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EARTHQUAKE VULNERABILITY MAPPING BASED ON MICROSEISMIC MEASUREMENTS IN THE CAMPUS AREA OF UNIVERSITAS SARJANAWIYATA TAMANSISWA YOGYAKARTA

PEMETAAN KERENTANAN GEMPA BERDASARKAN PENGUKURAN MIKROSEISMIK DI WILAYAH KAMPUS UNIVERSITAS SARJANAWIYATA TAMANSISWA YOGYAKARTA

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Abstract. Building damage caused by earthquakes is more prevalent in the sedimentary areas of Yogyakarta City compared to the hilly regions of Wonosari and Kulonprogo, which have harder soil layers. The campus of Universitas Sarjanawiyata Tamansiswa (UST) is one of the campuses located in Yogyakarta City, where the regional geology is dominated by the Merapi Young Volcanic Deposits Formation. The UST campus area is vulnerable to earthquakes due to its proximity to an active seismic zone, making earthquake vulnerability mapping based on microseismic data an important necessity to support disaster mitigation efforts. The microseismic method was used in this study, while data analysis employed the Horizontal-to-Vertical Spectral Ratio (HVSR). Microseismic measurements were chosen because they have the advantage of not damaging the surface conditions of the ground, thus preserving the environment, and are easy to use in urban areas. The research method stages include survey design, field data collection, data processing and interpretation, and the creation of earthquake vulnerability maps. Data points were collected from 7 locations covering the Universitas Sarjanawiyata Tamansiswa campus area. The research results indicate that the study area has a dominant frequency value ranging from 1.10 to 2.74 Hz. Meanwhile, the amplification value ranges from 1.25 to 2.2. The sediment thickness of the study area ranges from 32 to 79 meters. The Seismic Vulnerability Index (Kg) of the study area ranges from 0.57 to 4 on a low to high scale. Based on the

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dominant frequency values, amplification, and seismic vulnerability index, the areas of the UST campus that are more vulnerable to earthquakes are the northern, eastern, and central parts, while the southern part is relatively safer.

Abstrak. *Kerusakan bangunan akibat gempa bumi lebih banyak terjadi di daerah sedimen Kota Yogyakarta dibandingkan dengan daerah perbukitan Wonosari dan Kulonprogo yang memiliki lapisan tanah lebih keras. Kampus Universitas Sarjanawiyata Tamansiswa (UST) merupakan salah satu kampus yang terletak di Kota Yogyakarta, dengan geologi regional yang didominasi oleh Formasi Endapan Vulkanik Muda Merapi. Wilayah kampus UST rentan terhadap gempa bumi karena lokasinya yang berdekatan dengan zona seismik aktif, sehingga pemetaan kerentanan gempa bumi berdasarkan data mikroseismik menjadi kebutuhan penting untuk mendukung upaya mitigasi bencana. Metode mikroseismik digunakan dalam penelitian ini, sedangkan analisis data menggunakan Horizontal-to-Vertical Spectral Ratio (HVSR). Pengukuran mikroseismik dipilih karena memiliki keunggulan tidak merusak kondisi permukaan tanah, sehingga menjaga kelestarian lingkungan, dan mudah digunakan di daerah perkotaan. Tahapan metode penelitian meliputi perancangan survei, pengumpulan data lapangan, pengolahan dan interpretasi data, serta pembuatan peta kerentanan gempa bumi. Titik data dikumpulkan dari 7 lokasi yang meliputi wilayah kampus Universitas Sarjanawiyata Tamansiswa. Hasil penelitian menunjukkan bahwa wilayah studi memiliki nilai frekuensi dominan berkisar antara 1,10 hingga 2,74 Hz. Sementara itu, nilai amplifikasi berkisar antara 1,25 hingga 2,2. Ketebalan sedimen wilayah studi berkisar antara 32 hingga 79 meter. Indeks Kerentanan Seismik (Kg) wilayah studi berkisar antara 0,57 hingga 4 pada skala rendah hingga tinggi. Berdasarkan nilai frekuensi dominan, amplifikasi, dan indeks kerentanan seismik, wilayah kampus UST yang lebih rentan terhadap gempa bumi adalah wilayah utara, timur, dan tengah, sementara wilayah selatan relatif lebih aman.*

1. INTRODUCTION

Indonesia is located at the intersection of three major tectonic plates: the Indo-Australian Plate to the south, the Eurasian Plate to the north, and the Pacific Plate to the east. Additionally, the Indonesian archipelago is traversed by the Pacific Ring of Fire, a chain of volcanic mountains. These two factors make Indonesia one of the countries with a high level of seismic activity, both tectonic and volcanic. Areas prone to earthquakes are geographically relatively close to subduction zones (plate boundaries). The Special Region of Yogyakarta is one of the regions in Indonesia that is close to a subduction zone. In addition to subduction zones, there are also faults on land, such as the Opak Fault, which increase vulnerability to earthquakes (Purnama et al., 2021). Damage to buildings caused by earthquakes is also influenced by local site effects (Juarzan et al., 2023; Hesti et al., 2021; Satria et al., 2020).

One geophysical method that can be used to map potential damage from earthquakes is the microseismic method. This method utilizes microtremor recordings, or low-amplitude ground vibrations originating from both natural sources and human activity. In microtremor studies, it is quite common to keep frequencies below 1 Hz, because the instruments used for tremor data acquisition are broadband seismometers capable of detecting frequencies in the range of 0.2 Hz – 100 Hz. This frequency range is crucial because it allows the detection of the dominant local ground frequency, which plays a major role in determining how much earthquake wave amplification can occur in a region. The results of this analysis, such as the HVSR (Horizontal to Vertical Spectral Ratio) curve, can be used to map seismic vulnerability zones and form the basis for earthquake-resistant building and spatial planning. Microseismic measurements were chosen because they have the advantage of not damaging the surface of the ground, thus preserving the environment, and are easy to use in urban areas (Putra & Saputra, 2022; Satria et al., 2020).

