A Study of Geological Formation on Different Sites in Batu Pahat, Malaysia Based On HVSR Method Using Microtremor Measurement

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Abstract. Geological formation is a one of information need to know during site reconnaissance. Conventional method like borehole has been known is very accurate to identify the formation of geology of a site. However, the problem of this technique is very expensive and not economical for large area. In the last decade, microtremor measurement has been introduced as an alternative technique and widely used in the geological formation study. Therefore, the aim in this study is to determine the geological formation underneath of surface in Batu Pahat district using microtremor measurement. There are two parameters have been carried out from microtremor measurement in term of natural frequency and HVSR curves images. Microtremor measurements are done conducted at 15 sites surrounding of Batu Pahat. Horizontal to vertical spectral ratio (HVSR) method was used for analyzing microtremor measurement data, to determine the natural frequency and also HVSR curves image. In this study, values of natural frequencies are used to classify the soil types with range in the between 0.93 to 5.35 Hz, meanwhile the pattern of HVSR curve images has been shown exists a few groups of soil types surrounding Batu Pahat district. Hence, microtremor measurement indirectly can be used as a one technique to add value in the site reconnaissance in the future.

Keywords: Geological formation, natural frequency, microtremor.

1. Introduction

During site reconnaissance, determination of geological formation is important for geologist and engineers [1]. It is very useful in the collecting various information of soil and very required in the foundation design. A direct technique such as borehole is a common technique and was used for a long time. However, this technique is very limited in providing a details information caused by factors of costing and time. As a fulfilling a high requirement to obtain a complete information of geological formation, microtremor measurement has been introduced as alternative technique [2].

Microtremor is a constant vibration of the earth surface and generated by natural sources (wind, rain and ocean waves) and man-made such as traffic and industry activities [3]. Microtremor measurement based on Horizontal to vertical spectral ratio (HVSR) method, which was employed by Nagoshi and Iragashi (1970, 1971) and widespread by Nakamura [4]. Nowadays, HVSR method is widely used in the various of application such as site effects evaluating, seismic microzonation and basin structure [5].
2. **Geological Setting of Batu Pahat**

Generally, the geological formation of Batu Pahat district is underlying on the unconsolidated soils deposits classified in Quaternary zone and intrusive rock. In addition, there are a few parts in Batu Pahat located on the Permian deposits (Northern Batu Pahat). Mostly the topography of Batu Pahat is relatively flat. Figure 1 shows the geological formation of Batu Pahat districts [6]. There are 15 sites where the microtremor has been done as a listed in the Table 1.

![Figure 1. Geological formation at Batu Pahat district.](image)

| No. | Name of Locations                                                                 | Borehole |
|-----|-----------------------------------------------------------------------------------|----------|
| 1   | Rugby Field at Universiti Tun Hussein Onn Malaysia                                | Yes      |
| 2   | Faculty of Civil & Environmental Engineering, Universiti Tun Hussein Onn Malaysia | Yes      |
| 3   | Faculty of Mechanical & Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia | Yes      |
| 4   | Sekolah Kebangsaan Bukit Soga                                                     | Yes      |
| 5   | Sekolah Menengah Kebangsaan Dato’ Bentara Luar                                   | Yes      |
| 6   | Klinik Desa Sejagong                                                              | Yes      |
| 7   | Sekolah Kebangsaan Sejagong                                                       | No       |
| 8   | Sekolah Kebangsaan Seri Medan                                                     | No       |
| 9   | Sekolah Menengah Kebangsaan Seri Medan                                            | Yes      |
| 10  | Sekolah Kebangsaan Sungai Tongkang                                                 | Yes      |
| 11  | Masjid Pekan Rengit                                                               | Yes      |
| 12  | Masjid Punggor Kechil, Rengit                                                     | Yes      |
| 13  | Sekolah Menengah Kebangsaan Banang Jaya                                           | Yes      |
| 14  | Sekolah Kebangsaan Seri Molek                                                      | Yes      |
| 15  | Pantai Minyak Beku                                                                | No       |
3. Methodology
Microtremor measurement was done conducted on 15 sites surrounding Batu Pahat district. Only 13 from 15 sites have boreholes. All of location has been determine based on report as provided by IKRAM Selatan Sdn. Bhd. Meanwhile, microtremor measurement on the three locations without borehole reports are also conducted as a comparison data. Then, seismometer sensors were leveled on placed on the ground surface before recording. All of seismometer sensors are aligned to the True North as a benchmarking. Ten minutes of recording length for each measurement was taken with 100 Hz of sampling rate. The external noise disturbances such as extreme weather, transient noises, monochromatic sources and nearby structures were minimized to the lowest operational for the best result of natural frequency prediction as recommended by SESAME (2004) guideline [7]. Figure 2 shows the microtremor measurement equipment and positions of sensors on fieldwork in this study.

