Application of Microtremor to Identify Bedrock for Building Foundations (Case Study: Eastern of Diponegoro University, Semarang)

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Abstract— In this paper, we have analyzed and discussed the application of the microtremor method to identify bedrock beneath the soil surface. Measurements of 20 points have been carried out with a spacing of 150 m in the research area to the eastern of Diponegoro University. The result is a difference between the softer layer of soil and the harder soil layer beneath it with a difference in shear wave velocity below the surface. The value of the shear wave velocity in the area ranges from 220-3030 m/s. In the study area there are differences in the depth of bedrock at each measurement point, varying to a depth of 59 m. The wave velocity profile of all measurements can be used as a study of development plans in the area as well as a mitigation study.

Index Terms— Bedrock, Microtremor, HVSR, Shear wave velocity

1 INTRODUCTION

Development continues in the midst of the demands of technological progress, civilization, and society. In building construction, it is necessary to design structural and geotechnical designs so that the buildings to be built can last a long time from the risk of earthquakes and landslides and stand firm for the time required.

A foundation supports a structure by transferring loads to a layer of soil or rock that has sufficient load-bearing capacity and suitable settlement characteristics to support the structure. Bedrock is hard, solid rock that lies beneath surface material such as soil and gravel. Identifying bedrock is an important part of geology, geohazards, geotechnical engineering and civil engineering [1].

Horizontal-to-vertical (H/V) ratio based on recorded ambient vibrations used to identify wave profile velocity (Vs) [2]. The purpose of this research is to develop an initial approach to determine the depth of bedrock around Diponegoro University, which can be important information in studies related to construction planning and studies related to hazard mitigation.

2 METHODOLOGY

Lithology is the grouping of rocks in outcrops based on their characteristics. Each characteristic is different so the value of the shear wave velocity is also different. Shear wave velocity (V_S) can explain the lithology of the subsurface layer [3]. The smaller the shear wave velocity (V_S), the smoother the soil properties. On the other hand, the harder the soil properties, the higher the shear wave velocity (V_S). The sediment layer has a shear wave value (V_S) < 750, so it is categorized as medium soil, hard soil, and soft rock [2][4] . the relationship between site classification and value can be seen in table 1 and 2 [5].

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TABLE 1. TYPES OF SOIL AND ROCK [4]

Soil and Rock Type	*Vs* (m/s)
Hard and massif rocks	2700 - 4000
Very stiff	1500 - 2700
Stiff	700 - 1500
Moderate stiff but altered	400 - 700
Loose and soft	100 - 400
Soft and saturated	< 100

TABLE 2. SITE CLASSIFICATION [5]

Class Site	Vs (m/s)	N or N_{ch}	S_μ (kPa)
SA (hard rock)	> 1500	N/A	N/A
SB (rock)	750 - 1500	N/A	N/A
SC (soft rock)	350 - 750	> 50	≥ 100
SD (medium soil)	175 - 350	15 - 50	50 - 100
SE (soft soil)	< 175	< 15	< 50

The HVSR method is a method available for processing microtremor data by comparing the horizontal component of the microtremor signal to the vertical component which can be written as:

$$HVSR = \frac{\sqrt{(S_{NS})^2 + (S_{EW})^2}}{(S_V)^2} \quad (1)$$

where S_{NS} is the amplitude value of the north-south component spectrum, S_{EW} is the amplitude value of the east-west component spectrum, and S_V is the vertical component spectrum amplitude value. The processing result of this method is the H/V curve whose peak shows local site information (site effect) in the form of the dominant frequency value of ground vibrations and the amplification factor of the waves recorded in the soil [6]. The site effect occurs because of the soft soil layer above the bedrock.

Data acquisition was conducted at 20 points of microtremor measurement in Diponegoro University and the eastern of campus. There are 5 lines of cross sections that can be used to give 2D profiling of the shear wave velocity Each point obtained 1D profile of the shear wave velocity can be correlated with other points that crossed in measurement line.

The tools used in microtremor data acquisition are as follows:

- Grapthec MIDI LOGGER GL-240, a tool that functions as a data logger that receives and records signals from the *seismometer*.
- Three-component seismometer, a device that functions as a device or vibration sensor that detects seismic waves below the surface.
- Geological *compass*, a tool that serves to determine the direction of north on the y-axis of the seismometer.
- Global Position *System* (GPS), a tool that serves as a location indicator at each measurement point.

