http://journal.uir.ac.id/index.php/JGEET

E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol xx No xx 20xx

RESEARCH ARTICLE

Use of the Diffuse Field Assumption (DFA) Method to Determine The Condition of The Subsurface Layer in The Government Office Area of Bengkulu City, Indonesia

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Abstract

Bengkulu City lies in an earthquake-prone region because of tectonic activity along the Sumatra subduction zone. Subsurface characterization is critical for safe infrastructure planning. This study identifies subsurface conditions in the Bengkulu City Government office area using microtremor data analyzed with the Diffuse Field Assumption (DFA) approach. Researchers recorded 52 measurement points to determine key seismic parameters: dominant frequency (f_0), amplification factor (A_0), seismic vulnerability index (K_g), and shear wave velocity (V_s30). The results show that f_0 values range from 3.57 to 14.8 Hz, A_0 from 1.62 to 7.18, K_g from 0.30 to 6.35, and V_s30 from 189.29 to 740.48 m/s, indicating significant spatial variation in subsurface conditions. Areas characterized by low f_0, high A_0, and low V_s30, particularly at points T33 and T41, are identified as zones with higher seismic vulnerability. The application of the DFA approach enables a more reliable estimation of subsurface shear wave velocity and enhances the interpretation of site effects compared to conventional analysis. These findings highlight the importance of integrated seismic parameter mapping to support earthquake hazard mitigation and urban spatial planning in tectonically active regions.

Keywords: Bengkulu City, Diffuse Field Assumption, Microtremor, Seismic Vulnerability, V_s30.

1. Introduction

The Sumatra region has a significant potential for earthquake hazards, according to the earthquake hazard map (Khalqillah et al., 2025). Bengkulu is situated in the subduction zone of the Indo-Australian and Eurasian tectonic plates, rendering it particularly susceptible to seismic events (Natawidjaja and Triyoso, 2007). As a result of these tectonic plate movements, approximately 95% of earthquake sources are located in this region. Earthquakes can cause significant damage to infrastructure and pose serious risks to human life (BMKG, 2010).

The subduction process, characterized by the movement of tectonic plates near plate boundaries, was exemplified by the earthquakes that affected Bengkulu in 2000 and 2007 (BMG, 2007). One method for assessing rock hardness in areas prone to seismic disasters has been proposed by (Farid and Mase, 2020). This analysis is important for reducing the impact of seismic disasters on infrastructure and minimizing potential damage.

Earthquake damage in Bengkulu varies significantly across different locations, indicating that local site conditions play an important role. This variability suggests that factors beyond the magnitude of the earthquake and its distance, such as local geological conditions and building design, significantly influence the strength of earthquakes and the damage they cause (Sugianto et al., 2016). These variations are mainly influenced by differences in subsurface lithology and sediment thickness.

An earthquake's intensity is determined by how severe the damage is in the impacted area. The MMI (Modified Mercalli Intensity) scale is used to assess the degree of seismic intensity danger. This scale was developed in 1902 by Italian volcanologist Giuseppe Mercalli. When there isn't a seismometer nearby to gauge the magnitude of an earthquake, this scale is employed (Yahya et al., 2024).

Siregar (2023) previously studied the thickness of sediment layers in Selebar District, Bengkulu City, using microtremor measurement data and the Horizontal to Vertical Spectral Ratio (HVSR) Inversion Method. According to the findings, Selebar District's sediment layer thickness varies from 3.4 to 81.5 meters, with a relative sediment thickness value of 68.5 meters. Pekan Sabtu Village has a thin sediment layer thickness of 3.47–16.4 meters, and several locations, such as Sukarami Village and Pekan Sabtu Village, have a thickness of 81.5 meters. However, in this study, microtremor data were collected from 60 stations with a distance of 500 meters between points.

The HVSR method is widely used to evaluate site effects through parameters such as f_0, A_0, and V_s (Apriana et al., 2025), but it does not directly provide detailed information on subsurface shear wave velocity profiles. Therefore, this study used the Diffuse Field Assumption-based microtremor approach to determine parameters like dominant frequency (f_0), amplification factor (A_0), seismic vulnerability index (K_g), and average shear wave velocity to a depth of 30 m (V_s30). The DFA approach is widely used in seismic studies and earthquake hazard mitigation in urban areas, as it allows for non-destructive and efficient assessment of subsurface conditions. Furthermore, these parameters were analyzed spatially to describe subsurface conditions in relation to urban spatial planning and earthquake shaking (Kawase et al., 2018).

Every year, building construction continues to increase. To the northeast of the Masjid Merah Putih, there is the Bengkulu City Hall building, which is the center of government and public services for the city of Bengkulu, making soil stability in this area very important for the safety and sustainability of government activities. This study aims to identify subsurface conditions in the government office area of Pekan Sabtu Village, Selebar District, Bengkulu City based on f_0, A_0, K_g, and V_s30 parameters using the Diffuse Field Assumption (DFA) approach.

