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The stability analysis of Kalialang village area based on microseismic data

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Abstract. This micro-seismic survey was conducted to analyze the stability in Kalialang Village, which is one area that surrounding of the prone to landslides areas. Retrieval of data using a seismometer with many measurement points of 24 points. Data analysis in this study involves the Horizontal to Vertical Spectral Ratio (HVSR). Ground shear strain calculation is calculated by dividing the value of the soil layer deformation by the thickness value of the sediment layer and multiplied by the amplification. Data processing results show that Kalialang Village has a ground shear strain value that varies from 1.62 x 10^{-4} to 5.25 x 10^{-4}. Based on the ground shear strain value it's got, then the event in the region are crack in the bedrock and the settlement.

1. Introduction

Semarang is the Capital of Central Java Province. Based on Windraswara & Widowati's research, there are seven out of sixteen districts in Semarang that have landslide-prone points. The seven districts are Manyaran, Gunungpati, Gajahmungkur, Tembalang, Ngaliyan, Mijen, and Tugu. Kalialang Village, Sukorejo is one of the areas that surrounding of the prone to landslides areas in Gunungpati.

A landslide is a ground movement in the form of a mass transfer of soil or rock in an upright, horizontal or sloping direction from its original position. The triggering factors for soil movement are geomorphological conditions (slope), geological conditions, slope-forming soil conditions, climatic conditions, slope hydrological conditions, acceleration of ground motion, and earthquakes.

Ground shear strain value illustrates the ability of a soil material to stretch and shift when an earthquake occurs. Ground shear strain analysis can be used to determine areas prone to ground movement in the form of landslides, liquefaction, fractures, vibrations, and so on. High or low ground shear strain value of an area depends on the site effect of the area [1]. Therefore, mitigation efforts are needed to determine the level of vulnerability of an area to landslide hazards by conducting a study of subsurface characteristics in Kalialang village.

This research is expected to be a reference in minimizing casualties and damage due to landslides. With an analysis of micro-seismic records, natural frequencies, amplification factors, vulnerable points, and modal shapes could be determined. Information about Kalialang together with the brief formulation of the applied technique and result from the analysis are given sections. Soil movement is the movement of slope-forming material, in the form of rocks, pile material, soil or mixed material, moving downward and outward slope [2].

Micro-seismic is also called ambient noise. Noise is the generic term used to denoted ambient vibration of the ground and floor caused by sources such as tide, turbulent wind, the effect of wind on trees or buildings, industrial machinery, cars and trains, human footsteps, oceanic wave, volcanic tremor, etc [1]. One of the methods can be used to know the characteristic structure of the building without destroying it is analyses of micro-seismic recorded on the floor of a building, by using nature noise. [3,4]. Micro-seismic has based on ambient noise recordings to determine dynamical characteristic parameters (damping ratio, primary natural frequency) and transfer function (frequency and amplification) of building [5,6].

HVSR analysis method was first developed by Nakamura in 1989. HVSR method used to calculate the spectrum signal microtremor horizontal and vertical component. Micro-seismic waves are divided into two types namely Rayleigh waves and body waves. Rayleigh waves are surface waves that propagate on the ground, while body waves propagate through bedrock. In this condition, the HVSR equation can be written as follows [1][7][8].

$$H_f = A_h S_{HB} + S_{HS} \quad (1)$$

$$V_f = A_v S_{VB} + S_{VS} \quad (2)$$

So,

$$H/V = \frac{Hf}{Vf} = \frac{AhSHB + SHS}{AvSVB + SVS} \quad (3)$$

where *Hf* and *Vf* are the horizontal and vertical component of micro-seismic wave, *Ah* and *Av* are amplification factor of body wave, *SHB* and *SVB* are spectrum of horizontal and vertical motion in the bedrock, while *SHS* and *SVS* are spectrum of horizontal and vertical motion on the soil surface or sediment layers. HVSR curve is obtained by plotting H/V to frequency. The frequency of the highest amplitude in HVSR curve shows the natural frequency of ground layer [8][9][10].

Ground Shear Strains (GSS) describes the ability of soil material to shift during an earthquake [1]. The value γ is used to determine how the soil condition in the study area is related to landslides, liquefaction, cracked soils, land subsidence, and ground vibrations [12].

To get the γ value, the value of *fo*, A_o, *h* and a_g are needed. After that, the γ values used to get characteristics attacks below the surface. The Ground Shear Strain (GSS) equation can be written as follows:

$$\gamma = \frac{A_o}{h}\left(\frac{a_g}{(2\pi f_0)^2}\right) \quad (4)$$

γ = ground shear strain
A_o = Amplification
h = The thickness of the sediments
a_g = Acceleration value of ground vibration observation point (gal)
f_o = Natural Frequency

According to Nakamura (1997) value γ on the ground need to be considered. Table 1 explains the phenomena that occur in the soil based on the value of γ [1].

Table 1. Strain Values of Dynamic Soil Properties

Size of Strain g	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}
Phenomena	Wave, Vibration		Crack, Settlement		Landslide, Soil Compaction, Liquefaction	
Dynamic Properties	Elasticity		Elasto-Plasticity		Collapse Repeat-Effect, Speed- Effect of Loading	

2. Methods

The instruments used in this study include 3 component seismometer, digitizer, GPS (Global Positioning System), cables, compass.

