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Analysis of Microtremor Data Using Horizontal to Vertical Spectral Ratio (HVSR) Method of Makassar, South Sulawesi

[1*]R. Jamroni, [2]A.M. Imran, , [2]B. Azikin

[1]Master Student of Geology Department, Hasanuddin University
*Meteorological, Climatological and Geophysical Agency, Makassar
(ronie.jr@gmail.com)
[2]Geology Department, Faculty of Engineering, Hasanuddin University
(mudhimran@gmail.com)

ABSTRACT

Makassar has experienced earthquakes indicating that the city is an area vulnerable to earthquake hazards. The regional tectonic setting supports the hazard in which several major faults develop surrounding the area. Earthquake events in the Makassar Strait of 4.5 SR in December 2015 is one of the hazard in this area. However not all the area was shaking at the same magnitude. The assumption is the different rock formation composing Makassar. Data taken from microtremor measurement supported by coring suggest a dominant frequency distribution has a significant relationship with the rock formation. Low dominant frequency arose at the area with thin sediment deposit (dominantly Camba Volcanic rock) and a high dominant frequency value came up at the area with thick sediment deposits (alluvial). High seismic susceptibility index is found in thick sediment deposit. The area consists of interlayering between sand and clay and has shallow ground water table. On the other hand low vulnerability index is found in thin sediment deposit. It consists dominantly of tuff of Camba Volcanic Rock and has deep groundwater table.

Keywords: HVSR, Seismic Vulnerability Index, Sediment thickness

1. INTRODUCTION

Makassar city is one of the cities in South Sulawesi which is prone to earthquake due to its location surrounded by several major fault such as West and East Walanae Faults, Transform Fault (Fig. 1). Furthermore Makassar City its self lies above the Quaternary sediments that can lead to amplification and multi-reflection seismic waves. It encourages the authors to conduct research on the effect of the distribution of sediment thickness by using microtremor data on the seismic vulnerability index value for the area of Makassar City.

The degree of damage caused by earthquakes in a place is influenced by several factors such as earthquake mechanism, magnitude, depth, epicenter distance and local geological conditions [6]. The local site effect phenomenon appears in some of the world's destructive earthquakes occurring as a result of the contrast of impedance. The presence of thick layers of sedimentary over the bedrock triggers multi-reflection of seismic waves between the bedrock and the surface sediment layer. The study of the effect of sediment thickness on the seismic vulnerability index is one of the topics of interesting field research on mitigation of earthquakes.

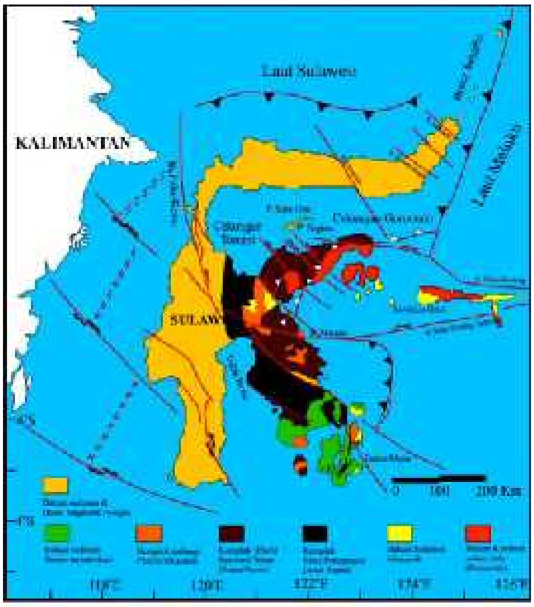

Fig. 1 Tektonic Setting of Sulawesi showing West and East Walanae Fault and Patenoster Fault in Makassar Strait [1, 2, 3, 4 and 5].

Rapid population growth of Makassar triggers rapid growth of human settlement and infrastructures. Therefore infrastructure should be mitigated in order to reduce risk of damage and fatality. To assess earthquake seismicity an indispensable earthquake mapping Seismic Vulnerability Index for Makassar City should be done.

2. RESEARCH METHODS

Study area locates in Makassar with coordinates 5.06 ° S - 5.25 ° S and 119.38 ° E - 119.54 ° E (Fig. 2a). The sample of study of microtremor measurement is 100 locations. The number of sampling is with considering with some of the requirements set by the SESAME European Research Project [7]. The microtremor data samples are the primary data to obtain frequency and amplification values that would be used to determine the sediment thickness in order to interpret a seismic susceptibility index.

