

Identification of soil characteristics in the Central Java Region using the HVSR (Horizontal to Vertical Spectral Ratio) inversion method

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Abstract. This research aims as one of the efforts to mitigate earthquake disasters by using the HVSR method based on microtremor data at 28 BMKG seismic stations in the central Java Island region to estimate the dominant frequency (f_0) and amplification (A_0) that describe the dynamic characteristics of the soil and analyse the shear wave velocity at a depth of 30 meters (V_{S30}). The dominant frequency values in the study area range from 0.648 to 18.257 Hz. The amplification values scattered in the study area ranged from 0.788 - 7.496. This research also produces dominant period parameters (T_0) and seismic vulnerability (K_g). The highest seismic vulnerability values are at BUJI in Buayan, Kebumen; GBJI in Gringsing, Batang; and SBJM in Sanden, Bantul. In addition, the V_{S30} value is helpful to determine how strong the building foundation resists earthquakes. Based on the V_s value in the ground profile with ellipticity curve modelling, the V_{S30} value ranges from 204.756 - 903.046 m/s. The distribution of V_{S30} values shows that the research points in central Java are spread by a variety of hard and very dense soil types to soft rock (SC).

1 Introduction

Central Java is an area that has the potential for earthquakes, although they are small and infrequent. This is due to active local faults and plate subduction zones in the southern part of central Java. However, compared to other active faults in Indonesia, the faults in Java, especially Central Java, have the lowest shear rates, resulting in low seismic activity caused by active faults in Central Java. Despite the infrequency of earthquakes in the area, several destructive earthquakes have occurred. Historical earthquake records show several destructive earthquakes have occurred in the central Java region. One of the worst earthquakes was the D.I. Yogyakarta earthquake on May 27, 2006, which resulted in more than 5,000 deaths, significant property losses, and environmental damage.

Knowing the ground conditions in the area is essential for earthquake disaster mitigation. This ensures that the number of casualties can be minimised during a large earthquake. Disaster mitigation is also crucial to planning the construction of vital facilities such as airports, industries, and nuclear reactors.

This research was conducted using one of the methods that can be used for earthquake disaster mitigation, namely the HVSR (Horizontal to Vertical Spectral Ratio) method. The results of the HVSR (Horizontal to Vertical Spectral Ratio) analysis show the natural frequency spectrum (f_0) and amplification factor (A_0) that describe the dynamic characteristics of the soil[1]. Calculations are

carried out to determine the dominant period of the soil and the seismic vulnerability index. After obtaining the H/V curve, inversion is carried out to get the average velocity of shear waves or V_{S30} . These parameters are needed to determine the subsurface conditions to estimate the earthquake hazard and the appropriate earthquake-resistant building standards[2].

In this study, the determination of the V_{S30} value using another alternative is done using the HVSR (Horizontal to Vertical Spectral Ratio) inversion method by utilising soil micro-vibrations obtained from microtremor measurements.

1.1 Microtremor

According to Kanai (1993), a microtremor is a continuous and minimal ground vibration caused by vibrations from human activities, traffic, wind, and others[3].

Microtremors can be used to design earthquake-resistant buildings by knowing the natural frequency of the local soil to avoid resonance. In addition, microtremors can be used to determine the type of soil based on its hardness.

Microtremors can be affected by human activities that can cause vibrations, but this has minimal effect on microtremors with frequencies below 0.1 Hz. Microtremor sources of natural origin, such as ocean waves or meteorological conditions on a broad scale, have low frequencies (below 1 Hz). At medium frequencies (1-5 Hz), microtremor sources usually come from nature,

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such as local meteorological conditions or human activities, such as population density, and at high frequencies (above 5 Hz), the primary source is human activity.

1.2 HVSR method (horizontal to vertical spectral ratio)

The HVSR method is performed by estimating the ratio of the Fourier spectrum of the vertical component to the horizontal component of microseismic waves. This method was first introduced by Nogoshi and Iragashi, who stated that there is a relationship between the ratio of horizontal and vertical components. Nakamura later refined this, saying, "The ratio of the H/V spectrum as a function of frequency is closely related to the site effect transfer for S (shear) waves".

The HVSR is assumed to be the same as the transfer function between the bedrock and the wave vibration of the sediment.

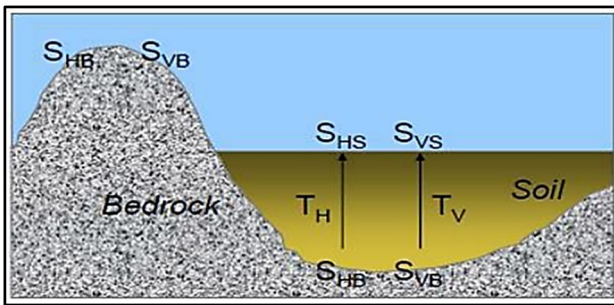


Fig. 1. Model of a basin containing sedimentary material[4].

