PAPER • **OPEN ACCESS**

Identification of landslide potential in Gajahmungkur village Semarang using ground shear strain analysis

To cite this article: Khumaedi *et al* 2019 *J. Phys.: Conf. Ser.* **1170** 012072

Identification of landslide potential in Gajahmungkur village Semarang using ground shear strain analysis

Khumaedi*, **N M D Putra and A Z Fikriyah**

Physics Department, Universitas Negeri Semarang, Semarang, Indonesia

*Corresponding author: medisas@mail.unnes.ac.id

Abstract.The Gajahmungkur village, based on slope and geological structure, are included in the landslide potential category. Research of landslide hazard due to earthquake in weak zone can be done by ground shear strain analysis (GSS). This study aims to provide information related to the potential landslide disaster in the Gajahmungkur village of Semarang city. The data were collected using microseismic method. The research area is 42,000 m^2 consisting of 12 points and 3 trajectories. Data processing is done using Software of Geopsy and Surfer to obtain the value of vulnerability index of subsurface ground, maximum ground acceleration value, and ground shear strain value. The result of data analysis shows that the research area at point 9, point 10, and point 12 has the value of vulnerability index which is much higher than the other point so that the value of ground shear strain in all three points is also high. The value of ground shear strain obtained at the order of 10^{-4} then the dynamic nature that occurs in the research points have a plastic character. This plastic characteristic characterizes the area as a landslide potential.

1. Introduction

Indonesia is a country with high disaster potential. This is because of its location in the meeting of three active plates, namely the Eurasian plate, the Indo-Australian plate, and the Pacific plate. The endogenous forces due to the dynamics of the plates also form the relief of the Earth's surface in Indonesia to be varied, from the steeply sloping mountainous areas with the potential for landslides to the coastal plains of a potentially sloping lowland plateau.

Semarang City with an area of 373.70 km^2 is the capital of the province of Central Java. Administratively, Semarang City is divided into 16 districts and 177 urban villages. Semarang city is very influenced by the natural conditions that form a city that has a characteristic that consists of hills, lowlands and coastal areas. Thus the topography of Semarang City shows the existence of various slopes of land ranging from 0 percent to 40 percent (steep) and altitude between 0.75 - 348.00 meters above sea level (meters above sea level). Gajahmungkur subdistrict is one of 16 subdistricts in Semarang City, Central Java Province. Gajahmungkur subdistrict is in the middle position of Semarang city (Figure 1).

The slopes in Gajahmungkur sub-district are based on the USDP (Urban Spatial Detail Plan) of Semarang City ranging from 0% - 40% [1]. On the geological map of the Magelang Semarang sheet [2], the geological structure of Gajahmungkur village is included in the Damar Formation where its rock structure consists of tuff sandstone, conglomerate, and volcanic breccia. This structure is one of the reasons the area has a track "weak", so that the area prone to erosion and soil movement occurs.

The occurrence of landslides in a region directly proportional or correlated to the contour of the area. Slope tilt parameter becomes the main factor of the occurrence of landslide itself. This is because the land conditions are too skewed. Based on the slope parameter and geological structure in Gajahmungkur sub-district, it is an area that has a landslide potential. Research of landslide hazard due to earthquake in weak zone can be done by ground shear strain analysis (GSS) [3–5].

