Identify the slip surface of land slide in Wirogomo Banyubiru Semarang Regency using HVSR method

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Identify the slip surface of land slide in Wirogomo Banyubiru Semarang Regency using HVSR method

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Abstract

Investigation of locations prone to landslide in Kendal Ngisor and Tlumpak areas in the Wirogomo Village is very important to reduce the impact of landslide. For this purpose, investigations have been conducted to determine potential points that are prone to landslide, and to determine the type of ground movement through the calculation of ground shear strain and Vs profile analysis using HVSR (Horizontal to Vertical Spectrum Ratio) method. Based on ground shear strain value and Vs profile can be obtained some conclusions: the mechanism of land movement in Kendal Ngisor is a rock fall type avalanche that occurs due to the fall of rock that occurs in the behind of SMPN 3 Banyubiru and the rotational slide slide type near Point 7 which is visually marked by the former old landslide. The landslide that occurred in Dusun Tlumpak was caused more by the blocked drainage of the water channel and spill over brought mud materials that fell on the houses.

Keywords: landslide, HVSR, ground shear strain

INTRODUCTION

Wirogomo Village is one of the areas in Banyubiru Sub-district of Semarang Regency which is prone to landslide. According to Gatot et al. (2016), in 2009 there were two events of landslides. In 2010, there were four similar events, and this was also repeated in 2015 with also four events. Based on the database available in Banyubiru sub district, there were two events of landslides in Kendal Duwur and Jeruk Wangi villages respectively. In 2010 there were four events of landslide in Jeruk Wangi, Pule, Wirogomo Tengah, and Wirogomo Lor, respectively. In addition, based on data from many sources, there were four events of landslide in Wirogomo Tengah, Kendal Ngisor, Tlumpak, and Sepakung villages, respectively. Other than that, on 6 January 2016, there was a landslide that cost a few lives in Kendal Ngisor village.

In May 2017 in Tlumpak village occurred a landslide resulting in the destruction of two houses, as shown in Fig 1. From many information obtained, the landslide was triggered by the obstruction of the flow drain and due to the accumulation of water causing the channel wall cannot hold water pressure so that water and mud material then spill over and hit two houses located under the water channel.

Figure 1: Avalanches of soil damaging two houses in Tlumpak

The value of ground shear strain in the soil layer can describe the ability of the soil material to shift during ground vibrated for example earthquake occur. This value is a reference that there are areas that have a high risk of land movement due to earthquakes such as land subsidence and liquefaction. The higher the value of ground shear strain indicates the character of the ground that will be deformed and collapsed. In determining the value of ground shear strain in this research used method HVSR (Horizontal to Vertical Spectral Ratio). Gatot et al. (2016) identified the value of ground shear strain with HVSR approach method for Wirogomo area, Banyubiru, Semarang regency. The highest value of ground shear strain is found behind SMPN 3 Banyubiru with value 0.018608 which can be assumed that this area is likely to experience movement. In general, the most prone zone is located south of Wirogomo (7.33839ºS, 110.3819ºE). This zone is visually marked with remnants of earlier landslides. Furthermore, investigation of locations prone to landslide in Kendal Ngisor and Tlumpak areas in the Wirogomo Village is very important to reduce the impact of landslide. For this purpose, investigations have been conducted to determine potential points that are prone to landslide and to determine the type of ground movement through the calculation of ground shear strain and Vs profile analysis using HVSR (Horizontal to Vertical Spectrum Ratio) method.

FACTORS AFFECTING LANDSLIDE

According to Nugroho (2008) factors that cause the movement of land, namely:

1. Climate (rainfall): rain with high intensity will go to the bottom of the slope through the soil that broke during the dry season so that the sandy clay soil wetter and cause the occurrence of landslides.

2. Slope steepnes: landslide can occur when the slope steepnes reaches more than 40 ° or higher.

3. Elevation: if an area is higher, the slope becomes steeper, otherwise if the lower the height of an area, the slope of the slope becomes more gentle.

4. Type of Soil: characteristics of loose soil, clay soil with a thickness of more than 2.5 meters has the potential for landslides.

5. Land Use: land use such as rice farms or plantations in upland areas and slope steeper to steep slopes may trigger landslides.

In addition to the slope factor, one cause of the occurrence of landslide is the presence of weathering rocks. This weathering rock travels through a plane called the slip plane. the slip plane usually consists of a hard layer and a soft layer. In case of rain, a hard layer (impermeable) will become slippery. The soft layer will move through the impermeable layer. The impermeable layer acts as a slip plane. The soft layer acts as a landslide material (Dona et al., 2015).

