Distribution of Vs30 in Poso kota sub-district

M Rusydi1*, M B Cyio2, Rahmawati3 and Ramlan2
1 Physics Department, Faculty of Mathematics and Natural Science Tadulako
University, Indonesia, Palu
2 Agrotechnology Department, Faculty of Agriculture Universitas Tadulako,
Palu, Indonesia
3Geography Education Department, Faculty of Teacher Training and Education
Tadulako University, Palu, Indonesia.

*email: rusydiutd@gmail.com

Abstract. Poso District, has three faults namely poso fault, tokararu fault and poso west fault, so this area needs to be conducted a seismic hazard assessment to reduce the risk of earthquake disaster, especially in densely populated areas. The research was focused in Poso Kota District. In estimating possible seismic hazards One of the steps taken is to microzone the local area by looking at the distribution of shear velocity (Vs30), which provides a basic analysis of the basic seismic hazards of the study area. The results obtained indicate that the magnitude of VS30 in the study location is classified into medium and soft soil types, with a medium land area of 3892 Ha, while soft land which is widely distributed in the west coast of Poso City has an area of 2688 Ha, for hard lands the total area is 2534 Ha.

1. Introduction
Earthquakes are natural disasters that occur suddenly and have a devastating impact on areas near the source of the earthquake, so it is very important to conduct research in areas prone to earthquake disasters [1]–[8]. One of the vulnerable areas is the Poso District, because there are three faults that cross this area, namely the Poso Fault, Tokararu Fault and West Poso Fault [9], [10]. The most recent earthquake occurred on March 24, 2019 with M = 5.7 and shocks were felt up to the scale of MMI IV, resulting in several buildings in Poso District being severely damaged. Earthquakes with magnitudes of 4 to 6 occur almost every year in this region, so a seismic hazard assessment is needed to reduce the risk of earthquake disasters, especially in densely populated areas. In estimating possible seismic hazards One of the steps taken is to microzone the local area by looking at the distribution of shear velocity (Vs30), which provides a basic analysis of the basic seismic hazards of the study area. The research area will be focused in Poso Kota sub-district, considering that this area is a densely populated area.

Vs30 is one of the parameters most often used in predicting shear wave velocity in sediment layers at a depth of 30 meters [11], [12]. The estimated value of vs30 is carried out by measuring using a microtremor, with 5 measurement points in Poso Kota sub-district. The measurement results of Vs30 at 5 points then become the basis for correcting the value of vs30 which is sourced from USGS, so that the distribution value of vs30 is obtained with interval distribution values per 1 km. Determination of the Vs30 value by microtremor was analyzed using the horizontal to vertical spectrum (HVSR) method [13]–[18]. The subsurface VS value obtained from the inversion results of the HVSR curve is used to estimate VS30 which is useful for soil classification based on earthquake vibrational strength due to local effects [19]–[22].

Obtaining a Vs30 value using a microtremor only illustrates the dynamic condition of the soil at the measurement location so to get an overview of the vs30 distribution in all Poso kota sub-districts, a correction to the Vs30 value of USGS is made. The Vs30 value of USGS was interpolated at 1 km intervals, then the vs30 value was corrected based on the rock types in the study area. The results obtained will illustrate the overall vs30 distribution in Poso Kota District. For this reason, secondary data related to geological conditions in the study area are needed.

A brief description of the geological conditions in Poso and surrounding areas can be seen from three geological slides (Figure 1) which have different rock characteristics and history of flooding,
namely; West Sulawesi Mendala in the west, East Sulawesi Mendala in the middle and east and Banggai - Sula in the easternmost [23]. The tectonic history that unites the three tributaries can be described starting from the Cretaceous era, namely when the East Sulawesi Mendala moves west following the sloping inclination movement to the west in the east of the West Sulawesi Mendala [24]. This subduction results in the formation of a tectonic and glaucopan schist. The next tectonic phase of the Oligocene, namely when the micro continent Banggai - Sula moves west along the horizontal fault (Sorong Fault) [25], [26], while the subduction in the eastern part of the West Sulawesi Mendala continues. In the Middle Miocene the three mendala fused with tectonic contact and a portion of rocks from the eastern part of the Sulawesi Mendala rose above the Mendala Banggai - Sula. At the end of the Middle Miocene to the Pliocene, sedimentary molasses deposited unconformably over the three tributaries, as well as granite breakthroughs in West Sulawesi [27]. In the Plio-Plisocene, the whole area experienced a flooding and breakthrough by granite which previously only occurred in the West Sulawesi Mendala [28]. After that it was followed by the appointment in all regions to produce a landscape appearance like now

![Geological map of poso district](image)

This study aims to examine the distribution of vs30 so that it can provide information related to the level of seismic vulnerability in Poso Kota District in more detail.

