# ANALYSIS OF SUBSIDENCE ZONE OF THE VILLAGE ACCESS ROAD IN JATIRUNGGO, SEMARANG REGENCY USING MICROTREMOR DATA

Harmoko U.[1] and Yuliyanto G.[2]
[1]Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Indonesia
[2]Research Cluster for Geothermal, Faculty of Science and Mathematics, Diponegoro University, Indonesia
E-Mail: gatoty@fisika.fsm.undip.ac.id

**ABSTRACT**

The rehabilitation of the subsidence phenomenon in Jatikurung sub-village, Jatirunggo village, Pringapus Subdistrict, Semarang Regency, Central Java, has been carried out for a long time however, it has never been successful. Every time an embankment is made, it is only a matter of time before another subsidence occurs. This research aims to investigate the subsurface structure of the subsidence sites. It is proposed to be used as a reference for structural planning in the treatment of road subsidence. Subsurface information is very useful in addressing the subsidence problem more effectively and precisely. The method used was by recording microtremor data and analyzing shear wave velocity and Poisson ratio as parameters to determine the type of subsurface layer. The obtained results are in the form of clay layers to bedrock layers at a depth of 35m. The movement occurred because of the soft or loose soil below and at the edge of the road above the impermeable clay layer. In addition, to the north side of the collapse point is a fairly deep cliff, which is a burden on the bedrock. When it was raining, the soil filled with water and there was even a flow of water in the soil deposits (piping) resulting in the ground movement toward the lower part.

**Keywords:** jatirunggo; subsidence; microtremor; shear wave velocity; Poisson's ratio.

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## INTRODUCTION

Ground displacement is the movement of soil material from one position to another due to forces and energy that affect the load capacity of the soil. The reduction of soil-bearing capacity such as fragile soil structure due to weathering, the increasing water content in the soil layer due to high rainfall, and the presence of high-energy vibrations are common causal factors of soil movement.

The ground movement phenomenon in the form of subsidence in the road section of Jatikurung Hamlet, Jatirunggo Village, Pringapus Subdistrict, Semarang Regency has been going on for a long time. Many efforts have been made by the communities to repair the collapsed road, including building embankments to backfill the subsiding road (as shown in Figure-1), even though the backfill material has reached dozens of trucks, the phenomenon, however, still occurs until the latest condition results in soil movement on the road section along approximately 60 meters with a depth of up to 1.5 meters. The mitigation of land subsidence that has been carried out by the communities requires a subsoil model so that further appropriate treatments can be taken.

Mapping bedrock morphology and determining its stratigraphy can be done by various geophysical methods such as gravity, audio-magneto telluric, resistivety, and seismic methods. Seismic is a suitable method for determining the stratigraphy, active seismic techniques, such as refraction and reflection methods, can provide the best resolution for detailed mapping of the bedrock surface (Maraio *et al*., 2018; Oldenborger *et al*., 2016; de Franco *et al*., 2009; Harmoko *et al*, 2021). Unfortunately, the implementation of these methods requires a large financial and technical effort to plan and conduct further research. In this context, the passive seismic method, namely the HVSR method, is an appropriate solution (Nakamura, 1989) (Mele *et al*., 2021).

**Figure-1.** Community and local government efforts to deal with road subsidence as putting stakes and sand in sacks.

Microtremors can be applied to characterize subsurface layers such as wave propagation velocity in soil layers, porosity, lithology, and so on. Microtremor is the vibration of natural harmonics with certain amplitude that can be used to describe the geological conditions of a particular region (Harutoonian *et al*., 2012; Harmoko *et al.,* 2019). This method is more environmentally friendly because it uses the earth's natural waves without causing a disturbance, additionally, the operation of the tool and the data collection process is easy and more efficient (Bour *et al*., 1998).

