Shear wave velocity profiling analysis

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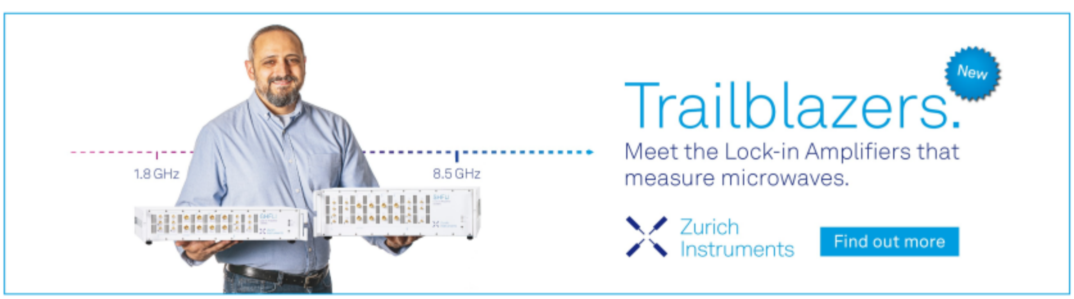

Shear Wave Velocity Profiling Analysis for Site Classification using Microtremor Single Station Method

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Abstract. Microtremor is harmonic vibration of land that occurs continuosly at a low frequency. In this paper presents the analysis of shear wave velocity profile to interpret site classification at Universitas Negeri Semarang. The data acquisition was done at 20 points by using microtremor single station method. The data was processed using Horizontal to Vertical Spectral Ratio (HVSR) method to obtain the HVSR curve and then inverted using ellipticity curve method to get 1D shear wave velocity profile. The value of shear wave velocity profile used to interpret subsurface layers to classification of the site. The result shows the range value of shear wave velocity profile is 160 m/s until 2900 m/s.The AIP Proceedings article template has many predefined paragraph styles for you to use/apply as you write your paper. This value show that site classification in research area consists of soft soil until hard rock.

INTRODUCTION

The Java island is one of the island in Indonesia that has a high level of seismicity. Most of the earthquake source in Java, especially in Semarang city comes from active faults in Java. Active faults that affect Semarang city are Opak Fault (Yogyakarta), Lasem Fault, Pati Fault and Kaligarang Fault. The most recent earthquake which was caused by Lasem Fault activity occurred in Jepara on October 23, 2015 with magnitude of 5 SR.

Semarang city has several seismic regions, such as Gunungpati and Mijen districts. Based on the vulnerability of ground movement zone map published by Pusat Vulkanologi Mitigasi Bencana Geologi (PVMBG), Gunungpati is also considered as an area that prone to soil movement. The value of ground shear strain show that subsurface structure in the research area are relatively not too high. But at some research areas has a value of ground shear strain too high that could potentially crack if hit by an earthquake [1]. Big or small the impact of earthquake not only comes from the magnitude and position of the earthquake source, but also influenced by subsurface structural conditions [2]. The classification of subsurface structure becomes very important to know soil characteristics that can be reference to minimize disaster risk.

Microtremor single station survey should be conducted to determine shear wave velocity that can be used to interpret subsurface [3]. From microtremor single station survey obtained seismic data recording to be analyzed with HVSR method and then inverted using ellipticity curve method to obtain shear wave velocity profiling. From the value of shear wave velocity can be interpreted to describe soil characteristics.

Based on these explanations, studies and analysis of shear wave velocity profile needs to be done to classification of the site in the Universitas Negeri Semarang area with microtremor single station methods to be used as reference for disaster earthquakes mitigation.

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THEORY

Horizontal to Vertical Spectral Ratio (HVSR)

The HVSR method computes the ratio between the fourier amplitude spectra of the horizontal and vertical components of seismic signal measurements at a single station. This method is based on the idea that frequency dependent ellipticity of surface wave motion can explain the HVSR spectral ratio shape [4]. This method was developed by Nakamura in 1989 [5]. Nakamura divided microtremor wave into two types which are Rayleigh wave and body wave. Rayleigh wave is surface wave that propagates in the surface, and body waves propagates through the bedrock [2]. Under these theory, the HVSR equation can be written as follows.

$$H/V = \frac{H_f}{V_f} = \frac{A_h S_{HB} + S_{HS}}{A_v S_{VB} + S_{VS}} \tag{1}$$

where H_f and V_f are the horizontal and vertical component, A_h and A_v are amplification, S_{HB} and S_{VB} are spectrum of horizontal and vertical motion in the bedrock, while S_{HS} and S_{VS} are spectrum of horizontal and vertical motion in the soil surface. The HVSR method is a still general method, where this method has not been able to describe the subsurface structure in detail. Data inversion with ellipticity curve need to get the shear wave velocity that can used to describe subsurface structure.