The results of this study are expected to support the evaluation of land suitability for seismic response and contribute to earthquake risk mitigation, spatial planning, and the development of more resilient building structures in accordance with disaster-based regional planning standards (Badan Standardisasi Nasional, 2019). One way to estimate the risk of earthquake damage to a building is to determine the subsurface layers. This is computed using microtremor readings to ascertain the local soil's inherent frequency (Mozalia, 2024).

This study presents a comprehensive application of the Diffuse Field Assumption (DFA) method for seismic microzonation in the Bengkulu City Government office area. Unlike previous studies that primarily focused on HVSR analysis or limited seismic parameters, this research integrates multiple seismic parameters, including dominant frequency (f_0), amplification factor (A_0), seismic vulnerability index (K_g), and V_s30, to provide a more detailed characterization of subsurface conditions. The novelty of this study lies in integrating DFA-based inversion with spatial microzonation analysis to support earthquake mitigation and urban planning in a tectonically active region.

2. Geological Conditions of the Research Area

From an oceanographic perspective, the coastal morphology and bathymetry of Bengkulu characterized by steep underwater slopes that face directly onto the Indian Ocean require a thorough understanding of geological data, as the Selebar sub-district is located quite close to the coast (Mayasari et al., 2025). The geological conditions of the Selebar Sub-district are dominated by alluvial deposits, swamp sediments, and andesite formations. These lithological variations significantly influence seismic site response. Soft and unconsolidated sediments tend to amplify seismic waves and are associated with lower shear wave velocity (V_s30), indicating higher seismic vulnerability, whereas harder materials such as andesite generally exhibit lower amplification (García-Jerez et al., 2016; Kawase et al., 2018).

In addition, variations in sediment thickness affect the dominant frequency of the ground, where thicker sediments correspond to lower frequencies, while shallow bedrock produces higher frequencies. These relationships highlight the strong connection between geological conditions and seismic response.

3. Methods

The methodology was designed in a systematic workflow, starting from data acquisition, followed by signal processing to obtain H/V spectral ratios, and subsequent inversion using the Diffuse Field Assumption (DFA) approach, ending with spatial analysis of seismic parameters. This study used microtremor techniques to model subsurface sediment layers. Microtremor data were collected at 52 points with coordinates 3°51'0"-3°50'25 south latitude (LS) and 102°21'0"-102°21'40" east longitude (BT). Covering a research area of 1,335 m². The points were placed according to field conditions, with a distance of approximately 76–207 meters between points. The study area is a residential area with fairly dense vegetation. This study was conducted from May 24 to June 2, 2025, in the Pekan Sabtu Village, Selebar District, Bengkulu City. This study collected microtremor data using a PASI Gemini-2 Broadband Seismometer, also known as a triaxial geophone, at the data recording location, as indicated in Figure 1.

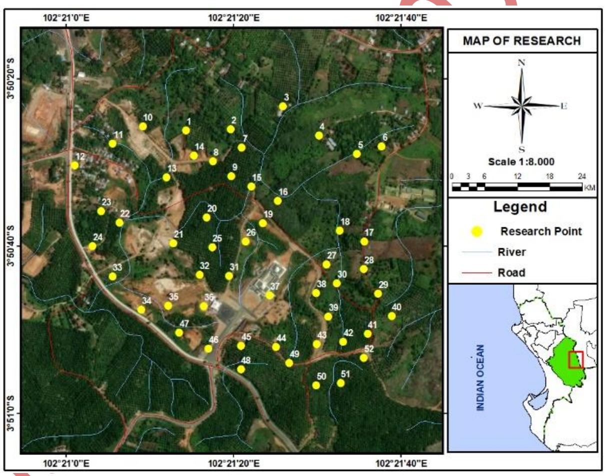

Fig. 1 Research Location Map

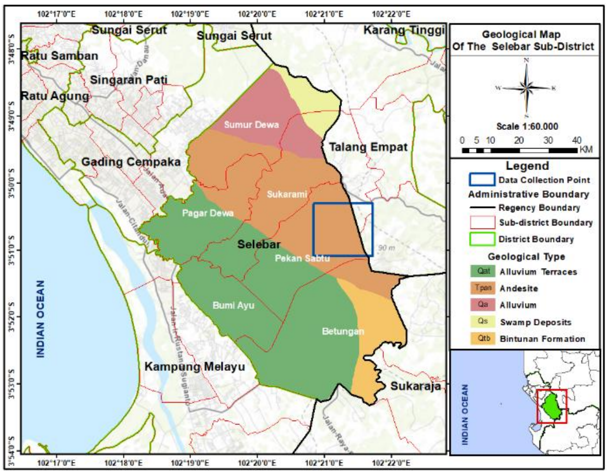

Fig. 2 Geology Map of The Selebar Sub-District, Modification of (Setiawan et al., 2025)

