Evaluation of Local Backfill Materials on Earthing Systems

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Abstract

Several backfill materials are freely available as industrial wastes or at a low cost in Ghana. However, their long-term performance remains unknown. In this paper, two proposed backfill materials, charred and uncharred coconut coir, were tested against two commercially available and traditionally used backfill materials, tyre ash and palm kernel cake. A reference rod was also buried, without any backfill material, alongside the other four with backfill materials for a period of 12 months. The earth rod used in this research was the copper-coated iron rods. Fall-of-potential method of measuring resistance was used in this experiment, where we took weekly resistance readings for a period of one year. A physio-chemical analysis of samples of the backfill material and soil from the study site was conducted at the Minerals Engineering Laboratory at the University of Mines and Technology, Tarkwa. The pH, heavy metals, and organic content of the samples were determined. The rods that were buried in the four backfill materials under consideration recorded lower resistance values than that of the reference rod, with tyre ash recording the least. This finding confirms the results of other researchers about the efficacy of tyre ash and also indicates the importance of using backfill materials in earthing systems.

Keywords: Earthing Systems, Earthing Rod, Backfill Materials, Resistance

1 Introduction

Electrical shocks and electrocution incidents in the home and at the workplace have been a canker for most countries. The question that keeps lingering around is, what could be the cause? Poor considerations and system failure, frequent electrical surges and sags, and dips in power have often led to many electrical shock accidents (Barbrauskas, 2010; Hammuda e*t al*., 2011). The list goes on and on but finally ends on faulty earthing systems or absence of them. Earthing system is a term used to describe the connection of a conductor or frame of a device to the earth (Eduful and Cole, 2009). It is often used interchangeably with grounding.

Earthing is very useful in the generation, transmission and distribution of electric power safely. This system ensures the disposal of unwanted electrical charges to the earth due to earth faults at low and high frequencies (Salam *et al*., 2017; Siow *et al*., 2013). It can also be connected with the interaction of the neutral point of a power source to the soil or earth to minimise danger during the discharge of electrical energy. The purposes of earthing (Yu, 2018) are to lower the resistance of the rod to the lowest value for easy passage of current, protect human lives and electrical devices from leakage current, keep the voltage values stable in the healthy phase, secure electrical systems and buildings from lightning strikes, and serve as a return conductor in electrical traction systems and communication.

An ideal electrical earthing system usually consists of three basic parts, earth continuity conductor, earthing lead, and earth electrode (Mohan, 2016), which are in various forms, such as plates, rods, strips, solid section wire, and mats. The metals or conductors that are suitable for usage as part of earthing systems include stainless steel, copper, galvanised iron, aluminium, and lead. One important fact to note is that all these parts come into contact with the soil, therefore, the soil cannot be left out of this experiment. This is because the nature of soils, i.e., the moisture content, pH, resistivity, and temperature may influence the attainment of the low resistance.

Csanyi (2016) suggested that an increase in the length of rods, the use of multiple rods, and treatment of the soil can help achieve low resistance. It is important to note that increase in rod length enables the rod to penetrate deep into the soil to reach the permanent level of the water in the soil (Csanyi, 2016). Soil moisture content increases with depth as the soil resistivity also decreases. Earth resistance decreases with depth of electrode in earth enabling the rod with a longer length to give low resistance values.

The use of additional ground rods is one of the best means of reducing the resistance to ground as was earlier suggested by Nyuykonge (2015). For example, the combined resistance of two properly spaced rods and connected in parallel should be 60% of the resistance of one rod; and the combined resistance of three rods should be 40% of that of a single rod. Multiple rods do have their limits in a way as the number of rods reach their saturation so constant addition of more rods do not affect the resistance in any way and another demerit is that, it is quite expensive getting more rods for this purpose.

Soil treatment involves introducing ground enhancing materials in areas of poor conductivity (Csanyi, 2016). Ground enhancing materials, also known as backfill materials, are special materials (organic or inorganic) that improve the quality of the earthing. Bentonite, gypsum, marconite, tyre ash, rice straw, coco peat, palm kernel cake, and coke powder are examples of organic and inorganic backfill materials. Some backfill materials are considered to be permanent (no need for replacement) whilst others are temporal (needs replacement). These materials perform three important roles, which include protection against corrosive processes, thus lengthening life expectancy, the establishment of appropriate contact with the soil (e.g. in rocky soils), and reduction in the resistance to earth values (Smohai and Ladanyi, 2015).