The results show that in the recordings at stations located in hard rock, the maximum value of the ratio of the horizontal component spectrum to the vertical component is close to 1. However, at stations located in soft rock, the maximum value is enlarged or amplified, which is more than 1.

$$\frac{S_{VB}}{S_{HB}} = 1 \quad (1)$$

Generally, microtremor data comprises many waves, mainly Rayleigh waves, because the spectrum ratio between the horizontal and vertical components is close to one. The disturbance recorded on the surface of the soil layer due to the Rayleigh wave effect can be removed so that only the influence of geological structures or site effect (Tsite). Where the site effect (Tsite) shows the amplification peak at the fundamental frequency at a location:

$$T_{SITE} = \frac{S_{HS}}{S_{VS}} \quad (2)$$

This formula is the basis for calculating the ratio of the microtremor spectrum of the horizontal component to the vertical component (HVSR), or can be formulated as follows:

$$HVSR = T_{SITE} = \frac{\sqrt{[(S_{North-South})^2 + (S_{East-West})^2]}}{S_{Vertical}} \quad (3)$$

The signal used is only in the 0.5 Hz to 20 Hz range. More than 20 Hz is considered noise. After obtaining the subsurface natural signal, the H/V calculation will be carried out, resulting in the natural frequency and amplification.

To obtain reliable HVSR curve results, quality control is required based on the SESAME 2004 standard. There are three reliable criteria for HVSR curves, including[5]:

1. $f_0 > 10/lw$
2. $nc(f_0) > 200, nc = lw \cdot nw \cdot f_0$,
3. $\sigma A(f) < 2$ to $0.5f_0 < f < 2f_0$ if $f_0 > 0.5$ Hz, or
 $\sigma A(f) < 3$ to $0.5f_0 < f < 2f_0$ if $f_0 < 0.5$ Hz

where lw is the window length, nw is the number of windows selected to obtain the average H/V curve, nc is the number of significant cycles, σA is the standard deviation of A H/V (f), and f_0 is the peak frequency in the H/V curve.

1.3 HVSR inversion method

One of the inversion methods used in this study is ellipticity curve modelling. The ellipticity curve modelling extracts the subsurface physical properties that cannot be determined by the HVSR method, which is then used to obtain the surface shear wave velocity parameter (v_s) at the measurement point in the form of a ground profile of v_s .

The Ellipticity Curve is very dependent on determining parameters that are close to experimental values by repeating. The accuracy of this process can be seen from the error (misfit); the smaller the error value of the iteration process, the better the shear wave velocity profile obtained[6].

1.4 Natural frequency

The natural frequency or dominant frequency in HVSR processing is the natural frequency found in the area; this states that if there is an earthquake or disturbance in the form of vibrations that have the same frequency as the dominant frequency, resonance will occur, resulting in amplification of seismic waves in the area.

The value of the natural frequency (f_0) of an area is influenced by several factors, namely the thickness of the sediment layer and the subsurface average velocity (v_s), so it can be written as:

$$f_0 = \frac{V_s}{4H} \quad (4)$$

Where f_0 is the natural frequency (Hz), V_s is the average s-wave or shear wave velocity (m/s), and H is the sediment layer thickness (m).

1.5 Dominant period

The dominant period is when it propagates through the surface sediment layer or experiences one reflection against its plane of reflection at the surface[7]. Marjiono (2014) concluded that the high value of the dominant

period indicates the more profound the wave reflection field, which means the thicker the sediment layer in the region.

The value of the dominant period can be found based on the following calculation:

$$T_0 = \frac{1}{f_0} \tag{5}$$

T_0 is the dominant period (s), and f_0 is the dominant frequency (Hz).

1.6 Amplification

Amplification is the magnification of seismic waves due to significant differences between layers; in other words, seismic waves will experience magnification when propagating in a medium to another medium that is softer than the medium passed before.

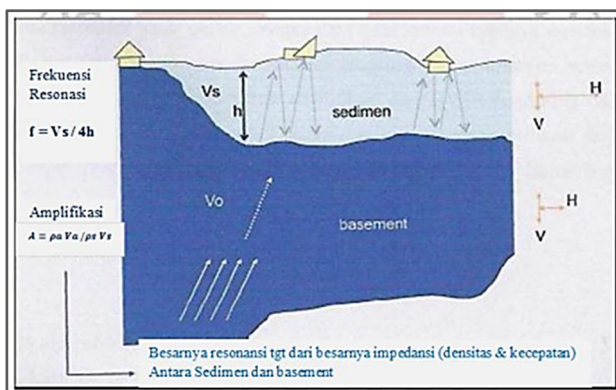


Fig. 2. Basic concept of seismic wave amplification[3].

The magnitude of the soil amplification value is related to the impedance contrast of the layer at the surface and the layer below. When the impedance contrast between these layers is high, there is a high amplification factor, and vice versa. So, the relationship between the impedance contrast comparison function can be expressed as follows:

$$A_0 = \frac{\rho_b V_b}{\rho_s V_s} \tag{6}$$

Where A_0 is the amplification factor, ρ_b is the bedrock density (m/s), V_b is the bedrock wave propagation velocity (m/s), ρ_s is the soft rock density (m/s), and V_s is the soft rock wave propagation velocity (m/s).

Table 1 shows the classification of amplification based on the magnitude of the amplification value of a region.

Table 1. Classification of amplification values[8].

