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The determination of slip surface layer in Trangkil settlement area, Sukorejo Village, Gunungpati District, Semarang Municipality using two dimensional resistivity method with dipole-dipole configuration

Tony Yulianto*, Rahmat Gernowo* and Wahyu Krisna**

**Department of Physics, Faculty of Mathematics and Sciences, Diponegoro University, Java,* Indonesia.
***Department of Geology, Faculty of Engineering, Diponegoro University.*

Abstract

Landslide movement is a product of disturbance process against slope balance, which may cause the movement of soil and rock masses to the lower place. The measurement using two dimensional resistivity method with dipole-dipole configuration with electrode distance a=10m, n=4, followed by a geological obseration in Trangkil settlement area, Sukorejo Village, Gunungpati District, Semarang Municipality can be used for determining a slip surface. The slip surface layer at the research location is situated in the depth of 10 meters and width of approximately 3 meters with the resistivity rate ranging from 32 to 191 Ωm at clay layer. The measurement is performed based on a geological observation. The study found moderate to high *leakage* rate under the *volcanic brexite* layer. Such condition allowed the water flow into the landslide points.

Keywords: *landslide, two dimensional resistivity, dipole-dipole, slip surface.*

INTRODUCTION

Fault geological structure in Semarang Municipality has been believed to cause problems, in particular unstable land and road damage, such as what can be found in Sekaran, Gombel, Sigarbencah, and Semarang-Ungaran TOL road in Gedawang. There was a lindslide incidence in the area in 2014, causing damage to the Sekaran-Sampangan route. In Gombel, the landslide caused damages to houses and even fatality. The disaster had forced some people in Trangkil to be relocated because their houses were destroyed.

The Directorate of Volaconolgy and Geological Disaster Mitigation [1] reported that landslide can be referred as land movement. It is defined as land or mixed materials (clay, gravel, sand, clod, and mud) that move along the slope or outside the slope due to earth gravity.

The landslide disaster is one of factors that cause poverty or inability. In addition to its "impoverishing/paralyzing nature", the disaster ist also costly because local government must allocate more fundings to develop new infrastructures and to perform post-disaster rehabilitation. In practice, landslide-prone areas will need more time for the area maintenance than that of stable areas.

Geological condition is one of factors that cause landslide. To detect the geological condition of the landslide-prone area, an approach to geophysical method is necessary. The geophysical method that can be applied is resistivity. Mapping method is used for finding out the rock spread resistivity in a lateral direction. This mapping method allows a prediction of the rock spread under the soil at the research location [2].

The two dimensional resistivity geophysical method is used for detecting the slip surface and shear surface. Darsono in his study indentified that slip surface had caused landslide in Pablengan Village, Matesih District, Karanganyar Regency. The slip surface observed was clay rock with the resistivity rates ranging from 19.3 Ωm to 36.6 Ωm and the depth ranging from 1.7m to 17m [3]

Trangkil, Gunungpati, is an area situated on Kaligetas Formation (Qpkg), consisting of *volcanic breccias*, lava tract, tuf, sandstone, *tufan*, and clay rock. The formation contains flow breccias and lava with lava inserts and smooth to crude tuf. The lower layer of this formation there is clay rock containing mollusk and tufaan sandstone.[4]

REVIEW OF LITERATURE

Resistivity Geoelectrical Method

One of methods used in a geophysical exploration is resistivity geoelectrical method. This method exploit the electrical resistivity characteristics of the rocks to detect and to map the under surface formation. The resistivity geoelectrical method is performed by measuring predictable *voltage,* which reflects the condition of the under surface layer of the earth. The characteristics of a formation can be illustrated by three fundamental parameters, i.e. electrical conductivity, magnet permeability, and dielectrical permissivity. [5]

The geoelectrical method follows a principle that resistivity is an electrical current injected into the earth nature through two current electrodes, whereas *voltage* that occurs is measured by two potential electrodes. The measurement of the electrical current and *voltage*, a variation of the electric resistivity value at the layer under the measurable point is obtained. Such variation informs the layering of the under the surface layer and which layer that becomes the major source of the landslide. This

landslide points are often marked with a resistivity constrast value between the upper and the lower surfaces of the affected slope.