Ellipticity Curve

The HVSR Inverse modeling method developed by Herak. Inverse modeling or commonly called inversion is a method to estimate the numerical values of model parameter based on observation data using a particular model. In inversion process also done data matching or data fitting to look for model parameters that produce the best models with small incompatibility values or commonly called minimum misfit [6].

The Ellipticity Curve is one of modeling method that can be used to inverse the HVSR curve. The principle of the method are to emphasize Rayleigh waves with respect to other wave types by summing a large number of specially tuned signal windows, calculate the energy on the vertical and horizontal summed signal and henceforward estimate Rayleigh wave ellipticity. Rayleigh wave ellipticity as a function of frequency is closely linked to underground structure, i.e., shear wave velocity profile and sediment thickness [7]. Hobiger explains the ellipticity curve method can be written in the following equation below.

$$\varepsilon = \sqrt{\frac{\int_0^{\Delta} \left(h_{f,s}(t)\right)^2}{\int_0^{\Delta} \left(v_{f,s}(t)\right)^2}} \tag{2}$$

The equation explains the ellipticity curve ∈ is calculated as the square root of the ratio of the energies in the buffered signal windows $h_{f,s}(t)$ and $v_{f,s}(t)$. Ellipticity curve can be used to estimate the proportion of Rayleigh waves in the wave field by comparing Ellipticity model results where the model only shows Rayleigh waves with HVSR measurements including all wave types. To inverse the model of ellipticity curve there are some parameters that must be determined. These parameters are S wave velocity (Vs), P wave velocity (Vp), ratio poisson and density [7].

Ratio poisson is the elasticity constant of the rock. Ratio poisson will be higher than normal conditions in the rock filed with liquid or can be said also rock relatively soft [8]. The ratio poisson relationship with velocity can be written in the following equation.

$$\sigma = \frac{(Vp/Vs)^2 - 2}{2\left[(Vp/Vs)^2 - 1\right]} \tag{3}$$

Rock density generally increase with increasing depth, because with increasing depth the pressure on rocks is also greater. The relationship between the density and the velocity of wave propagation in rocks is written as follows.

$$\rho = \alpha V^{1/4} \tag{4}$$

with ρ is density (gr/cm^3), α is constant of 0.31 and V is velocity (m/s) [9].

RESEARCH METHODOLOGY

Data collection was conducted at 20 points of microtremor measurement in Universitas Negeri Semarang area, where at each point obtained 1D profile of the shear wave velocity that can be correlated with other points by cross section as shown in Figure 1. Data collection was done using 3 component seismograph with duration 30 minutes at each measurement points.

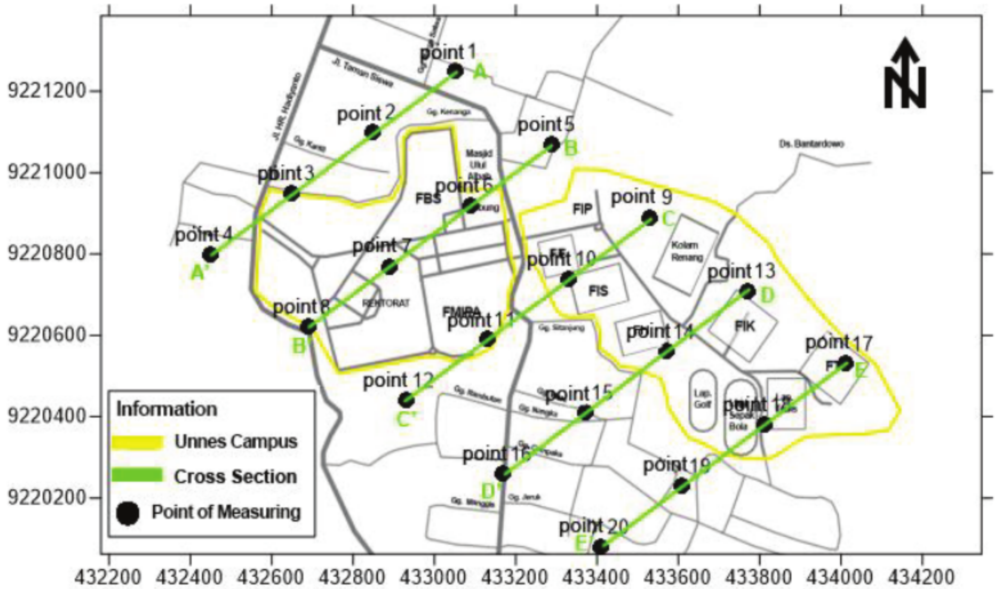

FIGURE 1. The data collection points at the research location

Based on Geology Map of Semarang-Magelang, the research area located above Kaligetas formation composed by Volcanic Breccia results of Ungaran Mountain deposition and claystone that coexists with sandstone.

