Analyzing of 2D resistivity data to determine the subsurface stratigraphy at Institut Teknologi Kalimantan (ITK) Balikpapan

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Abstract. This research was conducted to identify subsurface stratigraphy at Institut Teknologi Kalimantan (ITK) area. The information of subsurface stratigraphy becomes more important for minimizing the effects of changes in soil structure. We run the Geoelectrical resistivity method using Wenner-array along four measurement lines. Field data measured consists of electrical current and potential difference to calculated apparent resistivity values. Then, the apparent resistivity data were inverted to obtained true resistivity values. The results showed that subsurface stratigraphy was composed of three main layers. The first layer was characterized by higher resistivity values ranging from 39 to more than 86 ohm-meters interpreted as topsoil. The lower range of resistivity values at the second layer was identified as clay with resistivity values from 9.36 to 39 ohm-meters, while the higher resistivity values ranging from 39 to 86 ohm-meters and marked by Brown to red colour below the surface at the third layer was identified as clay sandstone.

1. Introduction
The topography of Balikpapan city mainly consists of 85% hilly terrain and only about 15% lowland, which is stretched on the coastal area [1]. Based on the topography condition, the construction of buildings in Balikpapan must be considered under the subsurface structure, because in the construction process, a strong and solid foundation become the most important parts of the structure. Foundation is the lowest part of the building or structure which directly transfers the structure loads into the ground [2]. Institut Teknologi Kalimantan (ITK) in the northern part of the Balikpapan city is a new campus currently under construction. On the building construction, it is necessary to design a multi-story building that has 3 (three) floors. In development planning, it is necessary to identify subsurface stratigraphy. The method which is common used for identifying subsurface is the geophysical method[3]. Geophysics is a subject of earth science that concerned with a physical approach, in geophysics, several methods known, including the gravity method, magnetic method, geo-electrical method, and seismic method [4]. In this study, the geo-electric method was used; this method studies the electrical resistivity properties of rock layers in the earth. This method is widely used, and the results are quite good to get a picture of the subsoil and the possibility of groundwater. Geo-electrical estimation is based on the fact that different material has different types of resistivity if the current pass through on the materials. In this research, we ran several Wenner arrays in the study area to reveal subsurface profiles. The subsurface profile method or resistivity mapping is a method that aims to study the...
horizontal resistivity variation of the subsurface layers [3]. This research was conducted to identify subsurface information based on resistivity values. The resistivity value information is used to determine subsurface stratigraphy at the Institut Teknologi Kalimantan as initial information for future construction activities.

2. Methods
This study was focused on the Institut Teknologi Kalimantan (ITK) area, which is located approximately 10 km from Balikpapan City, East Kalimantan of Indonesia. We conducted a geoelectrical resistivity survey using Wenner array-four measurement lines were measured on the area, ranging in length 100 m and applying electrode spaced by 10 m (Figure 1).

The geoelectrical survey is a kind of geophysical method which is used to determine subsurface condition based on material electrical properties [3]. One type of Geo-electrical method that usually used in the subsurface study is electrical resistivity [5]. The material properties such as compactness, porosity, density, and water content can contribute to the disparity of resistivity value. In Geo-electrical survey, we injected an electrical current through a pair of electrodes and measured the potential difference of subsurface materials from another pair of electrodes [6],[7]. The total of electrical current, potential difference and electrode configuration from the field will produce the end field measurement data represented by apparent resistivity which is expressed in the following mathematical equation (Equation 1) [6].

\[ \rho_a = \frac{\Delta V}{I} \cdot k \]  

where:
\( \rho_a \) : Apparent resistivity (Ohm.m)
\( \Delta V \) : Potential Difference (mV)
\( I \) : Total of electric current injected (mA)
\( k \) : Geometrical configuration

Several electrical resistivity configurations can be applied, which is most suitable for the type of investigation. In this research, we used one common type, is Wenner array how resistivity varies
laterally. Four electrodes are pushed into the ground at equal intervals, symmetrically about the junction of the tape measurement (Figure 2) [8].

