Analysis of the Value of Maximum Ground Acceleration in Earthquake Disaster Mitigation Efforts on the Lan

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Abstract. The Aceh region itself has a location that is within the scope of the Sumatran fault, areas on active faults can experience a high possibility of earthquakes. Earthquake epicenters on the mainland can occur due to shifts in the Sumatran fault which is indicated by the number of earthquakes along the fault and generally has shallow depths. The research was conducted to determine the value of the earthquake acceleration on the ground around the East Aceh Alue Genteng bridge. The results of this study found that the magnitude of the earthquake can affect the level of acceleration of the earthquake that occurs, the acceleration of the earthquake increases with the magnitude of the earthquake. Based on the results of calculating the acceleration of the earthquake using magnitude 7, 5 SR-9.3 SR, the earthquake acceleration occurred significantly and continues to increase. Earthquake acceleration data is one of the important data that can be used in earthquake mitigation such as in planning strong building structures that are able to withstand loads caused by earthquakes.

1 Introduction

Indonesia is an archipelagic country that has various potential natural disasters, one of which is an earthquake. Indonesian archipelago has a great risk of earthquakes, where 80% of Indonesia's territory is located in high-risk seismic areas in the world. This is due to the location of Indonesia which is surrounded by 3 large plates namely the Indo-Australian plate, the Eurasian plate and the Pacific plate. One of the islands that often experiences earthquakes is the island of Sumatra [1]. Sumatra Island is one of the areas located in an active plate zone so it has a high frequency of earthquakes. Subduction zones and faults are very active earthquake triggers. The earthquakes that occurred were not only sourced from subduction zone activity, but also from active fault systems along the island of Sumatra [2].
Aceh Province is one of the earthquake-prone areas because it is in the confluence of two very active tectonic plates, namely the Indo-Australian oceanic plate and the Eurasian plate [3]. On December 24, 2004 Aceh experienced an earthquake. The earthquake in Aceh had a magnitude of 9.3 according to the Richter scale and resulted in a tsunami throughout the Indian Ocean [4].

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Earthquakes are a symptom that often occurs in Indonesia and have a major impact on structural buildings. The longer the return period of an earthquake, the greater the effect of the earthquake on the building structure and the earthquake load that must be taken into account. Seeing Indonesia's condition which is prone to disasters, it is necessary to understand the disasters that occur, especially in the construction sector such as bridge construction. The development carried out must be in accordance with proper planning, implementation and supervision in order to produce construction that takes into account disaster factors. So if a disaster occurs and causes casualties and damage to infrastructure, the losses that occur are not too large [5].

Earthquake shocks will have an effect on the surrounding land, the effects can occur in various ways, such as shifting of the ground which impacts on the buildings above it, liquefaction, and other things. Earthquakes often occur even without any predictions though, the waves generated by earthquakes in the ground are scattered in various directions so that the effects of earthquakes are quite extensive, the waves that occur in the ground provide great movement to the surface. Areas that are in the epicenter area of the earthquake have a higher risk of the impact of the earthquake, so in building a building it is necessary to calculate the load from the earthquake disaster to be able to mitigate things that will impact the area [6]. Every earthquake incident produces seismic waves which will cause a ground acceleration value somewhere.

The size of the ground acceleration value is one of the parameters that can indicate the level of earthquake risk which must be taken into account as a part of planning earthquake resistant buildings. Maximum ground acceleration or Peak Ground Acceleration (PGA) is the largest value of ground acceleration at a place caused by earthquake vibrations in a certain period of time. PGA data due to earthquake vibrations at a location illustrates the level of earthquake risk at that location. The greater the PGA value that occurs somewhere, the greater the risk of an earthquake that might occur. The ground acceleration value to be calculated is the maximum ground acceleration value. The primary effect of an earthquake is damage to building structures, including buildings, public housing, public facilities, bridges and other infrastructure, caused by the vibrations they cause. Broadly speaking, the level of damage that may occur depends on the strength and quality of the building, the geological conditions of the area, the geotectonics of the building site, and the ground acceleration at the building site due to the vibrations of an earthquake.

To be able to mitigate this, a plan is needed when a construction will be carried out. The most basic planning is to ensure the strength of the soil that will accommodate the load on it is of good quality, so that the construction can survive and the soil can accept the load that is distributed properly. Areas that are in the epicenter area of the earthquake have a higher risk of the impact of the earthquake, so in building a construction it is necessary to calculate the load from the earthquake disaster to be able to mitigate things that will impact the area.[7].

