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Micro Zonation to Earthquake Vulnerability in West Semarang Coastal Indonesia Area Based on HVSR (Horizontal to Vertical Spectral Ratio) Microtremor Method

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ABSTRACT

Research has been carried out to determine the condition of vulnerability to earthquakes in the West Semarang beach region. The research was conducted by measuring the micro tremor signal with the HVSR (Horizontal to Vertical spectral Ratio) method in the area around the West Semarang Beach. Measurements were made by sampling a total of 89 points which were almost evenly distributed in the existing road area. Data collection was carried out in August 2020. The micro tremor signals were measured with a time digital seismograph type 303S, to record a GL 480 data logger, a Garmin III Plus GPS was used to measure the location, and to determine the north direction when installing the seismograph a geological compass was used. For processing, the software Gyopsi, Note Pad++, Excel and Golden Surfer were used. The results of the study indicate that the West Semarang Coast region has a vulnerability to earthquakes grouped into 3 parts, namely the low group, medium group and high group. Village areas with low vulnerability are Randu Garut, Mangkang Wetan, Karang Anyar, Gondorio, Ngalian, Purwoyoso and Mbangaruk. The villages with moderate vulnerability are Tambak Aji, Jerakah and Krapyak. Villages with high vulnerability values are Wonosari, Gondorio, Mangkang Kulon, Tugurejo and Tambak Harjo.

Keywords: West Semarang coastal, Vulnerability, Earthquake, Micro tremor, HVSR

INTRODUCTION

As a city that continues to grow, from time to time the growth of industry, settlements, trade and services in the city of Semarang Indonesia is increasing. In line with population development, the need for residential land has also increased, whether used as a residence or office (Pratiwi, et all, 2016). In general, the area on the west coast of Semarang is composed of alluvial deposits, as we know areas with alluvial deposits are very at risk in the event of an earthquake, for example the 2006 Yogyakarta Earthquake, the Bantul and Klaten areas which are mostly composed of alluvial deposits are the areas with the largest casualties (Daryono, 2015). The Alluvial deposits in Palu, Sulawesi during the 2018 earthquake were also the area with the largest casualties. Reflecting on this example, considering that the West Semarang Coastal Area is composed of Alluvial deposits and also around Semarang there are many active faults as Ungaran Fault, Kaligarang Fault, Lasem Fault, Banyubiru Fault (Tanden, et all, 1996), the potential vulnerability to earthquakes in the West Semarang Indonesia coastal area needs to be mapped as a conservation effort for mitigation in the future.

One of the geophysical methods commonly used to describe the condition of vulnerability to earthquakes in an area is by measuring micro tremor (Fergany, et all., 2017). Micro tremor measurement produces dominant frequency parameters (fo) and amplification factor (A), as well as their derivative parameters, namely: seismic susceptibility index (Kg), peak ground acceleration (PGA) and ground stress-strain (GSS). Seismic vulnerability index (Kg) is an index that describes the level of vulnerability of the subsurface soil layer to deformation during an earthquake. Peak Ground Acceleration (PGA) is the largest value of ground vibration acceleration that has ever been experienced in a place due to an earthquake (Putra, dkk, 2012). Based on the data regarding this PGA, it can help in the field of earthquake disaster mitigation and design earthquake-resistant building structures. Ground shear strain (GSS) is a parameter that shows the ability of the soil in an area to stretch or shift during an earthquake.

The Seismic vulnerability index Kg can be used to predict areas that will be damaged in the event of an earthquake (The relationship between seismic vulnerability index and damage ratio has been studied in Kobe, Japan (Nakamura et all., 2000), in Mexico City, Mexico (Gurler et. all., 2000), in Manila, Philippines (Saita, et all., 2004), and in California., United States (Nakamura, 2008), Bantul Yogyakarta earthquake 2006 (Daryono, 2015), Semarang coast (Irham, et al, 2023). The relationship between the seismic vulnerability index and the damage ratio using data from the 1995 Kobe earthquake has been studied (Nakamura, et all, 2000). The results of the study show that the distribution of the high seismic vulnerability index lies in the severe damage zone which is spread out by forming a damage path (Nakamura, et all, 2000, Daryono, et all, 2015).

The purpose of this study was to estimate the local effect of an earthquake in the coastal area of West Semarang and its surroundings. In addition, this study also aims to determine the distribution of dominant frequency values, amplification factor and seismic vulnerability index (Kg), based on micro tremor measurements using the HVSR method. The results of this study are a zoning map of vulnerability to earthquakes in the area around the West Semarang Beach which is expected to be additional information for the local government of the City of Semarang Indonesia in compiling spatial planning around the West Semarang Indonesia Beach.