HVSR METHOD AND GROUND SHEAR STRAIN

The method of Horizontal to Vertical Spectral Ratio (HVSR) is used to know the value of natural frequency and amplification value so that it can be calculated soil susceptibility value (Harahap, et al, 2013). The HVSR method is a method of comparing the spectrum of the horizontal component to the vertical component of the microtremor wave. Mikrotremor consists of a variety of Rayleigh wave base, it is assumed that the peak period of the H/V ratio of microtremor provides the basis of the wave period S. The H/V ratio in microtremor is the ratio of the two components that theoretically yield a value. The dominant period of a site can be approximated from a peak period of H/V microtremor ratio. Nakamura (1989) tried to separate the geological effects by normalizing the spectrum of horizontal components with vertical components at the same measuring point. The observation results show that the recording at the station located on hard rock, the maximum value of the horizontal component spectrum ratio to the vertical approaches the value of one. At the station located in soft rocks, the ratio of the maximum value to magnification (amplification), which is greater than 1. Based on these conditions, Nakamura formulated a microtremor HVSR transfer function. The effect of wave gain on horizontal component can be expressed by Eq. (1), that is:

$$S_E(w) = \frac{H_S(w)}{H_B(w)} \quad (1)$$

with the notation H_s (w) is the horizontal component's microtremor spectrum on the surface and H_B (w) is the horizontal component's microtremor spectrum in the bedrock. Reinforcement of waves in vertical components can be expressed as the ratio of the vertical component spectrum on the surface and in the bedrock given by Eq. (2), ie:

$$A_S(w) = \frac{V_S(w)}{V_B(w)}. \quad (2)$$

with the notation V_s (w) is the spectrum of the vertical component microtremor at the surface and V_B (w) is the spectrum of the vertical component microtremor in the bedrock. To reduce the effect of the source, the horizontal reinforcement spectrum S_E (w) is normalized to the source spectrum A_S (w) written as:

$$S_M(w) = S_E, \quad (3a)$$

$$\frac{(w)}{A_S(w)} = [H_S(w)/V_S(W)]/[H_B(w)/V_B(w)]. \quad (3b)$$

with the S_M (w) notation is the transfer function for the soil layer. If $\frac{H_B(w)}{V_B(w)} = 1$, then the soil transfer function will be the same as the value of the comparison of the microtremor spectrum value on the horizontal component surface with the vertical component written by :

$$S_M(w) = H_S(w)/V_S(W) \quad (4)$$

In the field observation there are two horizontal components measured that the north-south component and the west-east component so that the Eq. (4) becomes :

$$S_M(w) = \left[(H_{SN}(w)^2 + H_{WE}(w)^2)^{1/2}\right]/V_s. \quad (5)$$

With the $H_{SN}(w)$ notation is the microtremor spectrum of the north-south horizontal component and $H_{WE}(w)$ is the spectrum of the east-west microtremor component (Arifin, et al., 2013).

Ground shear strain is the ability of a material soil layer to stretch or shift during an earthquake. Areas that have high ground shear strain values have a high risk of ground motion due to earthquakes such as land degradation and liquefaction. According to Nakamura (1997) in identifying the phenomenon of soil susceptibility conditions based on the ground shear strain scores obtained are divided into three categories, namely:

1. If the value of strain ranged from 10^{-6} to 10^{-5} then the phenomenon that will occur is a wave or vibration. The dynamic nature of the soil belongs to the elastic category.

2. If the strain value ranges from 10^{-5} to 10^{-3} then the fennomena that will occur is the crack and the decline of the soil. the dynamic nature of the soil belongs to the category of elastic plastic.

3. If the strain value ranges from 10^{-3} to 10^{-1} then the phenomenon that will occur is landslide, land degradation, liquefaction. The dynamic nature of the soil belongs to the category of collapse.

MEASUREMENT POINTS

The locations of the HVSR measurement points are given in Table 1 based on visual observation, information from the community, and geological survey. Gatot et al. (2016) focused their investigation in Kendal Ngisor behind SMPN 3 Banyubiru up to the top of Mount Kelir or up to the north which on this track there are two former areas the landslide is just behind SMPN 3 Banyubiru and south of point 7. Based on satellite images, landslide line in the southern part behind SMPN 3 Banyubiru looks shorter than the northern part because the southern part has a steeper cliff. In this research, microtremor measurement is extent to the south from the point of landslide behind SMPN 3 Banyubiru and former landslide location in Tlumpak. Since the steepnes of trajectory field then the measurement is carried out on the path of the little road used by the residents to search for grass and firewood.