This method is an effective alternative to other conventional methods. The microtremor method can be used to obtain soil dynamic parameters related to soil load-bearing capacity, including wave propagation velocity in the soil layer, shear modulus, ratio of compression wave velocity to shear wave velocity or Vp/Vs ratio, and Poisson's ratio. The wave propagation velocity in a soil layer can give an idea of the subsurface geological structure. Shear modulus or rigidity (μ) is the resistance of rock to shear stress, the smaller value of rock rigidity indicates that the rock is not resistant to deformation efforts. The Vp/Vs value and Poisson's Ratio can determine the lithology of the rock which is related to the porosity of the rock (Yalcinkaya *et al*., 2016; Harmoko *et al*., 2023).

This research aims analyze the subsurface condition of the road section that collapsed and its surroundings in Jatikurung Subvillage, Jatirunggo Village, Pringapus Subdistrict. Interpretation is done based on the soil dynamic parameter model from the microtremor data obtained. The results obtained were profiles of shear wave velocity (Vs) and Poisson's Ratio. The profiles were used to identify the sliding plane in the area of the road collapse and also determine the depth of bedrock at the research site (Yuliyanto, *et al*., 2019).


**Figure-2.** Satellite view of measurement point distribution taken from google earth map.

## GEOLOGI OF RESEARCH AREA

The Jatirunggo, Pringapus, Ungaran area is an area situated in Semarang Regency, Central Java Province, Indonesia. The geology of this area is included in the Central Java basin, which is generally formed from sedimentary deposits of the Neogene age. The geological landscape of Jatirunggo, Pringapus, Ungaran is dominated by sedimentary rocks that consist of sandstone, clay, and limestone. The most predominant sandstone in the area is called the Kendeng Formation and Wonosari Formation.

The Kendeng formation is sandstone, siltstone, and limestone of Miocene to Pliocene age. They were originally formed by sedimentary deposits of mountainous origin and form thick layers scattered along the Central Java region. The Wonosari Formation is also a sandstone, siltstone, and limestone that was formed in the Miocene to Pliocene periods. These rocks are generally located in hilly areas and valleys of Central Java. In addition to sedimentary rocks, the study area also contains volcanic rocks formed from volcanic activity in the past. These volcanic rocks consist of andesite and andesite breccia originating from Mount Ungaran.

## METHODOLOGY

This method implements the characteristics and properties of microseismic waves, which can be used to evaluate the structural and soil conditions in a given area. Microtremor is a non-invasive geophysical method used to measure the geotechnical properties of soils so that the dynamic properties of the soil and the structural characteristics of the soil can be mapped (Pazzi *et al*., 2017).

Microtremors or ambient noise are ground vibrations with micrometer amplitudes generated by

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natural events or human activities that can describe the geological conditions of a region near the surface (Nakamura, 2000; Harmoko *et al*, 2019). Data acquisition was carried out at 35 measurement points as given in Figure-2. The points located in the courtyards of residents' houses are the points with the highest elevation of the research site so they are considered the reference points or points with a depth of 0 m.

The method is based on the assumption that the ratio of horizontal and vertical spectra of surface vibration is a function of displacement. The processing results of this method are H/V curves whose peaks show local information (site effect) in the form of predominant frequency values and amplification factors of waves recorded in the soil (Nakamura, 1989). In this study, a three-component single-station seismometer was used to record vibrations in the study area. The principle of shear wave resonance frequency f covers sedimentary layers up to the bedrock boundary. Assuming a stratigraphic layer, the fundamental resonance frequency is given by the equation (Rošer and Gosar, 2010):

$$f = \frac{V_s}{4h} \quad (1)$$

Where $v_s$ is the shear wave velocity at the sediment bed and $h$ is the sediment thickness.

## RESULTS AND DISCUSSIONS

The results of the subsidence profile of the road section based on the shear wave velocity are given in Figure-3 and Figure-4 with the analysis based on the reference Table-1, which is the rock site classification table based on the shear wave velocity (Vs) according to SNI 1726-2019, which is the soil type classification table according to Keçeli (2012).