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The Aceh region itself has a location that is within the scope of the Sumatran fault, one of the segments that is connected to the Sumatran fault is the Sumatran fault. This fault is very close to the research location, namely in the Peureulak area. In this study a review was conducted at the quarry land location to determine the acceleration of the earthquake that occurred on the land which has a sufficient distance to the Sumatran fault.

2 Methodology

This research was carried out by direct observation in the field, looking at conditions and taking research location points in the form of coordinates so that the research location to the distance of the Sumatra fault can be known.
This determination is made by studying the earthquake data that occurred and calculating the acceleration of the ground at the research location towards the earthquake source. This study was carried out using the magnitude of the earthquake and the distance of the hypostrum from the earthquake source to the testing ground location. The earthquake acceleration and earthquake magnitude have the following empirical relationship [8]:
Based on the results of earthquake acceleration data in Papua New Guinea, Japan, the United States, (Donovan, 1974) states the relationship as follows [9]:

$$a = (\text{Donovan, 1970})\frac{1080\, e^{0,5\, M}}{(d+25)^{1,52}} \tag{1}$$

$$a = (\text{Donovan, 1972})\frac{1320\, e^{0,58\, M}}{(d+25)^{1,52}} \tag{2}$$

According to the formula developed by Estevan based on the formula of AJ Hendron Jr. (Newmark, 1968). for hard soil is:

$$a = \frac{1230\, e^{0,8\, M}}{(d+25)^{2}} \tag{3}$$

Kawashumi namely with the following equation:

$$\log a = M–5.45–0.00084\ (d –100)+\log(100/d)*(1/0.43429) \tag{4}$$

Where:
M = earthquake magnitude (Richter Scale);
a = acceleration of the earthquake at ground level (m/s2);
d = distance of the hypocenter from the earthquake source (km);
e = Napier logarithm number (2.718281).

The hypocenter distance (d) from the epicenter is obtained using the Pythagorean formula by entering the depth of the earthquake (D) and the horizontal distance (R) from the epicenter of the earthquake as shown in Figure 1. The horizontal distance (R) is obtained by entering the coordinates of the epicenter and the coordinates of O (object), the horizontal distance is calculated by the following equation:

$$R=\sqrt{((\phi E-\phi S))^2+((LE-LS))^2} \tag{5}$$

Where:
ϕE = epicenter longitude coordinates (o);
ϕS = object longitude coordinates (o);
LE = epicenter latitude coordinate (o); And
LS = object latitude coordinate (o);

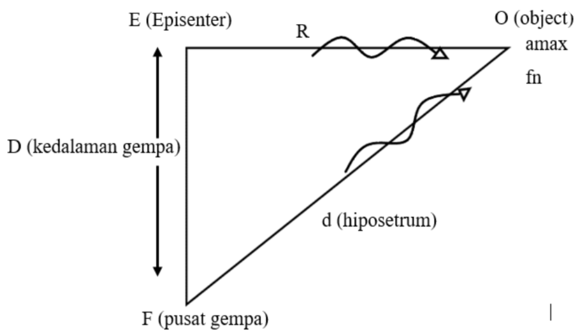

Fig. 1. Illustration of Horizontal Distance from Earthquake Center
Source: Das (1983)

3 Result and Discussion

In this calculation, researchers used the earthquake source from the Sumatran fault with an applied magnitude of 7.5 to 9.3 SR and a depth of 28 km; This data is in the form of data obtained from Columbia (2017) which says that the highest earthquake that ever occurred was on the Sumatran fault, which was 9.3 on the Richter scale with a depth of 28 km, the magnitude value was also used based on the value of the earthquake that had occurred in the Aceh area with the Sumatran fault source. as a comparison value.

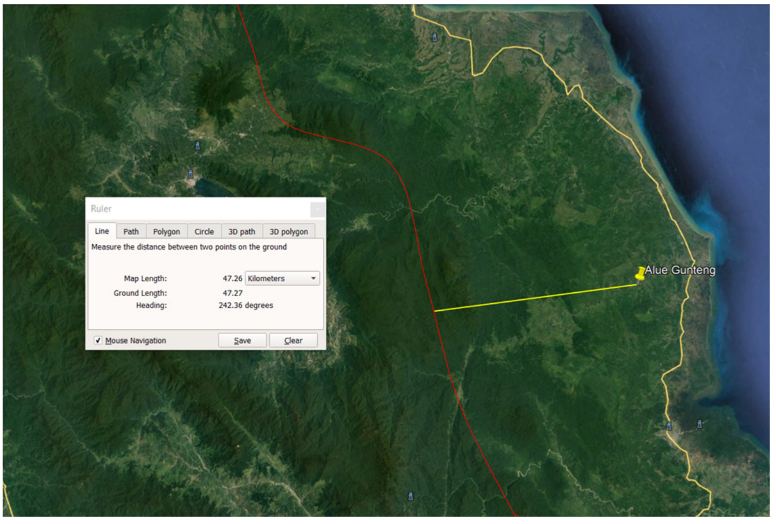

Fig. 2. Illustration of the distance of the earthquake point to the research location