DATA PROCESSING

From HVSR data processing we obtained frequencies and amplitude of amplification values then used to calculate peak ground acceleration, susceptibility index, and ground shear strain values. For the making of the Vs profile, the HVSR curve elipticity is then processed to obtain the Vs value to depth profile. Furthermore, using surfer program the Vs data from each measurement point then contoured Vs to depth for a given path. Inversion is carried out by using algorithm proposed by Sambridge (1999) and Wathelet (2008).

Table 1 The location of the HVSR measurement points

Kendal Ngisor	*Easting*	*Northing*	Tlumpak	*Easting*	*Northing*
1	431948.9	9188531	A	432364	9187840
2	431946.7	9188593	B	432346	9187711
3	431937.1	9188649	C	432317	9187731
4	431916	9188624	D	432227	9187707
5	431834.6	9188719	E	432064	9187786
6	431794.8	9188640			
7	431781.1	9188796			
8	431745.1	9188944			
9	431681	9188963			
10	431613.5	9188990			
22	431991	9188403			
24	431903	9188458			
25	431918	9188414			

RESULTS AND DISCUSSION

The calculation of ground shear strain of the research area was conducted using source Yogyakarta earthquake on 27 May 2006 with episenter 110.32° E and 8.03° S, depth 11.3 km, and magnitude 5.9 Mb. The result of ground shear strain calculation for each microtremor survey area is given in Table 2, Table 3 and Fig. 2.

Table 2: The result of ground shear strain of Kendal Ngisor

Kendal Ngisor	Kg (cm/s)	α (gal)	Ground shear strain
1	2.64E-04	58.62213	1.55E-02
2	4.16E-04	44.71365	1.86E-02
3	2.47E-05	204.2103	5.04E-03
4	1.28E-04	119.4817	1.53E-02
5	5.83E-05	167.9446	9.79E-03
6	2.47E-05	185.3696	4.57E-03
7	1.32E-05	201.8878	2.67E-03
8	2.74E-05	193.9023	5.31E-03
9	4.27E-05	97.43237	4.16E-03
10	3.32E-05	147.2113	4.88E-03
22	2.94E-04	45.10086	1.33E-02
24	2.75E-04	47.2305	1.30E-02
25	6.74E-04	30.20433	2.04E-02

Tabel 2 The result of ground shear strain of Tlumpak

Tlumpak	Easting	Northing	Kg (cm/s)	α (gal)	Ground shear strain
A	432364	9187840	4.14E-04	39.02011	1.62E-02
B	432346	9187711	3.5E-04	45.59886	1.60E-02
C	432317	9187731	2.0E-04	54.47853	1.09E-02
D	432227	9187707	2.83E-04	48.81348	1.38E-02
E	432064	9187786	3.68E-04	41.76954	1.54E-02