Geopsy software was used for HVSR analysis. A 10-sec of automatic window length selection with an anti-triggering algorithm and a cosine taper of 5% were used. Fourier spectra were computed for each window length and smoothed by a Konno Ohmachi smoothing constant of 40. The reliability and clarity for the significant peaks of mean HVSR curves were checked against the criterions recommended in the SESAME (2004) guideline.

Figure 2. (a) Microtremor equipments, (b) Microtremor measurements on fieldwork (c) Arrangement of seismometer sensors (d) Seismometer sensors are leveled and always aligned to True North.

4. Result and Discussion
Mean HVSR curves of 15 locations of measurements in this studies area have been computed for natural frequencies in the average of directional energy. Natural frequencies are refer to ambient noise signal from surface and used to determine the types of subsurface conditions. Kanai and Tanaka (1954) were the founders to purpose a method of ground classification based on the characteristics of the ambient noise signals [8]. Table 2 shows the natural frequencies at Batu Pahat area.
Table 2. Result of natural frequency ($F_o$) at Batu Pahat.

| Site No. | Natural Frequency, $F_o$ (Hz) |
|----------|-------------------------------|
| 1        | 1.26                          |
| 2        | 1.61                          |
| 3        | 1.61                          |
| 4        | 2.51                          |
| 5        | 2.27                          |
| 6        | 4.51                          |
| 7        | 4.51                          |
| 8        | 2.19                          |
| 9        | 1.91                          |
| 10       | 0.93                          |
| 11       | 0.96                          |
| 12       | 0.99                          |
| 13       | 4.55                          |
| 14       | 2.69                          |
| 15       | 14.49                         |

From Table 2, mostly subsurface at Batu Pahat district can be classified in the soft soil group [9]. Based on study cases in the Almeria city, natural frequencies values are 16.67 Hz on hard rock, to 2.5 Hz on medium soil and 0.70 Hz on very soft [5]. It is consistence with the geological map (see Figure 1), where most of Batu Pahat area located in the Quaternary deposits. Comparison with boreholes reports are also shows a same thing happen, where most of soils at Batu Pahat are consists from marine and continental deposits likely clay, silt, sand, peat with minor gravel. At the meantime, most of sites at Batu Pahat are dominated by single peak of HVSR curves, with the natural frequencies in the range 0.93 to 4.55 Hz. Figure 3 shows the HVSR curves from microtremor measurement at Batu Pahat district.

Figure 3. HVSR curve from microtremor measurement at Batu Pahat.
A single peak of HVSR curves are happen probably the existence of deep soil thickness with a large velocity contrast at the sites. In addition, a lower natural frequency (less than 2 Hz), at the most site is also contributes to exists a single peak of HVSR curve. However, there are 4 from 15 sites are shows the natural frequencies more than 3 Hz. Site No. 6, 7, 13 and 15 (see Table 2), the natural frequencies are high caused by geological factor. For site No. 6, existing of shallow bedrock (granite layer) has been founded at 7 to 10.5 m [6]. A same situations is happen for site No. 7 because this site located at the besides site No. 6. Slightly difference of soil composition between clay/silt, sand and gravel is a probably factor why the natural frequency at Sekolah Menengah Kebangsaan Banang Jaya (site No. 13) is high [7]. For site No. 15 (Pantai Minyak Beku), the natural frequency is 14.49 Hz and HVSR curve is multiple curves caused by the measurement is conducted on the outcrop of bedrock. Figure 4 shows the outcrop of bedrock at Pantai Minyak Beku.

Figure 4. Outcrop of bedrock at Pantai Minyak Beku.

5. Conclusion
Study of geological formation underneath of soil surface is very important to know the types and depth to hardlayer (bedrock). It is because these information are useful in the designing works especially to design the types of foundation. Borehole is common technique is used to obtain these information, but this technique is not economical for the large scale like to develop a geological maps. Therefore, microtremor measurement of HVSR method has been introduced as an alternative method in the subsurface exploration. Although, this method is still debated until now, but it is very useful in the mapping works because this method is very simple.

Based on microtremor measurement at Batu Pahat, natural frequencies are distributed in the range 0.93 to 14.49 Hz. Location of Batu Pahat is located on the Quaternary deposits shows most of site at this site have a natural frequency less than 2 Hz. In addition, existing a single peak of HVSR curves is helpful to answer the geological formation at Batu Pahat. Supported facts from site investigation report and geological map as provided by IKRAM Selatan Sdn. Bhd and Department of Minerals and Geosciences is evidence to prove the microtremor measurement of HVSR can be used is a one methods in the subsurface exploration.

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