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# INVESTIGATION OF DOMINANT FREQUENCY AND GROUND AMPLIFICATION BASED ON HVSR MICROTREMOR METHOD IN PANGURURUAN DISTRICT, SAMOSIR

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## ABSTRACT

In this study, microtremor wave measurements were carried out using the HVSR (Horizontal to Vertical Spectral Ratio) method to identify earthquake vulnerability in Pangururuan District, Samosir, North Sumatra. In this study, measurements were made at 4 points scattered around the area so that the data obtained represented data in the area. Measurement of signal recording data was carried out for 50-60 minutes for each measurement point. Based on the results obtained, the dominant frequency value of the soil is in the range of 2.29 - 12.78 with a very high classification at points RGR1, RGR3 and RGR4 with type I soil classification, namely hard rock, and point RGR2 is classified as low with type IV soil classification, namely soft soil. While the amplification value in Pangururan District is still classified as a low amplification category with an amplification value of <3.

***Keywords:*** *Dominant Frequency, Amplification, Microtremor, HVSR*

## PENDAHULUAN

North Sumatra is one of the regions in Indonesia that has a high vulnerability to earthquakes (Hapizah & Sutarman, 2024). Tectonically, earthquakes in North Sumatra are not only caused by the activity of the Sumatra Fault but also by the presence of subduction zones and the Mentawai Fault (Rai et al., 2023). In addition, volcanic activity originating from active volcanoes is a potential trigger for earthquakes (Syafitri & Didik, 2019), especially in areas that have soil characteristics that can magnify earthquake waves (Wibowo & Huda, 2020), such as in Pangururan District, Samosir.

Pangururan sub-district is located on Samosir Island in the centre of Lake Toba, which is a volcanic area formed by supervolcanic eruptions (Sihombing et al., 2024). In addition, Pangururan sub-district is also influenced by the volcanic potential associated with magmatic activity under Lake Toba (N.Nainggolan et al., 2018). These phenomena make Pangururan Subdistrict an investigation of soil properties to understand seismic wave response, particularly regarding soil dominant frequency and soil amplification.

Microtremor method with HVSR technique is a method used in identifying the local soil of characteristics (Fatimah et al., 2022). The HVSR method compares the horizontal and vertical components of the microtremor waves to obtain the dominant frequency ($f_0$) based on the H/V value of the high spectrum of the HVSR curve analysis

(Hidayat et al., 2020). The following is the HVSR equation (Budi Wobowo et al., 2024).

$$HVSR = \frac{(A_{(U-S)}(f))^2 + \left(A_{(B-T)}(f)\right)^2}{(A_{(V)}(f))} \quad (1)$$

The microtremor method is used to analyse the dominant ground frequency and amplification factors that can affect the level of damage to land and buildings due to earthquakes (Edison, 2022). The dominant frequency of the ground is influenced by the physical properties of the ground and the subsurface structure (Haifa Fadhilah et al., 2022), while the ground amplification shows how much seismic waves are amplified by the ground at the surface (Sari et al., 2024).

The dominant frequency of soil is also known as the natural frequency value of soil in a measurement area. The dominant frequency value can indicate the type and characteristics of a soil or rock layer in an area (Haerudin et al., 2020). According to Kanai (Demulawa & Daruwati, 2021), soils can be classified based on the dominant frequency value shown in Table 1.

**Table 1.** Classification of Soils by Frequency Dominant Frequency According to Kanai

| Soil Classification | Dominant Frequency | Soil Description |
|---|---|---|
| Type I | (6,67 – 20) Hz | Tertiary or older rocks. Consists of hard sandy gravel |
| Type II | (4 – 6,67) Hz | Alluvial rocks with a thickness of 5 m. Consists of sandy gravel, sandy hard clay, clay, loam and so on. |
| Type III | 2,5 – 4 (Hz) | Alluvial rocks that are almost the same as type II soils, distinguished only by the presence of unknown formations. |
| Type IV | < 2,5 Hz | Alluvial rocks formed from delta sedimentation, top soil, silt, soft soil, humus, delta deposits or silt deposits etc., which are classified as soft soil, with a depth of 30m. |

The dominant frequency of soil not only describes the natural response of soil to seismic waves, but is also closely related to the phenomenon of soil amplification (Setyo Rahman et al., 2013). Soil amplification occurs when seismic waves reach the soil layer and is amplified due to the matching of the wave frequency to the dominant frequency of the soil (Tanjung et al., 2019). Soil amplification is classified into 4 categories as shown in Table 2.

