Subsurface Identification of Campus I Universitas PGRI Yogyakarta using The Microtremor Wave Method

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Abstract. Thick layers of sediment can cause Prag damage to buildings in the event of an earthquake. The subsurface identification in the Campus I area of Universitas PGRI Yogyakarta needs to be done because of the increase of new multi-story buildings in the PGRI Campus area. The identification analysis uses HVSR (Horizontal to Vertical Spectral Ratio) so that the thickness of the sedimentary layer could show in the study area. The magnitude of the dominant frequency value was measured by the microtremor method somewhere illustrates the type of soil in the study area. Based on the results of data processing, it can show that the Campus I area of PGRI Yogyakarta University is composed of thick sedimentary layers with thicknesses ranging from 26.7 m - 59.3 m. Based on the distribution map, the most adhesive sediment layer is under the area of the Rectorate building and the Faculty of Business building. These results show the similarity to the Special Region of Yogyakarta, which is an area arranged in a basin with fill material in the form of volcanic deposits.

1. Introduction
Yogyakarta Province is one of the provinces that is prone to earthquakes, this is because Yogyakarta is close to the area where the Eurasian Plate meets the Australian Indian Plate [1]. DIY is located at 7˚33 ' - 8˚15' South Latitude and 110˚5 ' - 110˚50' East Longitude which is directly adjacent to an active volcanic volcano in the north and an active subduction zone in the south. Yogyakarta was hit by an earthquake in 2006 with a magnitude of 6.3 SR which claimed a lot of casualties and damaged buildings in large numbers [2]. The Yogyakarta earthquake killed more than 5,700 people and more than 200 thousand families were left homeless due to the earthquake [3]. The 2006 Yogyakarta earthquake covered the areas of Bantul, Yogyakarta Municipality, Kulonprogo, Gunung Kidul, Sleman, Solo, Karanganyar, Klaten, and Prambanan. Bantul Regency is the district with the highest number of casualties, namely 4,121 people died and 12,026 people were injured. Meanwhile, Yogyakarta Municipality, as many as 195 people died, 318 people were injured [3].

Damage from the impact of the earthquake is not only caused by the magnitude of the earthquake vibration strength, but also from the geology of an area [4]. An area prone to damage from earthquakes occurs in areas that have soft and thick sediments in the hard bedrock [5]. The Unit 1 campus area of Universitas PGRI Yogyakarta is located in Kasihan District, Bantul Regency, DIY. In the unit 1 area, there have been construction of new buildings in the last 5 years. Based on this, it is necessary to research the seismic susceptibility index with microzonation measurement methods using microseismic data to determine the level of potential hazards of earthquakes in the Unit 1 Campus area of Universitas
PGRI Yogyakarta. The advantage of this method is to know the distribution map of the level of vulnerability of an area to earthquake disasters considering that the area is a public area for educational activities.

2. Literature review

2.1. Microtremor

Microtremor is a very minimal or small ground vibration with a continuous intensity originating from various kinds of vibrations, including those from factory machine activities, vehicle traffic, construction construction, and so on [6]. Microtremor can be defined as a natural harmonic vibration from the ground that can occur continuously, trapped in the surface sediment layer, reflected from the presence of a layer boundary plane with a static frequency, caused by micro vibrations under the soil surface and other natural activities.

2.2. Wave Type in HVSR Microtremor

According to [7], HVSR is a body wave, in this case an SH wave and ignores surface waves (Rayleigh waves and Love waves). HVSR is considered to be the same as the transfer function between the wave vibrations in sediment and bedrock, which means that the amplitude and frequency of the HVSR peaks are local amplifications and frequencies. Different opinions were given by several researchers. HVSR curve is the contribution of surface waves [8]. According to [9] many studies have been done to classify the source of this vibration. Based on the results of these studies, [9] made conclusions by dividing natural vibration sources into two, namely natural (natural) and anthropic (urban) based on their frequency values as shown in Table 1 below.

| Frequency | Source                                      |
|-----------|---------------------------------------------|
| < 0.5 Hz  | Great sea waves and weather conditions.     |
| ≈ 1 Hz    | wind and local weather conditions¹         |
| > 1 Hz    | Human activity.                             |

The amplitude of the microtremor spectrum changes both daily and weekly. [10] in [9] state that the maximum amplitude during the day is higher than at night. The magnitude of the dominant period also differs between day and night. The predominant period at night is higher than the dominant period during the day.

