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DETERMINATION OF THE SOIL CONDUCTIVITY AND RESISTIVITY IN OLOGBO, EDO STATE FOR THE SUITABILITY OF TRANSMISSION CABLE.

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Abstract
Soil thermal resistivity or conductivity testing, measures the capability of the ground to conduct or dissipate heat away from the immediate surroundings of a pipeline or a transmission cable. In this article, thermal resistivity/conductivity measurement was carried out at the ELPS CS1 site at Ologbo Edo State, using a Terameter (SAS 1000). The measurements were carried out by strictly adhering to the IEEE 442 and ASTM Guide standard for soil thermal resistivity/conductivity measurement. Thermal resistivity values measured at the various points along the entire test sites shows range of thermal resistivity values is between 0.3966(^{o}C m/W) to 0.5961(^{o}C m/W), while the range for thermal conductivity which is an inverse of thermal resistivity is between 2.5214 (W/^{o}C m) to 1.6775 (W/^{o}C m) correspondingly. The values are within the safe limit of 0.9000^{o}C m/W standard, specified for buried underground facilities.

Key Words: Thermal Resistivity, Thermal Properties, Subsurface Characterization, Transmission Cables.

Introduction

Soil thermal resistivity or conductivity testing, measures the capability of the ground to conduct or dissipate heat away from the immediate surroundings of a pipeline or a transmission cable. A correct understanding of the thermal properties of a soil or made ground (backfill) is important for the design and installation of underground facilities (pipelines, transmission cables, etc), as improper installations often can lead to premature failures.

The safe optimum maximum value for soil thermal resistivity for underground facilities is 0.9000(^oC m/W), while the safe optimum minimum value for soil thermal conductivity is 1.111(W/^oC m) (Obrike *et al.* 2007). Hence, any value higher that 0.9000(^oC m/W) for soil thermal resistivity will be unsafe for buried underground facilities, therefore will require earthwork to improve the soil thermal properties, likewise any thermal conductivity value lower than1.111(W/^oC m).

Thermal resistivity/conductivity measurement was carried out at the ELPS CS1site at Ologbo Edo State. The thermal resistivity/conductivity tests were conducted at six points on the project site. The map of the survey area depicting the points of data acquisition for thermal resistivity/conductivity is shown in figure 1, while the coordinates of the points are shown in Table 1. Thermal resistivity/conductivity measurement is majorly carried out to evaluate the capability of the soil to dissipate the heat generated within its immediate vicinity. This is majorly achieved by injecting heat into the soil or made ground (backfill) through a probe, and monitoring the transient heat, which will be used to evaluate the thermal nature of the ground.

Table 1: Coordinates of the points where thermal resistivity/conductivity was conducted.

Thermal Points	Coordinates	
	Easting	Northing
TRT1 (TT1)	675759.980	799073.378
TRT2 (TT2)	675700.655	799092.376
TRT3 (TT3)	675935.893	799070.049
TRT4 (TT4)	675644.543	799059.686
TRT5 (TT5)	675642.893	799097.878
TRT6 (TT6)	675792.209	799119.970

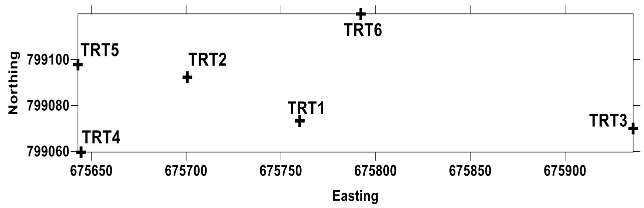

Figure 1: Work Layout showing the points where thermal resistivity/conductivity test was carried out.

Therefore, the aim of this test is to carry out a comprehensive thermal resistivity survey of the ELPS CS1site at Ologbo Edo State, and ascertain the thermal properties of the soil in place, which is necessary for underground facilities (pipelines, transmission cables etc) installation at the ELPS CS1 project site.