The initial stage is to make a survey design with 24 points. After that, collecting data in the field will be used as primary data in research. Retrieval of data by the technical requirements of SESAME. Then there are additional secondary data, the 2006 Yogyakarta earthquake data and the V_{s30} value obtained on the USGS website.

Analysis of the data in this study using HVSR. Of micro-seismic data, two components signal the vertical component and a horizontal component, while the horizontal component consisting of horizontal north-south and west-east. Micro-seismic data is analyzed by Geopsy software, performing windowing and cutting to the selection signal without noise and the subsequent analysis chart obtained HVSR. The results of the analysis are used to determine the value of GSS (γ).

In determining the GSS value, the earthquake vulnerability index value and the value of land acceleration are needed. The natural frequency value (fo) and the amplification factor value (A_o) obtained from the HVSR analysis are used as input data to calculate the seismic vulnerability (K_g). Ground acceleration (a_g) is obtained by entering earthquake parameters in the form of predominant periods (T_o), magnitude (M), latitude-longitude and hypocenter distance (R). Furthermore, the micro-zonation of γ was performed. The phenomenon that occurs from GSS (γ) corresponds to the table of the relationship between strain and the dynamic nature of the soil. After micro-zonation is obtained, 3D visualization is done using the Surfer 10 program.

3. Results and Discussions

Ground shear strain (γ) indicates the ability of the rock to stretch or shift when getting interference (earthquake). GSS value calculated using equation (4) then plotted using a software Surfer. Results plot GSS value can be seen in the image below.

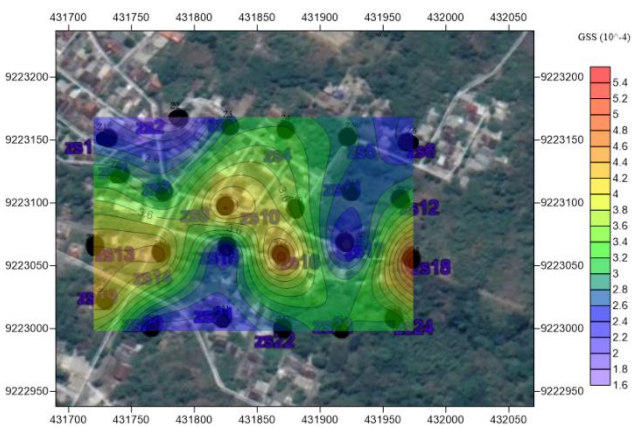

Figure 1. Map Contour GSS

The GSS values (Figure 1) in the Kalialang Village area of Sukorejo Gunungpati using the maximum ground acceleration with earthquakes originating from Yogyakarta having GSS values ranging from 1.62 x 10^{-4} - 5.25 x 10^{-4}. The largest ground shear strain value is located in the red zone with a ground shear strain value of 5.25 x 10^{-4}. Whereas the value of a small ground shear strain is in the purple zone with a ground shear strain value of 1.62 x 10^{-4}.

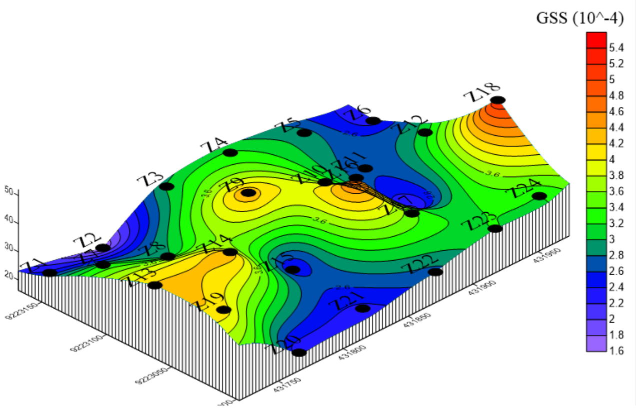

Figure 2. Combining GSS Contours With Topographic Contours

Figure 2. is a combining GSS Contours with topographic contours shape of the ground shear strain value in Kalialang village, Sukorejo, Gunungpati. Obviously the relationship between topography and GSS value, the higher the topography the higher the GSS value is formed, and vice versa

.Based on the results of the analysis, the value of the ground shear strain using the maximum ground acceleration sourced from the Yogyakarta earthquake data is in the order of 10^{-4}. based on table 2.3 the ground shear strain values in order 10^{-4} have plastic-elastic properties that are prone to cracks in the soil and settlement layers. These results are in accordance with the characteristics of the hills of Semarang [13]. Based on the ground shear strain value and the phenomena that occur, the research points are still safe but have the potential for landslides.

4. Conclusion

The value of the ground shear strain in Kalialang Village, Sukorejo Gunungpati is around 1.62 x 10^{-4} - 5.25 x 10^{-4}. The value of the ground shear strain in Kalialang Village, Sukorejo Gunungpati is around 1.62 x 10^{-4} - 5.25 x 10^{-4}. Kalialang Village has a ground shear strain value in the range of 10^{-4}. This value is the stability limit so that when there is an earthquake in the Kalialang area there will be a crack in the settlement.

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