Microzonation Efforts of Disaster Mitigation using Mikrotremor Refraction Method (ReMi) in Kuwu, Grobogan

Budi Legowo*, Harjana, Kidura Wildan Rantanaka
Physics Department, Faculty of Mathematics and Natural Science, Universitas Sebelas Maret, Surakarta

*Email: pakbeel@staff.uns.ac.id

Abstract. Microtremor refraction is one application of geophysical methods for disaster mitigation microzonation in a region based on dominant frequency value and amplification value. The purpose of this study is to determine microzonation of soil vulnerability index ($K_g$) from the result of the dominant frequency value ($f_0$) and amplification ($A_0$). This research has been done in the Kuwu of Grobogan District using P.A.S.I Seismograph Mod. 16S24-P and 3D Borehole Geophone Model GFA 60/100. Measurements at each point for 20 minutes and performed for 2 repetitions. The interval of each measurement point is about 350-400 m with a total of 12 points of measurement. Microtremor data processing using Geopsy and Surfer 11 software to create microzonation maps. The result of the dominant frequency value is between 2.14 Hz to 10.26 Hz with an amplification value between 1.47 to 2.40. The value of soil vulnerability index is between 0.23 to 2.20. The location with the highest soil vulnerability index value is at location 5 with a soil vulnerability index value of 2.20.

1. Introduction

Microtremor Refraction could be detected in natural frequencies in the soil conditions of a region. Microtremor refraction measurement is also effective and economical for the experiment because microtremor refraction could determine the characteristics of soil vulnerability index value of the land in a considerable area [1]. Microtremor measurement could be used for determining dynamic characteristics from soil conditions of a region, therefore could be used for microzonation purposes in an area [2]. Microtremor measurement could be used for determining dominant frequency, amplification, and vulnerability index value. The basic principle of the Horizontal to Vertical Spectral Ratio (HVSR) method is due to the Horizontal S wave’s is trapped in the sedimentary layer boundary with bedrock [3].

Dominant frequency in HVSR Method is the dominant frequency value in an area that often appears. In the event of an earthquake or ground movement that has the same frequency as the dominant frequency, resonance will occur in a layer which results in seismic wave amplification in an area. Amplification is a pattern of enlargement of seismic waves due to very significant differences between layers. Seismic waves will be enlarged if they propagate through a medium that is softer than the previous medium. The amplification value parameter and the dominant frequency value could be used to find the value of the soil vulnerability index. The value of the vulnerability index obtained from an area could be detected in weak zones or damage zones in the event of an earthquake or incidental ground movement. The higher the soil vulnerability index in an area, the higher the level of damage, because the level of soil structure stability in the region will be lower [4].
2. Research Method

This Research has been done in the Kuwu, Grobogan district. Kuwu has a geological subject, namely Kuwu Bledium or mud Volcano that comes out from the bowels of the earth continuously, thus mud Volcano could be affected by the surrounding soil conditions. In this research used the microtremor refraction method for measurement. The tool used is P.A.S.I Seismograph Mod. 16S24-P and 3D Borehole Geophone GFA 60/100 models for recorded microtremor signals. Measurements at each point for 20 minute and repeated two times. The interval of each measurement point is about 350-400 m with a total of 12 points of measurement. Global Positioning System (GPS) used to determine the coordinates at each measurement point. Data recorded by P.A.S.I Seismograph Mod. 16S24-P which is in the form of a data file format (.DAT) contained the recorded of the microtremor wave, then the file is processed used several software such as Microsoft Excel software, Sublime 3 text software, Geopsy software and Surfer11 software to get a map of the soil vulnerability microzonation index.

3. Data Analysis

The values of the dominant frequency ($f_0$) and amplification ($A_0$) at each measurement point are used as parameters could be required to determine the value of the soil vulnerability index ($K_v$). Dominant frequency value, amplification, and soil vulnerability index value are then visualized into microzonation maps based on measured parameters in Kuwu, Grobogan District.

3.1. Dominant Frequency

Based on the result of data processing obtained the value of the dominant frequency between 2.14 Hz to 10.26 Hz. Then it could be correlated with the soil classification based on the dominant frequency value of Kanai and Omete-Nakajima as follows:
Table 1. Dominant frequency result

| Location | Dominant Frequency |
|----------|--------------------|
|          | Type I | Type II | Type III | Type IV |
| Location 1 |       |         | 2.83     |         |
| Location 2 |       | 7.21    |          |         |
| Location 3 |       |         |          | 2.14    |
| Location 4 | 10.28  |         |          |         |
| Location 5 |       |         | 2.18     |         |
| Location 6 |       | 7.24    |          |         |
| Location 7 |       | 8.21    |          |         |
| Location 8 |       |         | 2.64     |         |
| Location 9 |       |         |          | 2.14    |
| Location 10 |      | 8.00    |          |         |
| Location 11 |      |         | 2.65     |         |
| Location 12 |      |         |          | 2.24    |

