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Ground Shear Strain and Rate of Erosion in The Coastal Area of North Bengkulu, Indonesia

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Abstract. North Bengkulu district has an area prone to earthquakes, because this area is very closed to the Sumatra subduction zone to the Eurasian tectonic plate. Coastal area in this region is experiencing with the very fast erosion. This is thought to have relation with earthquake-prone zones. This study aims to find the relationship between Ground Shear Strain (GSS) and rate of erosion in the coastal area of North Bengkulu. The data of coastal erosion rate was obtained by overlaying shoreline in 1947 and 2012. The GSS can be obtained by multiplying Seismic Vulnerability Index (SVI) and Peak Ground Acceleration (PGA) values around the shoreline. Seismic Vulnerability Index was obtained by processing microseismic data acquired using three component in short period of seismometers. The PGA was obtained from the historical earthquake and calculated by using Fukushima-Tanaka equation. The results show that the value of GSS varies between 0.0001 to 0.0055, and the SVI values is ranging from 1.2 to 16.1. In addition, we estimated that PGA value is 92 to 120 gal and the rate of erosion between 3.6 up to 5.8 m/yr. GSS value for each type of shore is 0.00046 for the shore of fine sandy flat, 0.0043 for shore of muddy flat, 0.0001 for shore of rocky flat, 0.0006 for shore of sandy rugged, 0.0003 for shore of steep lava rocky, 0.0014 for shore of steep rocky clay, 0.0011 for shore of tufa steep sandy stones, and 0.0014 for the shore of steep rocky tuffaceous clay. It is found that the GSS value depends on the type of coastal. In this case, flat coastal muddy show highest effect on the GSS. Both SVI and GSS can be estimated to be a quadratic relation to the erosion rate.

INTRODUCTION

North Bengkulu district has a coastal length of about 60 km, in the range between 3.2° - 3.6° south latitude, dealing with the Indian Ocean. Erosion occurs almost along the beach with a relatively high pace. Geological conditions which are dominated by Bintunan Formation consist of tuffaceous clay and sandy tufa stone. Both of these rock types eroded quite heavy. In addition to the geological conditions that allow the erosion, vibration condition that often occurs predicted earthquake accelerated the rate of erosion in North Bengkulu shore.

Erosion at many points along the coast of North Bengkulu estimated because the value of ground shear strain (GSS) is high. Higher GSS values is possible because the region is in soft soil conditions [1]. The erosion occurs due to the high vulnerability of the coastal ocean dynamics such as the pounding waves, the wind, the destruction of shade trees and ocean currents [2]. Erosion is

the destruction of the beach by the ocean waves beating against the wall continuously coast [3]. According Kodoatie and Sjarief [4], there is a relationship between the rate of shore erosion with seismics vulneribility index [5]. Based on Nakamura [6], the beach area has high seismic vulnerability index experienced a lot of physical damage during the earthquake [4]. No relationship between seismic vulnerability index with coastal erosion [1-5].

THEORETICAL FRAMEWORK

Ground Shear Strain (GSS)

GSS rate describes the ability of the material making up the terrain for each stretch and shift during earthquakes. GSS values is obtained by multiplying the seismic vulnerability index (K_g) and microseismic the maximum ground vibration acceleration in bedrock (α). The relationship between seismic vulnerability index with amplification factor and the resonance frequency has been published by Farid et.al [5], and the maximum ground vibration acceleration in bedrock (α) defined by the Fukushima-Tanaka [6] stated in Equation (1).

$$\text{Log } \alpha = 1{,}3 + 0{,}41\, M_w - Log\,(R\,.\,0{,}32\,.\,10^{\,0{,}41Mw}) - 0{,}0034\, R \quad (1)$$

In Equation (1), α = estimated value of PGA in gal, *Mw* = moment magnitude and *R* = distance from the hypocenter to station (km). GSS value (γ) in the surface soil layer describes the ability of the soil layer for each material stretched or shifted during the earthquake [7]. GSS value describes the conditions of deformations that occur in the ground surface layer.

According to the statement Isihara [8] which states that the ground surface layer will behave as plastic on the value of $\gamma = 1.000\times10^{-6}$, and if the value of $\gamma > 1.000\times10^{-6}$, the ground surface may have experience landslides and liquefaction [8]. GSS values can lead deformations on the ground surface layer. Erosion can cause shoreline changes. In areas prone to earthquakes, stress can also be occurred from the earthquake that vibrate on the beach wall.

DATA ACQUISITION

Microseismic data

Microseismic data are acquired directly through microseismic measurements at several locations on the waterfront of North Bengkulu. The number location of surveys for microseismic measurements were 11. Each location was measured for 30 minutes with a sampling frequency of 100 Hz. Microseismic survey technique is referred to standards SESAME European Research Project 2004. The tools used are short-period seismometers 3 components.

Coastal Erosion Data

Coastal erosion data are estimated by calculating the difference of distance of the position of the shoreline in 1947 and the position of the shoreline in 2012, with the assumption that shoreline changes is only caused by erosion factor.

