

Determination of Soil Strength Using 2D Geoelectric Methods and Direct Shear Test (Case Study in Istana Tidar Regency Housing – Jember)

Nurul Priyantari¹, Supriyadi^{2*}, Devi Putri Sulistiani³ and Winda Aprita Mayasari⁴

¹ Departemen of Physics, Natural Science Faculty, Jember of University
Jl. Kalimantan 25 Jember East Java

² Departemen of Physics, Natural Science Faculty, Jember of University
Jl. Kalimantan 25 Jember East Java

³ Departemen of Physics, Natural Science Faculty, Jember of University
Jl. Kalimantan 25 Jember East Java

⁴ Departemen of Physics, Natural Science Faculty, Jember of University
Jl. Kalimantan 25 Jember East Java

*Corresponding author's email : supriyadii [AT] unej.ac.id

ABSTRACT— 2D geoelectrical resistivity measurement and direct shear test has been conducted to determine soil type and soil strength on land settlement Istana Tidar Regency housing, Jember. Resistivity measurement is conducted at two line that have latitude 08.10'102" – 08.10'108" S, 113.43'404" – 113.43'408" E (line 1) dan 08.10'102" – 08.10'108" S, 113.43'410" – 113.43'414" E (line 2). Soil specimen were taken at 3 point, 2 point at line 1 and 1 point at line 2. Based on result of 2D geoelectrical resistivity measurement and direct shear test, this location was dominated by clay, silt and sandy silt are included in the type of cohesive soils. Soil strength of this type is capable to support light bulding contraction one or two floors.

Keywords— geoelectrical resistivity, direct shear test, soil type, soil strength

1. INTRODUCTION

Soil has an important role to plan the construction of a civilian building, its function is to proponent the foundation of the building (Hardiyatmo, 2012). As load-bearing of a building, soil often have movement especially on soft soil. Soft soil is soil which mostly consists of smallest particles such as clay or silt. Soil movement problems occur due to various factors, there are topography, geography, morphology, geologic structures, soil seepage and areas of earthquake potential. Therefore, before construct a civilian building requires knowledge of basic properties of soil in order to support load of building thereon. the basic properties of soil should know that physical properties and shear strength. The Factors are affecting the shear strength is the type of soil (cohesive and non-cohesive) and the water saturation level in cohesive soil. Soil cohesive is mostly composed of small grains which have a low shear strength. The shear strength of cohesive soil is determined from the grade of its cohesion. Examples of cohesive soil is clay, silt loam, sandy loam and silt. Non-cohesive soil is soil that contains a lot of coarse grains that do not have a bond between the grains. Non-cohesive soil is appropriate material to support load-bearing of building because it is easily compacted and has a high shear strength. Examples of non-cohesive soil are sand, gravel, and rock (Hardiyatmo, 2010).

Geoelectric methods can be used to map subsurface structures. Geoelectric methods is a geophysical methods used to study the properties of current in subsurface. Basics principle of geoelectrical resistivity method is record electrical current of the earth itself or through injection of DC (Direct Current) into the earth. Rohim, et al (2010) use geoelectrical resistivity method to determine the structure of the soil. Permana and Sopyan (2013) has also conducted research on the determination of soils type by using geoelectrical resistivity method. Electrods configuration frequently used in this methos is Wenner (Figure 1).

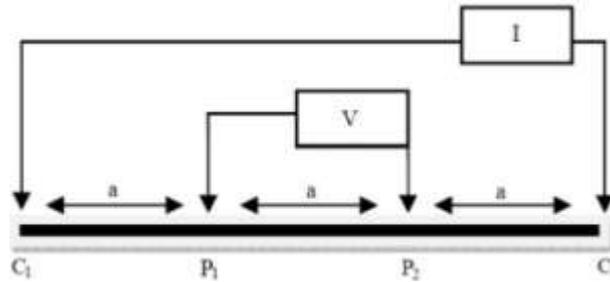


Figure 1. Wenner electrode configuration (Source: Loke, 1999)

