio-fillers to create efficient soil compositions, meeting the project's objectives and paving the way for further research and application in grounding systems. The soil composition with peat soil, seashells, and banana peels is shown in Fig. 8.

Fig. 8 *Banana peel, seashell and peat soil composition*

3.2 Grounding Resistance

Fig. 9 shows the results of the grounding resistance measurements over a 30-day period that clearly indicate that peat soil alone provides the most effective and stable grounding medium, with resistance values consistently around 8 ohms. This configuration demonstrated minimal variability and maintained low grounding resistance, making it a dependable option for grounding systems. The addition of banana peels to the peat soil slightly increased the grounding resistance to between 8.5 and 9 ohms, but the resistance remained relatively stable, indicating that banana peels are a viable bio filler that offers consistent performance, albeit with a modest impact on resistance.

This finding does not imply that the use of bio-fillers is useless. Bio-fillers like banana peels and seashells offer several advantages that justify their inclusion in grounding systems. They promote sustainability by repurposing organic waste, improving soil structure and moisture retention, and providing a cost-effective alternative to synthetic materials. Moreover, the stable performance of bio-filler-enhanced soil ensures reliable grounding resistance, while contributing to environmental conservation and resource efficiency. Therefore, the use of bio-fillers enhances the overall value and sustainability of grounding systems, making them a practical and environmentally friendly choice.

Next, the inclusion of seashells in the soil composition significantly increased the grounding resistance, with values consistently between 10 and 11 ohms, suggesting that seashells are less effective in enhancing grounding performance. The combination of seashells and banana peels resulted in grounding resistance values that were higher than peat soil alone but lower than seashells alone, showing a moderate impact on resistance. This finding can be attributed to the distinct properties of each bio-filler and their interaction within the soil composition. Banana peels, with their high moisture content, help reduce soil resistivity, partially offsetting the resistivity increase caused by seashells. Additionally, the organic matter and moisture retention properties of banana peels improve soil structure and reduce porosity, balancing the effects of seashells. Overall, while certain bio fillers like banana peels and seashells have varying effects on grounding resistance, peat soil alone remains the best option for achieving low and stable grounding resistance. These findings align with previous research [15] on bio fillers, such as pineapple leaves, which also show potential for optimizing grounding systems, although peat soil continues to perform admirably on its own.

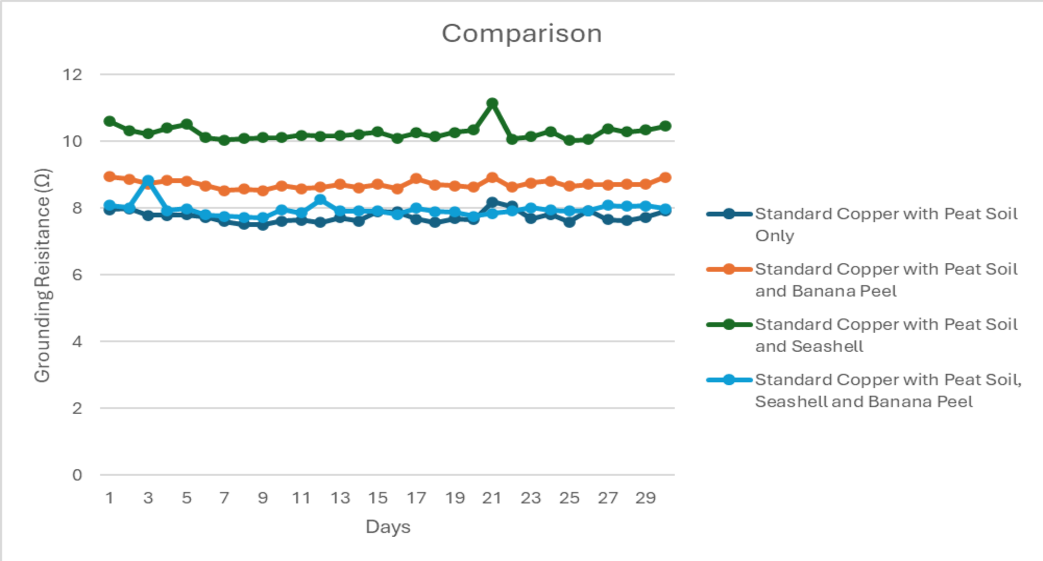

Fig. 9 *Data analysis*

4. Conclusion

The study's findings demonstrate that peat soil alone is the most effective grounding medium, providing the lowest and most consistent grounding resistance values, ranging from 7.5 to 8.4 ohms. This setup exhibited excellent stability and efficacy, confirming its dependability as a grounding medium. The incorporation of banana peels slightly increased the grounding resistance to an average of 8.5 to 9 ohms, but the values remained stable over time, indicating that banana peels can be considered a viable bio filler for maintaining consistent grounding performance.

Conversely, the addition of seashells significantly raised the grounding resistance, with values ranging from 10 to 11.4 ohms, highlighting their ineffectiveness in enhancing grounding systems. The combination of peat soil, seashell, and banana peel showed a moderate impact on grounding resistance, with values between 7.7 and 8.8 ohms, performing better than seashells alone but still higher than peat soil by itself. Overall, the research concludes that while banana peels can be a reliable option for grounding systems, seashells are less suitable due to their tendency to increase resistance significantly. Peat soil alone remains the optimal choice for achieving low and stable grounding resistance.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: study conception and design: Abdul Munzir Hakim Bin Abdul Malek, Nor Akmal Mohd Jamail, Qamarul Ezani Kamarudin; data collection: Abdul Munzir Hakim Bin Abdul Malek; analysis and interpretation of results: Abdul Munzir Hakim Bin Abdul Malek, Nor Akmal Mohd Jamail, Qamarul Ezani Kamarudin; draft manuscript preparation Abdul Munzir Hakim Bin Abdul Malek,. All authors reviewed the results and approved the final version of the manuscript.

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