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EFFECTS OF SHEAR STRENGTH PROPERTIES ON ELECTRICAL RESISTIVITY OF COMPACTED LATERITE SOIL: A CONCEPTUAL MODEL

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ABSTRACT

Laterite soil is commonly considered as a good natural foundation and building material. This type of soil is found in abundance in most of the tropical countries including Malaysia. In any project, the properties of laterite soil are determined through borehole sampling which is the actual determination of the subsurface soil but on contrary it is very expensive and time consuming process and also requires too much effort. Therefore, in order to save cost, time and energy, electrical resistivity method is an alternative method which could provide quick and rapid assessment of the subsurface soil without causing any disturbance to the soil and thus much time and money could be saved. In this research paper, a conceptual model for the assessment of strength properties of compacted laterite soil has been proposed based on the correlations of soil properties mainly cohesion and angle of internal friction with electrical resistivity values. The results analyzed from the study hopefully will contribute for the possible assessment of the electrical resistivity method to be used for the determination of geotechnical properties of laterite soil in geotechnical calculations such as factor of safety (FOS) and bearing capacity.

Keywords: laterite soil, electrical resistivity, shear strength, factor of safety, bearing capacity, geotechnical calculations.

INTRODUCTION

Laterite soil is red colored, clay rich soil found in tropical and sub-tropical regions. High temperatures and abundant rainfalls of the tropics are needed for laterite soil to be formed. The water works as a weathering agent and removes the bases and the silicic acid, thus enhancing soil with aluminum silicates, aluminum hydro silicates, iron oxides and iron hydroxides. The red color of the laterite soil is mainly due to the presence of iron oxides (Maji, Pal, and Adak, 2007).

In tropical regions, variation in geotechnical properties are caused by different formation factors, these differences in the results obtained from the investigation are common to find even within short lengths and depths (Omoniyi, 2014). Therefore, prior to their application in civil engineering work, the preliminary investigations of engineering properties of laterite soil is needed. Moreover, it does not only depend upon the abundance of the laterite soil but also its usefulness as a construction material or foundation for structures. However, this paper helps us to evaluate engineering properties of some laterite soil using electrical resistivity measurements.

It has been reported from the literature that lateritic soils can be used as fill materials in construction works in most of the tropical countries (Elarabi, Taha, and Elkhawad, 2013).

The acceptability of these soils for earthworks i.e. construction works depends on their classification and compaction characteristics (Oghenero, 2014). Thus, enhancing its importance to evaluate these properties for the purpose of achieving proper design, construction and to prevent road failure.

It is generally believe that due to high cohesion and angle of friction of laterite soil, it possess high bearing capacity, which may be the reason why it is good as a foundation materials for huge structures. It is also may be due to the impermeability of laterite soil that it has been used as a fill material in embankments.

It has been observed that the laterite soil is commonly considered as a good natural foundation and building material. Although, there are some unfavorable properties such as shrinkage, cracks, water sensitivity and uneven distribution. These properties are usually evaluated by borehole sampling which is the actual determination of the physical properties of the soil but on contrary it is very time consuming and expensive (Bai, Kong, and Guo, 2013). Therefore, electrical resistivity (E.R) technique offers a quick and rapid assessment of the sub surface properties without causing soil disturbance and save much time and energy.

By implementing disc electrode method of measurement, the resistivity (ρ) of laterite soil in ($\Omega.m$) will be determined using Equation (1):

$$\rho = \left(\frac{A}{L}\right) R \quad (1)$$

Where, A is cross sectional area (m^2) of the sample, L is length (m) and R is resistance (Ω).

LITERATURE REVIEW

The electrical resistivity of the soil is the measure of the potential difference to the passage of electrical current supplied through it. On the basis of potential

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difference, the electrical properties of sub surface soil formation is acquired (Samouëlian, Cousin, Tabbagh, Bruand, and Richard, 2005).

