Peak Ground Acceleration (PGA) and Peak Ground Velocity (PGV) Analyze for Microzonation of Earthquake Hazard Area: Case Study in West Nusa Tenggara

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Abstract. The Lombok region is located around a complex tectonic zone with an Indo-Australian oceanic crust transition zone with Australian continental crust in the west and Sundanese arc in the east. This complexity makes some area in West Nusa Tenggara have a high level of earthquake vulnerability and to determine the potential level of seismic damage risk this study was conducted by analyzing Peak Ground Acceleration (PGA) and Peak Ground Velocity (PGV) using earthquake data since 2000 - March 2020 with an intensity more than M4.5. Earthquake data are analyzed using the Yin-Min Yu formula to get the relationship between Peak Ground Acceleration (PGA), Peak Ground Velocity (PGV), and earthquake intensity, so areas with risk level of earthquake damage can be mapped as preliminary earthquake mitigation schemes. The results of the study show that the highest PGA value in West Nusa Tenggara is 74.73 gal at the bedrock and when it on the surface, the PGA value can increase due to amplification of local soil conditions. Likewise PGV value about 32.21 gal where this maximum value is located in East Lombok Regency and North Lombok Regency. According to the classification of PGA and PGV values, the study area has a potential high-risk level of earthquake damage.

1. Introduction

Based on the Central Statistics Agency (BPS), the population of West Nusa Tenggara reached 5,320,092 people per 2020 [1]. This condition is one of the high-risk vulnerability factors which at any time causes huge losses in the event of a natural disaster. The possibility of an earthquake disaster affecting West Nusa Tenggara includes two parts there are, the subduction zone in the south of West Nusa Tenggara and the Back-Arc thrust in the north of West Nusa Tenggara. This is the cause of frequent earthquakes in West Nusa Tenggara. Considering the high earthquake risk, earthquakes Hazard analysis in Mataram area is very necessary [2]. Peak Ground Acceleration (PGA) is the highest ground acceleration value that appears on the surface of the area within a certain period of time due to seismic vibration [3]. Whereas, Peak Ground Velocity (PGV) is the value of the maximum ground velocity on the surface that has occurred in an area with a certain time period due to earthquake vibrations [4].

The level of damage caused by the earthquake depends on the strength and quality of the building, geological, and geotectonic conditions as well as peak ground acceleration (PGA) in the area where the earthquake occurred [5]. Also, the empirical measurement of PGA and PGV is crucial in spatial planning, particularly in infrastructure development. Therefore, the microzonation of earthquake-prone areas can be utilized to minimize the occurrence of damage in these areas [6]. Accordingly, this research expects to provide input for the design of earthquake resistant buildings in West Nusa Tenggara.
addition, this earthquake disaster update is an important step in earthquake disaster mitigation in Indonesia.

1.1. Data Collection
The data used in this study are seismic data obtained from the official website of the United States Geological Survey (USGS) from January 2000 to March 2020. The seismic database is limited to 116,067° - 119,332° E and 8°-9° S, with magnitude ≥ 4.5. The seismic data used in this study is 321 events.

1.2. Calculation of Peak Ground Acceleration
The value of Peak Ground Acceleration (PGA) in this study was calculated using the empirical equation, as follows [7]:

\[ \text{PGA} = \exp \left( \frac{I - 0.7}{2} \right) \]

where,
\[ I = I_0 \exp^{-b \Delta} \]
\[ I_0 = 1.5 \times (M-0.5) \]
\[ I = \text{Intensity at the epicenter distance (observation station)} \]
\[ I_0 = \text{Intensity of the earthquake source} \]
\[ \Delta = \text{Epicenter distance} \]
\[ b = 0.00051 \]
\[ M = \text{Earthquake magnitude} \]

1.3. Calculation of Peak Ground Velocity
The empirical equation that correlated Peak Ground Velocity (PGV) and earthquake intensity, as follows [7]:

\[ \text{PGV} = \exp \left( \frac{I - 1.89}{2.14} \right) \]

where,
\[ I = I_0 \exp^{-b \Delta} \]
\[ I_0 = 1.5 \times (M-0.5) \]
I = Intensity at the epicenter distance (observation station)
I₀ = Intensity of the earthquake source
Δ = Epicenter distance
b = 0.00051
M = Earthquake magnitude

1.4. Data Analysis
Data analysis was carried out in three stages, are the analysis of the PGA and PGV values, an analysis contour map of PGA and PGV, and determining the relationship between the peak ground acceleration, velocity, and earthquake intensity. The peak ground acceleration and velocity then made into a contour map with an interpolation system using the Inverse Distance Weighted (IDW) method [8]. Then to obtain the relationship between the PGA and PGV, it is analyzed with excel by plotting the result data of PGA and PGV.

