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Microseismic Wave Measurements to Detect Landslides in Bengkulu Shore with Attenuation Coefficient and Shear Strain Indicator

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Abstract

It has been detected that the condition of landslides that occurred in Bengkulu Shore can change the position of the shoreline. This research aimed to (1) calculate of shear strain (γ) and attenuation coefficient ($\acute{\alpha}$) value based on microseismic data in coastal areas that experienced landslides; (2) determine the correlation between levels of landslides with shear strain and attenuation coefficient value (3) determine the correlation between the shear strain and attenuation coefficient value. Microseismic data were processed and analyzed quantitatively using the Horizontal to Vertical Spectral Ratio method (HVSR) to obtain the ground vibrations resonance frequency (f_o) and amplification factor (A). Shear strain value was calculated from the of f_o, A and Peak Ground Acceleration (α_{max}) value. Peak Ground Acceleration value was calculated based on 100-year period of recorded earthquake data. Attenuation coefficient was calculated based on the equation (2). The results of study showed that the value of shear strain in the coastal areas varied from 1.0 × 10-4 to 3.6 × 10-3, in accordance with the conditions of landslides. The attenuation coefficient value varied from 0.005 to 0.020. Level of landslides that occurred varied from moderate, to very severe. There was a tendency that the more severe the landslide level, the greater the shear strain and attenuation coefficient value were.

Keywords: Shear strain, attenuation coefficient, shore landslide

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1. Introduction

Landslides on the shore in large numbers will cause the shoreline to shift landward (retrogradation). Landslides can be triggered by the occurrence of earthquakes. Schulz, et al (2012) state that large earthquakes that occur every 300-500 years trigger landslides in the coast of Oregon-United States [1]. There is an empiric correlation between the magnitude of the earthquake and landslides [2]. The earthquakes in Chi-Chi Taiwan [3], in Costa Rica, El Salvador, Guatemala and Panama often trigger landslides. The magnitude of the landslide volume is proportional to the strength of the earthquake [4]. The factors of depth, quality of the rock mass, groundwater conditions and the

Figure 1: (a) Moderate-level Landslide; (b) Severe-level Land-slide; (c) Extremely severe-level Landslide.

strength of earthquakes affect the magnitude of the landslide volume [5]. There is a significant correlation between the magnitude moment and the volume of landslides.

The stronger the earthquake, the greater the landslide volume is [6]. This research was aimed at determining the correlation between shear strain at the sediment layers and landslide level and the correlation between attenuation coefficient and landslide level in the coastal areas. Landslide conditions in Bengkulu coast are shown in Fig.1.

2. Theoretical Framework

2.1. Shear Strain

Shear strain (γ) in the sediment layer indicates the ability of the soil layer to be stretched when an earthquake [7].

The value of γ is formulated as [8]:

$$\gamma = K_g(1000 \times 10^{-6})\alpha_{max} \tag{1}$$

Where γ is the shear-strain, K_g is the seismic vulnerability index, and α_{max} is the peak ground acceleration. Value of a_{max} is calculated using the Fukushima-Tanaka Eq. [9]

$$Log\ \alpha_{max} = 1.3 + 0.41M_w - Log(R \times 0.32.10^{.0.41Mw}) - 0.0034R \tag{2}$$

2.2. Attenuation Coefficient

Formulated as [10]

$$\acute{\alpha} = \frac{\pi(f2 - f1)}{v} \tag{3}$$

Where $(f_2 - f_1)$ is bandwidth, v is S-wave velocity.

