Seismic Site Effect Mapping Based on Natural Frequency Using Microtremor Method in Sidoarjo District

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Abstract. Sidoarjo is one of the satellite districts of Surabaya. The regency has important infrastructures that support Surabaya as a big city, such as the airport, bus terminal, industrial estate and warehouses which are important to support the sustainability of the industries in Surabaya City and East Java Province. With its important role, Sidoarjo Regency faces the risk of disasters in the form of earthquakes caused by earthquake sources in the form of land faults. Faults located closest to the district of Sidoarjo are Blumbang Fault, Pasuruan Fault, Surabaya Fault, and Waru Fault. With this risk, a research is needed to determine the local site effects of land related to seismicity. Therefore, microtremor research was held in Sidoarjo Regency to determine the local site effect in the form of dominant frequency of the soil. Measurements were done in 37 points spread throughout the Sidoarjo Regency. With dominant frequencies mapping, an analysis of earthquake hazard levels were carried out due to geological factors around the Sidoarjo Regency. After measuring natural frequencies, the range of natural frequencies were found to be between 0.8 - 3.65 Hz. Low natural frequency values were found in Waru District and high frequencies were found in Sedati District.

1. Introduction
Sidoarjo District is one of the districts which are located closest to the city of Surabaya as the capital city of East Java Province. Consequently, Sidoarjo became a satellite area that supports Surabaya as an industrial area. Sidoarjo has a few supporting infrastructures which are considered very important such as Juanda Airport, bus terminal, industrial area and warehouses. On the other hand, Sidoarjo faces disaster risk, one of them being earthquake. The earthquake that could potentially occur in Sidoarjo is caused by faulting of the land which has been confirmed as active by Kouali, et.al [1]. These faults are Blumbang Fault, Pasuruan Fault, Surabaya Fault, and Waru Fault. These faults are located less than 30 kilometers from Sidoarjo. Microtremor method was used to estimate soil properties. This method is often used for microzonation research in several area, as it was done by Arwananda, et.al [2], Baskoro, et.al [3], Hakim, et.al [4] Hidayat, et.al [5], and Syaifuddin, et.al [6]. Therefore, research is necessary due to the risk of an earthquake in Sidoarjo. Determination of earthquake hazard was done using local site effect mapping.
2. Theory

2.1. Geological Condition of Sidoarjo

East Java’s physiography is divided into seven physiographic units. The units in order from south to north are the southern mountains, the quarter volcanic arc, the Java depressive zone, the Kendeng zone, the Randublatung depression zone, the Rembang-Madura zone and the alluvial plains of northern Java [7]. The area of observation in this study, Sidoarjo Regency is located between the Kendeng Zone and the Randublatung Depression Zone. From the geological point of view, Sidoarjo is dominated by alluvium that is the youngest in stratigraphy. In this region there are several geological formations which are exposed at the surface, which are Alluvium, Kabuh Formation, Pucangan Formation and Lidah Formation [8].

![Figure 1. Sidoarjo Geological Map](image)

2.2. Microtremor Method

The earth’s surface always moves with seismic frequency, even if there is not a single earthquake on earth. Constant vibrations on the surface of the Earth is called microseismic or microtremor. Amplitude microtremor is usually very low with an order of $10^{-4}$ to $10^{-2}$ and far below the human senses. Although the vibrations are very weak, the microtremor represents a source of noise, and this allows researchers to record earthquake signals. If the amplifier gain is increased to record an earthquake with a very large source distance, the amplitude of the microtremor will increase proportionally [9]. Earthquake mitigation efforts can be carried out using the microtremor method, as in site effect research or microzonation in different places as described by Sutrisna [10]. Microtremors are commonly referred to ambient noise, caused by natural or artificial events such as wind, sea waves, or vibration caused by vehicle and can be used to describe the geological conditions of an area near the surface. From microtremor measurement data processing, one can obtain the value of the...
dominant wave period, the value of the average velocity of the S wave to a depth of 30 meters ($V_{s30}$), and the value of peak ground acceleration (PGA), so one can find out the ground welding around the area of research on earthquake response.

3. Methodology
The acquisition design was made by considering the geological conditions of the study area. Microtremor acquisition was performed at 37 measurement points covering the entire administrative territories of Sidoarjo. Measurements were carried out for thirty minutes at each point. Processing of microtremor data was performed using HVSR analysis, where the three components of the signal in the domain of time were transformed into a frequency domain. After the wave was converted to the frequency domain, smoothing and filtering was done with the Konno-Ohmachi filter. Disposal treatment was also done to data which were considered as noise that would interfere with the results of measurements, so that the obtained results were in the final form of the natural frequency values of the H/V spectrum.

![Research Workflow Diagram](image)

Figure 2. Research Workflow

4. Results and Discussion
Natural frequency values were obtained after processing, smoothing, and filtering. Obtained natural frequency was found to already meet the standards of reliability curve according to SESAME standard [11]. Microtremor data processing through HVSR approach generated natural frequency values in a range between 0.8 and 3.65 Hz in the district of Sidoarjo. The highest natural frequency values were found in the District of Tarik, while the lowest values were obtained in the Districts of Porong, Tanggulangin, and Jabon. Low natural frequency indicates soft land profile with thick sediment deposition. In contrast, high natural frequency indicates relatively thinner sediment deposition in the
subsurface and shallow bedrock position. Areas with thicker sediment deposition faces a higher risk of impact from the earthquake while thin sediment deposition faces less impact risk.

Figure 3. Natural Frequency Distribution Map of Sidoarjo District Based on Microtremor Measurements.

5. Conclusion
Natural frequency in the district of Sidoarjo occurred at the range of 0.8 to 3.65 Hz, with the highest found in Tarik District, while the lowest value was found in the Districts of Porong, Tanggulangin, and Jabon. Low frequency indicates thick soft sediments layer, otherwise high natural frequency indicates shallow bedrock. District of Porong, Tanggulangin, and Jabon with thicker sediment deposition face a higher risk of impact from an earthquake while Tarik District faces less impact.

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