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Comparing Two Models of Mapping the Peak Ground Acceleration (PGA) in Western Java

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Abstract
West Java is an area located in the subduction zone of two major plates of the world, Indo-Australian and Eurasian plates that cause high tectonic activity. This is marked by the number of earthquake events in this area. The accumulation of earthquake-induced shocks produces a ground movement. The ground movement provides various effects such as landslides, road fractures, cracks in walls and so on. These effects need to be addressed so that any activity to be performed on the surface can take place properly. There are some ground movement activity. One of them is Peak Ground Acceleration (PGA). This research was conducted to compare two models of Peak Ground Acceleration (PGA), *Faccioli* and *Donovan.* These models based on 50-years of catalog earthquakes event in period 1965 – 2015 on West Java with Magnitude ≥ 5 SR and the hypocentre ≤ 80 km. The results of this research will be compared with the 2010 Indonesian earthquake map.

Keywords : Peak Ground Acceleration (PGA), Faccioli, Donovan, West Java.

1. Introduction

Indonesia is located between two continents, namely the Australian continent and Asia, and is located between two oceans, the Indian Ocean and the Pacific Ocean. Thus, it can be said that Indonesia is in the cross position of the world (world cross position). Geological location is the location of an area based on the state of the rocks that exist on the surface of the earth. Geologically Indonesia is located between two circum, namely Mediterranean and the Pacific Circums, and also within 3 (three) main plate world that Australian Plate, the Eurasian and Pacific. This position causes Indonesia is an earthquake prone country and has many active volcanoes.

West Java Province is located in the western part of Java Island. Its territory is bordered by Java Sea in the north, Central Java in the east, Indian Ocean in the south, and Banten and DKI Jakarta in the west. North coast area is lowland. In the middle is a mountain, which is part of a series of mountains that stretch from west to east of Java Island. Its highest point is Mount Ciremay, which is in the southwest of Cirebon City. The important rivers are the Citarum River and Cimanuk River, which empties into the Java Sea.[1]

Figure 1 shows a map of the vulnerability zone of the Java land movement issued by the Indonesian Badan of Geological. The circle contained on the map shows the areas of Java island that have medium vulnerability characterized by yellow color while the high level is marked by the color purple. In areas with medium susceptibility to soil movement, especially in areas adjacent to river valleys, escarpments, road cliffs, or if the slopes are impaired. Old soil movements can be reactivated in the event of high rainfall and very strong erosion. As for areas that have a high level of vulnerability due to soil movement often occur here due to very high rainfall levels and very strong erosion so that the movement of old and new land in this area is always active as in the circled areas are black [2].

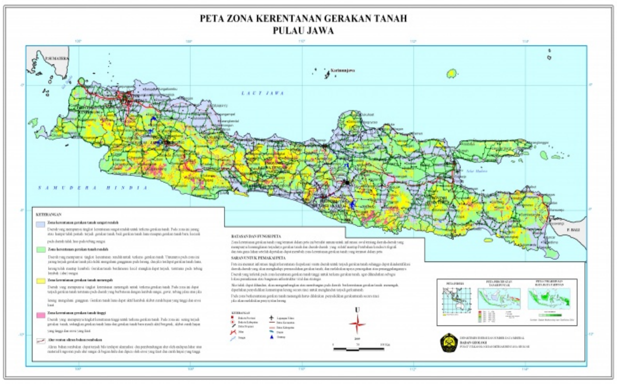

Figure 1. Map of Peak Ground Acceleration in Java Island (Badan of Geology, 2015)

Current practice in design of earthquake-resistant structures is to use peak ground acceleration as a measure of the severity of ground motion even though peak acceleration may not be the best parameter to represent this characteristic of ground motion. Peak acceleration is used because of its familiarity and wide acceptance in the engineering community as a measure of the lateral forces on high-frequency structural systems. For intermediate- and low-frequency systems, ground velocity and displacement data are more applicable [3].

Hypocenter (R) Formula :

$$R = \sqrt{(X_h - X_S)^2 + (Y_h - Y_S)^2 + (Z_h - Z_S)^2}\ (km) \quad (1)$$

Earthquake energy (magnitude) is a quantity of earthquake that states the amount of energy released by an earthquake (explosion) at its center. In the process of calculating the acceleration of the ground on the surface, the surface wave magnitude (Ms) is converted to the magnitude of the body (Mb). The amount of Mb value is converted in the following way.

$$M_S = 1{,}59\ M_b - 3{,}97 \quad (2)$$

$$M_S = \left(\frac{M_W}{1{,}1}\right) - 0{,}64 \quad (3)$$

Where, Ms is Surface wave, Mb is body wave. Mw is moment magnitude [4].

The United States Geological Survey developed an Instrumental Intensity scale, which maps peak ground acceleration and peak ground velocity on an intensity scale similar to the felt Mercalli scale. These values are used to create shake maps by seismologists around the world.