Figure 2 shows that the Swamp Deposits Formation (Qs) and Alluvium Deposits Formation (Qa) dominate the northern part of Selebar, At the same time, the Andesite Formation (Tpan) is located around the middle of the Selebar area. Nearly half of the Selebar region is dominated by the Alluvial Terrace Formation (Qat), while in the central part, the Bintunan Formation (Qtb) is located in the southeast. According to (Hadi, et al., 2021), information about the composition of rock formations is essential for determining the potential damage caused by seismic activity.

Pekan Sabtu Village, classified as Andesite (Tpan), is included in the volcanic stratigraphy. It often appears as andesitic lava, shallow intrusions (dikes or sills), and andesitic breccia or tuff that cover or intersect with the Bintunan Formation and Quaternary deposits. This is shown on the Selebar District geological map in Figure 2 (Setiawan et al., 2025).

The microtremor method is a passive seismic technique that utilizes the recording of natural vibrations on the earth's surface, which can originate from volcanic activity, ocean waves, or human activity. To assess the hardness or softness of the surface soil, microtremor wave analysis is used. The smaller the dominant period of a location, the softer the soil conditions, while a larger dominant period indicates harder soil (Nakamura, 1989).

An HVSR curve was created by processing the microtremor data collected in this study using the *Horizontal-to-Vertical Spectral Ratio* (HVSR) approach. The primary parameters that describe subsurface conditions, such as resonance frequency and amplification factor, were then identified by analyzing the curve (Prabowo et al., 2021).

In this study, the HVSR technique is used to obtain the H/V spectral ratio curves from microtremor data. These curves are then further processed using the Diffuse Field Assumption (DFA) approach to perform inversion and estimate subsurface shear wave velocity profiles.

The DFA approach is used in this study because it provides a more reliable estimate of subsurface shear-wave velocity than conventional HVSR analysis, which is generally limited to interpreting surface parameters. DFA enables inversion of H/V spectral ratios, enabling more detailed characterization of subsurface structures (García-Jerez et al., 2016).

Rayleigh waves are the main component in vibration recordings, as demonstrated by the horizontal-to-vertical component's spectral ratio, which is close to one. According to this condition, in the 0.2–20 Hz frequency range, the microtremor response to Rayleigh waves is relatively equivalent in both component directions (Anggi et al., 2025).

The data acquisition process begins by setting up the PASI Gemini-2 Broadband Seismometer sensor and connecting it to a laptop using a connecting cable. The sensor is oriented towards the north using a compass to ensure the horizontal channel direction is correct. After that, the three legs of the sensor are installed and then placed on the ground in a stable position until the spirit level on the sensor is exactly in the center of the circle. Acquisition settings are made on the PASI Gemini software on the laptop with a three-component recording configuration, Up-Down, North-South, East-West, a frequency of 5 ms (200 Hz), and a 16-minute recording period at each location. During the measurement process, environmental conditions must be observed so that the data is not disturbed by surrounding activities, such as vehicle traffic or vibrations from buildings.

The H/V curve display will yield the dominant soil frequency (f_0) and soil amplification factor (A_0) data for each test. Furthermore, more parameter values are required to enhance the microtremor research findings. The peak spectrum value is squared and divided by the dominant frequency to determine the seismic vulnerability value (K_g). The seismic vulnerability index (K_g) is calculated using the following equation:

$$K_g = \frac{A0^2}{f_0} \quad (1)$$

Where A_0 is the amplification factor and f_0 is the dominant frequency (Nakamura, 1997).

To calculate the total area of the research area by summing the areas of each polygon resulting from spatial classification. A particular class of microtremor parameters, such as dominant frequency (f_0), amplification factor (A_0), seismic vulnerability index (K_g), and shear wave velocity to a depth of 30 m (V_s30), is represented by each polygon, which is grouped into low-high categories and soil site classes. This can be seen in the following equation:

$$A = \sum_{i=1}^{n} a_i \quad (2)$$

From the above formula, a_i is used to calculate the study area's total area by adding the areas of all the polygons that are produced by spatial categorization. In this formula, A is the total area, while a_i is the area of the to-i polygon. The index i indicates the order of the polygons being summed, with i=1 representing the first polygon and i=n representing the last polygon. The value n represents the total number of polygons that make up the study area, so that the sum of all a_i results in the total area used in further spatial analysis (Burrough and Mcdonnell, 1998).