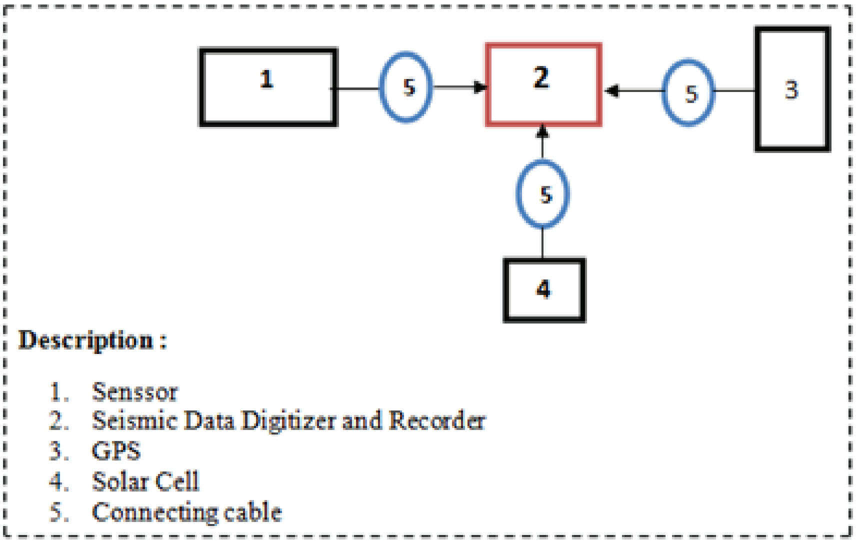

Figure 2: Parts of short period Seismometer.

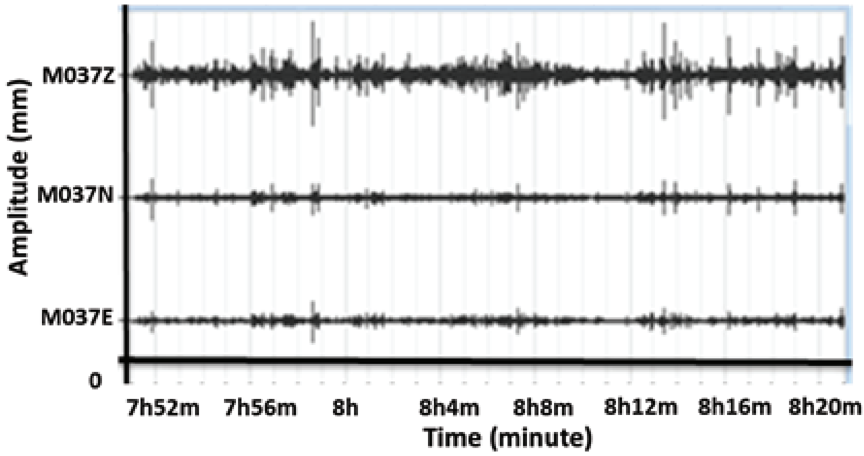

Figure 3: Data record of soil vibration in seismometer.

3. Data Acquisition

3.1. Microseismic Data

Microseismic data were acquired directly using the 3 components of short period seismometer, as shown in Fig. 2.

Data were recorded for 30 minutes at each measurement location. The sampling frequency was 100 Hz, the frequency ranged between 0.5 to 20 Hz, and filter used was a low pass filter. Microseismic survey technique conducted referred to the standard *SESAME* European Research Project 2004. Measurement data were recorded directly by seismometer as shown in Fig. 3.

Fig. 3 is a soil vibration recorded in the monitor and were analyzed with Geopsy using *HVSR* (Horizontal to Vertical Spectral Ratio) method. One of the results data processed can be seen in Fig. 4, a sepectral peak which represents f_o value at the horizontal

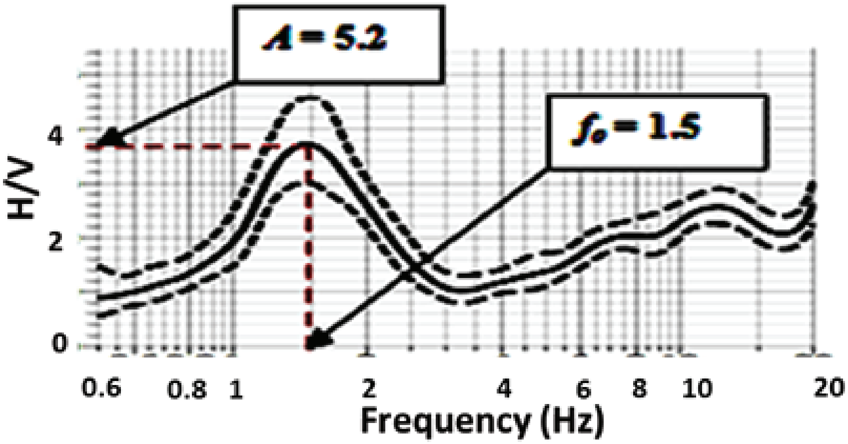

Figure 4: The results of the data processing Station-2.