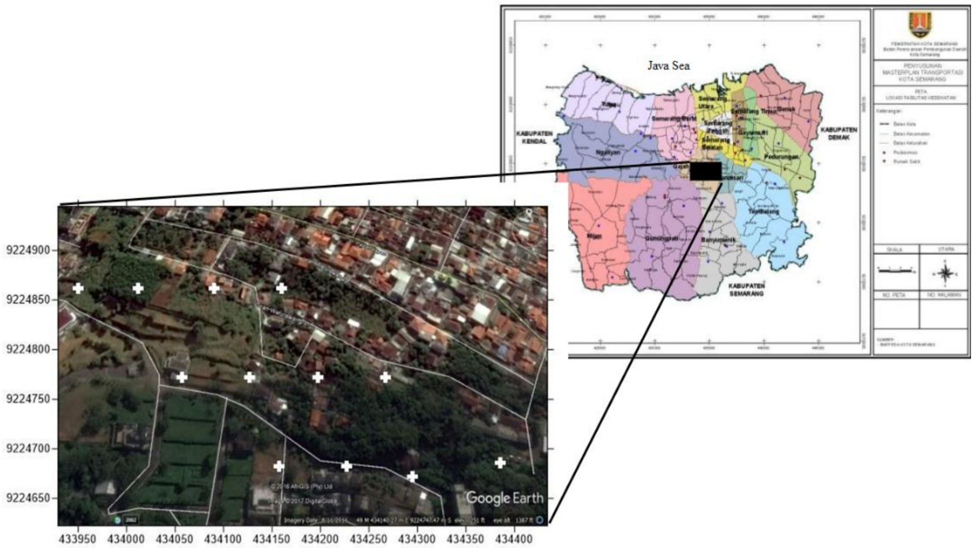


Figure 1. Location map for aquisition data in Gajangmungkur Subdistrict Semarang City

This study aimed to find out the value of the seismic vulnerability index, determine the value of the maximum ground acceleration, and potential landslides by the ground shear strain analysis in Gajahmungkur sub-district Semarang.

2. Materials and Methods

Data retrieval is done at 12 points divided on 3 tracks with spaces between points 100 m and spaces between tracks 70 m. The duration of recording microseismic data at each point is 30 minutes. The equipment was used during field research as follows: seismometer 3 components (vertical, north-south, west-east) Vibralog Type MAE, Flashcard for storing data, Compass, GPS. During data collection, the location of the measuring point is kept away from noise, and the soil at the measurement location is not loose because if loose soil will occur microseismic wave attenuation effects, which can affect the data captured by the seismometer [6].

Data processing uses Geopsy software to get the H/V ratio spectrum. The value of the H/V ratio spectrum is used for determining the dominant frequency (f_o) and amplification (A_o) values which are then used to calculate the value of seismic vulnerability index Based on natural frequency and amplification data can be determined the earthquake vulnerability (Kg), peak ground acceleration value (PGA), and ground shear strain (GSS). In the data processing PGA used data source Jepara earthquake in 2016 with magnitude 5 SR earthquake, and Tegal earthquake data in 2015 with earthquake magnitude 5.1 RS, and Yogyakarta earthquake in 2006 with magnitude 5.9 RS.

Analysis of GSS is performed on each calculation result with different magnitude. This analysis aims to determine the magnitude value that can trigger the occurrence of landslides. Analysis is done based on Ishihara **[6]**, that is, on the value of $\gamma > 1 \times 10^{-2}$ there will be deformation. If the hills are deformed, the hills will allow landslides.

3. Result and Discussion

3.1. *The HVSR value*

Measurements by Seismometer 3 component (vertical, north-south, west-east) Vibralog MAE type is a seismic wave graph in time function with vertical components, north-south component, and east-west component. The graph of time function is converted into the form of frequency function. Graphs in the form of these frequency functions are processed by the horizontal-to-vertical spectral ratio (HVSR) method in Geopsy software to obtain the H/V curve. This H/V curve produces the values of dominant frequency and amplification of each measurement point.

