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SEISMIC MICROZONATION USING MICROTREMOR MEASUREMENT FOR NATURAL DISASTERS MITIGATION OF EARTHQUAKE AT REGIONS SINGARAJA CITY THE PROVINCE OF BALI INDONESIA

Lantu, Sabrianto and A. Tenri Awali
Study Program of Geophysics, Hasanuddin University, Indonesia
E-Mail: geolantu@gmail.com

ABSTRACT

A research has been done to micro zoning the prone area of natural disasters at Singaraja city the province of Bali by using the mikroteremor method. The aim of this research was determine the dominant frequency, the velocity of S wave at 30 m depth and amplification an earthquake in the study areas and maping the prone earthquakes in the study areas to mitigate the risk of earthquake. Research locations is at coordinates 8.16768^{o} N to 1 8.08759^{O} N and 115.06535^{o} E to 115.14082^{0} E at the Singaraja, district of Buleleng, Bali. The data used obtained from the center of vulkanologi research and disaster geology mitigation geology as muchy as 82 points. Every point recorded for 20 minutes. From the analysis and data interpretation obtain that S waves velocity at the 30m of depth is 260.5 m / s -- 295 m / s, the dominant frequency dominant be range of 1.52 Hz - 7.34 Hz, with amplification between 1 6 - 6 1 times. The areas with high Vulnerability located at the northwestern of study areas.

Keyword: microzonation, dominant frequency, amplification.

INTRODUCTION

Indonesia was one archipelago country in Asia and In thoroughly geotectonic, Indonesia is the place of confluence four active plates tectonic in the world. Plate continent Eurasia moving slowly toward the southeast at a speed of about 0,4 cm / year ,Ocean Plates of indo - Australian moving toward the north with the velocity about 7 cm / year, the ocean pacific plate who moving to the west with the velocity about 11 cm / year and the plate philiphina sea s moving to the northwest with the velocity about 8 cm / (PVMBG, 2014). At the regional meeting of the plates, there is an accumulation of the energy up at any time on the layer of earth could no longer hold down a stack of this energy so that a tremendous earth quake a result of the tectonics, there are several regions in Indonesia including the disaster of earthquake prone, one of which is Bali island. Based on the geological map of Bali. Bali north has one seismic zone is a source of the earthquake, that is flores back arc crust thrust faults Sumatra, Java and Bali, this area is *Flores Back Arc Crust Thrust Fault*. According to Mc. caffrey and Nabelek (1987), The thrust is composed of 2 segments Namely flores zone in western and water thrust zone in eastern. There are not an earthquake in this zone caused by the earthquake source more than 25 km of depth. One effort mitigation was by mikrozonasi to map areas prone to the ravages of the earthquake by using mikrotremor survey ~ By doing survey mikrotremor so it can be seen the dominant relations frequency, vs30 and amplification to situations geology research area that could explain the vulnerability gempabumi which will be useful for planning development of area. From the table of destructive earthquake catalogue, (PVMBG2014), there are some great earthquake scene around the research area namely the earthquake Buleleng in 1862 (MMI VII) that causes the ruined of building and cracks and Seririt quake in 1976 with a value of MMI VIII-IX that cause 90 percent of buildings collapsed and broken. The level of damage due to earthquake also dependent on the geological condition of zone. To minimize risk of an earthquake then required its efforts to mitigate the, and one of its efforts to mitigate the risk is mapping the microzonation areas vulnerable to the ravages of earthquake by using microtremor survey. By doing microtremor survey, it can be seen the relationship between the frequency dominant, V_{s30} and amplification of geological condition to judge the vulnerability earthquake in a region. Based on that assumption has done a microtremor survey in urban area Singaraja Bali, to map the zone having risk in the earthquake. It is important because Bali island is the place tourism objects known around the world. The main purpose of this research is: the determination of value frequency dominant, vs30 and amplification. For realization of this mapping, the microtremor surving, the measurement was doing in 82 points.

MATERIALS AND METHOD

The condition of regional geological bali begins with study of activity tectonic in the ocean during the days of old miocene below which produce lava rocks and breccia intrusion by limestone. In southern happened a sediment deposit by limestone which later formed the south formation. In the bordering the edge of north of happened the deposition of sediment finer. At the end of the pliocene, all regions the sediment deposit appeared above sea level. At the same time happened removal and shift which causes various of fault against with the other. Generally while this set by the rocks organic or precipitate of material derived the sediment of which produces

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ARPN Journal of Earth Sciences

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formation grindstones. Based on geological map of Bali, study areas in the form of a geological fault and straightness and generally in northwestern - east southeast. Location of research area illustrate in Figure-1.