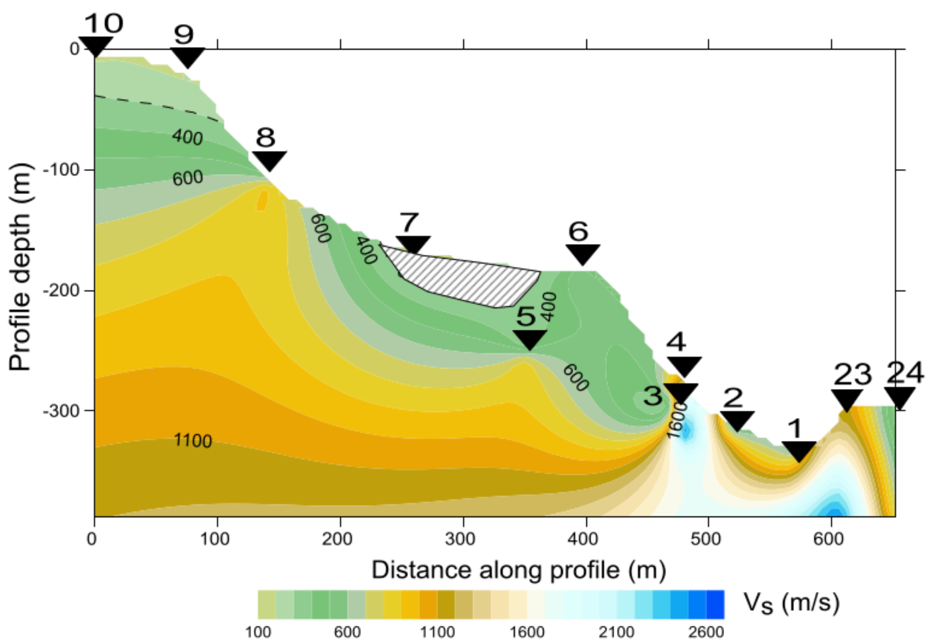

Figure 2 Vs value in Kendal Ngisor measurement area from Point 1 to Point 24 shows the existence of a slip surface from Point 7 to Point 6 (shaded area) with the approximate width of the slip surface on the track reaching 120 meters and depth reaching 35 meters

Based on Figure 2 it can be seen that the avalanche that occurs in the south of Point 7 occurs in the slip surface geometry has a depth of up to 35 meters and the width reaches 120 meters which is marked by small Vs value, while the lowest point behind SMPN 3 Banyubiru Point 1 has a large Vs value which is thought to be a bedrock which has meaning avalanche above Point 1 and the landslide passing through the south Point 7 has a different mechanism. Although the GSS value at Point 7 to the south is lower than the GSS points of Points 1,2 and 4 but has a much smaller Vs value. Type of lanslide above Point 1 is the rock falling, a sudden movement of the ground from the rocks that fall from a steep slope or cliff. Separation occurs along the fractured and rocky layers. This soil movement is strongly influenced by gravity, mechanicaly weathering, and the presence of water in rocks. The avalanche to the south of Point 7 is relative to a rotational slide or rotational slide or the movement of soil and rock masses in the upwardly shaped sliding field, and the movement of the landslide generally revolves on a single axis parallel to ground level.

Based on the Vs profile It can be imaged the soil layer of the constituent of the area, as shown in Figure 3, it is known that there is no slip surface in the area. The landslides that occur are solely caused by the blockage of water flow which then accumulates and broke the channel's wall.

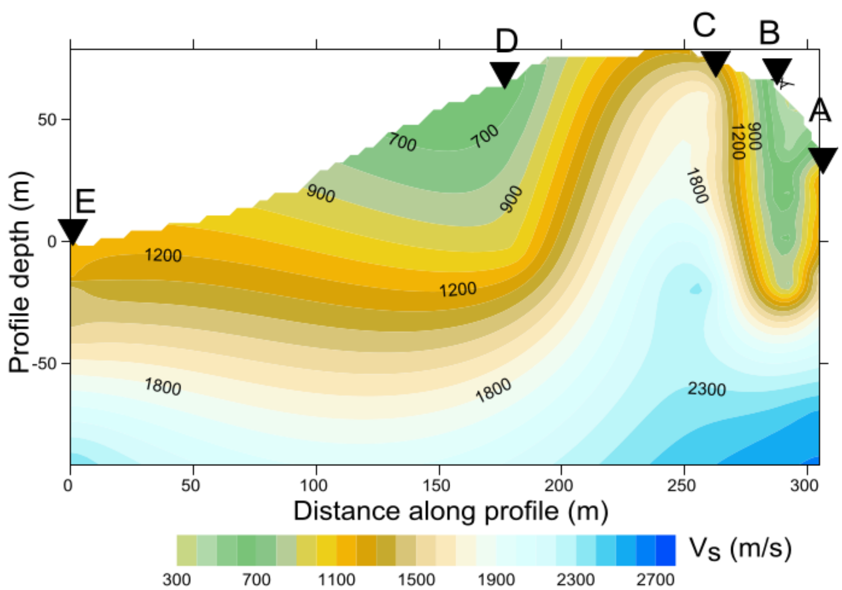

Figure. 3 Profile Vs in measurement area of Tlumpak. Point C is a measurement point as shown in Fig 1

CONCLUSION

Ground shear strain calculation to identify Slip surface of landslide zones in Banyubiru sub district using HVSR measurement lead to the following conclusion:

1. The mechanism of ground motion that may lead to landslide in Kendal Ngisor, behind the SMPN 3 Banyubiru, Wirogomo area is of rock fall type, and type of landslide near Point 7 is rotational slide which is elaborated with visually observed remnants of past landslides

2. Landslide that occurred in Tlumpak more caused by breakdown of blocked drains and bring mud materials that fall on the house of the population.

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