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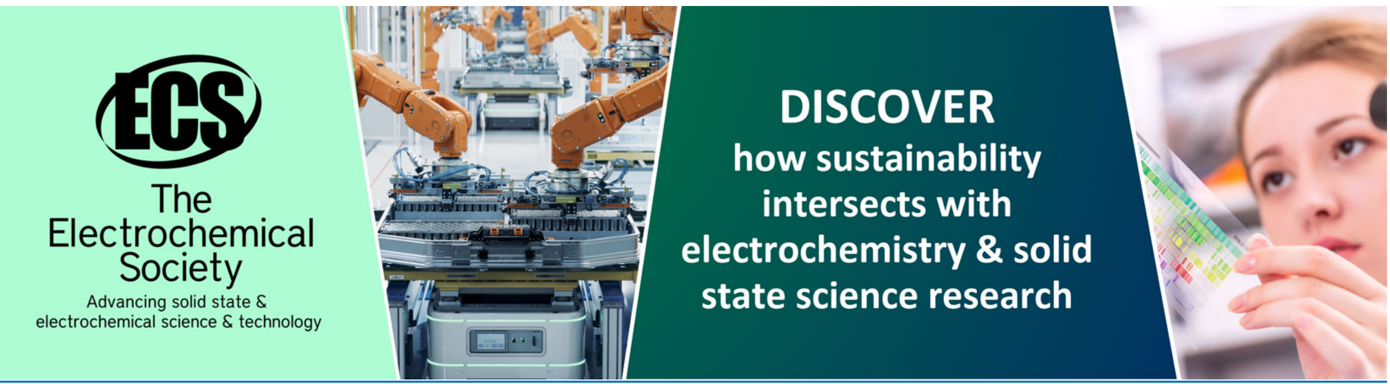

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A microtremor analysis for microzonation of seismic vulnerability index by using horiziontal to vertical spectral ratio in the southern area of Klaten regency

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Abstract. The dominant frequency and amplification factor are the parameter used to determine the value of seismic vulnerability index of an area. This research aims to determine the f_0 and A_0 in the southern area of Klaten regency. Besides, in this research a value range of K_g in the southern area of Klaten regency is obtained.This research was done in the southern area of Klaten regency by using P.A.S.I Seismograph Mod. 16S24-P, 3D Borehole Geophone Model GFA 60/100. The data acquisition was done in 12 different locations with the interval being about 5 km. In each location, the measurement needed 20 minutes and was done with three times repetition. The microtremor data obtained were processed by using the Geopsy software so that HVSR curve was obtained. From the HVSR curve, the f_0 and A_0 value can be determined which then were used to determine the value of K_g. After that, the value range of f_0, A_0, and K_g obtained was made into a contour map by using Software Surfer.The result of the research shows that the value of f_0 in the southern areas of Klaten regency is in the range of 4.104 Hz to 9.300 Hz, the value of A_0 is in the range of 1.326 to 2.328, and the value of Kg is in the range of 4.259 x 10-5 s2/cm to 59.873 × 10-5 s2/cm. The microzonation result with the minimum K_g value of 3.00 × 10−1 s2/cm is located in Pedan Subdistrict and the maximum K_g value of 15.704× 10−1 s2/cm is spread in Prambanan Subdistrict. Introduction

1. Introduction

Earthquakes are a natural phenomenon and they occur abruptly. It cannot be predicted when, where, or how strong they will be. Their impact is typically very significant and often causes substantial losses due to infrastructure damages and/or fatalities. The impact of an earthquake with a certain magnitude is often very diverse [11].