Zone	Classification	Amplification Factor Value
1	Low	$A < 3$
2	Medium	$3 < A < 6$
3	High	$6 < A < 9$
4	Very high	$A > 9$

1.7 Seismic vulnerability index

Nakamura (1989) states that an area's seismic vulnerability index (K_g) describes the level of vulnerability of a layer of soil that is deformed by an earthquake. The level of building damage is directly proportional to the soil vulnerability index (K_g). The seismic vulnerability value can be found with the equation[9]:

$$K_g = \frac{A_0^2}{f_0} \tag{7}$$

K_g is the seismic vulnerability index, A_0 is the amplification factor, and F_0 is the natural frequency (Hz).

1.8 S-Wave velocity at 30 m depth (V_{s30})

V_{s30} is the average shear wave velocity to a depth of 30 meters. This V_{s30} value can be used to estimate earthquake hazards and determine earthquake-resistant building standards[10]. V_{s30} is a crucial indicator of the ground response that usually dominates ground motion amplification due to an earthquake. The V_{s30} value can be calculated using the formula:

$$V_{s30} = \frac{30}{\sum_{i=1}^N \frac{h_i}{V_{si}}} \tag{8}$$

Where V_{s30} is the average velocity of the layer up to 30 meters depth (m/s), h_i is the thickness of the sediment layer 0 to 30 meters (m), V_{si} is the shear wave velocity of the i -th layer (m/s), and N is the number of layers.

After the V_{s30} value of each research point has been obtained, it can be classified based on SNI 1726:2012 according to the value in the following table.

Table 2. Classification of V_{s30} values[11].

Classification	V_{s30} (m/s)
SA (Hard Rock)	>1500
SB (Rock)	750-1500
SC (Hard, Very Compacted Soils and Soft Rocks)	350-750
SD (Medium Soil)	175-350

2 Methods

This study limits the scope of the research area to the Central Java region, which includes the Provinces of Central Java and D.I Yogyakarta, precisely at the geographical coordinates of $5^{\circ}37'30''$ - $8^{\circ}12'30''$ LS and $108^{\circ}32'30''$ - $111^{\circ}43'30''$ BT. This study uses secondary data obtained from the seismic network of the Meteorology, Climatology, and Geophysics Agency (BMKG) in the research area, namely central Java, which has 28 seismic stations installed with a recording date of January 1 - 2, 2023. BMKG seismic network data is available online on the website <https://geof.bmkg.go.id/webdc3/>. This website contains

access to a collection of seismic station data in the BMKG seismic catalogue.

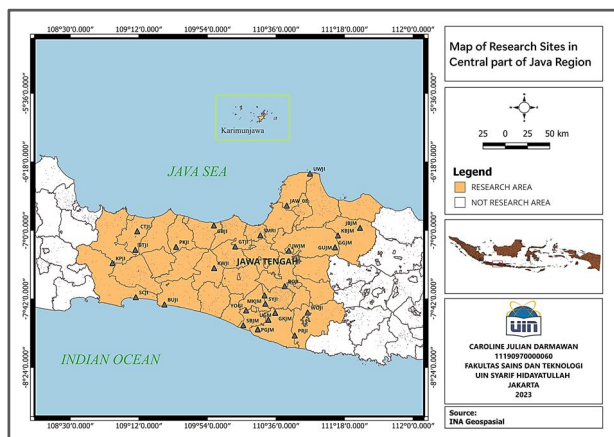


Fig. 3. Research location in the central part of Java with 28 BMKG seismic stations.

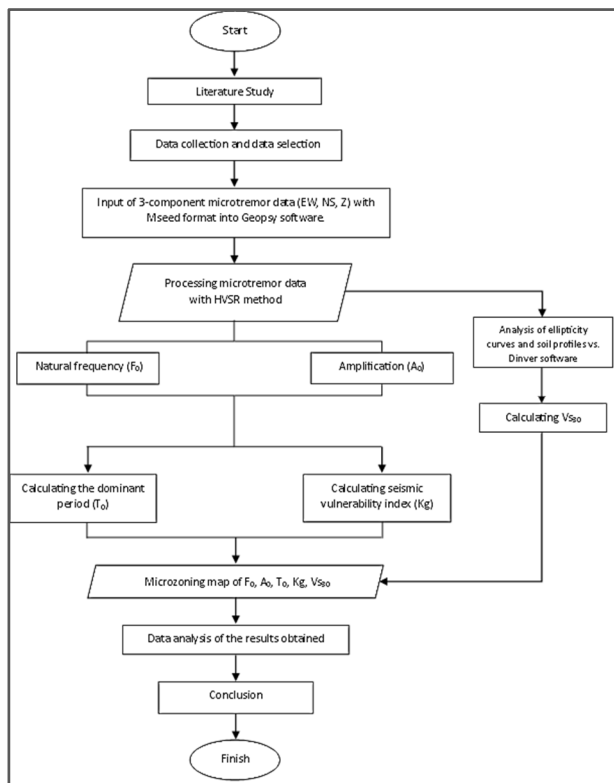


Fig. 4. Research flow chart.