SNI-1726-2012 explain about the earthquake resistance planning procedures for building and non-building structures, where Universitas Negeri Semarang as educational facilities included in category 4 which has a high earthquake risk [10]. Site classification is required as an initial reference data of subsurface conditions as a means of earthquakes mitigation. In Table 1 explain about site classification to provide criteria of seismic design that form of amplification factor in the building.

TABLE 1. Site Classification [10]

Class Site	Vs (m/s)	N or N_{ch}	S_{μ} (kPa)
SA (hard rock)	> 1500	N/A	N/A
SB (rock)	750 until 1500	N/A	N/A
SC (soft rock)	350 until 750	> 50	≥ 100
SD (medium soil)	175 until 350	15 until 50	50 until 100
SE (soft soil)	< 175	< 15	< 50
	Or every soil profile containing more than 3 m soil with the following characteristics: 1. Plasticity Index, PI > 20, 2. Water content, w ≥ 40 %, 3. Strong Shear, S_{μ} < 25 kPa		
SF (special soil)	The characteristics are • Vulnerable and potentially collapsed due to earthquake loads such as liquefaction easily, clays are too sensitive, and weakly saturated soils. • Clay is very organic or peat (thickness H > 3 m) • Clay that have high plasticity (thickness H > 7.5 m with Plasticity Index PI > 75) • Soft clay layer (thickness H > 35 m with S_{μ} < 50 kPa		

RESULT AND DISCUSSION

The results of data measurement from 20 points analyzed by HVSR curve. Therefore, HVSR curve inverted using ellipticity method to gets shear wave (Vs) profile. The results of HVSR inversion point 1 until 20 shown in Figure 2 - 6.

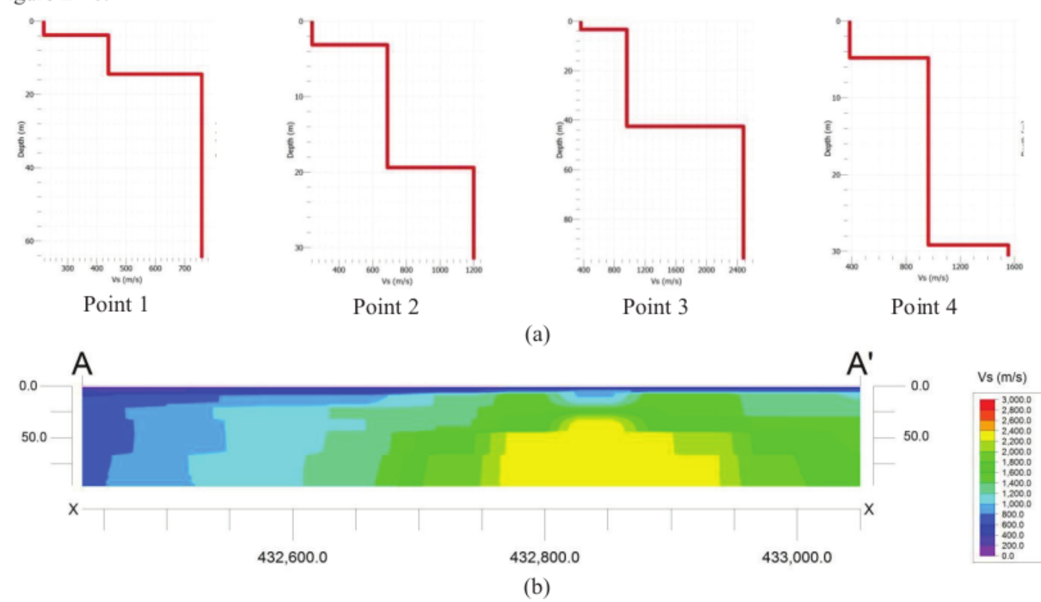

FIGURE 2. (a) 1D shear wave profile (Vs) for measurement points 1, 2, 3 and 4. (b) 2D cross section of shear wave profile (Vs) from measurement point 1 until 4 (A-A').

