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By Hita Pandita

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Characteristics of Collapse Time of Earthquake Source Rock As One Parameter to Prediction the Earthquake in Yogyakarta Region

Hita Pandita[1)], Sukartono[2)] and Agustinus Isjudarto[3)]
Department of Geology, Sekolah Tinggi Teknologi Nasional, Yogyakarta, e-mail: hita@indo.net.id
Department of Geology, Sekolah Tinggi Teknologi Nasional, Yogyakarta, e-mail: kartono_skt@yahoo.co.id
Department of Mining Engineering, Sekolah Tinggi Teknologi Nasional, Yogyakarta, e-mail: is_darto@yahoo.com

Abstract

Indonesia is a country with high potential to get an earthquake, one of them is Yogyakarta and surrounding areas. Although earthquake attack in Yogyakarta area have been several times, efforts to reduce the number of victims is dificult to do. It's cause the absence of parameters that can be used to estimate the arrival time of the earthquake. One of the parameters that may be used is predicted when a fault will move on, using an earthquake if get an increase of pressure constantly. This study aimed to find out when a rock will collapse if it get a varied pressures, so it can get a collapse rock time formula. If the formula is known, it can be modeled to the load received a fracture for understand when the fracture will move on. The research method used is a field investigation, and rocks compressive strength test. By using the test six variations of loading finally made it known pattern of the outbreak of the rock. Formulation successfully arranged by using four models of the curve, namely: linear, logarithmic, exponential and quadratic functions (power). Three types of rocks have been tested, and the results show the most likely around earthquake source rocks around Opak fault is a diorite rock, since the outbreak of this rock closest to the timeframe of seismicity induced by Opak fault.

Kata kunci: Prediction, Earthquake, Strength test, Time, Opak fault

INTRODUCTION

Yogyakarta is an area with high potential earthquake. A number of large magnitude earthquake hit the region like in 1867 and 2006 [1]. Damage and casualties from those earthquake is very large. The large number of souls who drift and loss of property caused by the lack of accurate predictions about when an earthquake will occur.

According from many geologist, most of the earthquake is cause by sudden release of strain energy that has built up over a period of time [2]. The pressure on the earth's crust in the earthquake areas are generally caused by the collision between two or more plates or continents and oceans. Based on the theory of occurrence of the earthquake, then the expected arrival of an earthquake in a region can be estimated from the time exceeding of the durability of rocks in the earth's crust. So understanding the durability of the rocks in the earth's crust will be able to help improve the accuracy of prediction of the earthquake in the region.

This study aimed to find out when a rock will collapse if it get a varied pressures, so it can get a collapse rock time formula. If the formula is understand, it can be modeled to the load received a fracture for understand when the fracture will move on. The research object is rocks which predicted as earthquake source around Opak Fault in Yogyakarta area. The choice of Opak Fault becaused many great earthquake occurred around this fault [1].

METHOD

The method used in this research is the field survey, stratigraphic analysis and compressive strength test. Field survey carried out in the Southern Mountain to determine the thickness of sedimentary rocks and understanding of earthquake source rock. The field investigation also taken rock samples were estimated as earthquake source rocks. Laboratory investigations carried out in the form of uniaxial compressive strength test of the earthquake source rocks.

REGIONAL GEOLOGY

The research areas included in border between the Southern Mountains of East Java Zone and Yogyakarta Depression (van Bemmelen, 1949) [3]. The boundary between these two physiographic zones by some

researchers suspected a Northeast-Southwest Fault known as the Opak Fault (Rahardjo, et al, 1995) [4]. Depression Yogyakarta is a lowland filled by deposition of volcanic activity of Merapi. Southern Mountains of East Java is a high land stretches from the eastern part of Yogyakarta to the southeastern tip of the island of Java.

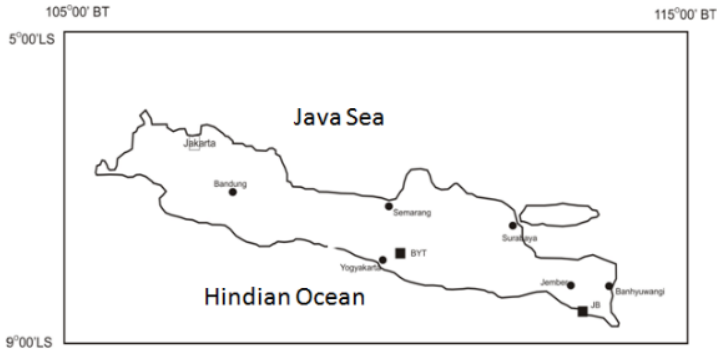
Regional stratigraphy research area has been reviewed by several researchers such as Rahardjo, et al (1995) [4], Surono, et al. (1992) [5] and van Bemmelen (1949) [3]. The thickness of sedimentary rocks in the Southern Alps is estimated at more than 5,000 m (Pandita & Sukartono, 2014) [6], the bedrock is estimated to be Cretaceous metamorphic complex. Unconformity at top of the bedrock deposited Limestone Formation-Wungkal Eocene. Series of volcanic deposits began to appear at Kebo-Butak Formation begins at Olgosen (Surono, 2008) [7]. Then sequentially formed Semilir Formation and Formation Nglanggran the Early Miocene to Middle Miocene. In the early Late Miocene volcanic series is gradualy being replaced by a series of carbonate rocks, beginning by Sambipitu Formation and ending by Formation Kepek (Pandita, et al, 2014) [6].