Current and potential electrodes placed symmetrically to the point of sounding. The distance between the current electrodes three times the distance of the potential electrode. In Wenner configuration, four electrode i.e C₁, P₁, P₂, and C₂ with the same space totally moved at a fixed distance. Geometry factor in this method is $2\pi a$. Resistivity values of various types of soil shown in Table 1

Table 1. Resistivity value for soils

Type of soils	Resistivity(Ωm)
Clay : very wet and moist	< 1.5
Clayey soils : wet to moist	1.5-3.0
Silty clay and silty soils : wet to moist	3.0-15
Silty and sandy soils : moist to dry	15-150
Bedrock : well fractured to slightly fractured with moist soil filled crack	150 – 300
Sand and gravel with silt	± 300
Bedrock: slight fractured with dry soil filled cracks	300 - 2.400
Bedrock : massive and hard	> 2.400

Source : Hunt, Roy E.1984

One methods that are well suited for shear strength test is direct shear test. Direct shear test has been conducted by Nugroho (2011) in a mixture of clay-sand soils. In direct shear test, the normal stress σ is obtained from the normal force F_n .

$$\sigma = \frac{F_n}{A} \quad (1)$$

While the value of shear stress contrary to shear movement can be calculated as (Endah, 1985).

$$\tau = \frac{F_g}{A} \quad (2)$$

Graph of normal stress versus shear stress will produce a regression equation to obtain the value of soil cohesion (c) and the friction angle in the soil (ϕ) suitable to the theory of Mohr-Coloumb

$$\tau = c + \sigma \operatorname{tg} \phi \quad (3)$$

Annotation:

σ = normal stress (kN/m²)

τ = shear stress (kN/m²)

F_n = normal force (N)

F_g = shear force (N)

A = sectional area of soils sample (m²)

c = cohesion (kN/m²)

ϕ = friction soil (°)

Based on the value of cohesion (c) and friction angle (Φ) which obtained from direct shear tests, can be determined the type of soil. Value cohesion (c) can be used to determine the classification of cohesive and non-cohesive soil (Muntohar, 2009). Where as for the value of the friction angle (Φ), soil type refer to Table 2.

Table 2. Values friction angle (Φ) for some types of soil

Soil type	Friction angle Φ (°)	
	Loose	Dense
Well-graded sand (angular grains)	32-36	35-45
sand (angular grains, subangular)	30-34	34-40
sand beach (round grains)	28-32	32-38
crushed gravel	36-40	40-50
Gravel on the cliff	34-38	38-42
Silty sands	26-35	30-36
Inorganic silt	26-35	30-35
Clay	20-25	20-25

Source: Bowles, J. E, 1984.

Based on above description, the goal of this research is to know the type of soil in Istana Tidar Housing Summersari Subdistrict Jember Regency. Geoelectric method is used to get an description of subsurface structure based resistivity values, which will be correlated with the type of soil. The result of geoelectric method is used to determine the points of soil sampling to be tested in the laboratory using direct shear test to get the value of cohesion and friction angle. The results of this research are expected to provide information on soil types in Istana Tidar Regency Housing so it can be a reference for development planning.

2. METHODS

Geoelectric Methods

The basics principle of the Wenner configuration in geoelectrical mapping method is: four electrode i.e C_1 , P_1 , P_2 , and C_2 with the same spacing as a whole moved at a fixed distance. The Spacing depends on the depth of the subsurface layer to be mapped. Wenner configuration has advantages and disadvantages. the advantage of Wenner configuration is great spaced of potential electrode so that it does not require sensitive equipment. While the disadvantages is all the electrodes must be moved for each reading on the resistivity (Burger, 2006). If the spacing between the electrodes is a , then:

$$r_1 = r_4 = a \text{ and } r_2 = r_3 = 2a \quad (4)$$

Thus, the potential difference at the point P_1 and P_2 are

$$\Delta V = \left(\frac{I\rho}{2\pi}\right)\left\{\left(\frac{1}{a} - \frac{1}{2a}\right) - \left(\frac{1}{2a} - \frac{1}{a}\right)\right\} \quad (5a)$$

$$\Delta V = \frac{I\rho}{2\pi}\left(\frac{1}{a}\right) \quad (5b)$$

so that

$$\rho_a = K \frac{\Delta V}{I} \quad (6)$$

where $K = 2\pi a$ (geometry factor of Wenner configuration)