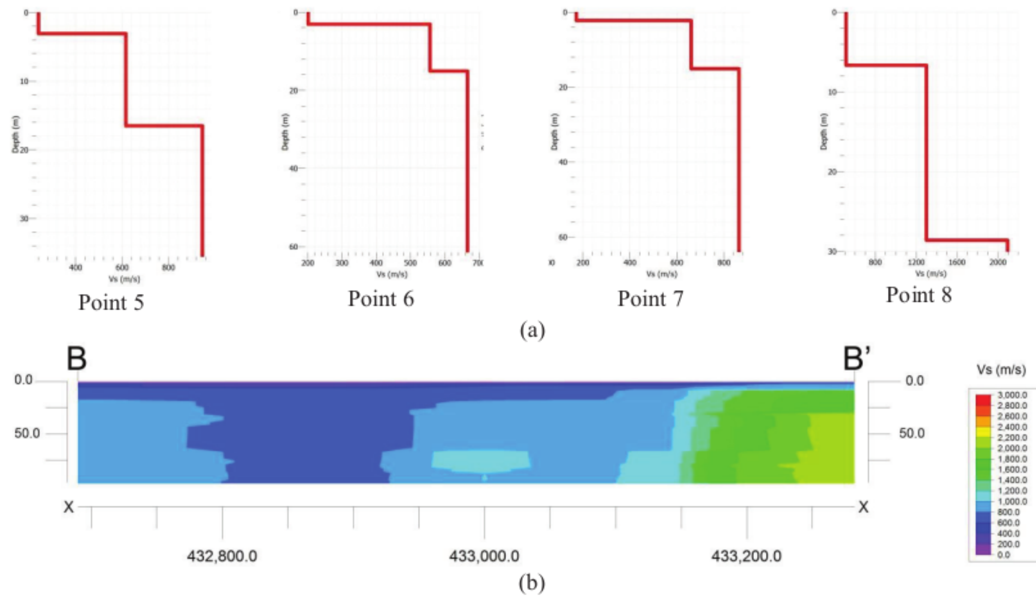

FIGURE 3. (a) 1D shear wave profile (Vs) for measurement points 5, 6, 7 and 8. (b) 2D cross section of shear wave profile (Vs) from measurement point 5 until 8 (B-B').

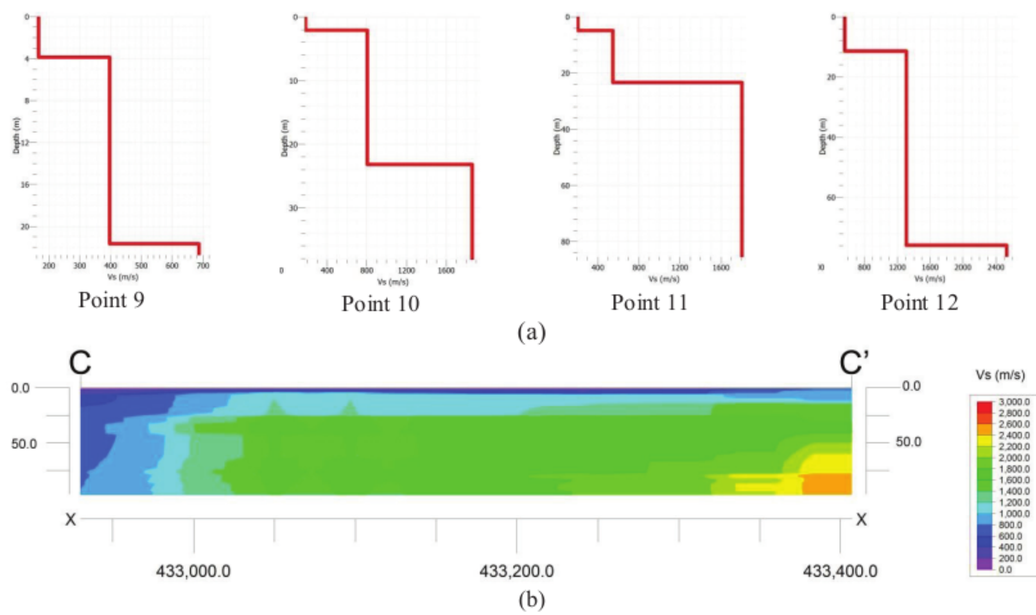

FIGURE 4. (a) 1D shear wave profile (Vs) for measurement points 9, 10, 11 and 12. (b) 2D cross of section shear wave profile (Vs) from measurement point 9 until 12 (C-C').