The microseismic method has been used by previous researchers, such as in studies by Riswandi et al. (2023) which uses microseismic data to map earthquake hazard zones using Probabilistic Seismic Hazard Analysis (PSHA) and peak ground acceleration (PGA). In addition to this research, Perdhana and Nurcahya (2019) conducted research using the microtremor method in Bantul and Klaten Regencies, Central Java. In addition, research on the vulnerability of multi-story buildings in the campus area has also been conducted by Putra and Saputra (2022). Penelitian terhadap kerentan gempa pernah juga dilakukan di ruangan Prodi Pendidikan Fisika UST oleh (Prabowo et al., 2020). The study used Floor Spectral Ratio (FSR) analysis, comparing the results with the classification applied in SNI 2002 on earthquake-resistant building design. The study showed that the microseismic method can be used to indicate the vulnerability of buildings and areas to earthquakes. This study improved on previous research by using microseismic data in the campus area of Universitas Sarjanawiyata Tamansiswa in Yogyakarta for microzonation.

Universitas Sarjanawiyata Tamansiswa Yogyakarta is one of the campuses located in the city of Yogyakarta. Universitas Sarjanawiyata Tamansiswa (UST) Yogyakarta is an educational institution located in a densely populated area with a high level of human activity. As a campus that is developing with various building infrastructures, it is important to know the level of seismic vulnerability in this area as an effort to mitigate and plan for safe construction against earthquakes. By mapping earthquake vulnerability using microseismic data, it is hoped that initial information can be obtained regarding zones that are potentially susceptible to earthquake wave amplification, so that the results can be used in disaster risk management within the campus environment.

The Universitas Sarjanawiyata Tamansiswa in Yogyakarta is situated on a young Merapi volcanic deposit formation composed of sedimentary rocks. Additionally, the campus area is adjacent to a river basin. River basins indicate regions rich in sedimentary rocks (Moechtar, 2021). This adds to the vulnerability caused by earthquakes in the campus area of Universitas Sarjanawiyata Tamansiswa in Yogyakarta. Based on this description, the researchers aim to map or microzone the campus area of Universitas Sarjanawiyata Tamansiswa in Yogyakarta using the microseismic method. They also aim to identify the thickness of the sediment beneath the surface of the campus of Universitas Sarjanawiyata Tamansiswa in Yogyakarta. Mitigation efforts are often only implemented after a disaster occurs. It is hoped that the mapping of earthquake-prone areas can be used as a form of mitigation or disaster response before a disaster occurs. As one of the higher education institutions located in an area prone to earthquakes, it is important to ensure that the campus has an adequate mitigation system in place.

2. LITERATURE REVIEW

The Special Region of Yogyakarta (DIY) has four regencies and one municipality, namely Kulonprogo Regency, Bantul Regency, Sleman Regency, Gunung Kidul Regency, and Yogyakarta Municipality. The DIY Province is located at the intersection of tectonic plates and active volcanoes. The campus area of the Universitas Sarjanawiyata Tamansiswa (UST) in Yogyakarta is one of the campuses located in the city of Yogyakarta. The UST campus is dominated by young volcanic rock formations. Based on **Figure 1**, the geology of the study area is located in a young volcanic deposit formation consisting of tuff, volcanic ash, breccia, agglomerate, and lava flows that cannot be separated (Handayani et al., 2019; Listyani, 2020).