**Table 2.** Classification of Amplification Values

| Zone | Classification | Amplification Factor |
|---|---|---|
| 1 | Low | A < 3 |
| 2 | Medium | 3 ≤ A < 6 |
| 3 | High | 6 ≤ A < 9 |
| 4 | Very High | > 9 |

Research on the dominant frequency and ground amplification in Pangururan Sub-district, Samosir has never been conducted, even though the area is located in an earthquake-prone zone influenced by the tectonic activity of the Sumatra Fault and volcanic activity around Lake Toba.

Based on the geological map of Pangururan (Figure 1), the Samosir formation (Qps) consists of tupaan sandstone, siltstone, conglomerate and thinly layered diatome soil. The Samosir Formation belongs to the Pleistocene age, which is the characteristic of the material layer that greatly influences the response of the soil to earthquakes so that it can increase the risk of shocks that are felt more strongly and have an impact on building damage around the area (Chesner et al., 2020). Therefore, research on the dominant ground frequency and amplification in Pangururan

Sub-district, Samosir is very important in seismic risk mitigation and safer development planning.

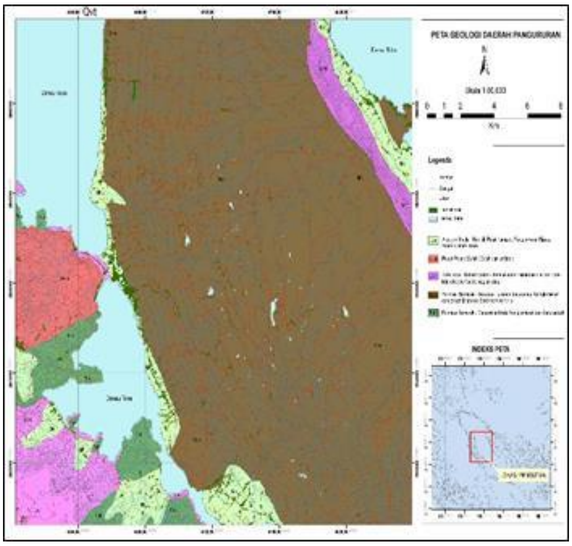


**Figure 1.** Pangururan Geological Map

## RESEARCH METHOD

Microtremor measurements were carried out in Pangururan District, precisely in Samosir Regency. In this study, measurements were made at 4 points scattered around the area so that the data obtained represented data in the area. The design map of microtremor measurement points can be seen in Figure 2.

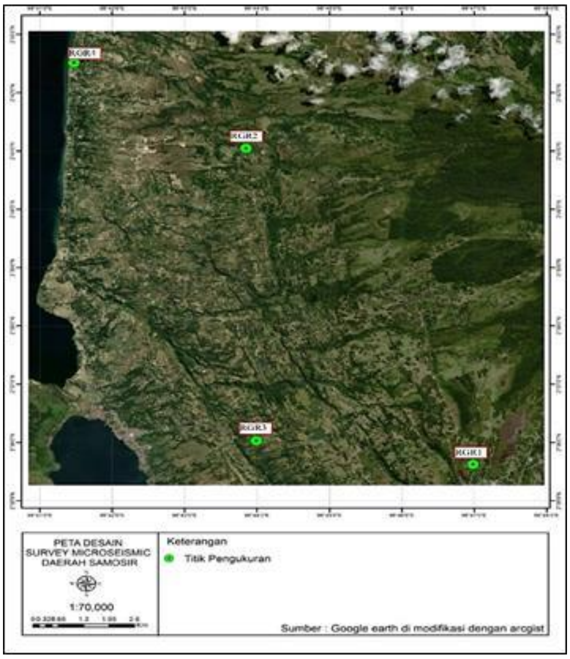


**Figure 2.** Microtremor Measurement Point

The research begins with a literature study, data acquisition, processing, and conclusion. The research flowchart can be seen in Figure 3.