GEOLOGY OF THE RESEARCH AREA

Geologically, the rock conditions in Semarang can be grouped into two parts, namely igneous rocks and sedimentary rocks. Sedimentary rocks can be grouped into 5 formations, namely the Kerek Formation (Tmk), Kalibeng Formation (Tmpk), Kaligetas Formation (Qpkg), Damar Formation (Qtd) and alluvium deposits (Qa). Igneous rocks can be grouped into Kaligetas igneous rocks (Qpk), Gajahmungkur igneous rocks (Qhg) and andesite igneous rocks (Tma). The research area is on the West Semarang Coast, dominated by alluvium deposits. The structure that developed in the research area is the Kaligarang Fault (Tanden, 1996).

MATERIALS & METHODS

The tools used in this research are hardware consisting of a computer, seismograph, data logger, GPS and compass and several software such as Gyopsy software, Notepad ++ software, Exel software and golden surfer software, Google Earth Pro. Micro tremor measurements are carried out by sampling the micro tremor signal values in the research area. Measurements should use a grid system, but because the conditions in the field are quite difficult, a semi-grid system is used using existing road tracks with a measurement distance of about 1 km west east and north south about 0.5 km. The measurement distribution can be seen in Fig. To measure micro tremor signals, a 3-component time digital seismograph type 303 S seismograph was used. To record, a data logger was used, to determine the north direction when installing the seismograph, a geological compass was used, to determine the location, Garmin III Plus GPS was used, and to describe the research location, Google Earth Pro was used.

The micro tremor data obtained was downloaded and then made into txt type using notepad++ software. The data in the txt type is then processed with Gyopsy software (open source) to see the HV curve and get the amplification and dominant frequency values. The SVI value is the squared amplification value divided by the frequency according to the equation (Nakamura, 2001)

$$K_g = \frac{A^2}{f_o} x 10^{-6} \quad (1)$$

where Kg is Seismic Susceptibility Index (s^2/cm), A is Amplification, fo is Dominant frequency (Hz).

The PGA value calculated using the Kanay equation can be written as follows (Irham et all, 2023)

$$PGA = \frac{5}{\sqrt{To}}\, 10^{0,6M - p\, logR + (0,167 - \frac{1,88}{R}} \quad (2)$$

where *PGA* is Maximum ground acceleration (cm/s^2), To is Dominant period (s), M is Magnitude (SR), R is Hypocenter distance (km), with p is (1.66 + 3.6R).

The GSS value is formulated as follows (Nakamura, 2000)

$$GSS = k_g x PGA \quad (3)$$

Where kg Seismic Susceptibility Index (s^2/cm), *PGA is* Maximum Ground Vibration Acceleration (cm/s^2)

