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PREDICTION OF SOIL ENGINEERING PROPERTIES USING ELECTRICAL RESISTIVITY VALUES AT CONTROLLED MOISTURE CONTENT-A CONCEPTUAL PAPER

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ABSTRACT

Geo-electrical assessment is an appealing instrument for depicting subsurface properties without soil unsettling influence and also can be considered as an intermediary for the spatial and fleeting variability of numerous other soil physical properties (i.e. structure, water substance, or liquid synthesis, porosity, degree of saturation etc.) and strength parameters (i.e. cohesion and angle of friction). Since the system is non-dangerous and exceptionally delicate, it offers an extremely fascinating apparatus for depicting the subsurface properties without burrowing. In this paper a conceptual model is developed for the assessment of slope stability and FOS using electrical resistivity values of the insitu soil at controlled moisture content (30%). The obtained results will be interrelated with soil physical properties (moisture content, plasticity index, specific gravity, porosity, degree of saturation etc.), chemical properties (Cation exchange capacity (CEC), p^H and mineralogy) and strength parametres of soil such as, cohesion and internal angle of friction. Assessment of geotechnical hazards will incorporate by applying 1D electrical resistivity survey on a laboratory scale using fabricated soil box. The established results will hopefully contribute in the calculations of bearing capacity, slope stability and factor of safety for soil.

Keywords: electrical resistivity, soil strength parameters, soil engineering properties, geophysical survey.

1. INTRODUCTION

Legitimate configuration and fruitful development of any structure require a precise determination of the engineering properties at the site. For this reason, geotechnical field tests (cone infiltration test, dynamic and static cone entrance test, in situ vane shear test, pressiometer and so forth.) are performed so as to get important information for the soils.

The progressions created on soil by escalated horticultural generation are variable in space and time. As an outcome, a constant and exact spatially and fleeting follow-up of the dirt physical and fabrication properties is needed. Geophysical strategies have been connected to soil sciences for an impressive period. The general standard of geophysical investigation is to non-rudely gather information on the medium under scrutiny (Scollar *et al.*, 1990)[1]. Among such systems, those in view of the electric properties appear to be especially encouraging in light of the fact that dirt materials and properties are emphatically corresponded and can be evaluated through the geoelectrical properties.

A soil examination project is important to give data to outline and development furthermore ecological appraisal. The principle design is to empower sufficient and temperate outline of the proposed undertaking. The scope of soil investigation depends on the type, size and variability of the structure [2]. In this paper, we review the literature on determining the electrical resistivity with soil properties. We first discuss the basic concept of soil resistivity and then it's interrelation with soil physical properties and strength parameters of soil (cohesion and angle of friction). In the end, advantages and limitations of electrical resistivity surveys on laboratory scale.

2. PROBLEM FORMULATION

The utilization of electrical resistivity by geotechnical engineers has been expanding overall. However, there are exceptionally restricted studies have been directed to get geotechnical parameters utilizing electrical resistivity tool. Acquiring geotechnical properties has turn into a vital issue in geotechnical building with a specific end goal to look at the progressions of frictional point and attachment with the varieties of soil sorts, porosity, immersion degree, dampness content, p^H, compaction energy and molecule size appropriation of soil[3]. These are most extreme important parameters in predicating the establishments of earth structures, element of security, bearing capacity and so forth. The relationships of diverse geotechnical properties with electrical resistivity will close the gap. Geophysical and geotechnical testing will have the capacity to interpret the geophysical information and use the data for their framework [4]. Therefore an option and brisk and less costly strategy for evaluating soil properties, (for example, water content, porosity, immersion degree, union, point erosion, unit weight and so forth.). Be that as it may, borehole examining is extravagant and time intensive. Traditional systems does not oblige any delicate element investigation, soil tests got without irritating the surface and afterward tried in lab by fusing soil electrical properties, for example, electrical resistivity and conductivity from the dirt surface to any profundity [2].