axis and *A* value in the vertical axis. The value of *f* at the spectral peak is dominant frequency (f_o) and the value of *H/V* at the spectral peak is amplification factor (*A*).

3.2. Earthquake Data

Earthquake data from 1900 to 2010 were taken from the office of the Meteorology, Climatology and Geophysics Agency as secondary data. The data included the magnitude, location and distance from the earthquake center to the station. From these data the value of the Peak Ground Acceleration (α_{max}) was calculated using Fukushima-Tanaka atenuation in the Eq. (2).

4. Results And Discussion

The results of data processing from one of station can be seen in Fig. 4, namely a spectral peak from data processing Sstation-2 which produce value f_o is 1.5 and *A* is 5.2.

The value of f_o and *A* used to calculate K_g, namely K_g is $A^2/\ f_o$. The value of α_{max} calculated using Eq. (2), so that γ in Eq. (1) can be calculated. The next step is to calculate the attenuation coefficient ($\acute{\alpha}$) by using Eq. (3), where f_2–f_1 is bandwidth and υ is s-wave velocity (υ_s) is calculated by using,

$$\upsilon_s = \frac{(\upsilon_p - 1.36)}{1.16} \tag{4}$$

The value of υ_p determined from USGS-table according to the coordinates of each station. The value of $f_2 - f_1$ manually calculated from the position of bandwidth, such as shown the Station-1 data in Fig. 5.

The value of $f_2 - f_1$ at the Fig. 5 is 1.7, υ_p value at Station-1 according to the USGS table is 311 m/s. By using Eq. (3) obtained $\acute{\alpha}$ is 0.02. Results of research on f_o, A, α_{max}, shear strain, and attenuation coefficient in the coastal areas can be seen in Table 1.

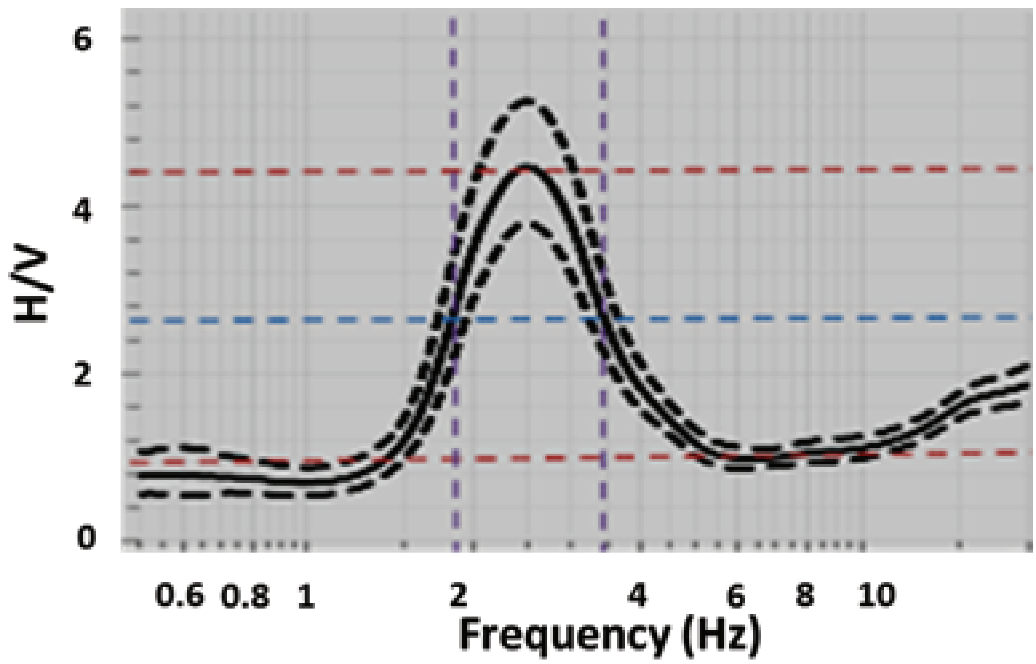

Figure 5: Method of measuring bandwidth ($f_2 - f_1$).

