Comparing the Mapping of Peak Ground Acceleration (PGA) Using Donovan And Campbell Methods In Java Island

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ABSTRACT

Java, the one big Island of Indonesia is located among three major active plates namely Pacific, Indo-Australia, and Eurasia. There is subduction zone in the Southern of Java caused by collition of Indo-Australia and Eurasia. This cause high tectonic activity and so many earthquakes occurs all the time. The ground movement caused by these earthquakes has some parameters one of the most popular is Peak Ground Acceleration (PGA). The PGA value always vary every new earthquake occurs. This PGA value could be measured by accelerometer or calculated by earthquake catalog. This research was conducted to compare two models of Peak Ground Acceleration (PGA), *Donovan* and *Campbell.* These models based on 50-years of catalog earthquakes event in period 1965 – 2015 on Java with Magnitude ≥ 5 SR and the hypocenter ≤ 80 km. The Donovan method resulting in maximum land acceleration of 0.127 g at coordinates of 9^0 SL – 116^0 EL and the lowest maximum ground acceleration of 0.0213 g at coordinates of $5{,}50^0$ SL - 105^0 EL and the Campbell method 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 of this research will be compared with The Indonesian National Standard of earthquake map on 2012 which is the results obtained from both methods 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.

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I. INTRODUCTION

Indonesia is an earthquake-prone area because it is located at a meeting of three plates. This condition makes the Indonesian island has a high risk of earthquake disposal. Activity of the movement of these plates will certainly lead to changes in geological structure at the boundaries of plate meetings depending on the type of meeting between the plates, can be earthquakes, volcanoes, the formation of mountains, folds and fractures. The Java subduction system is formed by subduction of oceanic plates under continental plates. While the island of Java is one of the areas that the pace of construction is very rapid. Therefore, the framework of the implementation of Java island development need to pay attention to the risks caused by the earthquake. In the event of an earthquake, one of the effects caused in a place is the acceleration of the soil on the surface so as to overthrow the sturdy building. The distribution of PGA can be used as a reference in the basis of building earthquake resistant building by knowing which areas are vulnerable to earthquakes. On that basis we are doing PGA research to know the maximum horizontal acceleration value of ground motion caused by earthquake vibration. By knowing the value distribution by comparison of Donovan and Campbell method so that it can be used to do development planning based on the level of risk caused by earthquake.

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 [1].

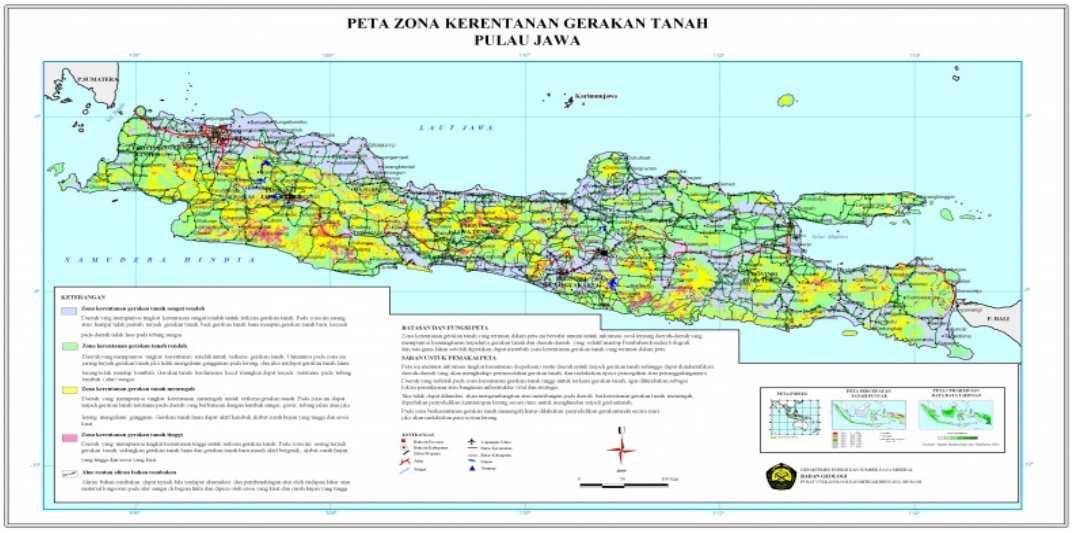

Figure 1. Map of Peak Ground Acceleration in Java Island (Badan of Geology, 2015)

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 [2].