General geology and Hydrology of the Work Area

Cretaceous to Tertiary Sedimentary formations occupies over eighty percent of Edo State. Some cretaceous sediments of Anambra Basin and tertiary sediments of Niger Delta sequences are found in the study area. These formations contain clay deposits. The Azagba-Ogwashi Formation has been often spelt as Ogwashi-Asaba Formation consists of clays, sands and grits and seams of lignite alternating with gritty clays. It grades upwards into the Benin Formation. The Ogwashi-Asaba Formation is exposed in stream channels at the northern parts of the Benin Region, west of Ekiadolor-Iwu and 4 km east of Utekon and north of Azalla; Reyment, (1965). The Benin Formation is assigned to the Oligocene-Pleistocene period in the continent of Africa and to the Oligocene-Pleistocene to recent at the sub oceanic (Short and Stauble, (1967). The formation is characterized by top reddish to reddish brown lateritic massive indurate clay and sand. This is often marked with reticulate mud racks. This cap the underlying more friable pinkish-yellowish white often gravelly-pebble sands clayey soils, sands and clay, Akujieze (2004). The sedimentary sequences are poorly bedded with discontinuous clay horizons at various depths.

It is estimated to be about 800m thick under Benin City and about 1,830 m near the seashore sections of the formation. They are exposed at various erosion sites, sand quarry sites, and road cuttings. Regionally, the Imo Shale, which sits on top of the Nsukka Formation, reveals a shallow marine shelf environment with preserved foreshore and shoreface sands according to Petters and Ekweozor, (1981); Obirike, (2012). It also contains black shales, blue-grey clays, and marl with interspersed calcareous sandstone, marl, and limestone Onyekuru, *et al.* (2018). According to Obirike et al. (2007) and Onyekuru *et al.* (2018), regression persisted throughout the Eocene and culminated in the formation of Lower and Middle Eocene deposits, which include the clastic Ameki and Nanka Formations. The transition back to regressive conditions is marked by the progradational Nanka Formation. In the northern parts of the Niger Delta, the Agbada Formation represents the subsurface deposits of the prograding shoreface and river plain, while the Akata Formation refers to the marine Imo Shale counterpart. The Oligocene-Recent Ogwashi-Asaba and Benin Formations dominate the area's uppermost lithostratigraphic units of the stratigraphic succession (Nwajide 2005; Okoye and Obi, 2011). In the Miocene period, the Niger Delta sediments accumulate and prograde seawards. As a result, the sea level is lowered during the Pleistocene. The Niger River cut wide valleys through its own delta. These troughs are being filled today as the sea level gradually rises, Okoye and Obi, (2011).

Materials and Method

A Terameter (SAS 1000) and GPS was used for data acquisition. The various locations within the investigated sites where thermal resistivity/conductivity values were measured as shown figure 1. It started by removing the top soil compose mainly of loose ground or humus layer by digging down to a depth of at least 0.1m, after which the electrodes were inserted into the soil from that depth, using the Schlumberger array configuration. The two outer electrodes are current electrodes, while the two inner electrodes are the potential electrodes. The reels of cables were connected to their corresponding electrodes, which were also connected to the SAS 1000 Terameter. The equipment was allowed to equilibrate until it achieved a steady state, while monitoring the rise in temperature rate. The heating and measurement cycle were conducted and noted, to determine the actual value of thermal resistivity/conductivity for that point.

Results

Table 2 showed the thermal resistivity values measured at the various points along the entire test sites. The range of thermal resistivity values is between 0.3966 (°C m/W) to 0.5961 (°C m/W), while the range for thermal conductivity which is an inverse of thermal resistivity is between 2.5214 (W/°C m) to 1.6775 (W/°C m) correspondingly. The values are within the safe limit of 0.9000°C m/W standard, specified for buried underground facilities.

Discussion

The results shows a clear indication that any soil surrounding any underground facilities buried within the site will effectively dissipate any heat generated by the buried facilities to keep it safe. The range of atmospheric temperature at the period of data acquisition is between 27.9°C and 33.3°C, with an average atmospheric temperature of 31.2°C.The range of soil ambient temperature, which to a reasonable extent is a function of the rate of sun intensity within the daylight period, is 24.8°C to 25.7°C, with an average ambient soil temperature of 25.2°C. 2D contour maps were generated for thermal resistivity and thermal conductivity as shown in figure 2 and 3, to get a general holistic view of the distribution of thermal resistivity/conductivity within the ELPS CS1 investigated site. The contoured map of thermal resistivity showed the distribution of thermal resistivity within the investigated site. Regions of high thermal resistivity are clearly demarcated from regions of low thermal resistivity. The thermal conductivity map also showed the distribution of thermal conductivity within the investigated site. It also depicts regions of different values of thermal conductivity within the investigated site, with the regions of low thermal conductivity clearly demarcated from regions of high thermal conductivity.

