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Investigation of Sediment Layer Thickness Estimation at Bengkulu University Hospital Based on Microtremor Data

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Abstract

Bengkulu is the capital of Bengkulu Province and is in the subduction zone between the Eurasian and Indo-Australian plates. Bengkulu is also close to the major faults of Sumatra, namely the Musi fault, the Ketahun fault, and the Manna fault. Therefore, regional planning and infrastructure development for earthquake mitigation is necessary. The purpose of this study is to estimate the thickness of the sedimentary layers in the construction zone of Bengkulu University Hospital during the earthquake attenuation phase. This study is conducted by surface geological analysis using the HVSR method; data analysis using microtremor data. The microtremor data were analyzed using the HVSR method to obtain the amplification value (A_0) and the dominant frequency (f_0). HVSR analysis gave dominant frequency (f_0) values from 5.1 to 5.8 Hz, amplification (A_0) from 1.64 to 5.91 times, and dominant period (T_0) from 1.49 to 2.81 seconds. The values of A_0, f_0, T_0 are interpreted with reference to the literature and surface geology as a moderate risk of seismic vulnerability, characterized by moderate to weak sedimentation and moderate amplification values.

Keywords: A_0; f_0; microtremor; sedimentary rocks; T_0.

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Introduction

Bengkulu is the capital of Bengkulu Province and is located at the subduction zone between the Indo-Australian and Eurasian plates. Bengkulu is close to the Great Sumatra Fault, which are the Ketahun section, the Manna section and also the Musi section (Irsyam et al., 2017).

Bengkulu Province itself is located at the coastal area of Sumatra Island that is directly facing Indian Ocean. Within last 10 years, the climate change effects had resulted several impacts to the environment in several areas around Indian Ocean, including Bengkulu City, the capital city of Bengkulu Province (Mase et al., 2022).

This situation makes Bengkulu subject to frequent earthquake disturbances (Lestari & Susiloningtyas, 2022). Tectonic plates move continuously and can be felt on the surface of the earth in phenomena called seismic tectonic events (Mase, 2017).

The Eurasian plate moves relatively southeastward very slowly, averaging about 0.4 cm, colliding with an oceanic plate, the Indo-Australian plate, at a speed of 7 cm per year in a relatively northern direction (Silitonga et al., 2023).

This of course makes Bengkulu Province very vulnerable to earthquake events. Regional governance and the development of facilities and infrastructure that are oriented towards earthquake disaster mitigation need and must be applied in areas prone to earthquake disasters.

Referring to this condition, the local government should be carefully considering the earthquake aspect for the spatial plan in Bengkulu City. The actions to define the spatial plan should cover safety, convenience, productivity based on hazard mitigation is prioritized. Natural Disaster Agency of Bengkulu Province or BPBD mentioned that the revised spatial plan is also destined to support Bengkulu City as the tourism and educating area and as the trading area in the coastal area of Western Sumatra Island, nationally and regionally (Farid & Mase, 2020).

Bengkulu University is one of the universities located in Bengkulu City. Bengkulu University always strives to provide great benefits to the community, one of which is by building health and education facilities in the form of Bengkulu University Hospital.

The principle of development in this hospital is to apply the principle of sustainable development which is become a public place that can be used for a long time. An environmental carrying capacity or "sustain" is very important in a sustainable development which is a way to keep what we have and must remain.

A step to keep the Bengkulu University Hospital sustainable is to build these public facilities based on the application of earthquake disaster mitigation, considering that the location of the hospital itself is in an area that is vulnerable to earthquake disasters.

The initial stage is to know the character of the sedimentary rock layer found at the construction site of this hospital. Where a layer that has a low frequency value and a high amplification value can cause a response to a larger wave to cause a stronger shock to the building on the surface of the earth (Ryanto et al., 2020).

Information on the frequency values of rock formations is important to reduce the effects of shaking in buildings that have similar frequency values when earthquakes occur (Saputra et al., 2022).

