IDENTIFICATION OF SITE CLASS USING MICROTREMOR HVSR MEASUREMENTS IN TANAH KAMPUNG DISTRICT

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ABSTRACT

This research was conducted to determine the site class of the soil in the Tanah Kampung District in Sungai Penuh City. In this case, the method used is the HVSR microtremor method. HVSR is a method of comparing the spectrum of the horizontal component to the vertical component of a microtremor wave that recorded by seismograph. HVSR parameters were used to calculated shear wave velocity (Vs30) to defined site class. It reveals this areas classified in site class SC and SD. The area is predominantly composed of SD. This areas are characterized by soft sediments that require special handling if heavy infrastructure development is planned above them. This can be done by compacting the soil layers and mixing them with limestone.

Keywords: *HVSR; Shear wave velocity; Vs30; Microtremor; Site class*

INTRODUCTION

Earthquakes are one of the destructive natural hazards that can potentially occur in Kerinci Regency and Sungai Penuh City, causing severe damage to infrastructure and even resulting in casualties. According to Badan Meteorologi, Klimatologi dan Geofisika (BMKG) seismic records, in the past 100 years, there have been approximately three significant tectonic earthquakes. The historical earthquake of M 7,3 was centered at junction between Siulak and Dikit segment, the earthquake of M 6,7, which occurred in 1995 along near end of Siulak segment, and the earthquake of M 6,6 along Dikit segment in 2009 (Wulandari, 2013; Hurukawa, 2014). These events had widespread effects, with areas near the earthquake source experiencing high levels of damage. These disasters have altered the geological landscape, including geological structures, physical rock properties, land use, and have triggered other disasters.

Tanah Kampung District is part of Sungai Penuh City, Jambi Province. It is located on a valley and crossed by Semangko fault, making them prone to earthquakes. Kerinci Regency and Sungai Penuh City are part of the Barisan Magmatic arc zone. This area also hosts one of the highest active volcanoes in Sumatra, Mount Kerinci. Therefore, natural disasters in this region can result in significant material losses and casualties. This was proven by the research conducted by Resta (2021), where Tanah Kampung District, which is part of Sungai Penuh City, was categorized on the VII MMI scale of seismic hazard zone. One aspect of developing Tanah Kampung District is planning, which includes technical design or spatial mapping necessary for infrastructure development. Planning infrastructure development requires information on land conditions and stability against soil movement risk, including geological information on soil and rock conditions. This information serves as an initial reference for detailed planning, ensuring the infrastructure is resilient to disasters, especially unpredictable ground movements, and minimizing building damage. Identifying the dynamic characteristics of soil layers to classify site class is one approach to obtaining geological information.

While earthquake hazards cannot be avoided, their impacts can be mitigated. For earthquake disaster mitigation, seismic measurements are needed to provide relevant information. Seismic measurements can be conducted using various developed methodologies. Previous researchers have used the microtremor method to evaluate site effects and produce site class maps in urban environments (Putti, 2020; Sedaghati, 2020). The Horizontal to Vertical Spectral Ratio (HVSR) approach is used to process microtremor data from free field measurements in order to generate H/V curves that show the physical characteristics of waves, such as natural frequency (f0) and amplification (A0). The value of A0 is assumed to reflect the HVSR amplitude of the superficial layers due to the multiple