3. LITERATURE REVIEW

Solidness of characteristic and uncovered inclines is the central part of geotechnical Engineering and assumes a fundamental part when planning building, streets, passages and other designing structures. Exact determination of building properties of soil is fundamental for fitting outline and fruitful development of any built structure. During geotechnical site examination, different building properties are examined by geotechnical designers. These building parameters are gotten at some key spots and extrapolated to more extensive zone. Malaysia is situated in tropical climatic zone of the world where mean yearly rainfall is more than 500mm[5]. In Malaysia, an expanded measure of lodging developments are being completed in slope side locales because of quick populace development, financial improvement, non-accessibility of level grounds, and some different elements, for example, alluring regular perspectives, fine ventilation, restrictiveness etc, [6]. In soil science, (Bevan, 2000) reported that the first known equipotential guide was accumulated by Malamphy in 1938 for archeological examination at the site of Williamsburg in USA. Since that early study, the enthusiasm for subsurface soil prospecting by electrical prospecting has relentlessly expanded.

Geophysical routines (i.e., geoelectric systems, GPR, seismic refraction, and so forth.) are non-intrusive, non-dangerous, moderately quick and practical. Subsequently, they are more habitually utilized as a supplementary overview for sub-surface soil examination, and additionally a control exploration amid the phase of execution and abuse of an article Standard, customary soil review systems for the estimation of A-skyline thickness, taking into account perceptions at soil pits or twist drill gaps, experience both methodological and temperate imperatives when utilized for whole scenes. Not just are these strategies amazingly drawn out and immoderate in light of the high work costs, they can likewise be exceptionally damaging, consequently expanding the danger to the dirt asset. Also, since just point perceptions are accessible exact mapping of soil properties of expansive regions may be immoderate because of the huge number of information focuses needed. One of the researcher studied the depths of water table in Afunbiowo (Nigeria) by utilizing the electrical and electromagnetic measurements. The understanding of the geoelectrical information uncovers that the close surface materials overlying the crystalline bedrock show huge varieties of resistivity qualities, running from 29 to 1400 ohm-m [7]. (Syed *et al*, 2012) proposed correlation of soil resistivity with cohesion, internal angle of friction and moisture content and somehow established the good relation between the selected parameters [8]. Geophysical procedures offer a different option for conventional soil testing strategies. These methods appear to be especially applicable since most soil qualities are firmly identified with the dirt geo-electrical properties [9]. Case in point, a huge relationship has been exhibited between the obvious electrical resistivity (ρ) or the electrical conductivity (EC) and the dirt properties of soil water content, dirt salt or supplement content or soil profundity [2, 10, 11]. Most distributed examination has been on the utilization of geophysical mapping to the evaluation of one particular soil properties.

Techniques of electrical resistivity utilized to quantify the subsurface varieties of electrical current stream, which are uncovered by the variety of electric potential between two terminals. The relationship in the middle of potential and current is introduced by electrical resistance which is identified with the variety of rock or soil sorts. Therefore, electrical resistivity technique is usually utilized while mapping and get ready geoelectric areas of geographical or anthropogenic arrangements. Based on the technique discussed above, some related work is summarized as:

a) Evaluating the nature of rock/soil chain for building industry [12].

b) Assessing groundwater level [13].

c) Mapping the association in the middle of salt and crisp water in seaside ranges [14].

3.1 Theory and basic principle

The main purpose of conducting the electrical resistivity survey is to know the soil resistivity distribution of the soil sounding volume. Falsely produced electric streams are supplied to the dirt and the subsequent potential contrasts are measured. Potential contrast examples give data on the type of subsurface heterogeneities and of their electrical properties [15]. Electrical resistivity is defined as the material property which demonstrates the propensity of a material to oppose stream of current through it. The physical standard behind electrical resistivity sensation is the Ohm's law. In its most straightforward structure, it is characterized as the proportion of potential drop over the transmitter to the measure of current connected, as shown in equation (1), where R is the resistance in ohms, ΔV is potential distinction and I is electrical current.