To calculate microtremor data inversion using the Diffuse Field Assumption approach, which separates the vertical and horizontal components of the spectrum. The subsurface shear wave velocity profile is then estimated using DFA by inverting the H/V curve data at each frequency (Nakamura, 1989). The inversion process uses DFA theory, which assumes homogeneous and heterogeneous seismic wave distribution (Sanchez-Sesma et al., 2011). This process makes it possible to obtain data models suitable for estimating subsurface shear wave velocity profiles (García-Jerez et al., 2016).

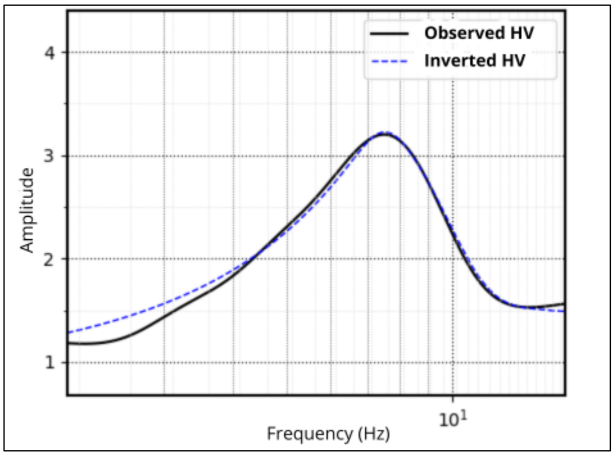

Fig. 3 Diffuse Field Assumption Curve Model

V_s30 is the shear wave velocity value at a depth of thirty meters. Subsurface lithology can be described in this way. To obtain V_s30 data, you can use topographic modeling methods such as those provided by the USGS or employ passive seismic measurements like microtremor or active seismic measurements like MASW. The average shear wave velocity (V_s30) is calculated using the following equation:

$$Vs_{30} = \frac{30}{\sum_{i=1}^{n} \frac{hi}{Vsi}} \quad (3)$$

Where hi is the thickness of the i-th layer, V_{si} is the shear wave velocity of the i-th layer, and n is the number of layers (Badan Standardisasi Nasional, 2019; Wibowo and Huda, 2020).

To generate an inversion curve model, data processing, such as windowing to separate microtremor data and transient data, is followed by frequency sampling to identify the curve peaks. Next, inversion is performed to generate a curve model and shear wave velocity model (Anggi et al., 2025), as shown in Figure 3.

4. Result and Discussion

The outcomes of analyzing microtremor data at 52 measurement locations in the Bengkulu City Government office area show a distribution map (f_0, A_0, K_g, V_s30, and Elevation). This study was conducted in Selebar District, Pekan Sabtu Village, which is astronomically located between 3°51'0"-3°50'25 south latitude (LS) and 102°21'0"-102°21'40" east longitude (BT).

Table 1. According to Kanai, soil classification is based on natural microseismic values and microseismic oscillation frequency (Ridwan et al., 2021).

Soil Classification		Natural	Kanai Classification			
Type	Class	Frequency (Hz)		Description	Location	Color
Type IV	Class 1	6.67 - 20	Tertiary or older rocks consisting of sand, gravelly hard rock, and other rocks.	Dominated by hard rock, the sedimentary surface is very thin.	T4, T5, T6, T7, T10, T11, T13, T15, T16, T20, T21, T22, T23, T24, T25, T26, T29, T30, T31, T32, T33, T34, T36, T37, T38, T39, T42, T43, T44, T48, T49, T50, T51, T52	
Type III	Class II	4.0 – 6.67	Tertiary rocks or older rocks composed of sand, gravel, and various types of hard rock.	The sediment surface thickness is moderate. 5-10 meters.	T1, T2, T3, T8, T9, T12, T14, T18, T19, T27, T28, T35, T40, T41, T45, T46, T47,	
Type II	Class III	2.5 - 4	Alluvial rocks thicker than 5 m consist of sand gravel, hard sandy clay, clay, and so on.	The thickness of the sediment surface that falls into the thick sediment category is around 10 to 30 meters.	T17	
Type I	Class IV	Lower than 2.5	Alluvial rocks are formed from the deposition of detritus, topsoil, silt, and other materials at different depths, ≥30 m.	The thickness of the mud surface is very high.		