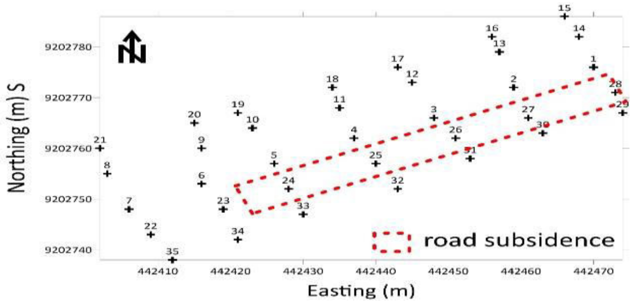


**Figure-3.** Secondary wave velocity profile, Vs (microtremor data processing results), simple layout distribution of measurement points.

**Table-1.** The comparative value between the Poisson ratio and rock type (Keçeli, 2012),

| Soil and rock-type | $V_p$ | $V_s$ | $V_p/V_s$ | Safety factor ($F_S$) |
|---|---|---|---|---|
| Hard and massif rocks | 6000-4200 | 4000-2700 | 1.45 – 1.5 | 1.5 |
| Very stiff | 4200-3000 | 2700-1500 | 1.5 – 2 | 1.5-2 |
| Stiff | 3000-2000 | 1500-700 | 2 – 3 | 2 |
| Moderate stiff but altered | 2000-1500 | 700-400 | 3 - 4 | 3 |
| Loose and soft | 1500-600 | 400-100 | 4 - 6 | 3-4 |
| Soft and saturated | >1300 | >100 | 5 - 8 | 4-5 |

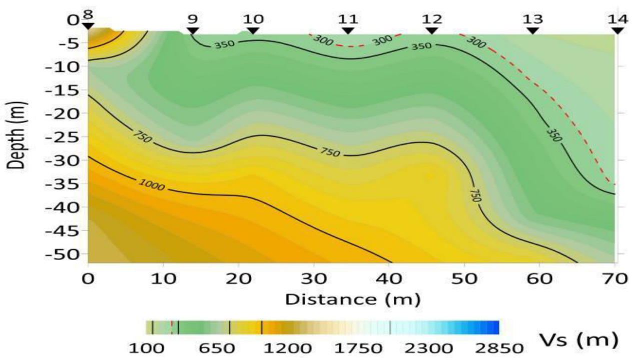


**Figure-4.** Based on the measurement trajectory of the incision at the same longitude as the road, the incision on the far side of the road.

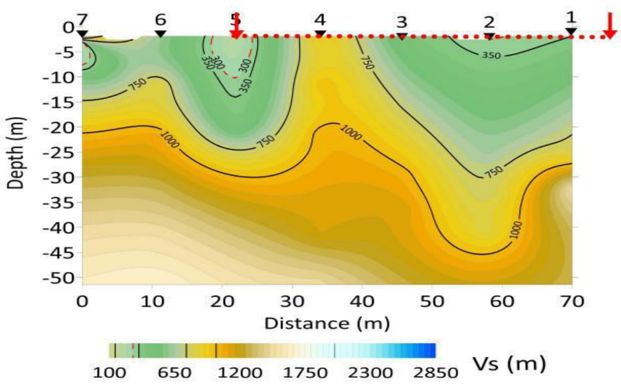


**Figure-5.** The next incision to the south.

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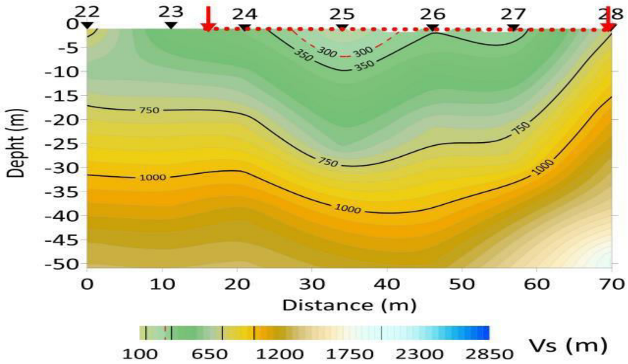


**Figure-6.** Incision at the main location of the subsidence.

Based on Figure-4, there are soft soils (Vs < 350 m, Table-1) with loose and soft properties (Table-2) on the road section that experienced subsidence as well as at the lower location (north of the road) with varying thicknesses of 1.5-35 m with the largest thickness being between point 13 and point 14.