Epicenter is a point on the surface of the earth that is drawn perpendicular from the center of the occurrence of earthquakes (hypocenter). In the calculation of the intensity and acceleration of the land distance parameters used between the epicenter to the point of observation (observation). There are several reference points (Abrahamson and Shedlock, 1997), some of which use epicenter points (distance: = R), earthquake focus point (distance = R_h), point closest to site (distance = R_c) and point [3].

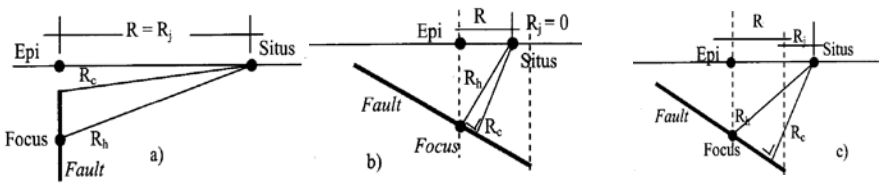

Figure 2. Types of Focus to Situs (Abrahamson & Shedlock, 1997)
Hypocenter (R) Formula :

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

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.

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

$M_S = (\frac{M_w}{1{,}1}) - 0{,}64$ (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]

Campbell (1981) conducted a study of earthquake acceleration attenuation based on the occurrence of shallow crustal inter-plate earthquakes. Primarily occurring on the west coast of USA, with an earthquake depth of <25 km. The quake observed is the earthquakes that are relatively close to the source (near source). Is an epicenter distance range 30 - 50 km. A number of earthquake data from various countries (world wide) is used as a study material. Campbell (1981) considers that although some of the data came from outside the USA are earthquakes along the plate boundaries (in the subduction zone area), but in general the conditions are somewhat similar to the intraplate earthquakes occurring on the west coast of USA.

Given the nature of the earthquake wave propagation in different from the shallow earthquakes, then once again this attenuation only applies to shallow earthquakes.

The attenuation model proposed by Campbell (1981) is in the form,

$PGA = a.e^{b.M} . (Rc + c.M)^{-d}$ (4)

Based on the data done regression gradually then the attenuation equation proposed is (tend to rock-site)

Campbell's equation (1981) :

$PGA_C = 0{,}0159. E^{0{,}868\ .\ M} . (R_C + 0{,}0606 . e^{0{,}70\ .\ M})^{-1{,}09}$ (5)

with PGA is the maximum ground acceleration (Peak Ground Acceleration) in gravity acceleration (g), Rc is the closest distance from epicenter to fault and Ms is surface magnitude [6].

Donovan's equation (1973) :

$PGA_D = 1080 (exp^{0.5\ M}). (R + 25)^{-1.35}$ (6)

2. RESEARCH METHOD

Figure 3. Flowchart in conducting PGA research using the Donovan and Campbell methods. Data which is historical data of earthquake in USGS period 1965 - 2015 with area limit $5^0$50 SL – 9^0 SL and 105^0 EL – 116^0 EL. Magnitude taken ≥ 5 SR and depth ≤ 80 km. Software used in Microsoft Excel, surfer 9, and ArcGIS 10.2 data processing.