$$R = \Delta V / I \quad (1)$$

For a uniform barrel shaped conductor, the resistance R is specifically relative to the length, L (m) and conversely corresponding to the cross-sectional territory, A (m^2), in this manner mathematical statement (2),

$$R = \rho L / A \quad (2)$$

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Where, proportionality constant ρ is the resistivity of the conductor. The equation (2) can be rewritten as follows:

$$\rho = RA/L \qquad (3)$$

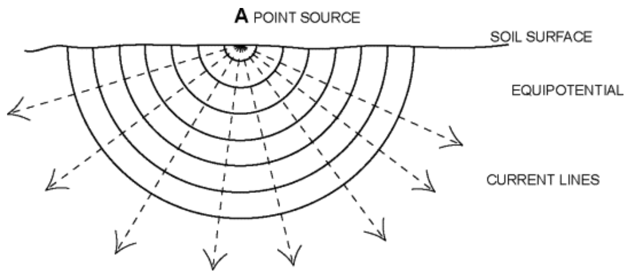

Figure-1. Current carrying through soil.

Electrical resistivity of soil relies on upon different elements, for example, mineralogy, porosity, pore liquid science, level of immersion, pore geometry, molecule size dispersion, saltiness, and temperature.

The amount and nature of water in soil has a huge impact on electrical resistivity. Electrical resistivity diminishes with expanding water content in soils. Electronic conduction is more inclined to happen in clayey soil. Soil minerals additionally have solid impact on electrical resistivity of soil as they are electrically conductive particles being able to retain and discharge particles and water atoms on its surface through a particle trade process [13, 14].

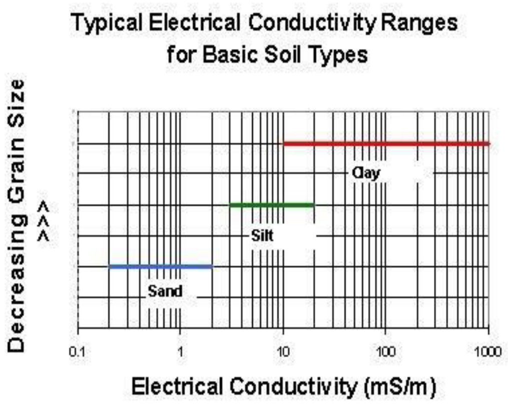

Figure-2. Typical values of electrical resistivity [8].

Temperature likewise assumes a crucial part in the electrical resistivity of soil as the increment in temperature build the portability of the particles and reason diminish in electrical resistivity of soil [15]. Regular conductivity values for distinctive earth materials are compressed in Figure-2.

3.2 Factors affecting soil resistivity

Soil is not a homogeneous substance, as this varies through one interval to other. In this regard following factors can be taken into consideration in affecting soil resistivity.

3.2.1 Moisture content

The measure of water present in the dirt is a standout amongst the most imperative parameters which geotechnical specialist needs to know. It can be characterized on the premise of volume or weight. In the event that dampness substance is measured by weight then it is called as gravimetric water content. In weight premise, the proportion of measure of water present in the void to the measure of solids is known as dampness content. It can be indicated in mathematical statement (1). The measure of water in soils incredibly influences its resistivity.

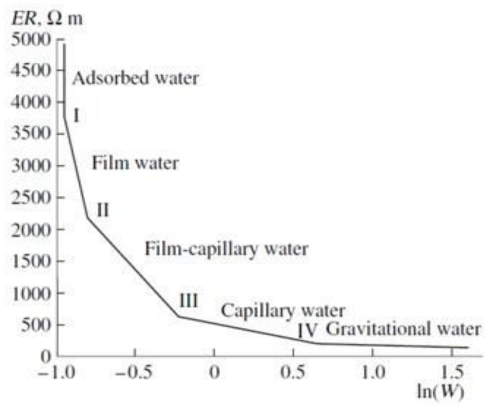

Figure-3. Linear relationship of natural logarithm of moisture content and electrical resistivity.

In coarse-grain soils, pore-water encourages flow conduction as particles can free moves in liquid medium, along these lines creates electrolytic conduction. Clayey soils by and large have lowerresistivity values as the present conduction happens through electrolytic and in addition electronic conduction. A few past scrutinizes demonstrated that dampness substance is key component that controls electrical resistivity in soil.