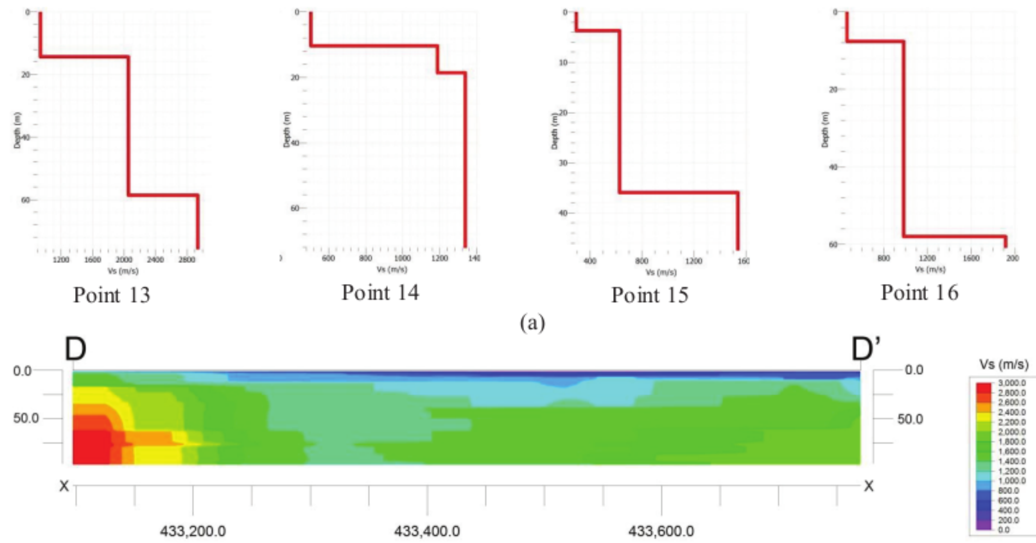

FIGURE 5. (a) 1D shear wave profile (Vs) for measurement points 13, 14, 15 and 16. (b) 2D cross of section shear wave profile (Vs) from measurement point 13 until 16 (D-D').

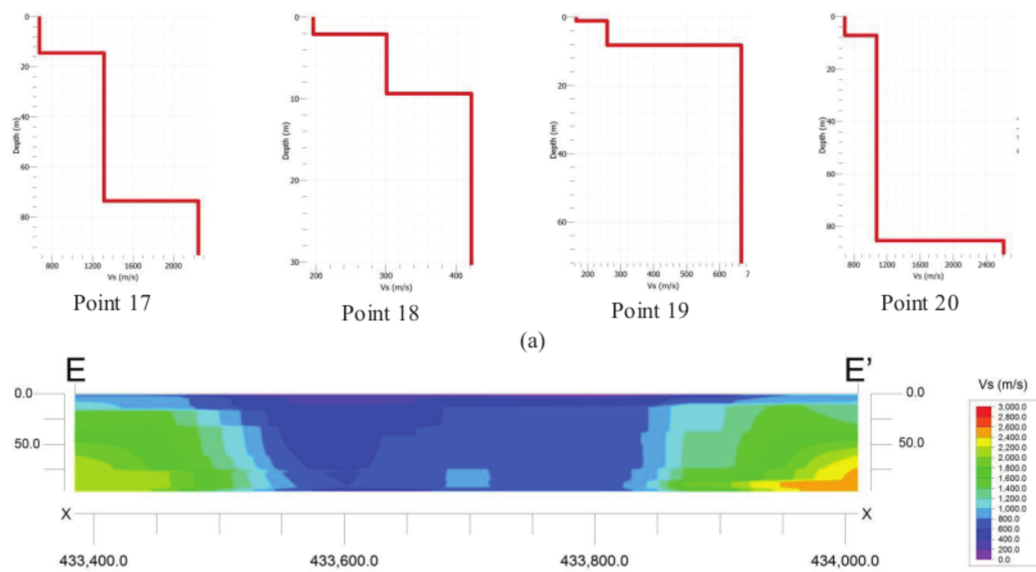

FIGURE 6. (a) 1D shear wave profile (Vs) for measurement points 17, 18, 19 and 20. (b) 2D cross section of shear wave profile (Vs) from measurement point 17 until 20 (E-E').

