Measurement of ground response of Semarang coastal region risk of earthquakes by Horizontal To Vertical Spectral Ratio (HVSR) microtremor method

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Abstract. The study was conducted to determine the response of the Semarang Coastal area to earthquakes by measuring the microtremor response with 3 component seismographs at 110 locations on the Semarang coastal region that were distributed almost evenly. From the microtremor data, it is processed using Gyopsy software to get the dominant frequency and amplification values. The dominant frequency value and its amplification are then made a map with surfer 13, and the results are then overlaid on the RBI map for qualitative interpretation. The results of this study are dominant frequency and their amplification in the Semarang coastal region maps. The dominant frequency values range from 0.5 Hz - 10 Hz. Based on the dominant frequency values, can be grouped into three categories, namely low frequency values that are less than 2.5 Hz associated with sediment thickness values of more than 30 m and areas with moderate frequencies with values between 2.5 - 4 Hz associated with sediment thickness 10 - 30 m, and high frequency indigo between 4 Hz - 10 Hz is associated with a sediment thickness of 5-10 m. Areas with low frequencies dominate the study area. Areas with medium and high frequency values are only a small part of the study area. The amplification values vary between 0.5 - 8.5. While the amplification value can also be grouped into 3 parts, namely the amplification of less than 2.75 associated with hard rocks almost dominates the central part of the study area, the amplification value between 2.75 - 5.15 associated rocks or soil with moderate violence is only a small part as between low and high values in the study area, and values of more than 5.15 associated with soft soils that dominate the northern and the southern part of the study area. If the area around Semarang has an earthquake, the location with a large amplification will be more prone to earthquake disasters.

1. Introduction
The island of Java in the southern and northern parts of Java Island frequently occurs with earthquakes with the epicenter at a depth of less than 100 km to 300 km below sea level [1]. The sources of the earthquakes that occurred on the island of Java, especially in the city of Semarang, mostly came from active faults on the island of Java. Active faults that can have a significant impact on the city of Semarang are the Opak Fault (Yogyakarta), the Lasem Fault, the Pati Fault, and the Kaligarang Fault [2.3.4]. Based on the seismotectonic map, the Opak Fault is located in the Yogyakarta area continuously from South to North Yogyakarta, precisely in the Bantul area, while the Lasem Fault and the Pati Fault...
are in the Jepara and Pati area continuously from northeast to southwest towards Semarang City [5]. If one of the faults experiences a shift, it will affect the shift of other faults which can cause minor faults. The activity of these faults can cause destructive earthquakes.

The city of Semarang, which has an area of 373.7 km², has a fairly high earthquake-prone area [6]. The impact that occurs due to an earthquake is caused by the intensity of the earthquake, the distance from the earthquake source, the earthquake scale, the size of the fault zone, the energy released by the rock, the geological type between the earthquake source and the location affected by the earthquake, and local geological conditions [7]. The level of damage caused by an earthquake does not only depend on the magnitude and distance from the epicenter, but local geological conditions also greatly affect the damage caused by the earthquake which is then known as the local site effect [8]. Local geological conditions cause the value of the seismic wave propagation acceleration caused by the earthquake to be different. The higher the acceleration value, the higher the risk of an earthquake because it is affected by ground movement.

The description of phenomena caused by earthquakes that have the potential to cause damage is called Seismic Hazard or seismic hazards. The parameters needed to analyze the level of Seismic Hazard in an area using geophysical methods are the value of earthquake vulnerability and maximum ground acceleration. The value of earthquake vulnerability and maximum ground acceleration can be determined by the micro seismic method [9]. Earthquake susceptibility is a value that describes the level of vulnerability of the surface soil layer to deformation during an earthquake [10]. Soil deformation is influenced by the thickness of the sedimentary layer, where the thickness of the sedimentary layer describes the thickness of the weathered layer in the soil surface layer above the bedrock. The thickness of the sedimentary layer also represents the depth of the bedrock. The deeper the bedrock, the more easily the ground layer above the bedrock will be deformed due to the earthquake [11].