3.1.1. *The dominant frequency*

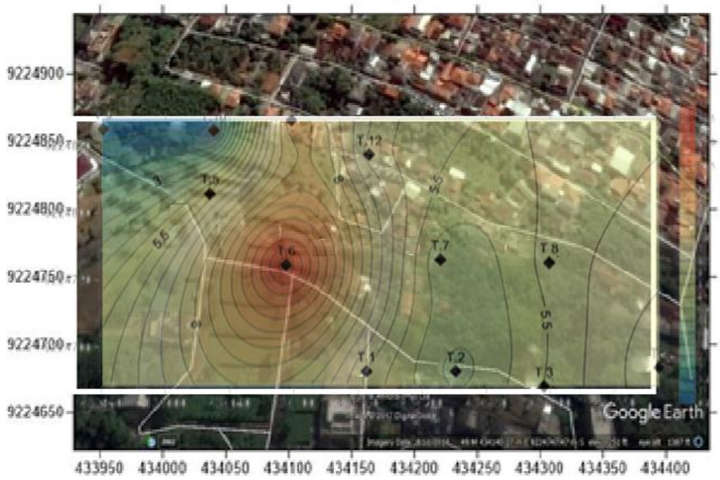


Figure 2. Contour Map on the Dominant Frequency in the research area

The dominant frequency value in the area of Gajahmungkur Semarang ranged from 0.6 to 12.5 Hz (Figure 2). The research area has a dominant frequency value with medium to high range so that the dominant frequency parameter has a low vulnerability to earthquake hazard, because only an area having low natural frequency characteristics has a high vulnerability to earthquake wave vibration hazard

3.1.2. *Dominant amplification*

The amplification values obtained in the study area ranged from 1.3 to 7.2. In contrast to the dominant frequency, the higher amplification value indicating the higher risk of earthquake hazards. Based on the contour map of Figure 3 shows there are research points that have high amplification value so that the risk to earthquake hazard

3.1.3. *Sediment layer thickness (h)*

The thickness of the sediment layer can be obtained based on the dominant frequency of the data obtained. The thickness of the sediment layer also explains the boundary between the softer layer and the harder rock (bedrock). The thickness of the soil layer in the study area ranges from 6.24 to 128.98 m (Table 1)

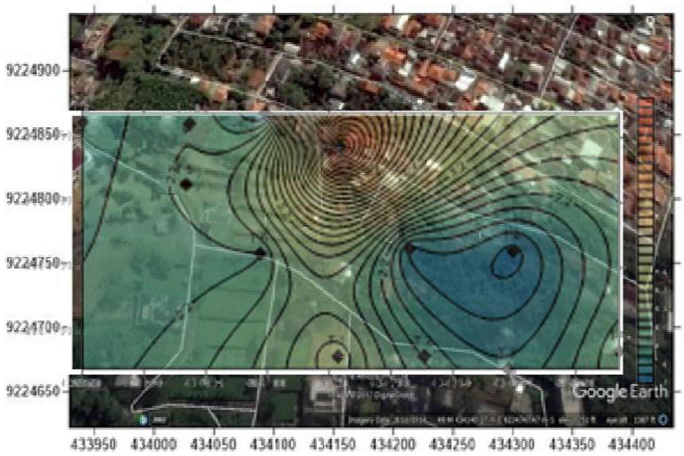


Figure 3. Map Contour of Dominant Amplification in Gajahmungkur research Area

Table 1. Sediment Layer Thickness Data

Positions	X	Y	f_0 (Hz)	H
1	434157	9224682	5.916	13.184
2	434227	9224682	4.297	18.151
3	434295	9224672	5.519	14.134
4	434385	9224686	6.909	11.289
5	434034	9224814	5.723	13.628
6	434094	9224761	12.489	6.246
7	434215	9224765	4.548	17.152
8	434299	9224763	5.725	13.625
9	433950	9224862	0.665	117.326
10	434037	9224861	0.605	128.987
11	434098	9224869	9.011	8.657
12	434159	9224843	6.238	12.504

3.2. *Seismic Vulnerability Index*

Seismic vulnerability index (Kg) is an index that describes the level of ease of surface soil layer structure to deformation during an earthquake.