Conductive backfills can be characterized by two main factors. First is the nature of the conductive backfill, which involves the material used, moisture retention abilities and pH levels. The other is the nature of the local soil, which encompasses the leaching capabilities of the local soil, and the type of soil. Based on these factors, Jasni *et al*. (2011) recommended that all ground electrode enhancing materials must possess the following characteristics; low resistivity, possibly below 0.2 Ωm, conductivity not dependent on the continuous presence of water, being a little alkaline in nature with pH value greater than 7 but less than 9, ability to absorb moisture, the capacity to remain above 10% moisture, not decomposing or leaching out with time, not polluting the soil or local water table, and meeting environmental and friendly requirements for landfills.

Much research has been conducted on the properties and usefulness of backfill materials. Eduful and Cole (2009) compared the performance of palm oil cake, tyre ash, wood ash, and powdered cocoa shells and picked tyre ash as the best material for backfilling. Androvitsaneas *et al*. (2012) experimented on bentonite, coconut coir peat and planting-clay soil. Their graphical results showed that natural materials, especially planting-clay soil are the best alternative to substitute bentonite as grounding filler since it recorded the lowest grounding resistance values at the end of the experiment. Jasni *et al*. (2010) investigated into long term performance of several backfill materials (metal oxide powder, granite power, bentonite, coke breeze, charcoal with salt, and cast-iron powder) over a 2-3-year period. They also concluded that these materials showed good performance with respect to reducing corrosion and resistivity. Coconut husk ash was used to treat stainless steel grounding system because of its ability to retain water, thereby recording lower ground resistance values (Saharom (2014). Akoto (2014) also treated three different soil types with tyre ash as a backfill material for a year with results showing a decrease in the ground resistance in all scenarios.

However, with regards to this research area, much has not been investigated on the impact of the constituent materials of the backfill materials on earthing rods. Thus, this research seeks to analyse four local backfill materials local to Ghana to know their makeup, and their ability to reduce ground resistances and preserve the copper coated iron rod for a longer time.

2 Resources and Methods Used

2.1 Materials Used

A piece of land adjacent to the premises of the Electricity Company of Ghana and opposite the University of Mines and Technology, Tarkwa was chosen as the study site for reasons of proximity and easy access. An area of 252.81 m^2 was cleared of weeds and debris and five holes were dug for burying of the rods. Each hole had a depth of 1 m and diameter of 0.38 m. The interval between adjacent holes was 5 m and the holes were dug to form a straight line.

The following materials and equipment were used for the experiment:

- Backfill materials (Tyre ash, Palm kernel cake, Charred coconut husk and Coconut coir);
- One end threaded 0.015 m in diameter by 1.2 m length copper coated iron earth rod;
- A 4-terminal digital earth tester;
- Four insulated wire conductors;
- 7.5 m long measuring tape;
- Hammer;
- Gloves;
- Scale;
- Two PVC pipe of diameter 0.1016 meters;
- Machete;
- Wooden mortar and pestle;
- Beam balance; and
- Three pairs of scissors.

2.2 Preparation of Backfill Materials

Four different backfill materials were used in this experiment, namely, tyre ash, palm kernel cake, coconut coir, and charred coconut husk. This subsection provides details of the preparation of the listed materials before usage as backfill materials.

Tyre Ash: This was obtained from Ashaiman Tulaaku, around Michelle Camp, in the Greater Accra Region of Ghana, where the vehicle tyres are burnt to singe slaughtered cattle.

Palm Kernel Cake: Two cakes of palm kernel were bought at a cost of GHS5.00 (US$1.00) and pounded into powder using a wooden mortar and pestle. It was mixed with water into a paste before usage.

Coconut Coir: Two sacks of coconut husk were collected from a Refuse Dump close to the Railways Police Station, Tarkwa. A portion of the coconut husk was milled into powder form before being used as backfill material. Figures 1, 2 and 3 depict the stages for the preparation of the coconut coir, i.e., collection of the coconut, cutting the husk into pieces for milling, and the milled coconut husk, respectively.