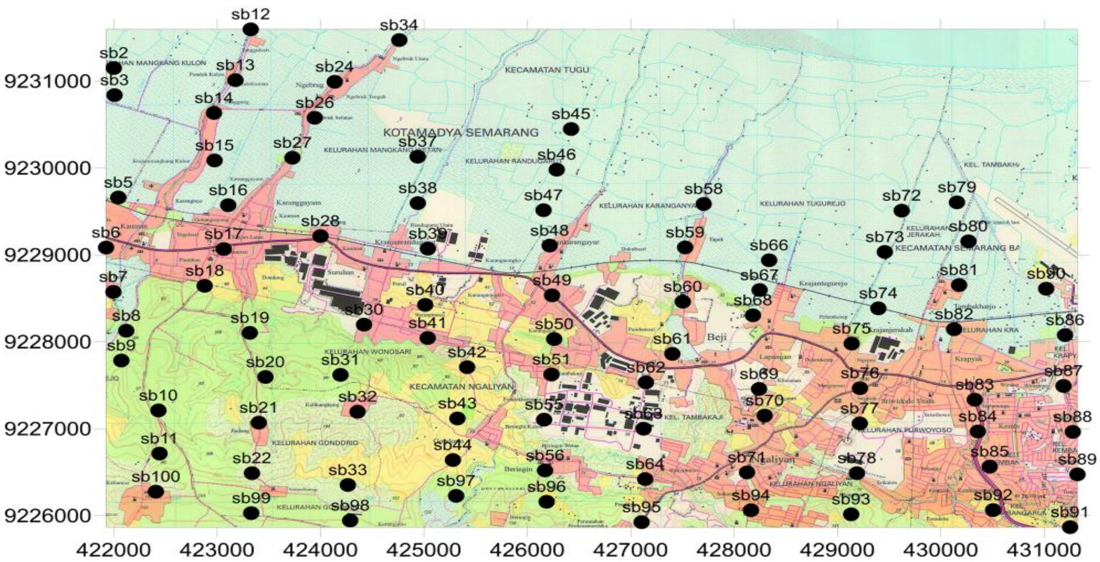


Figure 1, The location of Micro tremor data collection in UTM Map

RESULT AND DISCUSSIUON

The results of this study are an amplification map for the coastal area of West Semarang which is shown in Figure 2. The amplification value is in the low category, namely the amplification value is less than 3 which is indicated by blue to light green and the medium category with a value of more than 3 is indicated by color green to red.

Areas with moderate amplification values cover almost 50 percent of the research area consisting of Gondorio Village, Randu Garut Village, Karanganyar Village, Tambak Aji Village, Part of Krapyak Village, Purwoyoso Village and Ngaliyan Village. Meanwhile, the area with moderate amplification value also covers almost 50% of the research area which includes Kaliancar Village, Wonosari Village, Mangkang Kulon Village, Mangkang Wetan, Jerakah Village, Tugu Rejo Village, Krapyak Village and Mbang Arum Village.

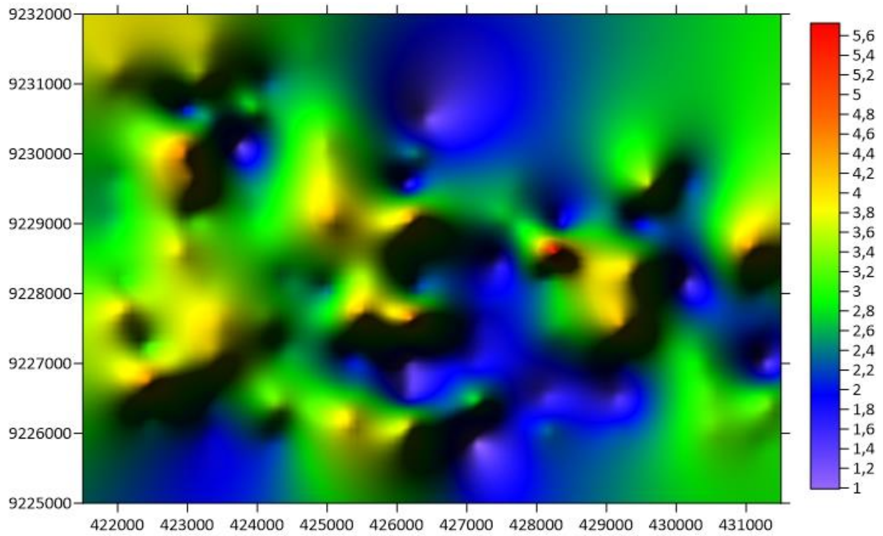


Figure 2, Amplification in the research area

The dominant frequency value of micro tremor measurement results in this study is shown in Figure 3. The dominant frequency value varies from 0.5 Hz to 7.5 Hz. According to the classification commonly used in micro tremor surveys, it can be classified into 3 parts, namely low frequency with a value of less than 2.5 Hz associated with thick underlying sediment, medium frequency with a value between 2.5 Hz - 4.0 Hz associated with sediment thickness. below it 10-20 m and the high frequency group from 4 Hz – 9 Hz which is associated with the thickness of the sediment below it ranging from 5 – 10 m. Referring to Figure 4, almost all areas of the study area are associated with areas with low frequency values shown in blue to light green, some areas with moderate frequencies are shown in light green to light yellow and very few areas with high frequency values are shown in color. yellow to red covering the center of the study area.