2.3. Fourier transform

The Fourier transform in microseismic is a method most often used for signal analysis because the quantity that determines a signal is in the frequency domain. Whereas a collection of sinusoidal harmonic waves is also called the Fourier Series. The principle of Fourier transform is used in order to convert data from time domain into frequency domain. This can be shown in the equation below:

\[ F(w) = \int_{-\infty}^{\infty} f(t)e^{-iwt}dt \]  

\( F(w) \) is a form of Fourier transformation of \( f(t) \). The transformation can be calculated faster by using FFT (Fast Fourier Transform) with digital computing.

2.4. Sediment layer thickness (h)

The thickness of the sediment is related to the dominant frequency and the velocity of the S wave. The relationship between the thickness and the resonant frequency can be determined based on the closed organa pipe rule. The relationship between these three quantities can be explained from a simple model in the form of 2 layers of surface where the hard rock from the basement is covered by a layer of soft
sediment with a thickness of S wave velocity and (Figure 1).

![Diagram of sediment thickness and amplitude](image)

**Figure 1.** Relationship between sediment thickness and amplitude (modified from [11])

The resonant frequency of this system occurs for the thickness of the sediment which is an odd multiple of $\lambda/4$. The transfer function has a maximum value at the resonant frequencies $(f_r)$ [11].

$$f_r = \frac{nV_S}{4h} \quad (n = 1, 3, 5, \ldots)$$  \hspace{1cm} (2)

At the fundamental frequency, $n = 1$, the relationship between the fundamental frequency and the thickness of the sediment is given by:

$$f_0 = \frac{V_S}{4h}$$  \hspace{1cm} (3)

Thus the thickness of the sediment layer is expressed by the following equation.

$$h = \frac{V_S}{4f_0}$$  \hspace{1cm} (4)

### 3. Research Methodology

Microtremor data collection was carried out in the Campus Area of Unit 1 PGRI Yogyakarta University, Kasihan District, Bantul Regency, Yogyakarta Special Region. Data obtained from measurement results at 14 points with a distance of 15-20 meters. The survey design map in this study can be shown in figure 2.

In this study, a Lennartz Electronic type LE 3D / 20s seismometer was used. The microtremor data obtained is single station microtremor data in the form of signals in 3 components, namely the horizontal north-south (N-S), east-west horizontal (E-W), and vertical (Z) components. The time required at each recording point is 20-30 minutes. The data obtained from measurement is in the form of time series data, meaning that the measurement data is still in the time domain. The signal obtained from the measurement consists of a transient signal and a stationary signal. In the microtremor, the required signal is a stationary signal, which is a signal that has the same amplitude and does not vary with time. The data obtained were then processed with Geopsy software to obtain the maximum value of the dominant frequency and amplitude with the HVSR analysis process.
Figure 2. Measuring Point Map

Figure 3. Research Methodology Flowchart
The signal processing process in Geopsy software, baseline corrections are carried out to remove trendlines from data caused by very low frequency noise. Baseline correction aims to bring the signal to oscillate on a balanced axis, namely on the $y = 0$ axis, so that the results of the FFT peak are not dominated by the zero hertz frequency and in order to make the processed data symmetrical between the maximum and minimum amplitudes. The next step is windowing to select stationary signals by eliminating transient signals. In the windowing stage, some data is selected manually and can also be done automatically by the program. This window selection is based on the signal in the most stationary time zone which will later be Fourier transformed into the frequency region.