Non-straight relationship in the middle of resistivity and water substance has been seen in all distributed writing [6]. Previous studies demonstrated that dampness substance is the most overwhelming element which greatly influences the electrical resistivity of soil. Free electrical charges reasons diminish in electrical resistivity under the utilization of electric field. It is seen electrical resistivity of soil reductions quickly with the increment of dampness substance more than 15% [9]. Archie [7] was the first to examine electrical resistivity of water-immersed strata. Voronin [16] presented break focuses in relationship bend of resistivity and water substance partitioned into four straight portions, i.e.

consumed, film, film-fine, and gravitational water zone. Figure 3, demonstrates the work of Pozdnyakova *et al.* [9] essentially in light of Voronin's idea [16].

3.2.2 Organic content

Persistent soils frequently contain natural matter, which made out of rotted plants and creatures. Cation trade limit (CEC) of natural soil is for the most part high [17]. Increment in cation trade limit (CEC) expands the electrical conductivity of soil and in this manner resistivity diminishes. The natural mixes in soil, for example, humic and fulvic acids have high separation rates and electrical charge versatility [9]. Ekwue and Bartholomew additionally watched that increment of peat substance expanded the conductivity at consistent dampness substance [18].

3.2.3 Temperature

Increment in temperature diminishes the electrical resistivity of soil because of particles disturbance. Campbell *et al.* [19] found that increment in temperature by $1^{o}C$ expands the electrical conductivity by 2.02% in this way diminishing the electrical resistivity. Abu Hassanein et al,[20] concentrated on that impact of warming and cooling on three distinctive soil tests. Scope of temperature was -20 ^{o}C to 80 ^{o}C. A huge drop in resistivity was seen after zero

0 ^{o}C. Fikri [2] performed research facility investigate three diverse sorts of soil, i.e. top soil, palm oil soil,and kaolinite mud at different temperatures and discovered comparative conduct as settled in past studies [9, 19, 20]. (Adli *et al.* 2010) performed field and lab resistivity estimations to explore the distinction of both estimations.

Resistivity qualities acquired in lab condition were constantly higher than those got in field [21].

Based on the above literature review it can be concluded that so far, very limited work has been done to correlate the electrical resistivity with soil strength properties. The current research work will close the gap by establishing a relationship of laboratory electrical resistivity with insitu soil engineering properties.

4. PREVIOUS WORK

So far restricted studies have been done to correspond the dirt properties with laboratory electrical resistivities which are far most critical to contribute in deciding the bearing limit and element of wellbeing (FOS) in geotechnical designing. (Siddiqui, 2012) investigated the relationship of field resistivity survey with soil strength parameters. Total 79 samples were used to demonstrate the study. His investigation produces the moisture content ranges from 6.11% to 52.42%. and laboratory resistivity values were found to be 15 to 4500 Ωm [8]. Wei bai, 2013 investigated electrical resistivity of laterite soil with temperature, dry density and followed by moisture content. The method of determining resistivity was disc-electrode as shown in Figure-4 [22].

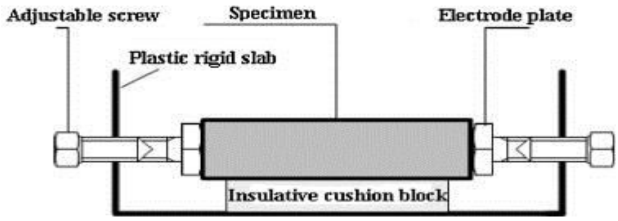

Figure-4. Disc-electrode method

5. PROPOSED RESAERCH MODEL

The fundamental approach behind this research model is to establish a relationship of electrical resistivity with soil engineering parameters. The research work will include extensive laboratory work and collection of samples from 40 different sites of Malaysia. The purpose of collecting 40 samples is to gather the data and to know the behavior of different soil under different atmospheric conditions which will also allow us to generate a strong data points to be correlated. The laboratory work will be as follows:

5.1 Soil sample collection

Soil samples will be obtained from different locations of Malaysia. The depth will be around 0.5 meters as the approach is to obtain insitu soil samples. The obtained sample will be brought to the laboratory to conduct physical and chemical properties of soil by means of laboratory tests according to BS standard 1990.