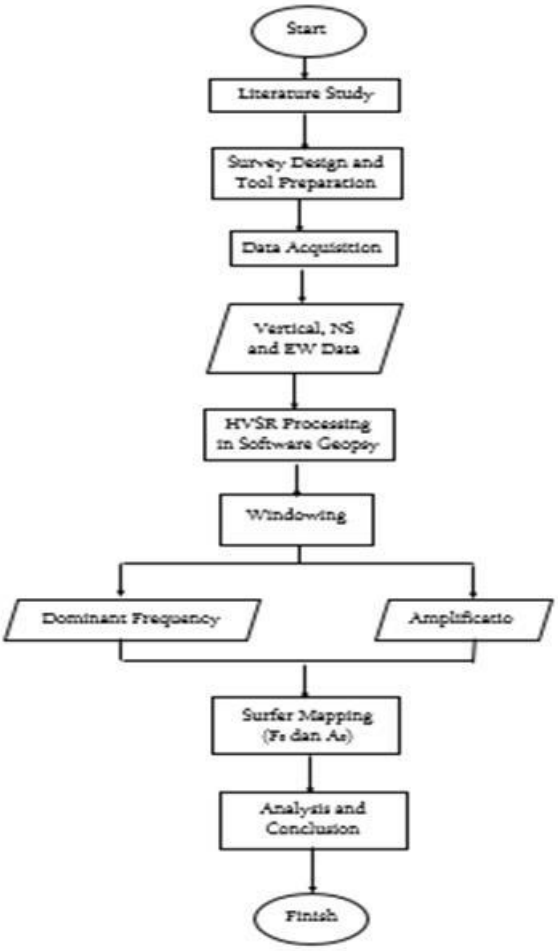


**Figure 3.** Research Flowchart

The data collection process in this study uses 1 set of Pegasus Trilium Compact TC120-PH2 seismograph equipment used to obtain microtremor signal recordings on the ground with 3 components, namely vertical components, North-South horizontal components and West-East horizontal components and laptops to capture signal recordings generated by the tool. The microtremor signal recording results that enter the computer screen must be stable. If the signal is interrupted, then re-recording is done. Measurement of signal recording data was carried out for 50-60 minutes for each measurement point. The signal recording data obtained is then processed using Geopsy software to calculate the dominant frequency value and amplification value through the HVSR analysis process. During the data processing process, the signal recording data must be filtered to eliminate or reduce noise in the resulting signal, then a manual windowing process is carried out to obtain the main and more stable signal.

## RESULT AND DISCUSSION

The results of microtremor analyses conducted with the HVSR (Horizontal to Vertical Spectral Comparison) method are used to generate H/V curves that show the dominant frequency values and amplification factors. The following are the results of the H/V curves for the four measurement points in Pangururan District, Samosir.

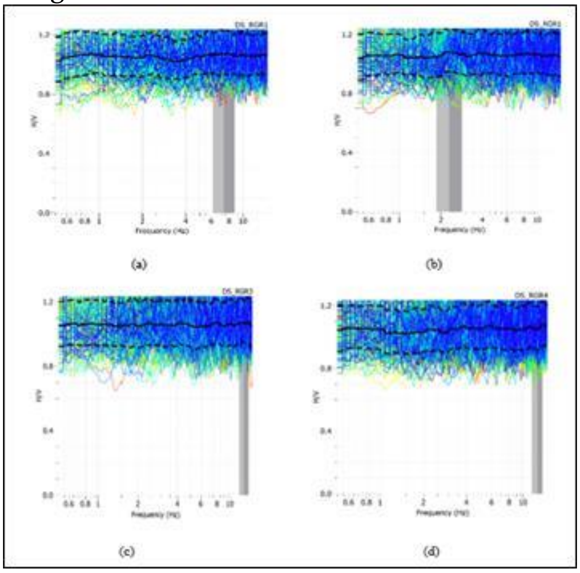

**Figure 4.** H/V Curve at (a) RGR1 (b) RGR2 (c) RGR3 (d) RGR4

### Dominant Frequency of Soil

The dominant frequency of soil in an area is used as a reference in disaster mitigation for building planning due to resonance to minimise damage to buildings. The value of the dominant frequency of the soil describes the geological conditions in the study area (Fauziah et al., 2023). The low dominant frequency value of the soil (<2.5) illustrates that the area is composed of soft rock and thick sedimentary layers because these sediments have a higher water content, making the soil easily vibrate when shaking (Saman et al., 2017). Therefore, areas with low values of dominant ground frequency are prone to earthquakes, while high values of dominant ground frequency indicate that the area is composed of hard rock and thin sedimentary layers (Widyawarman & Fauzi, 2020). Table 3 shows the dominant frequency values of the soil based on Figure 4 on the H/V curve in Pangururan District, Samosir.

**Table 3.** Soil Dominant Frequency Value

| Point | Dominant Frequency (Hz) | Soil Classification |
|---|---|---|
| RGR1 | 7,33 | I |
| RGR2 | 2,29 | IV |
| RGR3 | 12,78 | I |
| RGR4 | 12,55 | I |

The following is a map of the dominant frequency distribution in Pangururan sub-district, Samosir based on the H/V curve in Figure 4 and Table 3.