Klaten is a city that becomes a part of Surakarta City, Central Java, Indonesia. As a city possessing strong tourism potential, Klaten becomes one of culture-based tourism destinations that is interesting to be visited. Referring to the tourism potential of Klaten above, it is expected that generally the infrastructures including public facilities will be provided by central government or local government as the public service to support and foster the tourism activities in Klaten. The prepared construction also needs to be adjusted to the soil's geological condition, so that the building can stand firm. Considering that the southern area of Klaten regency is located in the area having a quite high potential of earthquake, an information is needed to give a description about the earthquake vulnerability level as a reference in the construction of earthquake-resistant buildings. In making the planning for the construction of earthquake-resistant buildings, it is needed to perform an analysis of soil vulnerability that is caused by the earthquake which later on a seismic vulnerability map depicting the vulnerability level toward earthquakes for the need of spatial and territorial planning or construction of earthquake-resistant buildings, will be obtained.

One of the methods that can be used to create a vulnerability zonation of seismic activity is micro tremor method. The micro tremor data measured can be used to measure the seismic vulnerability index by using HVSR method. The parameter produced from the HVSR method is the predominant and amplification frequencies.

Microtremor HVSR method is generally used to microzonation and research the areal response. This method reviews that the amplification produced by surface layer can be estimated through the comparison of horizontal and vertical spectral amplitude. This method is known as Nakamura technique.[4]

HVSR value can be measured by using the comparison of maximum horizontal movement with the maximum vertical movement which is related with the soil's solidity and amplification factor. The result of HVSR can be used to determine the soil's characteristics based on the dominant frequency and amplification factor. The equity of HVSR can be written as follows:

$$HVSR = \frac{\sqrt{(A_{(U-S)}(f))^2 + (A_{(E-T)}(f))^2}}{(A_{(v)}(f))} \tag{1}$$

Explanation:

$A_{(U-S)}(f)$ = The spectrum amplitude value of eastern-southern component frequency

$A_{(E-T)}(f)$ = The spectrum amplitude value of western-eastern component frequency

$A_{(V)}(f)$ = The spectrum amplitude value of vertical component frequency [10]

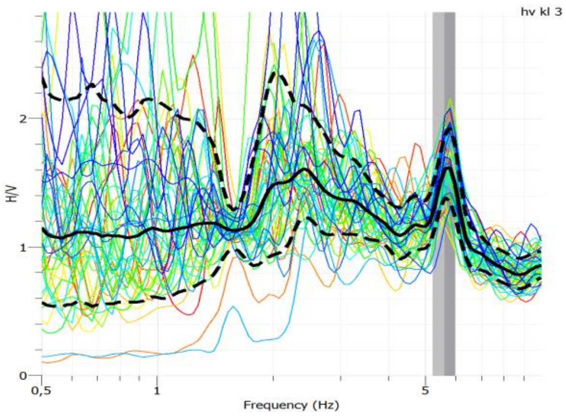

Figure 1. An example of HVSR curve

Lachet dan Brad (1949) [3], did a simulation by using 6 simple geological structure with a combination of contrast variation of the wave speed and soil thickness showing that there is a correlation between the dominant frequency and geological condition.

Table 1. Soil Classification based on the Soil Dominant Frequency [1]

Soil Classification	Dominant Frequency Hz	Kanai Classification	Explanation
Type I	6.6 - 20	Tertiary rocks	The layer is not thick and consists of hard rocks (< 5m)
Type II	10 - 4	Pebbly sand	The layer's thickness is thicker than that of type I (5-10)
Type III	2.5 - 4	*Alluvial* rocks and buff formation	The layer's thickness is 10-30m
Type IV	< 2.5	Alluvial rocks formed from sedimentation	The layer's thickness is very thick.

Amplification happens because of seismic waves undergoing an enlargement and having significant differences between the layers. It is caused by the propagation of seismic wave from a medium to another medium which causes wave enlargement. The comparison between the soil surface layer and the lower surface layer will depend on the amplification factor.