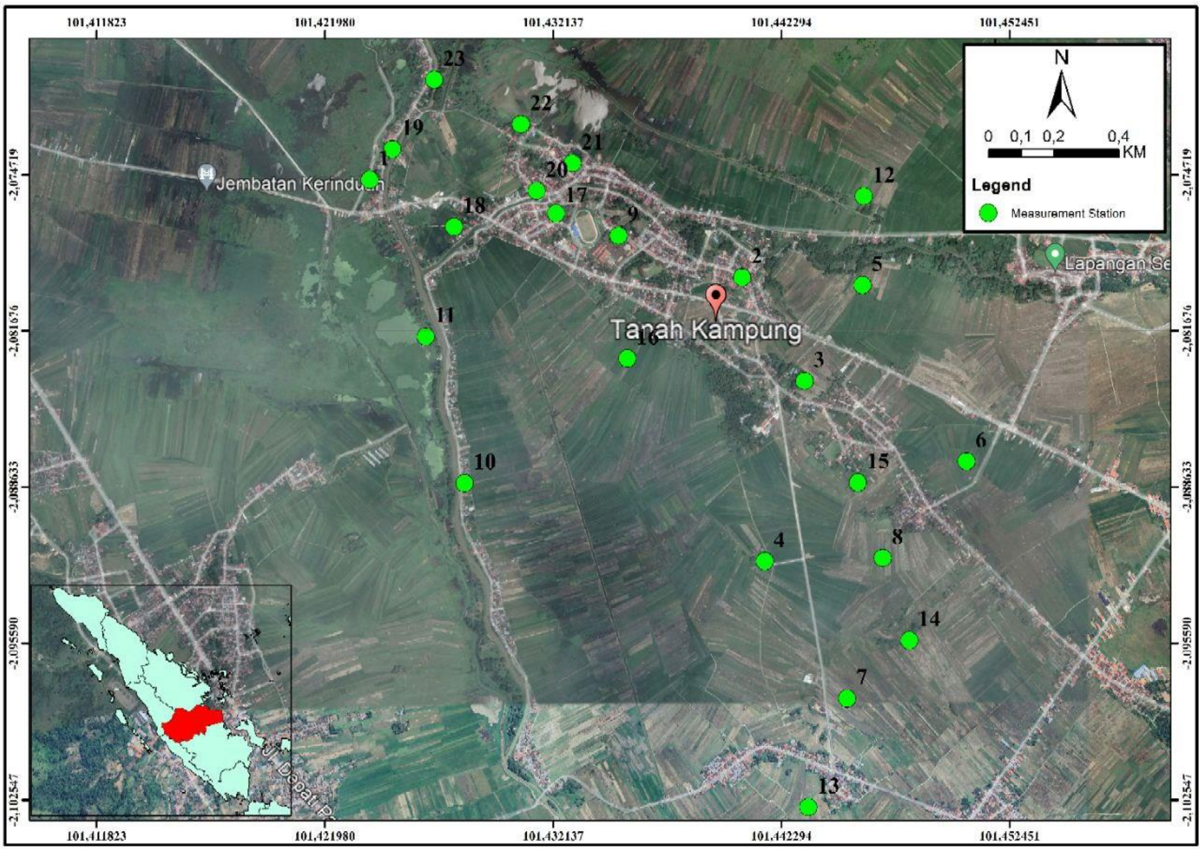

Figure 1. The Spatial Distribution of Measurement Station over in Tanah Kampung District

reflections of the horizontal shear waves at frequency f0 (Nakamura, 2019). Both of physical properties was used to calculate shear wave velocity values (Vs30) as parameter to classified site class.

METHODS

The shear-wave velocity down to engineering bed rock (at least 30 m depth) is employed to conduct site classification for the 23 sites using HVSR microtremor data. Several acquisition and processing criteria has been implemented in order to acquire dependable HVSR curves. The most critical criteria are the accurate and appropriate installation of the instrument and the reliable selection of time intervals.

The following is the methodology for the site classification-based microtremor in this study: A single station measurement with a 3-component seismometer was used to capture ambient vibration data. Continuous recordings of ambient noise signals consisting of three components were taken at a frequency of sampling about 1000 samples per second. According to the specifications published by Sesame (Sesame, 2004), the recommended minimum duration for recording using the HVSR technique varies based on the estimated fundamental frequency of the soil. Notably, a number of articles recommend that microtremor recordings be made for 20 to 30 minutes (Molnar, 2018). So, this work utilises a recording duration of 30 minutes.

The Geopsy software, available at http://www.geopsy.org, is an open-source software used to process the microtremor readings. In order to accurately compute the H/V spectral ratio, it is crucial to select reliable windows that can effectively identify the site effect. This is particularly important when dealing with background noise, which consists of numerous unrelated sources. The 3-component dataset was split into some non-overlapping windows. The HVSR, or Horizontal-to-Vertical Spectral Ratio, was calculated for each window through determining the geometrical average of the horizontal component spectrum and dividing it by the vertical spectrum. The output is commonly shown as a maximum value on a semilogarithmic graph that represents the spectral ratio H/V as a function of frequency. The maximum value (shown as peak curve) correspond to both the maximum value of the spectral ratio H/V (sometimes referred to as A0) and the dominant frequency (f0) of soil. Both of output that obtained is utilised for site classification. In order to assess the risk of future structures prior seismic events occur, international guidelines recommend classifying the site type according to Palemón-Arcos

