

Analysis of Physical Vulnerability Assessment Due to 2015 Swarm Earthquake Based on Amplification Zone in Jailolo District

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ABSTRACT

Swarm earthquake in the Jailolo region based on data from the Geophysical Station BMKG Ternate in November 2015, there were 701 event earthquakes. Measurement of the value of physical vulnerability based on amplification factors produces a map of the physical vulnerability of an area by welding, which uses 3 classes, namely low, medium, and high. This information is used as a disaster mitigation effort and becomes a recommendation for regional development spatial planning and earthquake-resistant infrastructure in the Jailolo region. The method used is quantitative descriptive from microtremor data and physical vulnerability assessment. Microtremor measurements using a seismometer TDS-303 type. The physical vulnerability indicators used are the percentage of the built area, the number of buildings, the road network, and the Regulatory chief of BNPB 2012. The result is the level of physical vulnerability in Jailolo District by 28% of villages with a category of high physical vulnerability, the value of soil amplification (A0) in Jailolo District ranged from 4.67 - 50.98. So it can be concluded that the villages that are categorized as high physical vulnerability and high amplification value are the Acango Village with a physical vulnerability index value of 2.6 and an amplification value of 15.26.

Keywords: *physical vulnerability, microtremor, amplification, swarm earthquake*

1. INTRODUCTION

The earthquake phenomenon occurs because of the sudden release of energy from the movement of the earth's plates. The release of energy creates seismic waves that cause vibrations or shocks on the surface of the earth so that humans feel like an earthquake. Earthquakes are classified based on their causes including tectonic earthquakes, volcanic earthquakes, impact earthquakes, collapse earthquakes, and artificial earthquakes. Meanwhile, according to Kiyoo Mogi (1963), based on its type, earthquakes are classified as Type I earthquakes (the emergence of a mainshock) without a fore-shock followed by aftershocks with a decreasing force and frequency of occurrence), Type II earthquakes (emergence of earthquakes beginning with a preceding earthquake (fore-shock) before a major earthquake occurs followed by many aftershocks with the strength and frequency of events that continue to decrease), and Type III earthquakes (a series of small magnetic earthquake activities with very high frequency of occurrence, lasts for a long time in an area, without a strong earthquake as the main earthquake). Type III earthquake activity is usually referred to as a swarm earthquake. Swarm earthquake activities that occur in West Halmahera can be seen in Figure 1.

Swarm earthquake activities that occur in the Jailolo region are influenced by the movement of several other main and small plates, namely the Pacific plate, Eurasian plate, Indo-Australian plate, Philippine plate, Maluku Sea plate, Sangei plate, and Halmahera plate. As a result of the movement of the plate, the Jailolo area is included in the subduction path and active faults and forms a row of volcanoes that stretch from the town of Jailolo in the South to the town of Galela in the North. Earthquakes that occur in the Jailolo region are Type III earthquakes, namely, swarm earthquakes. Based on data obtained from Ternate Geophysical Station data for earthquake swarm in 2015 in November, the Jailolo region has experienced 701 earthquakes. Earthquake swarm has happened a lot in Indonesia but has not been well documented and comprehensive.

The vibrations produced from swarm earthquakes that reach the surface usually cause damage to buildings on the earth's surface. The earthquake center is in shallow depth with magnitude < 5 SR in the Jailolo region forming a cluster concentrated on Mount Jailolo, in the village of Bobanehena. Where Bobanehena Village is the area that has the most severe damage due to earthquake swarms.

Jailolo is a type of stratovolcano that has not erupted for a long time. Based on data (BNPB, 2015), the Jailolo region was heavily affected by the swarm earthquake that occurred in 2015, although there were no fatalities the damage caused by this disaster reached 1,593 damaged housing units, of which 145 houses were severely damaged, 273 damaged medium, and 1,175 slightly damaged. In addition, it also damaged 2 schools, 8 worship facilities, and 3 regional government offices. This earthquake greatly disrupted the activity and caused public unrest.

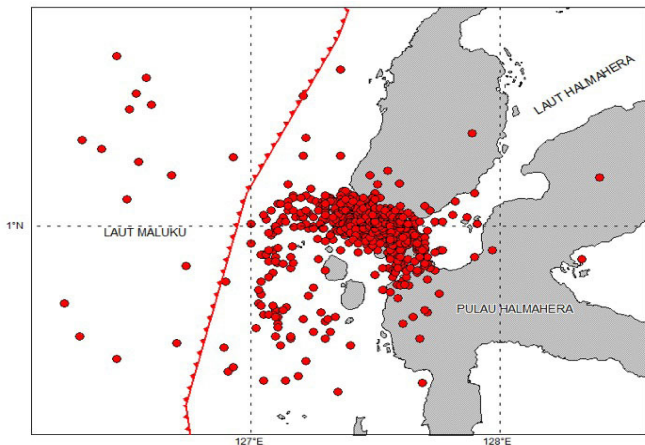


Figure 1. The epicenter of Jailolo Swarm Earthquake (Source: BMKG, 2015)