Fig. 2 Study area in which two rivers bordering Makassar, Tallo river in the north and Jeneberang river in the south

The data collected from the field area was analyzed at Meteorological, Climatological and Geophysical Agency (BMKG), Makassar, South Sulawesi using:

A set of short period seismograph / portable velocity of type TDL-303S (3 Components), consists of seismometer sensor, digitizer, GPS antenna, connector, power (solar cell / accu), and a set of laptops for data processing.

Some software / software support such as data-pro (convert raw data Geopsy, excel, surfer and arc-GIS to be used to process and analyze microtremor data and drill data (Fig. 4).

Microtremor data processing using Horizontal to Vertical Spectral Ratio (HVSR) method. The data of the field measurement is the ground vibration data in the time function recorded in 3 components, namely vertical component, north-south component, and west-east component, In general the spectrum analysis process in Geopsy is as follows:

1. The microtremor recording data (3 components) in the mini-seed format will be filtered using an anti-triggering algorithm to avoid part of the transient noise recording. After the transient noise is detected, then the recording portion which is ambient noise is divided into several windows, the length of each window is 20 seconds. According to the SESAME European Research Project (2004), it is recommended that the window length determination be at least lw = 10 / f_o, in this case fo is the resonance frequency and lw is the window length.
2. Processing Fourier transforms to signals within the time zone of the windowing process which aims to convert the signal from the time zone to the frequency region so that the fourier spectrum is obtained. Averaging fourier spectrum of horizontal component (east-west and north-south) in the research area with fourier spectrum of horizontal component at reference region (SSR Method), then averaging fourier spectrum of horizontal component (east-west and north south) with spectrum Fourier vertical components in the study area to obtain the H / V spectrum (HVSR method). GEOPSY software output results in a flat spectrum microtremor. From this spectrum we can know the value of resonance frequency (fo) and microtremor spectrum peak (A) at the measurement location.
3. Calculate the depth of sediment by dividing the shear wave velocity value at a depth of 30 meters (Vs30) with four times the resonance frequency (f0) at the study site.

3. RESULT AND DISCUSSION

Makassar City is bordered by two rivers Tallo River in the north of the city and Jeneberang River in the south (Fig. 2). Tallo River has a length of 66 km and its river flow area of 417 km2 and is a river whose estuary is strongly influenced by sea tides. Jeneberang River flow area has an area of 727 km2 with a river length of 75 km2. Both rivers play an important role in sediment formation in Makassar [8].

The dominant frequency value (f_0) of Makassar is obtained from the top of the spectrum using the HVSR method of three components microtremor data processing. The dominant frequency value (f_0) ranges from 1.1 Hz to 9,1 Hz. The dominant frequency of HVSR average in research area is 3.0 Hz and the lowest value is 1.1 Hz, which locates in Tanjung Merdeka 1 (MT019), Tamalate. In contrast, the highest dominant frequency (f_0) HVSR value is 9.1

Hz arising in Karampuang (MT054), Panakkukang.

The sediment thickness ranges from 6.5 meters at Karampuang to 46.9 meters at Ujung Tanah (Fig. 3). The Karampuang area is covered by Volcanic Camba as a basement of the sediment material, on the other hand Ujung Tanah area is dominated by alluvial deposits. This case indicates the strong relationship between HVSR resonance frequency and sediment thickness with correlating value equal to - 0,992 (Fig. 3). The relation between low frequencies and thick sediment layer (vice versa) has been studied by Daryono [9].

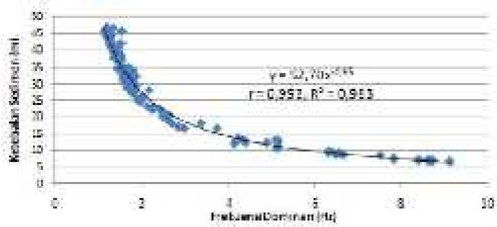

Fig. 3 Graph showing relation between sediment thickness and dominant frequency of HVSR resonance.

The microtremor data can also use to analyze Seismic vulnerability index (Kg) by calculating the designation of the HVSR spectrum. The calculation result of seismic vulnerability index (Kg) in Makassar ranges from 0.1 to 62.2 (Fig. 3). The high variation in seismic susceptibility index value (Kg) is strongly influenced by the dominant frequency value (f_0) and the peak of the spectrum / amplification factor (A_0). The lowest seismic susceptibility index is found at Tamalanrea Jaya 1 with a seismic susceptibility index value of 0.1. The value is obtained by calculating the dominant frequency value (f_0) of 5.1 Hz and an amplification factor (A_0) of 0.9. The area consist dominantly of Camba Volcanics.