Figure 2-6 shows that the value of shear wave velocity in form 1D and 2D with velocity range is 160 until 3000 m/s. The inversion results show different depth (Figure 2a-6a), for example at points 14 and 20 there is a difference of velocity profile and depth from other points around it. This is because the inverted HVSR curve from each point is different. The difference of the HVSR Curve is affected by many factor, among others measurement areas that too much noise and rock structure in subsurface. The noise can be derived from human activities, river flows and soft soil conditions that can lead to attenuation. To obtain soil classification, shear wave velocity profiles are interpreted by table of site classification (Table 1). The interpretation results of shear wave velocity profiles shown on Figure 7.

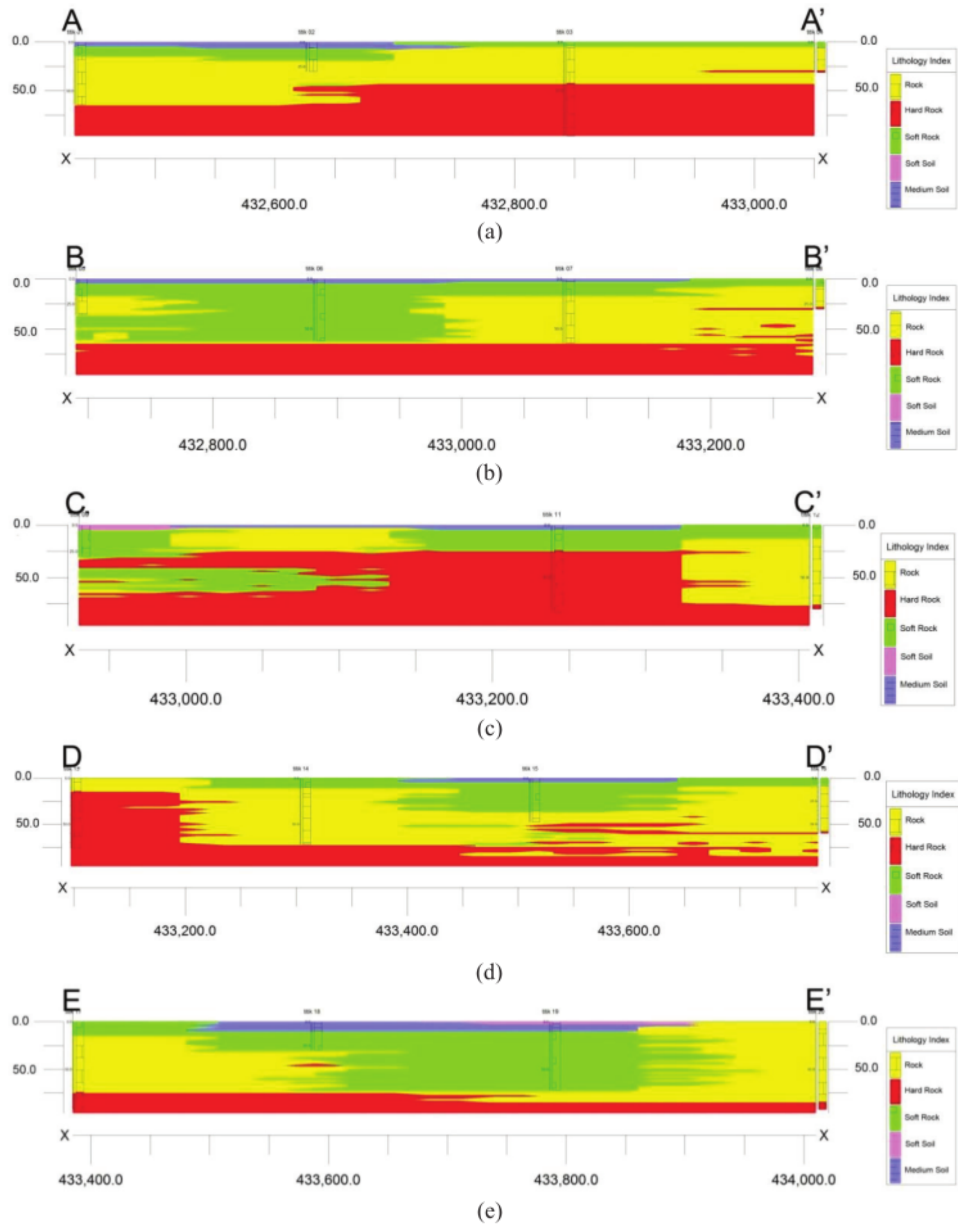

FIGURE 7. 2D interpretation of site classification from (a) measurement point 1-4, (b) measurement point 5-8, (c) measurement point 9-12, (d) measurement point 13-16, and (e) measurement point 17-20.