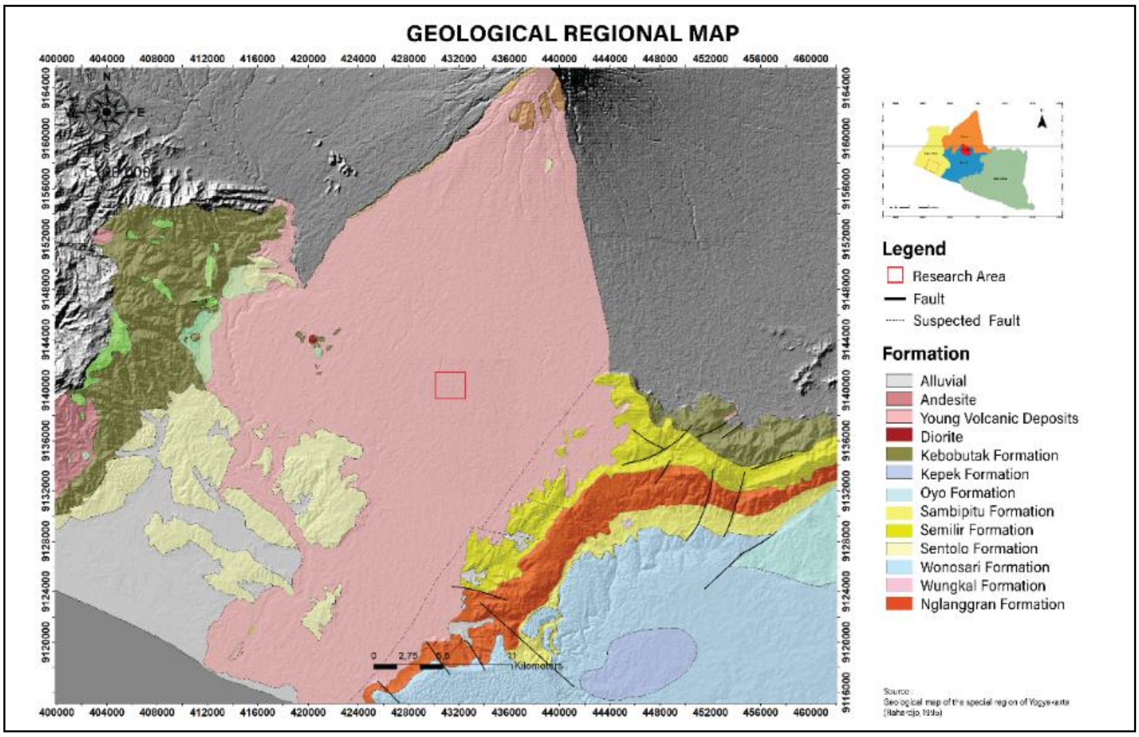

Figure 1. Geological Map of Daerah Istimewa Yogyakarta Regency (DIY) (Rahardjo et al., 1995).

3. RESEARCH METHODS

Microseismic data was collected at seven measurement points within the Universitas Sarjanawiyata Tamansiswa campus, with a distance of 10 meters between each point. Measurements were taken using the microseismic method with Lenartz seismometers, geological compasses, and GPS devices. The Lenartz broadband seismometer has an operational frequency range from 0.2 Hz – 100 Hz, allowing it to accurately record very low to high ground vibrations in microseismic studies and earthquake monitoring. The HVSR (Horizontal to Vertical Spectral Ratio) method is a microseismic (microtremor) signal technique used to identify the local dominant frequency (f_0) and amplification (Ao) of a location. This method compares the spectrum of the horizontal component to the vertical component of ground vibrations. The standard operating procedures for these instruments were based on the SESAME European research project, with a measurement duration of 30 minutes for each point (Bard et al., 2004; Chatelain et al., 2008). The 30 minutes duration was chosen because it is able to produce stable, representative data and minimize interference, and is in accordance with standard practices in microseismic analysis using the HVSR method. This study was conducted at the Universitas Sarjanawiyata Tamansiswa Campus in Yogyakarta, which is bounded by coordinates -7.802000° to -7.800800° South Latitude and 110.391500° to 110.393100° East Longitude, as shown in **Figure 2.**

Figure 2. Microseismic Measurement Points at the Universitas Sarjanawiyata Tamansiswa Campus.

The research method used in this study was microseismic data collection with HVSR (Horizontal to Vertical Spectral Ratio) analysis. The processed data has complied with the SESAME (2004) criteria, including: (1) determining that the HVSR analysis results are considered valid if the curve shows a clear and sharp peak, with a stable dominant frequency value (f_0) in the range of 0.1 to 10 Hz; (2) and an amplification factor (A_0) of at least 2; (3) Peaks that are too shallow or too high (>5) need to be re-evaluated because they can be influenced by noise or non-contrasting geological conditions. The microseismic processing scheme using HVSR analysis is shown in **Figure 3**. The data was processed using Geopsy software. Microseismic data processing using the HVSR (Horizontal to Vertical Spectral Ratio) method produced dominant frequency values (f_0), amplification factors (A_0) from the HVSR curve, and Seismic Vulnerability Index (Kg).

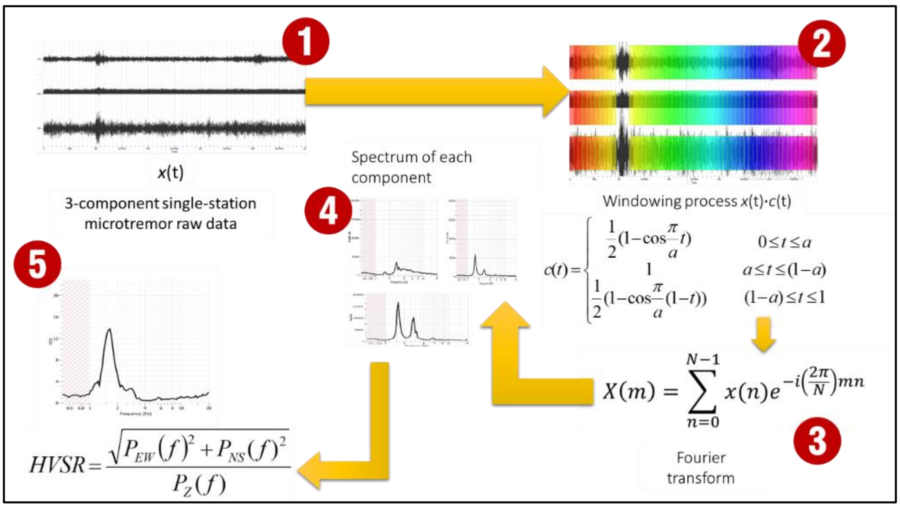

Figure 3. Microseismic data processing scheme.

In general, the HVSR equation used for microseismic processing is shown in Equation 1.

$$HVSR = \frac{\sqrt{A_{EW}(f)^2 + A_{NS}(f)^2}}{A_Z(f)} \quad (1)$$

With AEW, ANS, and AZ representing the amplitude spectrum of the east-west, north-south, and vertical components, respectively. The resulting spectrum is used to determine the dominant frequency. The HVSR method eliminates measurements from the bedrock layer to obtain the sediment basin transfer function (Bodin et al., 2001).