The highest seismic vulnerability index (Kg) with seismic vulnerability index value greater than 60 is located at the Wajo Baru, Layang and Pampang. The dominant frequency value (f_0) is between 1.4 and 1.6 Hz with an amplification factor (A_0) of 9 to 10.

The value of low seismic vulnerability (Kg) index (0.1 to 5) locates in the north and east part of Makassar (Panakukang, Manggala, Tamalanrea and Biringkanaya). Those areas consist predominantly of Camba Formation which is massive rock. On the other hand the high seismic vulnerability index (more than 5) covers western and southern parts of Makassar. The area dominantly composes of alluvial deposits. Considering the lithology with relation to the seismic vulnerability index, it can be explain that the massive rock provides low seismic vulnerability index and vice versa.

The results of microtremor measurements showed that seismic vulnerability index values in the study area ranged from 0.1 to 62.6 (Figure 2b). Based on the relationship between the seismic vulnerability index, the type and thickness of the sediment, water table, the research area can be seismically grouped into two classes of vulnerability, ie: high vulnerable and low vulnerable areas. High vulnerable area means that the area experienced an earthquakes and has a vulnerability index value of > 1. While low vulnerability is an area which does not locally experience during earthquakes. It has seismic vulnerability index values < 1. This classification has also been explained by Daryono [8].

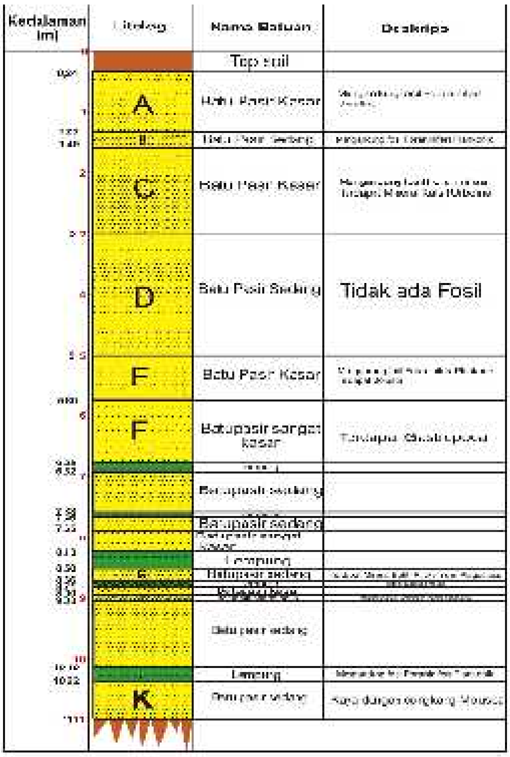

Fig. 4 Stratigraphic sequence of Quaternary deposit for core Lakkang (Tello Rivers), Makassar. Most of the sediments are sand size and few thin layers from clay.

Seismic distribution of high vulnerable area covers the distric of Mariso, Mamajang, Tamalate, Rappocini, Makassar, Ujung Pandang, Wajo, Bontoala, Ujung Tanah, Tallo and Panakukang. The area of high vulnerability consists of alluvial alluvium (sand, silt and clay) and has shallow ground water level (less than 2 meters). Such condition can be potentially to occur liquefaction during earthquakes. Low vulnerable areas is found in 3 sub-districts of Manggala, east and north, Tamalanrea and Biringkanaya. This low vulnerable area has index value < 1. The area distribution consists of volcanic rock of Camba Formation with a thin sediment thickness. The area has a groundwater level more than 2 meters. The seismic vulnerability dispersion map is presented in Fig. 5.

Fig. 5 Seismic vulnerability dispersion map showing two groups (red color: high index and green: low index)

4. CONCLUSION

Seismic vulnerability index of Makassar, South Sulawesi shows a significant correlation to the thickness of sediment deposit. Low seismic vulnerability index corresponds to the thick sediment deposit, whereas high seismic vulnerability index corresponds to the thin sediment deposit.

Groundwater level affects the distribution of seismic vulnerability index values. The high seismic vulnerability index is located at thick sediment deposits characterized by silt and clay material, and shallow groundwater level. In contrast, low seismic vulnerability index is characterized by thin sedimentary deposits composed of sand material and tuff. The area has deep ground water level.

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