Figure 2. The electrode arrangement of the Wenner array [9].

Figure 2 shows the electrode spacing, respectively AM=NB=a and AN=MB=2a, then geometrical configuration ($\kappa$) (Equation 1) can be computed.

\[
k = \frac{2a}{\left( \frac{1}{a} - \frac{1}{2a} \right) - \left( \frac{1}{2a} - \frac{1}{a} \right)}
\]

\[
k = 2\pi a
\]

Where 'a' is the electrode distance whose value changes depending on the desired extent. Each 'a' value changes the datum point to be different.

3. Result And Discussion

After measurement and calculating data obtained, 2-dimensional inversion is then performed using the non-linear least-square optimization method. The results of two-dimensional inversion showed a cross-sectional image of the subsurface resistivity distribution under the study area. From the results of 2D inversion, we obtain the subsurface resistivity distribution that is represented by a different color. Based on the three resistivity cross-sections, three different parts of the image respectively produce apparent resistivity distribution of field data (a), resistivity distribution based on the calculating data of apparent resistivity (b) and the third image is resistivity distribution of inversion result representing true resistivity value (c) (Figure 3). The inversion results in the form of true resistivity value are revealed from the apparent resistivity and calculating data. Based on modelling and true resistivity, an error percentage of apparent resistivity will be obtained in terms of RMS error. The RMS error does not have to be small. However, the value is considered optimal if resistivity variation and system of subsurface rock correspond to geological conditions of the investigation area [10]. The following, Table 1 represents several resistivity values of material on the earth.

| Material       | Resistivity ($\Omega$m) |
|----------------|------------------------|
| Limestone      | $5 \times 10^2 - 10^5$ |
| Sandstone      | $2 \times 10^2 - 8 \times 10^3$ |
| Shale          | $20 - 2 \times 10^3$    |
| Sand           | $1 - 10^3$             |
| Clay           | $1 - 10^2$             |
| Ground Water   | $0.5 - 3 \times 10^2$   |
| Gravel         | $10^2 - 6 \times 10^2$  |
Figure 3. Shows resistivity investigation resulted from the study area, (a) represents apparent resistivity of field data, (b) represents apparent resistivity of calculating data, and (c) represents true resistivity distribution of inversion result.

Based on the inversion results (Figure 3), The range of resistivity values is 9.36-86 Ohm meters obtained along 4 times of iteration and 9.4 % of percentage error with a maximum penetration depth is 15.9 meters. Based on Figure 3, three main layers can be identified. The first layer is topsoil which is characterized by yellow to brown color with resistivity values varied from 39 up to more than 86 ohm-meters and buried in various depth from 3.75 to 6.38 meters from the surface. The higher resistivity values at the surfaces are related to dry soil condition when measurement filed was conducted. The lower resistivity values at the second layer are interpreted as clay which is characterized by dark blue to green color. This layer has a resistivity value ranging from 9.39 to 39 ohm-meters and buried in various depth from 3.37 meters to infinite from the surface, while the green to yellow color in this layer is due to differences in moisture level and clay content. The interpretation of this layer is strongly represented by the resistivity value, in range 1-100 ohm-meters (Table 1). The higher range of resistivity values at electrode distances from 55 to 65 meters marked by Brown to red color below the surface at the third layer is identified as clay sandstone with resistivity values 39-86 ohm-meters. The presence of clay which is buried in various depth from the surface and tends to be shallow and ticks should be considered in development planning. The clay soil is not ideal for building construction because clay has a high sensitivity to changes in water content, which causes the shear strength of the soil to be low and its compressibility to be high [11].

4. Conclusion
Based on the results reviled by applying geoelectrical resistivity survey using Wenner array on the study area, we conclude that the geoelectrical resistivity survey provides information about subsurface stratigraphy at ITK area. From the analysis results, we obtained subsurface structures based on resistivity values ranging from 9.36 to 86 ohm-meters can be interpreted into three different main layers respectively are topsoil, clay, and clay sandstone by a maximum penetration depth is 15.9 meters from the surface.
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