DETERMINATION OF SEISMIC VULNERABILITY INDEX AND SEDIMENT THICKNESS USING THE HVSR METHOD IN PALU CITY AREA

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ABSTRACT

The Palu City area is one of the areas that are vulnerable to the impact of the earthquake, seen from the seismicity and the Palu-Koro fault. Therefore, it is necessary to analyze the seismic vulnerability index and the thickness of the sediment layer in the Palu city area. This study uses the microtremor method with HVSR (Horizontal to Vertical Spectrum Ratio) analysis. The HVSR method produces natural frequency parameters (fo) and amplification (Ao) which are presented in the form of an H/V curve so that this method can estimate the seismic vulnerability index (Kg). The H/V then becomes the input for the ellipticity curve analysis to get the thickness of the sediment layer (h). The results of the study show that the Kg value ranges from 0.16 to 37.09. The lowest Kg value is located at the point MP2234-14 (Kawatuna Village).) and the highest Kg value is located at MP2234-06 (Petobo Village), the high Kg value tends to be in the valley area and areas close to the coast, while the hillside tends to be low. The results of the analysis of the thickness of the sediment layer (h) ranged from 7 m to 128 m, the thick sediment layer is in the valley and coastal areas, while the thin sediment layer tends to be in the area oh the hills..

1. Introduction

Earthquake natural disasters are a destructive natural phenomenon and often occur in Indonesia, almost 70% of Indonesia's territory is in earthquake-prone areas (Ramadhani, 2011). Natural disasters often occur in areas around plate confluence, between continental plates and oceanic plates as a result of collisions between these plates (Meidji, 2014). Regionally, one of the active faults in this region is the Palu-Koro fault (Widyaningrum, 2012). Sulawesi, especially Palu City and its surroundings, is in an area that is prone to earthquakes and can cause them damage to the environment, infrastructure, causing loss of life and loss of property.

Based on historical records, the major earthquakes that occurred in Central Sulawesi have been recorded since the 19th century, some of them in 1907, 1927, 1930, 1938 (7.6 SR), 1968 (6.0 SR), 1982 (4.5 SR) , 1983 (5.8 SR), 1994 (5.9), 1996 (7.0 SR), 1998 (6.1 SR), 2000 (6.2 SR), 2002 (5.8 SR), 2005 (6.2 SR) (Ramadhani, 2011), 2011 (5.3 SR) (BMKG, 2011) and 2018 (7.5 M) (PuSGeN,

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2018). Based on topographical and geological conditions, the City of Palu has the potential to be damaged by earthquakes, including secondary disasters (Ramadhani, 2011).

The BMKG earthquake history record and the 2018 National Earthquake Study Center state that the Palu-Donggala earthquake on September 28 2018 (M 7.4) had occurred 160 aftershocks in the period up to October 3 2018. The results of the relocation of the epicenters show that there is a pattern of distribution of epicenters/lineations parallel to the fault Palu-Koro (Dwiyanti et al, 2020). One way to know the geological conditions The local method is to use the microtremor method with the HVSR technique introduced by Nakamura (1989) to characterize soil structure (Sungkono and Santoso, 2011). The dynamic characteristics identified are natural frequency (f0) and amplification factor (A0), then calculations are performed to determine the seismic vulnerability index (Kg) and the thickness of the sediment layer (h).

Nakamura (1989) showed that HVSR is a method that can be used to interpret soil characteristics such as soil type and sediment layer thickness in an area obtained from the interpretation of the H/V curve as a function of natural frequency and its amplification factor. Asten and Dhu's research (2002) also explains that the HVSR curve can be used to estimate the thickness of the sediment layer (Daryono, 2011).

The seismic vulnerability index (Kg) is a number that can express the vulnerability of the surface soil layer due to changes in the shape of the soil layer during an earthquake, so that it can be used to determine the high or low potential for an area to suffer damage (Utami, 2017), mathematically it can be written as:

$$K_g = \_ \qquad (1)$$

This Kg equation shows that the seismic vulnerability index is inversely proportional to the dominant frequency and directly proportional to the amplification. Areas with higher Kg values are more prone to earthquakes, while areas with a lower seismic vulnerability index are more resistant to earthquake hazards.