Figure 7 shows that site classification on the research area. In general the subsurface layers of the research area are composed by soft soil shown in pink, medium soil shown in blue, soft rock shown in green, rock shown in yellow, and hard rock shown in red. The result of interpretation shows that there is a thin layer of soft soil and medium soil with depth around 5-10 m from surface.

Based on information from geological map, the layer of soft soil and medium soil is estimated as top soil and clay layer with shear wave velocity is around 175-750 m/s. This layer easily deformed, either due to seismicity or due to heavy loads of the building.

In around the depth 10-50 m there is a soft rock and rock layer. This layer is estimated as sandstone layer with shear wave velocity value are in the range 750-1500 m/s. This layer has the potential run into liquefaction because porosity of sandstone is relatively high so that the incoming water can change rock structure becomes softer. The distribution of the layer is relatively uneven, this is predicted the sandstone layer tend to be inserted with claystone layer that becomes compiler rocks of Kaligetas formation.

On the depth more than 50 m there is a hard rock layer, where this layer is predicted as volcanic breccia with shear wave velocity more than 1500 m/s. Volcanic breccia is sediment rock that composed from volcanic rocks, where the volcanic rocks is usually a igneous rocks with a compact structure and hard. Figure 8 shows that information of distribution of shear wave velocity which is compiled with site classification.

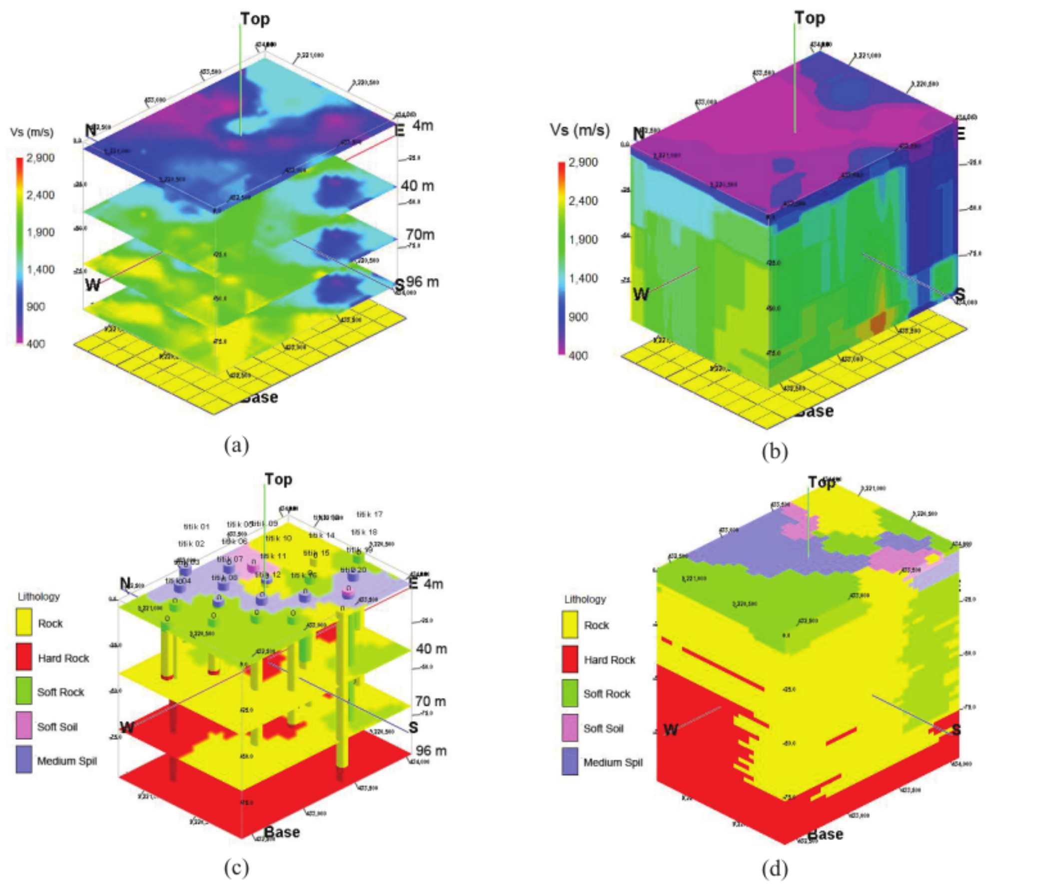

FIGURE 8. (a) Shear wave velocity distribution at depth 4 m, 40 m, 70 m and 96 m, (b) 3D shear wave velocity modeling, (c) log plot site classification at depth 4 m, 40 m, 70 m, and 96 m, (d) 3D site classification modeling

Figure 8 shows that the area with shear wave velocity is relatively low and include the classification of soft soil and medium soil dispersed at point 1,2,5,6,7,9,10,11,15,18, and 19. Soft soil and medium soil layers there is a surface until depth around 10 m.