The seismic vulnerability index is obtained using input parameters of dominant frequency (fo) and amplification factor (Ao), with the following equation (Nakamura, 1989; 2000):

$$Kg = Ao^2 / fo \quad (2)$$

Where, Kg is the seismic vulnerability index, Ao is the amplification factor, and fo is the dominant frequency. The results of the microseismic data processing are then used to create earthquake vulnerability maps.

The HVSR method produces a dominant frequency (f_0) that is directly related to the sediment thickness above the bedrock. The recorded resonance occurs because Rayleigh waves are trapped between the surface and the underlying hard layer boundary. If the shear wave velocity (Vs) is known, the sediment thickness (H) can be calculated using the following empirical formula:

$$h = \frac{V_s}{4f_o} \quad (3)$$

Where, h is the sediment thickness (m), V_s is the shear wave velocity (m/s) and f_0 is the dominant frequency of HVSR (Hz).

4. RESULTS AND DISCUSSION

Earthquakes cause damage to buildings due to seismic wave amplification (Jannah et al., 2024; Putri et al., 2017). According to Nakamura (2000) seismic wave amplification occurs due to impedance contrast between sediment layers and bedrock layers. Based on previous research from Purnama et al. (2021), buildings that suffered damage due to earthquakes had an amplification value of at least 4. In general, there are four types of curves that indicate the geological conditions of the area (SESAME, 2004). The first type of curve is a single peak, the second is a double peak, the third is a flat curve, and the fourth is a multi-peak. Differences in the peaks on the HVSR curve generally indicate seismic impedance contrasts at different depths within the subsurface structure. This is closely related to the complexity of the local stratigraphy, such as the presence of multiple layers with different physical properties (e.g., a soft layer above a stiffer layer, or between sediments of varying densities).

In this study, the differences in peaks and frequencies were not significantly different. The main peak (dominant frequency) usually reflects the resonance between the soft soil and the underlying bedrock. However, if there is more than one layer with significant impedance contrast, the HVSR curve may show more than one additional peak. This could be related to local resonances in shallow or intermediate layers, or the effects of complex structures such as fractures or thin bedding. The frequency range of 0–20 Hz was chosen because it is the optimal and relevant range for identifying the dominant ground frequency and avoiding distortion due to high noise outside this range. The results of HVSR data processing are shown in **Figure 4.**

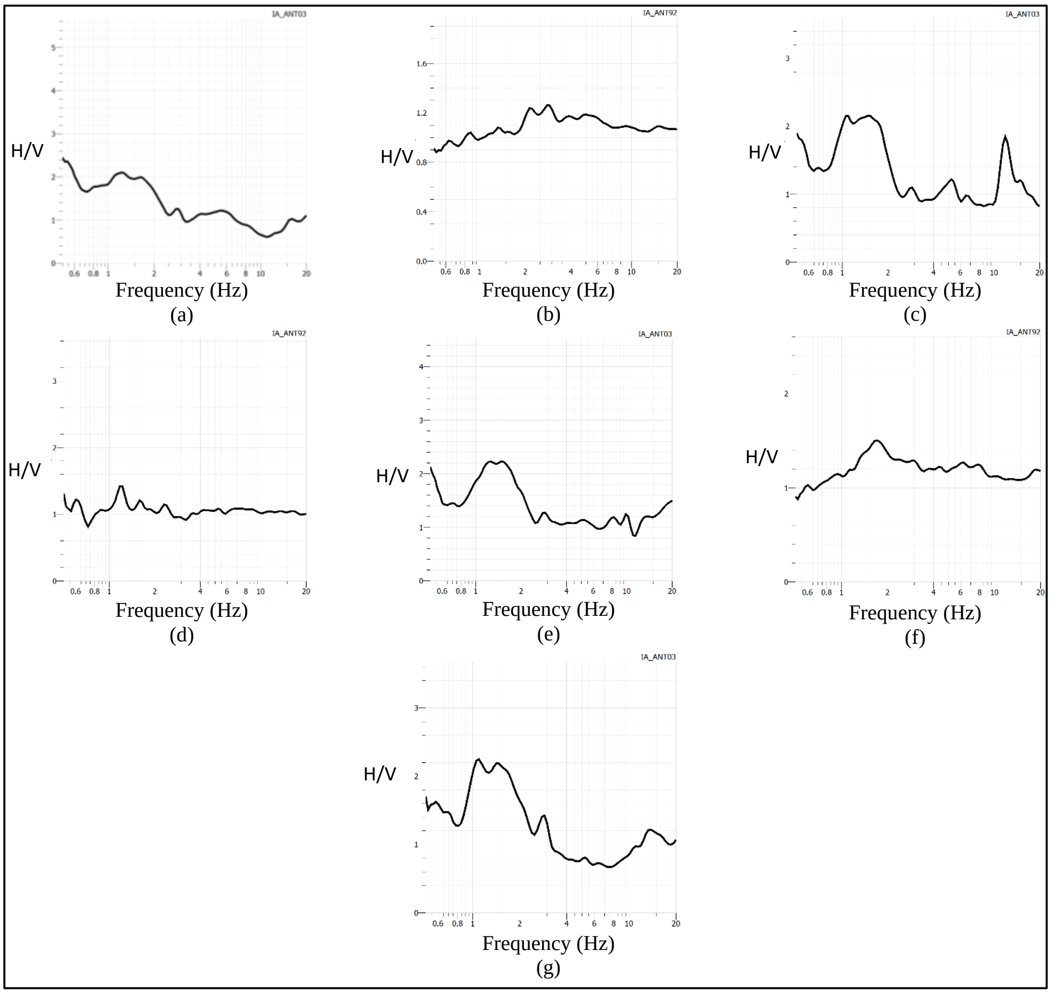

Figure 4. a) Measurement point 1 (b) Measurement point 2 (c) Measurement point 3 (d) Measurement point 4 (e) Measurement point 5 (f) Measurement point 6 (g) Measurement point 7.