In principle, such method can be approached by using a concept of perambatan arus listrik in an isotropical anomaly medium, in which electrical current moves to all directions with the equal values. The measurement contains information about the distribution of the resistivity under the surface layer. The value of the rock resistivity is determined by its own rate. Hantaran listrik in the rock is mostly affected by electrolite distribution in the rock pores. To find out the under the surface structure, the distance of each current electrode and potential electrode is enhanced gradually. The longer the space of the electrode, the deeper the effect of penembusan arus downward. This technique is used for finding out the physical characteristics of the deeper rocks. [6]

The interpretation of the measurement goes with an assumption that the surface consists of several layers with aried resistivity rates. Each layer is split by a horizontal border and is an isotropic homogeneous medim. In order to determine the layer resistiity and the horizontal border according to the measurement of voltage and electrode space, a mathematical correlation must be obtained between the measured parameters and the parameters that define the distribution of the under the surface layer distribution and the resistivity of different rocks (Table 1).

Table 1. Resistivity rate of different rocks [7]

No	**Rocks**	**Resistivity rate (Ωm)**
1	Clay	1-100
2	Silt	10-100
3	Clay rock	3-70
4	Quartz	$10\text{-}2\text{x}10^8$
5	Sandstone	50-500
6	Limestone	100-500
7	lava	$100\text{-}5\text{x}10^4$

The apparent resistivity depends on the geometry of the electrode composition to be used, which is deterimed by K geometrical factor. There are three major types of electrode configurations, the two being named after their founders, Frank Wenner and Schlumberger, respectively. The third one is referred as dipole-dipole. The dipole-dipole configuration uses four electrodes, i.e. a current electrode (AB) pair namely current dipole, and a potential electrode (MN) pair namely potential dipole. In this configuration the current electrode and potential bias electrode are situated assymetrically.

Analysis of factors that affect landslide

Landslide or land movement is a shift of slope-making materials, such as *batuan asli*, weathering soil, landfill material, or a combination of these materials, which move downward and outside the slope [8]. Many factors have been believed to affect the landslide, among others slope, lithological type, geological structure, rainfall, and land use.

Inclination a degree reflected in the morphology. The greater the inclination, the greater possibility of the landslide. Such condition occurs because of gravity that pulls rock masses from the upper layer to the lower layer. The higher the inclination, the easier the rocks to be pulled downward, causing land movement.

Lithology may consist of rocks or soils the result of the rock leakage. It is an important factor that causes the landslide. High resistancy lithology such as frozen rocks will unlikely cause the landslide. Conversely, low resistancy lithology has the greater possibility to cause the landslide. Erosion and leakage processes also play a significant role in controlling the resistancy rate of a particular lithology.

Geological structure is a weak zone of rocks or lithology. Rekahan that occurs may loosen the rock daya ikat so that decrease the resistance of the rocks. Besides, the formed rekahan also becomes a pathway for the water to enter the rocks, causing leakage. Once the leakage has occurred, erosion may become more intensive. Rocks that exposed to a quite intensive structure will have greater potential to develop landslide. Land use management is a cultural result of human activities. The land is used for settlement, roads, rice fields, plantation, etc. The land use management also affects the landslide incidence. It may increase burdens at the expense of a lithology. When the burdens become bigger than the strength of the lithology, landslide may occur [9]. Vegetation is defined as all vegetation species that grow in the area, such as grasses and bushes. Vegetation also affects the stability rate of a slope. Some vegetation species are capable of improving the slope stability because their roots' ability to fasten the rock masses. However, some other species tend to have weaker roots, causing unstable situation of the slope, and, therefore, landslide incidence.

RESEARCH METHOD

1. Research Location

This study took place in the settlement area of Trangkil, Sukorejo Village, Gunungpati District, Semarang Municipalty, at the coordinates of 110°23’24.9” East and 07°01’53.5” South with the average elevation of 135 MSL. The geological observation and resistivity geoelectrical measurement was performed in dry season.

2. Geological Observation

Geological observation of this study covered morphology and lithology according to visualization result in the field and penampakan singkapan batuan.

3. Resistivity Geoelectrical Measurement

Figure 1 contains the dipole-dipole composed electrode configuration. The space between the current electrode pairs was represented by "a" equal to the space between the potential electrode pairs. Another unit in this configuration was represented by "n", a comparison between two current electrode or potential electrode pairs. The "a" unit was made constant, whereas the "n" unit increased from 1 to 2 to 3 to 6 to improve the depth of investigation.