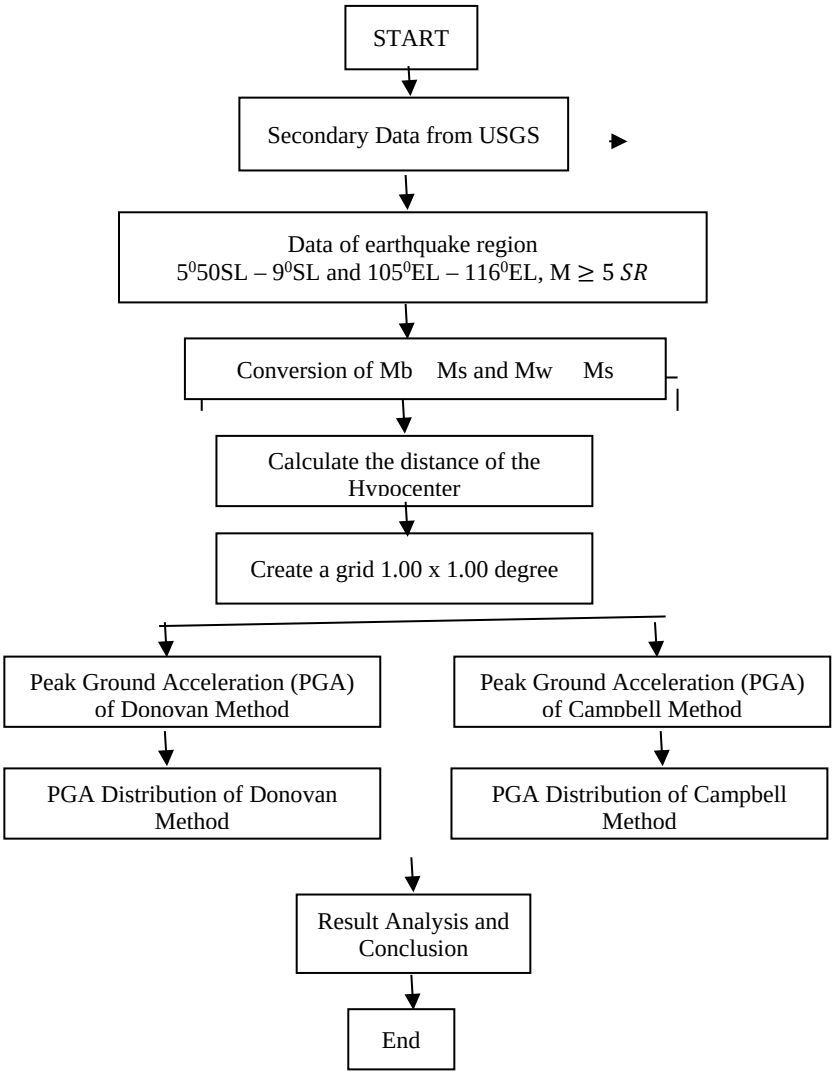

Figure 3. Flowchart of Research method

3. RESULTS AND ANALYSIS

From calculation data of PGA value with both method of Donovan and Campbell 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 Java region

Figure 4 shows the distribution of peak ground acceleration (PGA) values by using the Donovan method resulting in maximum land acceleration of 0.127 g at coordinates of 9^0 SL – 116^0 EL and the lowest maximum ground acceleration of 0.0213 g at coordinates of $5{,}50^0$ SL - 105^0 EL.

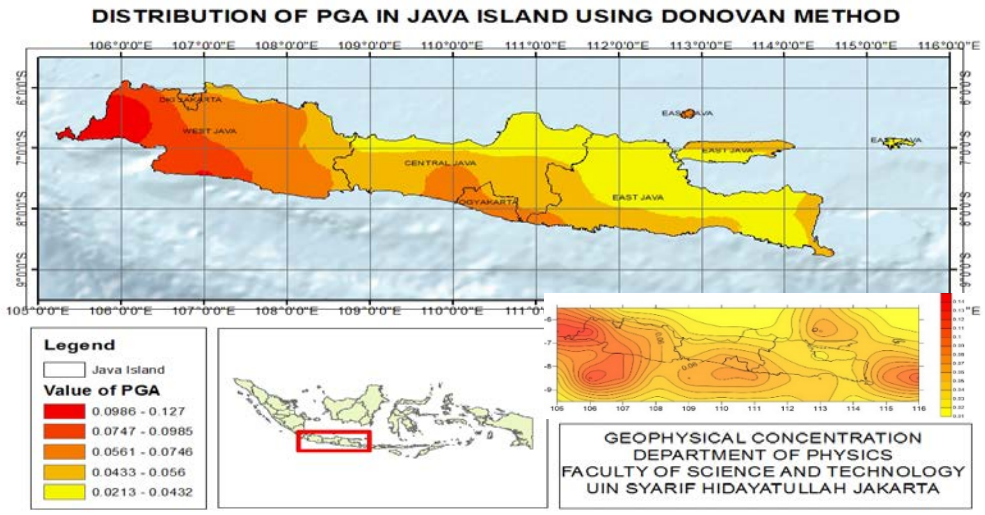

Figure 4. Distribution of Donovan method

Figure 5 shows the distribution of peak ground acceleration (PGA) values by using the Campbell method 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.