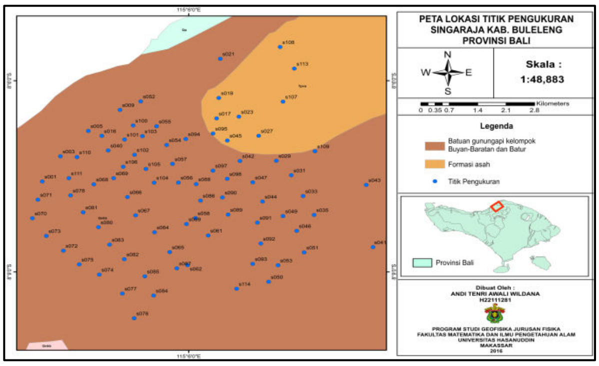

Figure-1. Geological map and location of measure at research area.

Seismic mikrozonation using mikrotremor

Microzonation seismic can be assumed as the process to estimate response and mannerisms subsoil or sediment as a result of the earthquake. This way be held to find out seismic activity and predicts damage in the earthquake. Microtremor are small scale vibration that occur in ground from a known source and have amplitude range about 1 to 10 µm and between 0.1 to 1 ms in period. Seismic microzonation be considered asmas the process to estimate responses and behavior of layers ground or sediment towards an earthquake. This measure should be aimed to determine seismic activity and predict damage that might happen in the more specific earth quake, (Nakamura, 2008). Method mikroseismik is a method that uses passive source (seismic wave's nature) that can be applied to analyze the impact of a potential location to minimize damage. This method also known as mikrotremor. According to Ishiyama (2006), mikrotremor is a tremor (vibration) with very small amplitudonya and continuous of land or structures caused by the activity at the surface of ground, and others. Mikrotremor instrument is very comfortable used to estimate the effect of geology at the surface on the movements of seismic without requiring geological other information ~ This method interesting because provide facilities of the data collection and be applied in place of low area or no earthquake event, (Nakamura, 2008). The method of mikrotremor aims to observe the characteristics of ground motion of the ground in terms of the velocity of seismic wave's propagation with emphasize on variation amplitude, and the frequency of vibrations. On data mikrotremor, wave's propagations is dominated by Rayleigh wave that propagates in sedimentary layer above the basement. The Rayleigh waves was the surface wave with low frequency and high amplitude propagate cause the effect of free surface and a difference of the elastic properties. The velocity of Rayleigh wave according to Telford, (1993) is

$$V_r = 0.92\, V_S^{0.5}. \quad (1)$$

For the microzonation process is used the transversal wave at 30 m of depth.

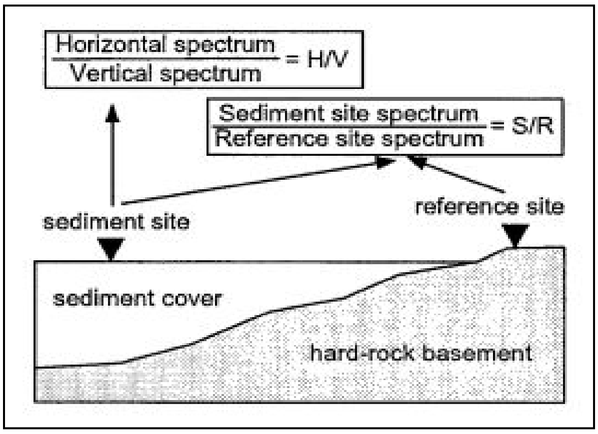

Figure-2. Technique comparison spectra for evaluation response site (Seht and Wohlenberg, 1999).

Only V_{s30} used because according to Wangsadinata (2006), only up to 30 m of thickness affecting the enlargement amplitude of earthquake waves. Then indigo of V_{s30} used designate classifications the power of vibration an earthquake. It is assumed that the source of mikrotremor very local thus, the contribution the source from the deep layer can be neglected. Thus the spectrum amplitude of microtremor source estimated as a function of frequency:

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

Where V_s is the vertical component the spectrum amplitude vibration at the surface and V_B is amplitude spectrum vertical component vibration in half-space Nakamura set the response of local estimation S_E as:

