Determination of bedrock depth at Faculty of Medicine Universitas Sebelas Maret Surakarta by using seismic refraction method

A T Pridasiwi¹*, B Legowo¹ and S Koesuma¹

¹Department of Physics, Sebelas Maret University, Indonesia

*Corresponding author : annashrpridasiwi@gmail.com

Abstract. The study of determination of bedrock depth has been done at Faculty of Medicine Sebelas Maret University Surakarta using seismic refraction method. The study was conducted on 3 lines using seismograph PASI type 16S24-P with spread length of 46 meters, interval between geophone 2 meters, 5 shots in each spread. Data processing is done using WinSism11.6 software and intercept time calculation method. Results of seismic data processing obtained 2 dimensions interpretation of 3 layers structure. In the first line, the P wave velocity (600-2000) m/s with the depth of 11 meters, the second line (400-2000) m/s with the depth of 11 meters and the third line (600-2000) m/s with the depth of 7 meters. Based on the P wave velocity that have been correlated with the drill data, the rock lithology of the 3 lines are consist of top soil, sand with silt and clay (massif). It was concluded that bedrock lies at depth 11 meters.

1. Introduction
Sebelas Maret University Surakarta needs to improve facilities and infrastructure along with the increase in the number of students. Improving the quality of facilities and infrastructure is done by adding student study space. According to policy by P3LB-UNS 2010, starting 2014 UNS no longer doing development horizontally. However, due to limited land, the development of the student study space is done in vertically. According to the website launched by the Faculty of Medicine UNS, the Faculty of Medicine building of University of Sebelas Maret Surakarta which has been built in the north location of the former Faculty of Medicine building. This building has a number of eight floors with a building area of 12,000 m² and built on a land area of 2,000 m². From the phenomenon it is necessary to investigate the depth of bedrock needed as a parameter of the strength of the foundation of the building.
Figure 1. Geology Maps of Surakarta [1].

Based on geological map in Surakarta area, Surakarta has lithology of rock consist of alluvium, older alluvium, and volcanic rocks as in the Figure 1. Bedrock is a rock and soil derived from the original rock is formed from the cooling of liquid magma and weathering. Factors that affect the rapid wave propagation of seismic rocks are density and elasticity of rocks. Rapid propagation of large seismic waves if the elasticity of rocks has a value greater than the value of its rock density. Other factors that may affect the seismic wave velocity in rocks are lithology, porosity, depth, pressure, rock age and temperature [2].

Building foundations are sometimes secured by drilling to the “rock-head”. Soil and unconsolidated rock often cannot support the weight of a building, and the building may sag or sink. Aquifers, underground pockets of water, exist in porous bedrock formations, such as sandstone [3]. Deposits of petroleum and natural gas can also be found and accessed by drilling through bedrock. Civil engineers rely on accurate measurements and assessments of bedrock to build safe, stable buildings, bridges, and wells (Table 1). Engineers also rely on bedrock to make sure bridges are safe and secure [4].

Table 1. Correlation between wave velocity and rock lithology [5].

| Material                      | P-Wave Velocity (m/s) |
|-------------------------------|------------------------|
| Weathered Layer               | 300 – 900              |
| Soil                          | 250 – 600              |
| Alluvium                      | 500 – 2000             |
| Clay                          | 1000 – 2500            |
| Sand (unsaturated)            | 200 – 1000             |
| Sand (saturated)              | 800 – 2200             |
| Sand and Gravel Unsaturated   | 400 – 500              |
| Sand and Gravel Saturated     | 500 – 1500             |
| Methamorphic rock             | 3500 – 7000            |
| Sandstone and shale           | 2000 – 4500            |
| Limestone                     | 2000 – 6000            |

The main objective of this study is to know the depth of bedrock that will be used as one of the information in laying the foundation of the building. Method to identifying bedrocks can use seismic refraction method. The seismic refraction method is an effective method for the determination of shallow geological structures [6]. The basic principle of measurement seismic refraction method is
based on the nature of the seismic wave propagation reflected in the boundary layers due to the critical angle. Seismic refraction data are relatively easy to obtain [7]. A source charge is detonated a few meters the surface and the arrival time of the first shock wave is recorded by detectors (geophones) which are located at various distances from the source [8].