Figure 4a to **Figure 4g** are HVSR curves processed using Geopsy software with the x-axis representing the dominant frequency and the y-axis representing the amplification value. Based on (SESAME, 2004) The HVSR curve in the study area shows a single peak (measurement points 5 and 6), a flat curve (measurement points 2 and 4), a multi-peak (measurement point 7), and a double peak (measurement points 1 and 3). **Figure 4** shows the amplification values obtained as follows: measurement point 1 is 2.01, measurement point 2 is 1.25, measurement point 3 is 2.1, measurement point 4 is 1.42, measurement point 5 is 2.2, measurement point 6 is 1.5, and measurement point 7 is 2.07. The HVSR curve at measurement point 5 has a higher amplification value compared to the amplification values of the 6 HVSR curves at other measurement points. According to the research (Purnama et al., 2021), buildings that collapsed due to the 2006 Yogyakarta earthquake had an amplification value of at least 4. Based on this, it is predicted that the Universitas Sarjanawiyata Tamansiswa campus will not experience building damage or collapse in the event of an earthquake. The HVSR curve in the Universitas Sarjanawiyata Tamansiswa campus area shows the same pattern, indicating that there are geological similarities in the study area.

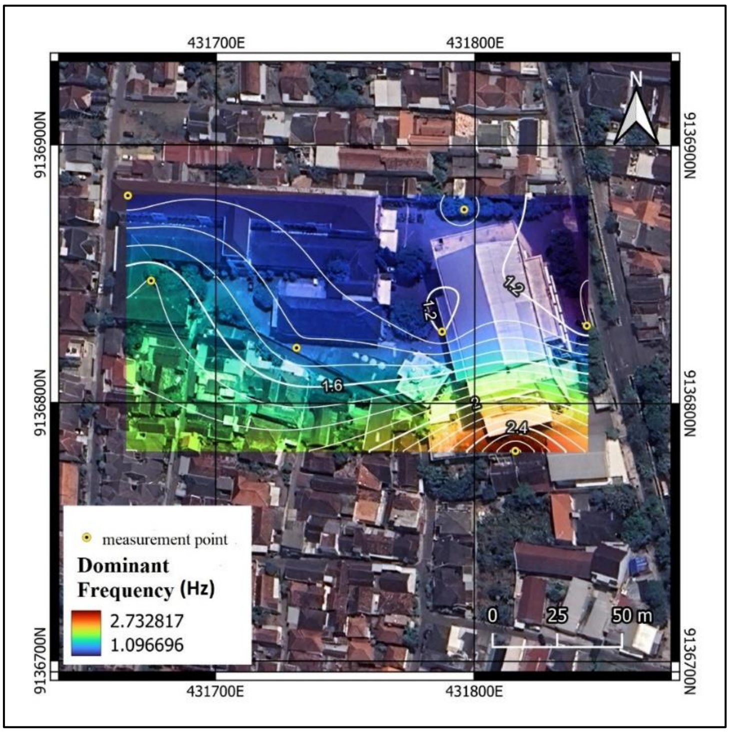

Figure 5. Dominant Frequency of UST Campus.

Based on the HVSR curve obtained, a map was then created based on the dominant frequency, amplification, and seismic vulnerability index. The dominant frequency is the frequency that appears frequently, marked by a large amplitude value (Kornhuber et al., 2017; Su et al., 2018). The distribution of dominant frequency values for the Universitas Sarjanawiyata Tamansiswa campus area is shown in Figure 5. Figure 5 shows the dominant frequencies in the Universitas Sarjanawiyata Tamansiswa Campus area. Low frequencies are mostly located in the north, east, and center of the campus with a range of 1.1 to 1.22 Hz. Meanwhile, medium frequencies range from 1.22 to 1.42 Hz. The high dominant frequencies have a range of 1.42 to 2.74 Hz. The dominant frequency values also indicate sediment thickness, with high dominant frequencies indicating thin sediment layers and low dominant frequencies indicating thick sediment layers (Li et al., 2019). This dominant frequency value correlates with earthquake damage to buildings, as shown by research Wibowo and Huda (2020). Based on the dominant frequency values, we can estimate the sediment thickness using the equation used by (Satria et al., 2020).

Sediment thickness in the study area ranges from 32 to 79 meters. Sediment thickness is obtained by dividing the sediment velocity by 4 times the dominant frequency. Sediment thickness is calculated using the average Vs30 value for Yogyakarta City, which is 115 m/s (Muzli et al., 2016). Seismic wave amplification is the peak value of the HVSR curve. According to (SESAME, 2004) and (Nakamura, 2000) Amplification is the impedance contrast between the sediment layer and the bedrock layer. The amplification value for the Universitas Sarjanawiyata Tamansiswa Campus area is shown in **Figure 6**.