2. Research Methods

The research location is in Palu City, Central Sulawesi. This research was conducted in 46 sub-districts and 8 sub-districts. Microtremor data was obtained from measurement data carried out by a team from the Palu City BPBD in 2018 (before the September 28 2018 earthquake) as many as 283 measurement points. Each point is measured for 40 to 72 minutes with intervals of 400 to 1000 meters between measuring points. The following is the process of processing and interpreting data:

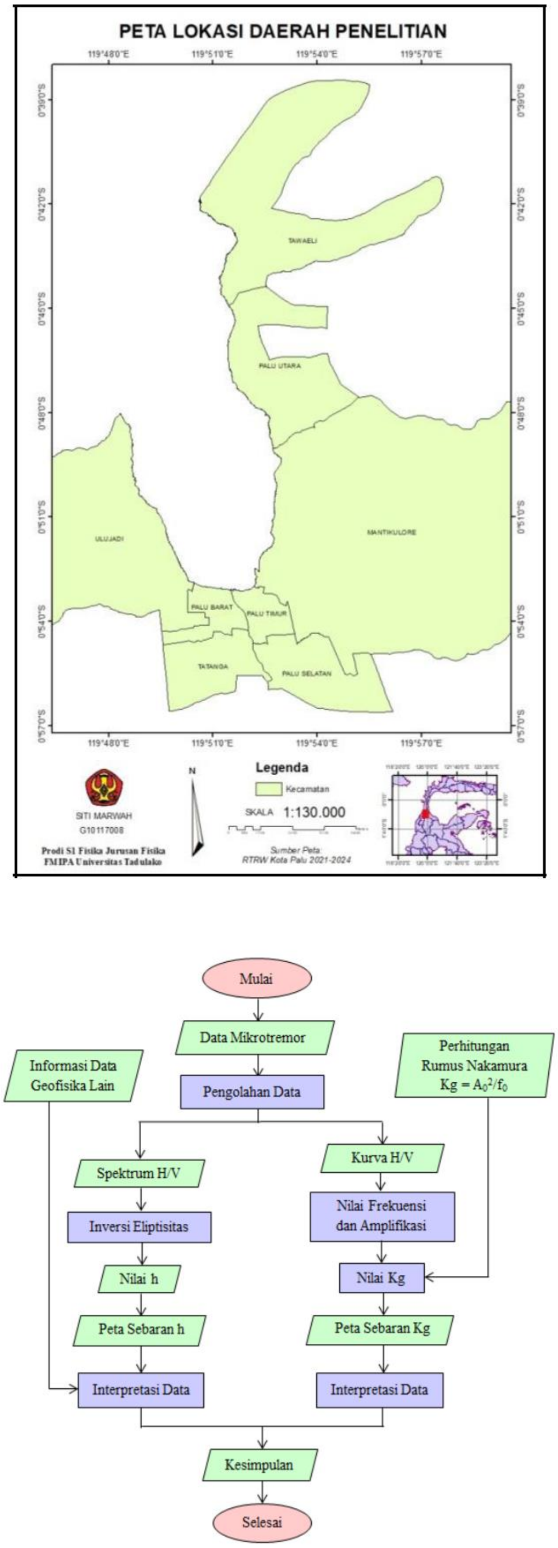

Figure 1. Map of the Palu City Regional Research Location & Study Area Flowchart

Secondary microtremor data is processed to produce an HVSR curve for the relationship between natural frequencies (f0) and amplification factor (A0), both values are used to obtain the seismic vulnerability index (Kg) from the empirical formula according to Nakamura (2008). Furthermore, to obtain the value of the thickness of the sediment layer (h), the results of the processed HVSR spectrum will be analyzed again using the ellipticity inversion method

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and the results of the sediment layer thickness obtained will be supported by several previous studies which are still in the city of Palu.

Table 1. Soil classification based on natural microtremor frequency values by Kanai

Classification Land *Type*	Type	*Frequency* natural (Hz)	Classification Kanai	Description
Type IV	Type I	6.667 - 20	Tertiary rocks or older. Consist of Hard rock sandy, gravel, and others.	Thickness sediment surface very thin, dominated by rocks hard
Type III	Type II	4.0 - 10	Tertiary rocks or older. Consist of Hard rock sandy, gravel, and others.	Thickness sediment surface enter in category medium 5-10m.
Type II	Type III	2.5-4	alluvial Rock, with more thickness from 5m. Consists from Sandy gravel, sandy hard clay, loam, and others.	Thickness sediment surface enter in category thick, approx 10-30m.
Type I	Type IV	< 2.5	alluvial Rock, formed from sedimentation deta, top soil, mud, and other.	Thickness sediment surface really thick.