Table 2. Zone Clarification based on amplification factor (fa) [2]

Zone	**Amplification Factor**
Zone 1 (low amplification)	fa< 3
Zone 2 (medium amplification)	3≤fa<6
Zone 3 (high amplification)	6≤fa<9
Zone 4 (very high amplification)	fa≥9

The higher comparison the impedance contrast, the higher the amplification factor will be. The amplification value has a linear comparison toward the value of horizontal and vertical ratio (H/V) [8]. The seismic susceptance index is an index showing the degree of susceptibility of a land surface layer to a soil deformation during an earthquake [5]. Areas that have low seismic susceptibility indexes are potentially small to be damaged in the event of an earthquake. Meanwhile, areas with high seismic susceptibility indexes are potentially damaged during earthquakes seismic vulnerability index value can be formulated as [6]:

$$K_g = \frac{A_0^2}{f_0} \quad (2)$$

2. Experimental Methods

The method used in this research is a microtremor method. In the data collection process, a location map to determine the points which data will be acquired is needed. There are 12 points in which data acquisition will be done, the distance of each point is about 5 km. In each point, altitude position, latitude, and longitude will be noted in order to determine the position of the point acquired.

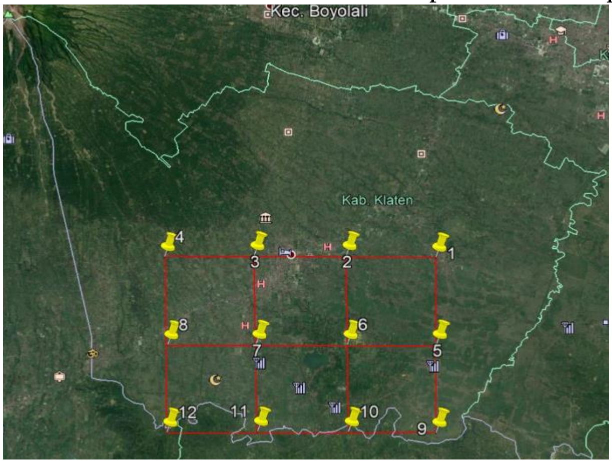

Figure 2. Location map of research area.

The microtremor measurement data acquired from the field are in the form of natural wave files with (.DAT) format. Those files were converted first into the format (.saf) which was done by using Geopsy software so that the waveform data will be able to be read in the form of numbers. After converting the data, the microtremor data in the form of natural wave files were then processed by using Geopsy software so that the value of dominant frequency and amplification is acquired. In this stage, the data in the form of coordinate points, f_0, A_0, and K_g were put in a table by using Microsoft Excel Software. Those data were then inputted in the Software Surfer 11 so that a conation contour map toward earthquake vulnerability could be made.

3. Results and Discussion

The results show that the southern region of Klaten district has the dominant frequency (f_0) varswies with a minimum value of 4.104 Hz in Trucuk Subdistrict and a maximum value of 9,300 Hz in Pedan Subistrict. Based on the predominant frequency microzonation (f_0) of Figure 3, the dominant frequency (f_0) obtained with a mean value of 2.6 Hz to 6.67 Hz spread in the Trucuk Subdistrict, Pedan Subdistrict, Klaten Utara Subistrict, Karangnongko Subistrict, Bayat Subistrict, Klaten Selatan Subistrict, Jogonalan Subdistrict, Gantiwarno Subistrict, and Prambanan Subdistrict. Meanwhile, the dominant frequency value (f_0) with the value of 6.67 Hz to 9.5 Hz spread in Pedan Subdistrict, Cawas Subdistrict, and Gedang Sari Subdistrict. Dominant frequency value is a reflection from the soil's physical condition which is thick or the thin sediment layer of an area. Petermans *et. al*. (2006) [9] stated that predominant frequency value has a strong relationship with the sediment thickness, which means the lower the predominant frequency, the thickness of the sediment layer will be higher.

Amplification is a wave-strengthening factor which is produced by the structure of a layer. Therefore, it can be concluded that an area having small dominant frequency has the potential to have more severe damage during an earthquake because it has high amplification compared to the one having great dominant frequency but its amplification is low. Based on the microzonation map shown in figure 4, the amplification factor in the southern area of Klaten regency is included as having low amplification with the highest amplification is the area located around Prambanan Subdistrict with amplification factor value (A_0) of 2.32845.