The existence of a sliding plane in the form of a clay layer indicated by a shear wave velocity value of about 300 m/s is under the track of the road section that collapsed, but the potential for movement in the direction of the road track (west-east) is relatively small because the isovalue profile of the 300 m/s value forms an upward basin with left-right symmetry and both directions of the track have flat topography. Of particular concern is the slide plane in Figure-5 between points 12 and 13 to point 14, which has a depth of up to 32m and leads to point 14, a de facto residential house. (point 14 was in front of a house that was moved to the eastern side adjacent to another house due to ground movement).

Figure-7 shows the shear wave velocity (Vs) profiles oriented perpendicular to the roadway trajectory. There are 3 traverse profiles with the profile Figure-9 being the profile with the westernmost traverse

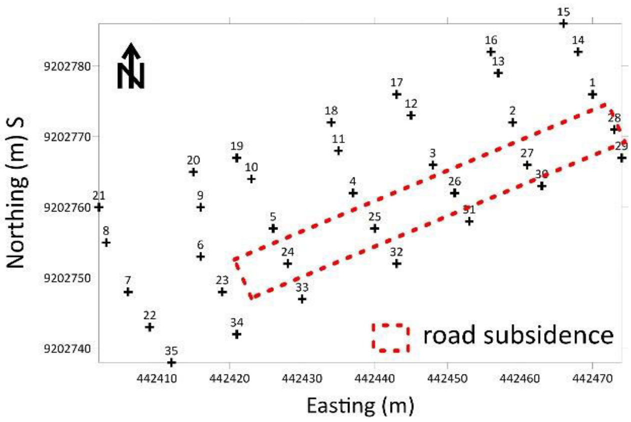


**Figure-7.** Secondary wave velocity profile Vs (microtremor data processing results), simple design of the distribution of measurement points.

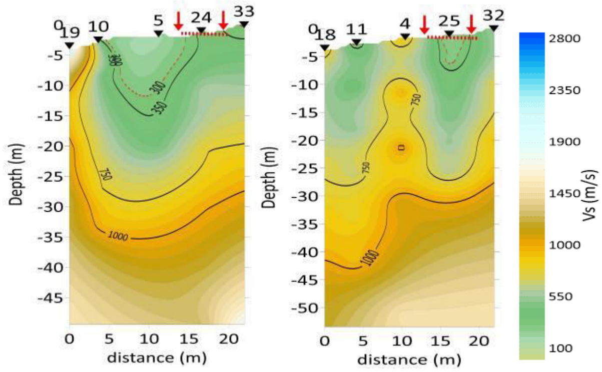


**Figure-8.** Based on the measurement trajectory of the incision in the cross-section with the direction of the road, incision on the westernmost side.

and the profile in Figure-9 is the profile with the easternmost one. The trajectory of the profiles is north-south with the highest elevation in the south (residential yard). Road sections are marked with arrows and dashed red lines. The profiles that contain the road section in Figure-10 are the center left-center-right and bottom left-center images.