Fig. 1 Coconut Husk from Refuse Dump

Fig. 2 Coconut Husk Cut into Pieces for Milling

Fig. 3 Milled Coconut Husk

Charred coconut husk: The remaining portion of the coconut husk obtained from the refuse dump was charred and pounded into powder form. Figures 4 and 5 show the steps for the preparation of charred coconut husk, i.e., the charred coconut husk and pounded charred coconut husk, respectively.

Fig. 4 Charred Coconut Husk

Fig. 5 Pounded Charred Coconut Husk

2.3 Burial of Earth Rods

The earth rod used for the study was made of iron, which was coated with copper. It had a length of 1.2 m and diameter 0.015 m. About 0.1 m of the rod length was driven into the floor of the whole. The hole was then filled with a backfill material. Two resistance reading were recorded five minutes apart, one before and the other after the backfilling. The remaining rod length, i.e. 0.1 m, was left in the atmosphere and was used for the resistance measurement. Fig. 6 shows a sketch of the cross-sectional view of the arrangement of the earth rod and backfill material in the ground. Fig 7 also shows a picture of a hammered rod in the dug hole.

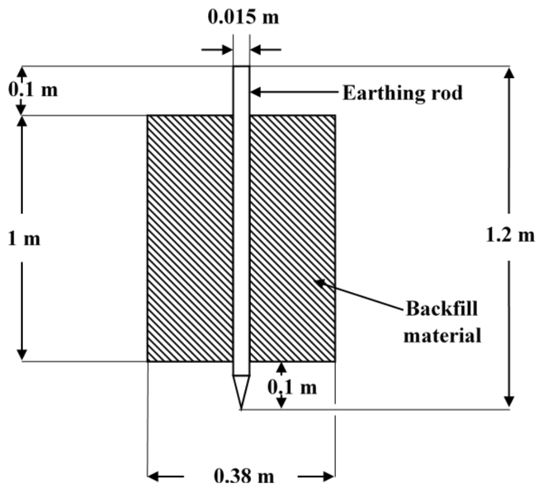

Fig. 6 Arrangement on the Field Site

Fig. 7 Hammered Rod in the Dug Hole

To ensure that the earth rod had good contact with the backfill material, a 0.9 m long and 0.1 m diameter PVC pipe was put in the dug hole to surround the hammered rod. The PVC pipe was then filled with the backfill material and allowed to settle. The space around the PVC pipe was then filled with the soil that was dug from the hole. The PVC pipe was finally removed. This procedure was repeated for all the backfill materials.

2.4 Measurement Methods

The fall-of-potential method of measuring resistance was used in this experiment and the measuring instrument employed was the Megger Det 32. The instrument consisted of three leads, 50 m, 30 m, and 3 m leads, 4 probes, a mallet, and a 7.5 m long measuring tape. The readings were taken once a week. Fig. 8 shows the Megger being used for resistance readings and Fig. 9 shows the probe ploughed to the rod for readings.

Fig. 8 Megger Used for the Resistance Readings

Fig. 9 Probe Attached to the Rod for Resistance Readings

The soil and backfill material samples were taken to the UMaT Minerals Laboratory for analysis.

3 Results and Discussion

3.1 Laboratory Measurements

The Laboratory Facility at the Minerals Engineering Department of University of Mines and Technology was used to perform physio-chemical analysis of the backfill materials and soil sample from the study site. The pH, organic carbon, exchangeable bases, particle size, heavy metals and soil moisture content were the parameters considered. Tables 1 and 2 show selected physiochemical properties of backfill materials, and soil sample.

Table 1 shows that tyre ash has a pH value of 6.06 which is acidic. However, charred coconut husk followed with pH value of 9.8, which is basic. Table 2 reveals five (5) heavy metals that were present in all the backfill material samples in different quantities.

The potassium content was the opposite of the pH values. That is, tyre ash recorded the highest value of 142 mg/kg, followed by charred coconut husk 123 mg/kg and palm kernel cake of value, 56 mg/kg.

