DETERMINATION OF SLIP SURFACE AREA USING GEOELECTRIC, MASW, AND SOIL MECHANICS DATA IN CIMUNCANG VILLAGE, WEST JAVA, INDONESIA

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Introduction

A landslide is defined as the movement of a mass of rock, debris, or earth down slope. Landslide are a type of “mass wasting”, which denotes any down-slope movement of soil and rock under the direct influence of gravity.

Almost every landslide has multiple causes. Slope movement occurs when forces acting down-slope (mainly due to gravity) exceed the strength of the earth materials that compose the slope. Causes include factors that increase the effects of down-slope forces and factors that contribute to low or reduced strength.

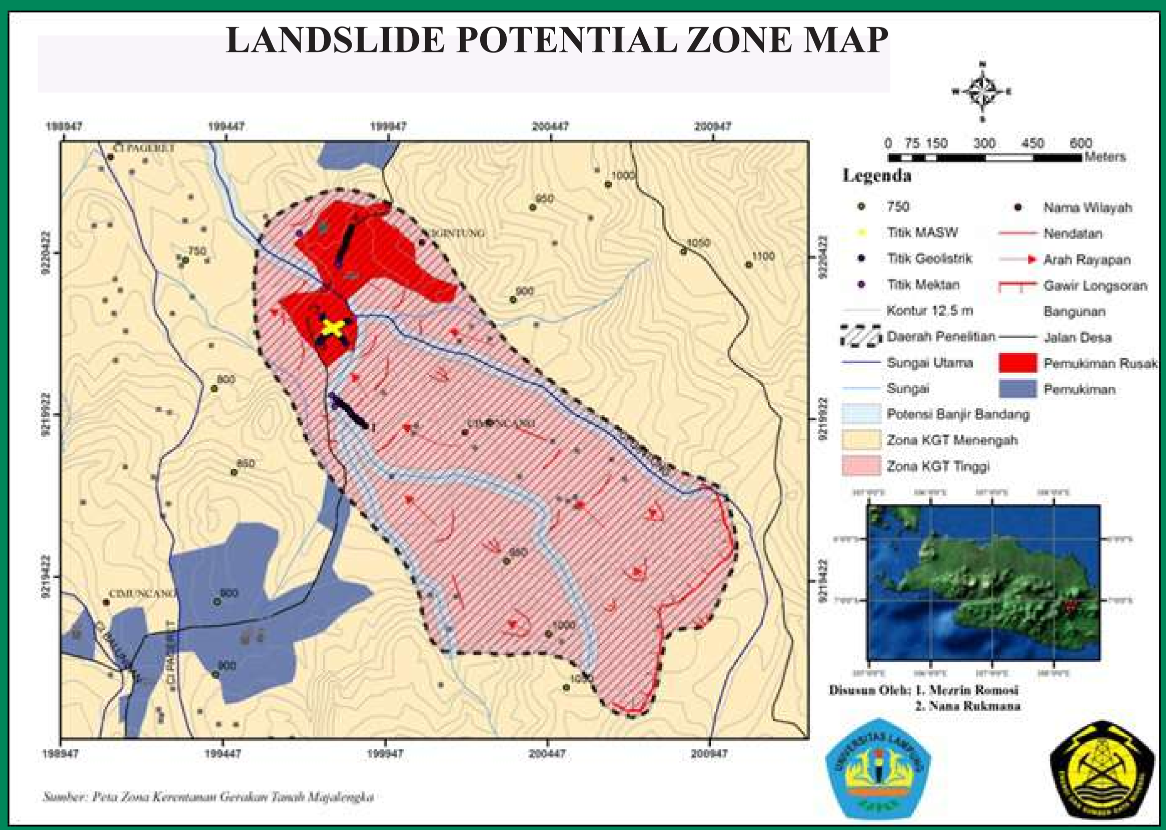

Figure 1. Landslide potential zone map

Based on Landslide potential zone map (PVMBG, 2014), the study area is located in the medium to high potential zone. National Disaster Management Agency (BNPB) inform, in 2013 there are at least 83 cases of landslide events in West Java, including those that occurred in Dusun Cigintung Cimuncang Village, Malausma District, Majalengka. On April 14th, 2013 which resulted in the destruction of settlements, farmland, and roads.

The main objects in this research is slip surface, because its layer will act as a plane, causing ground motion or landslides.

Methods

A. Geo-Electric

In the resistivity method, artificially-generated electric currents are introduced into the ground and the resulting potential differences are measured at the surface. Deviations from the pattern of potential differences expected from homogeneous ground provide information on the form and electrical properties of subsurface inhomogeneities (Kearey, 2002). **Figure 2** shows the range of resistivities expected for common rock types. It is apparent that there is considerable overlap between different rock types and, consequently, identification of a rock type is not possible solely on the basis of resistivity data.