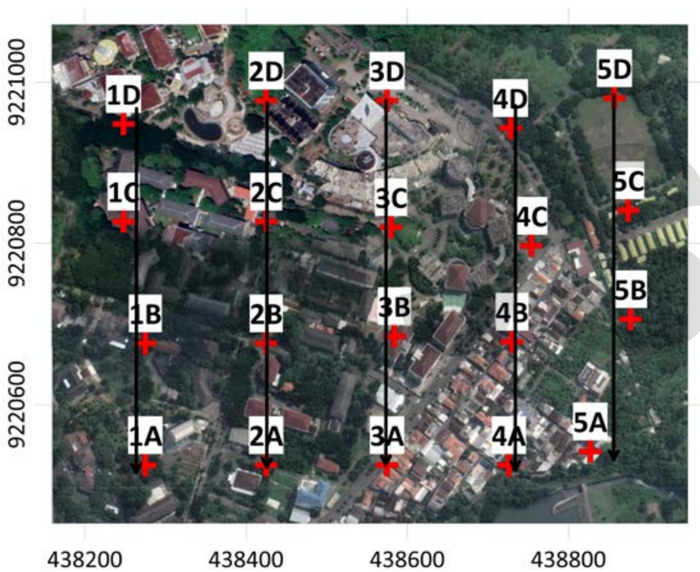


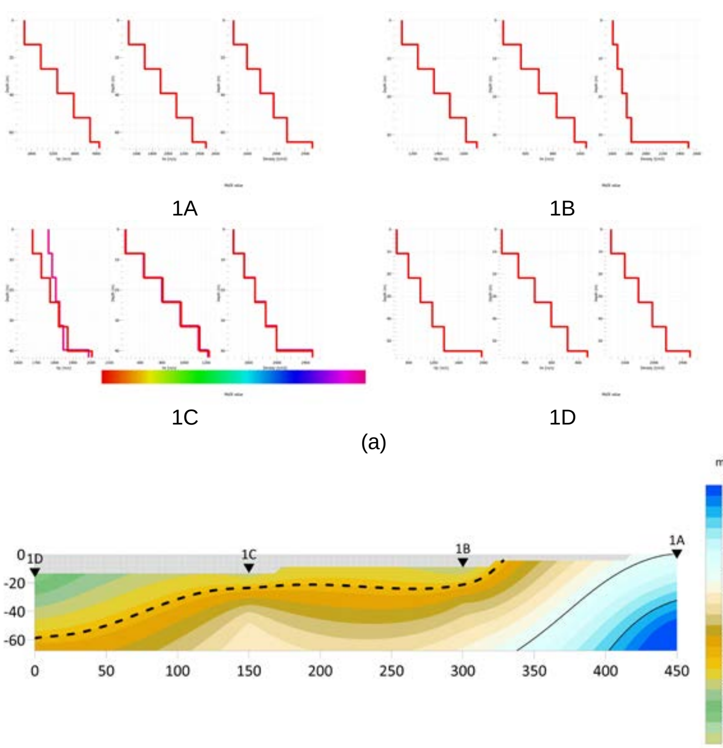
Figure 1. Data acquisition points at the research location

3 Result and Discussion

The results of data measurement from 20 points analyzed by HVSR curve. Therefore, HVSR curve inverted using ellipticity method by Dinver software to gets shear wave (*Vs*) profile. The results of HVSR inversion shear wave (*Vs*) profiles for Line 1 until Line 5 shown in Figure 2 - 6. Information on the sites and the parameter values obtained in this study are given in Table 3. The same processing steps were carried out for all twenty sites.

