



## Liquefaction Potential Analysis Using The Horizontal to Vertical Spectral Ratio (HVSr) Method in The Arang Beach Area of Labuhan Ijuk Village, Moyo Hilir District, Sumbawa Regency

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**Abstract:** The phenomenon of liquefaction has become a serious threat in earthquake-prone areas, especially in the Arang Beach Area, Moyo Hilir District, which is dominated by alluvial sediments and located near an active subduction zone. This study was conducted to identify the potential for liquefaction through seismic parameter analysis using the Horizontal to Vertical Spectral Ratio (HVSr) method. A total of 70 microtremor measurement points were processed using Geopsy and Dinver software to obtain the natural frequency ( $f_0$ ), amplification factor ( $A_0$ ), shear wave velocity ( $V_s$ ), seismic vulnerability index ( $K_g$ ),  $VP/VS$  ratio, and Poisson's ratio ( $\sigma$ ). The study results show  $f_0$  values ranging from 0.274–17.644 Hz, a maximum  $A_0$  of 0.800, low ( $V_s$ ) (< 300 m/s) in the northern coastal area, the highest ( $K_g$ ), of 227.729 in the northern coast, and a  $VP/VS$  ratio > 2.0 in water-saturated sediment layers indicating high vulnerability to liquefaction. Meanwhile, the northern and western parts of the area. However, what needs to be considered is the need to increase disaster mitigation through structural and non-structural efforts in the Arang Beach area.

**Keywords:** HVSr, microtremor, liquefaction,  $VP/VS$ , Arang Beach Area.

### Introduction

Indonesia is located at the confluence of three major tectonic plates: the Eurasian, Indo-Australian, and Pacific plates, which causes high seismic activity. The interaction of these plates forms subduction zones, active faults, and frequently triggers earthquakes. The impact of an earthquake is influenced not only by the source but also by local geological conditions. Thick, soft sedimentary layers can amplify seismic waves due to the contrast in stiffness with the underlying bedrock, increasing the level of surface damage.

West Nusa Tenggara Province is an earthquake-prone region due to its influence from the subduction zone in the south and the Back Arc Thrust system in the north. The 2018 Lombok earthquake demonstrated the

significant influence of soil conditions on the extent of damage. One significant earthquake-derived hazard in coastal areas is liquefaction, the loss of strength and stiffness of water-saturated soil due to seismic vibrations. This phenomenon generally develops in sandy, water-saturated sediments with shallow groundwater levels, which are common in coastal areas.

Microtremor is a minimal and continuous ground vibration that originates from various kinds of pulses such as traffic, wind, human activities, and so on. Microtremor, also known as ambient vibration, comes from two primary sources: nature and humans. At low frequencies below 1 Hz, the microtremor source is natural. Ocean waves give rise to ambient vibration with a frequency of about 0.2 Hz. In comparison, about 0.5 Hz

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is caused by the interaction between the ocean and shore waves. For frequencies below 0.1 Hz, the microtremor is associated with activity in the atmosphere. At high frequencies of more than 1 Hz, human activities such as traffic vehicles, machines, and others are the primary source. Source location is usually at ground level and varies day and night.

Microtremor is a ground vibration with a displacement amplitude of about (0.1 - 1)  $\mu\text{m}$  and a velocity of (0.001 to 0.01) cm/s. Microtremors are classified into two types based on their period range. The first type is a short period microtremor with less than 1 second. It is associated with shallow subsurface structures, several tens of meters thick. The second type is a long-period microtremor with a period of more than 1 second. This condition is related to deeper soil structure, showing the basis of hard rock. The variables obtained from the HVSR method are:

Dominant frequency ( $f_0$ ) is the frequency value that often appears. It is recognized as the rock layers' frequency value to show the rock's type and characteristics.

The dominant period's ( $T_0$ ) value is when it takes microtremor waves to propagate through the surface sediment deposition layer or experience one reflection of the plane of reflection to the surface. This dominant period is an inversion of the dominant frequency.

Amplification factor ( $A_0$ ) is an enlargement of seismic waves that occurs due to significant differences between layers. The soil amplification value is related to the contrast ratio between the surface layer's impedance and the layer below it. If the two layers' impedance contrast ratio is high, the gain factor value is also high, and vice versa. The amplification value is directly proportional to the horizontal and vertical (H/V) spectral ratio. The amplification value can increase if the rock has undergone deformation (weathering, folding, or expansion), which changes the rock's physical properties. The amplification value could vary according to the rock body's deformation in the same rock. Based on these values, it, then, is classified based on high and low values, as shown in **Table 1**.

The seismic vulnerability index (Kg) is an index that describes the level of vulnerability of the surface soil layer to soil deformation during an earthquake. The seismic vulnerability index's value is related to the level of vulnerability of an area, so the risk of earthquakes' risk of damage due to earthquakes is getting more significant. The seismic vulnerability index value obtained has taken into account the local geological conditions (local site effect). In areas with high seismic vulnerability index values, the resonance frequency is very low. This phenomenon indicates that the sedimentary layer covering the bedrock is relatively thick. A thick layer of sediment, if a high amplification

value accompanies it, the layer will produce a sizeable seismic vulnerability index value.