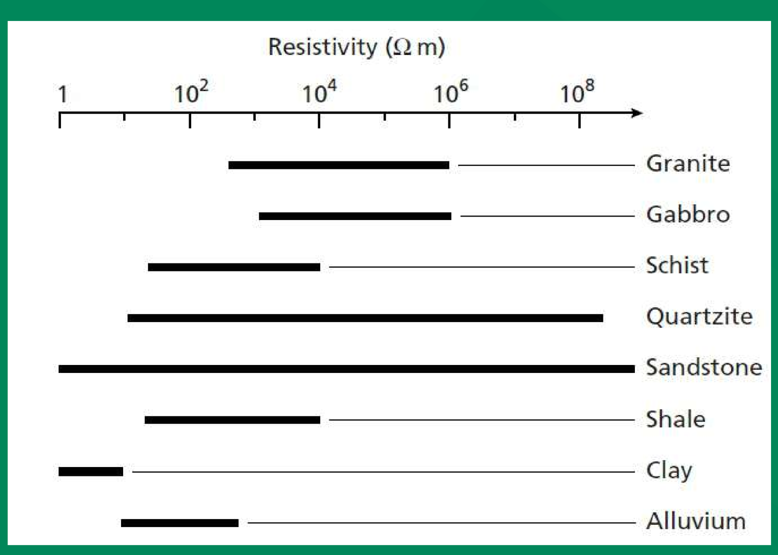

Figure 2. The approximate range of resistivity values of common rock types

B. MASW

The multichannel analysis of surface waves (MASW) method is one of the seismic survey methods evaluating the elastic condition (stiffness) of the ground for geotechnical engineering purposes. MASW first measures seismic surface waves generated from various types of seismic sources such as sledge hammer analyzes the propagation velocities of those surface waves, and then finally deduces shear-wave velocity (Vs) variations below the surveyed area that is most responsible for the analyzed propagation velocity pattern of surface waves. Shear-wave velocity (Vs) is one of the elastic constants and closely related to Young’s modulus. Under most circumstances, Vs is a direct indicator of the ground strength (stiffness) and therefore commonly used to derive load-bearing capacity. After a relatively simple procedure, final Vs information is provided in 1-D, 2-D, and 3-D formats. (Park et.al., 1999)

C. Morgenstern-Price Method

This method is one of the methods based on the principle of equilibrium limits developed by Morgenstern and Price (1965), where the process of analysis is the result of the equilibrium of every normal forces and moments acting on each slice of the slope. In this method, the analysis of Safety Factor (SF) slope is done by two principles, equilibrium moment for circular field (Fm) and force equilibrium (Ff).

$$F_m = \frac{\sum (c'\beta R + (N - u\beta) R \tan\phi')}{\sum Wx - \sum Nf \pm \sum Dd}$$

$$F_f = \frac{\sum (c'\beta \cos\alpha + (N - u\beta) \tan\phi' \cos\alpha)}{\sum N \sin\alpha - \sum D \cos\omega}$$

The terms in the equations are:

c'	=	effective cohesion
ϕ'	=	effective angle of friction
U	=	pore-water pressure
N	=	slice base normal force
W	=	slice weight
D	=	concentrated point load
β, R, x, f, d, ω	=	geometric parameters
α	=	inclination of slice base

Results and Discussion

Based on 2D geo-electrical model, the slip surface is the contact of clay with tuff layer (approximately < 25 ohmm). It is supported also by 2D MASW modeling results, the contact layer being the slip surface is the contact between the soft soil layer (Vs 40-183 m/s) and the stiff soil layer (Vs 183-366 m/s) marked by a red line shading (**Figure 3 and 4**). Grouping of soil profile based on classification NEHRP (Athanasius & Solikhin, 2015).

Table 1. NEHRP Soil Classification

Site Class	*Soil Profile Name*	*Average Properties in Top 100 feet (as per 2000 IBC section 1615.1.5) Soil Shear Wave Velocity, Vs*	
		Feet/Second	*Meters/Second*
A	*Hard Rock*	Vs > 5000	Vs > 1524
B	*Rock*	2500 < Vs ≤ 5000	762 < Vs ≤ 1524
C	*Very dense soil and Soft rock*	1200 < Vs ≤ 2500	366 < Vs ≤ 762
D	*Stiff soil profile*	600 < Vs ≤ 1200	183 < Vs ≤ 366
E	*Soft soil profile*	Vs < 600	Vs < 183