Geophysics is a branch of science that is utilized in order to obtain information about the state of subsurface structures. The subsurface of sedimentary rocks can be identified using the microtremor method (Moustafa et al., 2022).

In this study using the analysis of estimating the thickness of the sedimentary layer structure at the bottom of the top using microtremor data by considering the geological conditions at the construction site of the Bengkulu University Hospital. The purpose of this study is to estimate the thickness of the sedimentary rock layer at the construction site of the Bengkulu University Hospital, as part of the preparedness stage in the event of an earthquake disaster. This study was also carried out to support the robustness of the building.

Materials and Methods

The Horizontal to Vertical Spectral Ratio (HVSR) method is one of the methods that can be used to utilize microtremor data. It can generate the dominant frequency value and amplification of the soil in an area, to compute the seismic vulnerability index and the thickness of the sedimentary layer. The purpose of this study was to determine the level of seismic vulnerability in the study area by making a map of the distribution of the dominant frequency value, amplification factor, seismic vulnerability index, shear wave velocity and sediment layer thickness (Isburhan et al., 2019).

The microtremor data is obtained from the 3 (three) component short-period digital seismometer, which consists of 2 (two) horizontal components (north-south direction and east-west direction) and 1 (one) vertical component. The data is stored in digital waveform with sampling rate 100 Hz, and it must be transformed into frequency domain so the spectral ratio can be analyzed. The process of transforming the data from time domain into frequency domain is called Fast Fourier Transform (FFT) (Amirudin et al., 2023).

The HVSR value is the peak of the spectrum at the dominant frequency at one measurement point. HVSR also calculate the amplification as the micro zonation parameter. The amplification factor is mostly influenced by the wave velocity and rock density, if the wave velocity is getting lower, the amplification will be larger (Asnawi et al., 2020).

The sites' resonance frequency and peak amplitude can be obtained without any high energy sources, both naturally occurring (earthquake activities) and manmade ones (Imposa et al., 2018).

This research was conducted at the construction site of the Bengkulu University Hospital, using the microtremor method with a total of 15 measurement points, with a space between measurement points of 15 meters. The research survey design map can be seen in Figure 1.

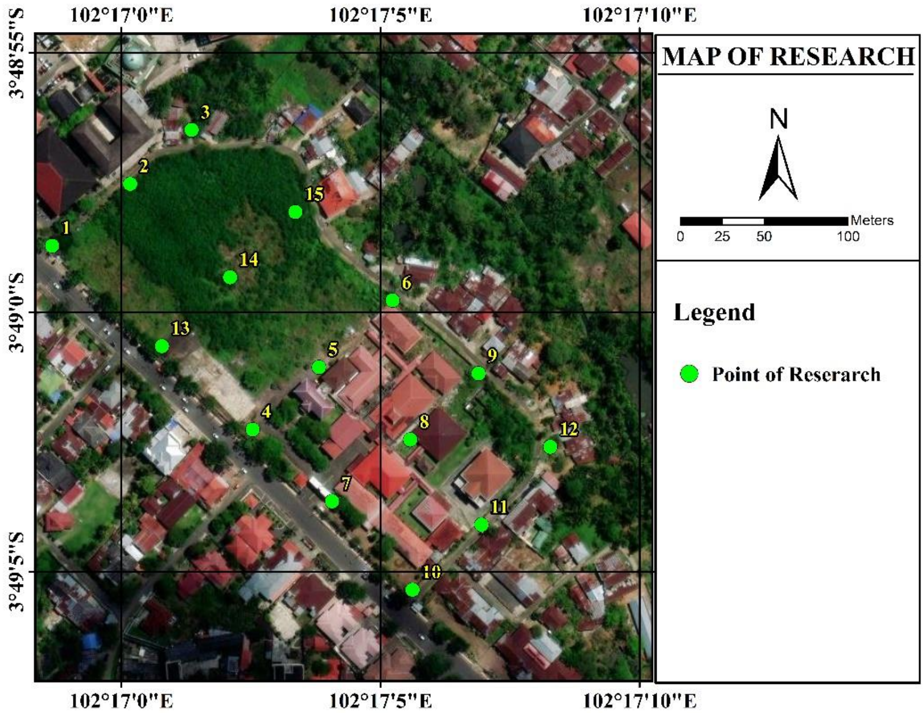

Figure 1. Map of Research Location

Initial data obtained from microtremor measurement results in .csv format After that it was converted to saf. After being replaced, continued with processing using the Geophysical Signal Database for Noise Array Processing (GEOPSY) version 3.4.2 application with HVSR analysis.