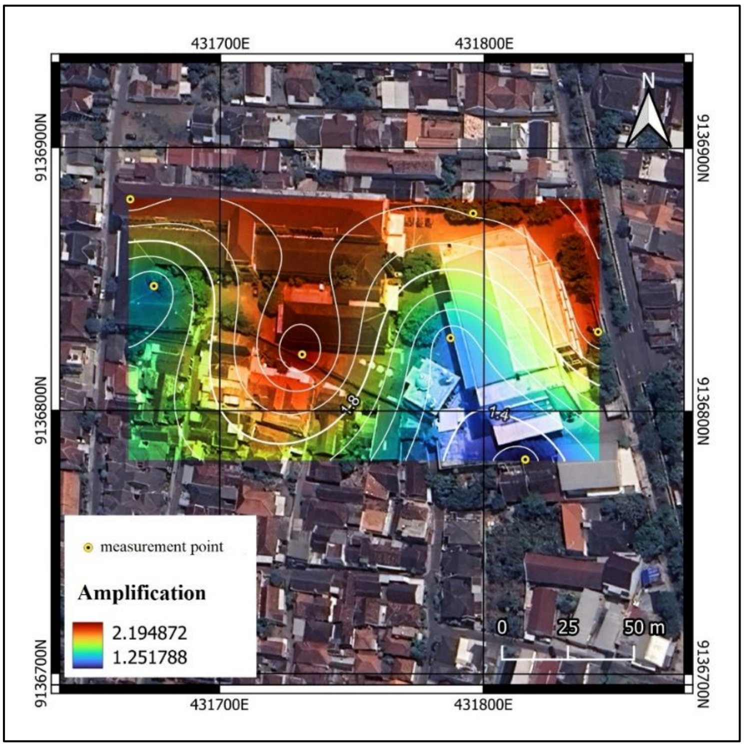

Figure 6. Amplification of the UST Campus.

Based on **Figure 6**, it is known that areas with high amplification values are dominated in the northern part of the campus and in the middle of the campus. The highest amplification value is 2.2 at measurement point 5. Low amplification is mostly located in the southern part of the campus with a range of 1.25 to 1.42 Hz. Meanwhile, moderate amplification has a range of 1.42 to 2 Hz. High amplification values have a strong correlation with earthquake-induced damage, according to research from (Nakamura, 2000) and (Bessason & Bjarnason, 2016). Microseismic measurements were conducted at the Universitas Sarjanawiyata Tamansiswa Campus in Umbulharjo District. Based on data on building damage caused by the 2006 Yogyakarta earthquake from Marjuki and Yogafanny (2008), Umbulharjo subdistrict is the area that suffered the most severe damage in the municipality of Yogyakarta. Umbulharjo subdistrict suffered severe damage to 4,875 buildings and 2,552 buildings collapsed. According to research Purnama et al. (2021), Umbulharjo has a high amplification value compared to other subdistricts. The amplification value is consistent with previous research results, partly because the microseismic measurements were taken during quiet periods. As in the research from (Heidari et al., 2014) which shows the amplification values calculated on holidays, indicates good agreement with previous research results, meaning that industrial noise can be minimized.

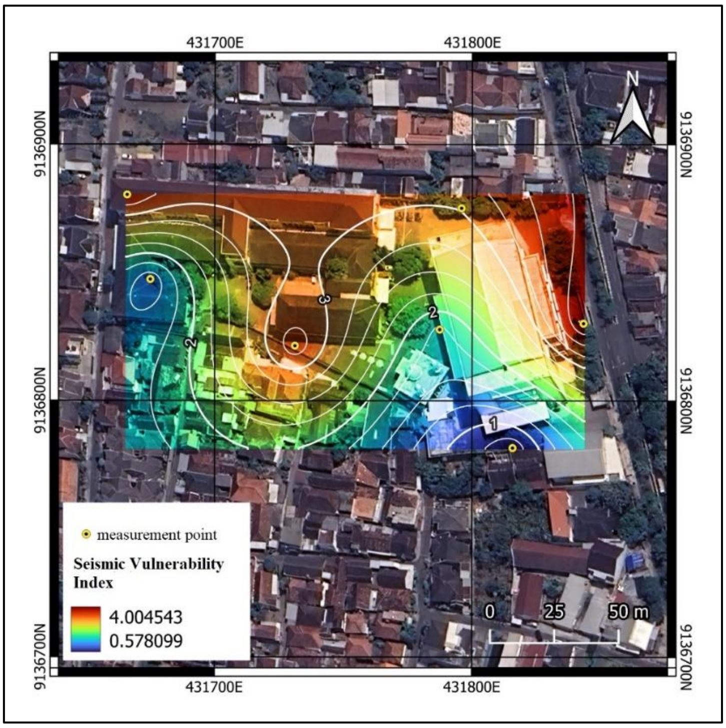

Figure 7. Seismic Vulnerability Index (Kg) of the UST Campus.

Based on the amplification values and dominant frequency values obtained, we can create a seismic vulnerability index (kg) for the Universitas Sarjanawiyata Tamansiswa campus area, as shown in **Figure 7**. The seismic vulnerability index can be used to provide recommendations in regional planning so as to minimize the level of damage that will occur. As in the research conducted by (Febriani et al., 2013) who conducted research in earthquake-prone areas in the city of Bengkulu. Based on **Figure 7**, the seismic vulnerability index (kg) in the UST Campus area ranges from 0.5 to 4. The relatively high kg values, indicated by red, are located east of the campus near the river, ranging from 3 to 4, while the central part of the campus has moderate kg values, shown in orange, ranging from 1.7 to 3. The low kg values, indicated by green to blue, are located south of the UST campus, ranging from 1.3 to 1.7. Based on the dominant frequency values, amplification, and seismic vulnerability index values, it was determined that the UST campus areas at risk of earthquake vulnerability are the northern, eastern, and central parts of the campus. These areas have low dominant frequency values, high amplification, and high seismic vulnerability indices.