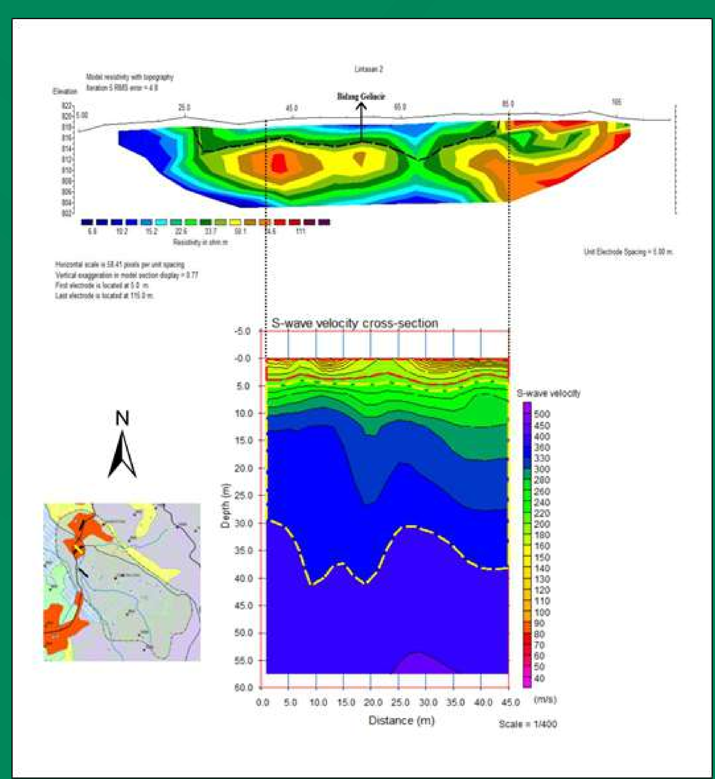

Figure 3. 2D model of geo-electrical (above) and MASW (below) that showed prediction of slip surface in line 2.

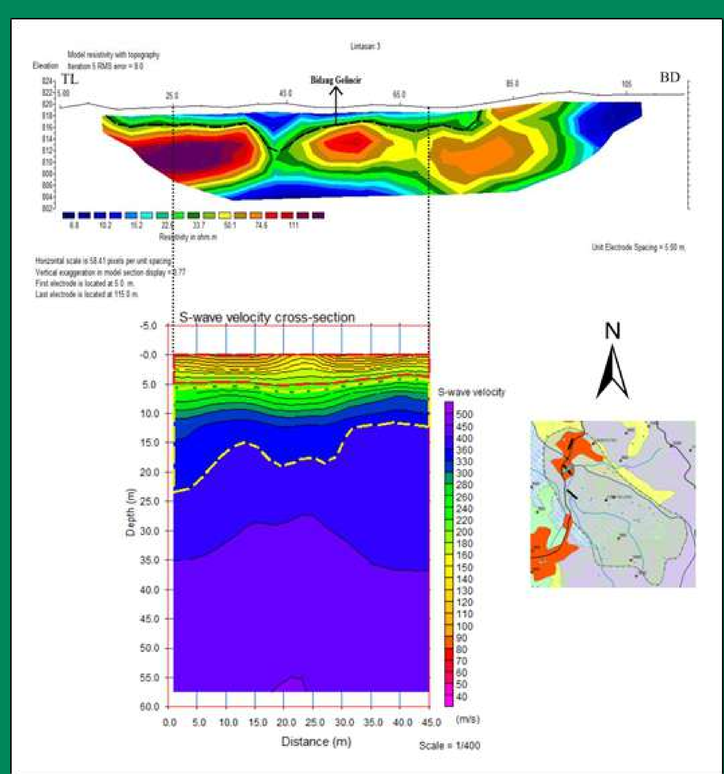

Figure 4. 2D model of geo-electrical (above) and MASW (below) that showed prediction of slip surface in line 3.

Based on Safety factor model (SF) (**Figure 5**a) on the line-1, there are two layers: the top and bottom layers. In the top layer consists of a clayey silt with silt content (0.005-0.075 mm) of 59.72%, clay (0.005 mm) of 23.56%, fine sand (0.075-0.420 mm) of 13,94%, medium sand (0,420-2,000 mm) equal to 2,78%. If seen from the limit of Atterberg is the liquid limit (LL) of this layer is equal to 54.97%, plastic limit (PL) of 32.71% and plastic index (PI) of 22.26% which is considered this layer is more low plasticity. While the bottom layer, consists of layers of silty clay with clay content of 91.94% and silt by 8.06%. When viewed from the limit of Atterberg is the liquid limit (LL) of 137.09%, plastic limit (PL) of 33.10% and plastic index of 104.00% which is considered this layer is more plastic high. The value of Safety Factor (SF) is 1.261, can be conclude the slope is relatively stable.