Table 3. Data Station of Measurement

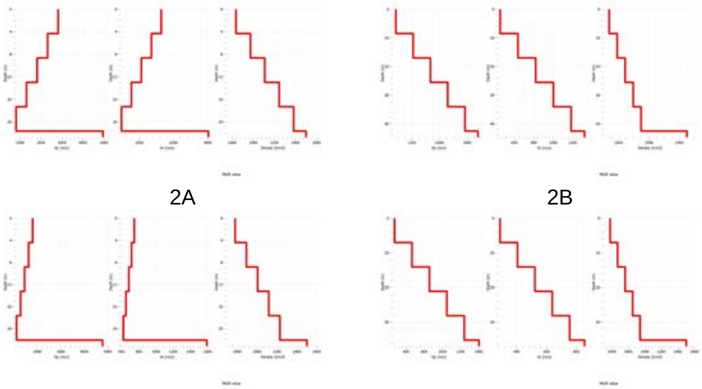
Station	East.	North.	Elev. (m)	f_0 (Hz)	A_0
1A	438275	9220525	204	0,815488	1,32862
2A	438425	9220525	199	5,83482	1,25102
3A	438575	9220525	201	1,26833	2,7526
4A	438726	9220525	195	0,73244	1,22869
5A	438827	9220542	191	7,93033	5,15596
1B	438275	9220676	198	7,2109	2,01975
2B	438425	9220676	192	6,63383	2,26352
3B	438584	9220685	196	0,787017	3,54153
4B	438730	9220678	197	7,05752	1,32994
5B	438877	9220706	196	0,631368	1,4629
1C	438248	9220827	194	0,597998	2,6272
2C	438425	9220827	189	7,34595	1,26516
3C	438580	9220820	190	1,14124	7,21427
4C	438754	9220797	195	0,799312	3,75747
5C	438874	9220841	197	1,10673	2,04477
1D	438248	9220948	191	5,528981	5,57021
2D	438425	9220977	191	3,0082	1,91685
3D	438575	9220977	196	1,64182	1,61287
4D	438728	9220943	200	0,860322	2,23935
5D	438857	9220980	195	0,715215	1,31112
1E	438288	9221132	189	0,631002	7,12196
2E	438425	9221128	191	0,632636	4,55309
3E	438568	9221141	156	0,684048	0,969882
4E	438734	9221160	158	0,640506	1,65356
5E	438872	9221148	172	0,721437	1,54236



(b)

Figure 2. (a) 1D primary wave (*Vp*), shear wave profile (*Vs*) and density (ρ) for measurement points 1A, 1B, 1C and 1D. (b) 2D cross section of

shear wave profile (*Vs*) Line 1



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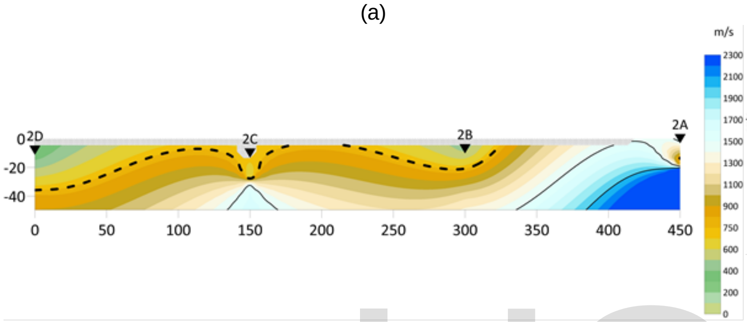
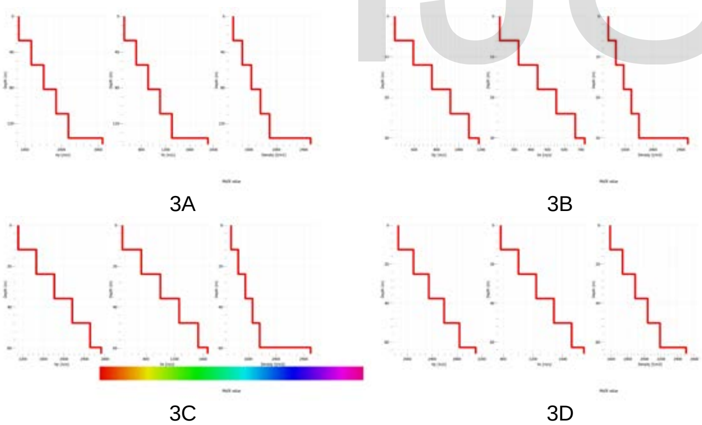


(b)

Figure 3. (a) 1D primary wave (Vp), shear wave profile (Vs) and density (r) for measurement points 2A, 2B, 2C and 2D.(b) 2D cross section of shear wave profile (Vs) Line 2