Table 2: Thermal Resistivity Points, Acquisition Locations and Parameters

S/N	Date Carried out	Thermal Points	Easting	Northing	Air atmospheric Temperature °C	Soil Ambient Temperature °C	Measured Thermal Resistivity Values (°C m/W)	Measured Thermal Conductivity Values (W/°C m)
1	07-08-2023	TRT1 (TT1)	675759.980	799073.378	27.9	25.2	0.4225	2.3670
2	07-08-2023	TRT2 (TT2)	675700.655	799092.376	33.3	24.8	0.4747	2.1068
3	07-08-2023	TRT3 (TT3)	675935.893	799070.049	31.3	25.7	0.4854	2.0510
4	07-08-2023	TRT4 (TT4)	675644.543	799059.686	32.0	25.3	0.3966	2.5214
5	07-08-2023	TRT5 (TT5)	675642.893	799097.878	30.1	25.2	0.5961	1.6775
6	07-08-2023	TRT6 (TT6)	675792.209	799119.970	32.6	25.0	0.4594	2.1767

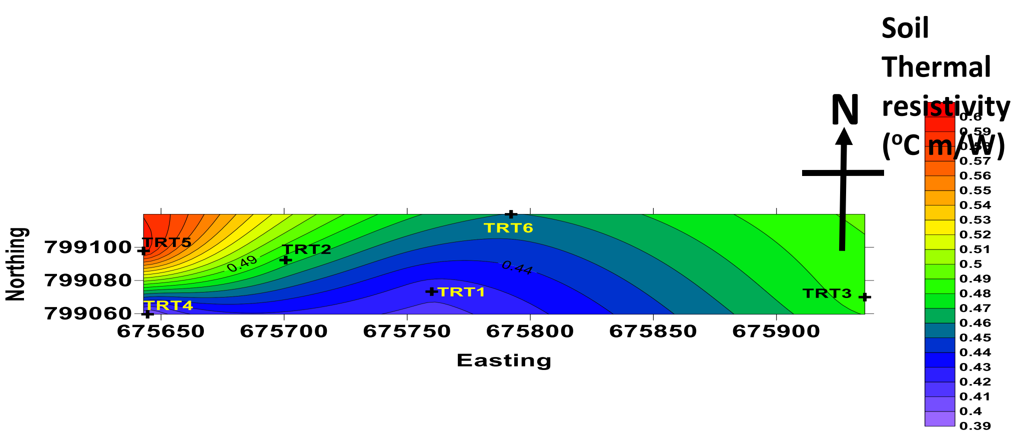

Figure 2: Thermal resistivity distribution at the investigated site, the dark cross on the contoured map represents the investigated points.

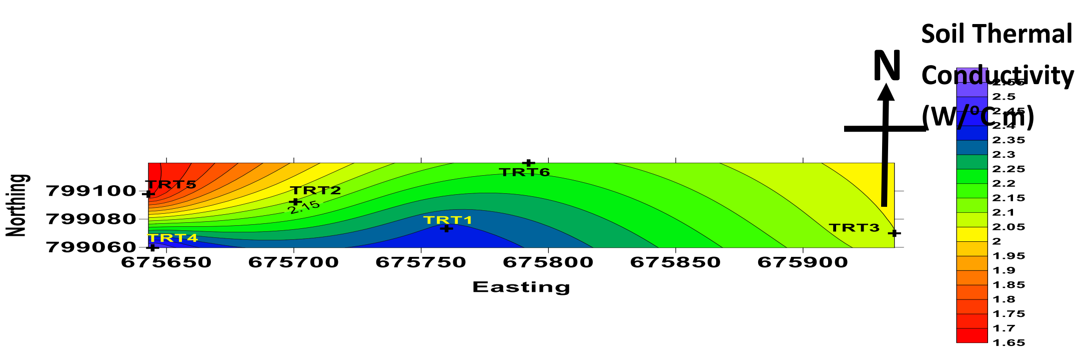

Figure 3: Thermal conductivity distribution at the investigated site, the dark cross on the cross on the map represents the investigated points.