Direct Shear Test

Direct shear test apparatus is consist of a metal box which containing a soil specimen to be tested. The box is divided into two sides in the horizontal direction. Soil specimen were used formed into a circular or square cross-section. Soil specimen size generally used is about 3-4 inch² (1935.48 - 2580.64 mm²) cross section and a height of 1 inch (25.4 mm). The normal force in soil specimen obtained by placing a dead weight on top of the soil specimen. The dead weight can cause pressure on the soil specimen up to 150 Psi (1034.2 kN / m²). The shear force applied to push the sides top of the box until a shear failure in soil (Endah, 1985). The diagram of a direct shear test apparatus can be seen in Figure 2.

Figure 2. A diagram of the direct shear test apparatus (Source: Endah, 1985)

3. RESULTS AND DISCUSSION

Data acquisition of 2D geoelectrical resistivity is conducted in the Istana Tidar Regency housing results soil

resistivity values. Apparent resistivity obtained by multiplying that value by the geometry factor of Wenner configuration. Inversion of the apparent resistivity values result a 2D pseudosection of the subsurface resistivity distribution. Data acquisition is conducted on vacant land consists of two line and resistivity imagery shown in Figure 3 and Figure 4.

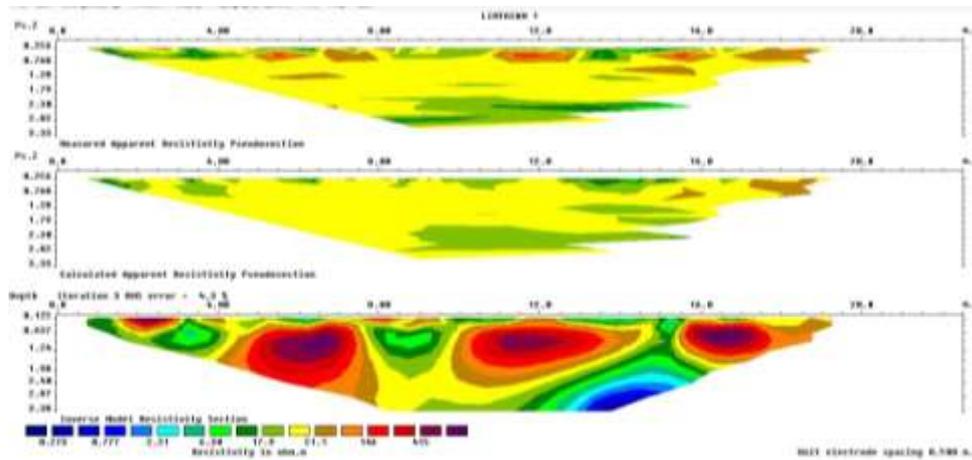


Figure 3. Results of pseudosection resistivity values on line 1

Line 1 is located at coordinates 0810'102"-0810'108" S and 11343'404"-11343'408" E, stretches from south to north. This line has a length of 20 m with the smallest electrode spacing of 0.5 m. Based on Figure 3, obtained a model subsurface resistivity layer with values ranging between 0.273 Ω m - 415 Ω m. This line is dominated by clay with gravel trapped between clay. Low resistivity shown by the blue color is interpreted as the ground water level at a depth of 2.5 m.