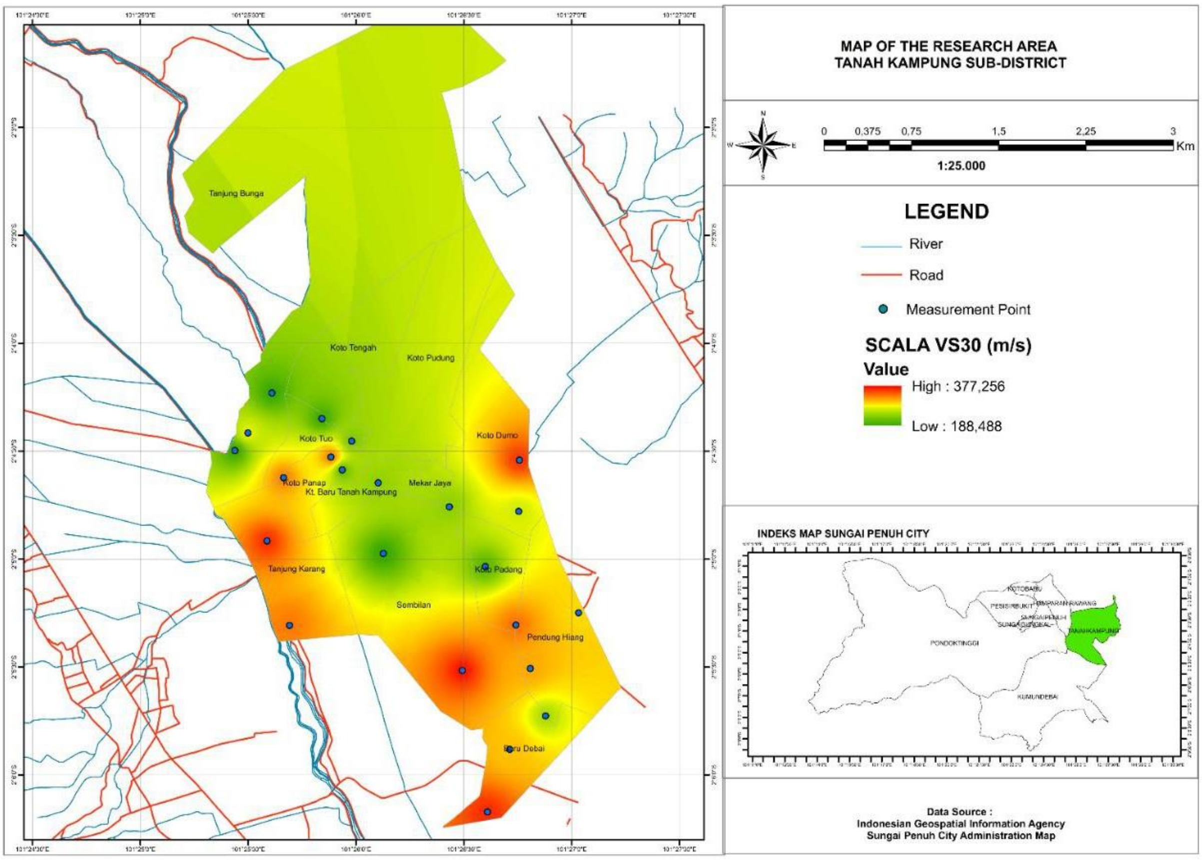

Figure 2. The Spatial Distribution of Vs30 value in research area

(2020), the value of Vs30 is a reliable measure that has been widely used to describe the behavior of a site in response to seismic activity. The previous study conducted by Pergalani in 2020 emphasized the usefulness of this parameter in the establishment of construction regulations, the design of earthquake-resistant structures, and the analysis of seismic zoning in urban environments. The soil classification for site class according to NEHRP (2001) based on Vs30 value is shown in Table 1.

Table 1. Type of site class according to NEHRP (2001) based on the average shear velocity to a depth of 30 m

Soil Type	General Description	Vs30
A	Hard rock	$Vs30 > 1500$
B	Rock	$760 < Vs30 < 1500$
C	Hard and/ or very stiff soil	$360 < Vs30 < 760$
D	Rigid Soils	$180 < Vs30 < 360$
E	Semi-rigid soils	$Vs30 < 180$
F	Soils that require specific calculations	Does not apply

RESULT AND DISCUSSION

The objective of this study is to investigate the soil's dynamic attributes in order to define the site class. This classification will serve as supporting data for regional planning of development processes in the Tanah Kampung District. A map of site class classification is the output of this investigation. The site class classification map obtained is the result of calculations from shear wave velocity (Vs30).