Table 2. Soil classification based on the dominant frequency value [5][6]

| Soil Classification Type | Dominant Frequency (Hz) | Kanai Classification | Description |
|-------------------------|-------------------------|----------------------|-------------|
| I                       | 6.667 - 20              | Tertiary rock or older. Consists of hard sandy, gravel, etc | The thickness of the sediment surface is very thin and is dominated by hard rock |
| II                      | 4 - 10                  | Alluvial rocks with a thickness of 5m. Consisted of sandy-gravel, sandy hard clay, loam, etc. | The surface sediment thickness entered into the medium category of 5-10 meters |
| III                     | 2.5 - 4                 | Alluvial rocks with a thickness of > 5m. Consisted of sandy-gravel, sandy hard clay, loam, etc. | Surface sediment thickness entered into the thick category, about 10-30 meters. |
| IV                      | < 2.5                   | Alluvial rocks formed from delta sedimentation, topsoil shows, sludge, etc. with a depth of 30 meters or more. | The thickness of the surface sediment is very thick. |
Figure 2. Dominant frequency microzonation map

Figure 2 Shows the area in location 1, 3, 5, 8, 9, 11 and 12 is dominated by orange with the dominant frequency range between 1 Hz to 3 Hz. Areas in locations 2, 6, 7 and 10 are dominated by green with the dominant frequency range between 6 Hz to 8 Hz. The area in location 4 is dominated by blue with the dominant frequency range between 8.5 Hz to 10.5 Hz. Based on the results of the research, the area is dominated by orange colour the sediment layer thicker compared with the area dominated by green and blue colors. Areas dominated by blue are classified as soil type I, because these types of soil are classified as tertiary or older rock classifications consisting of hard sandy and gravel which are very thin and dominated by hard rock. The thicker the sediment layer will produce a small dominant frequency value [7].

3.2. Amplification

Based on the results of data processing obtained the amplification values between 1.47 to 2.40. Then it could be correlated based on 4 zone amplification factor values in Table 3. and Table 4.

Figure 3. shows the area at locations 4, 7 and 12 is dominated by blue colour with an amplification range between 1.45 to 1.70. The area in locations 1, 2, 3 and 11 is dominated by green colour with an amplification range between 1.80 to 1.95. Areas in locations 5, 6, 9 and 10 are dominated by orange colour with an amplification range between 2.10 to 2.40.

In this research, if the area is hit by a shock, the area dominated by orange colour on the map will experience a higher level of damage than the green and blue colour’s area. This could have occurred because the amplification value is affected by the wave velocity, if the wave velocity is smaller than the amplification factor gets bigger, this shows that the amplification factor is related to the level of rock density, so the reduction in rock density will be increased the amplification factor value [8].
Table 3. Amplification result

| Location   | Amplification |
|------------|---------------|
| Location 1 | 1.86          |
| Location 2 | 1.88          |
| Location 3 | 1.99          |
| Location 4 | 1.55          |
| Location 5 | 2.19          |
| Location 6 | 2.40          |
| Location 7 | 1.57          |
| Location 8 | 1.72          |
| Location 9 | 2.14          |
| Location 10| 2.30          |
| Location 11| 1.90          |
| Location 12| 1.47          |

Table 4. Amplification factor value in 4 zones [9][10]

| Zone                        | Amplification Factor |
|-----------------------------|----------------------|
| Zone 1 (low amplification)  | af<3                 |
| Zone 2 (medium amplification)| 3≤af<6               |
| Zone 3 (high amplification) | 6≤af<9               |
| Zona 4 (very high amplification) | af≥9         |

Figure 3. Amplification Microzonation map

3.3. Soil Vulnerability Index

Soil vulnerability index ($K_v$) is an index that shows the vulnerability of deformed soil layers. Therefore, the value of the soil vulnerability index is useful for detecting weak zones (unconsolidated sediment) or areas that have the potential due to damage, and soil pressure during shocks. The higher
the soil vulnerability index in an area, the higher the level of damage caused by shocks and earthquakes [11].

**Table 5. Soil vulnerability index result**

| Location  | $K_g$ |
|-----------|-------|
| Location 1 | 1.23  |
| Location 2 | 0.49  |
| Location 3 | 1.85  |
| Location 4 | 0.23  |
| Location 5 | 2.20  |
| Location 6 | 0.80  |
| Location 7 | 0.30  |
| Location 8 | 1.12  |
| Location 9 | 2.14  |
| Location 10| 0.66  |
| Location 11| 1.36  |
| Location 12| 0.97  |

Based on data processing in Table 5. The smallest value of soil vulnerability index 0.23 is at location 4 and the highest is 2.20 at location 5. In Figure 4. Shows the area in locations 2, 4, 6, 7, and 10 is dominated by blue color with a range of soil vulnerability index between 0.20 to 0.70. The area in locations 8 and 12 is dominated by green color with a range of soil vulnerability index between 0.80 and 1.00. Areas in locations 1, 3, 5, 9 and 11 are dominated by orange color with a range of soil vulnerability index between 1.10 and 2.30.