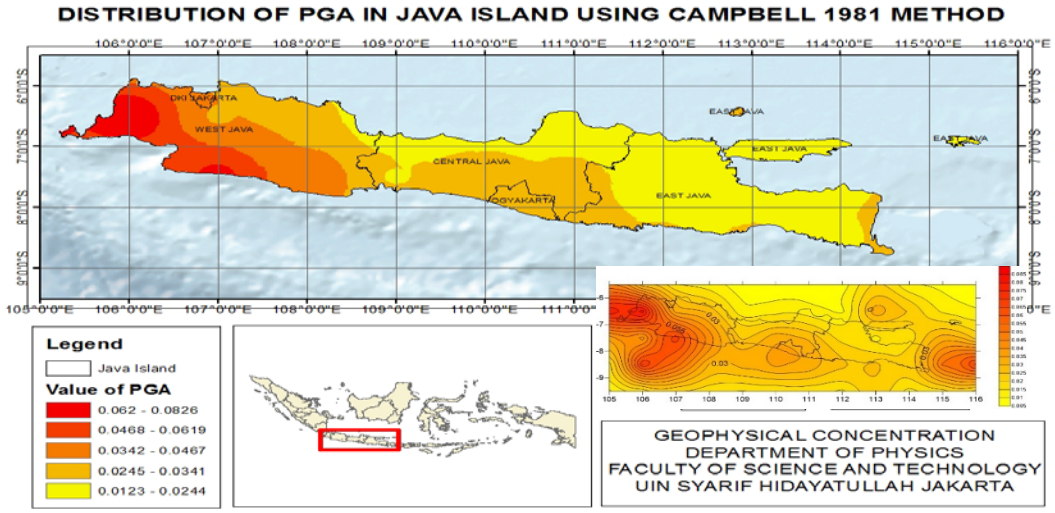

Figure. 5 Peak Ground Acceleration distribution of Campbell method

From the results obtained using the maximum value of Donovan method that is 0.127 g including class VI with shock rate occurs strong earthquake and potential damage to light. While using the Campbell method the maximum value of 0.0826 g including class V with the shock rate occurs moderate earthquake and very light damage potential. However, both methods 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 methods 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 method 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 method 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 methods 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.

REFERENCES

[1] Rika Mayasyafa, Adi Susilo, Ph.D, Wasis, M.AB. Analisis Terhadap Percepatan Tanah Maksimum Gempabumi Provinsi Jawa Timur dengan Metode Mc. Guirre R.K. Jurusan Fisika, FMIPA. Universitas Barwijaya.
[2] Hays, W, Walter. Procedures for Estimating Earthquake Ground Motions. Geological Survey Professional Paper 1114. US Government Printing Office : Washington, 1980. 28 p.
[3] Widodo, P. Seismologi Teknik & Rekayasa Kegempaan. Guru Besar Jurusan Teknik Sipil & Manajemen Rekayasa Kegempaan (MaRK). Universitas Islam Indonesia . Yogyakarta, 2012. 330 p.
[4] Suharno. Nilai Percepatan Maksimum Gerakan Tanah Daerah Jawa Bagian Barat. Jurnal Sains dan Teknologi, Desember 2006. Vol 12, No. 3, Hal :167 – 172.
[5] Correlation with the Mercalli Scale. The United States Geological Survey Developed. (https://en.wikipedia.org/wiki/Peak_ground_acceleration, access on 24 August 2017)
[6] Widodo, P. Seismologi Teknik & Rekayasa Kegempaan. Guru Besar Jurusan Teknik Sipil & Manajemen Rekayasa Kegempaan (MaRK). Universitas Islam Indonesia . Yogyakarta, 2012. 335 p