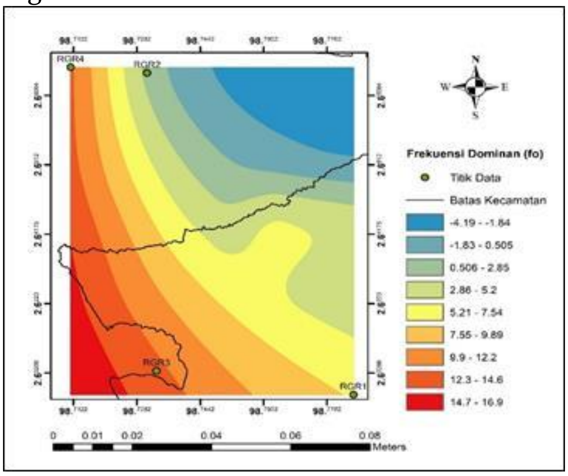


**Figure 5.** Dominant Frequency Distribution Map Soil

Based on Figure 5, the range of dominant frequency values of soil in the study area is between 2.29 Hz to 12.78 Hz. When compared with the soil classification table according to Kanai, Pangururan District, Samosir is included in the classification of type I soil (points RGR1, RGR3 and RGR4) and type IV soil (point RGR2). The soil layer in soil type I has a high dominant frequency value marked with yellow to orange colour at points RGR1, RGR3 and RGR4 classified as hard pebbly sandstone which is able to reduce earthquake vibrations so that it is safer in terms of infrastructure. While the soil layer in soil type

IV has a low value of the dominant frequency of the soil marked with blue to light blue colour at point RGR2 is classified as soft soil that is prone to earthquakes. The soil layer is composed of alluvial rocks derived from the delta sedimentation process, top soil, mud and silt which are very prone to earthquakes. The composition of the soil layer at point RGR2 corresponds to the Pangururan geological map (Figure 1), which is included in the Samosir formation consisting of tupaan sandstone, siltstone, conglomerate and thinly layered diatomaceous earth.

### Soil Amplification

Ground vibration amplification values indicate seismic susceptibility. The greater the value of the amplification factor, the more dangerous the ground vibrations are when earthquake shaking occurs and vice versa. Soil amplification values in Pangururan Sub-district, Samosit can be classified based on Table 4.

**Table 4.** Soil Amplification Factor

| Point | Amplification | Classification |
|---|---|---|
| RGR1 | 1,07 | Low |
| RGR2 | 1,07 | Low |
| RGR3 | 1,07 | Low |
| RGR4 | 1,04 | Low |

The following is a map of the distribution of soil amplification in Pangururan District, Samosir based on the H/V curve in Figure 4 and Table 4.

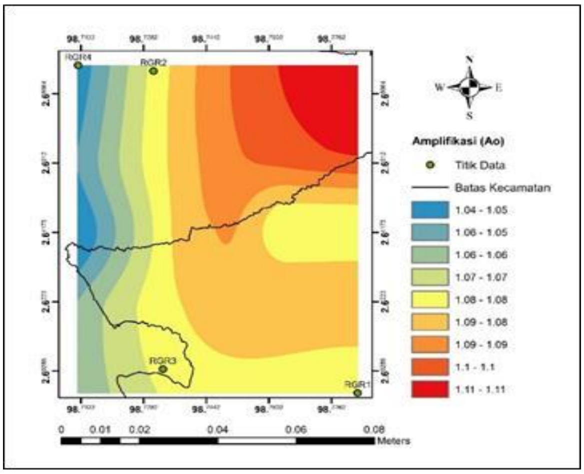


**Figure 6**. Soil Amplification Distribution Map

Based on Figure 6, the range of amplification values in the study area is between 1.04 and 1.07. The amplification values fall within the low amplification zone marked with blue to yellow colours. This shows that in the event of an earthquake, there is no potential for strong shaking and the area is still safe from earthquakes. The amplification factor can increase if the rock is deformed, changing the physical properties of the rock. In the same rock, the amplification factor can vary because it is influenced by the degree of weathering of the rock.

## CONCLUSION AND SUGGESTION

Based on the research that has been done, it can be concluded that point RGR2 has the lowest dominant frequency value compared to points RGR1, RGR3 and RGR4. Low dominant frequency means that the soil is classified as soft soil, which is soil prone to earthquakes. While the soil amplification value for point RGR4 is lower than the soil amplification value at points RGR1, RGR2 and RGR3. meaning that the potential for earthquake shocks is stronger than point RGR4 but the area is still safe from earthquake shocks.

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