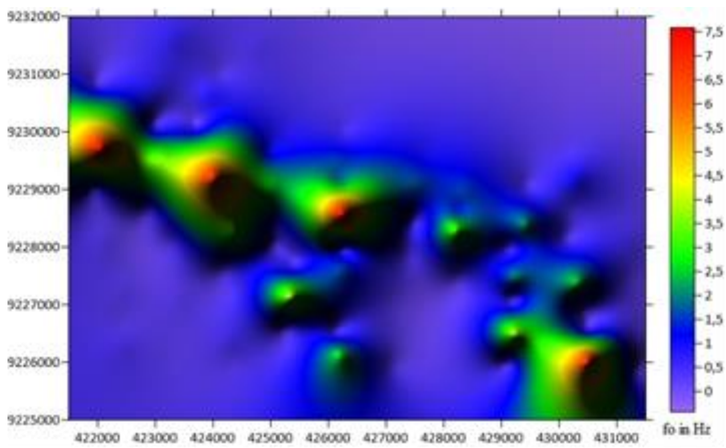


Figure 3, Dominant Frequency in the research area

The results of the calculation of the value of Seismic vulnerability in the research area are shown in Figure 4. The value of the Seismic Vulnerabity index (Kg) varies between 5 – 150 s^2/cm. The value of Kg can be grouped into 4 parts, namely values less than 10 s^2/cm shown in purple, in this area when an earthquake occurs it is estimated that no damage will occur. Kg values between 10 – 50 s^2/cm are shown in blue to turquoise, in this area, if an earthquake occurs, light damage is estimated. Kg values between 50-100 s^2/cm are shown in green to light yellow, in this area if an earthquake occurs, moderate damage is estimated. Areas with a value of 100-160 s^2/cm are shown in yellow to red when an earthquake occurs, it is estimated that heavy damage will occur.

The results of the calculation of the PGA value (peak ground acceleration) using the Canay (1969) formula with the source of the Yogyakarta earthquake on 27 May 2006 with an earthquake magnitude of 5.9 SR are shown in Figure 5. PGA values vary from 1-24 gal which can be grouped into 3 i.e. with a value of less than 5 with no earthquake effect felt, a value of 5-10 gal with an earthquake effect felt by people who were in the house as if a truck was passing or things hanging in the house were swaying and a value of 10-25 gal with the effect of the earthquake felt by people outside the house with the liquid visible to move, people sleeping can be awakened.

The results of the calculation of the GSS (ground stress-strain) value are shown in Figure 6. The GSS value varies between 0.0016 - 0.032 which can be grouped into 3 groups, namely the first group with a value of less than 0.01 indicated in purple and blue, the second group with values between 0.01 – 0.02 are indicated by a turquoise to yellow color and the third group with a value of more than 0.02 is indicated by reddish yellow to red. This GSS value is a measure of whether or not the subsurface material of the earth is deformed during an earthquake, the greater the value, the more vulnerable it is to earthquake disasters. According to Ishihara (19982) the GSS value is correlated with the dynamic properties of the soil as shown in table-1. Based on table 1, most of the coastal areas of West Semarang in the event of an earthquake can experience subsidence or liquefaction.