4. Results and discussion
The results obtained from measurements in the form of natural frequency ($f_0$) and amplification ($A_0$) values are presented in the HVSR curve which is then used to determine the thickness of the sediment layer in the study area. The measured HVSR curve is shown in Figure 4.

![Figure 4. HVSR curve point UPY-09 and UPY-13](image)

The dominant frequency value describes the thickness of the sediment layer below the surface and the speed of the waves passing through the medium. The greater the value of a dominant frequency, the smaller the thickness of the sediment layer, and vice versa. If the value of the dominant frequency is high, then an area tends to have a low level of vulnerability. The distribution of the dominant frequency values at Campus I PGRI Yogyakarta University ranges from 1.27 Hz to 2.79 Hz. Amplification is an enlargement of seismic waves that occurs due to significant differences between layers. The value of the sediment thickness is influenced by the resonant frequency and secondary wave velocity. The resulting sediment thickness ranges from 26.20 m to 52.35 m.
5. Conclusion

Based on the results of the discussion analysis, it can be concluded that the value of the dominant frequency in the Campus I area of the PGRI University Yogyakarta ranges from 1.27 Hz to 2.79 Hz and the distribution of amplification values is 1.28 to 2.05. The dominant frequency ($f_0$) value indicates a thin layer of sediment. The low dominant frequency ($f_0$) indicates the presence of a thick layer of soft sediment, so it greatly affects the danger of long-period vibrations that can threaten high-rise buildings. The thickness of the sediment layer in the study area ranges from 26.20 m to 52.35 m.

References

[1] Brotopusipto, K.S, Tiar P., dan Ferry M.W., 2006, Percepatan Getaran Tanah Maksimum Daerah Istimewa Yogyakarta 1943-2006, J. Geofisika, 2006/1.
[2] Sunarjo, Gunawan, M.T., Pribadi, S., 2012, Gempabumi Edisi Populer, Badan Meteorologi Klimatologi dan Geofisika, Jakarta.
[3] Wuryanto, L. E. dan Hadi, S., 2006, Penilaian Awal Kerusakan dan Kerugian Bencana Alam di Yogyakarta dan Jawa Tengah, BAPPENAS, Yogyakarta
[4] Daryono, Sutikno, Sarthadi, Dulbahri, dan Brotopusipto, 2009, Pengkajian Local Site Effect di Graben Bantul Menggunakan Indek Kerentanan Seismik Berdasarkan Pengukuran Mikrotremor, Jurnal Kebencanaan Indonesia, 2(1), pp 456-467
[5] A. Wulandari, S. Suhanro, R. Rustadi, dan R. R. (2016) ‘MICROZONATION MAPPING THE PRONE EARTHQUAKE AREAS OF’, Jurnal Geofisika Eksplorasi, 4(1), pp. 33–48.
[6] Kanai, K. (1983) Seismology in Engineering. Tokyo, Japan: Tokyo University.
[7] Nakamura, Y., 2000, Clear Identification of Fundamental Idea of Nakamura's Technique and its Applications, Proc XII World Conf. Earthquake Engineering, New Zealand.
[8] Arai, H. and Tokimatsu, K., 2000, Effects of Rayleigh and Love Waves on Microtremor H/V Spectra, Proc XII World Conf. Earthquake Engineering, New Zealand.
[9] SESAME, 2004a, Site Effects Assessment Using Ambient Excitations, Project No. EVG1-CT-2000-00026, European Commission – Research General Directorate
[10] Kanai, K., 1966, Improved Empirical Formula for Characteristics of Stray (sic) Earthquake Motions. Page 1-4 of: Proceedings of the Japanese Earthquake Symposium. Not seen. Reported in Trifunac & Brady (1975).
[11] Seht, M. I. and Wohlenberg, J., 1999, Microtremor Measurements Used to Map Thickness of Soft Sediments, Bulletin of the Seismological Society of America, Vol. 89, No. 1, pp. 250-259.