**Figure 4. Soil vulnerability index microzonation map**

Figure 4. shows the relation of dominant frequency parameters ($f_0$) and amplification factors ($A_0$) to the value of the soil vulnerability index ($K_g$). If the greater the value of the amplification factor, it
tends to have the potential for large resonance in the area, and vice versa with regions that have low amplification factor values. The greater the value of the dominant frequency, the region will be more resistant to shocks and movement of the land. Based on Figure 4. The orange colour location has a higher level of vulnerability to shocks compared to areas that are green and blue colors when shocks occurred in the research area.

Figure 4. shows the area dominated by blue colour is getting to the north, the smaller the soil vulnerability index value, while the more south gets bigger the soil vulnerability index value. Areas that are dominated by orange colour in locations 5 and 9 needed to be concerned in this research because in the south direction the research area approaches the source of Mud Volcano namely Bledug Banjar and Bledug Grabagan.

In this research area, it is necessary to have a mitigation effort based on the value of the soil vulnerability index. One mitigation effort that could be done is by built buildings that meet the requirements as buildings that resisted shock against earthquakes and incidental ground movements. Meanwhile, both the society and the local government must always be vigilant and cautious that in a region with a high vulnerability index, there will be more damage if an earthquake or ground movement occurred incidentally.

4. Conclusion
The dominant frequency value in the Kuwu area is between 2.14 Hz to 10.26 Hz with an amplification value between 1.47 to 2.40. The value of the soil vulnerability index 0.23 to 2.20. The location with the highest soil vulnerability index value is at location 5 with a soil vulnerability index value of 2.20. The higher the land vulnerability index in an area, the higher the level of damage caused by shocks.

References
[1] Nurrahmi, Efendi, R., & Sandra. (2015). Analisis Kecepatan Gelombang Geser Vs30 Menggunakan Metode Refraksi Mikrotremor (ReMi) di Kelurahan Talise. Gravitasi, Vol. 14 No.1 ISSN : 1412-2375.
[2] Kyaw, Z. L., Priumijoyo, S., Husein, S., Fathani, T. F., & Kiyono, J. (2015). Seismic Behaviors Estimation of the Shallow and Deep Soil Layers Using Microtremor Recording and EGF Technique in Yogyakarta City, Central Java Island. Procedia Earth and Planetary Science, Vol 12, 31-46.
[3] Mucciarelli, M., Other, C., Gosar, D., Herak, A., & Albarello, M. (2008). Assessment of Seismic Site Amplification and of Seismic Building Vulnerability in the Republic of Macedonia, Croatia and Slovenia. The 14th World Conference on Earthquake Engineering, (pp. 12-17). Beijing, China.
[4] Rahmaningtyas, A. P., Purwanto, S. M., & Widodo, A. (2017). Identifikasi Percepatan Tanah Maksimum (PGA) Dan Kerentanan Tanah Menggunakan Metode Mikrotremor I Jalur Sesar Kendeng. Jurnal Geosaintek, 03, 02.
[5] Kanai, K. (1983). Seismology in Engineering. Japan: TokyoUniversity.
[6] Arifin, S. S., Mulyatno, B. S., Marjiyono, S., & Roby. (2014). Penentuan Zona Rawan Guncangan Bencana Gempa Bumi Berdasarkan Analisis Nilai Amplifikasi HVSR Mikrotremor dan Analisis Periode Dominan Daerah Liwa dan Sekitarnya. Jurnal Explorasi, Vol 2, 1.
[7] Prastowo, D. (2015). Klasifikasi Tapak Lokal Berdasarkan Data Mikrotremor Menggunakan Metode HVSR Di Daerah Epimetal Borobudur Kabupaten Magelang. Skripsi. Yogyakarta: Universitas Gajah Mada.
[8] Putri, Y. D. (2016). Mikrozonasi Indeks Kerentanan Seismik Di Kawasan Jalur Sesar Opak Berdasarkan Pengukuran Mikrotremor. Skripsi. Yogyakarta: Universitas Negeri Yogyakarta.
[9] Setiawan, J. R. (2009). Mikrozonasi Seismitas Daerah Yogyakarta Dan Sekitarnya. Tesis. Bandung: Institut Teknologi Bandung.
[10] BMKG. (2010). Kajian Kerawanan Bahaya Gempabumi di Kabupaten Bantul, DIY. Laporan
Hasil Kerja, Pusat Penelitian dan Pengembangan Badan Meteorologi Klimatologi dan Geofisika.

[11] Winoto, P. (2010). Analisis Mikrotremor Kawasan Universitas Brawijaya Berdasarkan Metode HVSR. Thesis. Malang: Universitas Brawijaya.