4.1 Analysis of Dominant Frequency Value (f_0)

The dominant frequency value of the soil is observed during microtremor recording (Siregar and Madlazim, 2017). The basic resonance of the soil layer is the natural frequency (f_0), which depends on shear wave velocity (V_s) and sediment height. Increased sediment depth results in a decreased natural frequency (Mulyana et al., 2026). Figure 4 shows a map of the distribution of dominant frequency values (f_0), indicating significant variation in the dynamic response of the soil in the study area. Based on the f_0 distribution map and soil classification according to Kanai, the study area is dominated by the f_0 class of 6.36-10 Hz, which is classified as relatively hard to medium soil, covering an area of 983 m² or about 73% of the total study area. The f_0 class of 3.57-6.36 Hz, which represents soil with medium to slightly soft characteristics, occupies an area of 138 m² or about 10%. Furthermore, the f_0 10-12 Hz and 12-14.8 Hz classes, with harder soil and relatively thin sediment layers, cover an area of 181 m² (14%) and 34 m² (3%), respectively. The dominance of the medium to high frequency classes indicates that the research area's subsurface conditions are generally composed of fairly compact material, in accordance with Kanai's classification in Table 1. Low f_0 values indicate thicker sediment layers, while high amplification (A_0) reflects stronger ground motion response. These conditions suggest that certain areas are more susceptible to seismic amplification effects.

The results of microtremor analysis at 52 measurement points show quite complex subsurface characteristics. These variations indicate lithological heterogeneity in Pekan Sabtu Village, Selebar District. Subsurface lithology varies in the Bengkulu City Government office area, The variation of f_0 values indicates significant heterogeneity in subsurface lithology, where lower frequencies correspond to thicker sediment layers, while higher frequencies suggest shallow bedrock conditions. This pattern confirms the influence of local geological conditions on seismic response with dominant frequency (f_0) values ranging from 3.57 to 14.8 Hz. The HVSR theory states that sediment thickness and impedance contrast between soil layers and bedrock affect the dominant frequency (Nakamura, 1989).

SESAME (2004), states that changes in sediment thickness and subsurface layer stiffness are directly correlated with variations in resonance frequency. Furthermore, the f_0 distribution pattern in this region is consistent with the geology of Selebar District, which consists of andesite, alluvium, and young quaternary deposits (Setiawan et al., 2025). This reinforces the interpretation that lithological changes are a factor in seismic response variations.

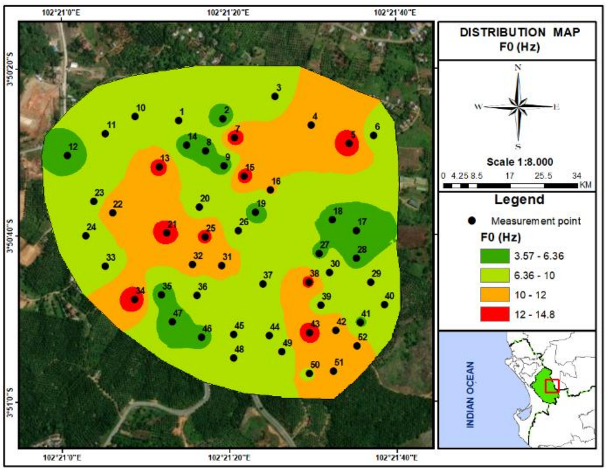

Fig. 4 Distribution Map of Dominant Frequency (f_0)

4.2 Analysis of Amplification Value (A_0)

The term amplification refers to the strength of a wave as it travels through a certain medium (Putra et al., 2023). According to (Setianegara et al., 2023), for amplification values, there are four risk levels: low risk ($A_0 < 3$), moderate risk ($3 < A_0 < 6$), high risk ($6 < A_0 < 9$), and very high risk ($A_0 > 9$), as shown in Table 2. During an earthquake, areas with high amplification factor values can experience wave amplification, which can cause significant damage to building structures (Januarta et al., 2020).

Amplification Value Map (A_0) Figure 5 shows the variation in area and percentage for each value class. Class A_0 1.62-3.00 occupies an area of 305 m² or about 23% of the total study area. Class 3.00-4.40 is the most dominant class with an area of 818 m², equivalent to 61% of the total study area. Furthermore, class A_0 4.40-6.00 covers an area of 192 m² or about 14%, while class 6.00-7.18 has the smallest area, namely 20 m², with a percentage of about 2%. The dominance of the medium amplification class indicates that most of the study area has a dominant seismic wave amplification level.

Table 2. Amplification value classification.

Zone	Category	Values of amplification factors	Location	Color
1	Low	$A_0 < 3$	T1, T2, T8, T9, T10, T15, T17, T18, T19, T26, T27, T28, T29, T30, T40	
2	Medium	$3 \leq A_0 < 6$	T3, T4, T5, T6, T7, T12, T13, T14, T16, T20, T21, T22, T23, T24, T25, T31, T32, T35, T36, T37, T38, T39, T41, T42, T43, T44, T45, T46, T47, T48, T49, T50, T51, T52	
3	High	$6 \leq A_0 < 9$	T11, T33, T34	
4	Very high	$A_0 \geq 9$		

The amplification value (A_0) ranges from 1.62 to 7.18, indicating variations in the seismic wave amplification level in the study area. Areas with high A_0 values are located in the northwest, southwest, and part of the center, indicating greater potential for ground acceleration during an earthquake. Based on the classification by (Setianegara et al., 2023). A_0 values > 6 are classified as high risk, which could potentially cause structural damage if not accompanied by earthquake-resistant building design. The correlation between high A_0 and loose (soft) sediment lithology in this study is directly proportional to the findings of (Januarta et al., 2020), which show that uncompact sediment layers tend to amplify seismic waves at certain frequency ranges. This is relevant considering that most of the Pekan Sabtu area is composed of alluvial deposits and young Quaternary material that has not been fully compacted.

