Mapping Seismic Vulnerability Index on Hasanuddin Area Using Spectral Ratio for Disaster Prevention

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ABSTRACT

Makassar city has an earthquake vulnerability relatively low compared with other regions in Indonesia, however the mapping detail related to the amplification of seismic waves need to be done in the interests of civil engineering, planning and others. It's become general knowledge that the magnitude of the damage during the earthquake was strongly influenced by the dynamic characteristics of the building as a function of amplification of seismic waves. Level of amplification of seismic waves depends on several factors, including the thickness of sedimentary layers, the level of compaction and geological age factor. Therefore the purpose of this research was to investigate the seismic vulnerability in Makassar, particularly in the universities Hasanuddin area using spectral ratio through mikrotremor measurement. Compare with numbers of approaches, microtremor is the easiest and cheapest method to understand the dynamic characteristics of this without causing damage effects.

In this research, data collection carried out for 35 minutes using three component seismograph measurements at 43 points with spacing of 100 meters. The data recorded in time function were analyzed using the spectral ratio method, known as the Horizontal to Vertical Spectral Ratio (HVSR). Results from this analysis are dominant frequency (f_0) and amplification factor (A) is used to obtain seismic vulnerability Index (SVI). The results showed the dominant frequency range between 0.61 - 8.6 Hz with an average below 1 Hz and the amplification is in the interval 0.8 to 2.7. Interval value for seismic vulnerability index is 0.2 to 2.3. The low seismic vulnerability index value indicates that the University of Hasanuddin area doesn't have high levels of earthquake damage effect to the buildings.

Keywords : seismic vulnerability index, HVSR, dominant frequency, amplification factor

Introduction

Almost all major cities in Indonesia have high levels of earthquake vulnerability is quite high, but not supported by a detailed mapping of areas vulnerable to earthquakes (seismic microzonation).

Seismic microzonation is the process of division of areas that potentially have the damage caused by seismic activity and earthquakes taking into account the geological and physical characteristics of the sediment layer. Characteristics considered include ground shaking (ground shaking), vulnerability to collapse (liquefaction susceptibility), ground movements and others.

Seismic microzonation also useful for seismic disaster mitigation because can provide very important information for development planning in order to be able to withstand earthquake shocks, such as the dominant frequency and the amplification.

There are several methods that can be used to perform the seismic microzonation. The most common procedure introduced by Borcherdt (1970) is by comparing seismograms spektum with the spectrum obtained at the station closest to the epicenter. The distance to the epicenter and the source of this radiation will be considered to determine the difference spectrum. Anomalous results that show will be considered as the effect of geologic conditions and physical properties of a region.

The other method that easily implemented and inexpensive is Namakura method (1989). Lermo and Chavez-Garcia (1993) found that it is possible to estimate the dominant period of the site response and the overall amplification factor based on the H/V ratio, for most site geologies. They also said that The best results were obtained with Nakamura's technique, which also gives a rough estimate of amplification of seismic waves when the local geology is relatively simple. Bour et al. (1998) performed microzonation using Nakamuras method in the plain near Rhone Delta in Southern France. With their results, they produced maps to characterize amplification effects of the region. These included a resonance frequency map and maps of amplification amplitudes as a function of frequency range, leading to a seismic microzonation for the region.

This technique attractive since it gives ease of data collection and it can be applied in area of low or even no seismicity. With this method, we can know the characteristics of sediments such as dominant frequency and amplification factor, that can be used to know potential damage to the local area of research and very useful for the planning of development in the future.

Data and Methodology

Microtremor

Constant vibration of the earth's surface is called microtremor (Okada, 2004). The source of microtremor comes from human activity (movement of plant machinery and vehicles) and natural phenomena (wind, rain, variations in atmospheric pressure and ocean waves). Vibration what we means is not short duration event such as earthquakes and explosions (Seht and Wohlenberg, 1999).