Table 1. Mercalli Scale of Peak Ground Acceleration (PGA)

Instrumental Intensity	Acceleration (g)	Velocity (cm/s)	Perceived Shaking	Potential Damage
I	< 0,0017	< 0,1	Not Felt	None
II – III	0,0017 – 0,014	0,1 – 1,1	Weak	None
IV	0,014 – 0,039	1,1 – 3,4	Light	None
V	0,039 – 0,092	3,4 – 8,1	Moderate	Very Light
VI	0,092 – 0,18	8,1 – 16	Strong	Light
VII	0,18 – 0,34	16 – 31	Very Strong	Moderate
VIII	0,34 – 0,65	31 – 60	Severe	Moderate to Heavy
IX	0,65 – 1,24	60 – 116	Violent	Heavy
X+	>1,24	>116	Extreme	Very Heavy

(Wikipedia, 2017)[5]

Donovan's equation (1973) :

$$PGA_D = 1080\ (\exp^{0.5\,M}).\ (R + 25)^{-1.35} \quad (4)$$

Faccioli's equation (1978) :

$$PGA_F = 108{,}6\ .\ 10^{0{,}265\,.M}\ (R + 25)^{-0{,}808} \quad (5)$$

2. Research Model

Figure 3. Flowchart in conducting PGA research using the Donovan and Faccioli models. Data which is historical data of earthquake in USGS period 1965 - 2015 with area limit 5^0 SL – 9^0 SL and 105^0 EL – 109^0 EL. Magnitude taken ≥ 5 SR and depth ≤ 80 km. Software used in Microsoft Excel, surfer 9, and ArcGIS 10.2 data processing.

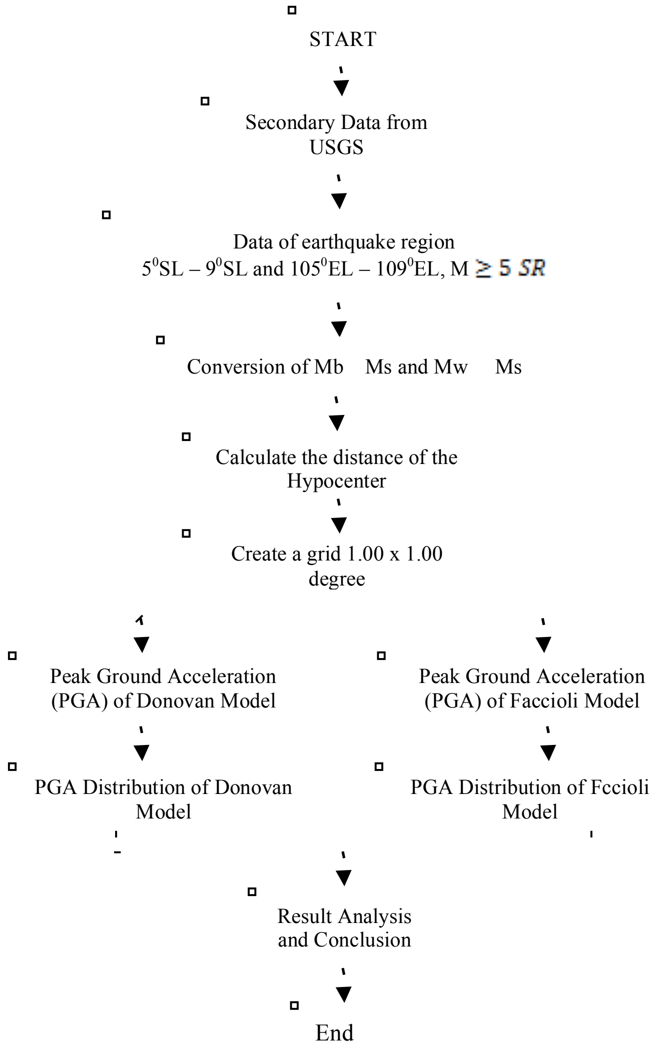

Figure 2. Flowchart of Research model

3. Result and Analysis

Figure. 3 shows the Peak Ground Acceleration combined with the seismicity distribution obtained from the USGS shows that the earthquake distribution is centered in the south on the western island of Java. The red sign indicates shallow earthquakes are related to the value of ground movement and include active ground movement zones or have large soil movement values so that in areas located on red markings indicate active ground motion.