The data processed in the HVSR processing using Geopsy software is 1-day seismic recording data consisting of 3 components: North-South, East-West, and Vertical. In processing the HVSR curve, a windowing process is carried out to eliminate transient signals and smooth the HV curve. The smoothing of the H/V curve is done using the Konno-Ohmachi method with a bandwidth coefficient of 40 and a width of 5%.

Inversion processing uses ellipticity curve modelling by opening Dinver in Geopsy software. The result of the model is a ground profile of V_s by performing data matching (fitting) until a final model is obtained that matches the measured HVSR curve at the smallest misfit value, and calculations are made to get the V_{s30} value

based on the V_s value in the ground profile model to a depth of 30 meters.

All parameter results were microzoned using QGIS software, and then the results obtained were analysed to determine the subsurface conditions in the study area.

3 Results and discussion

In this study, the parameters resulting from processing microtremor data with the HVSR method are the dominant frequency and amplification factors used to analyse soil characteristics in the study area. Other parameters obtained from this research are the dominant period value (T_0), seismic susceptibility index (K_g), and average shear wave velocity to a depth of 30 meters (V_{s30}). Then, the resulting parameters are modelled in a micro zonation map to be more easily interpreted.

3.1 HVSR results analysis

Data processing was performed using a window width of 25 seconds according to the presence of noise. The smoothing process was performed using the Konno & Omachi method with a smoothing constant 40. After manually selecting the windowing, the H/V spectrum was analysed to obtain the HVSR curve graph.

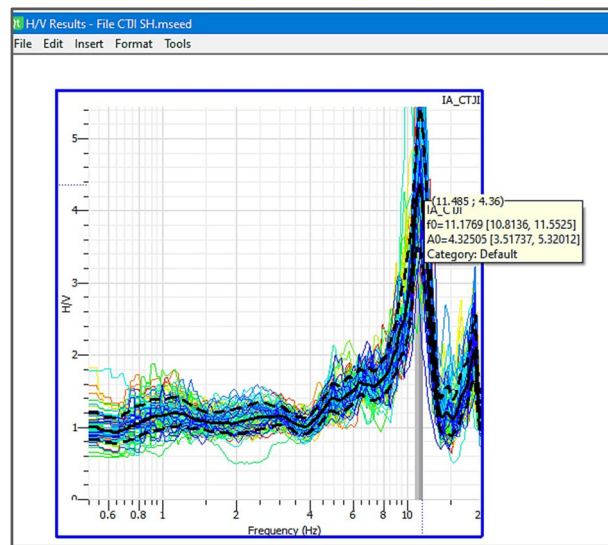


Fig. 5. H/V curve of CTJI point.

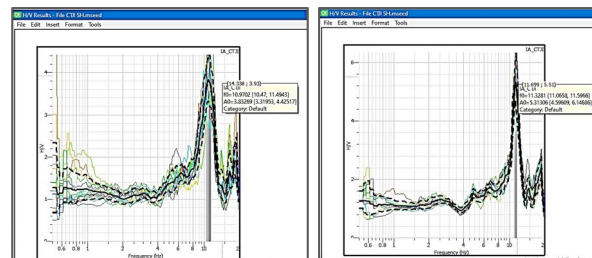


Fig. 6. Difference in H/V curve results during the day and night at CTJI points.

The results of the H/V curve analysis using the HVSR method obtained the value of the natural frequency and

amplification factor at the CTJI measurement point obtained at 11.1769 Hz and 4.32505.

To find out the effect of the results obtained from the two different times, it can be done by cutting the 1-day recording time into day time, namely 06:00:00 - 09:00:00 UTC or 13.00 - 16.00 WIB and night time, namely 17:00:00 - 20:00:00 UTC or 00.00 - 03.00 WIB with a recording duration of 3 hours each.

From the two results in Figure 6, it can be stated that the difference in measurement time does not significantly affect the dominant frequency value or amplification of a research point. However, the measurement results at night are stated to be more accurate because there is less human activity at this time, thus reducing unwanted noise.

3.2 Dominant frequency microzonation analysis

The dominant frequency values of the 28 processed microtremor measurement points in the central part of the Java region show varying values ranging from 0.647811 to 18.2568 Hz.

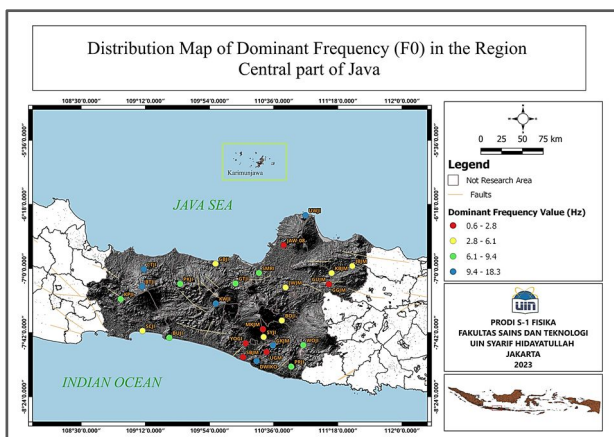


Fig. 7. Distribution Map of Dominant Frequency (F₀).