According to, the classification of the seismic vulnerability index is presented in **Table 2**.

**Table 1.** Classification of the amplification factor.

Value of A	Classification
$A < 3$	Low
$3 \leq A < 6$	Moderate
$6 \leq A < 9$	High
$A \geq 9$	Very high

**Table 2.** Classification of the seismic vulnerability index (Kg)

Value of Kg	Classification
$< 3$	Low
$3 \leq Kg < 6$	Moderate
$> 6$	High

Sediment thickness (d) is one of the factors that cause the local site effect during an earthquake. The natural frequency influences the thickness of the sedimentary layer. The natural frequency is inversely proportional to the thickness of the sediment layer. The smaller the natural frequency, the greater the thickness of the sediment layer, and vice versa. The dominant period of seismic waves in an area is directly proportional to the sediment layer's thickness. The thickness of the sediment layer can be estimated using the H/V spectrum ratio. The method is based on the trapping of SH wave vibrations in the sediment medium above the bedrock. The relationship between sediment thickness and dominant frequency can be determined based on the rules for closed the Organa pipes.

This study aims to determine the characteristics of soil dynamics in the Pantai Arang area, Labuhan Ijuk Village, Moyo Hilir District, by determining the values of soil natural frequency ( $f_0$ ), amplification factor ( $A_0$ ), and Poisson's ratio ( $\sigma$ ), as well as mapping the distribution of the soil seismic vulnerability index (Kg).

## Method

This research was conducted from August 2025 to December 2025 at the Disaster Mitigation Master's Studio at the University of Mataram. The data collection location, Labuhan Ijuk Village, Moy Hilir District, Sumbawa Regency, is shown in **Figure 1**.

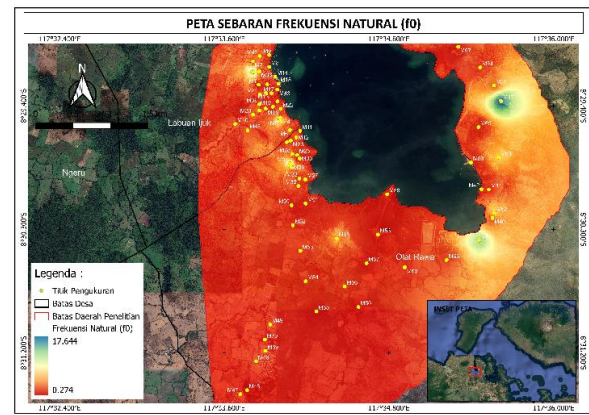
The data processing in this research use Geopsy (3.5.2) and Qgis for plotting the results of data processing. The procedure of the research is shown in **Figure 2**.

## Results and Discussion

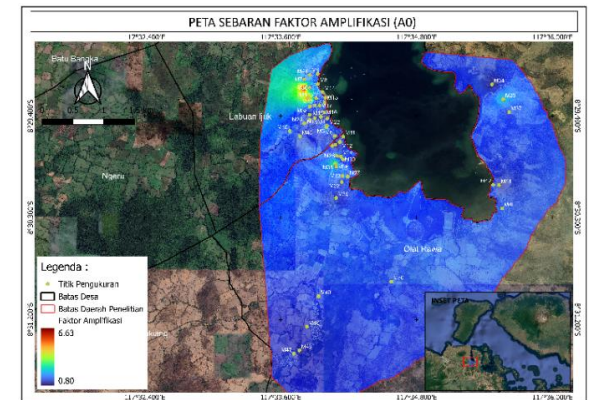
Microtremor measurements in the field are transient data of time-domain seismic signals in seismic records (seismograms). With the analysis using the

Horizontal to Vertical Spectral Ratio (HVSr) method, data is obtained in the form of dominant frequency and amplification factor extracted from the H/V curve. In addition to these two parameters, the HVSr process can also analyze the subsurface characteristics that cause the local site effect during an earthquake and the site class based on the dominant period ( $T_0$ ) and ( $V_s$ ) in the study area.

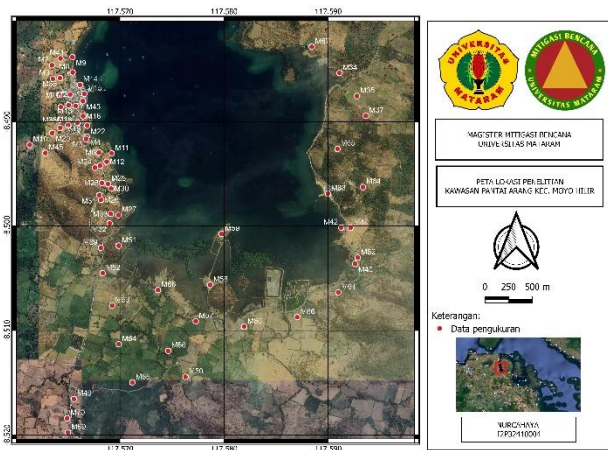
The HVSr analysis results show the dominant frequency ( $f_0$ ) distribution at 70 measurement points shown in **Figure 3**. The range of values for the dominant frequency is 0,274 – 17,644 Hz. The amplification factor ( $A_0$ ) has been superimposed on the map shown in **Figure 4**.