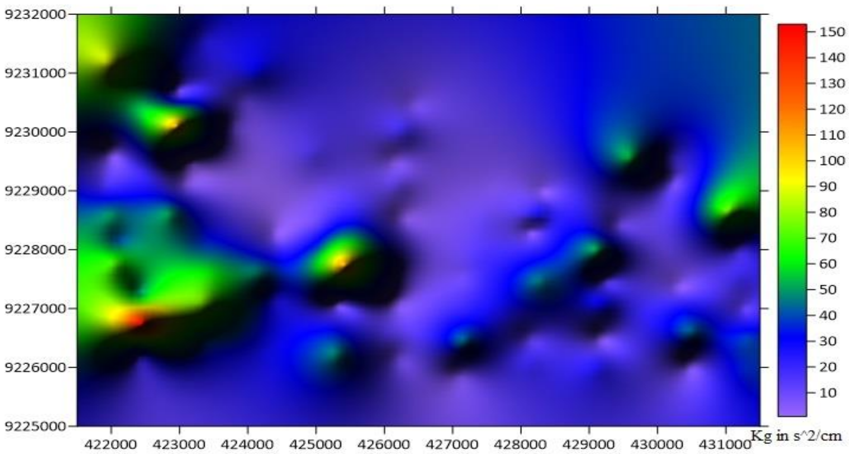


Figure 4, Seismic vulnerability index map in the research area

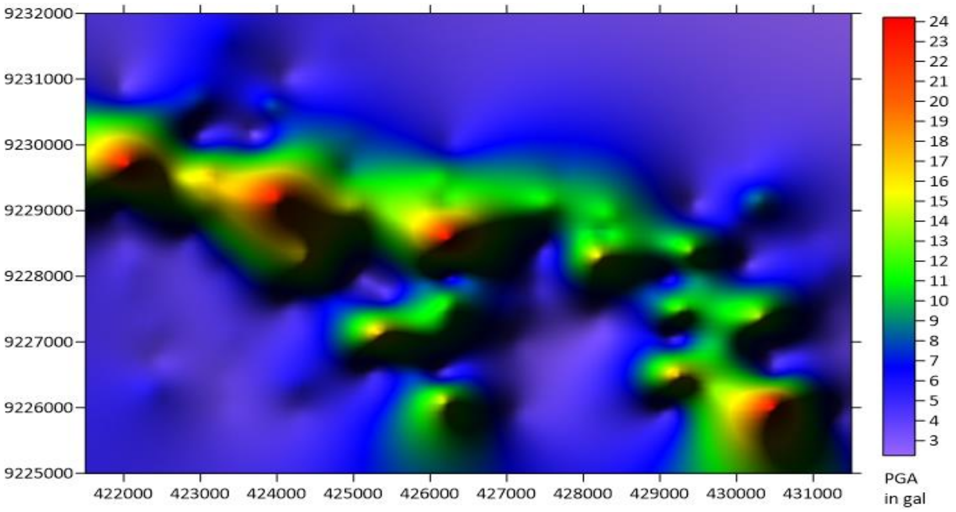
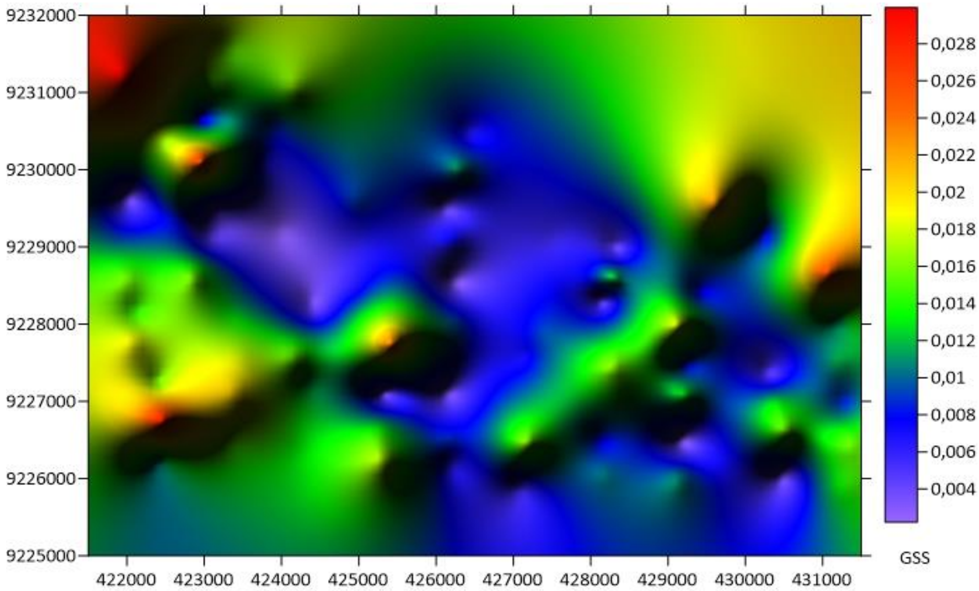


Figure 5, PGA (Peak Ground Acceleration) map in the research area.

Table-1. Relationship of strain with the dynamic nature of soil (Nakamura 1997)

Size of Strain (γ)	10^{-6} 10^{-5}	10^{-4} 10^{-3}	10^{-2} 10^{-1}
Phenomena	Wave, Vibration	Crack, Settlement	Landslide, Soil Compaction, Liquefaction
Dynamic Properties	Elasticity	Elasto-Plasticity	Collapse
			Repeat- Effect, Speed-Effect of Loading



CONCLUSION

Based on the description and discussion that has been presented above, the vulnerability of the West Seamarang coastal area in the event of an earthquake can be grouped into 3 groups, namely areas with low vulnerability, areas with medium vulnerability and areas with high vulnerability. Village areas with low vulnerability are Randu Garut Village, Mangkang Wetan Village, Karang Anyar Village, Gondorio Village, Ngalian Village, Purwoyoso Village and Mbangaruk Village. The villages with moderate vulnerability are Tambak Aji Village, Jerakah Village and Krapyak Village. Villages with high vulnerability values are Wonosari Village, Gondorio Village, Mangkang Kulon Village, Tugurejo Village and Tambak Harjo Village.

Declaration by Authors

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Conflict of Interest: The authors declare no conflict of interest.

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