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Assessing the Effectiveness of Tyre Ash as A Conductive Backfill

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Abstract

Tyre ash is found to reduce ground electrode resistance and compares favourably with other local conductive backfills. This paper presents the results of field measurements of tyre ash as a conductive backfill. The study aims to investigate the effectiveness of tyre ash for predictable performance in ground resistance reduction. Hence the resistivity, seasonal variation and the most favourable ratio of tyre ash mixed with cement were assessed. Resistivity of tyre ash was found to be 2.037×10^{-5} Ω.m and this resistivity improved upon the local soil resistivity by 41.76%. To assess the effectiveness of the application of tyre ash to seasonal variation, three rods were installed. One rod was embedded in the natural soil, one fully covered and one partially covered with the same quantity of tyre ash and measurements taken. The tyre ash reduced ground electrode resistance by 70.42% and 75.24% when applied on full length and about one-third of the length of the electrode with seasonal variation of 56.40% and 27.05% respectively. To determine the optimum ratio of tyre ash mixed with cement to enhance performance, 11 rods were installed. 9 rods were embedded in different ratios of tyre ash mixed with cement and compared with the two: 1 embedded in the natural soil and the other embedded in pure tyre ash. The optimum ratio was found to be 14:1 and this ratio reduced the electrode resistance by 84.62%.

Index Terms— **Tyre ash, conductive backfill, ground electrode, soil resistivity, cement**.

1. Introduction

A low ground rod resistance is essential for effective grounding system. In a situation where it is difficult to achieve low ground rod resistance by conventional means, chemical treatment of the soil is used. The chemical treatment of soil surrounding ground rods is preferable and in some cases the only economically sound solution in obtaining low impedance of the ground system [1]. In relation to the increasing cost of land, materials and space constraints, studies are ongoing on local conductive backfills for ground resistance reduction. Since 2006, Eduful, Okyere and others have tested many local substances such as palm kernel oil cake, tyre ash, wood ash and powdered cocoa shells for use as conductive backfills for ground resistance reduction [2], [3]. Prominent among the conductive backfills tested is tyre ash. Tyre ash was selected as the most effective among the local conductive backfills because of its stability over the period under study and low acidic content. The impact of tyre ash as a conductive backfill, on non-uniform soil, has been monitored by Eduful et al [4]. For tests done so far, the application of tyre ash was on the full length of ground rods.

Soil resistivity is the single most important factor affecting the resistance of a ground system. With resistivity data available, ground system design becomes predictable so that the final ground resistance to expect after installation can be computed. The test period in [3], [4] was about three months which did not cover the wet & dry seasons to know when electrode resistance variation is the highest. The resistivity of tyre ash and the optimum ratio of tyre ash mixed with cement are not clear in literature. Commercial conductive backfills like SAN-EARTH, ground enhancement material (GEM) and FurseCEM contain cement in suitable proportions for corrosion and leaching reduction. Tyre ash mixed with cement has been confirmed to reduce corrosion [5]. The use of tyre ash for ground resistance reduction could help reduce the problem of used tyre disposal.

This paper evaluates the resistivity, presents the results of field measurements to assess the influence of seasonal variations on ground electrode resistance and determines the optimum ratio of tyre ash mixed with cement, with a view to investigating the effectiveness of the use of tyre ash for predictable performance in ground resistance reduction.

2. Methodology

A. *Resistivity of Tyre Ash*

In order to determine the resistivity of tyre ash, a quantity of the tyre ash was placed in a glass capillary tube of inner diameter 8mm. The tyre ash was then compressed using a table vice with stainless steel contacts placed at either end of the capillary tube as shown in figure 1. When the tyre ash was tightly packed, the resistance of the assembly was measured with an ohmmeter. The measurements were done at room temperature.

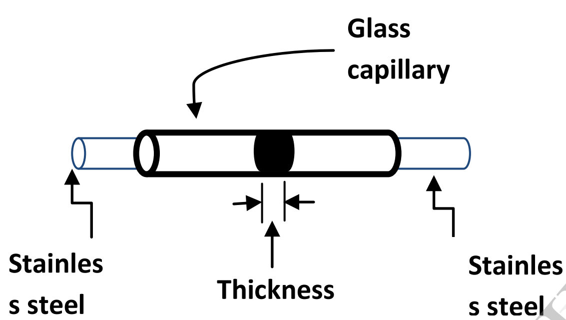

Fig1: Set-up for calculation of resistivity of tyre ash

The thickness of the tyre ash was varied, and the resistance measured, giving the results shown in table 1.

Using the relation:

$R = \frac{\rho l}{A}$ (Equation for metals, assumed to hold for the packed tyre ash), (1)

A plot was made of the resistance against the thickness (or length), so that the gradient of the graph yielded the value ρ/A. The cross-sectional area of the sample was calculated with $A = \pi r^2$. The resistivity of tyre ash was found to be 2.037×10^{-5}. The experiment was performed at Physics Laboratory of the University of Ghana.