Mikrotremor surveys can be done in two ways (Mukhopadhyay and Bormann, 2004). The first approach is the recording made simultaneously on two or more locations. One of the recording tools must be put in the area of hard rock (hard rock) that does not indicate a strengthening of the frequency due to ground movement. Ratio spectra obtained at other places (soft rodck) will be compared with that recorded on the hard rock that will get the response to mikrotremor site. The problem with the way this survey will be difficult because it requires the area or areas that have a place with a hard rock as a comparison. The other problem is this method requires a relatively large earthquakes that are not suitable for areas with low seismisitas.

The second way was introduced by Nakamura (1989), he named it H/V spectral ratio. Nakamura technique only need one station, this is because the spectra ratio of horizontal and the vertical components recorded at the same site (H/V spectral ratio).This technique attractive since it gives ease of data collection and it can be applied in area of low or even no seismicity. Nakamura assumes that the H/V ratio reflects the amplification of ground motion. With this method of measurement does not need to be done with the requirements of the hard rock.

Stasiun site can be seen in Figure 1. A measurement performed using a set of short-period seismograph-303S portable type TDL (3 components), each of which consists of a digitizer, sensors, laptops, batteries and GPS.

Ambient noise data (microtremor) obtained from 43 measurement points are scattered in the area Hasanuddin Univeristy with a distance of 100m for each point (figure 1). Recording the data at each point measurements were performed for 35 minutes.

An example of one stasiun of data collection can be seen in figure 2

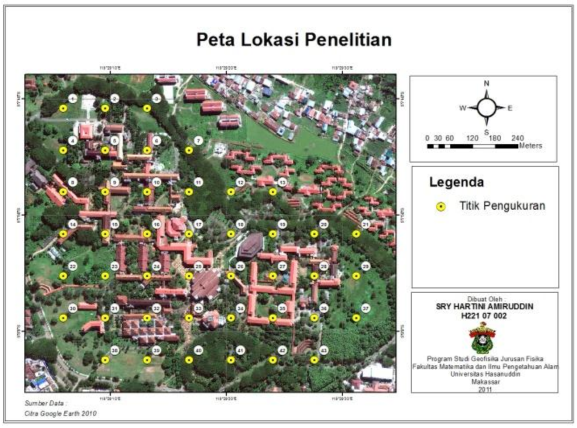

Figure 1. Map of research site

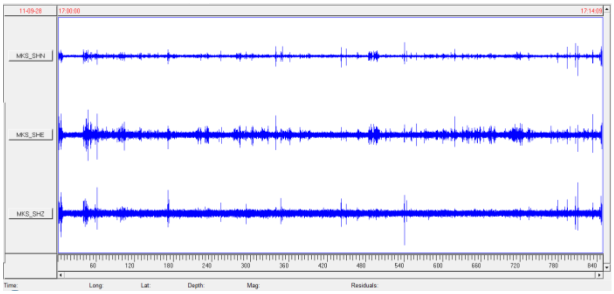

Figure 2. An example raw data from microtremor measurement

In processing data we used Geopsy software. This software contains information of recording time, the amount of data, and other supporting data. The result is a spectrum at each stasiun will then be analyzed to obtain the HVSR peak value (A) and predominant frequency (f_0).

At the time of processing using GEOPSY software, data is divided into several windows (Figure 3). If the data is large enough sorting window is automatically provided by the software. Windowing is the process to sort data between the tremor signals and transient event (especially specific sources such as footsteps and vehicle passes). The function of this process is to avoid the processing of transient events in the analysis. Comparison between the short term average (STA) and long term average (LTA) and also using anti triggering logarithm is the way to detect transient signals. STA is the average value of short-term amplitude (0.5-2.0 seconds) and LTA is an amplitude value of the average long-term (> 10 seconds). When comparison result from STA / LTA exceeds a predetermined threshold, then it can be referred to as "event".