Based on site classification table (Table 1), the 3D model (Figure 8b and 8d) can be interpreted that layers with relatively low velocities are soft and medium layer layers that have relatively thin thickness compared to other layers. As for soft rocks, rocks and hard rock layers are scattered almost throughout the measurement point with thick enough thickness. Hard rock layers are usually layers with more compact rock structures, where layers are bedrock or bedrock. Based on the geological map can be interpreted that the layer of soft soil and medium soil composed of top soil and clay. Then, the layers of soft rock and rock can be estimated composed by sandstone layers, while for hard rock layer is estimated composed by volcanic breccia rock.

The classification of site becomes very important to know condition of subsurface. Subsurface classification is usually used to provide information on local geological conditions, where local geological conditions can affect the risk of damage caused by earthquakes or known as site effects [11]. The layer of soft soil and medium soil that relatively thick can cause earthquake wave strengthening or amplification.

CONCLUSION

The values of shear wave velocity at research area in range 160 m/s until 3000 m/s, where this value can be classified as soft soil, medium soil, soft rock, rock and hard rock. Soft soil and medium soil spread at several points of measurement, among others in point 1, 2, 5, 6, 7, 9, 10, 11, 15, 18 and 19. The thickness of the soft soil and medium soil is not too thick and depth. In general the layer in research area is composed of soft soil to hard rock that can be interpreted as claystone, sandstone and volcanic breccia.

REFERENCE

[1] Sulistiawan H, Supriyadi, I Yulianti. 2017. Seismic Hazard Analysis based on Earthquake Vulnerability and Peak Ground Acceleration using Microseismic Method at Universitas Negeri Semarang. IOP Conf. Series: Journal of Physics: Conf. Series 812 (2017) 012002.

[2] Nakamura Y. 2000. Clear Identification of Fundamental Idea of Nakamura's Technique and Its Application. The 12nd Word Conference on Earthquake Engineering. Tokyo, Japan.

[3] Kanli, A. 2011. Surface Wave Analysis for Site Effect Evaluation. US: University of California Santa Barbara.

[4] Benjumea B, A Macau, A Gabas and S Figueras. 2016. Characterization of A Complex Near-surface Structure using Well Logging and Passive Seismic Measurements. Solid Earth, 7, 685-701, 2016.

[5] Nakamura Y. 1989. A Method for Dynamic Characteristic Estimation of Subsurface using Microtremor on The Ground Surface. Q.R. of RTRI. Vol. 30, No. 1, page 25-33.

[6] Herak M. 2008. Model HVSR-A Matlab Tool to Model Horizontal to Vertical Spectral Ratio of Ambient Noise. Computers and Geosciences 34 (2008) 1514-1526.

[7] Hobiger M, P. Y. Bard, C Cornou, and N. Le Bihan. 2009. Single Station Determination of Rayleigh Wave Ellipticity by using The Random Decrement Technique (RayDec). Geophysical Research Letters, Vol. 36, L14303.

[8] Manzella, A. 1990. Geophysics Methods in Geothermal Exploration. Pisa, Italy: Italian National Research Council International Institute for Geothermal Research.

[9] Sheriff, R.E. and L.P. Geldart. 1995. Exploration Seismology. Cambridge University Press, Second Edition.

[10] SNI 1726:2012. 2012. Tata Cara Perencanaan Ketahanan Gempa untuk Struktur Bangunan Gedung dan Non Gedung. National Standardization Agency of Indonesia.

[11] Nguyen F, H. Teerlynck, G. Van Rompaey, M. Van Camp, D. Jongmans, and T. Camelbeeck. 2004. Use of Microtremor Measurement for Assessing Site Effects in Northern Belgium-Interpretation of The Observed Intensity during The Ms5.0, June 11, 1938 Earthquake. Journal of Seismology, 8(1) 41-56, 20.

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GRADEMARK REPORT

FINAL GRADE

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GENERAL COMMENTS

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