B. *Evaluation of the Effectiveness of Tyre Ash Application on Ground Electrodes and seasonal variation*

To evaluate the effectiveness of tyre ash as ground resistance reduction agent, rods were installed at a site; refer to figure 2, and measurements taken with an earth tester. The rods used were all of 1.2m length and 16mm diameter. The rod buried in the natural soil was referred to as R_{ref} (A). The rod fully covered with tyre ash in a hole of diameter 15.24cm was referred to as R_{full} (B). The rod with tyre ash covering about 30% of its length in a hole of diameter 45.72cm was referred to as $R_{partial}$ (C).

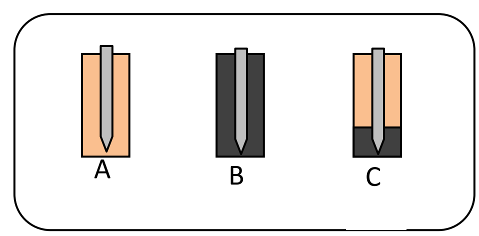

Fig.2: Grounding arrangement (A) R_{ref} (B) R_{full} and (C) $R_{partial}$.

C. *Determining Optimum Ratio of Tyre Ash Mixed with Cement*

Cement is a bonding material having cohesive and adhesive properties which makes it capable to unite different construction materials to form compacted assembly. Cement is used to treat soils to amend undesirable properties of problem soils or substandard materials so that they are suitable for use in construction. The amount of cement added to the soil is less than that required to produce a hardened mass but is enough to improve the engineering properties of the soil [6].

In the mining industry, to prevent secondary minerals of backfill from contaminating ground water after mine closure, cement is added to the backfill. Addition of cement to backfill changes both the chemical and physical characteristics of the backfill [7]. Cements are widely used in waste management applications to immobilize pollutant ions as they offer a unique combination of: (i) physical solidification of slurries, granular materials or weak solids by mixing with cement and subsequent hardening; (ii) absorption mechanisms, where pollutant ions such as heavy metals are absorbed into gel phases, by virtue of their enormous surface areas and their capacity to provide a wide variety of reaction sites onto which ions can bond; and (iii) chemical stabilization or immobilization, since the solubility of many pollutants is severely reduced by the high pH environment within a cement paste [8]. Cement was therefore mixed with the tyre ash to verify the optimum ratio that could improve its ability of ground resistance reduction.

To find out the optimum ratio of the mixture of tyre ash and cement to enhance performance, 11 rods of 1.2m length and 16mm diameter were installed: 9 rods were embedded in different ratios of tyre ash mixed with cement from 8:1 to 16:1, 1 rod in the natural soil (R_{ref}), and 1 rod in pure tyre ash (R_{PTA}) as shown in figure 3. The ratios of the mixture of tyre ash to cement were compared with pure tyre ash and reference electrodes. The same quantity of water was used for all the mixtures.

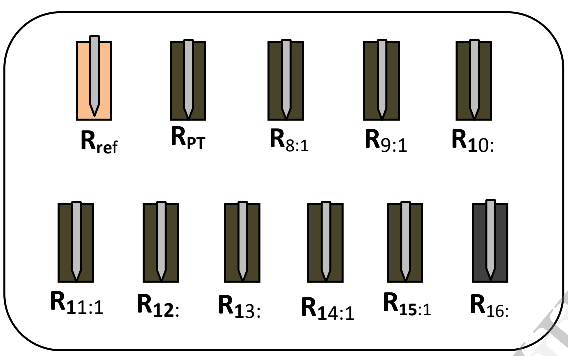

Fig.3: Comparism of ground resistance of rods: R_{ref}, R_{PTA} and $R_{m:n}$

Where R_{PTA} = electrode resistance of pure tyre ash and for

$R_{m:n}$ R = resistance, m = ratio of tyre ash portion and n = ratio of cement portion of the mixture.

D. Determining the Soil Resistivity

Wenner method was used to determine the soil resistivity of the site using Megger DET4TD2 digital earth tester and the resistance obtained directly read in ohms. With consecutive incremental spacing from an initial of 0.3m up to 5.1m, the average resistivity of the site was found to be 244.46Ω.m and 248.81Ω.m at a spacing of 1.2m using the formula,

$$\rho = 2\pi AR \qquad (2)$$

Where: ρ = resistivity of the native soil in Ω.m, A = spacing between test electrodes in m and R = resistance measured by the instrument.

For comparative analysis, Deep-driven method was used for ground resistance measurements of the 1.2m length rod in the native soil and the Dwight equation:

$$R = \frac{\rho}{2\pi L}\left[\ln\frac{4L}{d} - 1\right] \qquad (3)$$

was used to determine the soil resistivity.