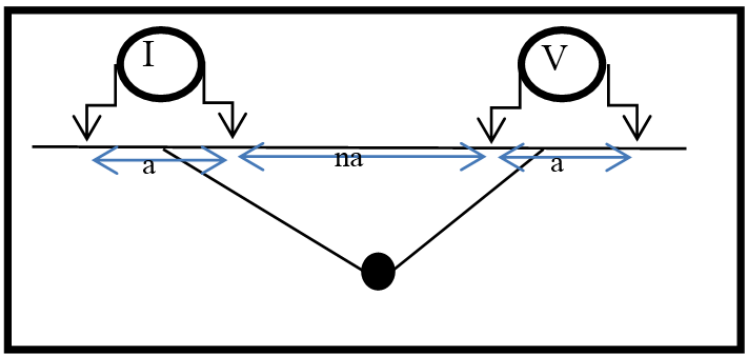

Figure 1. Dipole-dipole Configuration [2]

Each electrode composition has its own sensitivity rate that shows measurable data accuracy related to the factor unit "n" in use. Figure 2 contains the composition sensitivity for "n" from 1 to 6 namely two dimensional resistivity measurement.

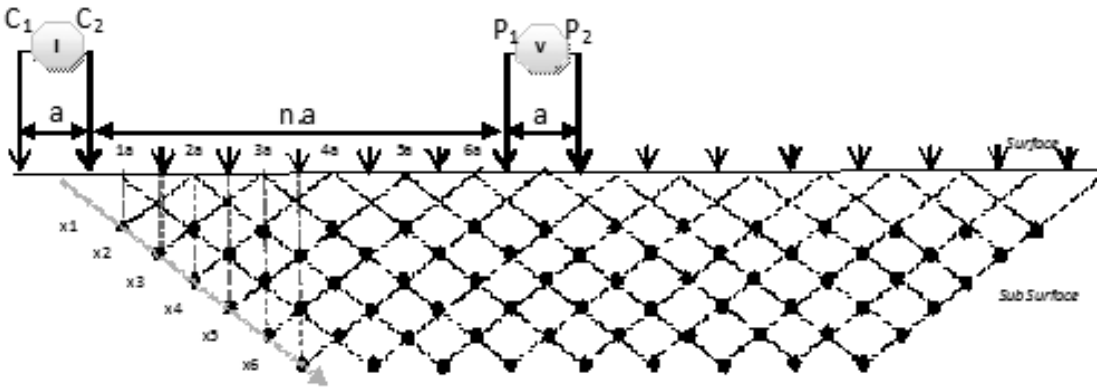

Figure 2. Vaue variation of n against *depth of investigation* [2].

In order to improve the depth of penetration, the space between the current dipole and the potential dipole (na) has to be lengthened albeit the constant space between the current and the potential electrode. This is the advantage of the dipole-dipole configuration compared to either Schlumberger or Wenner configurations because a

deeper rock detection can be performed without lengthening the cable. The following equation is used to explain apparent resistivity.

$$\rho_{a=\frac{V}{I}}\pi a(n+1)(n+2) \tag{2.11}$$

where :

ρ= *apparent resistivity* (Ωm)
a = electrode space (from C1 to P1) (m)
R = *resistivity immediately measurable on field* (Ω)

The above equation shows that πa is a geometrical factor of the dipole-dipole configuration.

RESULTS AND DISCUSSION:

1. The Geology of Research Location

Morphology

The study found that the morphology of the research location was an undulating hill with inclinations ranging from 15° to 45°. the processes taking place were cliff erosion and rock mass movement. This location contained vegetations, in particularly trees and bushes and was used for settlements and fields.

Figure 3. Research location morphology profile

Lithology

According to mapping, the research location had two lithologies, i.e. carbonatan clay stone and volcanic breccias.