2. Method
The study begins by designing the concept of field acquisition, so that a detailed picture is obtained related to the acquisition to be carried out. The next step is the acquisition of microtremor at the point of the acquisition that has been previously designed. Data acquisition is carried out data processing to get the natural frequency and amplification value. The data processing used HVSR (Horizontal to
Vertical Spectral Ratio) data analysis. Furthermore the HVSR curve from the HVSR analysis is converted to get the VS value which is then used to estimate the VS30 value.

All acquisition data is processed using Geopsy software. Soil acquisition data were analyzed using the HVSR technique, namely the ratio of horizontal and vertical amplitude spectra with the following equation 1:

\[ R(t) = \sqrt{\frac{F_{NS}(t)^2 + F_{EW}(t)^2}{F_{Z}(t)^2}} \]  

where \( R(t) \), \( F_{NS} \), \( F_{EW} \) and \( F_{Z} \) are the vertical to horizontal ratio spectrum, the Fourier spectrum in NS, the Fourier spectrum in EW and the Fourier spectrum in Z (vertical direction).

The ground microtremor data in the Geopsy software is performed by selecting stationary windows between 20-50 seconds non-overlapping. Then Fourier spectrum analysis is performed to change the initial data acquisition in the form of time domain to frequency domain. The FFT results performed Konno Ohmachi smoothing with a bandwidth coefficient of 40 \[10, 11\]. Processing is followed by HVSR analysis to obtain the HVSR value indicated by the highest peak of the HVSR curve considered as the natural frequency of the soil. Measurements were made at 12 points spread in Poso Kota sub-district.

VS30 estimation is generated from VS resulting from the inversion of the HVSR curve for each microtremor data acquisition point. VS30 estimation is carried out using Equation 2. Furthermore, the VS30 value generated allows the classification of seismic vulnerability levels.

\[ V_{S30} = \frac{30}{\sum_{i=1}^{N} d_i V_i} \]  

Where \( d_i \) is the thickness of the sedimentary layer (m), \( V_i \) is the shear wave velocity (m/s) and \( N \) is the number of layers above a depth of 30 m.

The Vs30 estimation results obtained are then used as a reference to correct the vs30 values sourced from USGS, so that they can describe in detail the seismic hazards in intervals of 1 km in all Poso Kota sub-districts. With seismic hazard information can later indicate which areas have a high level of vulnerability due to earthquakes.

3. Results and Discussion

3.1. Results

The measurement results use a distance of 5 meters for each geophon. The number of geophones used was 12 so the length of each stretch of the track was 55 m. Data retrieval is carried out as many as 5 tracks at different locations. From the measurements that have been made, the results obtained record as shown in Figure 2 to Figure 6.

![Figure 2. Recorded wave propagation on Line-1](image)
Location of data collection on Line-1 is in the area of SDN Sedoa at coordinates 120° 20' 23.5" to 120° 20' 25.2" East and 1o 21' 13" to 1o 21' 13.2" LS. This track is stretched to 101° eastward with elevation 1,203 m above sea level, the exact measurement location is next to the school with the surrounding conditions of wild grass and a lot of building debris. In the west stretch there is the Lariang river and in the east there are roads and mountains. Based on Figure 2 shows the recorded wave data in the form of wave propagation time and the distance between the geophones and the source of the passive wave. From the picture it can be seen that the waves recorded at 0 - 500 msec have a large wave amplitude, this is the noise recorded at the time of data collection, this is because recording data is taken at the time school hours and many students passing by around the location of data collection, causing noise.

Figure 3. Recorded wave propagation on Line-2

Measurements on line-2 are carried out in the Sedoa Village Consultative Agency (BPD) office yard. This track is in the coordinates of 120° 20' 26.3" to 120° 20' 27.3" East and 1o 21' 1.6" to 1o 21' 12.1" LS with elevation of 1,204 m asl. This track stretches 143° southeast. In Figure 3 shows the recording of waves in the form of wave propagation time and distance between geophones. This recording shows that at 2,800 - 3,000 msec there is noise. This is because in the west stretch there is the Lariang river and in the east there is a highway so that the roar of the river water and the traffic on the highway interferes with the wave recording.

Figure 4. Recorded wave propagation on Line-3
Figure 4 is a recording of wave propagation on Line-3 which is carried out at coordinate points 120° 20’ 24” to 120° 20’ 25.8” East and 1° 21’ 9.2” to 1° 21’ 9.4” LS with elevation 1,203 m asl. This track is located in the field of Sedoa Village and stretches 269 ° west. The conditions around the stretch in the west, north and south are residents’ houses and in the east there are Sedoa Village offices. From Figure 4, no noise can be seen when recording data.