Where; ρ = resistivity of the native soil in Ω.m, L = length of electrode in m, and d = diameter of electrode used in m.

The value obtained was compared with that of the 1.2m Wenner method spacing.

3. Results and Analysis

The resistivity of tyre ash found to be 2.037×10^{-5} Ω.m makes it a good chemical for use as a conductive backfill in areas where ground resistance is high. This low resistivity value and its possible impact on local soil resistivity could help in the design of grounding systems when tyre ash is to be used as a conductive backfill.

Table I. The variation of thickness of tyre ash with its resistance.

Thickness (cm)	Resistance (Ω)
0.2	1.4
0.4	3.6
0.5	3.8
0.6	5.0
0.7	8.5
0.9	12.8

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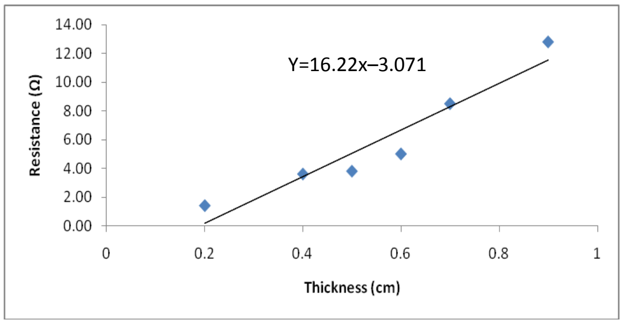

Fig. 4: Graph of resistance against thickness of tyre ash

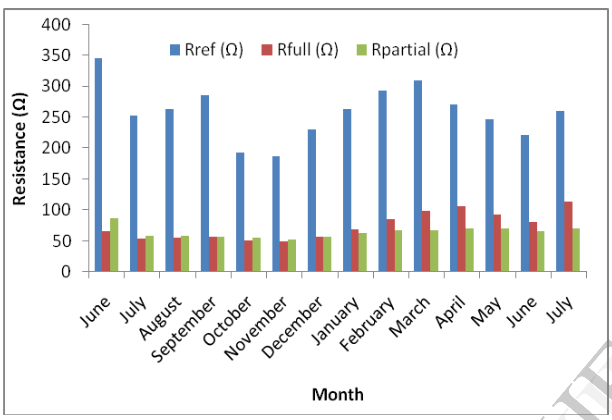

Fig. 5: Comparism of resistance of rods: R_{ref}, R_{full} & $R_{partial}$

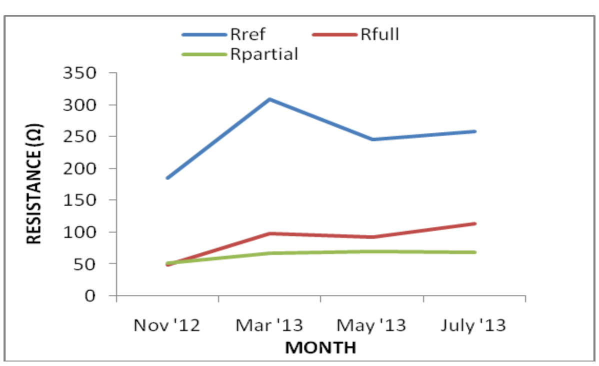

Fig. 6: Variation of electrode resistance of R_{ref}, R_{full}, and $R_{partial}$ during the wet & dry seasons

Figures 5 & 6 compare the performance of R_{ref}, R_{full} & $R_{partial}$ and their seasonal variations. Figure 6 shows the minimum and maximum values of R_{ref}, R_{full} & $R_{partial}$ recorded between July 2012 and July 2013.The one-year study period made it possible for the influence of seasonal variations on ground electrode resistance to be monitored. After settling, between July 2012 and July 2013, all three electrodes R_{ref}, R_{full} & $R_{partial}$ recorded their lowest values in November 2012 but their highest values in March, July and May respectively. Within the period R_{ref} varied by 39.75%, R_{full} varied by 56.40% and $R_{partial}$ varied by 27.05%. R_{ref} and R_{full} fluctuated significantly, but $R_{partial}$ reached a plateau in March 2013 the point at which R_{ref} had its highest recorded figure. During the raining season R_{full} gets a slightly lower resistance value than $R_{partial}$ but in the dry season $R_{partial}$ gets a significantly lower resistance value than $R_{full.}$ Moreover, $R_{partial}$ was the most stable with seasonal variation of 27.05%. $R_{partial}$ would therefore be more effective in ground resistance reduction in dry ground than R_{full} when using tyre ash as a conductive backfill. Between July 2012 and July 2013, R_{ref}, R_{full} & $R_{partial}$ had average electrode resistances of 251.26Ω, 74.32 and 62.22 respectively. Relative to the reference electrode, R_{full} reduced the electrode resistance by 70.42% and $R_{partial}$ by 75.24%.

