Determination of rock dynamics characteristics using microtremor array measurement data (A case study: Biromaru Sigi Region, Central Sulawesi)

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Abstract. The Biromaru area is located on the Palu-Koro fault line so it is very prone to earthquake shocks. This area is one of the zones that experienced destruction and caused heavy damage to settlements and various infrastructure. In an effort to mitigate seismic disasters, it is necessary to carry out studies related to rock dynamics in the area. This study was conducted with the aim of knowing the dynamic characteristics of rocks using micro tremor data. The dynamic characteristics of the rock are determined based on several parameters, including the average speed of the shear waves at a depth of 30 meters, and amplification factor. The results showed that this area has a type of still rock structure. Thus, the study area has a high susceptibility to damage due to earthquakes.

1. Introduction

Natural phenomena that cause disasters for the community are very important facts, especially in the Biromaru area, Sigi Regency, Central Sulawesi Province. Surface lithology and subsurface sediment thickness are local of geology factors that influence the magnitude of ground vibration due to earthquakes [1, 2]. Research on the characteristics of subsurface dynamics in the valley and the surrounding area using microtremor data has been carried out by [3, 4]. The damage caused by earthquakes has been widely investigated using microtremors, for example [5] investigating local effects in the city of Anjar Tua India using Multi Analysis Surface Wave and horizontal to vertical spectral ratio. Various research have also shown that earthquake amplification and shaking are stronger in areas with lower shear wave velocities (Vs). When earthquake waves spread from the bedrock to the surface, the waves will experience amplification. The amount of amplification is determined by the type or physical properties of the rock. The velocity of the shear wave from the surface to a depth of 30 meters (Vs30) is used as the standard for the magnitude of the amplification.

The purpose of this research is to estimate the dynamic characteristics of subsurface rock according to the velocity of shear wave and its amplification using the Microtremor Array Measurement (MAM) technique. This technique is very useful in providing information about the dynamic properties of the soil. The MAM method can also provide an accurate subsurface velocity of shear wave profile. The velocity of shear wave (Vs) is better than that of the longitudinal wave (Vp) since the curve of Rayleigh
dispersion is more of sensitive to Vs than Vp particularly for half the space below the surface wherein the effects of Vp are neglected[6].

2. Location and geology setting
Geological conditions of the research location are very important in predicting the subsurface conditions of the area under study. The location of this research is in Biromaru, Sigi Regency. The rock formations in this area are the lithology of alluvium formations and coastal sediments consisting of gravel, sand, mud and coral limestone. The alluvium is the youngest unit formed as a result of the collapse of the hilly area that borders it. In addition, there is also the Molasa Selebes Sarasin formation which consists of conglomerates, mudstone and limestone. The Tinombo formation consists of shale, sandstone, conglomerate, volcanic rock, limestone and flax. There is also a metamorphic rock complex consisting of mica schists, amphibolite schists, genes and alabaster [7] which can be seen in Figure 1.

![Geology map of research sites](image)

Figure 1. Geology map of research sites [7]

3. Methods
3.1. Determination of shear wave velocity
Measurements were made on several tracks at different locations. The number of geophones used is 12 with a space of 5 meters, each track has a length of 60 meters. The microtremor recording data processing to determine the shear wave velocity was carried out with the SeisImager from Geometrics. According to [8], Vs30 is a good indicator parameter to describe the stiffness and strength characteristics of the soil which can be detected at a depth of up to 30 m. This parameter value is used to classify rocks according to the magnitude of earthquake vibrations caused by local influences and for purposes of planning buildings that are safe from earthquake shocks. Vs30 is an important data and is often used in geophysical applications to identify the properties of subsurface structures up to a depth of 30 meters [9]. The velocity of the shear wave up to 30 meters is used as standard for magnitude of the amplification. The value of Vs30 can be determined using equation (1)

$$V_{s30} = \frac{\sum_{i=1}^{n} t_i f_i}{\sum_{i=1}^{n} t_i / V_{s,i}}$$

(1)

