Seismic Vulnerability Index Calculation for Mitigation Purposes at Cilacap District

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Abstract. Seismic vulnerability index is one of the key factors in mitigation that shows the vulnerability of the soil layer beneath when passed through with a wave, the more vulnerable the soil layer, the more damage it done when an earthquake happens. Seismic vulnerability is calculated using two variables, that is dominant frequencies and amplification that are obtained by analyzing HVSR curve. HVSR are used to determine the dominant frequency by determining the maximum amplification in that area. HVSR curve is obtained by measuring microbemor data in 163 spots with 30 minutes-minimum duration in Cilacap with a portable seismograph. Mierotremor is a natural vibration that is caused by continuous vibration that come from beneath the surface, sometimes mixed up by the vibrarion that is caused by human activities such as pipe-flow, vehicles, etc. Thus, the purposes of this research are to determine which area is more vulnerable than others, based on the seismic vulnerability index, so it could be a reference for regional development to classified is it safe or unsafe to build in that area, remembering Cilacap is one of the most developed Districts in Central Java.

1. Introduction
In a high seismic prone area, such as Cilacap, human and economic loss are more likely due to construction or not seismically designed. When an earthquake happens in the surface, the buildings are being hit by seismic wave that could be separated as horizontal and vertical component. The vertical component isn’t threatening life because the array is in line with gravity, meanwhile the horizontal component threatening because it creates a movement that caused the building above it to swing. This condition could cause the building to collapse [6].

Because Cilacap is one of the developed District at Java, it is necessary to make a mitigation attempt so it could be used a reference to understand which area is more vulnerability when passed by a seismic wave than the other. One of the methods that could be used to understand this is by mapping the seismic vulnerability index, which gotten by measuring microtremor in certain place. If compared to Jakarta which consist of Basin, it is assumed that the seismic vulnerability index in Cilacap would look alike in Jakarta [4].

2. Data and Methods

2.1. Data
The data in this research is the results of measuring microtremor wave in area which shown below:
Figure 1. Microtremor measurement at Cilacap

Microtremor wave are measured using TDS-303 Portable Seismograph for a 30 minutes-minimum of data recording. $A_0$ and $f_0$ then determined using Nakamura technique [7] on Geopsy [9].

2.2. Methods

The list of authors should be indented 25 mm to match the abstract. The style for the names is initials then surname, with a comma after all but the last two names, which are separated by ‘and’. Initials should not have full stops—for example **A J Smith** and not **A. J. Smith**. First names in full may be used if desired. If an author has additional information to appear as a footnote, such as a permanent address or to indicate that they are the corresponding author, the footnote should be entered after the surname.

2.2.1. Estimating Soil classification based on dominant period

Soil classification can be determined using dominant period gained from the microtremor using equation:

$$T_0 = \frac{1}{f_0}$$

Where $f_0$ is dominant frequency of HVSR wave

2.2.2. Calculating Seismic Vulnerability Index.

Seismic Vulnerability Index can be calculated using:

$$K_g = \frac{A_0}{f_0^2}$$
Where:
$A_0$ = maximum amplitude of HVSR wave
$f_0$ = dominant frequencies of HVSR wave.

2.2.3. Flow Chart

![Flow Chart Diagram]

**Figure 2.** Flow Chart

3. Results

$A_0$ and $f_0$ estimated using HVSR data from processing microtremor data using Geopsy [9], as below:

![Microtremor Data Processing in Geopsy]

**Figure 3.** Microtremor data processing in Geopsy

The data that has been recorded using portable seismograph then processed with Geopsy to obtain the frequency based on the amplification value. Then, the value of dominant period is calculated to classify the soil. Meanwhile the seismic vulnerability index is calculated with the frequencies and the amplification value.

3.1. Dominant period estimation

This research is using microtremor data that measured in 162 spots in Cilacap, which varied from 0.345 — 3.809 s that can be classified into Type III (sand, clay that categorized as alluvium) and Type IV (delta sedimentation) soil which is shown below:
Figure 4. Dominant period microzonation

3.2. Amplification estimation
This research is using microtremor data that measured in 162 spots in Cilacap, which varied from 1.95 — 6.159 that was obtained from peak amplification on a HVSR curve on Geopsy, which is shown below:

Figure 5. Amplification microzonation

3.3. Seismic vulnerability index calculation
The seismic vulnerability index is showing which area are more prone due to seismic activity based on the geological condition. The area that’s way more prone are shown in red, while the safer area is shown in green. The seismic vulnerability index is varied from 3.184-56.827 as shown in figure below:
4. Discussion

Based on dominant period calculation, Cilacap is composed of Type III and Type IV soil based on Kanai and Tanaka’s Soil Classification [1], where Type III soil is consists of sand, clayclay, and alluvium soil, while Type IV soil consist of delta’s sedimentation, topsoil, mud, humushumus, or soft soil with 30 m depths. The Type III soil are seen in the South-Westnorthern area of Cilacap, while the rest of Cilacap are covered in Type IV soil. According to Elnashai & Sarno (2008) [4], the importance of geological surface condition effects soil vibration. Site effect had important role because of the geological difference between every area that determines the amplification and dominant frequencies.

Calculation of seismic vulnerability index are depended by the dominant frequency and the amplification. In this study, even though the seismic vulnerability index is varied, if compared to the geological map [2] are categorized as Qac (coastal deposit) that generally consists of well-medium sorted sands, very loose and categorized as shallow, with highest seismic vulnerability index located in southern Cilacap. Based on the calculation of seismic vulnerability index, the South-West area has seismic vulnerability index higher than the rest of Cilacap, it is estimated during earthquake the South-West area of Cilacap to have more destruction during earthquake. While the seismic vulnerability index microzonation is compared to the dominant period microzonation, it can be assumed that the higher the dominant period of the area, the higher the seismic vulnerability index. This can be explained in softer soil, the earthquake wave that traveled through the soil is being reflected and refracted in the soil because of the different length between soil particle in soft soil, while in harder soil the earthquake wave could traveled through the soil without being much reflected and refracted because of the rigidity of the soil. This caused the building in soft soil to shake more than the building in hard soil [5].

Variation of the seismic vulnerability index could be correlated to level of destruction of an earthquake, region with higher seismic vulnerability index tend to have more destruction when an earthquake happens. It is important to conduct a seismic risk evaluation based on past earthquake event and planning mitigation plans are required to minimize the damage of the earthquake. Mitigation plans that could be approached for this area such as: foundation engineering, building a better structure, or even avoiding building houses and offices in that area. This study also shows the important need of local geological study (not only on the surface), but also the thickness of the sediments that have an impact when an earthquake happens.
5. Conclusions
According to microzonation, seismic vulnerability index is higher in area with harder soil. While seismic vulnerability index at the South-West area of microzonation area in Cilacap is the highest than other area (56,827).

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