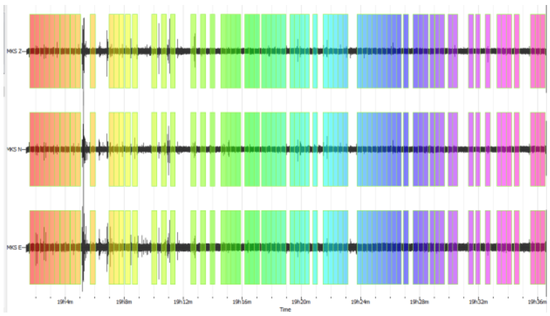

Figure 3. Windowing the raw data before doing FFT.

After a transient is detected then the data in addition to transient divided into several windows. Window length used in this study was 20.48 s or 2048 data. This is to meet the reliability criteria using the FFT processing. However, based on the manual GEOPSY, window length can be specified with any value (but still consider the minimum recommendation SESAME project) because in the process, this software uses an algorithm developed by Matteo Frigo and Steven G. Johnson (2005), known as FFTW (Fastest Fourier Transform in the West). SESAME European Research Project the length of the window has a minimum requirement lw = 10 / $f_o$which is lw is the frequency and f_o is predominant. the window length must be more than 20 seconds to get the frequency up to 0.5 Hz. In this research we choice selection window automatically because the amount of data. Selected SLA is 2 seconds and LTA is 30 s following the recommendation SESAME project.

The next is fast Fourier transform(FFT), which involves the process of smoothing. Smoothing process is done by using Konno and Omachi algorithms (1998) with a bandwidth b coefficient by 40. In this process we also done cosene taper to minimize border effect or boundary effects due to the selection process window.

To obtain the spectral ratio between horizontal and vertical components, Average Square of two horizontal components should be made before divided by horizontal component. This process is done for each of the selected window. Spectral ratio H / V is obtained from the ratio of average H / V of the entire selected window. To have low standard deviation value then the value of H / V is good to be worth more than 0.4 because the value below will have a very high standard deviation.

The end result of the processing of data in the form of spectral ratio H / V (Figure 4). From this spectrum we can determine the value of the dominant frequency (fo) and peak spectral ratio H / V (A) at the measurement site mikrotremor. Based on the relationship T = $1/f_0$ then we will get the value of a dominant period in the measurement site (Sesame, 2004).

Nakamura (HVSR) Technique

This technique widely used for microzoning and engineering purposes proposed by Nakamura (1989). The H/V spectral ratio [$T_{H/V}(\omega)$] was obtained by dividing the average spectra of the horizontal component of sediment site [$s_{NS}(\omega)+s_{EW}(\omega)$] by the spectrum of the vertical component [$S_v(\omega)$] of the sediment site :

$$T_{H/V(\omega)} = \frac{s_{NS}(\omega)+s_{EW}(\omega)/2}{S_V(\omega)} \quad (1)$$

Based on Nakamura Idea, amplitude effect of Source can be estimate by the ratio :

$$A_S = \frac{V_S}{V_B} \quad (2)$$

Where amplitude spectrum of the vertical component of motion at the surface and amplitude spectrum of the vertical component of motion at the half space defined as V_S and V_B. Nakamura also estimates site effect of interest in earthquake engineering (S_E), as ratio

$$S_E = \frac{H_S}{H_B} \quad (3)$$

Where H_S and H_B are Fourier amplitude spectra of the horizontal component of motion at the surface and the base of soli layer

Using assumption:

$$\frac{H_B}{V_B} = 1 \quad (4)$$

We can calculate modified site affect spectral ratio (S_M) as

$$S_M = \frac{S_E}{A_S} = \frac{\frac{H_S}{V_S}}{\frac{H_B}{V_B}} = \frac{H_S}{V_S} \quad (5)$$

Assumption H_B/V_B= 1 was verified by Nakamura experimentally using microtremor measurement at depth in a borehole. A more detailel about this method can be found in Lermo dan Chaves-Garcia (1993,1994)

The H/V spectral ratio [$T_{H/V}(\omega)$] was obtained by dividing the averaged spectra of the horizontal components of the sediment site $s_{NS}(\omega)$ and $s_{EW}(\omega)$ by spectrum of the vertical component $S_V(\omega)$ of the sediment site :

$$T_{H/V}(\omega) = \frac{s_{NS}(\omega)+s_{EW}(\omega)/2}{S_V(\omega)} \quad (6)$$

Result and Discussion

HVSR Spektrum Ratio

HVSR spectrum obtained from analysis of microtremor signal recording using Geopsy software. This process can be determined values of A and f_0 for each measurement point. Figure 4 shown there are two dotted lines above and below which is standard deviation for all values of the ratio of the resulting spectrum. The line in the middle is the average value of the FFT analysis of the entire value of H/V ratio, while the thin line is colourful curves H/V spectrum ratio of each window.