2. Results and Discussion
The calculations result shown the relationship between PGA and earthquake epicenter intensity in equation (1) and the relationship between PGV and earthquake epicenter intensity in equation (2). Based on the seismicity map of West Nusa Tenggara that we determined, it can be seen that the event occurred in the study area were scattered with various magnitudes. Where events with M4.5 - 4.9 are scattered in almost all regions of West Nusa Tenggara both on land and sea, but for events with M5.7 - 6.9 it is only found in coastal areas to sea parts of West Nusa Tenggara. In addition, the study area is surrounded by active faults wherein the tectonic arrangement of West Nusa Tenggara is affected by the Flores back arc thrust in the north and the subduction zone in the south. Subduction often produces deep events. On the contrary, the back-arc thrust tends to produce shallow seismic events [9].

**SEISMICITY MAP OF WEST NUSA TENGGARA PROVINCE (2000-2020 PERIOD)**

![Seismicity Map of West Nusa Tenggara](image)

*Figure 2. Seismicity Map of West Nusa Tenggara*

An empirical approach is necessary for further earthquake studies due to the lack of acceleration and velocity of ground data on the accelerograph. So that from the maximum ground intensity and acceleration data for each coordinate, the contour map can be obtained for the microzone of the area.
In Figure 3, it can be seen that the Peak Ground Acceleration value from West Nusa Tenggara is divided into 7 classes, with the first class with the lowest PGA value scale of 12.404 - 20 gal and the PGA value of this class relatively dominates in West Nusa Tenggara. Then for the areas that were found to have the largest PGA value with 70.001 - 74.733 gal, the coverage area is still wide, therefore microzonation is carried out by dividing into two maps (Figure 5 and Figure 6), is the PGA map of the districts of North Lombok and East Lombok, so that the mapping of distribution of ground acceleration is more specific.
The results of the modeling of the Peak Ground Velocity (PGV) value obtained from the interpolation using the Inverse Distance Weighted (IDW) method, it is known that the PGV value in West Nusa Tenggara with the smallest classes is 6.0328 - 10 gal and the highest with a value of 30.001 – 32.210 gal, so that microzonation was also carried out in areas with the highest PGV value, are North Lombok and East Lombok districts (Figure 7 and Figure 8).

**Figure 4.** Peak Ground Velocity Map of West Nusa Tenggara.

**Figure 5.** Peak Ground Acceleration Map of East Lombok
Figure 6. Peak Ground Acceleration Map of North Lombok

The microzonation map shows both East and North Lombok PGA values are quite high, are 65 - 74.733 gal also with PGV values where both have 25 – 32.313 gal. When viewed from the tectonics, both areas do have a direct impact when there is an activity from the Flores back arc thrust, for example during the 2018 Lombok earthquakes measuring $M_w$ 7.0 and caused a lot of material loss and lives [10]. As we have known before, due to the compression between the Australian continental plate and the Eurasian plate[11], the tectonic model of Lombok is formed by the large thrust of the south subduction and the back-arc thrust, so it causes the south subduction to tend to produce deeper earthquakes and the rear thrust of North Flores tends to produce shallow earthquakes. Then, the earthquake ground motion will be affected by the source, propagation, and site effects [12]. The 2018 Lombok's earthquake seems to influence by the seismic activity of Flores back-arc thrust [13].

Figure 7. Peak Ground Velocity Map of East Lombok
The curve shows a linear relationship between PGA and PGV. This shows the relationship between the two parameters in determining earthquake-prone areas. The greater the PGA value and the PGV value indicates the higher earthquake risk level [3], it can be seen that PGA and PGV are directly proportional (Figure 9).

3. Conclusion

1. The Highest value of Peak Ground Acceleration (PGA) and Peak Ground Velocity (PGV) in West Nusa Tenggara in January 2000 to March 2020 with the intensity of $\geq$ M4.5 are in East Lombok Regency and North Lombok Regency, are PGA is 74.733 gal and PGV is 32.210 gal.
2. The minimum Peak Ground Acceleration value (PGA) in West Nusa Tenggara in 2000 - March 2020 with intensity ≥ M4.5 is 12.404 gal and the value and Peak Ground Velocity (PGV) is 6.032 gal.

3. Regions that have a high PGA value also have a large PGV value. The greater PGA value and PGV value, also have the greater intensity value, then, greater the intensity value makes higher earthquakes risk level.

4. The areas that have the highest earthquake risk level are East Lombok Regency and North Lombok Regency.

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