From the dominant frequency map, it can be seen that the points with the highest dominant frequency values with values > 14 Hz marked with light blue to dark blue colours are at the BTJI research point in Bumijawa, Tegal, and PGJM and DWIKO in Panggang, Gunung Kidul. The area is an upland area, such as hilly and mountainous areas. When associated with the geological setting map of the central part of Java, the BTJI point in Bumijawa is on the Central Volcano track, where this point is close to several volcanoes so that rocks from volcanic eruptions, lava, and breccia dominate this area. PGJM and DWIKO are part of a series of limestone mountains in southern Central Java. According to Kanai, areas with high dominant frequency values are areas with type I soil classification, indicating very thin surface sediment thickness and dominated by hard rock.

As for the low dominant frequency value obtained with a value of < 2 Hz which is marked in red at the research point GGJM in Gabus, Grobogan; GUJM in Gubug, Grobogan; MKJM in Manisrenggo, Klaten; SBJM in Sanden, Bantul; UGM at Wanagama Station, Gunung Kidul; YOGI in Balecat, Yogyakarta; and JAW_08 in Purwogondo, Jepara. The research point is thought to be in a lowland area with Kanai's type IV soil

classification with a very thick surface sediment thickness of more than 30 meters.

To make it easier to read the classification results of the natural frequency distribution at all research points in the central part of Java, it can be seen in Table 3.

Table 3. Natural Frequency Classification of the central part of Java.

Research Point	Dominant Frequency Value (Hz)	Soil Classification	Zone
BTJI, BUJI, CTJI, DWIKO, GKJM, KPJI, KWJI, PGJM, PKJI, SMRI, UWJI, dan WOJI	6,716 – 18,257	Type I	The thickness of surface sediments is very thin, dominated by hard rock, smaller than 5 meters.
BOJI, GBJI, GTJI, JWJM, KBJM, PRJI, and SCJI	4,342 – 6,6	Type II	Its surface sediment thickness is 5-10 meters in the medium category.
JBJM and SYJI	3 – 3,40	Type III	The thickness of surface sediments is in the thick category, about 10-30 meters.
GGJM, GUJM, MKJM, SBJM, UGM, YOGI, JAW_08	0,647 – 1,904	Type IV	The thickness of surface sediments is very thick, more than 30 meters.

3.3 Amplification factors microzonation analysis

It can be interpreted that all research points have amplification values ranging from 0.788 - 7.496.

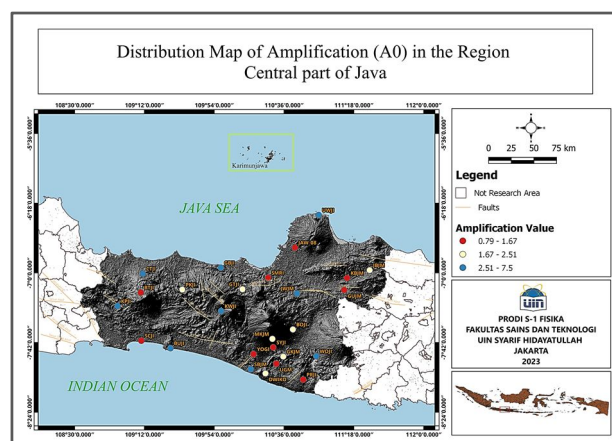


Fig. 8. Distribution Map of Amplification (A₀).

Table 1 shows that the highest amplification values are at the BUJI point in Buayan, Kebumen, and GBJI in Gringsing, Batang, with values > 6 marked with a blue colour scale. High amplification values indicate that these points risk severe damage in an earthquake. Based on the geological setting map of the central part of Java, these points have thick sedimentary layers dominated by

alluvium. Thick sedimentary layers slow the duration of wave propagation so that waves propagating during an earthquake experience large wave amplification.

While areas with low amplification values with values < 3 represented by red to orange colours are mostly scattered in highland areas such as at points BTJI in Bumijawa, Tegal; MKJM in Manisrenggo, Klaten; and KWJI in Kertek, Wonosobo, it is suspected that these areas have thin sedimentary layers and are indicated to have a low risk of damage.

To make it easier to read the classification results of amplification distribution at all research points in the central part of Java, it can be seen in Table 4, which has been classified based on the amplification value of the research points.

Table 4. Amplification Classification of the central part of Java.

Research Point	Amplification Value	Classification
BOJI, BTJI, DWIKO, GGJM, GKJM, GTJI, GUJM, JBJM, KBJM, KWJI, MKJM, PGJM, PKJI, PRJI, SCJI, SMRI, SYJI, UGM, UWJI, YOGI, and JAW_08	A < 3	Low
CTJI, JWJM, KPJI, SBJM, and WOJI	3 < A < 6	Medium
BUJI and GBJI	6 < A < 9	High

3.4 Dominant period microzonation analysis

The value of the dominant period at all research points in the central part of Java ranges from 0.05 - 1.54 s. This can be interpreted that all research points are dominated by low-value periods.