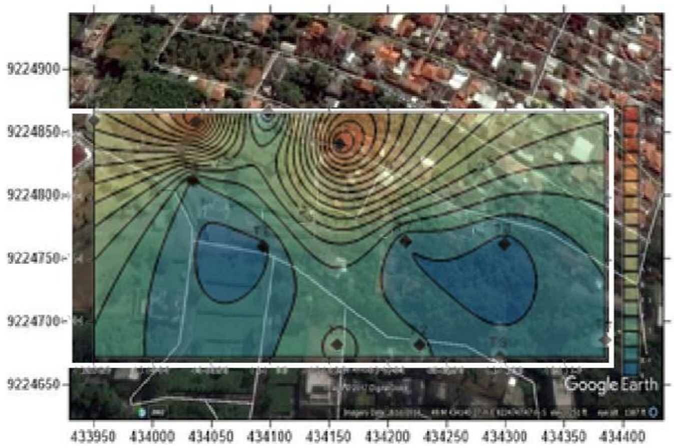


Figure 4. The Contour Map of Seismic Vulnerability Index (K_g) in Gajahmungkur Area

The value of vulnerability index in Gajahmungkur area is in the range 0.3 to 8.5 s^2/m. Overall, most of Gajahmungkur has small value seismic vulnerability index (Figure 4). The smaller value of the seismic vulnerability index of a region, the less vulnerable the region is to the earthquake hazard [7].

3.3. *Maximum ground acceleration*

The maximum ground acceleration in this study was calculated using the Kanai method. Based on the equation, the maximum ground acceleration value is affected by the dominant period of soil (To), the magnitude of the earthquake (M), and the measurement point distance against the seismic hypocenter (R). The higher of intensity of the quake that the higher value of the maximum ground acceleration.

Based on the source of the Tegal earthquake, Gajahmungkur Region has a maximum ground acceleration value of 0.3 to 1.6 gal (Figur 5.a). The maximum acceleration value of PGA < 1.7 gal. This value is covered in the scale I of MMI with the description of the impact not felt by people but recorded by earthquake recorder [8].

Gajahmungkur region using available resources Jepara earthquake have a peak ground acceleration value from 0.6 to 14 gal (Figur 5.b). Based on the results of the maximum acceleration value with the source of Jepara earthquake, the research at point 9 and 10 value of PGA <1.7 gal where this value is on I scale of MMI with description not felt by person but recorded by earthquake recorder[8–10]. While for the other 10 research points PGA values are in the range of 1.7 to 14 gal where this value is on the scale of MMI II and III with felt by people who break, especially on the second floor and the objects hanging swaying, vibrating lightly.