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

where H_S is a horizontal component amplitude of vibration at the surface and H_B is horizontal component of spectrum amplitude of vibrations in the base of layers sediment. To compensate S_E with the effects of source, we calculated the modification function of local response (S_M) as:

$$S_M(\omega) = \frac{S_E(\omega)}{A_S(\omega)} \quad (4)$$

Or in the other formula as

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ARPN Journal of Earth Sciences

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

By assuming that $\frac{H_B(\omega)}{V_B(\omega)} = 1$

Then local functions of response were corrected by the source effects of can be recorded: as follows:

$$S_M(\omega) = \frac{H_S(\omega)}{V_S(\omega)} \quad (6)$$

Comparison spectrum H/V obtained by dividing the spectrum the average components horizontal and the spectrum the average components vertical, (Lermo and Chavez-Garcia, 1993).

$$T_{H/V}(\omega) = \frac{[S_{NS}(\omega)+S_{EW}(\omega)]/2}{S_V(\omega)} \quad (7)$$

$T_{H/V}$ is the ratio of H/V spectral, S_{NS} is a horizontal component of southern north, S_{EW} is the ratio of H/V is horizontal component in east-west and S_V is the vertical component. The ratio H/V of the Rayleigh wave be limited to certain top period which will cause trouble to find the correlation between amplification factors for S wave and the ratio H/V of Rayleigh wave. It can be avoided by smoothing data process before calculate the ratio H/V of Rayleigh waves. The smoothing data were doneto minimized the aliasing effect, so the result of rarefaction data will not greatly differ with the pattern of the preliminary data. The formulation that used in smoothing process of the data based on a method of Konno and Ohmachi (1998).

$$W_B(f, f_c) = \left[\frac{\sin(log_{10}(\frac{f}{f_c})^b)}{log_{10}(\frac{f}{f_c})^b}\right]^4 \quad (8)$$

Where Wb = windows bandwidth, f = frequency (hz), fc = center frequency (hz) and b = bandwidth coefficient.

Velocity of S Waves at 30 m of Depth (Vs30)

The velocity of S waves to be used in mikrotremor process is the waves velocity at the depth of 30 m vs_{30}). The Vs30 will be used to determine classifications rocks based on the power of vibration earthquake vibration by the local effects. The V_{S30}Value determined based on the following equation

$$V_{s30} = \frac{30}{\sum_{i=1}^{N} \frac{h_i}{v_i}} \quad (9)$$

With h_i is thickness (m), V_i is at wave velocity sl (m / s) and N is the number of layers above 30 m of the depth. To transform the data from time domain to the frequency domain is use the fast Fourier Transformation.

The research location at the Singaraja city district of Buleleng Bali Indonesia. Research sites are on coordinates 8.16768^0 Nto 8.08759^oN and 115.06535^0 E to 115.14082^oE. The data microtremor performed on 82 point of measuring with duration 20 minutes for every measurement point. The distance of any point of measurement as far as 500 m. There were 82 points measurements had been done on this research where every measurement lasted for 20 minutes. Data recorded in 3 components the vertical, north-south and east-west components.

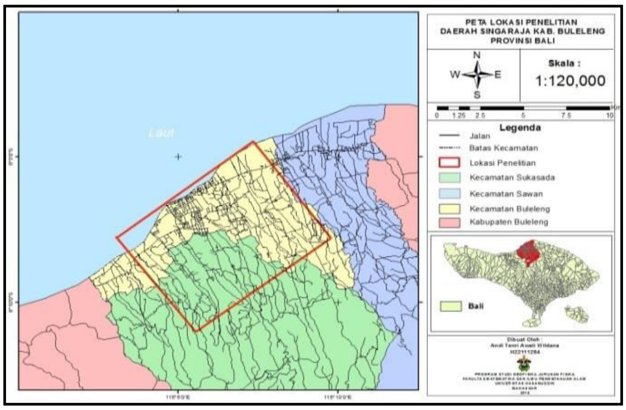

Figure-3. Map research locations.