Depth
≥30m.

Source: (Arifin et al, 2014)

3. Results And Discussion

In data processing using the HVSR method, it is necessary to select the frequency so that there are no waves with a frequency > 20 Hz, because the microtremor data is composed of Rayleigh waves as the main wave which propagates in the sediment layer above the bedrock, so the frequency selection is from 0.2 Hz - 20Hz. The parameters that will be used as an initial model in data processing in determining the thickness of the sediment layer are Vp values 100-3000 m/s, Vs 50-2000 m/s (see Table 2.4), Poisson's ratio 0.2-0.5 and density 1000 -3000 kg/m3 (see Table 2.3). Furthermore by running the program until the smallest missfit value is obtained.The range of natural frequency values obtained in the study area (Figure 3), ranges from 0.26 Hz to 16.53 Hz. Ulujadi District is in the western part of Palu City with a value range of 0.32 Hz to 14.98 Hz. West Palu District with a value range of 0.41 Hz to 2.81 Hz, Tatanga District with a value range of 0.29 Hz to 3.91 Hz, East Palu District with a value range of 0.3 Hz to 1.54 Hz and South Palu District with a value range of 0.26 Hz to 1.39 Hz is in the middle of Palu City. Mantikulore District is in the eastern part of Palu City with a value range of 0.26 Hz to 16.53 Hz. Meanwhile, North Palu District and Tawaeli District are in the northern part of Palu City with a range of values of 0.29 Hz to 3.41 Hz and 0.27 Hz to 13.11 Hz, respectively.

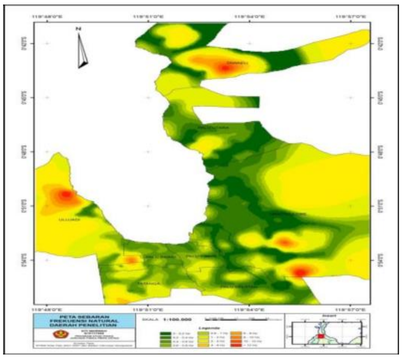

Figure 3. Natural Frequency Map of the Study Area

If viewed based on soil classification by Kanai (Table 1), the natural frequency value of the study area in Ulujadi District, Mantikulore District and Tawaeli District is in type IV type I which describes the thickness of the surface sediments as very thin and dominated by hard rock. West Palu District, Tatanga District and North Palu District are in type II type III which is estimated to be thick Surface sediments are in the thick category of around 10-30 m. East Palu District and South Palu District are in type I type IV which is estimated to be very thick sediment thickness in this area.

Referring to the Geological Map of Sheet Palu (Sukamto et al, 1973), Ulujadi District, which is to the west of Palu City, is located in tinombo, alluvium and coastal deposits, granite and granodiorite formations. The sub-districts of West Palu, Tatanga, East Palu and South Palu, which are to the east of Palu City, are located in alluvium formations and coastal deposits. Mantikulore subdistrict is in the Celebes Sarasin and Sarasin molasses formations and is slightly in the metamorphic rock complex to the east, and North Palu and Tawaeli Subdistricts are in the north of Palu city are in the Celebes Sarasin and Sarasin molasses formations and are slightly in alluvium and sediment formations. beach.

The results of the HVSR spectrum show that the central part of the study area and the area near the coast have low frequency values and increase in height towards the west and east. The further towards the coast the lower the dominant frequency value of the study area, this is in accordance with the morphology of the study area in the form of alluvium deposits and coastal deposits.

The value of the seismic susceptibility index (Kg) at each research point is obtained from the square of the amplification factor divided by the dominant frequency value (Equation 1) which is then mapped in (Figure 4), from this calculation the Kg values range from 0.16 to 37.09 . The lowest Kg value is located at point MP2234-14 (Kabinauna Village) and the highest Kg value is located at MP2234-06 (Petobo Village).

High Kg values tend to be in valley areas and coastal areas, when viewed from the geological map, these areas are alluvium formations and coastal deposits. Kg values tend to be low in the hills. This is consistent with the seismic vulnerability index values obtained in studies conducted by Nakamura (2000 and 2008) and Gurler, et al., (2000).

