Delineation of the new site of Ngempon temple in Ngempon village, Bergas district, Semarang regency using the microtremor method

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Abstract. Ngempon Temple was discovered below the ground level caused by collapsed land in 1952 in Ngempon Village, Bergas Sub-district, Semarang Regency. The HVSR method is used in the three-component microtremor to identify the bedrock response frequency. Additionally, this method can be used to determine the dominant resonance frequency ($f_0$) and the peak value of HVSR (A), which shows the dynamic characteristics of sediments. This study aims to determine the position and types of archaeological objects that are still hidden and make a modeling of the subsurface conditions. The method used in this study is a trapezoidal measurement geometry by measuring spaces within 2 meters. Data retrieval duration is 10 minutes for each point, and the specified frequency sampling is 10 Hz. The H/V curve generated from data processing will result in the frequency value and amplification that will be analyzed and linked to the Ngempon Temple archaeological data. The results obtained from this study indicate the existence of the temple's fundamental rocks and rock debris model below the surface indicated by the contours of the HVSR spectrum profile. They are an amplification value of 1.3 and the response frequency with a sensitivity of up to 4 Hz from the surface, and an amplification value of 1.3 and the response frequency with a sensitivity of 5.8-10 Hz. The sensitivity to measurements is based on whether the response passes the excavation of BPCB Central Java. If it passes, then the response indicates an anomaly of the fundamental rocks. Vice versa, if the measurement does not pass the object of research, the response only shows the existence of temple rocks fragments. The amplification value and frequency of response shows a difference between the temple rock and the sediments above it.

1. Introduction
Indonesia is a vast country that has many tribes and cultural heritages and relics in the past. Cultural relics that are often found in Indonesia are buildings, writings, works of art, and customs [7]. One of the relics in the past is the Ngempon Temple building located in the District of Bergas, Semarang Regency. Ngempon Temple is located on six temples, but only four were reconstructed or built; this is historical evidence that has been inventoried as cultural preservation in Semarang Regency [4].

Ngempon Temple site is not yet known for certain. Based on architectural characteristics, this temple was built in the VIII-IX AD century, which has a Hindu background. Ngempon Temple is also often called the Appearing Temple, which is interpreted as a place for galvanizing Brahmins caste to be educated as MPU or masters in the field of kanugrahan, cultural literature and spirituality [1]. Based on
news from the newsstands and detik.com news on October 10, 2018, it was found that rocks were still interconnected, which was estimated to be the foundation of a temple and was part of dozens of sacred religious buildings in the mountainous Ungaran landscape. Therefore research is needed to detect the presence or absence of Ngempon Temple, which is still buried. Geophysical measurement is needed to determine the subsurface structure; one of the measurement methods is Microtremor measurement.

Microtremor method can identify the sediment layer based on the resonant frequency domain \( f_0 \) and the peak value of HVSR \( A \), which shows the characteristics of the sediment. The results are two character zones; the frequency value is between 10.4 - 13.25 Hz with a range value \( f_0 \) 3.05 - 5.45 Hz [3].

Sitorus et al. conducted a study using the HVSR microtremor to analyze subsurface geological structures using natural frequency analysis and amplification. It obtained amplification values range between 1.3 - 6.2 and estimated to be moderate rock density levels. The natural frequency values range between 1.70 - 10.39, and the estimated thickness of the surface is classified as a medium between 10 - 15 meters [6]. Awanis has examined the relationship of HVSR (Horizontal to Vertical Spectral Ratio) response to a hidden object with a rectangular prism model and get deeper results in the depth of the buried object; the frequency value is low. Otherwise, if the depth of the object is superficially buried, then the frequency value is higher [2].

2. Research method
The data was collected in July 2019 in Ngempon Temple Area, Semarang Regency. This study successfully measured 39 points of microtremor field measurements. The microtremor field measurements use the DI 710 Midi Data Logger and 3 components seismometer. The distribution of the data collection is shown in Figure 1.

![Figure 1 Location of microtremor data collecting.](image)

The results of data collection are position data and microtremor signals in a time function. It consists of three components, namely two horizontal components; component X (E-W) and component Y (N-S), and one vertical component. They are then processed into dominant frequency data using Fast Fourier Transform (FFT) from the Geopsy software to obtain the HVSR spectrum curve. Dominant frequency can indicate the type and characteristics of the soil or rock layers in the region [3], and the amplification factor is the magnification of seismic waves that occur due to significant differences between layers. Seismic waves will experience magnification if it propagates in a medium that is softer than the primary
medium in its path. The higher the contrast of the wave propagation parameters (density and speed) in the two layers, the higher the amplification value [4]. The output value in the form of frequency and amplification values is used as input to make the contour in Surfer 13. The research was conducted in the Ngempon Temple Reservoir area by taking 39 measurement points, as shown in Figure 2.