RESULT

Material And Location

Sampling locations for compressive strength test selected based on the type of rock to be tested. Sampling in the form of surface samples from some rocks that are suspected as earthquake source rocks. Pandita, et al. (2014) [6] and Prasetyadi (2007) [8] based on stratigraphic studies predict that the bedrock of the Southern Mountains are metamorphic complex. Santosa (2014) [9] is based on the gravity study estimated bedrock Southern Mountains is characterized like diorite rocks. Sribudiyani, et al. (2003) [10] and Smyth, et al (2007) [11] estimates that the bedrock of East Java is the continental crust.

Based on the study of the researchers mentioned above, then there are three possible earthquake source rocks around Opak fault, namely the continental crust rocks (granite), metamorphic complex and diorite. According to these, there were three locations selected for sampling. Two locations of the Bayat region, namely in the Pendul hill (BYT14) and Jokotuo (BYT10), whereas one location area Rajegwesi, Jember (Figure 1). At BYT10 of samples taken in the form of marble rocks of the complex metamorf Bayat. At BYT14 samples taken form of diorite rock. Location Rajegwesi an analog samples of the continental crust in the form of dacite rock.



Gambar 1. Samples location, BYT = Bayat, dan JB = Jember

Uniaxial Test

Three rocks prepared for uniaxial test, with each rock type was prepared in six different loading. Samples were prepared in the size of 5x5x5 cm appropriate standard test ISO 2825: 2008 [12]. Tests carried out at the Laboratory of Materials and Construction Engineering at the Faculty of Civil Engineering UII Yogyakarta. Condition of the sample in a dry state. Compressive strength testing is done with six different loading speeds, namely: 1 kN/s, 2 kN/s, 3 kN/s, 4 kN/s, 5 kN/s and 6 kN/s. Full results of the compressive strength test can be seen in Table 1.

Table 1. Result of uniaxial test from three rocks

Rock Sample	Wide (cm^2)	v (KN/s)	t (second)	σca (Mpa)
Diorit	19.78	1	416.41	77553.08
	26.46	2	116.19	86545.73
	28.05	3	90.3	58823.53
	24.96	4	110.25	66426.28
	23.04	5	107	65190.97
	27.03	6	37.14	73251.94
Marble	26.5	1	810.06	92150.94
	29.16	2	271.67	62825.79
	27.03	3	110.53	45024.05
	28.08	4	63.85	76210.83
	28.08	5	79.69	87500.00
	28.62	6	36.54	99510.83
Dacite	27.04	1	2009	176516.27
	26.5	2	218	104905.66
	25	3	92	72000.00
	26.5	4	87	135471.70
	26.5	5	71	131698.11
	30.24	6	59	161210.32

Analysis

Data processing was performed using Excel 2007 program to get formula using Power curve (quadratic function). Power curve (quadratic function) is the best results were obtained through a series of processing from the other curves (Figure 2). The curve shows the X-axis as speed of loading in kN/sec, the Y axis is the collapse time of the rocks in a seconds.

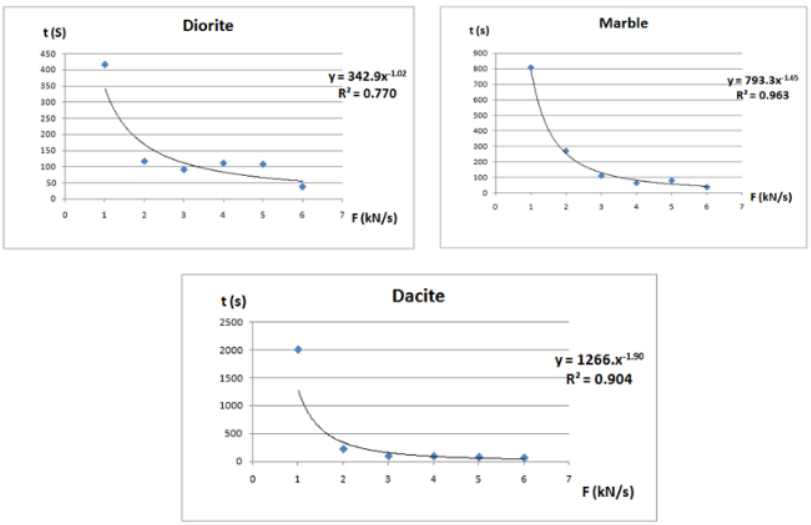


Figure 2. Quadratic function curve relationship between variations in the speed of load with the broken times of rocks results from processing using Excel program.