Figure 5 shows the A_0 value analyzed from the H/V curve provides important information about the potential for seismic wave amplification on the ground. The distribution of A_0 shows that the moderate risk category is the most dominant with 34 points, followed by the low risk category with 15 points. The high-risk category only covers 3 points, and there are no areas with very high risk. This pattern shows that the study area is generally in the medium amplification class, which means that most locations tend to experience seismic wave amplification. However, points with high amplification, such as T11, T33, and T34, indicate that there are areas that need special attention in construction planning. High A_0 values are usually found in places with soft sediment layers or in lithological transition conditions. As a result, wave energy tends to be trapped and experience greater resonance (Nakamura, 2000).

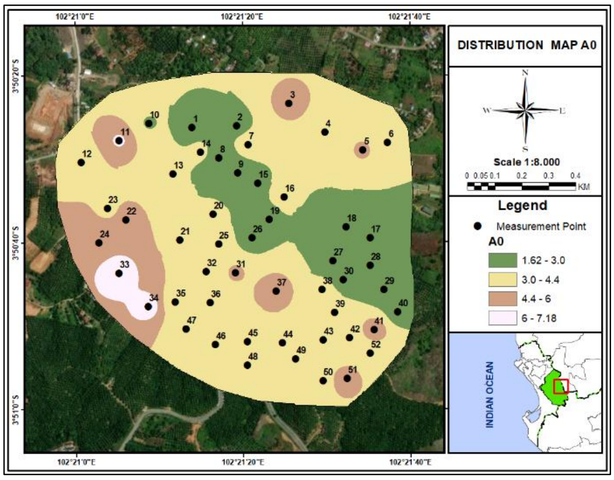

Fig. 5 Distribution Map of Amplification (A_0)

4.3 Analysis of Seismic Vulnerability Index (K_g)

The value of dominant frequency (f_0) and amplification value (A_0) affect the seismic vulnerability index (K_g) value obtained in the study area. If the K_g value is greater, the vulnerability of the subsurface layer to ground movement will be greater. Conversely, if the K_g value is lower, the vulnerability of the subsurface layer will be lower (Airunisa et al., 2024).

The seismic vulnerability index (K_g) distribution map in Figure 6 shows different variations in area and percentage for each class. The 0.30-1.81 K_g class dominates the study area with an area of 757 m² or about 56% of the total area, reflecting a zone with a relatively low level of seismic vulnerability. The 1.81-3.33 class occupies an area of 491 m² or about 37%, indicating moderate seismic vulnerability in part of the study area. Meanwhile, the 3.33-4.84 class covers a limited area of 75 m² 6%, and the 4.84-6.35 class has the smallest area, namely 12 m² or about 1%, which indicates a zone with a high level of seismic vulnerability. This distribution shows that, in general, the study area is dominated by soil conditions with low to moderate seismic vulnerability. This vulnerability pattern is influenced by local geological and lithological conditions, making it important for disaster mitigation, spatial planning, and earthquake-resistant land development. T33 and T41 were identified as the areas most vulnerable to earthquake shocks in the government office area of Bengkulu City.

Seismic wave velocity indicates how fast waves propagate beneath the surface. The seismic velocity characteristics of each layer differ due to differences in the composition of each level and are usually within a relatively consistent range. In addition, each layer of rock or soil has a different level of rigidity, so it tends to vibrate at different speeds (Rasyid et al., 2024).

Figure 6 shows the combination of f_0 and A_0 affects the Seismic Vulnerability Index (K_g) value that is derived. The K_g map shows variations between 0.30 and 6.35, indicating significant differences in soil response to earthquake shocks. Low K_g values (0.30–1.81) indicate areas with high stiffness and relatively good stability, while moderate to high K_g values (1.81–4.84) indicate areas with greater potential for amplification. In areas with the highest K_g values (4.84–6.35), found in several locations such as T33 and T41, the region is among the most vulnerable. Low shear wave velocity (V_s30), high amplification, and low dominant frequency are ideal conditions for significant shock amplification, resulting in high K_g values at these points. High K_g values indicate high soil vulnerability due to local resonance and dominant sediment thickness.

