Preliminary site characteristics for urban seismic hazard in pasuruan fault from microtremor measurements

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Abstract. The Pasuruan fault is one of active faults in East-Java with the minimum estimated earthquake magnitude to be 6.6 Mw. Although the Pasuruan fault is relatively small in term of estimated earthquake magnitude, because the area is highly populated, earthquake along the fault could pose a significant hazard to the densely populated region and infrastructure. This study mainly focuses on site characteristics of along the Pasuruan fault based on microtremor Horizontal-to-Vertical spectral ratios (HVSR) as a part of the seismic hazard assessment. Through this measurement, the output the site natural frequency, the amplification and the soil vulnerability maps which will be used to make an urban seismic hazard map for along Pasuruan fault. The microtremor measurements were carried out at 48 locations to investigate the natural frequencies and the amplifications at sites. The results showed that the natural frequency \( f_0 \) values range from 1 Hz to 10 Hz and the amplification factor \( A_0 \) values range from 2 to 8. Correlations between the natural frequency with the geological formation and topographic were established. Variations of both parameters are also indicated as a result of variations in surface soil parameters. The vulnerability index (Kg) is indicated the soil damage level due to ground motions. The weak zone failed during an earthquake on the Southwest site was identified by the highest Kg value.

1. Introduction

In the Java region, especially East Java is an earthquake-prone region of Indonesia. The seismotectonic lane of active faults in Java is closely related to the presence of active fault structures including the Kendeng fault. It has stretches 300 kilometers south of Semarang, Central Java, and East Java. Kendeng Fault was formed due to the mechanism of compression or compression of the existence of volcanic arcs in the zone of Central Java to East Java during the mio pliocene period [1].

The Pasuruan region is crossed by Kendeng fault and known Pasuruan fault. It is clearly seen through the topography that is by the existence of fault faults that extend Northwest (-7.647552, 112.964661) to the Southeast (-7.716522, 113.107158), along ± 13 km. This fault escarpment cut volcanic deposits which indicate that this fault is younger than the Pleistocene. An indication of the movement of the fracture down has been found and has been mapped along this fault [2].
Gayatri [2] has conducted research by making an age model for the four dates of earthquake events which shows that the time of the earthquake was not periodic. The repetition period of 239 to 365 years is estimated with a median of 302 years. This data implies that the Pasuruan fault is an active fault, and the estimated damage that might result from this fault is ± 13 km. Thus the minimum earthquake magnitude is estimated at 6.6 Mw. In addition, Gayatri [2] estimates that the level of movement in this area is at least 0.2 mm/year.

Measurement using a microtremor have been carried out to obtain information on natural frequency and amplification factors of the sedimentary layer through the HVSR method, namely by the relationship of the fourier spectrum ratio of the horizontal component microtremor signal to its vertical component.

2. Location and geology setting
Research locations in the Pasuruan region with tectonic settings include the Kendeng zone which stretches from the southern districts of Bojonegoro, Jombang, Mojokerto, Situbondo, and Bondowoso [3]. Pasuruan regency is also included in the coastal area of the North coast of East Java in general with a low altitude, i.e., 1-8 meters. Figure 1 shows the Kendeng Zone divided into 3 parts, namely the Western part which lies between Ungaran and Solo (North Ngawi), the Central part stretching to Jombang and the East from East Jombang to Brantas River Delta and continuing to Madura Bay [4], the study area is included in the East Kendeng Zone.

![Figure 1. Physiography of Eastern Java Island [4]](image)

The Pasuruan region is crossed by a Kendeng fault that stretching from Semarang, Central Java to the northern waters of the island of Bali. Based on the geological map of Malang sheets and Probolinggo sheets [5] as shown in Figure 2, the North coast of Pasuruan city has relatively high potential for vulnerability due to earthquakes.
Figure 2. Geological map and cut fault location [5]
The history of earthquakes around the fault has been recorded in the International Seismological Center Database. Earthquake data that had occurred around the fault were recorded on March 27, 2016, at 19:10:14 WIB, with Latitude -7,610 and Longitude 112,870 positions, at a depth of 13 km and magnitude 2.5 Mw.

3. Methodology

Microtremor is ground vibration other than earthquake, it can be a vibration due to human activities and natural activities [6]. For example due to the vibration activity of factory machines, wind, car vibrations, ocean waves, and natural vibrations from the ground. Microtremors have a general period of between 0.05 - 2 seconds and frequencies higher than earthquake frequencies. Microtremor waves can be used to determine the presence of bedrock (bedrock) based on its depth. The greater the natural frequency value \( f_0 \), the deeper level \( h \) of the shallower bedrock, and vice versa, according to the equation:

\[
f_0 = \frac{V_s}{4h}
\]

where \( f_0 \), \( V_s \) and \( h \) are respectively natural frequency (Hz), shear wave velocity (m/s) and bedrock depth (m).