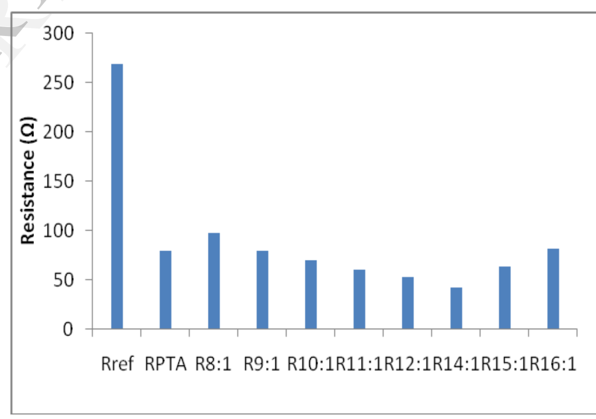

Fig. 8: Graph of resistance of rods in native soil, pure tyre ash and in different ratios of tyre ash mixed with cement

The formula [IEEE Std. 80, (2000)]:

$$R_b = \frac{1}{2\pi l}\left[\rho\left(\ln\frac{8l}{D_b}-1\right)+\rho_b\left(\ln\frac{8l}{d}-1\right)-\rho_b\left(\ln\frac{8l}{D_b}\right)\right]\Omega \qquad (4)$$

Used to determine the resistance of the electrode in the backfill of tyre ash gave 103.72Ω.

Where:

R_b = resistance of vertical ground electrodes in conductive backfill, ρ_b = resistivity of conductive back fill, D_b = backfill hole diameter, l = length of electrode and d = diameter of electrode.

Using the Dwight equation:

$$\rho = \frac{2\pi \times 1.2 \times 103.72}{\left(\ln \frac{4\times 1.2}{0.008} - 1\right)} \quad (5)$$

144.90 Ω.m was obtained as the effective resistivity with the backfill applied. The application of the tyre ash backfill improved upon the local soil resistivity (248.81Ωm) by 41.76%.

With the Deep-driven method using the 1.2m rod, the resistivity of the local soil was found to be 304.77, varying by 18.36% from the Wenner method of 1.2m spacing. The electrode resistance reduction observed is consistent with that of Eduful et al in 2011 [4].

Optimum ratio of tyre ash mixed with cement was found to be 14:1 within the period which gave a significant 84.62% earth resistance reduction. The 84.62% improvement gives a multiplying factor of 0.1537. Considering the example in [9] where using the same conditions a single rod yielded a ground resistance of 29Ω at which place four rods in parallel reduced the ground resistance to 8.31Ω. If the optimum ratio of tyre ash mixed with cement backfill is used on a rod of ground resistance 29Ω, 4.4573Ω would be obtained as the ground resistance of that rod.

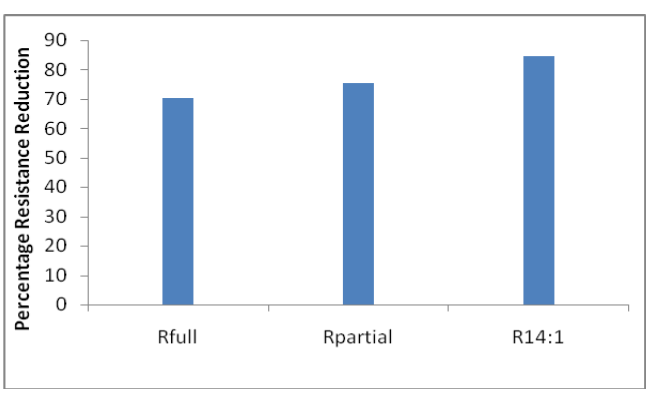

Fig. 8: Comparism percentage electrode resistance reduction of R_{full}, $R_{partial}$ and $R_{14:1}$

Comparing R_{full}, $R_{partial}$ and $R_{14:1}$, it can be observed from figure 8, that tyre ash reduces ground electrode resistance by over 70%. However, with a mixture of tyre ash and cement in a ratio of 14:1 over 84% electrode resistance reduction is obtained with already established added advantage of corrosion and leaching reduction.

4. CONCLUSION

Tyre ash has a low resistivity which gives a positive impact on local soil resistivity. The use of tyre ash as a conductive backfill is a cost effective means of reducing high ground resistance. Placing the conductive backfill at about one-third of electrode length at the bottom gives a more stable electrode resistance reduction than when placed on the full length, especially during dry seasons. The mixture of tyre ash with cement in a ratio of 14:1 further enhances ground resistance reduction. The influence of seasonal variation on electrode resistance observed could be helpful in the design of a grounding system when tyre ash would be used as a backfill.

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