Travel time for the two layers case is the total travel time obtained from the seismic signal path that radiates below the earth's surface (Figure 2). The equation for finding travel time in two layers case is as follows:

\[
T = \left( \frac{1}{V_2} \right) x + 2z \left( \frac{\cos \theta_{ic}}{V_1} \right)
\]  

(1)

For the case of 3 layers of travel time equation as follows:

\[
T = \frac{x}{V_3} + \frac{2z_2 \cos \theta_{ic}}{V_2} + \frac{2z_1 \cos \theta_1}{V_1}
\]

(2)

Where the depth of the first layer can be determined using the following equation:

\[
z_1 = \frac{\frac{1}{V_1} V_2}{2 \sqrt{(V_2^2 - V_1^2)}}
\]  

(3)

\[
z_2 = \frac{\frac{1}{V_2} V_2}{2 \sqrt{(V_3^2 - V_2^2)}} - z_1 V_2 \sqrt{(\frac{V_3^2}{V_1} - V_1^2)} V_1 \sqrt{(V_3^2 - V_2^2)}
\]  

(4)

**Figure 2.** Simple ray path for a two layers structure [9].

### 1.1. Description of the study area

This research was conducted at the Faculty of Medicine Sebelas Maret University Surakarta. According to the geological maps, this area has a lithology which is dominated by alluvium. This research used 3 lines (Figure 3).
2. Methods
The first step of this research begins by conducting line survey and equipment survey. The study was conducted on 3 lines using seismograph PASI type 16S24-P with 46 meters spread length and interval between geophone is 2 meters with 5 seismic sources point by using in-line method. Data processing using WinSism11.6 software with intercept time method to produce the two-dimensional seismic profile.

The acquisition method for geophone configuration is the in-line method, which is the method of arranging the geophone with the source of vibration in one line. The intercept time method is a seismic interpretation method called the T-X method. The seismic waves received by each geophone are stored in the function of time and amplitude. The results of the acquisition obtained the distance value of each geophone, then processed along with the arrival time of waves on each geophone will produce speed based on the curve T-X or curve travel time [10].

The data obtained from the acquisition process is the data of wave propagation on each geophone in the form of data (.dat). Then data (.dat) converted in the form of data (su). The extension data (.su) is then analyzed (picking first break). Picking first break is selecting the first amplitude of the seismic wave from 24 geophones. The result of picking first break is the arrival time of the seismic wave and the position distance at 24 geophones. These results are generated in the form of travel-time curve. From the travel time curve, slope difference can be obtained. Difference slope can be used to determine the velocity and thickness of each layers by using intercept time method. To display a two-dimensional sophisticated profile first set all the parameter profile.

3. Result and discussion
The results of data acquisition process has been processed using software that is the data of wave propagation in each geophone. Seismic recording data is then analyzed by selecting the first wave (picking first break time). The result of picking first break time is the arrival time of seismic wave at 24 geophones and position 24 geophones in the form of travel time curve of each spread.

The seismic profile can be illustrated through the travel time curve using the intercept time calculation method. Intercept time method is used for determination of depth and rapid wave propagation with three layers assumption. To display a two-dimensions seismic profile, the parameter profile is set first. The result of setting the parameter profile produces a two-dimensions seismic
profile at the rate of each different layer. The wave velocity obtained correlated with literature of P wave velocity correlation with rock lithology. The following is the result of a two dimensions profile (Figure 4, Figure 5, and Figure 6).