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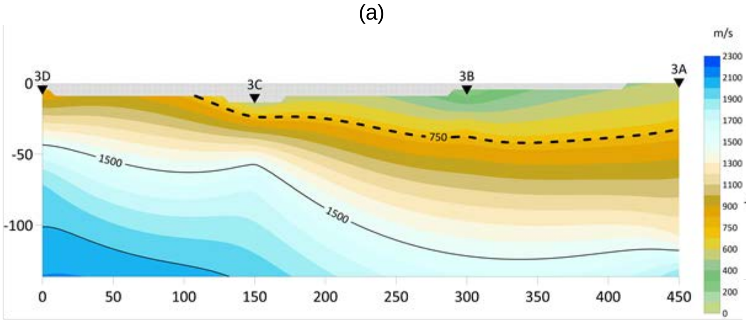

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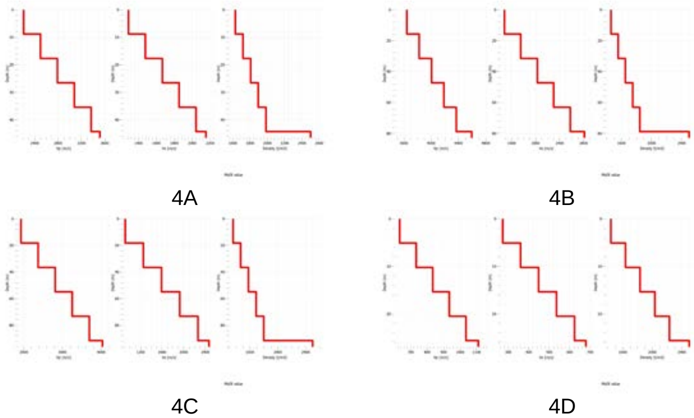
Figure 4. (a) 1D primary wave (*Vp*), shear wave profile (*Vs*) and density (ρ) for measurement points 3A, 3B, 3C and 3D. (b) 2D cross section of shear wave profile (*Vs*) Line 3



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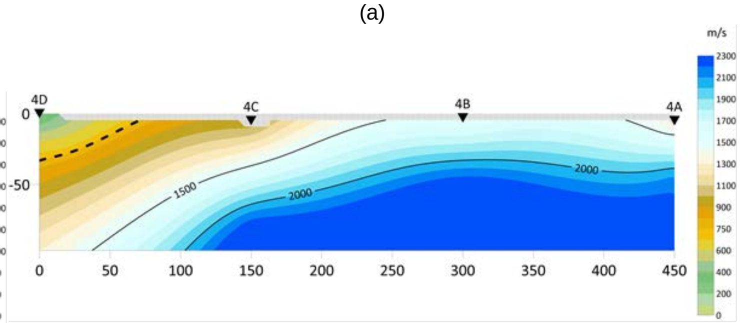

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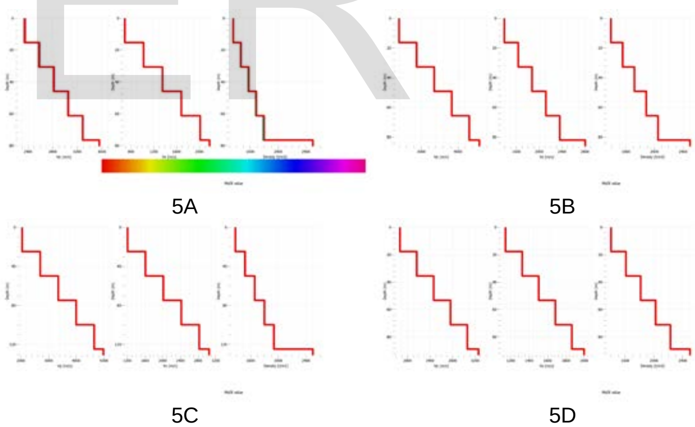
Figure 5. (a) 1D primary wave (*Vp*), shear wave profile (*Vs*) and density (ρ) for measurement points 4A, 4B, 4C and 4D. (b) 2D cross section of shear wave profile (*Vs*) Line 4



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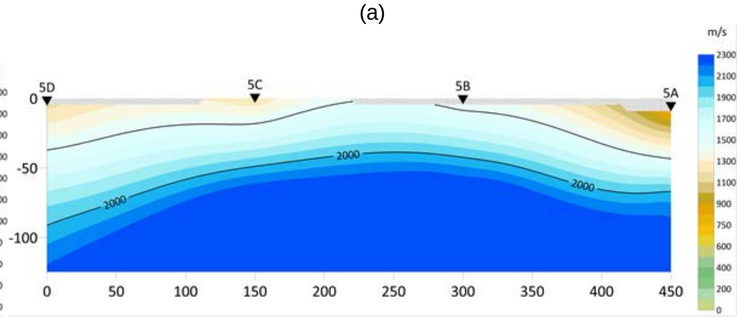