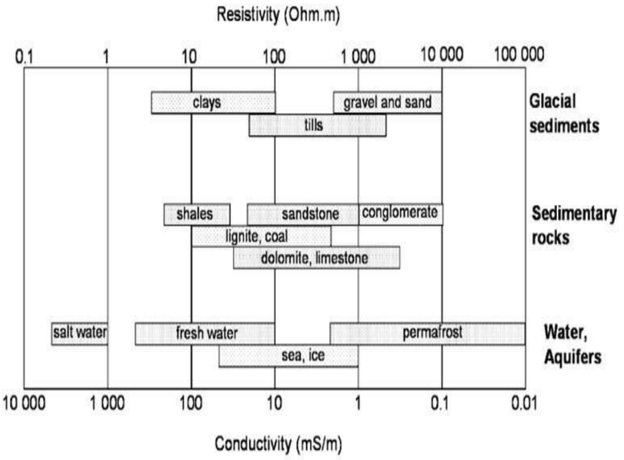

Figure-1. Typical ranges of electrical resistivity and conductivity of earth material (Samouëlian *et al.*, 2005).

Soils have been classified in three phases i.e. the solid phase, the liquid phase and the gaseous phase.

Electrical resistivity is determined by injecting the current into the ground based on paired electrodes whereas the potential difference is measured at another pair resulting in the determination of the apparent resistivity. However, the sub surface resistivity of the soil is obtained by inverting the apparent resistivity providing the information regarding different layers and objects (Bongiovanni, de la Vega, and Bonomo, 2011).

There are various types of electrode arrangements that could be used in field for the determination of electrical resistivity including Wenner, Schulumberger, Wenner- Schulumberger, Dipole-dipole, Pole-pole, Pole-dipole and square array.

(Zhu *et al.*, 2011) conducted study on electrical resistivity in order to locate an unmapped karst conduit. This study is carried out by implementing electrical resistivity measurements such as (surface2D survey, quasi-3D survey, and time-lapse survey) for the purpose of mapping and characterizing resistivity anomalies. Electrical resistivity method has been found to be useful in locating conduit.

Electrical resistivity survey has been carried out to explore its relationship with soil properties.

(Siddiqui and Osman, 2012) carried out correlation of electrical resistivity with water content, unit weight and internal frictional angle and found good relationship between E.R values, water content and angle of friction. In contrast, weaker correlations of E.R with cohesion and unit weight of soil were obtained.

The knowledge of electrical resistivity is also used to determine the feasibility of the resistivity method for the study of the spatial and temporal soil moisture variations. It has been found that there is a good relationship between electrical resistivity and soil water content as compared to Time Domain Reflectometer (TDR) method. (Calamita *et al.*, 2012).

(Bai *et al.*, 2013) investigated the electrical properties of lateritic soil using electrical conductivity measurements on a self-developed testing device. An increment in the conductivity value of laterite soil has been reported with the increase in water content, degree of saturation and dry density and subsequently tends to be constant if there is a certain increase made in the values of above mentioned soil properties. It was also found that electrical conductivity increases with the increase of temperature and decreases with the increase of the number of wetting drying cycles.

Electrical Resistivity is also used collectively with standard penetration test (SPT) and dynamic cone penetration test (DCPT) for the purpose of investigating geotechnical properties.

The variation in electrical resistivity with soil strength based on particle size distribution, cementation, porosity and saturation was used to correlate the resistivity with the number of blows acquired from SPT and DCPT data. It was observed that electrical resistivity is cost effective, efficient and consumes less time comparatively with the geotechnical methods such as SPT and DCPT (Sudha, Israil, Mittal, and Rai, 2009).

Recently, investigations on electrical resistivity have been conducted by (Kowalczyk, Maślakowski, and Tucholka, 2014)to evaluate the effect of E.R on non-cohesive soils and degree of compaction. The study analyzed that the E.R method is the potential method for the determination of degree of compaction.

Recently, another study was conducted on electrical resistivity tomography imaging for the purpose of monitoring temporal and spatial moisture content changes in clay embankments. The study was based on the correlation between fill resistivity and moisture content resulting the image variations in resistivity in terms of changing in moisture content. It was concluded that the ERT imaging can also be used as a monitoring framework to manage moisture differences and ascertain failure conditions within embankments, thus providing low cost early investigated method (Gunn *et al*., 2015).