The research procedure is broken down into stages, which are field data acquisition sessions, data processing and data interpretation and analysis. The data collection method uses the single station microtremor method. Measurements in the field used the 3D Geophone / Surface Gemini 2 tool, with a measurement time of

30 minutes with a sampling rate 200 Hz (PASI, 2013).

The length of time of this measurement aims to obtain the maximum frequency value distribution. The measurement results are recorded in the form of a signal in .csv format on the device.

Interpretation is done by analyzing data from the results of processing with the HVSR method, which are data analysis of the dominant period (T_0), dominant frequency (f_0) and amplification (A_0) (Ghuge, 2023). The interpretation uses literature data, geological data, so that more accurate interpretation results can be obtained (Mase et al., 2021).

Results and Discussion

The results of this research data processing produce 2 types of curves. This type of clear peak curve dominates over the multi-peak curve where only one point out of 15 measurement points is a multi-peak curve (Dal Moro & Panza, 2022). The clear peak curve is an ideal curve for processing microtremor data because the reliability of clear peak curve data has been verified according to the European SESAME Project. In this case, the characteristic frequency obtained from the peak curve analysis can be considered as the natural frequency of the site. Data analysis using the HVSR method refers to the research results of SESAME for reliable data (Mohamed et al., 2021).

This type of clear peak curve dominates over the multiple peak curves where only one point out of 15 measurement points is a multiple peak curve. The clear peak curve is an ideal curve for processing microtremor data because the reliability of clear peak curve data has been verified according to the European SESAME Project. In this case, the characteristic frequency obtained from the peak curve analysis can be regarded as the natural frequency of a site.

Research that has been conducted with the same concept has been conducted by Hesti et al. (2021) that the results obtained in the UNILA Hospital area, the research area is a vulnerable area when an earthquake occurs characterized by thick and soft sedimentary layers and medium amplification values.

Distribution map of dominant frequency value analysis (f_0)

Based on data processing with the HVSR method, the distribution map of dominant frequency values is obtained as shown in Figure 3, which is interpreted that the area of Bengkulu University Hospital has a dominant frequency value ranging from 5.1 - 5.8 Hz. The dominant frequency value of an area indicates the level of sediment thickness and rock type as described in Table 1. The distribution of dominant frequency values in the research area ($5.1 < f0 < 6$ Hz) according to Haryanto et al. (2020) and Ridwan et al. (2021) is an area with type II classification with an indication that the thickness of surface sediments is in the middle category of 10 meters and is included in tertiary rocks. Medium sedimentary rock layers have a moderate risk of earthquake shaking.

Distribution map of dominant period value analysis (T_0)

Based on the dominant period value distribution map in Figure 4, it can be interpreted that the Bengkulu University Hospital area has a dominant period value between 1.49 - 2.81 s. The grouping of soil types refers to the value of the dominant period according to Omote-Nakajima (Haryanto et al., 2020) divided into 4 types, which are type I with a frequency value between 0.05-0.10 s which indicates the character of hard sedimentary rock types, type II with a period value of 0.10-0.25 s indicates the character of medium sedimentary rocks, type III with a period value of 0.25-0.4 s indicates the character of soft sedimentary rock types, and type IV with a period value of more than 0.4 s indicates the character of very soft sedimentary rock types. The distribution of the dominant period value in the Bengkulu University Hospital area is T_0>0.4 s. The area is an area with type III classification according to Omote-Nakajima (Haryanto et al., 2020) with an indication of the character of very soft sedimentary rock types in the form of alluvial rocks, which are formed from delta sedimentation, top soil, mud. Based on data from the geological map, the research area is an alluvial deposit consisting of sand, clay, and gravel. Areas with soft sedimentary layers on the earth's surface are vulnerable to earthquake shocks.