(b)

Figure 6. (a) 1D primary wave (*Vp*), shear wave profile (*Vs*) and density (ρ) for measurement points 5A, 5B, 5C and 5D (b) 2D cross section of shear wave profile (*Vs*) Line 5

Line 1 consists of 4 measuring points with a track length of 450 m. The obtained measurement depth reaches 70 m. The lowest shear wave velocity (Vs) is 235 m/s while the highest is 2480 m/s. At point 1D the bedrock layer is at a depth of 59 m. At point 1C the bedrock layer is at a depth of 23 m. At point 1B the bedrock layer is at a depth of 21 m. At point 1A indicates the presence of a layer of hard rock on the surface. The overall soil layer has a site classification of SD, SC, SB and SA [4].

Line 2 consists of 4 measuring points with a track length of 450 m. The obtained measurement depth reaches 50 m. The lowest shear wave velocity (Vs) is 280 m/s while the highest is 2980 m/s. At point 2D the bedrock layer is at a depth of 35 m. At point 2C the bedrock layer is at a depth of 28 m. At point 2B the bedrock layer is at a depth of 21 m. At point 2A indicates the presence of a layer of hard rock on the surface. The overall soil layer has a site classification of SD, SC, SB and SA [4].

Line 3 consists of 4 measuring points with a track length of 450 m. The depth of measurement obtained reaches 135 m. The lowest shear wave velocity (Vs) is 220 m/s while the highest is 2105 m/s. The 3D point shows the presence of a layer of hard rock on the surface. At point 3C the bedrock layer is at a depth of 24 m. At point 3B the bedrock layer is at a depth of 38 m. At point 3A the bedrock layer is at a depth of 32 m. The overall soil layer has a site classification of SD, SC, SB and SA [4].

Line 4 consists of 4 measuring points with a track length of 450 m. The obtained measurement depth reaches 97 m. The lowest shear wave velocity (Vs) is 275 m/s while the highest is 2850 m/s. At point 4D the bedrock layer is at a depth of 33 m. At points 4C, 4B and 4A indicate the presence of hard rock layers on the surface. The overall soil layer has a site classification of SD, SC, SB and SA [4].

Line 5 consists of 4 measuring points with a track length of 450 m. The measurement depth obtained is 125 m. The lowest shear wave velocity (Vs) is 760 m/s while the highest is 3030 m/s. At points 5D, 5C, 5B and 5A indicate the presence of hard rock layers on the surface. The overall soil layer has a site classification of SB and SA [4].

4 Conclusion

Based on the results and discussion of the research on the application of microtremor to identify bedrock for building foundations on the eastern part of Diponegoro University, Semarang, it can be concluded as follows:

1. Based on the HVSR microtremor analysis showed variations in subsurface characteristics and bedrock depth. Rock *characteristics* and lithology are indicated by the value of shear wave velocity (V_s)
2. Line 1 profile has a value of which is included in the category of Loose and soft – Very stiff profile. Line 1 has bedrock depth variations between 21-59 m at point 1D-1B. Point 1A indicates the presence of a layer of hard rock on the surface.
3. Line 2 profile has a value of which is included in the category of Loose and soft – Hard and massive rocks profile. In Line 2, the bedrock depth varies between 21-35 m at point 2D-2B. Point 2A indicates the presence of a hard rock layer on the surface.
4. Line 3 profile has a value of which is included in the category of Loose and soft – Very stiff rocks profile. The 3D point shows the presence of a layer of hard rock on the surface. Line 3 has bedrock depth variations between 24-38 m at point 3C-3A.
5. Line 4 profile has a value of which is included in the category of Loose and soft – Very stiff rocks profile. At point 4D the bedrock layer is at a depth of 33 m. At points 4C, 4B and 4A indicate the presence of hard rock layers on the surface.
6. Line 5 profile has a value of which is included in the Stiff – Hard and massive rocks profile category. At points 5D, 5C, 5B and 5A indicate the presence of hard rock layers on the surface.

By knowing the soil layer profile in the research area, it can help validate data in the planning and design of building construction in the research area. Planning and design of building construction must also pay attention to subsurface structures and follow procedures from the International Building Code to reduce the risk of damage due to earthquakes [6].

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