Figure 5. Recorded wave propagation on Line-4

Line 4 is in the community garden with an elevation of 1,181 m asl at the coordinates of 120° 20’ 47.5” to 120° 20’ 46.7” East and 1° 20’ 51.4” to 1° 20’ 52.9” LS. The direction of the stretch on this track is 41° northeast with conditions around the track there are rice fields and cocoa fields and in the south there is the river Lariang. In Figure 5 it can be seen that the data recorded on line-4 is quite good because there is no visible noise. This is because when recording location data is very quiet so there are no disturbances.

Figure 6. Recorded wave propagation on Line-5

Figure 6 is a wave propagation record on Line-5. Measurements were carried out at the coordinates of 120° 20’ 47.1” to 120° 20’ 48.1” East and 1° 20’ 42.7” to 1° 20’ 44.2” LS, which is still located in the community garden with an elevation of 1,199 m above sea level. This track stretches 347 ° north. Around the stretches there are chocolate gardens and rice fields. Based on recorded data, this track also does not show any noise or disturbance when recording. Location at the
The time of data retrieval is very good or bad determines data. The location on Line-5 is very quiet and far from residential areas, so the data generated is also quite good. The second step uses WafeEq software to get the 1D model of the shear wave velocity to the depth shown in Figure 7 to Figure 11.

**Figure 7.** Dispersion curve on Line-1

Figure 7 is a dispersion curve on Line-1. Dispersion curves are curves that describe the change in phase velocity with respect to wave frequency. In the dispersion curve it can be seen that the phase velocity ranges from 0 - 2,000 m/s and the wave frequency ranges from 0 - 15 Hz. The minimum frequency of the wave is 2.5 Hz and the maximum frequency of the wave is 10 Hz marked with red dots on the curve which is the maximum amplitude of each wave frequency.

**Figure 8.** Dispersion curve on Line-2

Figure 8 is a dispersion curve on Line-2 with a minimum wave frequency of 3.12 Hz and a maximum wave frequency of 14.64 Hz. The frequency is indicated by red dots on the curve with blue contrast.
At Line-3 the wave frequency ranges from 0-15 Hz with a maximum wave frequency of 14.64 Hz and a minimum wave frequency of 3.5 Hz as shown in Figure 9.

The dispersion curve at Path-4 shows the phase velocity ranging from 0 - 2,000 m / s with the maximum frequency of the wave being 14.64 Hz and the minimum frequency of the wave being 5 Hz. This frequency is indicated by the presence of red dots at each frequency as shown in Figure 10.
Figure 11 is a dispersion curve at Path-5 with a wave frequency ranging from 0-15 Hz, a minimum wave frequency of 5 Hz and a maximum wave frequency of 14.64 Hz with phase velocity ranging from 0 - 2,000 m / s. The resulting dispersion curves for each trajectory were then inversed with an initial model that is based on depth with a depth of 30 m and obtained a profile of the shear wave velocity at each path.

The wave velocity profile obtained at each trajectory can be determined by subsurface layer structure based on shear wave velocity (Vs) and depth (h). The value of Vs can determine the value of Vp based on the relationship between Vs and Vp in equation 2.4 which is indicated by a green line on the shear wave velocity profile.

Vs and Vp produced on each track show the same type of rock or subsurface material to a depth of 30 m. The relationship between shear wave velocity to depth can determine the value of VS30 with equation 2.7, the calculation of the data can be seen in Appendix 5. The resulting VS30 value allows classification of subsurface rock types by referring to Table 2.2, the VS30 value and the classification of rock types at each path at the research location can be seen in Table 1.

| Site | VS30 (m/s) | Soil Class | Site Class |
|------|------------|------------|------------|
| Li   | 180.5      | D          | Medium Soil |
| Li   | 220.8      | D          | Medium Soil |
| Li   | 167.8      | E          | Soft Soil   |
| Li   | 222.2      | D          | Medium Soil |
| Li   | 235.4      | D          | Medium Soil |

Based on the shear wave velocity profile, the rock density (ρ) layer obtained from WaveEq software is stored in the form of .txt. Rock density is one of the parameters in determining shear modulus (G). While the modulus of elasticity (E) is obtained from the relationship between shear
modulus and Poisson ratio (σ) of each path as shown in Appendix 5 and the calculation results can be seen in Table 2.

| Location | Density (Kg/m³) | Slide Modulus (N/m²) | Poisson Ratio | Modulus Elasticity (N/m²) | Elastisitas |
|----------|-----------------|----------------------|---------------|---------------------------|-------------|
| Line -1  | 0.001787        | 56.66                | 0.49346       | 169.23                    |             |
| Line -2  | 0.001795        | 102.05               | 0.48916       | 303.94                    |             |
| Line -3  | 0.001783        | 54.82                | 0.49363       | 163.78                    |             |
| Line -4  | 0.001799        | 88.05                | 0.49046       | 262.47                    |             |
| Line -5  | 0.001805        | 101.58               | 0.48925       | 302.55                    |             |