The fault closest to the location of the research was carried out in the Peureulak road segment, namely the Sumatran Fault segment. With the existence of the Sumatran fault which is the closest fault location to Peureulak, the research location is assumed to be the place where construction was established and calculations are carried out by taking the distance perpendicular to the research location from the nearest Sumatran fault point.
To calculate the value of the acceleration of the earthquake that occurs, the value of R is needed, namely the value of the distance of the object and the point on the surface where the earthquake occurred. For this reason, the value of R is calculated using the following formula:

$\mathrm{R} = \sqrt{(\phi\mathrm{E} - \phi\mathrm{S})^2 + (\mathrm{LE} - \mathrm{LS})^2}$
$R = \sqrt{(5{,}583 - 5{,}544)^2 + (95{,}902 - 95{,}321)^2}$
$\mathrm{R} = 0{,}032807005$

1 degree = 111.319888 Km
$\mathrm{R} = 0{,}032807005 \text{ x } 111{,}319888$
$\mathrm{R} = 47{,}26 \text{ Km}$

Calculating the hypostrum distance of the earthquake:
$\mathrm{d} = \sqrt{\mathrm{R}^2 + \mathrm{D}^2}$
$\mathrm{d} = \sqrt{46{,}19^2 + 28^2}$
$\mathrm{d} = 54{,}01\mathrm{km}$

The acceleration of the earthquake and the magnitude of the earthquake have the following empirical relationship:

1. Based on the results of earthquake acceleration data in Papua New Guinea, Japan, the United States, Donovan stated the relationship as follows:
   a = (Donovan, 1970)$\frac{1080\ e^{0,5\ M}}{(d+25)^{1,52}}$
   a =$\frac{1080\ (2{,}71828183)^{0,5\ x\ 7,5}}{(54{,}01+25)^{1,52}}$
   a = 0.00014 gal
   a = (Donovan, 1972)$\frac{1320\ e^{0,58\ M}}{(d+25)^{1,52}}$
   a =$\frac{1320\ (2{,}71828183)^{0,58\ x\ 7,5}}{(54{,}01+25)^{1,52}}$
   a = 0.00034 gal

2. Newmark as follows:
   a =$\frac{1230\ e^{0,8\ M}}{(d+25)^2}$
   a =$\frac{1230\ (2{,}71828183)^{0,8\ x\ 7,5}}{(54{,}01+25)^2}$
   a = 0.00008 gal

3. Kawashumi as follows:
   log a = M – 5.45 – 0.00084(d –100)+log(100/d)*(1/0.43429)
   log a = 6.5 – 5.45 – 0.00084 (54.01 –100)+log(100/54.01)*(1/0.43429)
   a = 0.00052 gal

Table 1. The value of the acceleration of the earthquake against the soil of the Peureulak road section

No	Depth (km)	Magnitude	d (Km)	a-max (g)			
				Donovan	Donovan (a*2,5)	Newmark	Kawashumi
1	28	9,3	54,015	0.00039	0.00097	0.00034	0.03257
2	28	9,2	54,015	0.00036	0.00091	0.00032	0.02587
3	28	9,1	54,015	0.00034	0.00086	0.00029	0.02055
4	28	9.0	54,015	0.00032	0.00081	0.00027	0.01633
5	28	8,9	54,015	0.00031	0.00077	0.00025	0.01297

No	Depth (km)	Magnitude	d (Km)	a-max (g)			
				Donovan	Donovan (a*2,5)	Newmark	Kawashumi
6	28	8,8	54,015	0.00029	0.00072	0.00023	0.01030
7	28	8,7	54,015	0.00027	0.00068	0.00021	0.00818
8	28	8,6	54,015	0.00026	0.00064	0.00020	0.00650
9	28	8,5	54,015	0.00024	0.00061	0.00018	0.00516
10	28	8,4	54,015	0.00023	0.00057	0.00017	0.00410
11	28	8,3	54,015	0.00022	0.00054	0.00015	0.00326
12	28	8,2	54,015	0.00020	0.00051	0.00014	0.00259
13	28	8,1	54,015	0.00019	0.00048	0.00013	0.00206
14	28	8.0	54,015	0.00018	0.00045	0.00012	0.00163
15	28	7,9	54,015	0.00017	0.00043	0.00011	0.00130
16	28	7,8	54,015	0.00016	0.00040	0.00010	0.00103
17	28	7,7	54,015	0.00015	0.00038	0.00010	0.00082
18	28	7,6	54,015	0.00014	0.00036	0.00009	0.00065
19	28	7,5	54,015	0.00014	0.00034	0.00008	0.00052