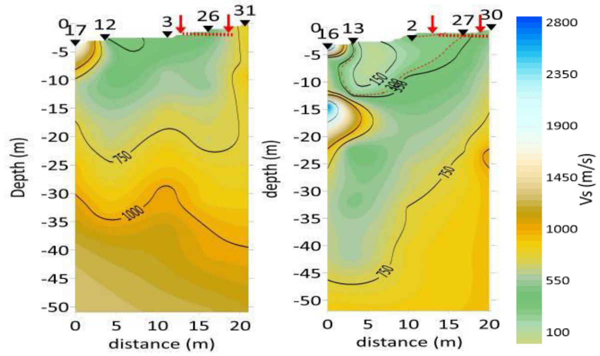


**Figure-9.** The next incision to the east.

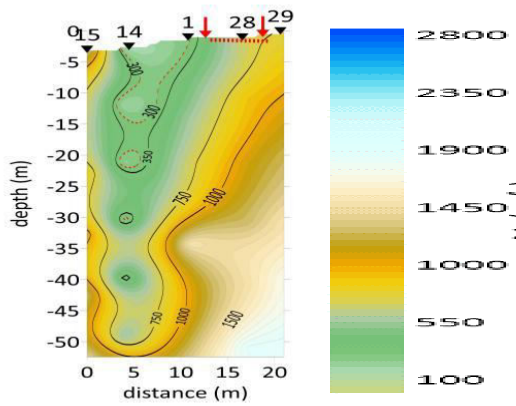


**Figure-10.** Incision at the main location of subsidence.

In this north-south oriented Vs profile, the thickness of soft, loose soil (Vs < 350 m/s) varies from 8 m to 20 m with the largest soft soil thickness located between point 14 and point 1 (Figure-5d) or in the easternmost trajectory. Due to the downward-sloping topography to the north, the profiles in Figure-5(d) have

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the greatest potential for land movement in the form of subsidence. In the center of Figure-5, there is a soft soil layer as well as a sliding plane around the bottom of point 25 but the soil layer to the north of this point is hard, highly compacted soil and soft rock with moderate stiffness properties, making it relatively more resilient to ground movement.

The results of the road section subsidence profile based on Poisson's Ratio are given in Figure-4 and Figure-5 with the analysis based on the reference of Table-4, which is the relationship between soil type and Poisson's Ratio value. The type of clay that acts as a sliding plane due to its impermeability in Table-4 has three classifications: sandy clay with a Poisson's Ratio of 0.2-0.3, unsaturated clay with a Poisson's Ratio of 0.1-0.3, and saturated clay with a Poisson's Ratio of 0.4-0.5. Lithological analysis based on the clay layer in the study of subsidence in the Jatikurung Hamlet road section is based on the Poisson's Ratio value greater than 0.4, which indicates the presence of a saturated clay layer with the depth of this saturated clay layer reaching 31 m.

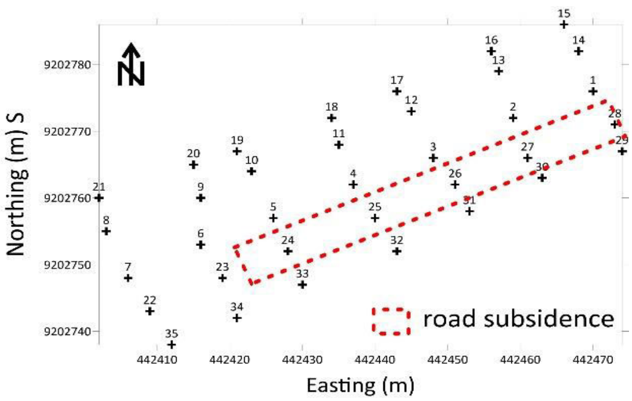


**Figure-11.** A Poisson's ratio trajectory profile (the result of microtremor data processing) simple design of the distribution of measurement points.

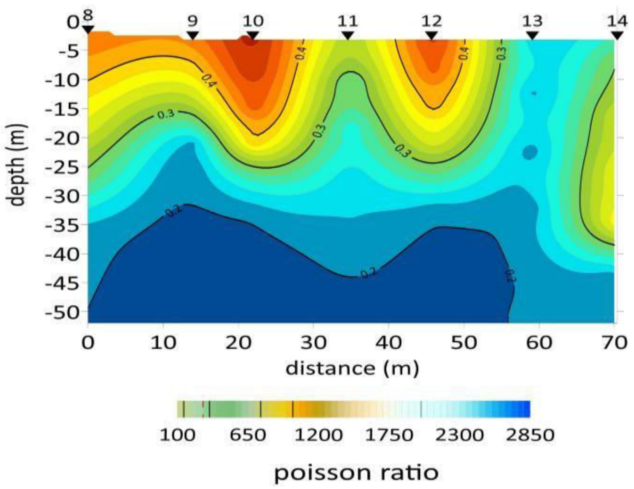


**Figure-12.** Based on the measurement trajectory of the incision in the transverse longitude with the direction of the road, incision on the westernmost side.