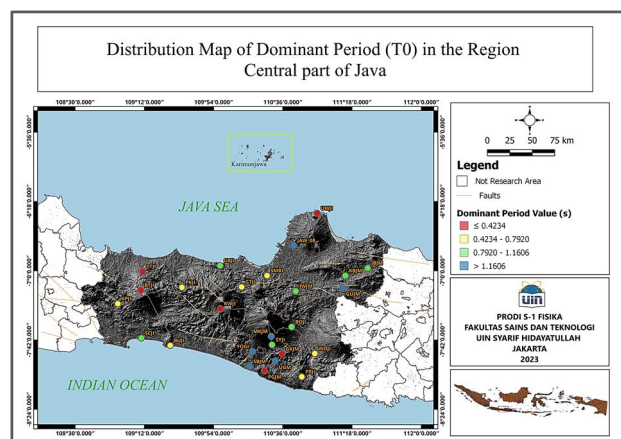


Fig. 9. Dominant Period Distribution Map (T_0).

The highest period values range from 1.163 - 1.544 s marked in blue on the map are scattered at points GGJM and GUJM in Grobogan; JAW_08 in Purwogondo, Jepara; and YOGI in Balekatun, Yogyakarta. According to the soil classification based on the period value by Kanai, the dominant period at the point is included in the soil

classification type IV; this area is indicated to be vulnerable to earthquakes because it has a very soft soil type.

To make it easier to read the results of the distribution of the dominant period at all research points in the central part of Java, it can be seen in Table 5, which has been classified based on the value of the dominant period of the study area.

Table 5. Dominant Period Classification of the central part of Java.

Research Point	Dominant Period Value (s)	Soil Classification	Character
BTJI, BUJI, CTJI, DWIKO, GKJM, GTJI, KPJI, KWJI, PGJM, PKJI, PRJI, SMRI, UWJI, and WOJI,	0,055 -0,154	Type I	Hard
BOJI, GBJI, JWJM, KBJM, and SCJI	0,172 – 0,230	Type II	Medium
JBJM and SYJI	0,29 – 0,35	Type III	Soft
GGJM, GUJM, JAW_08, MKJM, SBJM, UGM, and YOGI	0,525 – 1,544	Type IV	Very Soft

3.5 Seismic vulnerability microzonation analysis

It can be seen that the seismicity vulnerability index values at all research points in the central part of the Java region range from 0.09 to 9.98.

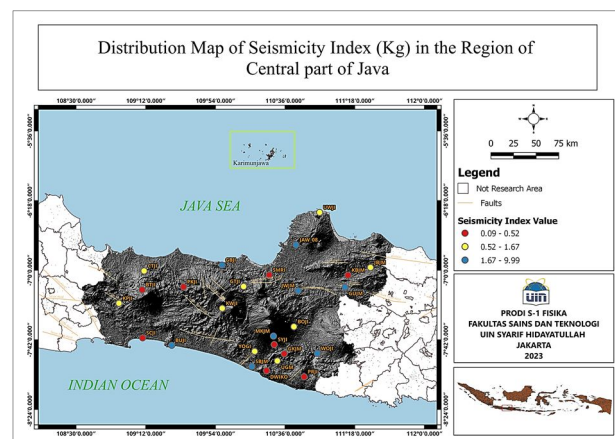


Fig. 10. Distribution map of seismicity index.

The GBJI research point in Gringsing, Batang, showed the highest seismicity index value of 9.986. Referring to the geological map of the study area, this point is located on the north coastal strip of the central part of Java, and it is suspected that the surface of this area consists of coastal alluvial deposits. The BUJI point in Buayan, Kebumen also shows a high seismicity index value, although the thickness of the surface deposits is thought to be thin; this

is because the Indonesian ocean to the south of the island of Java is a meeting of the Eurasian and Indo-Australian plates which has the potential to be a source of earthquake tectonics. Meanwhile, the point with a low seismicity index value is at point BTJI in Bumijawa, Tegal, with a seismicity index value 0.093. This point is located near the foot of Mount Slamet and is dominated by rocks from volcanic eruptions in the form of volcanic breccia, agglomerate, lava, and tuff.

This supports the opinion of Daryono (2011), where the seismic vulnerability index is related to geomorphological conditions where in low-lying areas, the seismic vulnerability index value shows a high value, while in hilly/mountainous areas, it shows a low seismic vulnerability index value. Areas that experienced severe damage are the plains with alluvial geological conditions and coastal areas with high seismic vulnerability index values.

Table 6. Seismic Vulnerability Classification of the central part of Java.

Research Point	Kg Value	Classification
BOJI, BTJI, CTJI, DWIKO, GKJM, GTJI, JBJM, JWJM, KBJM, KPJI, KWJI, PGJM, PKJI, PRJI, SCJI, SMRI, SYJI, UGM, UWJI, YOGI, and JAW 08	$Kg < 3$	Low
GGJM, GUJM, MKJM, and WOJI	$3 \leq Kg \leq 6$	Medium
BUJI, GBJI, and SBJM	$Kg > 6$	High

3.6 HVSr inversion results analysis

Model vs. generated by modelling four layers of material to a depth of 50 meters at each measurement location.