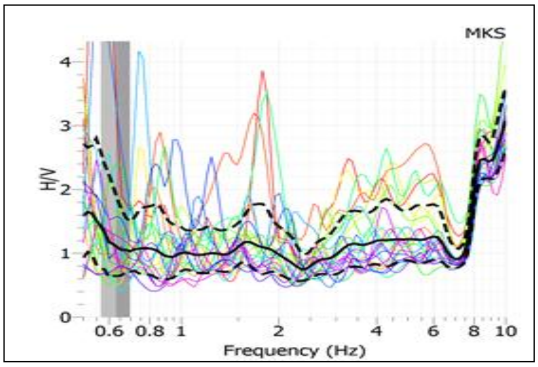

Figure 4. an example of H/V specral ratio

F_0 values are in the interval of values from 0.61 to 8.60 Hz at all points of measurement, while the value of A is the interval of values from 0.95 to 2.73.

Distribusi Frekuensi Dominan (f_0)

The spectrum of H / V obtained showed that almost half of the study area has a value of f_0 on the interval value from 0.61 to 0.65 Hz. From 43 measurement points only 12 points have high value f_0, namely: Station 3, 7, 8, 10, 15, 19, 27, 30, 33, 34 and station 42 with f_0 values between 8.1 to 8.6

Hz. Dominant frequency contour map (f_0) are shown in Figure 5.

Dominant frequency value (f_0) is useful parameter in planning and development. In building planning f_0 values should not be equal to the frequency of the building so that the building can withstand from an earthquake. F_0 value from structures must be estimated properly so as not to have the same f_0 value from the site, as it will resonance during the earthquake. This will lead to an increase in the vibration caused by the earthquake. In addition, the very low value of f_0 will be very susceptible to high-rise buildings of the vibration waves of long period earthquakes.

Results of this study shown that f_0 values are relatively low because it has a value less than 10 Hz. However, to prevent the damaging effects of earthquakes, development in the Hasanuddin University should consider the value of the existing dominant frequency.

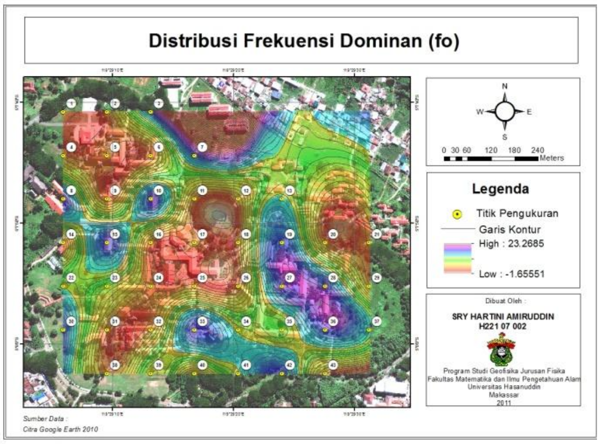

Figure 4. Contour map of dominant frequency

HVSR Peak Value Distribution

From the analysis of the spectrum of H/V can be seen that the study area has a peak value HVSR at intervals of values from 0.8 to 1.5. Station 15 and station 42 have high value respectively 2.34 and 2.73. Contour map HVSR peak value (A) is shown in Figure 6.