Micro seismic is a geophysical method that is often used for preliminary surveys of petroleum exploration, geothermal, monitoring / monitoring of volcanic activity and can also be used to detect rock layer instability by utilizing small vibrations from seismic waves propagating through rock layers [12]. Micro seismic is a method that is still new and not widely used for geophysical research. The micro seismic method is a passive method, so it differs from the seismic method which is an active method that requires a source of vibration in data collection. Micro seismic is a method that is relatively inexpensive and environmentally friendly, because micro seismic take advantage of weak vibrations in the earth which are continuous due to the presence of vibration sources such as micro-earthquakes, human activities, industry and traffic [13, 14]. The working principle of the micro seismic method is the same as the seismic method where the signal in the time domain known to generate seismic waves traveling through the subsurface is reflected or refracted back to the surface where the signal can be detected [15].

The microseismic method is very suitable for determining the value of natural frequencies possessed by soil layers and earthquake susceptibility in an area. The result is that the lower the natural frequency value, the higher the earthquake susceptibility level in an area. Micro seismic methods can also be used to study subsurface geological conditions [16]. The results of these studies describe the depth of the bedrock and describe the thickness of the sedimentary layer or weathered layer above the bedrock. The deeper the bedrock, the higher the earthquake susceptibility value. Seismic hazard analysis is very important to provide an overview of the earthquake-prone zone and ground deformation due to vibrations that occur within the earth. This study aims to map the risk of earthquake disasters in the coastal area of Semarang using the HVSR microtremor method. The micro seismic method can be used as information for earthquake mitigation in the coastal areas of Semarang.

2. Geologic research area
Geological maps of Magelang and Semarang sheets illustrating the stratigraphic arrangement of the Semarang and surrounding areas can be grouped into several formations (Figure 1), which are generally in the form of sedimentary rock groups and volcanic rock groups [17].
The sedimentary rock groups found in the city of Semarang and its surroundings consist of several formations, there area. Kerek Formation (TmK) which consists of alternating marl claystone, tuffaceous sandstones, conglomerates, volcanic breccia and limestone. Claystone lithology is light gray - dark, limestone, partially embedded with siltstone, sandstones containing fossils of mollusks and coral colonies. This formation is Late Miocene, exposed in Banyumanik, east of Ungaran, the Kali Kreo valley, Kali Kripik and Kali Garang as well as around Jabung.

Kalibeng Formation (Tmpk): This formation is located incongruously above the Kerek Formation with lithology consisting of solid marl at the top and locally containing carbon, tuffaceous sandstone insert marl and limestone. Based on the fossil content of bentonic foraminifera, it is known to be deposited in a deep sea environment. This formation is Miocene - Pliocene in age and is exposed in the vicinity of Kali Creo, Kali Kripik and Kali Garang as well as in the areas of Tembalang, Meteseh, Rowosari, Kali Pengkol Valley and Kali Bade Valley.

Kaligetas Formation (Qpkg): This formation consists of volcanic breccias including lava, tuffs and claystone. Generally, it has experienced quite intensive weathering to produce reddish brown soil material, exposed in Tembalang, Banyumanik, Grobogan, Wonorejo and Pringsari. Damar Formation (Qtd): This formation is located incongruously above the Kalibeng Formation and consists of tuffaceous sandstones, conglomerates, volcanic breccias and tuffs. Sandstones consist of feldspar and mafic minerals, partially tuffaceous and locally limestone. As for breccias, fragments are generally alkaline volcanic rocks and outcrops are found in Kedung Mundu, Karanganyar, and Ngadirejo. The age of this formation is Late Pliocene - Early Pleistocene.