5. CONCLUSION

An earthquake vulnerability map for the Universitas Sarjanawiyata Tamansiswa campus in Yogyakarta has been created based on physical parameters, namely dominant frequency, amplification, and seismic vulnerability index. The UST campus has a low dominant frequency value in the north, ranging from 1.1 to 1.22 Hz. This indicates the presence of fairly thick sediments. Meanwhile, high amplification values are observed in the northern, eastern, and central parts of the campus, ranging from 2 to 2.2. The seismic vulnerability index in the northern, eastern, and central parts of the campus is relatively high, ranging from 3 to 4, while the southern part has a lower index, making it safer.

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REFERENCES

Bard, P., Duval, A., Koehler, A., & Rao, S. (2004). Guidelines for the Implementation of the H/V Spectral Ratio Technique on Ambient Vibrations Measurements, Processing and Interpretation. *Interpretation A Journal Of Bible And Theology*, 169(December), 1–62. https://doi.org/DOI 10.1111/j.1365-246X.2006.03282.x

Bessason, B., & Bjarnason, J. Ö. (2016). Seismic Vulnerability of Low-Rise Residential Buildings Based on Damage Data From Three Earthquakes (Mw6.5, 6.5 and 6.3). *Engineering Structures,* 111(June 2000), 64–79. https://doi.org/10.1016/j.engstruct.2015.12.008

Bodin, P., Smith, K., Horton, S., & Hwang, H. (2001). Microtremor Observations of Deep Sediment Resonance in Metropolitan Memphis, Tennessee. *Engineering Geology,* 62(1–3), 159–168. https://doi.org/10.1016/S0013-7952(01)00058-8

Chatelain, J. L., Guillier, B., Cara, F., Duval, A. M., Atakan, K., Bard, P. Y., Azzara, R., Bonnefoy-Claudet, S., Borges, A., Sorensen, M. B., Cultrera, G., Di Giulio, G., Dunand, F., Fäh, D., Guéguen, P., Ripperger, J., Costa, P. T., Vassiliades, J. F., Vidal, S., & Wassner, J. (2008). Evaluation of The Influence of Experimental Conditions on H/V Results From Ambient Noise Recordings. *Bulletin of Earthquake Engineering,* 6(1), 33–74. https://doi.org/10.1007/s10518-007-9040-7

Febriani, Y., Daruwati, I., & Hatika, R. G. (2013). Analisis Nilai Peak Ground Acceleration dan Indeks Kerentanan Seismik Berdasarkan Data Mikroseismik Pada Daerah Rawan Gempa Bumi di Kota Bengkulu. *Jurnal Ilmiah Edu Research*, 2(2), 85–90.

Handayani, S., Niyartama, T. F., & Wibowo, N. B. (2019). Studi Site Effect (Tapak Lokal) Berdasarkan Pengukuran Mikrotremor di Kecamatan Ngluwar Kabupaten Magelang Jawa Tengah. *Prosiding Seminar Nasional Fisika Festival*, Yogyakarta, November, 92–101.

Heidari, R., Ghayamghamian, M. ., & Shomali, Z. . (2014). Site characterization of the source microtremors using the H/V method. Iranian Journal of Geophysics, 8(3), 74–85.

Hesti, H., Suharno, S., Mulyasari, R., & Hidayatika, A. (2021). Analisis Karakteristik Lapisan Sedimen Berdasarkan Data Mikrotremor di Area Rumah Sakit Pendidikan Unila. *JGE (Jurnal Geofisika Eksplorasi),* 7(2), 150–159. https://doi.org/10.23960/jge.v7i2.123

Jannah, D. M., Khoirunnisa, S., Rosyida, H., & Christalianingsih, F. E. (2024). Analisis Indeks Kerentanan Seismik Berdasarkan Nilai V S30 Pada Zona Terdampak Gempa Bumi (Studi Kasus: Gempa Cianjur 21 November 2022) Analysis of Seismic Vulnerability Index Based on Vs30 Values in Earthquake-*Affected Zones.* 9(2), 107–116. https://doi.org/10.33579/krvtk.v9i2.4972

Juarzan, L. I., Jafar, W. A. W., Hamimu, L. H., & Indrawati, I. (2023). Analisis Ketebalan Lapisan Sedimen Menggunakan Metode Horizontal to Vertical Spectral Ratio (HVSR) di Wilayah Pesisir Kecamatan Moramo Kabupaten Konawe Selatan. *Jurnal Rekayasa Geofisika Indonesia,* 5(03), 137–145. https://doi.org/10.56099/jrgi.v5i03.27

Kornhuber, K., Petoukhov, V., Petri, S., Rahmstorf, S., & Coumou, D. (2017). Evidence for Wave Resonance As A Key Mechanism For Generating High-Amplitude Quasi-Stationary Waves In Boreal Summer. *Climate Dynamics,* 49(5–6), 1961–1979. https://doi.org/10.1007/s00382-016-3399-6

Li, W., Yue, D., Wang, W., Wang, W., Wu, S., Li, J., & Chen, D. (2019). Fusing Multiple Frequency-Decomposed Seismic Attributes With Machine Learning for Thickness Prediction and Sedimentary Facies Interpretation in Fluvial Reservoirs. *Journal of Petroleum Science and Engineering*, 177(March), 1087–1102. https://doi.org/10.1016/j.petrol.2019.03.017

Listyani R.A.T. (2020). Identifikasi Petrofisik Batuan sebagai Pendukung Karakteristik Hidrolik Akuifer pada Sub DAS Code, Yogyakarta. *Jurnal Geosapta,* 6(2), 103. https://doi.org/10.20527/jg.v6i2.7473

Marjuki, B. & Yogafanny, E. (2008). *Profil Kebencanaan Provinsi Daerah Istimewa Yogyakarta.*