Distribution map of amplification value analysis (A_0)

Based on the amplification value distribution map in Figure 5, it can be interpreted that the Bengkulu University Hospital Development area has an amplification value ranging from 1.64-5.91 times. The soil amplification zone according to Meng et al. (2023) can be divided into 4 risk descriptions, which are low risk category with amplification value ($0<A_0<3$ times), medium risk category with amplification value ($3<A_0<6$ times), high risk category with amplification value ($6<A_0<9$ times), and very high-risk category with amplification value ($A_0>9$ times).

Based on the results of the amplification calculation value in the Bengkulu University Hospital Development Area ranges from 1.64-5.91 into the medium category, so it can be said that the Bengkulu University Hospital Development Area is included in an area with a medium risk category against earthquake shocks

Table 1. Soil classification based on natural microseismic frequency value by Kanai ((Ridwan et al., 2021).

Classification soil Type	Classification soil Class	Natural Frequency	Kanai Classification	Description
IV	I	6.67 – 20	Tertiary rocks or older. Consists of Hard rock sandy, gravel, and others.	Thickness sediment surface very thin, dominated by rock hard rocks.
III	II	4.0 – 10	Tertiary rocks or older. Consists of Hard rock sandy, gravel, and others.	Thickness sediment surface in category medium 5-10 m.
II	III	2.5 – 4	Alluvial rocks with thickness of more than 5m thick. Composed of sandy gravel, sandy hard clay, loam, and others.	Thickness sediment surface in category thick, about 10-30 m
I	IV	< 2.5	Alluvial rocks which formed from the sedimentation of delta, top soil, mud, and others. Depth ≥ 30m	Thickness sediment surface very thick
I	IV	< 2.5	Alluvial rocks which formed from the sedimentation of delta, top soil, mud, and others. Depth ≥ 30m	Thickness sediment surface very thick