PREVIOUS STUDIES

Very limited research work has been conducted so far to evaluate the relationship between electrical resistivity and strength properties for compacted laterite soil such as cohesion and internal angle of friction.

Correlations between electrical conductivity for compacted lateritic soil and various properties such as water content, saturation, dry density, temperature and soil structure has been analyzed by (W. Bai *et al*., 2013). The research recommends to examine the effects of shear strength properties of compacted lateritic soil in relation with electrical resistivity which would enable electrical resistivity to eliminate the physical parameters in calculations and designing for the foundation and construction purposes.

PROPOSED RESEARCH MODEL

The fundamental and main concept behind this conceptual model is to investigate the strength parameters of compacted laterite soil that is cohesion (c) and internal angle of friction (φ) and find out its relation with electrical resistivity. Moreover, some other soil properties such as plasticity index, particle size distribution, unit weight and water content will also be investigated and subsequently be correlated with resistivity values. Laboratory work will be carried out based on the following steps:

Step 1. Laboratory electrical resistivity test

Electrical resistivity measurements will be carried out using simple multimeter and DC power source. E.R values would be calculated using equation (1) as discussed above. Figure-2 shows a lab resistivity testing procedure.

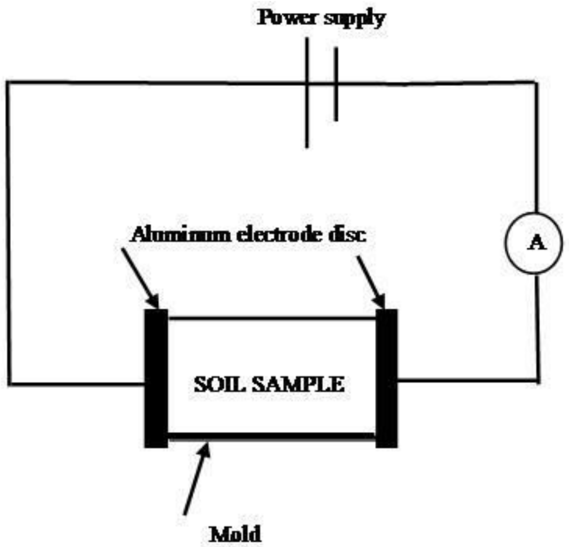

Figure-2. Electrical resistivity test setup at laboratory scale.

Initially the laterite soil will be compacted in the proctor mould in three layers using automatic compaction machine which provides effective and effortless performance instead of conventional proctor hammer and then E.R calculations will be performed on the mould. Before E.R calculations, plastic bag will be used as a lining material along the sides of the mould so that the mould steel could not affect the resistivity values.

Figure 3 presents schematic view of mould with dimensions. After completion of the E.R test, sample will be obtained from the mould for determination of shear strength parameters and will be brought to the direct shear test. Direct shear test being a simple method is selected for determination of shear strength properties as this test provides an average shear strength values as compared to other methods which are somehow complex and time consuming.

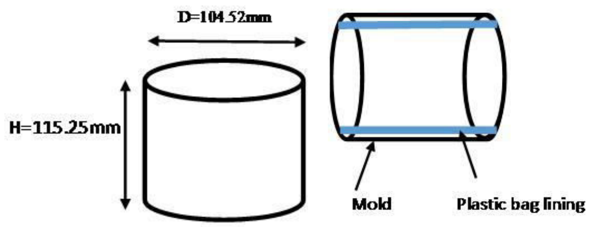

Figure-3. Steel mould setup with dimensions.

Step 2. Soil sampling

This research work will involve 30 number of disturbed laterite soil samples collected from different field sites near Perak state and will be investigated at laboratory basis in accordance with BS 1377 standard. Samples obtained from field site will then be brought to determine the soil characterization test in the laboratory and to investigate its relation with electrical resistivity values.

Step 3. Soil characterization tests

Soil characterization (e.g. Direct shear test, Particle size distribution, Atterberg's limit test, Moisture content, Unit weight and specific gravity will be carried out on Laterite soil sample. Direct shear test will be carried out for the determination of shear strength properties i.e. cohesion and frictional angle. Figure 4 shows the research project flow chart.