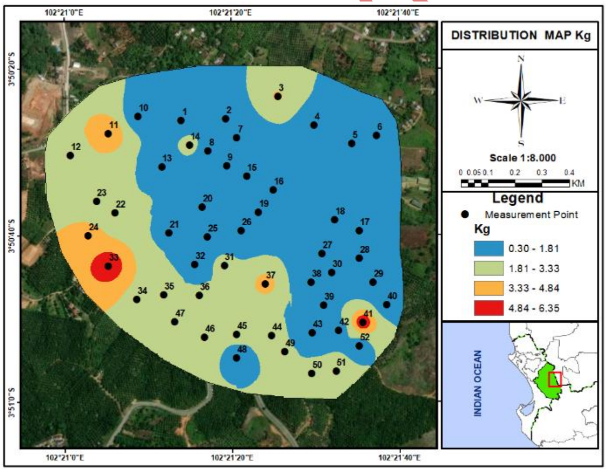

Fig. 6 Distribution Map of Seismic Vulnerability Index (K_g)

4.4 Analysis of Shear Wave Velocity (V_s30) and Elevation (m)

V_s30 is the shear wave velocity at a depth of thirty meters below the surface. The V_s30 values in the study varied from 189.29 m/s to 740.483 m/s. Figure 7 shows a map of V_s30 values. Areas with low values are more susceptible to shocks. This is because the stiffness of the rock determines the speed of seismic waves passing through it. If the V_s30 value decreases, the rock is soft, and vice versa (Fauziah and Pohan, 2023).

Analysis of the distribution map of average shear wave velocity to a 30-meter depth (V_s30) associated with elevation conditions shows significant differences in area between low and high classes. The low V_s30 class, with a value of around 189.29 m/s, dominates the study area with an area of 1,049 m² or around 80% of the total area, which is associated with low to moderate elevation and reflects relatively soft soil conditions. Conversely, the high V_s30 class, with a value of approximately 740.48 m/s, occupies an area of 286 m² or about 20%, which tends to be scattered in zones with higher elevations and indicates the presence of stiffer soil material. The dominance of the low V_s30 class indicates that most of the study area has the potential to experience greater seismic response during an earthquake; this must be considered while designing and planning building structures. This pattern shows that soil stiffness increases with elevation, while lowlands contain soft sediments and are therefore more susceptible to wave amplification Figure 7 (Boore, 2004).

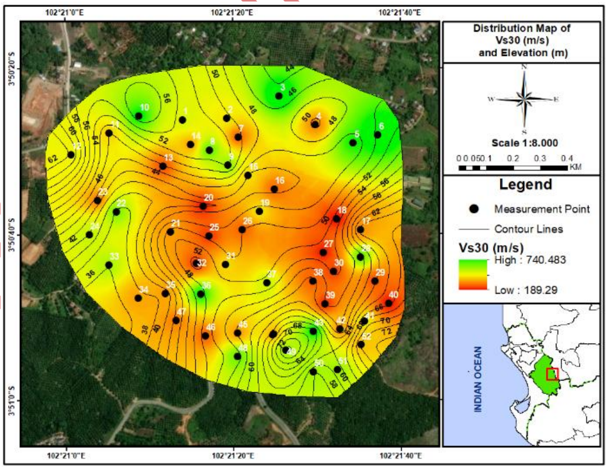

Fig. 7 Distribution Map of V_s30 (m/s) and Elevation (m)

Table 3. Soil type categories based on Badan Standardisasi Nasional (2019)

Soil Site Class	Description	V_s30 (m/s)
SA	The rock is very hard and dense.	> 1500
SB	Hard rock	750 - 1500
SC	Very dense soil / soft rock	350 - 750
SD	Hard soil	175 - 350
SE	Soft soil, (Very young deposits)	< 175

4.5 Analysis of Shear Wave Velocity (V_s30) Based on Soil Site Class

Based on Table 3 Badan Standardisasi Nasional (2019). Classification that uses the average shear wave velocity to a depth of 30 meters to distinguish soil types at a location. Figure 8 It is a map of V_s30 distribution, illustrating the diverse soil conditions in the study area. Based on the results of the V_s30 value distribution mapping, the study area is dominated by SD site classes, with V_s30 values ranging from 190 to 350 m/s, covering an area of approximately 1,049 m², or about 80% of the total study area. and SC site class with V_s30 values between 350 and 740 m/s, covering an area of 286 m² or about 20%. These conditions indicate that the soil characteristics in the study area are mostly in the medium soil class (Site Class SD), with some areas having higher stiffness included in the SC class. The classification of soil sites class based on the V_s30 parameter refers to this classification.