There are several steps done in the process of data analysis to get the parameter of physics that relating to the microtremor activity and vulnerability of the earthquake. The physical parameters that will be calculated are the dominant frequency of earthquake, the velocity of transversal waves at the depth of 30 m and amplification of earthquake. The first step was windowing aimed for smoothing data with a window size between 5 s to 10 s. Process of smoothing be made to reduce noisy arising at the acquisition microtremor data. The second step is spectral analysis to obtain of the dominant frequency of the microtremor activity. Spectral Analysis begins with transform data the domain of time to the frequency domain use Fast Fourier Transformation with bandwidth frequencies 1 Hz - 10 Hz. calculate the dominant frequency use inverse modeling to obtain the spectral HVSR (horizontal to vertical spectral) by using Monte Carlo Method. In the inverse modeling boundary as initial value using the value of velocity propagation Vs, Vp, densityρ, depth h and quality factor Q. The last step is the velocity analysis and calculates the amplification the earthquake activity. In this research using the velocity at the 30 m of depth. The calculation of amplification done to estimate of the increasing the strength of earthquake which causes greater damage. Amplification is a scaled up waves seismic due to differences in the significant velocity between the layers. The bigger the difference speed of velocity, hence amplification experienced the surge will be bigger. In engineering study of earthquake, lithology more lenient have higher risk if earthquake,

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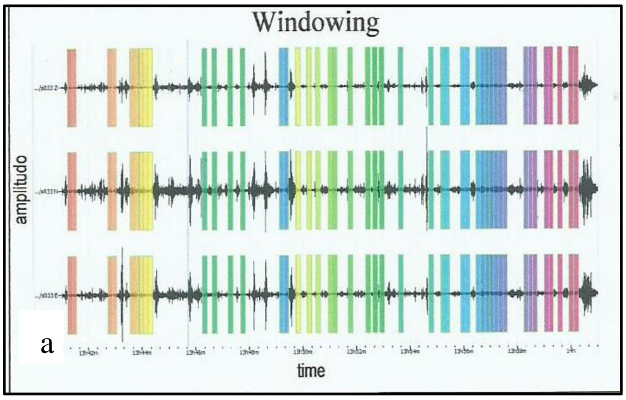
because its amplification will bigger. Wakamatsu (2000) calculated the amplification on the velocity value vs30 based geomorphology as formulated follows:

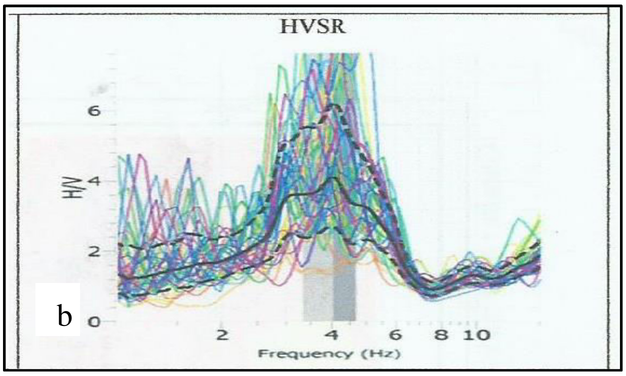
$$:\log G = 2.367 - 0.852 \log V_{s30} \pm 0.166 \qquad (10)$$

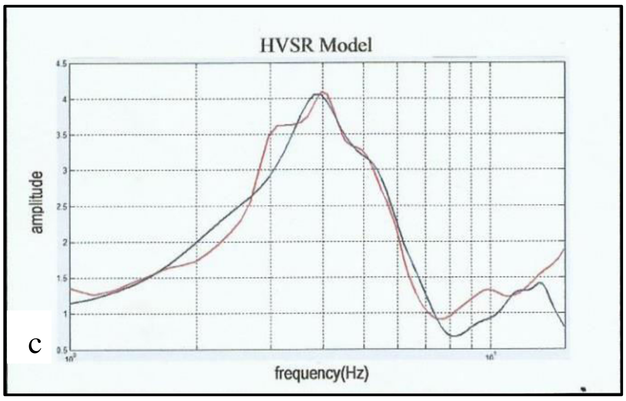
where G is Amplification

RESULT AND DISCUSSIONS

From analysis of data on all of the measurement points (there are 82 points), the parameter of physics of earthquake, consisting of the dominant frequency, velocity of wave at to depth of 30 m (vs30) and the amplification of earthquake can be calculate. As an example the result of data analysis, displayed the result process and analysis of the data at the measurement point s033. The frequency spectrum of obtained by transform data mikroteremor the domain time to the domain frequency by using fast fourier transformation. The curves of HVSR data processing mikrotremor in geopsy. spertia in figure following. For example the data analysis to research used point s011 and s033. At the measurement obtained the dominant 4.07 hz, vs30 is 217.26 m / s and strengthened by 4.14 times. Using the similar method, the physical parameter at all the other points can be calculated. Thus the characteristic of the earthquake at research area can be mapping.