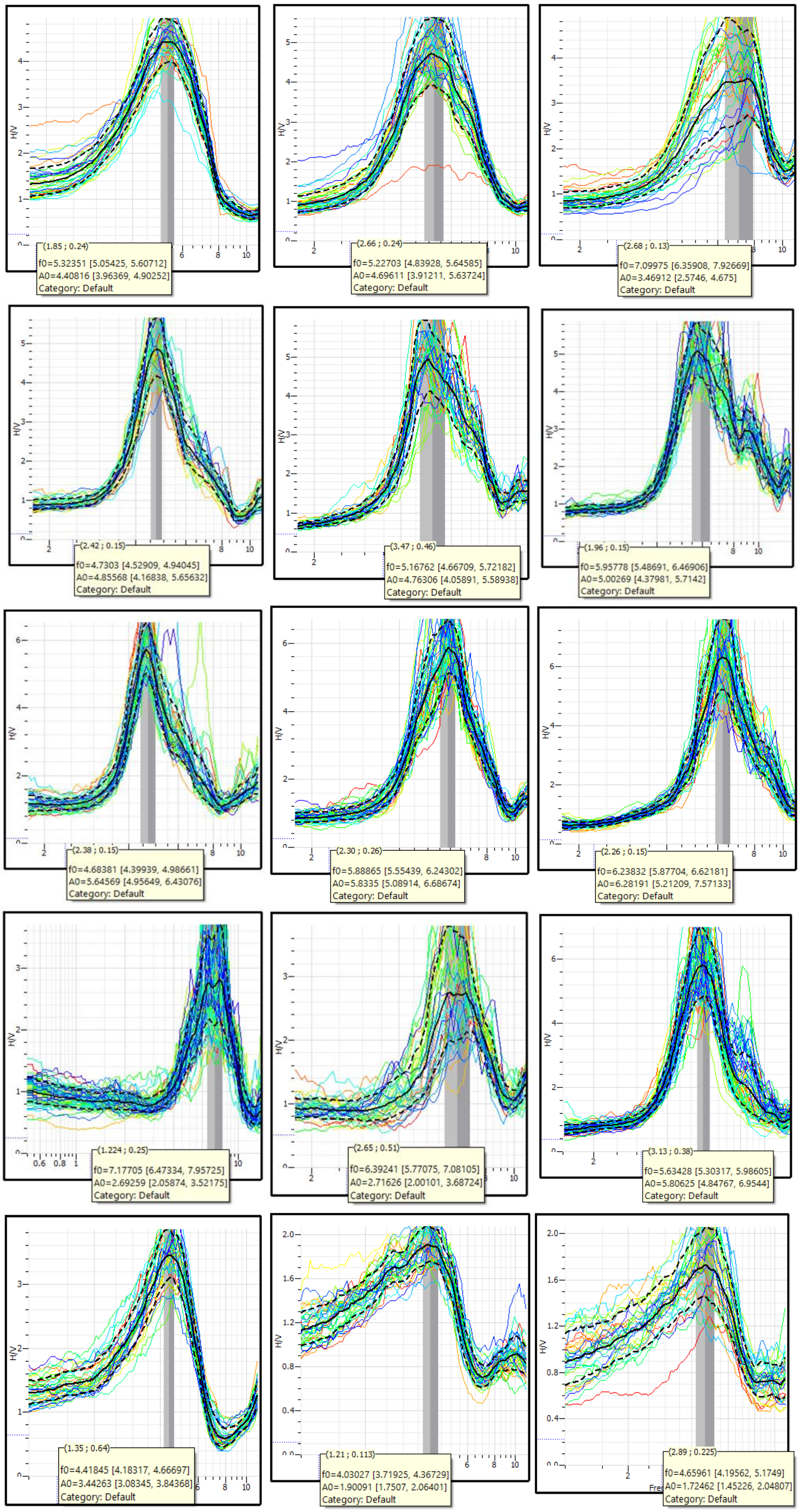

Figure 2. The curve of microtremor data processing results of HVSR method in 15 measurement points.