Moechtar, R.A.T. (2021). Dinamika Proses Pengendapan Sedimen Holosen di Hilir Sungai Bengawan Solo serta Wilayah Pasang Surut di Gresik dan Sekitarnya, Jawa Timur. *Jurnal Geologi Dan Sumberdaya Mineral*, 22(1), 9. https://doi.org/10.33332/jgsm.geologi.v22i1.553

Muzli, M., Mahesworo, R. P., Madijono, R., Siswoyo, S., Pramono, S., Dewi, K. R., Budiarta, B., Sativa, O., Sulistyo, B., Swastikarani, R., Oktavia, N., Moehajirin, M., Efendi, N., Wijaya, T. A., Subadyo, B., Mujianto, M., Suwarto, S., &

Pramono, S. (2016). Pengukuran Vs30 Menggunakan Metode Masw Untuk Wilayah Yogyakarta. *Jurnal Meteorologi Dan Geofisika,* 17(1), 25–32. https://doi.org/10.31172/jmg.v17i1.374

Nakamura, Y. (1989). Method for Dynamic Characteristics Estimation of Subsurface Using Microtremor on The Ground Surface. In *Quarterly Report of RTRI (Railway Technical Research Institute) (Japan)* (Vol. 30, Issue 1, pp. 25–33).

Nakamura, Y. (2000). Clear Identification of Fundamental Idea of Nakamura's Technique and Its Applications. *Proceedings of the 12th World Conference on Tokyo,* Paper no. 2656. http://www.sdr.co.jp/papers/n_tech_and_application.pdf

Perdhana, R. & Nurcahya, B. E. (2019). Seismic a Damage Distribution of 2006 Yogyakarta Earthquake. *E3S Web of Conferences*, 76, 4–7. https://doi.org/10.1051/e3sconf/20197603008

Prabowo, U. N., Budhi, W., & Amalia, A. F. (2020). Analisis Mikrotremor Untuk Mengevaluasi Kerentanan Gempabumi Ruangan Prodi Pend Fisika Ust. *Science Tech: Jurnal Ilmu Pengetahuan dan Teknologi,* 6(1), 10–16. https://doi.org/10.30738/jst.v6i1.6569

Purnama, A. Y., Nurcahya, B. E., Nurhanafi, K., & Perdhana, R. (2021a). Mikrozonasi Berdasarkan Data Mikrotremor dan Kecepatan Gelombang Geser di Kotamadya Yogyakarta. *Positron,* 11(2), 86. https://doi.org/10.26418/positron.v11i2.46860

Purnama, A. Y., Nurcahya, B. E., Nurhanafi, K., & Perdhana, R. (2021b). Mikrozonasi Berdasarkan Data Mikrotremor dan Kecepatan Gelombang Geser di Kotamadya Yogyakarta. *Positron*, 11(2), 86. https://doi.org/10.26418/positron.v11i2.46860

Putra, R.R. & Saputra, D. (2022). Assessment Tingkat Kerentanan Bangunan Bertingkat di Kampus Universitas Negeri Padang Menggunakan Gelombang Rayleigh. *Jurnal Serambi Engineering*, 7(1), 2638–2648. https://doi.org/10.32672/jse.v7i1.3826

Putri, A., Purwanto, M. S., & Widodo, A. (2017). Identifikasi Percepatan Tanah Maksimum (PGA) dan Kerentanan Tanah Menggunakan Metode Mikrotremor Jalur Sesar Kendeng. *Jurnal Geosaintek*, 3(2), 107. https://doi.org/10.12962/j25023659.v3i2.2966

Rahardjo, W., Sukandarrumidi, H. M., & Rosidi, R. (1995). *Peta Lembar Yogyakarta*, *Jawa Skala 1:100.000.*

Riswandi, H., Ikhsan, I., Maharani, Y. N., Wijayanto, W., Sunardi, B., Ekarsti, A. K., Rizkianto, Y., & Syaifudin, M. (2023). Pemetaan Mikrozonasi Bahaya Gempabumi Sebagai Upaya Pengurangan Risiko Bencana Di Yogyakarta. *Jurnal Mineral, Energi, Dan Lingkungan*, 7(1), 23. https://doi.org/10.31315/jmel.v7i1.7743

Satria, A., Resta, I. L., & MZ, N. (2020). Analisis Ketebalan Lapisan Sedimen dan Indeks Kerentanan Seismik Kota Jambi Bagian Timur. *JGE (Jurnal Geofisika Eksplorasi),* 6(1), 18–30. https://doi.org/10.23960/jge.v6i1.58

SESAME. (2004). Guidelines for the Implementation of the H/V Spectral Ratio Technique on Ambient Vibrations: Measurements, *Processing and Interpretation* (S. E. R. P. WP12 (ed.); pp. 1–62). SESAME European Research Project WP12.

Su, G., Shi, Y., Feng, X., Jiang, J., Zhang, J., & Jiang, Q. (2018). True-Triaxial Experimental Study of the Evolutionary Features of the Acoustic Emissions and Sounds of Rockburst Processes. *Rock Mechanics and Rock Engineering,* 51(2), 375–389. https://doi.org/10.1007/s00603-017-1344-6

Wibowo, N. B. & Huda, I. (2020). Analisis Amplifikasi, Indeks Kerentanan Seismik dan Klasifikasi Tanah Berdasarkan Distribusi Vs30 D.I.Yogyakarta Analysis of Amplification, Seismic Vulnerability Index and Soil Clasification Based On Vs30 In Yogyakarta. *Buletin Meteorologi, Klimatologi, dan Geofisika,* 1(2), 21–31. http://usgs.maps.arcgis.com/apps/we