Based on the power curve (quadratic function) obtained formula the relationship between speed of loading with the collapse time of the rock. The formula are (Fig. 2):

Marble: $y = 793.3x^{-1.65}$ .....1)

Dacite: $y = 1266.x^{-1.90}$ .....2)

Diorite: $y = 342.9.x^{-1.02}$ .....3)

Because x represents the magnitude of loading, whereas the compressive strength test loading has notation v, then a notation "x" changed to "v". Likewise with "y" which is the time, and in a general sense the notation is "t", so the notation "y" replaced with "". Thus the formula can be changed to:

Marble: $t = 793.3v^{-1.65}$ ……..4)

Batuan Dasit: $t = 1266.v^{-1.90}$ ……..5)

Batuan Diorit: $t = 342.9.v^{-1.02}$ ……..6)

DISCUSSION

Force of Collision

Until now there has been no study that calculates the magnitude of the force or load that occurs as a result of plate collision in the southern island of Java. To get these formulations then were calculated theoretically based on the general character of the type and speed of plate. Calculation of two types, namely the imposition of macro and micro load. The macro loading according to its natural condition based on area of collision in the plane of Opak fault. Imposition of a micro is simulation if the size of the collision area corresponding scale of laboratory test. For the calculation required data of the volume of plate, speed of plate movement and density.

On a macro scale counting the length of the plate is calculated from the collision point to the spreading point, based on a calculation from the Google Earth obtained 2790.97 km. Width has calculated from the collision area with the Opak fault, ie 21.35 km. The thickness is calculated based on the average thickness of the oceanic plates, which is 5 km. The final result of the volume can be seen in Table 2.

Table 2. The results of the theoretical calculation of geometry and its burden on the Indo-Australian plate movement against geometry of Opak fault.

Scale	Macro	Micro
Volume (km^3)	297980.1944	0.000007
Density (g/cm^3)	3.3	3.3
Weight (gr)	9.8×10^{17}	2,302,555,025
Speed (cm/year)	6	6
Speed (cm/sec)	2.22×10^{-7}	2.22×10^{-7}
Load (kN/sec)	1870.9	4.38×10^{-5}

Calculation of macro-scale load can be calculated by knowing the average speed of the Indo-Australian by 6 cm / yr (Whittaker et al., 2007) [13] or 1.9 x10-7 cm/sec. By using an average density oceanic plates 3.3 gr/cm^3. It can be seen from the plate macro load of 1870.9 kN/sec.

Because in this study did not test the sample size variable, then the load on a macro scale can not be used to calculate the time of rupture of rocks. In this connection it is necessary to micro-scale modeling or calculation in accordance with a surface area in the laboratory tests. On a micro scale modeling of some value on a macro scale still, the only difference being the volume due to changes in the loading area. The final result obtained at the micro scale imposition of 4.38×10^{-5} kN/sec (Table 2).

Earthquake Prediction

Formulas of the collpase time of each rock will use to calculate the earthquake prediction. Calculations performed by a micro scale load, this is due to micro-scale approach the area on a scale laboratory tests. value of v is taken from the amount of pressure that occurs in kN/sec, while t is the time of earthquake prediction searched in seconds.

The result of calculation shows that dacite rock takes more than 7,800 years to get an earthquake, marble rocks need 400 years and diorite rocks need 173 years (Table 3). The study on the history of seismicity around Opak fault, there are two major earthquakes that in 1867 and 2006. This represents an interval of 139 years between the first quake toward the second quake. Based on that show diorite rocks closest to the earthquake time interval. So there is a great possibility the earthquake source rock is diorite rocks.

Table 3. Calculation time prediction of an earthquake on Opak fault of the three types of seismic source rocks.

Rocks	Load (kN/sec)	Prediction Time (t)	
		second	Year
Marble	4.38×10^{-5}	1.2×10^{10}	400.78
Dacite	4.38×10^{-5}	2.42×10^{11}	7861.72
Diorite	4.38×10^{-5}	5.33×10^{9}	173.24

Seeing the time difference between simulation on rock diorite with intervals of earthquake that occurred on Opak fault, it is likely due to several things:

1) Opak Fault is already a weak field, so it does not require loading large when compared with the condition before the fracture.
2) The possibility of an earthquake source rocks have lower resistance values of diorite.
3) There are many assumptions in this study like the volume of the Indo-Australian plate, the density of which is taken from the average value oceanic plate, thus affecting the value of the load.

CONCLUSION

This research is still an early stage in an effort to prediction of earthquake in the future in the Yogyakarta area. However, this study has shown the possibility of the arrival of an earthquake can be expected from collapse time of the earthquake source rocks. This research still needs to be improved, with a variety of other rock samples and also variations in loading time, so that the preparation of the formula becomes more accurate.

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