Likewise that microtremor waves can also be used to determine earthquake vulnerability index \( K_g \), i.e. that the soil vulnerability index will increase if the natural frequency value \( f_0 \) decreases, and vice versa, according to the equation:

\[
K_g = \frac{A_0^2}{f_0}
\]

where \( K_g \) and \( A_0 \) are vulnerability indexes and amplification factor values.

Figure 3 shows a research flowchart that begins with field data acquisition by recording position data and microtremor data, then the data is processed by the HVSR method (with the help of Geopsy and Surfer software), then natural frequencies \( f_0 \) and amplification factors \( A_0 \) will be obtained. Furthermore, through the calculation obtained the vulnerability index \( K_g \), then enter the most important part, namely the analysis of results with geological information, geomorphology, and fault map due to earthquake, and ends with a conclusion.
The method used in the acquisition of microtremor in this study is the HVSR method which explains the ratio of horizontal to vertical spectra by transferring waves from bedrock to surface [6]. The dominant period and peak value of the ratio spectra (H/V) have in common with the natural period and amplification factor of the soil layer, the H/V value is obtained from a comparison between the fourier amplitude spectrum of the horizontal wave component against the vertical wave.

The amplification factor value of a place can be known from the height of the peak spectrum of the HVSR curve measured by microtremor at that location, the amplification of large ground motion during the earthquake may be due to local site characteristics [7]. The value of dominant period or dominant frequency obtained from the HVSR curve has a correlation with the thickness level of the sedimentary layer.

Microtremor data collection was carried out in the vicinity of the fault in Pasuruan which included 4 sub-districts namely, Rejoso, Lekok, Grati and Nguling. Microtremor measurements were carried out in 48 points, however, because in data processing, there were 10 points that did not meet the verification of the Sesame European Research Project [8], so the data used were only 38 points with geographical range, Latitude -7.715938 to -7.651868 , and Longitude 112.959093 to 113.080752.

4. Results and discussion
The results obtained state that the Northeast of the fault line (white) has a higher natural frequency \( f_0 \) value (around 10 Hz) than in the Southwest (around 1 Hz), as shown in Figure 4.
Figure 4. The natural frequency ($f_0$) from 1 Hz (blue) to 10 Hz (red) in the active fault area

According to Santoso and Suwarti [5], in the measurement area has a geological composition in the form of Rabano Tuff ($Q_{vtr}$) in the form of lithic tuff, pumicous tuff, tuffaceous sandstone, volcanic breccia and conglomerate, also the Old Tengger Volcanic Rocks ($Q_{pvt}$) in the form of volcanic breccia, tuff, lava, agglomerate and lahar. Because of the same soil composition in the fault area, this will cause the same $V_s$ value in the area.

By using equation (1), with the value of $V_s$ which tends to be uniform, it is found that in the Northeast (Figure 4) has a depth level ($h$) of bedrock shallower than in the Southwest part of the fault line. This is in accordance with the geological model from Santoso and Suwarti [5], as shown in Figure 2.

Figure 5 shows the distribution of the amplification factor ($A_0$) value around the fault line (white), whereas in the Southwest of the fault line has a higher $A_0$ value (around 8) than in the Northeast (around 2).
Likewise with the vulnerability index \((K_g)\), in accordance with equation (2), where the \(K_g = A_0^2\) value is found that in the Southwest of the fault line is higher (around 30) than in the Northeast (around 1), such as shown in Figure 6. From Figures 5 and 6, it is clear that both the amplification factor \((A_0)\) value and the vulnerability index \((K_g)\) in the Southwest of the fault line have higher values than in the Northeast. The highest value of \(K_g\) occurs in the Southwest fault line and on the west site (around 32).
By looking at these conditions, the form of an earthquake in the study area can be said to be important, because this factor cannot be predicted at the time of its occurrence, but risk reduction efforts can be made if this earthquake disaster actually occurs.

All stakeholders including academics, government, business people and the general public must be familiar with these conditions in their area, so that earthquake risk reduction can be increased by mitigating earthquakes, namely making safe regional planning in the event of an earthquake.

5. Conclusion
Pasuruan fault is an active fault in East Java with an estimated minimum of 6.6 Mw earthquake. Even though the magnitude is relatively small, earthquakes which occur along the fault can pose significant hazards to densely populated areas and infrastructure.

This study focuses on the characteristics of the local site effect along the Pasuruan fault based on the horizontal to vertical spectral ratio (HVSR) as part of the seismic hazard assessment. The measurement results obtained that the value of natural frequency ($f_0$) ranges from 1 Hz to 10 Hz and the amplification factor value ($A_0$) ranges from 2 to 8.

The vulnerability index ($K_g$) is indicated as a measure of the level of soil damage due to ground movement, in the Southwest of the fault line having a higher value than in the Northeast. Thus, the weak zone at the time of the earthquake was in the Southwest site, because it has the highest $K_g$ value (around 32).

6. References
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