3.2. Discussion

The resulting shear wave velocity profile shows that each trajectory has the same type of rock or subsurface material to a depth of 30 m, but each layer has different seismic wave velocity values. This is due to differences in rock density so that the wave velocity possessed is also different. The greater the density of rocks, the more compact or compact the rock, so that the wave velocity will tend to increase. The obtained wave velocity values are used to determine the parameters of soil dynamics. These parameters are VS30, shear modulus, and elastic modulus. The VS30 value was obtained based on the relationship between the shear wave velocity and the depth of the bedding on each path and the classification of rock types in Sedoa Village was carried out. While the value of shear modulus and elastic modulus are obtained based on the value of the shear wave velocity and the speed of the primary wave or compression wave.

The results showed that Sedoa Village is an area with a layer of soil in the form of alluvium which is clay mixed with sand. The results obtained are in accordance with the geological conditions at the data collection points which are lake deposits with constituent rocks in the form of clay, silt, sand and gravel.

The wave velocity is directly proportional to the dynamic parameters of the ground. The lower the wave velocity, the lower the dynamics parameters of the soil. While the lower the soil dynamics parameters, the higher the level of vulnerability to damage when an earthquake occurs. This area is very vulnerable to damage, with low soil dynamics parameters, namely shear modulus ranging from 54.82 - 102.05 N / m² and modulus of elasticity ranges from 163.78 - 303.94 N / m². The lowest soil dynamics parameters are in the field (Track-3) and in the SDN Sedoa area (Track-1). The buildings around the field that were badly damaged were the church. At present the church has been torn down and rebuilt. Sedoa Elementary School building was also badly damaged, the building was destroyed and could not be used anymore. But now the school building has been rebuilt and can be used, but the debris of the old building still exists and has not been completely demolished. The area with the highest soil dynamics parameters is around the BPD office (Track-2). The BPD office building was also damaged, but the damage did not bring the building down. Areas that have high soil dynamics parameters are also found around community gardens, namely on Lintsan-4 and Track-5, but this area has no buildings so that no significant damage is seen in the area.

Areas with low wave speeds are very easily deformed during an earthquake. Earthquakes trigger dynamic forces, especially shear forces that can deform rock, thereby reducing soil stiffness. The greater the value of the shear wave velocity, the greater the value of soil stiffness or harder and denser. Low soil stiffness will cause liquefaction, subsidence of land or buildings in the surrounding area to collapse if an earthquake occurs.
The shear wave velocity is also very influential in determining VS30. The shear wave velocity is low so the value of VS30 produced is also low. Based on VS30 the research location is classified into medium and soft soil types. Medium soil that is on Line-1, Line-2, Line-4, and Line-5 with values ranging from 180.5 to 235.4 m/s. While soft soil is on Line-3 with a value of 167.8 m/s. Similar to the shear modulus and elastic modulus, the area which has a level of vulnerability to earthquake damage is found in Line-3, the type of soft soil.

The measurement results of vs30 at 5 points were used as the basis for correcting Vs30 USGS, so that information was obtained related to the distribution of vs30 in Poso Kota District. Information obtained showed that in Poso sub-cities the soil types consisted of soft, medium and hard soils (Figure 12). The size of the area can be seen in the table below:

| Soil Type   | Area (Ha)     |
|-------------|---------------|
| Medium      | 3892          |
| Soft        | 2688          |
| Hard        | 2534          |

Earthquakes tend to expand in soft soils compared to hard soils. Soft soil will provide a higher vibration response when an earthquake occurs [30]. The lower the value of VS30 the more susceptible to damage experienced in the area. Based on the Figure 12, shows that Poso Kota Subdistrict is dominated by medium land with an area of 3892 Ha, while soft land which is widely spread in the west coast of Poso City has an area of 2688 Ha, for hard land the area is 2534 Ha. In soft soil areas with a high level of amplification of earthquakes, the settlement density is relatively lower than the density of settlements located on medium soils. So that for the sake of geotechnical engineering in the construction of buildings or settlements, moderate and soft soil layers need to be done with geotechnical engineering [31]. Engineering is carried out to harden the rock so that it can be used as a building base by compacting the soil layer [12].

4. Conclusions
Based on the research, information is obtained that the amount of VS30 in the research location is classified into medium and soft soil types, with a medium land area of 3892 Ha, whereas soft land which is widely distributed in the west coast of Poso City has an area of 2688 Ha, for hard lands the
total area is 2534 Ha. In soft soil areas with high amplification of earthquakes, the settlement density is relatively lower than the density of settlements located on medium soils.

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