Station	Location		f_o	A	α_{max}	Shear Strain (γ)	Atenuation Coeff. (?)
	Latitude	Longitude					
1	-2.70	101.27	2.5	4.4	250	0.0019	0.02
2	-2.65	101.31	1.5	5.2	302	0.0032	0.015
3	-3.22	101.60	5.0	4.0	433	0.0013	0.022
4	-3.27	101.66	13.9	7.8	592	0.0027	0.022
5	-3.55	102.09	1.5	3.6	161	0.0014	0.01
6	-3.80	102.26	6.5	8.1	451	0.004	0.04
7	-3.53	102.05	4.3	4.4	279	0.0013	0.01
8	-4.02	102.35	0.7	1.1	193	0.0003	0.006

Table 1: The results of measurement of f_o, A, α_{max} and the calculation of γ, $\acute{\alpha}$.

The correlation between the shear strain and the attenuation coefficient is shown in Fig. 6.

The values of shear strain and attenuation coefficients changed according to landslide level which occurred in Bengkulu Shore. This difference was indicated by the geological and geomorphological conditions at the shore. The correlation between shear strain and attenuation coefficient tended to be linear. The linear conditions tended to have impacts on the landslide volume. Fig. 1 shows the greater the shear strain and attenuation coefficient values, the greater of landslide volume was. Isihara [11] states that the value of the shear strain will indicates the condition of deformation that occurs on the surface of the soil layer. At the order of shear strain value of 10-6, the sediment only experiences the thrill, but at the order of 10-3, sediment will experience landslides and liquefaction.

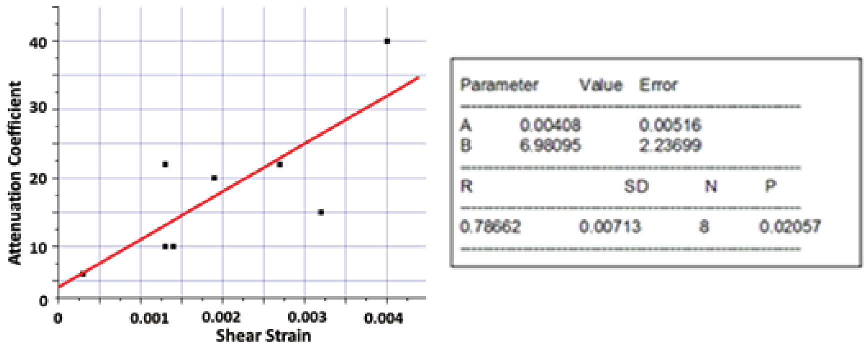

Figure 6: The correlation between shear strain and attenuation coefficient.

There is a tendency that the greater the shear strain, the more severe the landslide level will be. Similarly, there is a tendency that the greater attenuation coefficient value, the worse the condition of the landslide will be. Marzorati [12] stated that the earthquake which occurred in 1997 in Umbrië-Marche, Central Italy triggered landslides and rock falls when soils were strained. Malamud et al. [6] reported a significant correlation between the magnitude moment and landslides volume. Kudo [13] showed the geographical changes for coastal landslides due to shear strain. Our present research has managed to link the value of shear strain with landslides that occurred in Bengkulu coast, similar to research conducted by Isihara [11]. Fig. 2 shows a linear correlation between the value of shear strain and attenuation coefficient. These correlation proved that both can be linked to landslide levels.

5. Conclusion

There is a tendency, that the greater the value of shear strain or attenuation coefficient will the greater the chances of landslides in the region. Correlation between shear strain and attenuation coefficient tend to be linear.

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