![Figure 4](image)

**Figure 4.** 2-D seismic profile of the first line.

The first line figure 3 was done with data acquisition with spread length 46 meters and 5 seismic sources with interval between geophone 2 meters. In this line there are three layers, with wave velocity from 600 m/s to 2000 m/s. The first layer has a wave velocity of 600 m/s up to 800 m/s with depth 4 meters and lithology consist of top soil. The second layer has a wave velocity of 800 m/s up to 1000 m/s with thickness 7 meters and lithology consist of sand with silt. The third layer has a wave velocity of 1800 m/s up to 2000 m/s with the depth from 11 meters and lithology consist of clay (massif).

![Figure 5](image)

**Figure 5.** 2-D seismic profile of second line.
In the second line figure 2, data acquisition with spread length of 46 meters with interval between geophone 2 meter and the amount of seismic sources is 5. From the interpretation result obtained three layers with wave velocity from 400 m/s up to 2000 m/s. The first layer has a wave velocity of 400 m/s up to 600 m/s with depth 2.5 meters and lithology consist of top soil. The second layer with a wave velocity of 800 m/s up to 1000 m/s and the thickness is 8.5 meters and lithology of the rock is sand with silt. The third layer has a wave velocity of 1800 m/s up to 2000, the depth starts from 11 meters with lithology consist of clay (massif).

![Figure 6. 2-D seismic profile of third line.](image)

The acquisition on the third line using the same length of the spread as in the first and second lines. From the interpretation results obtained three layers with wave velocity range from 600 m/s to 2000 m/s. In the first layer the resulting wave velocity is 600 m/s up to 800 m with depth of rock at 2.5 meters and lithology consist of top soil. The second layer has a wave velocity of 800 m/s up to 1000 m/s with thickness 4.5 meter and the lithology are sand with silt. The last layer of the third layer has a wave velocity of 1800 m/s up to 2000 m/s with depth of rock start from 7 meter and the lithology is clay (massif). Based on the results of the analysis of the three paths known that the bedrock on each track can be expressed in Table 2.

| Line | Bedrock | Lithology       |
|------|---------|-----------------|
| 1    | 11 meter| Clay (massif)   |
| 2    | 11 meter| Clay (massif)   |
| 3    | 7 meter | Clay (massif)   |

The line is suitable as the location of the high rise building that is on the third line. The foundation on the third track can be placed at a depth of 7 meters. This result is due to research on the third line, the bedrock lies at a depth of 7 meters with the greatest wave velocity rate of 1800 m/s up to 2000 m/s.
4. Conclusion
The result shows that the bedrock in research location of Faculty of Medicine Sebelas Maret University Surakarta on the first line bedrock is at depth on 11 meters. The bedrock on the second line is at a depth of 11 meters. On the third track the bedrock is at a depth of 7 meters. These three lines have same bedrock lithology consisting of clay (massif).

References
[1] Koesuma S, Ridwan M, Nugraha A D, Widiyantoro S and Fukuda Y 2017 J Math Fund Sci 49
[2] Coulouma G, Samyn K, Grandjean G, Follain S and Lagacherie P 2012 Geoderma 17 39
[3] Murty A S N, Rao P Koteswar, Dixit M M, Rao Kesava G, Reddy M S, Prasad B R and Sarkar 2011 Journal of Asian Earth Sciences 40 40
[4] Badaoui M, Berrah M K and Mebarki A 2010 Engineering Structures 32 590
[5] Nurcandra N, Darsono and Koesuma S 2013 Indonesian Journal of Applied Physics 3 29
[6] Nichols J, Mikesell D and Wijk K V 2010 Geophysical Prospecting 58 1011
[7] Juan I, Sabbione and Velis D 2010 Geophysics 75 V67
[8] Selim E I, Elqady G, Hafez M A and Basher A A 2010 International Journal of Geosciences 3 155
[9] Reynolds J M 1997 An Introduction to Applied and Environmental Geophysics (New York: Wiley)
[10] Piatti C, Socco L V, Boiero D and Foti S 2012 Geophysical Prospecting 61 77