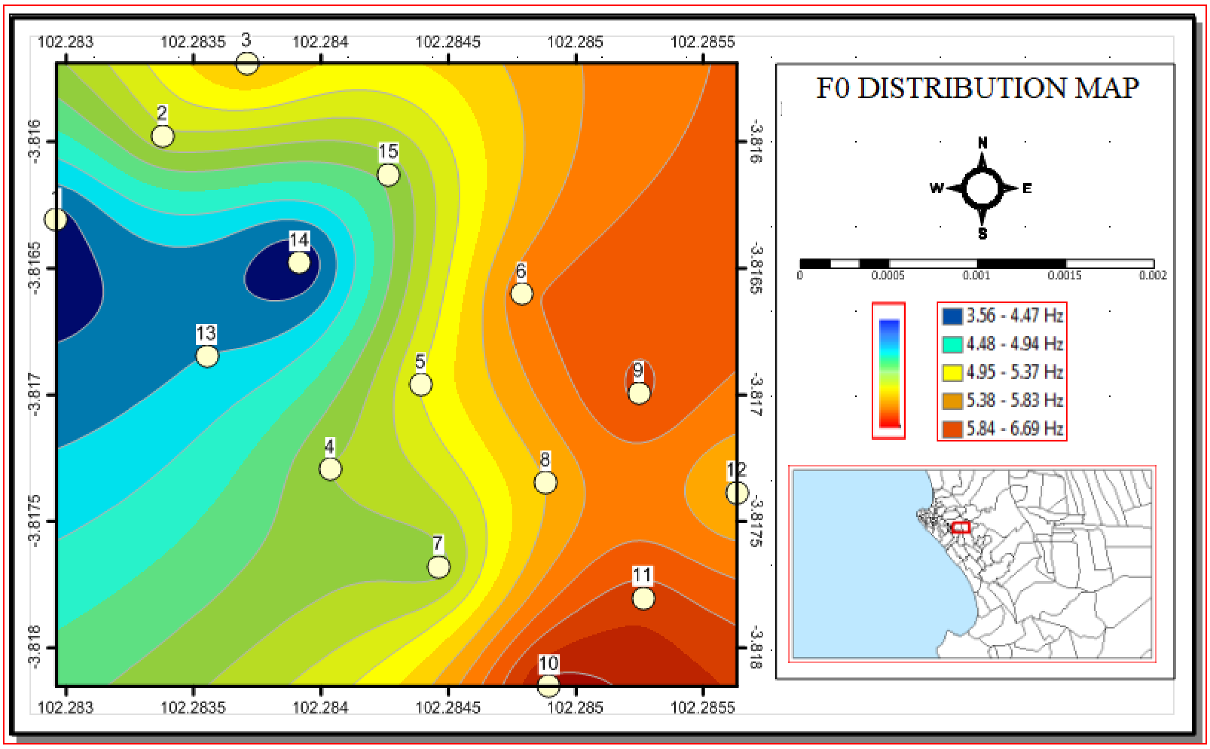

Figure 3. Distribution map of dominant frequency (f0).

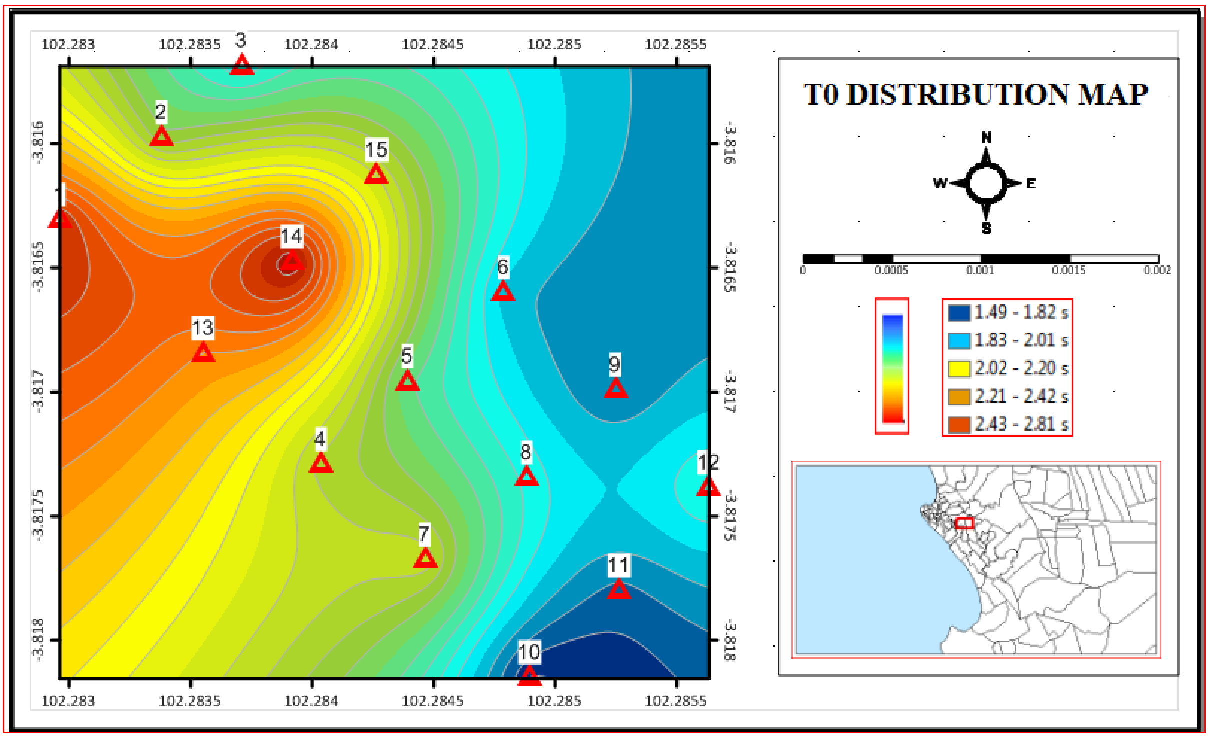

Figure 4. Distribution map of the dominant period (T0).