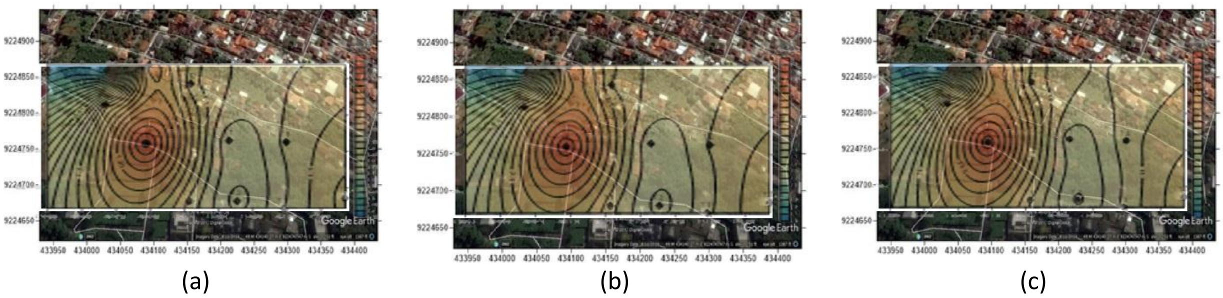


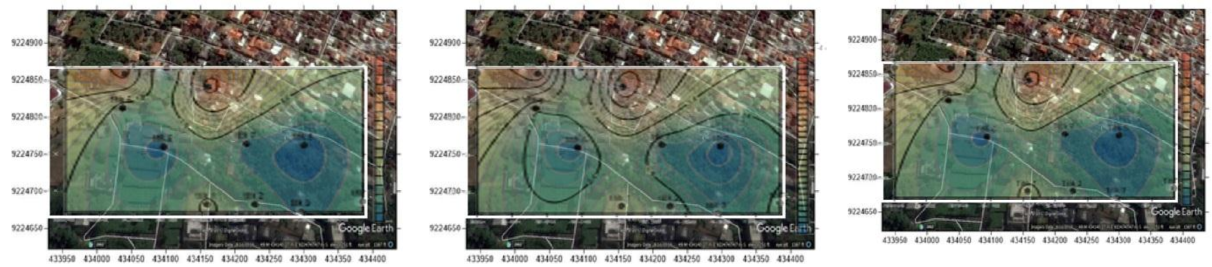
Figure 5. Contour Map of PGA based on Earthquake Source of (a) Tegal (b) Jepara and (c) Yoyakarta in Gajahmungkur area Semarang

Semarang Gajahmungkur region using available resources Yogyakarta earthquake have a ground acceleration maximum value from 3.4 to 15.9 gal (Figur 5.c). Based on the result of maximum acceleration with Yogyakarta earthquake source, the research at point 9 and point 10 of PGA value 3.4-7 gal where this value is on MMI II scale with description of impact is felt by people who break especially on the floor two[8]. While for 10 other research points PGA values are in the range of 7 – 15.9 gal where this value is on the scale III - IV of MMI with the description of the impact are hanging objects shake, vibrate lightly and vibration passing truck, windows, doors, and glassware objects collided and rang[8,11].

3.4. *Landslide potential based on GSS analysis*

The GSS value is influenced by the seismic vulnerability index value, the maximum land acceleration value, and the seismic wave velocity in the base rock (C_b). The higher GSS, more risky the soil or rock in the area is to deformation that can be a change in rock or soil properties to plastic, liquefaction occurs, and landslides occur during an earthquake. If the GSS values reaching $\gamma \cong 1 \times 10^{-3}$ soil begin to show non-linear or plastic characters, while $\gamma > 1 \times 10^{-2}$ landslides or significant deformation changes will occur . Deformation changes can be in the form of landslides, liquefaction, and land subsidence.

IOP Conf. Series: Journal of Physics: Conf. Series **1170** (2019) 012072 doi:10.1088/1742-6596/1170/1/012072



(a) (b) (c)

Figure 6. Contour Map of GSS based on (a) Tegal (b) Jepara and (c) Yoyakarta Earthquake Source in Gajahmungkur Area Semarang

The GSS value in the Gajahmungkur area of Semarang using the Tegal earthquake has values ranging from 0.7 x 10^{-4} to 4.2 x 10^{-4}. Based on the results of the analysis, the GSS value using Tegal earthquake is in the order of 10^{-4} (Figure 6.a). The ground shear strain in the order of 10^{-4} dynamic properties that occur at the study points have plastic characters. This soil structure that has a plastic character will cause phenomena that occur at the research point to have cracks in the soil and settlements. Based on the GSS value and the phenomenon that occurs, at the research points there is no potential for landslides.

Calculation of GSS values in the Gajahmungkur area of Semarang using the source of Jepara earthquake has values ranging from 1.3 x 10^{-4} to 7.4 x 10^{-4} (Figure 6.b). Based on the results of the GSS value, in the order of 10^{-4} dynamic properties that occur at the study points have plastic characters. This soil structure that has a plastic character will cause phenomena that occur at the research point to have cracks in the soil and settlements [12–14]. So, this area is not potential for landslides.

While the calculation of the ground shear strain value in the Gajahmungkur area of Semarang by using the Yogyakarta earthquake data resulted in values ranging from 7.8 x 10^{-4} to 4.22 x 10^{-3} (Figure 6.c). Based on the results of the analysis, the ground shear strain value using maximum ground acceleration originating from the Yogyakarta earthquake reached the order of 10^{-3}. The ground shear strain value at the order of 10^{-4} to 10^{-3}, the ground layer still has dynamic properties which means that at the research points it has plastic character. This soil structure has a plastic character in the event of an earthquake like in Yogyakarta, it will cause phenomena in the soil at the research point to experience cracks and also in settlements [12,15]. Based on the ground shear strain value and the phenomenon that occurs, at the research points there is no potential for landslides.