The volcanic breccias had a dark gray megascopic profile and gravel-sized (2-4mm) to clod-sized (>256mm) andesitic fragments, lapilli-sized matrices (2-64mm), poor sortation, open packing, and medium to high weathering rates. At some observation points there were fractures in the vertically-directing volcanic breccias cob. The clod

was possibly caused by rock loading due to presipitating water into the rock body. It had potential to be a surface water tract that may accelerate weathering process and erosion nearby the location. These processes might cause rock mass movement leading to landslide. The volcanic breccias rock infiltrated into Kaligetas Formation (Qpkg), which was possibly deposited as *lava sediment* [4]. This rock formation had approximately 90% distribution rate around the research location.

Figure 4. Volcanic breccias outcrop profile with medium weathering condition.

Figure 5. Volcanic breccias megascopic profile.

The clay rock at the research location had a gray megascopic profile, clay-sized particles (<1/256mm), *carbonatan* cement. The rock was in a severe weathering as evidenced by froth existence after it was dripped by the HCl solution. It had a distribution rate of 10% and was situated in the east point. This clay rock was outcropped under the volcanic breccias, which only contained water during the rainy season. The clay rock was an impermeable rock, therefore, resistant to the lanslide.

Figure 6. Clay rock outcrop with severe weathering condition.

Figure 7. *Carbonatan* clay rock megascopic profile.

2. Geoelectrical Resistivity

Result of the two dimensional resistivity modeling at the research location on the line 2 with the coordinate points of 110º23'26.0" East 07º01'54" South and the elevation of 131 MSL documented that the top layer contained 3-5-meter wide top soil rocks with the resistivity rates ranging from 0.884 to 3.96 Ωm. The layer was composed of landfill. The second layer consisted of 1-meter wide volcanic breccias rocks with the resistivity rates ranging from 3.96 to 40.5 Ωm. The third layer contained 3-meter wide clay rocks with the resistivity rates ranging from 40.5 to 191 Ωm. The fourth layer was composed of sandstones with the resistivity rate of <191 Ωm.

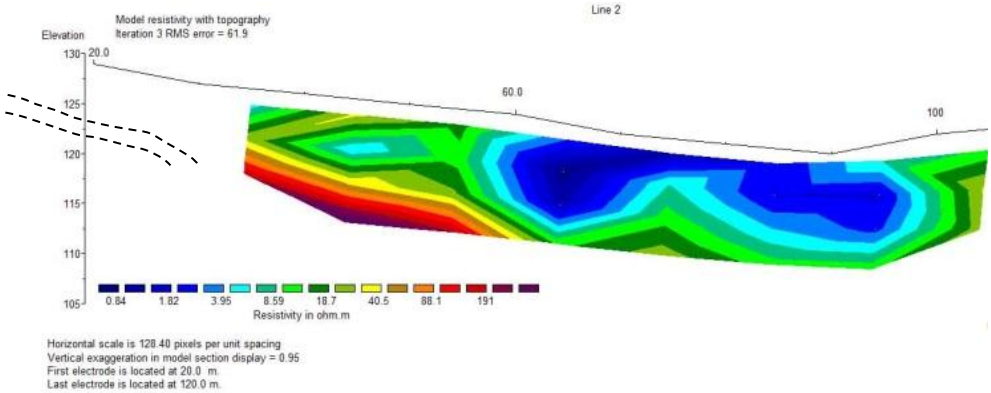

Figure 8. Result of modeling on line 2.

The line 3 measurement was done at the coordinate points of 110º23'27.2" East 07º01'54.8" South with the elevation of 133 MSL. The modeling revealed that the first layer was composed of 3 to 7-meter wide top soil rocks with the resistivity rates ranging from 3.01 to 6.7 Ωm in the form of landfill; the second layer was composed of 1-meter wide volcanic breccias rocks with the resistivity rates from 33.1 to 164 Ωm; the third layer contained 3-meter wide clay rocks with the resistivity from 33.1 to 164 Ωm; and the fourth layer was composed of sandstones and sandy rocks with the resistivity rates ranging from 164 to 811 Ωm.