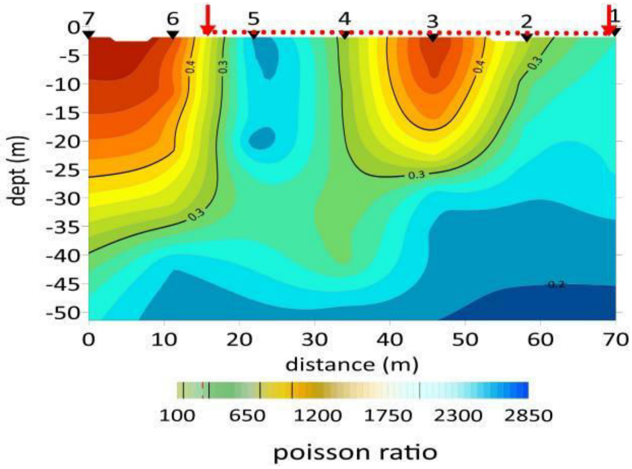


**Figure-13.** The next incision to the east.

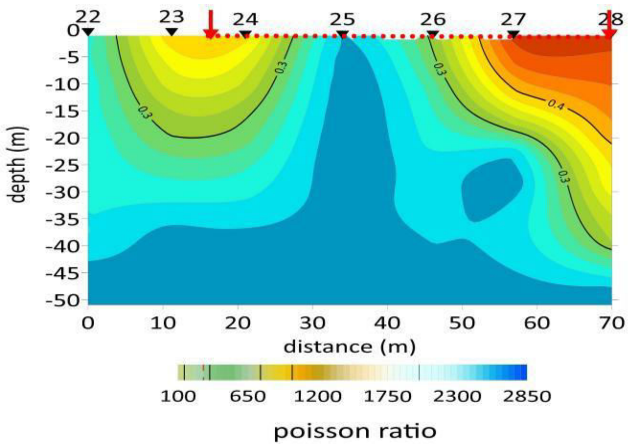


**Figure-14.** Incision at the main site of the subsurface.

The presence of saturated clay is indicated under the road body and around the road body. In Figure-4, the soil layer parallel to the road section with high Poisson's Ratio values is identified as appearing in the southern part of the road or the location point in the yard of a resident's house, increasing in size in the eastern part but decreasing in the western part below the road section, then increasing in size in the middle and western part on the north side of the road section and then expanding in the track profile to the north or lower part. Point 7, which is close to the spring on the north side of the road in the western part of the data acquisition site, has the largest Poisson's Ratio value (Yuliyanto *et al*., 2023)

Based on Figure-14, Point 7 (the location close to the spring on the northern edge of the road in the western part of the study site) is also the point with the largest Poisson's Ratio value. Based on the results of the soil investigation, a technical design for soil movement countermeasures can be prepared. It is possible to make horizontal drainage channels buried in the ground under the road (making flutes), utilizing surface drainage so that no surface water enters the embankment soil on the road body, and installing piles on the north side of the road.

## CONCLUSIONS

Based on the analysis of the processing results and analysis of microtremor data to identify the subsurface layer in the subsidence road section in Jatikurung Sub-village, Jatirunggo Village, Pringapus Sub-district, Semarang Regency based on the shear wave velocity profile (Vs), and Poisson's Ratio, it can be concluded that there is a clay layer at the location of the road subsidence which acts as a sliding plane and the average bedrock depth at the subsidence location is 35m. Ground movement occurs because the soft or loose soil below and at the edge of the road is above the impermeable clay layer. When it rains, the soil is filled with water and there is even a flow of water in the embankment (piping occurs) so that ground movement occurs in the direction towards the lower part.

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