The results of the GSS using the source of the Tegal, Jepara and Yogyakarta earthquake have the range of values from 10^{-4} to 10^{-3}. Based on soil classification according to Kanai, point 9, point 10, and point 12 have a much higher earthquake vulnerability value than the other research points so that the ground shear strain point 9, point 10, and point 12 are also much higher than with other points. The results of this study indicate that the points that have a high ground shear strain value are plastic structures. This plastic characteristic characterizes the area as prone landslide.

4. Conclusion

The value of seismic vulnerability index in Gajahmungkur Semarang area varies in the range 0.3 s^2/m to 8.5 s^2/m. With the largest seismic vulnerability index value is at point 12. As for the smallest seismic vulnerability index value is at point 8.

Based on the calculation of peak ground acceleration value using Tegal earthquake data on November 12, 2015 in Gajahmungkur Semarang has acceleration value ranges from 0.3 gal to 1.6 gal. While based on the calculation of peak ground acceleration using data of Jepara earthquake on October 23, 2015 in Semarang Gajahmungkur region have acceleration values ranging from 0.6 to 2.8 gal, and Based on the peak ground acceleration value calculation using data from the Yogyakarta earthquake on May 27, 2006 in Semarang Gajahmungkur region has a value ranging from 3.4 gal to 15.9 gal.

The value of ground shear strain obtained by using the source of Tegal, Jepara and Yogyakarta earthquake in Gajahmungkur Semarang area is on the order of 10^{-4} up to 10^{-3}. Point 9, point 10, and point 12 have a much higher earthquake vulnerability value than the other point so that the value of ground shear strain point 9, point 10, and point 12 is also much higher than the other points. The points that have a high value of ground shear strain are plastic soil structures. This plastic character characterize those areas prone to landslide.

References

[1] Abidin R and J P Yulianto S 2017 *Jurnal Teknologi Informasi dan Komunikasi* **8** 65
[2] Thaden R E 1975 Geologic map of the Magelang and Semarang quadrangles, Java
[3] Warnana D D, Soemitro R A A and Utama W 2011 *Int. J. Basic Appl. Sci. IJBAS-IJENS* **11** (04) 73
[4] Matsui T and San K-C 1992 *Soils Found.* **32** 59
[5] Thein P, Pramumijoyo S, Brotopuspito K S, Kiyono J, Wilopo W and Setianto A 2014 *Int. J. Innov. Sci. Math.* **3** 420
[6] Herak M ModelHVSR—A Matlab® tool to model horizontal-to-vertical spectral ratio of ambient noise - ScienceDirect
[7] Putra R R, Kiyono J, Ono Y and Parajuli H R 2012 *J. Nat. Disaster Sci.* **33** 59
[8] Wald D J, Quitoriano V, Heaton T H and Kanamori H 1999 *Earthq. Spectra* **15** 557
[9] Hough S E, Taniguchi T and Altidor J-R 2012 *Bull. Seismol. Soc. Am.* **102** 2704
[10] Saafizaadeh M and Bagheripour M H 2017 *Sci. Iran.: Int. J. Sci. Technol.* **In Press** DOI: 10.24200/SCI.2017.4236
[11] Sulistiawan H, Supriyadi and Yulianti I 2017 *J. Phys.: Conf. Ser.* **812** 012002
[12] Nakamura Y 1997 *Seismic Vulnerability Indices for Ground and Structures Using Microtremor* (Florence: World Conggress on Railway Research)
[13] Rathje E M, Chang W-J, Stokoe K H and Cox B R 2004 Evaluation of Ground Strain from In Situ Dynamic Response *Proceeding of 13th World Conference on Earthquake Engineering (Canada)* 3099
[14] Balendra T and Li Z 2008 *Electron. J. Struct. Eng.* ***8*** 57
[15] Yuliyanto G, Harmoko U and Widada S 2016 *Int. J. Appl. Environ. Sci.* **11** 1497