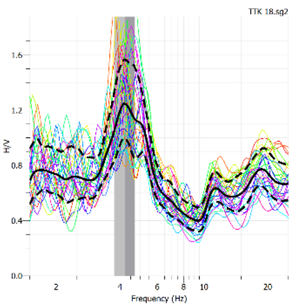

Figure 3. Example Result of HVSR curve. The average H/V spectral curves are defined by a solid black line

Free-field microtremor measurement of 23 stations (Figure 1) are used for site classification according to Vs30. After achieving the 23 HVSR curve computed by the software Geopsy, the output parameters (f0 and A0; Figure 3) was used to calculate Vs30.

After generating the individual station HVSRs, we visually examine the data to identify distinct peaks and determine if there are any peaks present or not on both the stations with weak and strong motion. In order to determine the pick uncertainty, we manually select the peak frequency on the average HVSR estimations and the 2σ standard deviations for stations with unambiguous peaks. Stations are regarded as having no results if there is no visible HVSR peak. The thickness (h) and average S-wave velocity (Vs) of the softer geologic material close to the surface are connected to a site's resonance frequency (f0) (Castellaro and Mulargia, 2009). Meanwhile, recent ground motion prediction models employ site amplification factors that are determined by broad soil classes, often defined by the average shear-wave velocity in the upper 30 meters (Vs30).

The average shear wave velocity map in Tanah Kampung District, which shows values down to 30 metres below the surface (Vs30), shows a range of 188,488 to 377,256 m/s (Figure 2). Most of area, particularly from the centre to northern parts, is dominated by values around 188,488 m/s to 250,560 m/s. The southern region, shows the highest values relatively, with values ranging from around 250,561 to 377,256 m/s.

In soil class mapping (site class), the estimated shear wave velocity values up to a depth of 30 meters below the surface (Vs30) are used as information regarding the material characteristics of the subsurface layers of an area. Higher Vs30 values indicate an amplification effect on soil stiffness. Hence, the southern region regarded as area with an amplification effect on soil stiffness. Conversely, lower Vs30 values, from the centre to northern parts suggest that the area is composed of soft-structured materials. The same results were obtained in the study conducted by Petersen (2008), lesser Vs30 values are linked to softer soils and site amplification of 1,5-2, whereas higher Vs30 values are connected with strong, dense rock and lower levels of ground shaking.

The site class classification was defined by using Table 1. It reveals this areas classified in site class SC and SD (Figure 3). When compared to SC, the site class SD has the most stations, while the site class SA, SB, SE and SF are not present from any locations that the data are available. These results are consistent with the interpretation of the regional geology of the study area. Reviewing the Regional Geology Map of Painan Sheet (Rosidi, 2011) and Sungai Penuh Sheet (Kusnama, 1992), there is a correlation with the Kumun Formation (Tmk), Pengasih Formation (QTp), and Alluvial Deposits (Qa), indicating that most of the study area is likely composed of loose sedimentary materials and soft rocks that have not been fully compacted.

The area is predominantly composed of SD. It is shown that soil class D estimations are generally related to regions with thick sediment deposits. Meanwhile, soil classified as SC and results of HVSR with no distinct peak are frequently observed in higher elevation areas. The same results can be found in another study by McNamara (2015).The SC areas are characterized by hard or compact sediments, the SD areas are characterized by soft sediments that require special handling if heavy infrastructure development is planned above them. According to Lee (2020), for geotechnical purposes such as building construction or other infrastructures, it is necessary to perform geotechnical engineering on weathered and medium soil layers. Geotechnical engineering aims to harden soil layers so they can be used as a strong foundation base for buildings. This can be done by compacting the soil layers and mixing them with limestone. This solution can help minimize damage in regional planning due to earthquake shocks.

CONCLUSION AND SUGGESTION

The average shear wave velocity up to a depth of 30 meters below the surface in Tanah Kampung District varies between 188,488 to 377,256 m/s. The soil class classification map shows that Tanah Kampung District consists of site class SC and SD. The area is predominantly composed of site class SD. The area with site class SD is characterized by soft sediments that require special handling if heavy infrastructure development is planned above them. It is recommended to construct solid foundations by compacting soil layers and mixing them with limestone. This will enhance the resilience of buildings and infrastructure against earthquake damage. Additionally, detailed site-specific studies should be conducted to further understand the seismic risks and to design appropriate mitigation measures. Incorporating modern building techniques and materials that can withstand seismic forces will also be crucial in reducing potential damage.

Furthermore, it is important to continuously monitor and update the geological and seismic data of the region to ensure that the infrastructure development aligns with the latest safety standards and risk assessments. Public awareness and preparedness programs should also be implemented to educate the community about earthquake risks and safety measures.

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