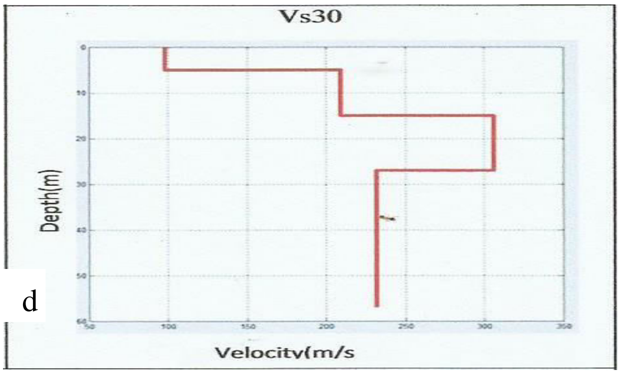


Figure-4. Data analysis at measurement S033 (a) HVSR spectrum (c). Model of HVSR (b) Frequency dominant (d) Velocity at Vs30.

The dominant frequency at any measurement points obtained between 1.52 hz - 7.34 hz .Blue areas are having the value of frequencies between 1.52 hz -- 2.68 hz, green color is the region with a dominant frequency between 2.68 hz -- 3.85 hz, A yellow color is the region with the dominant frequency between 3.85 hz -- 5.01 hz, the orange color is the region with the dominant frequency between 5.01 hz -6.18. And red is the region with the dominant frequency between 6.18 hz -7.34 hz. This indicates that the thickness of the layer weathered in the study areas were quite diverse.

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ARPN Journal of Earth Sciences

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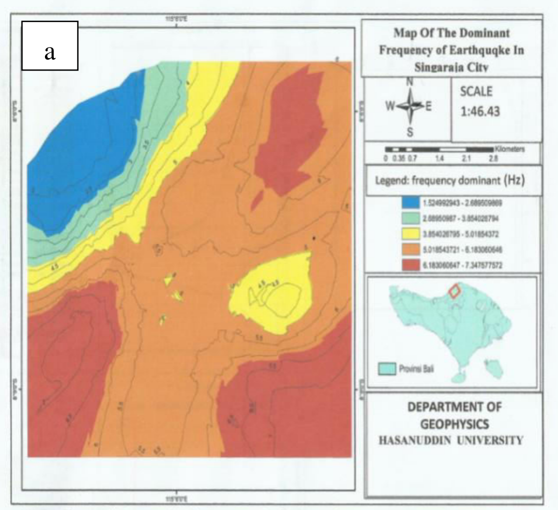


Figure. 7 Contour distribution map the dominant frequency at singaraja regions

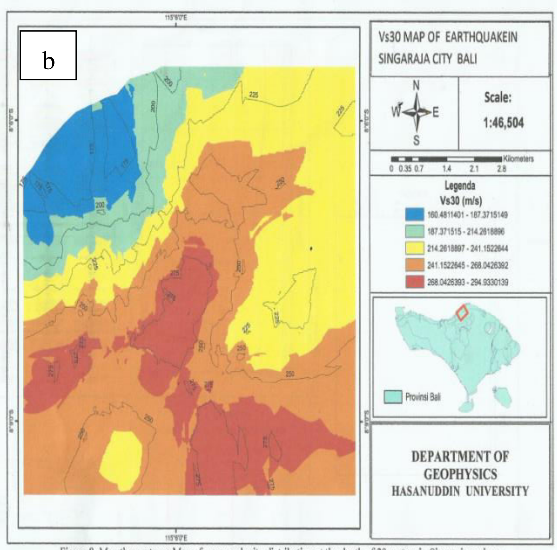


Figure 8. Map the contours Map of wave velocity distribution at the depth of 30 meters in Singaraja regions

Figure-5(a). the frequency dominant of earth quake b. velocity distribution at 30 m of depth.