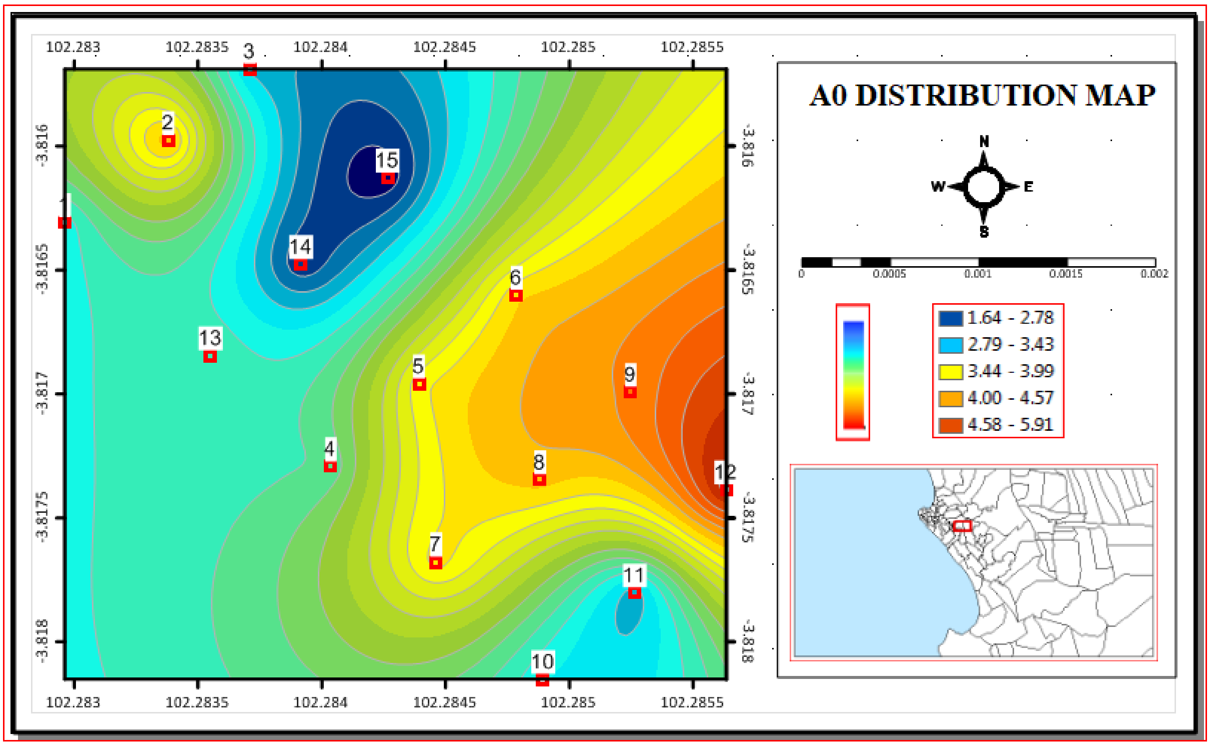

Figure 5. Amplification distribution map (A0).

Conclusion

First, the natural frequency value in the Bengkulu University Hospital area ranges from 5.1 - 5.8 Hz. This shows that the Bengkulu University Hospital area is in the class II type III soil classification, which is composed of alluvial rocks formed from sedimentation with a thickness of about 10 meters. The second one, the research area includes areas that have a moderate risk of vulnerability when an earthquake occurs, characterized by medium and soft sedimentary layers and medium amplification values.

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Author Contribution

The preparation of this research journal, each author is divided into several job desks for collecting literature sources and preparing journals by Hana Raihana. Making research survey design, data processing by Andre Rahmat. Observers and supervisors in writing this journal are M. Farid and Arif Ismul Hadi.

Conflict of Interest

The authors declare no conflict of interest.

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