The range of thermal resistivity/conductivity values recorded in Table 2 and the thermal resistivity/conductivity distribution depicted in figures 2 and 3 gave a very good indication that the site is characterize with thermal resistivity values that are within the optimum safe value of 0.9000ºC m/W. Also, the thermal conductivity values within the test site are also within 1.111(W/ºC m) recommended for optimum safe range for buried underground facilities. The implication of this outcome for the investigated site is that, any heat generated by buried underground facilities or within its vicinity, from top soil down to a depth of 5 m at the test site will be effectively dissipated to keep the buried underground facilities safe.

Conclusion

The thermal resistivity and conductivity measurements conducted at the ELPS CS1 site in Ologbo, Edo State, demonstrate that the soil properties are well within safe limits for underground transmission cable installation. The recorded thermal resistivity values ranged from 0.3966 to 0.5961 °C m/W, while thermal conductivity values varied between 1.6775 and 2.5214 W/°C m. These results confirm that the soil effectively dissipates heat, ensuring the safe operation of buried infrastructure.

The study adhered to IEEE 442 and ASTM standards, utilizing a Terameter (SAS 1000) for precise measurements. The findings indicate that no additional soil treatment is required, as all values fall below the critical threshold of 0.9000 °C m/W for thermal resistivity and above the minimum 1.111 W/°C m for thermal conductivity.

This research provides essential data for engineers and planners, confirming the site's suitability for underground power transmission systems. Future studies could explore seasonal variations in soil thermal properties to ensure long-term reliability.

References

Akujieze, C.N. (2004). Effects of Anthropogenic Activities (Sand Quarrying and Waste Disposal) on Urban Groundwater System and Aquifer Vulnerability Assessment in Benin City, Edo State, Nigeria. *PhD Thesis, University of Benin, Benin City, Nigeria.*

Nwajide, C.S. (2005). A guide to geological field trips to Anambra and related basins in Southeastern Nigeria. *Great AP Express Publishers Ltd.*

Obrike, S.E. (2012). Evaluation of Imo clay-shale deposit (Paleocene) from Okada, Edo State, Southwestern Nigeria, as drilling mud clay. *Journal of Applied Technology of Environmental Sanitation 1 (4): 311-316.*

Obrike, S.E., Osadebe, C.C. and Onyeobi, T.U.S. (2007). Mineralogical, geochemical, physical and industrial characteristics of shale from Okada area, southwestern Nigeria. *Journal Mining and Geology 43 (2): 109-116.*

Okoye, I.P. and Obi, C. (2011). Synthesis and Characterization of Al- Pillared Bentonite Clay Minerals. Research Journal of Applied Sciences 6: 447-450.

Olorunfemi, M. O., Fasuyi, S. A. (1993). Aquifer types and the geoelectric/hydrogeologic characteristics of parts of the central sedimentary basin of Nigeria. *Journal of African Earth Sciences, 16*(3), 309-

317. https://doi.org/10.1016/0899-5362(93)90002-R

Onyekuru, S.O., Iwuoha, P.O., Iwuagwu, C.J., Nwozor, K.K. and Opara K.D. (2018). Mineralogical and geochemical properties of Clay deposits in parts of Southeastern Nigeria. *International Journal of Physical Sciences 13 (14): 217-229.*

Petters, S.W. and Ekweozor, C.M. (1981). Origin of Cretaceous black shales in the Benue Trough, Nigeria. *Journal of PalaeogeographyPalaeoclimatologyPalaeoecology 40: 311- 319.*

Reyment, R.A. (1965). Aspects of the Geology of Nigeria. *Ibadan University Press, Ibadan.*

Short, K.C. and Stauble, A.J. (1967). Outline of the Geology of Onitsha, Owerri and Benue Provinces. *Geological Survey of Nigeria, Bulletin No. 21.*

Tijani, M. N., Okunlola, O. A., Ajibade, L. M. (2010). Hydrogeochemical and environmental impact assessment of shallow groundwater systems in the basement complex area of Nigeria. *Environmental Earth Sciences*, *60*(4), 873-887. https://doi.org/10.1007/s12665-009-0223-1

Ukpong, E. E. (2012). Geotechnical evaluation of some soils in the Niger Delta for earthworks. *Journal of Engineering and Applied Sciences*, *7*(2), 145-152.