Earthquake Data

The data used are a secondary data of the historical earthquakes from 1900 to 2011. The data were obatined from the Meteorology, Climatology and Geophysics Bengkulu province. Data that using this research is the magnitude of the earthquakes, location, and distance between hipocentrum and stations. From the data, we calculated the value of Peak Ground Acceleration (PGA) using Fukushima-Tanaka equation as shown in Equation (1).

RESULT AND DISCUSSION

The results show that the resonance frequency values are 0.7 to 13.9 Hz, while the amplification factor are 2.35 to 7.99. In addition, we also obtained that PGA is ranging from 110-179, and GSS varies from 0.00015 to 0.00148. We also estimated the erosion rate in coastal area of North Bengkulu is 1.1 to 5.8 m/yr. The GSS value depends on the type of coastal as shown in Fig. 1.

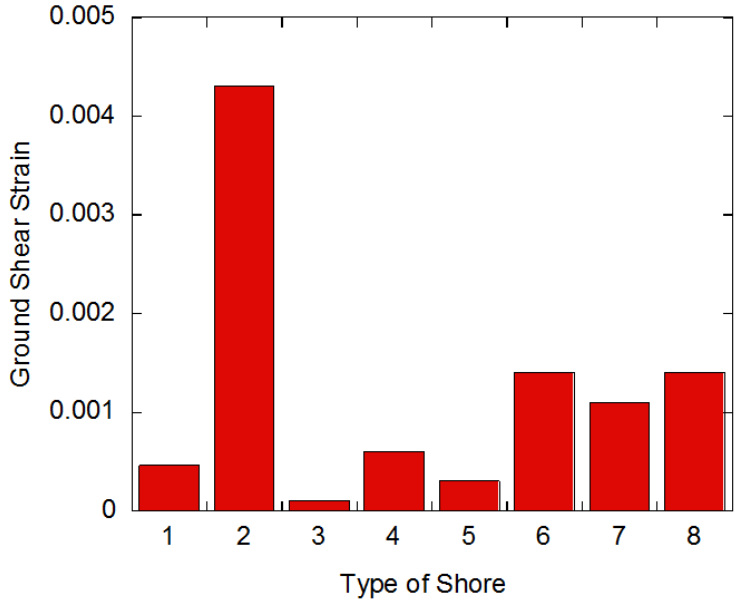

Figure 1. Ground Shear Strain versus types shore of (1) fine sandy flat, (2) muddy flat, (3) rocky flat, (4) sandy rugged, (5) steep lava rocky, (6) steep rocky clay, (7) tufa steep sandy stones, and (8) the steep rocky tuffaceous clay.

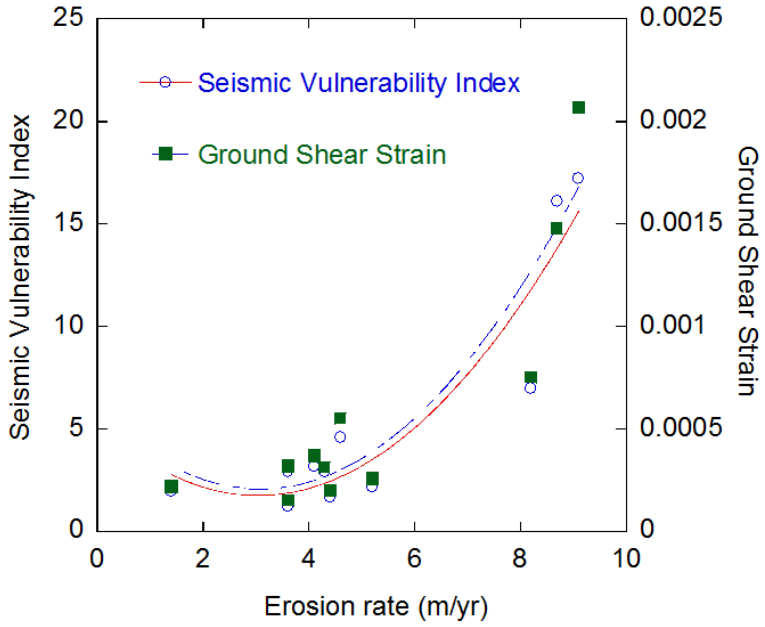

Figure 2. Relationship between SVI, GSS and rate of coastal erosion

The relationship between SVI, GSS and rate of coastal erosion is shown in Fig.2. It indicates that the coastal areas are experiencing high erosion rate has a high seismic vulnerability index. The GGS and SVI tend to be nonlinear to erosion rate. Based on Fig.2, the relation between SVI, GSS and erosion rate can be estimated as $y = a_o + a_1 x + a_2 x^2$ (see Table 1 for the value of each parameter).

Table. 1 Erosion rate

Parameters	SVI ($\times 10^{-5}$)	GSS
a_o	59.114	5.2524
a_1	-0.24.98	-2.2977
a_2	4.058	0.37751
R	92449	0.93613

This information is useful to be used as a reference in urban development planning. Earthquake vulnerability and seismic risk assessment have been also carried out for urban areas in high seismic regions [9-11].

CONCLUSION

The investigation of dependence GSS on the rate of erosion in the coastal area of North Bengkulu has been carried out. It is found that the GSS value depends on the type of coastal. In this case, flat coastal muddy show highest effect on the GSS. Both SVI and GSS can be estimated to be a quadratic relation to the erosion rate.

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