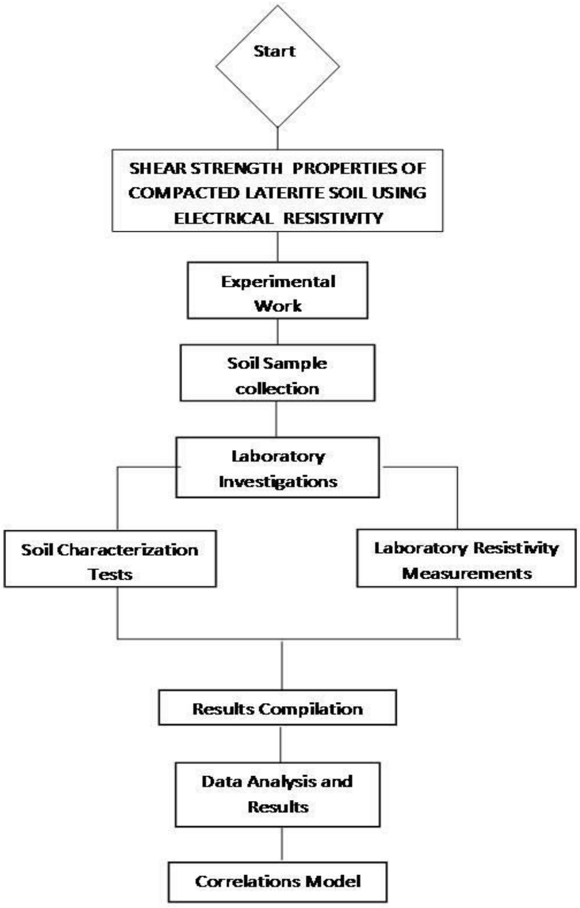

Figure-4. Research project flow diagram.

Step 4. Data analysis and correlations

Finally, the results analysis will be made to establish relationship between electrical resistivity values and soil properties obtained from laboratory experiments.

Regression analysis will be performed using Microsoft Excel 2007 or 2013 which is simple and easily operated tool. The correlations between electrical resistivity and various properties of soil samples will be evaluated using least-squares regression method, Linear, logarithmic, polynomial (quadratic and cubic), exponential and power curve fitting approximations will be applied and the best approximation equation with highest correlation coefficient will be selected.

RESEARCH SIGNIFICANCE

The purpose of this research work is to apply quick and rapid assessment technique in testing of laterite soil for analyzing physical properties by correlating the shear strength parameters such as cohesion and internal angle of friction with electrical resistivity. Thus, reduces the usage of borehole sampling which is time consuming and expensive. It is anticipated that the obtained correlations will help in the actual calculations of FOS and bearing capacity for compacted lateritic soil.

EXPECTED RESULTS

This research work will help us to generate relationships between electrical resistivity and different soil (laterite) properties including cohesion, frictional angle, plasticity index, particle size distribution, unit weight and water content in the form of graphs and charts. The obtained correlations would allow us to determine the soil properties without causing soil disturbance and save much time. Figure-5 shows a diametrical representation of proposed model utilizing laboratory electrical resistivity measurements. The soil strength properties that are cohesion and internal angle of friction will be acquired from the obtained correlations model.

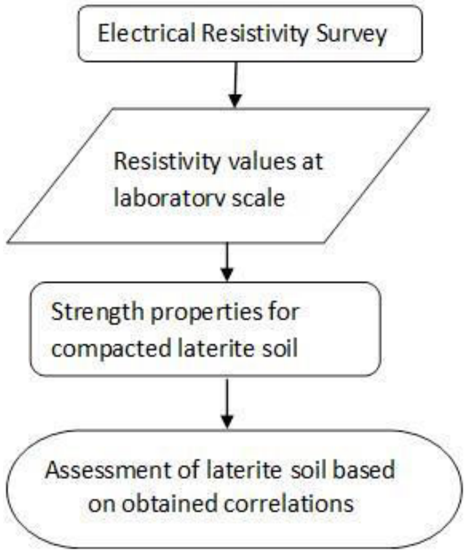

Figure-5. Proposed conceptual model for assessment of compacted laterite soil using electrical resistivity survey.