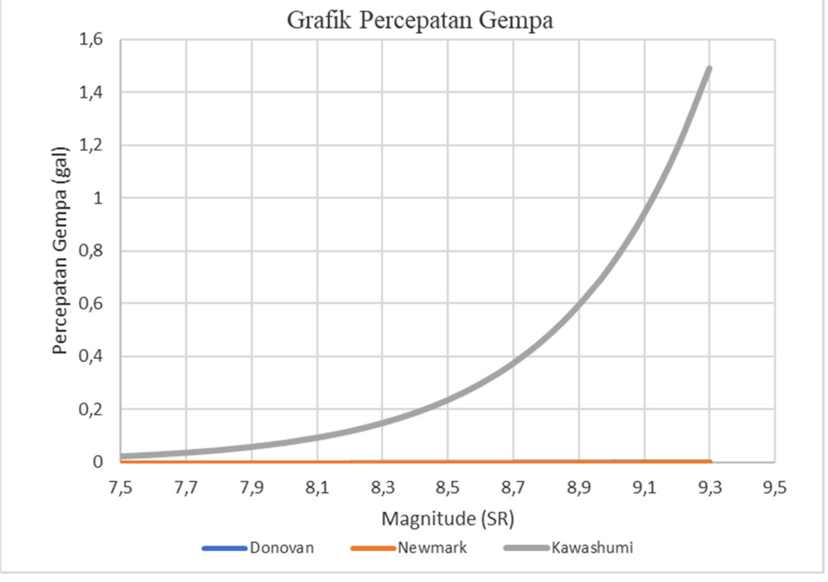

Fig. 3. Graph of the relationship between earthquake acceleration and magnitude

From the calculation results it can be seen that the greater the magnitude value or the amount of energy released when an earthquake occurs, the greater the resulting acceleration so that the speed of the earthquake wave propagation increases.

Maximum acceleration data is very important in earthquake disaster mitigation because it can be used to determine the level of vulnerability of an area to earthquakes, map earthquake hazard, and calculate the strength and stability of buildings when an earthquake occurs. Several ways to mitigate the impact of earthquakes by utilizing ground acceleration data include:

1. Determination of the maximum ground acceleration value in an area by utilizing microtremor, seismicity, and geology measurement data.
2. Earthquake risk analysis to determine the level of vulnerability of an area to earthquakes.
3. Earthquake hazard mapping using ground vibration acceleration data.
4. Building structure planning taking into account ground acceleration data at that location to ensure the strength and stability of the building during an earthquake. By knowing the relationship between the amount of earthquake energy and the acceleration and propagation of earthquake waves, this data can be used in planning earthquake-resistant buildings. Engineers and architects can use this data to design building structures that can withstand earthquake shocks more effectively, thereby reducing the risk of damage and loss caused by earthquakes.
5. Selection of building locations that are safe from earthquakes by considering ground acceleration data in the area.
6. This data can also be used in earthquake zoning, namely the division of areas based on the level of risk of an earthquake that might occur. By understanding the relationship between the magnitude of earthquake energy and the acceleration and propagation of earthquake waves, the government and geologists can identify areas that have the potential to experience high magnitude earthquakes. This information can be used to regulate development in these areas, such as limiting the construction of tall buildings or tightening building standards.
7. This data can also be used in the development of an earthquake early warning system. By understanding the relationship between the magnitude of earthquake energy and the acceleration and propagation of earthquake waves, scientists and researchers can develop models and algorithms to detect and predict earthquakes more accurately. An effective early warning system can provide warnings before an earthquake occurs, thereby enabling early mitigation and evacuation measures to be taken, which can reduce the risk to life and damage.

By paying attention to these factors, we can mitigate the impact of earthquakes and ensure building safety and human safety.

4 Conslusion

From the calculation results it can be seen that the greater the magnitude value or the amount of energy released when an earthquake occurs, the greater the resulting acceleration so that the speed of the earthquake wave propagation increases. From the results it can be seen that at an earthquake strength of 7.5 on the Richter scale, the earthquake acceleration value results with the Donovan formula of 0.00064 gal, with the Newmark formula of 0.00018 gal and Kawashumi of 0.00236 gal.

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