Rock properties are necessary to understand the dynamic properties of rocks, so as the shear strength and stiffness of rocks could be identified based on the average velocity of shear waves up to a depth of 30 meters.
Table 1. Rock type according to Vs30 and amplification factor based on NEHRP standards [10, 11]

| Soil type | General description                  | Vs30 Average SWV to 30m |
|-----------|--------------------------------------|------------------------|
| A         | Hard Rock                            | > 1,500 m/s            |
| B         | Rock                                 | 760-1,500 m/s          |
| C         | Very Dense Soil and Soft Rock        | 360-760 m/s            |
| D         | Stiff Soil                           | 180-360 m/s            |
| E         | Soft Soil                            | <180 m/s               |

3.2. Determination of amplification and dominant period

The study conducted by [12] has simplified the method by showing the relation among amplification of ground vibrations and the mean velocity of shear waves at a depth of 30 m and incorporating it into the NEHRP program. The current NEHRP approach classifies soils into six classes (A - F) based on the vertical shear wave velocity profile [11]. Soil amplification can be calculated based on the vs30 value as expressed by [13] through the equation below.

$$\text{Log Amp} = 2.367 - 0.852\text{logVs30} + 0.166$$

(2)

where Amp is the amplification factor.

4. Results and discussion

Data processing and analysis of the shear wave velocity structure in the study area were carried out using the Multi Array Microtremor (MAM) method with a passive source. This method uses the dispersive properties of surface waves which occur because the direction of the motion of the particles is perpendicular to the direction of the wave propagation. Shear waves occur because of the direction of the propagation of the motion which is perpendicular to the direction of propagation. Dispersion curves are used as the basis for constructing an initial model of the velocity structure of the subsurface shear waves. Then, inversion is done to obtain the rock layer velocity of shear wave profile. Furthermore, to obtain the value of Vs30 used equation (1) and the amplification factor used equation (2). Based on the Vs30 value and the amplification, a classification of subsurface rocks in the Biromaru area was carried out based on Table 1.

The value of Vs30 and the amplification factor that were scattered in the study area were interpolated to obtain the Vs30 value and the amplification for areas where data were not measured and recorded. The results of the interpolation of the Vs30 value and amplification factor are presented in the form of a map as in Figures (2) and (3) below.

The dynamic characteristics of a rock can be determined by knowing the velocity of the shear waves propagating below the surface and their amplification. The current earthquake resistant building design uses the rule (code) average speed of shear waves above 30 m (Vs30) and amplification. Vs30 and the amplification factor can be used to identify the dynamic characteristics of the rock around the surface.

The results of determining Vs30 and amplification at the respective research locations are shown in Figure 2 and Figure 3. The distribution of Vs30 values is around 205 m/s to 266 m/s with an interval of the difference in the Vs30 value which is not too significant. The central and southern part of the study site. The highest Vs30 score is located in the middle of the study site. The amplification value is around 2.9 to 3.7 as shown in Figure 3. It can be seen that the amplification distribution has the same distribution pattern as the value of Vs30. In the northern part, the amplification value is relatively lower than in other parts of the study area. The highest amplification is located in the middle of the research location. The Vs30 value interval and the
amplification at each measuring point in the study location showed insignificant differences. This shows that the subsurface rock conditions are relatively the same. Based on the value of Vs30 and its amplification factor and referring to the rules of the National Earthquake Hazards Reduction Program (NHERP) as shown in Table 1, it shows that the soil classification at the research location is included in the stiff soil category.

Figure 2. Distribution of the average velocity of shear waves at a depth of 30 m (Vs30) at the study location

Figure 3. Distribution of amplification values at research locations
5. Conclusion
Based on the value of Vs30 and the amplification factor, it can be concluded that the dynamic characteristics of the rock at the study site are classified as stiff soil. The value intervals of both Vs30 and amplification have insignificant difference values. This shows that the subsurface rock conditions are relatively the same.

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