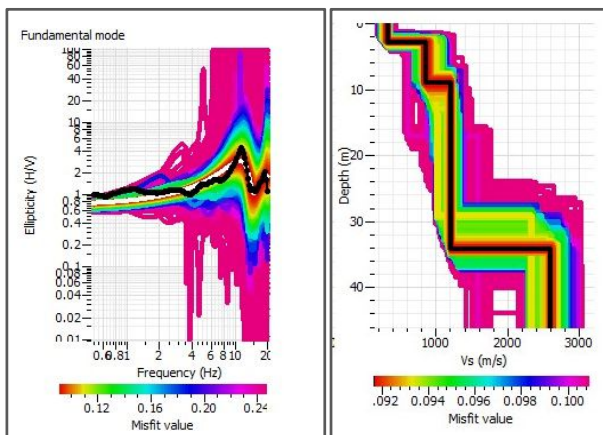


Fig. 11. Ellipticity curve and Ground profile vs. CTJI point.

The following table shows the value of each layer and its thickness to facilitate the interpretation of the ground profiles.

Table 7. Vs Value and Layer Thickness.

Layer thickness (m)	vs (m/s)
2,9	330,38
6,1	854,71
25,2	1213,9
13,8	2602,45

The vs value of each layer above is then calculated to a depth of 30 meters to produce a Vs₃₀ value at the CTJI point, as follows:

$$\begin{aligned}
 V_{s30} &= \frac{30}{\sum_{i=1}^N \frac{h_i}{V_{si}}} \\
 &= \frac{30}{\frac{2,9}{330,38} + \frac{6,1}{854,71} + \frac{20,98}{1213,9}} \\
 &= 903,046 \text{ m/s}
 \end{aligned}$$

Referring to SNI 1726, the CTJI research point at Cacaban Reservoir obtained a Vs₃₀ value of 903.046 m/s, categorised as rock (SB) at a depth of 30 meters from the surface. Based on the calculation of Vs₃₀ values at 28 research points, it shows that 28 research points in the central part of Java are spread by a variety of hard and very dense soil types to soft rock (SC).

3.7 Shear wave velocity at 30-meter depth (Vs30) microzonation analysis

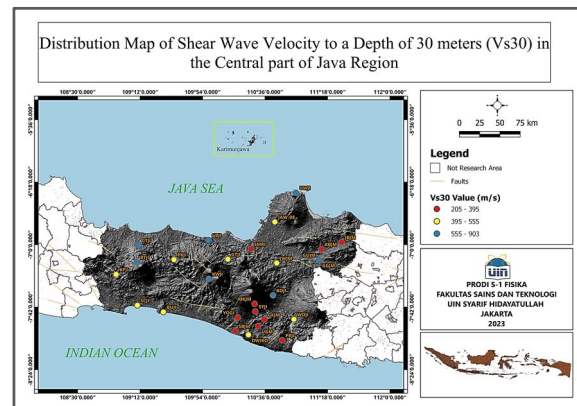


Fig. 12. Vs30 distribution map.

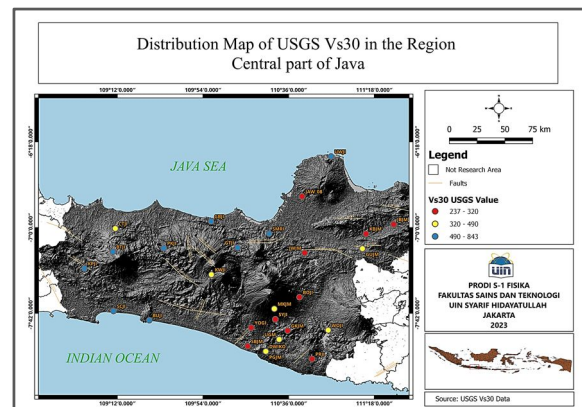


Fig. 13. USGS Vs30 distribution map.

According to Wangsadinata (2006), only rock layers up to 30 m deep determine the magnification of earthquake waves.

Based on the calculation of the V_{s30} value by HVSR inversion, the V_{s30} value at 28 BMKG seismic stations in the central part of Java varies between 204.756 to 903.046 m/s with the following classification.

Table 8. Calculated V_{s30} Classification in the central part of Java.

Research Point	V_{s30}	Site Classification
GKJM, KBJM, MKJM, PRJI, SBJM, SMRI, SYJI, dan YOGI	$175 < V_{s30} \leq 350$	Medium soil (SD)
BOJI, BTJI, BUJI, DWIKO, GBJI, GGJM, GTJI, GUJM, JBJM, JWJM, KPJI, KWJI, PGJM, PKJI, SCJI, UGM, UWJI, WOJI, dan JAW 08	$350 < V_{s30} \leq 750$	Very dense soil and soft rock (SC)
CTJI	$750 < V_{s30} \leq 1500$	Rock (SB)

V_{s30} values that tend to be low are scattered, with a range of 204.756 - 345.303 m/s. This zone includes research points GKJM in Gedangsari, Gunung Kidul; KBJM in Kunduran, Blora; MKJM in Manisrenggo, Klaten; PRJI in Pracimantoro, Wonogiri; SBJM in Sanden, Bantul; SMRI in Semarang; SYJI in Sleman, Yogyakarta; and YOGI in Yogyakarta, which indicates that these points are included in the medium soil category (SD) based on SNI 1726: 2012. While the V_{s30} value tends to be high, such as at point CTJI in Cacaban Reservoir, Tegal, with a value of 903.046 m/s, this point is located in a hilly area, so it has a relatively high V_{s30} value. It is included in the rock category (SB) based on SNI 1726:2012.