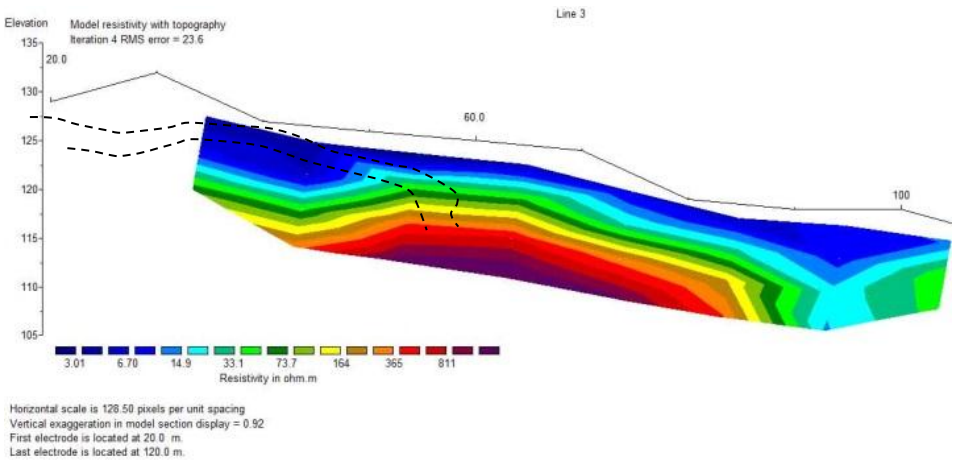

Figure 9. Result of modeling on line 3.

The line 5 measurement was done at the coordinate points of 110°23'30.1" East 07°01'55.7" South with the elevation of 139 MSL. The modeling revealed that the top layer consisted of 7 to 10-meter wide top soil rocks with the resistivity rate from 1.23 to 8.72 Ωm, spreading in some covered parts due to the volcanic breccias weathering. The second layer was composed of volcanic breccias rocks with a widht of 1 meter and resistivity rates between 8.72 and 32.22 Ωm. The third layer consisted of 3-meter wide clay rock with the resistivity rates of 32.2-119 Ωm.

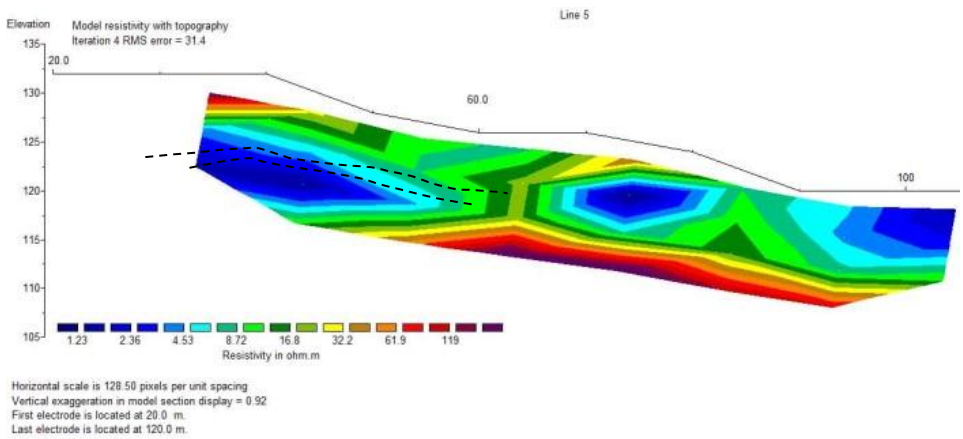

Figure 10. Result of modeling on line 5.

The line 2 measurement revealed that the resistivity at this line proved a lindslide at the corner side (the upper part of the measured location) at the depth of 10 meters. The field observation showed inclined buildings due to land movement. The movement was assumed to be caused by the foundation depth less than 10 meters.

On the line 3, the landslide was found in the middle part of the measured line. This location was relatively stable compared to the line 2 and line 5. The study did not find fractures of the volcanic breccias rock used as the surface water tract during the rainy season.

On the line 5 the upper part of the landslide consisted of volcanic breccias rock fractures in a vertical direction. This phenomenon had a potential of being the surface water tract, which accelerated the weathering and the erosion nearby the fractured points.

CONCLUSION

The slip surface layers were situated at the depth of 10 meters with a width of approximately 3 meters and resistivity rates of 32-191 Ωm on the clay layer. The volcanic breccias rock fractures in a vertical direction had a potential of being a

surface water tract, which might accelerate the weathering and erosion nearby the fractured points. The volcanic breccias rock in the observation area had the medium to high weathering rates. Therefore, it could be the place for the surface water tract, which, in turn, flew to the landslide-prone area.

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