CONCLUSIONS

Malaysia being a tropical region has laterite soil in abundance. Shear strength of soil is an important parameter to assess the stability of soil and shear strength of soil reduces due to the rain water infiltration resulting subsequent failures to occur. Therefore, it is necessary to determine the shear strength properties of laterite soil. This study is limited for laterite soil only and soil characterization tests along with E.R measurements will be conducted at laboratory scale. E.R values will be obtained using disc electrode method. The end results of this research project hopefully will contribute in preliminary findings of geotechnical calculations such as slope failures and bearing capacity. The obtained relationships from the current study i.e. electrical resistivity with shear strength properties along with some index properties hopefully will enable us to reduce the probability of failures in laterite soil formations by conducting the preliminary investigations.

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REFERENCES

Bai, W., Kong, L., and Guo, A. 2013. Effects of physical properties on electrical conductivity of compacted lateritic soil. Journal of Rock Mechanics and Geotechnical Engineering, 5(5): 406-411.doi: http://dx.doi.org/10.1016/j.jrmge.2013.07.003.

Bongiovanni, M. V., de la Vega, M., and Bonomo, N. 2011. Contribution of the resistivity method to characterize mud walls in a very dry region and with GPR. Journal of Archaeological Science, 38(9): 2243-2250. doi: 10.1016/j.jas.2011.03.026.

Calamita, G., Brocca, L., Perrone, A., Piscitelli, S., Lapenna, V., Melone, F., and Moramarco, T. 2012. Electrical resistivity and TDR methods for soil moisture estimation in central Italy test-sites. Journal of Hydrology, 454-455, 101-112. doi: 10.1016/j.jhydrol.2012.06.001.

Elarabi, H., Taha, M., and Elkhawad, T. 2013. Some Geological and Geote chnical Properties of Lateritic Soils from Muglad Basin Located in the South-Western Part of Sudan.

Kowalczyk, S., Maślakowski, M., and Tucholka, P. 2014. Determination of the correlation between the electrical resistivity of non-cohesive soils and the degree of compaction. Journal of applied Geophysics, 110, 43-50.

Maji, S. K., Pal, A., Pal, T., and Adak, A. 2007. Adsorption thermodynamics of arsenic on laterite soil. Journal of Surface Science and Technology, 23(3/4), 161.

Oghenero, A. E., Okey, A. T., Brume, O., SE, O., and Jerry, O. 2014. Classification and compaction characteristics of lateritic soils of Warri, Delta state, Nigeria.

Samouëlian, A., Cousin, I., Tabbagh, A., Bruand, A., and Richard, G. 2005. Electrical resistivity survey in soil science: a review. Soil and Tillage Research, 83(2), 173-193. doi: http://dx.doi.org/10.1016/j.still.2004.10.004.

Siddiqui, F. I., and Osman, S. B. A. B. S. 2012. Electrical resistivity based non-destructive testing method for determination of soil's strength properties. Paper presented at the Advanced Materials Research.

Sudha, K., Israil, M., Mittal, S., and Rai, J. 2009. Soil characterization using electrical resistivity tomography and geotechnical investigations. Journal of applied Geophysics, 67(1), 74-79. doi: 10.1016/j.jappgeo. 2008.09.012.

Zhu, J., Currens, J. C., and Dinger, J. S. 2011. Challenges of using electrical resistivity method to locate karst conduits-A field case in the Inner Bluegrass Region, Kentucky. Journal of applied Geophysics, 75(3), 523-530. doi: 10.1016/j.jappgeo.2011.08.009.

Gunn, D. A., Chambers, J. E., Uhlemann, S., Wilkinson, P. B., Meldrum, P. I., Dijkstra, T. A., Glendinning, S. 2015. Moisture monitoring in clay embankments using electrical resistivity tomography. Construction and Building Materials, 92(0): 82-94. doi: http://dx.doi.org/10.1016/j.conbuildmat. 2014.06.007.