The V_{s30} calculation results can be validated by comparing the USGS V_{s30} results.

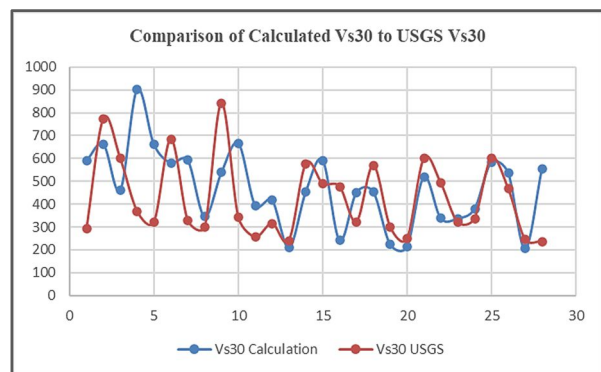


Fig. 14. Comparison graph of calculated V_{s30} and USGS V_{s30} .

Table 9. Comparison of calculated V_{s30} values with USGS V_{s30} values.

Research Point	V_{s30} USGS	V_{s30} Calculation	V_{s30} Ratio
BOJI	293	591,20	2,02
BTJI	775	662,11	0,85
BUJI	600	460,45	0,77
CTJI	368	903,05	2,45
DWIKO	322	660,89	2,05
GBJI	685	579,83	0,85
GGJM	328	592,85	1,81
GKJM	299	345,30	1,15
GTJI	843	538,69	0,64
GUJM	342	666,54	1,95
JBJM	255	394,67	1,55
JWJM	314	417,97	1,33
KBJM	240	208,74	0,87
KPJI	577	454,45	0,79
KWJI	490	592,15	1,21
MKJM	477	241,09	0,51
PGJM	322	450,81	1,4
PKJI	570	453,81	0,8
PRJI	300	223,87	0,75
SBJM	248	213,20	0,86
SCJI	600	519,78	0,87
SMRI	492	337,60	0,69
SYJI	320	337,20	1,05
UGM	337	379,02	1,12
UWJI	600	584,22	0,97
WOJI	467	536,81	1,15
YOGI	245	204,76	0,84

From the comparison of the two values above, it can be concluded that there is no significant difference between the calculated V_{s30} and the USGS V_{s30} value. However, the USGS only approaches the V_{s30} value with slope parameters obtained through satellite imagery, so the accuracy of the USGS V_{s30} value cannot be confirmed.

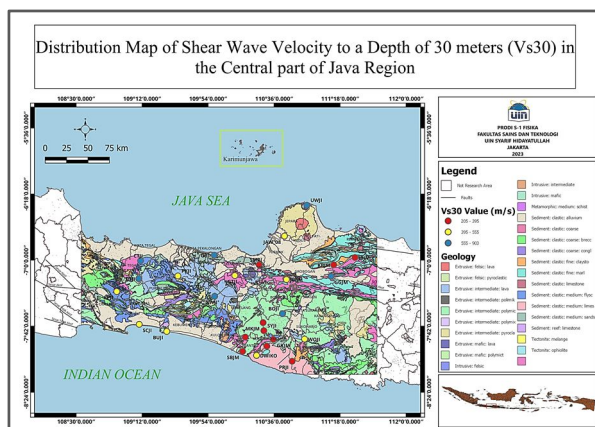


Fig. 15. Geologic overlay map and V_{s30} values.

Based on the results of overlaying geology with measured V_{S30} values in Figure 15, it is suspected that high V_{S30} values are scattered in hilly/mountainous areas with old geological age, such as BTJI point in Bumijawa, Tegal. Meanwhile, low V_{S30} values are scattered in several research points in D.I. Yogyakarta and its surroundings, such as SBJM points in Sanden Bantul and MKJM in Manisrenggo, Klaten, with soil distribution that has a moderate level of hardness.

4 Conclusion

Based on the results and discussion in this study, conclusions can be drawn:

1. The data processing results from 28 BMKG seismic stations in the central part of Java using the HVSR method show that low dominant frequency values with high dominant period values describe areas with indications of soft soil/rock, and vice versa. High amplification values are found in lowland areas with indications of soft soil. The distribution map of seismic vulnerability index values shows that low vulnerability values dominate 28 BMKG seismic stations in the central part of Java Island. One of the common seismic vulnerability values is at the BTJI point in Bumijawa, Tegal, where this point is near the foot of Mount Slamet and is dominated by rocks resulting from volcanic eruptions in the form of volcanic breccias, agglomerates, lahars, and tuffs. While the high seismic vulnerability value is one of them at the GBJI point in Gringsing, Batang, this point is on the north coast of Central Java, and it is suspected that the surface of this area consists of coastal alluvial deposits.
2. The V_{S30} micro zonation shows that up to a depth of 30 meters, several BMKG seismic stations in the central part of the Java region are dominated by hard soil and very dense to soft rock. Low V_{S30} values are scattered in several research points in D.I. Yogyakarta and surrounding areas dominated by medium soils.

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