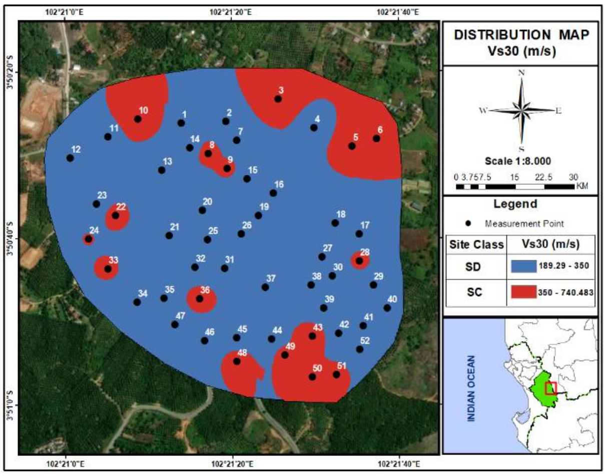

Fig. 8 Distribution Map of V_s30 (m/s)

The shear wave velocity values in the research area were determined using the V_s30 analysis, which ranged from 189.29 to 740.483 m/s, which places the study location in the SC and SD site classes according to Badan Standardisasi Nasional (2019). The SC class indicates very dense soil or soft rock, while the SD class indicates stiff soil typically found in alluvial areas. Low V_s30 values were found in the orange-reddish area, where there is low elevation and young sediment deposits that have not been well compacted. On the other hand, high V_s30 values were found in yellow-green areas with higher elevations and harder lithology Figure 7. This variation supports the findings of (Airunisa et al., 2024), who stated that seismic vulnerability (K_g) values increase in areas with soft sediments and low V_s30. Thus, the combination of low f_0, high A_0, and low V_s30 values at several points, such as T33 and T41, identifies these areas as zones with the highest potential for seismic amplification that need to be considered in office areas. Seismic waves tend to propagate more slowly in low-lying areas that consist mostly of fine materials and Quaternary sediments. As a result, the V_s30 value becomes lower, and the risk of amplification increases (Wibowo et al., 2025).

When all parameters f_0, A_0, K_g, and V_s30 are integrated, the general pattern shows that areas with thick sediments, low dominant frequencies, and slow wave propagation are the most prone to amplification and seismic vulnerability. Measurement points T33 and T41 exhibit this combination of low f_0,, high A_0,, and low V_s30, indicating thick unconsolidated sediments and strong amplification effects. These conditions classify the area as having a higher level of seismic vulnerability compared to surrounding locations.

This risk zone is very important to note because the study area is part of the Bengkulu City government office area, which requires strong building foundations and earthquake-resistant structural designs. This vulnerability pattern is also related to Bengkulu's seismic history, which often experiences moderate to strong tremors as a result of tectonic activity in the Sumatra subduction zone (Siagian et al., 2025).

Overall, this study shows that subsurface conditions in the office area of Pekan Sabtu Village, Bengkulu City, vary in terms of seismic vulnerability, which is influenced by lithological conditions, sediment thickness, topography, and subsurface structure. The results indicate that microzonation mapping based on microtremor data is crucial for disaster mitigation, spatial planning, and the design of safe construction buildings in seismically active regions such as the government office area in Bengkulu City. The integration of f_0, A_0, K_g, and V_s30 parameters reveals consistent patterns of seismic vulnerability, where areas with low f_0, high A_0, and low V_s30 correspond to zones of higher seismic risk.

5. Conclusion

Based on microtremor analysis using the Diffuse Field Assumption (DFA) method, the subsurface conditions in the Bengkulu City Government office area show varying characteristics, marked by dominant frequencies of 3.57-14.8 Hz, amplification of 1.62-7.18, seismic vulnerability index of 0.30-6.35, and V_s30 values of 189.29-740.483 m/s, which are classified as SC and SD soil sites according to Badan Standardisasi Nasional (2019).

The application of the Diffuse Field Assumption (DFA) method enables a more reliable estimation of subsurface shear wave velocity and provides a more comprehensive characterization of subsurface conditions compared to conventional approaches. The integration of seismic parameters (f_0,, A_0,, K_g, and V_s30) successfully identifies zones with higher seismic vulnerability, particularly at measurement points T33 and T41.

These findings highlight the importance of integrated seismic parameter analysis in supporting earthquake hazard mitigation and urban spatial planning, especially in developing earthquake-resistant infrastructure in the Bengkulu City Government office area.

Acknowledgement

We would like to express our gratitude to the Geophysics Study Program at Bengkulu University and the Geophysical Data Processing Laboratory for their assistance and support in this research. We would also like to thank the administrators of the Merah Putih City Hall in Bengkulu, as well as the residents of Pekan Sabtu Village, who welcomed us warmly during our research.

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