Based on Safety factor model (SF) (**Figure 5b**) on the line-4, there are two layers: the top and bottom layers. In the top layer consists of a silty clay with silt content (0.005-0.075 mm) of 8.06%, clay (<0.005 mm) of 91.94%. If seen from the limit of Atterberg is the liquid limit (LL) of this layer is equal to 90.49%, plastic limit (PL) of 30.85% and plastic index (PI) of 59.64% which is considered this layer is high plasticity. While the bottom layer, consists of layers of silty clay with clay content of 30.92%, silt 29.32%, fine sand 16%, medium sand 7.9%, coarse sand 8.64% and granule 7.22%. When viewed from the limit of Atterberg is the liquid limit (LL) of 63.41%, plastic limit (PL) of 30.86% and plastic index of 32.56% which is considered this layer is less plastic. The value of Safety Factor (SF) is 0.98, can be conclude the slope is relatively labile.

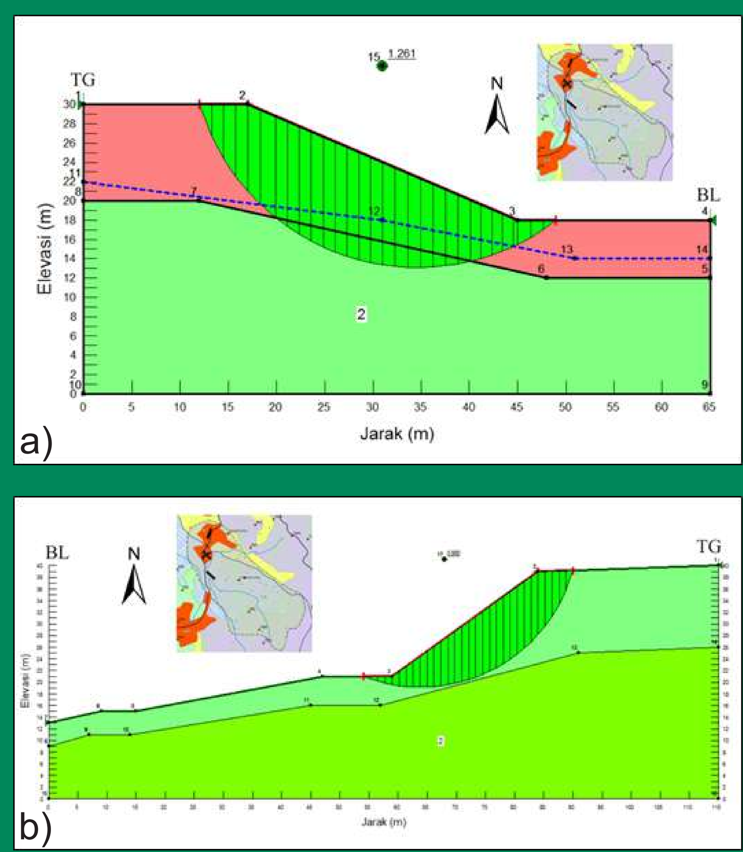

Figure 5. a) slope analysis model with Morgenstern-Price method in line-1 and b) line 4.

Conclusion

Based on the results that has been obtained, it can be concluded that:

1. The slip surface based on geo-electric modeling is the contact between the clay and the tuff layer with a depth of approximately 5-7 m, while based on the MASW modeling between the soft soil and rigid soil layer with a depth of approximately 5 m.
2. Safety Factor (SF) value in the Southeast is 1.26 which means the slope is relatively stable and in the Northwest is 0.98 which means the slope is unstable.

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References

Athanasius, C. and A. Solikhin. 2015. *Pendugaan Kecepatan Gelombang Permukaan (VS30) di Pulau Sulawesi Berdasarkan Klasifikasi Geomorfologi dan Aplikasinya*. Pusat Vulkanologi dan Mitigasi Bencana Geologi. Bandung.

Kearey, P., Brooks, M., and Hill, I., 2002. *An Introduction to Geophysical Exploration*. Blackwell Publishing.

Morgenstern, N.R. and V.E. Price. 1965. *The Analysis of the Stability of General Slip Surface.* Geotechnique, Vol. 15, No.1, pp. 70-93.

Park, C.B., R.D. Miller., and J. Xia. 1999. *Multichannel Analysis of Surface Waves*. Geophysics, Vol. 64, No. 3 (May-June 1999); P. 800-808.

PVMBG. 2014. *Peta Zona Kerentanan Gerakan Tanah Kabupaten Majalengka.* Pusat Vulkanologi dan Mitigasi Bencana Geologi. Bandung.

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