3. Results and discussion

The results of data collection are position data and microtremor signals in a time function. It consists of three components; namely two horizontal components; component X (E-W) and component Y (N-S), and one vertical component. They are then processed into dominant frequency data using Fast Fourier Transform (FFT) from the Geopsy software to obtain the HVSR spectrum curve. The output values in the form of frequency and amplification values are used as input to make contours in Surfer 13 software.

| Measurement point | X | Y | Frequency (Hz) | Amplification |
|-------------------|---|---|----------------|--------------|
| Point A9          | 9 | 6 | 0.326832       | 2.49511      |
| Point A11         | 11| 6 | 0.197249       | 1.41818      |
| Point A13         | 13| 6 | 0.158644       | 1.56135      |
| Point A15         | 15| 6 | 0.176888       | 1.44379      |
| Point A17         | 17| 6 | 0.200158       | 1.41915      |
| Point A19         | 19| 6 | 0.149052       | 1.41359      |
| Point B1          | 1 | 4 | 0.41557        | 1.62892      |
| Point B3          | 3 | 4 | 0.158331       | 1.151557     |
| Point B5          | 5 | 4 | 0.150181       | 1.33286      |
| Point B7          | 7 | 4 | 1.05487        | 1.5801       |
| Point B9          | 9 | 4 | 0.160445       | 1.20002      |
| Point B11         | 11| 4 | 0.152088       | 1.00001      |
| Point B13         | 13| 4 | 0.156409       | 1.40493      |
| Point B15         | 15| 4 | 0.246549       | 1.73437      |
| Point B17         | 17| 4 | 0.149525       | 1.16407      |
| Point B19         | 19| 4 | 0.322565       | 1.41166      |
| Point B21         | 21| 4 | 0.388849       | 1.65347      |
| Point C1          | 1 | 2 | 0.174291       | 1.46525      |
| Point C3          | 3 | 2 | 0.134145       | 1.10361      |
| Point   | Frequency Value | Amplification Value |
|---------|-----------------|---------------------|
| C5      | 0.153891        | 1.45727             |
| C7      | 0.189551        | 1.5189              |
| C9      | 0.428071        | 1.58235             |
| C11     | 0.161869        | 1.70166             |
| C13     | 0.128173        | 1.822207            |
| C15     | 0.128179        | 1.82207             |
| C17     | 0.13114         | 1.12633             |
| C19     | 0.138048        | 1.52275             |
| C21     | 0.141888        | 2.71958             |
| D1      | 0.283737        | 1.33538             |
| D3      | 0.134463        | 1.04798             |
| D5      | 0.239841        | 1.37401             |
| D7      | 0.136895        | 1.79467             |
| D9      | 0.143863        | 2.07287             |
| D11     | 0.156216        | 1.52125             |
| D13     | 0.162666        | 1.33055             |
| D15     | 0.21878         | 1.72479             |
| D17     | 0.130266        | 1.48758             |
| D19     | 0.130266        | 1.48758             |
| D21     | 0.143863        | 2.07287             |

Frequency is the number of vibrations that occur in units of time. Frequency values can indicate the type and characteristics of these rocks.

**Figure 3** Frequency contours in the study area

Amplification describes the distance of changes in movement acceleration in the ground from the bedrock to the surface. Amplification value can increase if the rock has been deformed (weathering, folding, or enlarged), which changes the physical properties of the rock. In the same rock, the amplification value can vary according to the level of deformation and weathering in the body of the rock [5].
Figure 4 Amplification contours in the study area

Figure 5 Line A

Figure 6 Line B
4. Conclusion
Based on the results of research that has been done, it can be concluded that from the acquisition of 39 points in the location of the Ngempon Temple excavation located in northeast of Ngempon Temple, an anomaly which indicates a constituent rock and rock shape similar to the shape of the temple pavilion was found, and the presence of splinters - temple rock fragments, as indicated by contours at points C13, C15, A13, B7 and D9 was found. In addition, points C13 and C15 that indicate 2.5 x 2.5 m of stone temple pavilion obtained an amplification value of 1.3, and the response frequency has a sensitivity of up to 2 - 4 Hz. The existence of temple rock fragments is at point A13, B7, and D9 with frequency values of 2 Hz, 5 Hz, 8-10 Hz, and amplification values of 1.3 for each.

Acknowledgement
Authors and member Laboratory of Geofisika University of Diponegoro, Mr. Miftah owner landlord, Mr. Puryanto temple keeper and BPCB (Institution of Cultural Preservation) who gave the opportunity to finish this research.
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