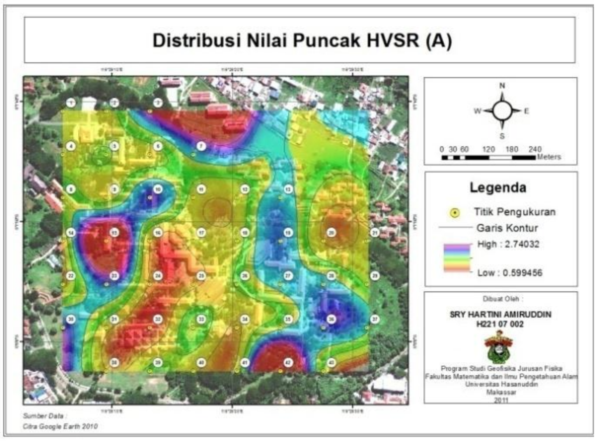

Figure 6. Contour map peak value of HCSR (A)

HVSR peak value (A) correlated with the damage caused by the earthquake. If an area has a low f_0 value and a high value of A will produce a high level of damage to buildings. From the data obtained, the value of A at all points of measurement below 3 with f_0 values varied. It is pointed out that the area of Hasanuddin University not have high levels building damage that caused by an earthquake .

Seismic Vulnerablity Indeks (SVI) Distribution

Seismic vulnerability index (SVI) is an index that shows the vulnerability of a layer of soil to be deformed. Therefore, SVI is useful for the detection of areas that are weak zone (unconsolidated sediment) at the time of the earthquake (Winoto, 2010). SVI values can be calculated from microtremors measured easily everywhere and it is not impossible to estimate the vulnerabilities of all structures and ground concerned (Nakamura, 1997).

Seismic Vulnerability Index (SVI) at each stasion can be determined using value of Amplitudo (A) and dominant frequency (f_0). Formula to calculate SVI can be written as:

$$\mathrm{SVI} = \frac{A^2}{f_0} \qquad (7)$$

Nakamura (2000) shown that some of the destructive earthquake events showed the areas often exposed to major damage caused by the earthquake has SVI values between 20-100 while for areas that save from the damage has SVI under 5 .Daryono (2009) shown that the areas affected by major damage due Yogyakarta earthquake in 2006 had a value of more than 6 SVI.

Analytical results obtained from the calculation of the value of f_0 and A, the study area has a value of SVI at intervals of values from 0.8 to 2.3. Lowest value found in station 22 and the highest value at station 5 with values respectively 0.17 and 2.33. Contour map of seismic vulnerability index (SVI) is shown in Figure 7.

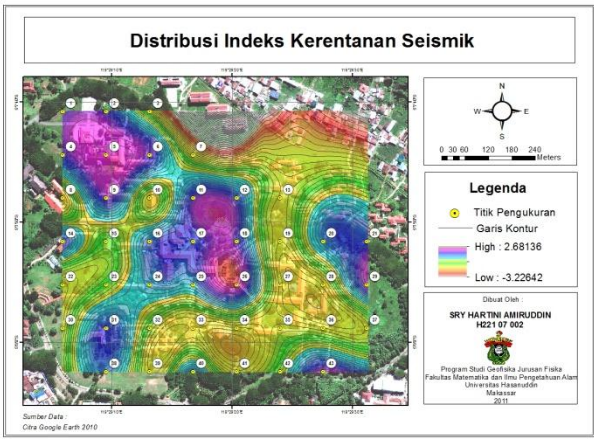

Figure 7. Contour map of Seismic Vulnerability Indeks (SVI)

Results obtained from the study indicate areas Hasanuddin University has a low SVI values, which is between 0.2 to 2.3. This indicates that the region Hasanuddin University does not have a high potential for damage in case of earthquakes.

Conclusion

Dominant frequency (f_0) values for the University of Hasanuddin are at intervals of values from 0.61 to 8.6 Hz. This suggests that the study area has low value of f_0 (<10 Hz).

HVSR peak value (A) is in the interval of values from 0.8 to 2.7 and the value of the seismic vulnerability index (SVI) is in the interval of values from 0.2 to 2.3. The value of f_0, A, and low SVI indicates that the University of Hasanuddin area doesn’t have high levels of earthquake damage effect to the buildings.

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