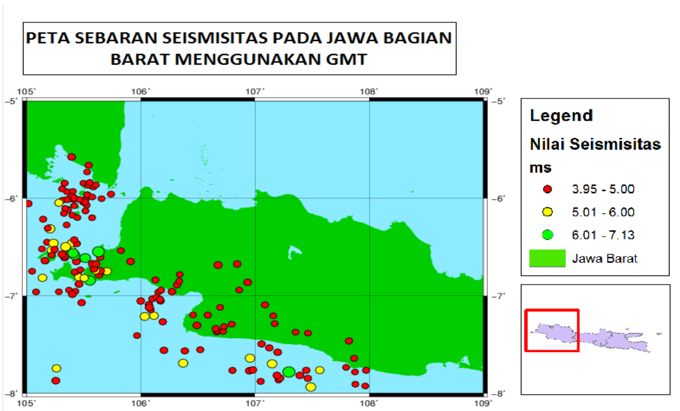

Figure 3. Seismicity Distribution Map in Western Java with GMT

From calculation data of PGA value with both model of Donovan and Faccioli then interpreted using Surfer 9 and ArcGis 10.2 software so that can be seen distribution map which have happened in range 1965 - 2015 with magnitude ≥ 5 and hypocenter ≤ 80 km in West Java region

Figure 4 shows the distribution of peak ground acceleration (PGA) values by using the Donovan model resulting in maximum land acceleration of 0.191 g at coordinates of 9^0 SL – 109^0 EL and the lowest maximum ground acceleration of 0.12 g at coordinates of 5^0 SL - 105^0 EL .

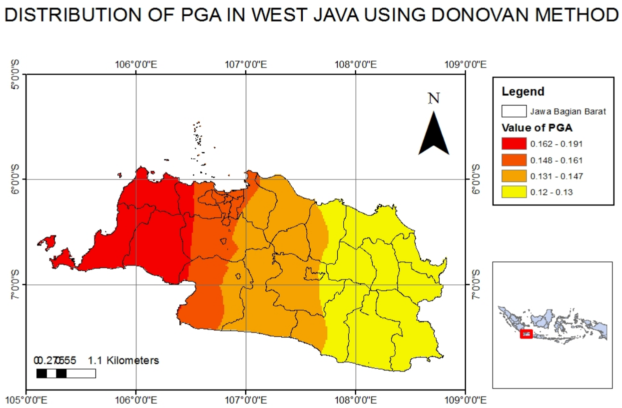

Figure 4. Peak Ground Acceleration of Donovan Model Distribution

Figure 5 shows the distribution of peak ground acceleration (PGA) values by using the Faccioli model resulting in maximum land acceleration of 0.247 g at coordinates of 9^0 SL – 109^0 EL and the lowest maximum ground acceleration of 0.235 g at coordinates of 5^0 SL – 105^0 EL.

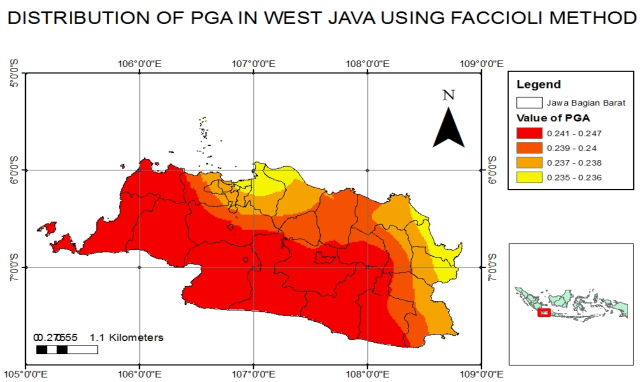

Figure 5. Peak Ground Acceleration of Faccioli Model Distribution

From the results obtained using the maximum value of Donovan model that is 0.191 g including class VI with shock rate occurs strong earthquake and potential damage to light. While using the Faccioli model the maximum value of 0.247 g including class VII with the shock rate occurs moderate earthquake and very light damage potential. However, both models show the same where the maximum PGA value is in the southern part of Java and the minimum PGA value is in the northern part of Java.

The values are quite varied and shows the value of PGA in the java region seen from the map of its spreading of the western part of Java has a PGA value tends to be high compared to the eastern part of Java because in western Java is very close to the subduction region. The results of this research will be compared with The Indonesian National Standard of earthquake map on 2012 which is the results obtained from both models do not get a significant difference value and get the maximum Peak Ground Acceleration value in accordance with the history of the earthquake on the island of Java

4. Conclusion

The distribution of peak ground acceleration (PGA) values by using the Donovan model resulting in maximum land acceleration of 0.127 g at coordinates of 90 LS - 1160 BT and the lowest maximum ground acceleration of 0.0213 g at coordinates of 5,500 LS - 1050 BT and the distribution of peak ground acceleration (PGA) values by using the Campbell model resulting in maximum land acceleration of 0.0826 g at coordinates of 9^0 SL – 116^0 EL and the lowest maximum ground acceleration of 0.0123 g at coordinates of $5{,}50^0$ SL – 105^0 EL. The results obtained from both models do not get a significant difference value and get the maximum Peak Ground Acceleration value in accordance with the history of the earthquake on the island of Java. The greater the price of horizontal acceleration Maximum movement of the ground hinted that the greater the risk of earthquake on infrastructure On the island of Java.

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