The thickness of the sediment layers in the study area ranges from 7 m to 128 m (Figure 5) for 283 measurement points, the thinnest layer is located at points MP2312-05 (Buri Village), MP2412-01 (Layana Indah Village), MP4124-03 and MP4213 -03 (Baiya Village) and the thickest one is located at point MP2323-07 (Bururi Village).

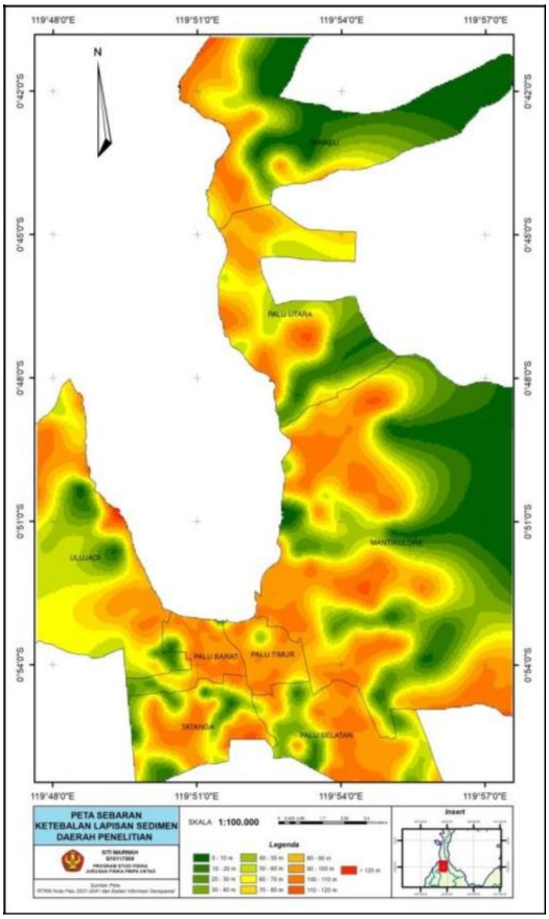

Figure 4. Map of the seismic vulnerability index (Kg) of the study area

The high thickness of the sediment layer is in the valley and coastal areas, while the sediment layer low sediments tend to be in hilly areas (Figure 5). The thickness of the sediment layer (h) in the study area follows the shape of the lithology of the area, if it is correlated with the natural frequency value, then the study area is in the valley section (Subdistricts of West Palu, Tatanga, East Palu and South Palu) and areas close to the east coast (Mantikulore and North Palu Districts) is included in the low natural frequency value, meaning that it is very possible that the sediment layer in this area has a thick layer because the deposition of sediment layers occurs in this section and tends to be thin towards the hills. Meanwhile, if the thickness of the sediment is correlated with the Kg value, then the Kg value of the study area which is in the valley (West Palu, Tatanga, East Palu and South Palu Districts) and areas close to the east coast (Mantikulore and North Palu Districts) tends to have a sufficient value. high and has a fairly thick sediment thickness.

The value of the thickness of the sediment layer from the research results is strengthened by supporting data, namely the results of drill data which are still in the Palu City area. Several studies that have been carried out can be seen in the following table:

Table 2. Value of h drill data at several locations in Palu city

Data Drill	***Location***	***h* (Drill Data)**	***h* (Microtremor)**
1	Jl. Basuri Rahmat	30m	42m
2	Jl. PDAM	22m	25m

The results of the drill data are almost consistent with the results obtained in this study.

4. Conclusion

The conclusions that can be formulated from the results of this study are as follows:

1 The seismic susceptibility index (Kg) value using the HVSR method with filtering 0.2 Hz to 20 Hz in the study area obtained Kg values ranging from 0.16 to 37.09. High Kg values tend to be in valley areas and areas close to the coast. If viewed from the geological map, the area is an alluvium formation and coastal deposits and Kg values which tend to be low are in the hills.

2 The value of the thickness of the sediment layer (h) in the study area obtained values ranging from 7 m to 128 m. The thickness of the sediment layer (h) in the study area follows the shape of the lithology of the area, the high thickness of the sediment layer is in the valley areas and areas close to the coast, while the low sediment layer tends to be in hilly areas.

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