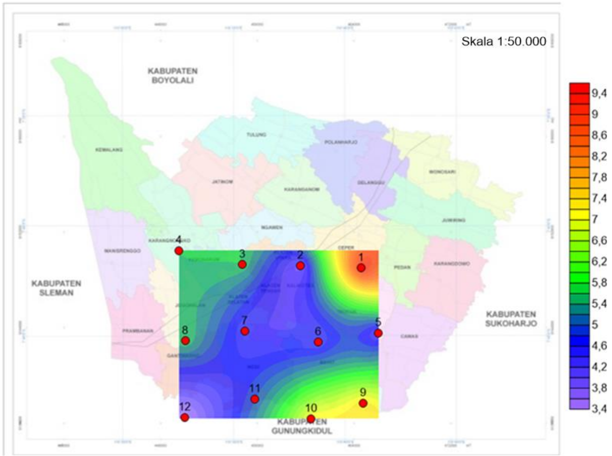

Figure 3. Dominant Frequency Microzonation (f_0) in the Geological Formation Unit in Southern Area of Klaten Regency

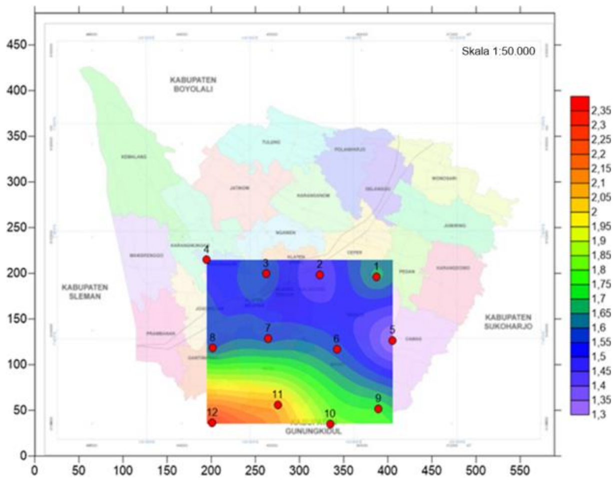

Figure 4. The Microzonation of Amplification Factor (A_0) in Southern Area of Klaten Regency

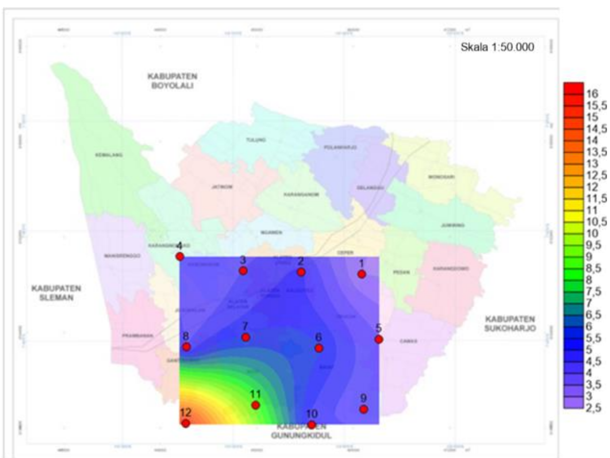

Figure 5. The microzonation of seismic vulnerability index (K_g) in the southern area of Klaten regency

Seismic volneravility index gives information about the vulnerability level of the soil's surface during an earthquake, so that it can be used to determine the potential of an area exposed to damage. The microzonation resulted from the measurement of seismic vulnerability index is shown in Figure 4. Based on the microzonation map of the seismic vulnerability index, there are various values with the minimum value of 3.00 × 10−1 s2/cm in Pedan Subdistrict and the maximum value of 15.704 × 10−1 s2/cm around Prambanan Subdistrict.

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