The dominant Frequency t indicates the existence of bedrock, if the dominant frequency is low means the bedrocknya deeper. The value of low dominate frequency be on the northwestern study areas, and value the high frequency be in the northeastern to southeastern and southwest of the study. Velocity analysis at 30 of depth as shown in Figure-6. To get the velocity of S waves at the depth of 30 m obtained using inversion Monte Carlo method. The process of inversion done by inserting the initial conditions consist of six physical parameters the vp, vs, ρ, h, Qp and Qs that corresponded to HVSR observation. The velocity vs30 used to predict the earthquake risk and the determination of standard of earthquake building resistant, because according to some research, only the layer of soil to a depth of 30 m just that affects amplification earthquake waves gmpathe of earthquake. Based on the value of the contours of their distribution are waves value speed s padasetiap tiik measurements in the research area ranged between 160.5 m/ s -295 m/ s. the blue color is the zone with the velocity between 160.5m/s - 187.4 m/s, the green color is zone with the velocity between 187.4 m/s to 214.3 m/s, the yellow color is the zone with the velocity between 214, 3 m/s to 241.15 m/s, the orange color is the zone with the velocity 241.15 to 268 m/s and the red color is the zone with the velocity 268 m/s to 295 m/s. The value of amplification on the site of peneltian the formula was calculated based on empirical of wakamatsu on equation (10). The value of distribution implication remained in a range between 3.32-6. Times. In this study, the amplification expressed in five categories. The first categories is the implication with the value between 33.3 - 3.88 time (the bluecolor), the second categories is 3.9 - 4.44 times, the third categories is the amplification with value between 4.44 to 5.0 times, the fourth categories is between 5.0 - 5.55 times and the fifth categories is the amplification with the value between 5.55 to 6.11 times. To k now the vulnerable an earthquake, the study was conducted reclassify based on the value of dominant frequency, vs30 and amplification. The value of the debt divided into five classes and to be weighting and then made a map the prone area an earthquake as shown in Figure-9.

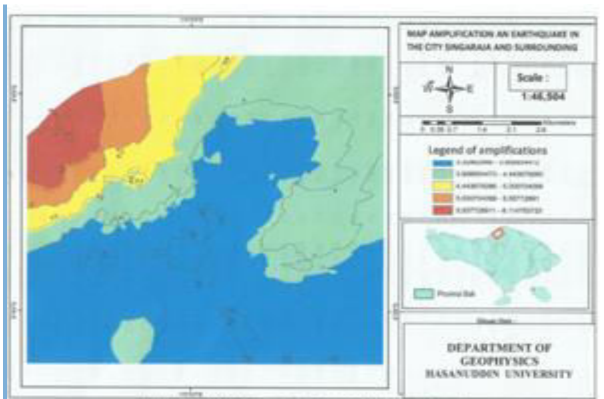
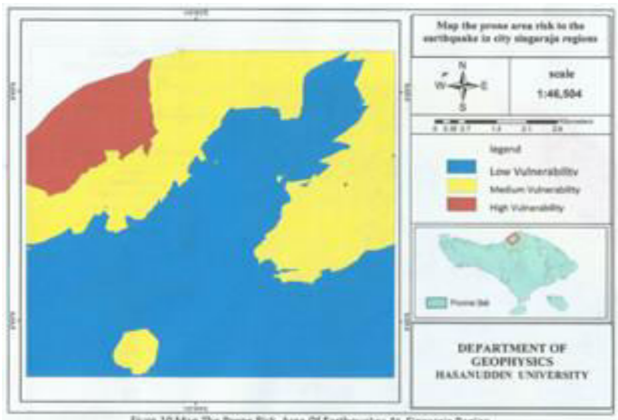


Figure.9 Contour Map the distribution of amplification in singaraja region

(a)



Fiure.10 Map The Prone Risk Area Of Earthquakes At Singaraja Region

(b)

Figure-6. Map of amplification and earthquake prone.

ARPN Journal of Earth Sciences

Table-1. Value of weighting and rank earthquake.

Attribute	Weighting	Alternative	Rank
Vs3o(m/s)	3	187.4	5
		214.3	4
		241.2	3
		268.0	2
		294.9	1
amplification	2	3.9	1
		4.44	2
		5.00	3
		5.56	4
		6.10	5
dominant frequency	1	2.69	5
		3.90	4
		5.00	3
		6.20	2
		7.34	1

CONCLUSION AND RECOMMENDATION

From the analysis and interpretation of microtremor datas in the survey locations it can be concluded that.

a) The value of the frequency of the dominant to the research area is at range 1.52-7.34 hz. This indicates that study areas having value frequency dominant low. One of speed waves s at the depth of 30 meters range 160.48 m/s -294.93 m / s and value of the amplification was between 1.55-2.84 times to 3.32-6.11 times. Which means that if the area occurred an earthquake, so the earthquake waves will be amplification about 1.55 to 6.11 times?
b) Based on a map the vulnerable of earthquake at the research area, most of the study areas have the low vulnerable so that are unlikely to any serious damage. The regions having high sensitivity level of earthquake situated upon the northwestern study areas (the area around the sea).

RECOMMENDATION

Should map of microtremo zone constitutes one of the references to design and construction high stage infrastructure building and the high activity (multistoried high building, road and reil) to reduce the risk when earthquake damage.

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