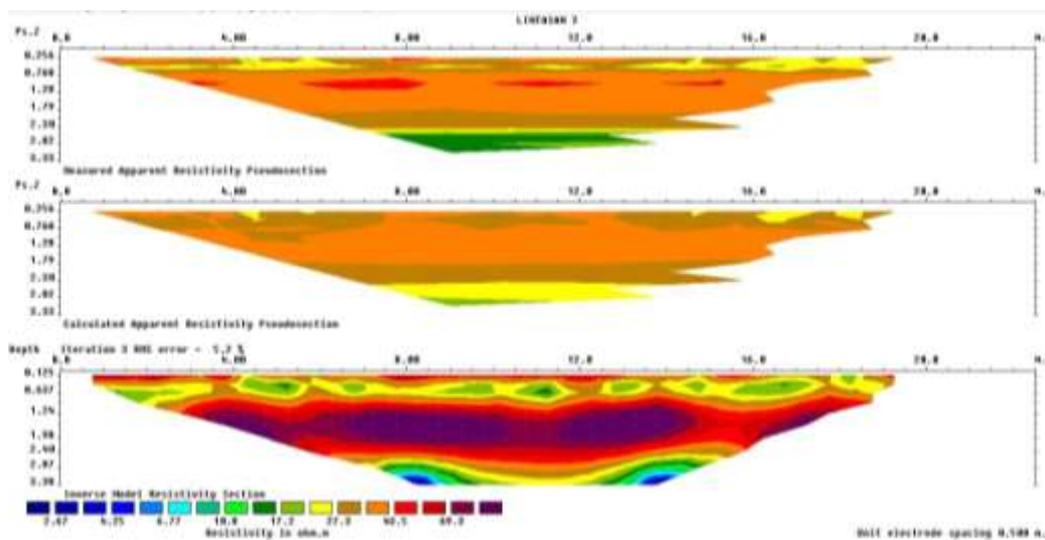


Figure 4. Results of pseudosection resistivity values on line 2

Line 2 is located at coordinates 0810'102"-0810'108" S and 11343'410 " 11343'414" E. This line parallel and stretches as far as 12 m from line 1 position with a length of 20 m and the smallest electrode spacing of 0.5 m. Figure 4 shows that the variation of the resistivity of the subsurface structure of line 2 ranged between 2.67 Ω m - 69.3 Ω m. This line is thought to have the type of soil in the form of sand and clay.

Having obtained the model of the subsurface structure (Figure 3 and 4) performed soil sampling. There are three points we tested the soil specimen that point 1 is located in the line 1 with coordinates 810'105" S and 11343'404" E, Point 2 is located in the line 1 with coordinates 810'105" S and 11343'407" E, and Point 3 is located in the line 2 with coordinates 810'108 " S and 11343'410" E. The value of cohesion (c) and friction angle (Φ) of three soil specimen shown in Table 3.

Table 3. The value of cohesion (c) and friction angle (Φ) of three soil specimen

Soil specimen	Resistivity (Ωm)	friction angle ($^\circ$)	cohesion (kg/cm^2)	Soil type
Point 1	17,9 - 51,1	40	0,076	silty clay, silty soil wet mushy, silty soil, sand, sand slightly graded.
Point 2	6,3	25	0,080	silty clay, silty soil wet mushy or silty sand.
Point 3	10,8-17,2	32	0,160	silty clay, silty soil wet mushy, clay, silt, silty sand, sand slightly graded

In Table 3, soil specimen at point 1 has a value of friction angle 40° . Base on Table 2, friction angle 40° suspected soil type angular sand for dense soil and crushed gravel for loose soil. Point 2 have a value friction angle 25° , suspected to be soil type of clay. Whereas point 3 have a value friction angle 32° , suspected to be silty soil or silty sand. The test result of soil specimen from 3 point at depth 2-2.5 m using direct shear test, the soil type such as clay, silt, silty sand, and angular sand. Cohesion grade for the 3 point are small and the difference is quite small ie 0,076-0,160 kg/cm^2 .

The results of geoelectric and direct shear tests showed that the location is dominated by clay, silt, silty sand and sandy soil, which means have a lot of fine grains that can be called a cohesive soil. Cohesive soil has a low shear strength, and has a carrying capacity of soil is very small. Cohesive soil can only be used for lightweight construction with a load that is not too large, such as building one floor to two floors.

4. CONCLUSION

Based on the measurements results of geoelectrical resistivity 2D Wenner configuration and direct shear tests, the soil type in Istana Tidar Regency Housing is dominated by clay, silt and silty sand. Both of these measurements can be complementary in which geoelectric measurements obtained the subsurface structure model while soil strength information obtained from direct shear tests.

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