Alluvium Deposits (Qa): Consists of gravel, sand. Crust and silt with a thickness of 1 - 3 m which is river sediment. It is exposed in the Kali Pengkol valley and its surroundings [17]. The group of rocks resulting from volcanic activity consists of several units, namely:

a. Kaligesik Volcano Rock (Qpk). These rocks are the result of volcanic activity in the form of augite olivine basalt flow, exposed on the northern slopes of Mount Ungaran.
b. Gadjah Mungkur Volcano Rocks (Qhg). Consists of augite hornblende andesite which is generally in the form of lava flows and is exposed at the top of Mount Ungaran and surrounds the distribution of the Kemalon and Sangku Volcanic Rocks.
c. Andesite (Tma) Igneous Rocks. It is a breakthrough rock of acid andesite hornblende augite type, exposed around Mangunsari, Gunung Turun and Pudak Payung.
d. Basalt Igneous Rock (Tmb). These rocks are basalt augite and were found at G Klesem as hacks. On Mount Sitapel can find plagioclase porphyry and on Mount Mergi it is olivine-augite andesite basalt [17].
3. Methods
The type of research carried out is descriptive quantitative research, namely by taking data in the form of micro tremor measurements in the form of a time-domain seismic signal transient, which aims to determine the value of natural frequency and amplification in the coastal area of Semarang [18,19]. Data retrieval in this study was carried out by recording micro tremor data at 110 location points in the coastal area. The research implementation is conducted in August 2019.

Seismograph equipment type Time Digital Seismograph (TDS) - 303S, is used to record micro tremor signals and Garmin III Plus Global Positioning System (GPS) as a determinant of coordinates, a compass as a determinant of the cardinal directions. For the installation of a Seismograph and a laptop, several software are used, including Note pate ++. Software, Google Earth Pro software for making measurement points, Geopsy software for Horizontal to Vertical Spectral Ratio (HVSR) analysis, Microsoft Excel software for calculating data and Golden Surfer 12 for mapping [18,19].

This microtremor measurement was carried out with an almost even distribution, namely a distance of about 1 km from west to east and a distance of about 500 from north-south as shown in Figure 2. In this study, 110 points were successfully measured with a measurement duration of 10 minutes per point.
Seismic micro data obtained from the field in the form of seismic signals that are transferred to a computer in the form of numeric data. This data is then converted to .dat format so that it can be processed by the HVSR process. This data must be converted to SAF format using datapro software so that it can be processed with geopsy software. The output of the geopsy software is the average micro tremor spectrum. From this spectrum, it can be seen the value of the dominant frequency ($f_g$) and the peak of the micro tremor spectrum (A) at the measurement location [18,19]. The natural amplitude and frequency values obtained are then made a map with surfer software, and overlaid on a map of the earth's appearance for interpretation.

Figure 2. Location Microtremor data collection point

4. Results and discussion

The dominant frequency value shows the frequency value that often appears in the area and can provides an overview of the thickness of the sediment in the area. The dominant frequency can indicate the rock type and characteristics classified by Kanai [20], and has a close relationship with the thickness of the sediment (bedrock) [21]. The contour map of the dominant frequency values shown in Figure 3, which has been overlaid is shown in Figure 4.

According to Kanai, the dominant frequency values in this research area can be grouped into 3 groups [20]. The first group is those that have a dominant frequency value less than 2.5 Hz which is associated with very thick sediments in Figure 3 shown in blue. The second group is a group with a frequency value between 2.5 Hz - 4 Hz which in Figure 3 is shown in green to light yellow. This group is associated with a sediment thickness of about 10 m - 30 m. The third group is the group with a dominant frequency value between 4 Hz - 7.5 Hz which in Figure 3 is shown in yellow to red. The group is associated with sediments with a thickness of 5 m-10 m.

The amplification value is the value of the amplification of earthquake waves when passing through the area. Large amplification values are usually associated with large amplification waves and the risk of earthquake disasters. The contour map of the amplification value of the study area which is overlaid on the RBI map is shown in Figure 4. In general, the study area is grouped into three parts, namely the low amplification value is shown in purple to blue. Moderate amplification values are indicated by green to light yellow values, while high amplification values are shown in yellow to red. Based on the amplification value, most of the research areas are at high risk of earthquake disasters.
Figure 3. Frequency dominant map in the research area

Figure 4. Amplification map in the research area

5. Conclusion
From the research results as stated above, it can be concluded as follows: From the dominant frequency and amplification value, the research area can be grouped into three parts of the risk of earthquakes. The low risk area is in the middle of the study area, the medium risk area is in the western and southern parts of the study area. The areas with high earthquake risk are in the north west and east of the study area.
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