Table 1 Selected Physio-Chemical Properties of Backfill and Soil Samples

Sample ID	Soil fraction			Texture	Moisture (%)	pH	OC (%)	Avail. P
	Sand	*Silt*	*Clay*			1:1		mg/kg
Soil sample	41.38	20.69	34.48	Clay Loamy	13.65	7.82	0.25	1.272
Palm Kernel Cake						5.36	37.74	71.55
Tyre Ash						6.06	45.16	10.4
Charred Coconut Husk						9.8	67.73	7.025
Coconut Coir						6.06	42.00	2.532

Table 2 Selected Heavy Metals

Sample ID	Mass of Element (mg/kg)				
	Calcium	*Iron*	*Magnesium*	*Potassium*	*Sodium*
Soil sample	13.25	135.7	1.531	2.635	0.9772
Palm Kernel Cake	47.04	6.443	46.99	54.63	5.472
Tyre Ash	124.5	296.3	21.98	142.7	53.4
Charred Coconut Husk	13.84	7.209	13.02	123.8	44.06
Coconut Coir	11.66	12.23	5.787	47.07	15.99

3.2 Field Measurements

As discussed in Section 2.4, the readings were taken weekly using the megger after the rods were buried for a period of one year. Fig. 10 is a graph showing the immediate effects of the backfill materials after being buried for five minutes. It depicted that the resistance values increased when they were backfilled. For the second readings, palm kernel and coconut coir recorded resistance values of 99.4 Ω and 89.9 Ω, respectively, which were less than that of the reference, i.e. 109.5 Ω. Tyre ash and charred coconut husk also recorded resistance values of 125 Ω and 156.1 Ω, respectively, which are all higher than that of the reference.

Fig. 11 shows a graph of the weekly resistance readings for 2018. It shows that from 6th January to 14th April, tyre ash performed very well, followed by charred coconut husk and palm kernel cake. The values reduced drastically from 30th May through to the end of August with an average value of 60 Ω. This period was characterised by heavy rains, which led to favourable resistance readings. Tyre ash and charred coconut husk had the least resistance values from September to December. Lastly, the reference rod recorded the highest value ranging from 130 Ω to 210 Ω.

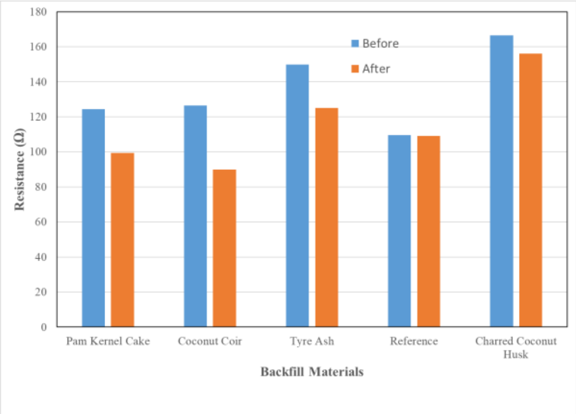

Fig. 10 Graph of the Resistance Values before and after Backfilling

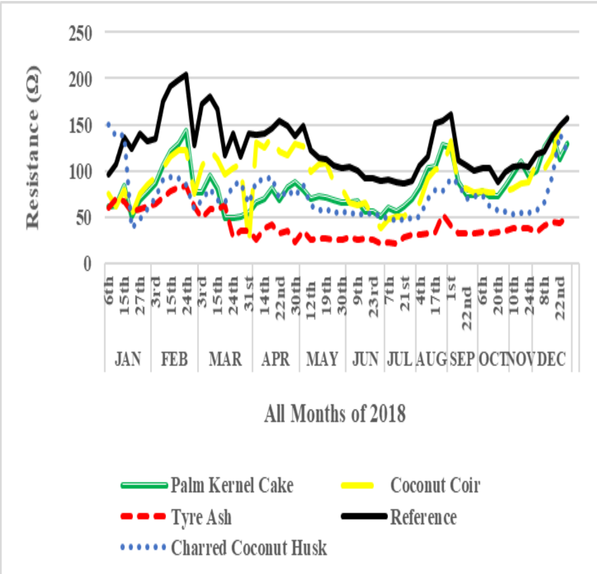

Fig. 11 Resistance Values for the Year 2018

4 Conclusions and Recommendations

4.1 Conclusions

All the backfill materials under consideration successfully improved the earth resistance when compared with that of the reference. Tyre ash recorded the least resistance values. The nature of the rainfall pattern in Tarkwa had a major effect on the values, that is, the values reduced drastically in the rainy seasons and increased in the dry seasons.

4.2 Recommendations

The relationship between the properties of the backfill materials such as heavy metals, organic carbon and the available phosphorus and corrosion should be established.

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