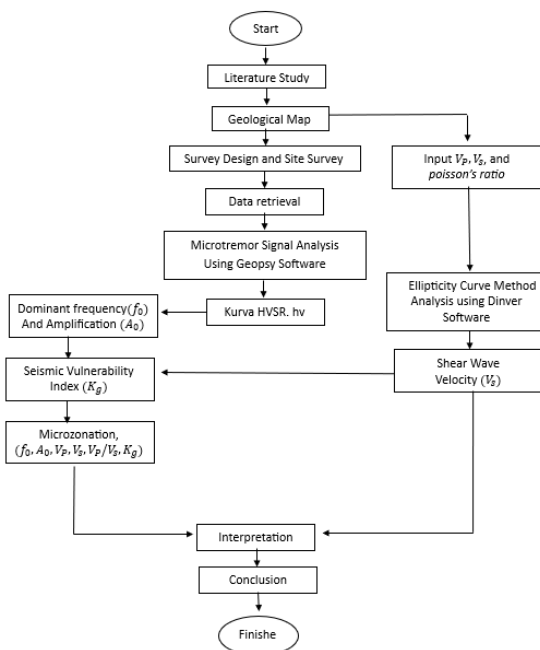
**Figure 3.** Map of Dominant Frequency Values



**Figure 4.** Map of Amplification Factor Value



**Figure 1.** Map of the research location of the Arang Coast area



**Figure 2.** The research procedure

The distribution of amplification values ( $A_0$ ) in the Arang Beach area, which includes Labuhan Ijuk Village and Olat Rawa Village in Moyo Hilir District, shows clear spatial variations due to differences in surface geological characteristics, sediment thickness, and pore water saturation levels. The distribution map of the amplification factor ( $A_0$ ) in the Arang Beach area shows quite significant spatial variations, with amplification values ranging from 0.800 - 15.906 Hz.

The seismic vulnerability index ( $K_g$ ) value is influenced by the amplification factor and the research location frequency. The results of the seismic vulnerability index ( $K_g$ ) are shown in Figure 5. This map shows that the seismic vulnerability index value ranges from (0,188 – 227,729)  $\mu s^2/cm$ . The region with a low seismic vulnerability index value concentrated in the highlands or hilly areas. The hilly area has a solidified rock structure condition, which indicates it has a high-density value. It does not suffer significant damage caused by the earthquake. The region with medium to high seismic vulnerability index value is distributed along the coast, composed of alluvium deposits. It has a structure soft soil structure or has a low-density value. The seismic vulnerability index's high value makes the area vulnerable and can severely damage an earthquake.

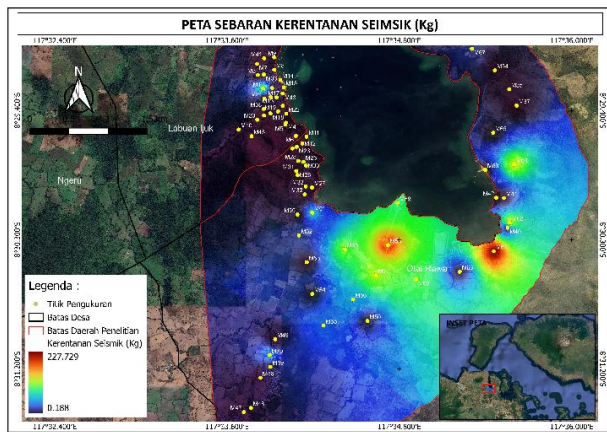


Figure 5. Map of Seismic Vulnerability Index Value

## Conclusion

Based on the distribution map, the ( $f_0$ ) value is relatively uniform and ranges from 0.274-17.644 Hz, with high ( $f_0$ ) values in the East and North. While low ( $f_0$ ) values are in the central to southern parts of the research area. The amplification ( $A_0$ ) value ranges from 0.800 Hz-15.906 Hz with the highest ( $A_0$ ) value dominant in the central to southeastern part of the research area. While the low ( $A_0$ ) value is in the Olat Rawa Village area which is located in the northern part. Based on the distribution map of ( $K_g$ ) values in the research area, it ranges from 0.188 to 227.729. The Arang Beach area in Moyo Hilir District at the research location has a high ( $K_g$ ) index of 227.729. When correlated with factors ( $A_0$ ) and ( $f_0$ ), it has the potential to experience liquefaction.

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## Author Contributions

The first author collected and analyzed microtremor data using the HVSR method and drafted the initial manuscript. The second and third authors contributed to the design of the methodology, validation and interpretation of the results, and review and refinement of the manuscript.

## Conflicts of Interest

The authors declare no conflict of interest.

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