5.2 Soil investigations

Soil investigations (e.g. particles size distribution, moisture content, porosity, degree of saturation, bulk density, dry density, plasticity index, specific gravity, CEC, Ph and mineralogy and so forth) will be carried out on insitu soil samples obtained from the site. The direct shear test will be performed by using a cylindrical tube after the electrical resistivity survey.

5.3 Laboratory resistivity setup

Laboratory resistivity test will incorporate in fabricated soil box (380×200×200 mm) in dimensions; by using 1D wenner array method as this is the most simple to operate and so far produced reliable results in predictating electrical resistiviy of soils. Whereas, other array methods are difficult to operates and are time consuming. The insitu soil will be sieved through 2mm sieve according to BS standard in order to get the different size of soil particles including silt, clay and sand.

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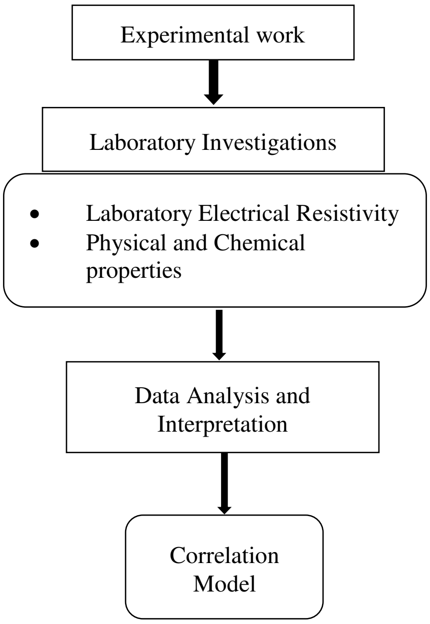

Figure-5. Project flow diagram.

Total 15kg of soil will be used in a fabricated box by compacting through standard proctor hammer about maximum 45 numbers of blows. The project flow chart is described in Figure-5.

5.4 Analysis and correlations

The last stage of research is to analyse the data and correlations of various soil physical, chemical and strength parameters of soil obtained from laboratory electrical resistivity survey. The proposed correlation will produce in the form of charts, graph and empirical formula by using SPSS software because, SPSS can take information from any sort of document and utilize them to produce organized reports, graphs, and plots of dispersions and patterns, expressive insights, and behavior of complex measurable analyses. SPSS is among the most generally utilized projects for `realistic examination as a part of social sciences. The aobtained correlation would be liable in the calculation of bearing capacity of soils and slope stability for the factor of safety (FOS) in soils.

6. EXPECTED RESULTS

This research however will produce correlations between insitu soil electrical resistivity and various soil physical and chemical properties (e.g. cohesion, internal angle of friction, moisture content, plasticity index, porosity, degree of saturation, bulk density, dry density, CEC, P^H, mineralogy, grain size distribution) in the form of charts, graph and empirical formulas. The obtained correlations will lead us in possible assessment of calculating bearing capacity and factor of safety of slope stability. The strength properties of soil such as, cohesion and internal angle of friction will be obtained from proposed correlation model. Figure-6 shows the graphical representation of a proposed model. Any slope could be checked and if the FOS falls inside of a certain scope of an "prescribed value" which shows high hazard, a further confirmation of the FOS will then be directed through the real soil exhausting sampling or whatever other broad strategy.

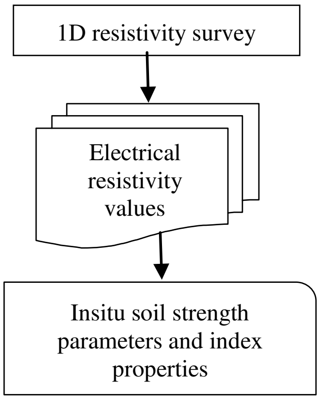

Figure-6. Graphical representation of model.

7. CONCLUSIONS

Noteworthy, quantitative and subjective connections have been gotten in the middle of resistivity and water content. So far researchers have done good work on calculating the possible correlations but more laboratory work on insitu soil is needed to be done on different soils from different geological environments in order to establish more precise and generalized relationship between strength parameters and electrical resistivity of heterogeneous soil engineering properties. Therefore, possible correlations will lead us in establishing the bearing capacity and slope stability calculations.

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