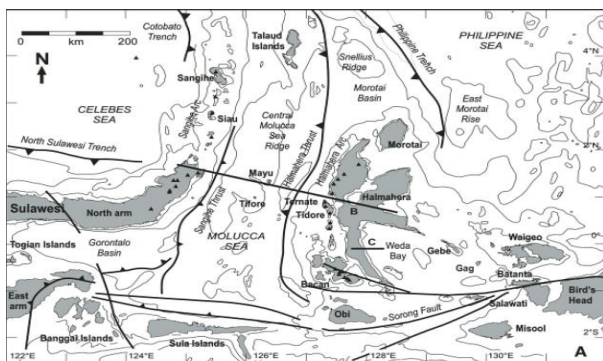


Figure 2. Description of the Tectonic Halmahera and its Surroundings (Source: Waltham, Hall, Smyth, and Ebinger, 2008)

Building damage is an indicator of physical vulnerability that describes a physical condition that is prone to earthquake hazard factors. Indicators to identify physical vulnerabilities include physical building typology, building vulnerability, infrastructure vulnerability, and building distribution. In planning earthquake-resistant infrastructure, it is necessary to have ground movement parameters, namely Peak Ground Acceleration (PGA). By calculating PGA, the earthquake load that works in a building can be determined. To calculate the PGA value, one of them is by looking for amplification factors by conducting microtremor research (Nakamura, 1989). The amplification factor provides an illustration of the change in acceleration of ground motion from bedrock to the surface (Partono, W., et al, 2013).

Microtremor is a measurement method to obtain the frequency of scientific resonance in a location and explain the symptoms of amplification caused by earthquakes. Buildings that are damaged are strongly influenced by 3 factors, namely amplitude, frequency, and duration of vibration. If fulfilling one of these factors, the building will be damaged. In addition, geological conditions such as areas compiled by soft sediments and amplification of earthquake vibrations that often occur also control the level of damage caused by earthquakes. The amplification factor of earthquake vibrations in local conditions has a very important role in spatial and regional settings. Information about the distribution of physical vulnerability based on amplification factors in the Jailolo region due to the 2015 swarm earthquake is essential. The results of the information obtained can be used for spatial mapping in areas that have conditions where the community cannot face the threat of swarm earthquake. Also, this information is used as a disaster mitigation effort, to identify earthquake-affected areas, and to become a recommendation for earthquake-resistant regional and infrastructure development spatial planning in the Jailolo region.

II. METHODS

The data collection method used in this study is divided into 3 stages, namely the pre-field stage, the field stage, and the post-field stage. The pre-field stage prepared a map of the research location that was used to design the location points during data acquisition with the microtremor method and the physical vulnerability assessment. The physical vulnerability indicators used are the percentage of the built area, the number of buildings, the road network, and the Regulatory chief of BNPB 2012. In the field stage, microtremor measurements were carried out using a TDS-303 type seismometer (3 components) with 40 point locations. Post-field stage, processing microtremor data to produce amplification data using the MATLAB program. Mapping data on amplification and the physical vulnerability of community buildings using the QGIS program. Whereas for the analysis of microtremor data to obtain the results of amplification data is the Horizontal Vertical to Spectral Ratio (HVSr) analysis method.

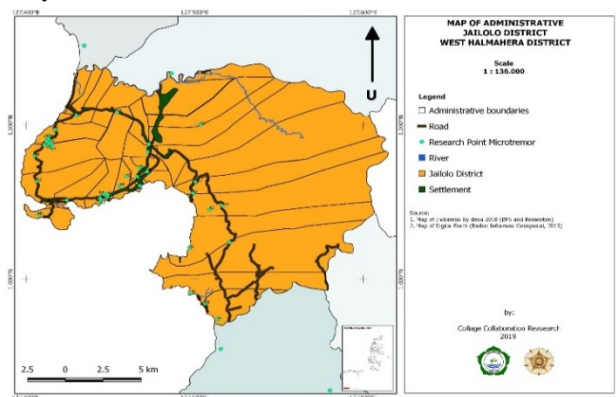


Figure 3. Location of Jailolo Subdistrict, West Halmahera Regency

III. RESULTS AND DISCUSSION

a. Physical Vulnerability

Indicators used for physical vulnerability are housing density (permanent, semi-permanent and non-permanent), availability of public buildings/facilities and availability of critical facilities (PERKA BNPB, 2012).

Physical vulnerability illustrates the potential physical impact on buildings and populations. The magnitude of the level of damage to buildings at risk of disaster is expressed on a scale of 0 (no damage) to 1 (total damage) (Westen et al., 2011). Measurement of the value of physical vulnerability in the Jailolo District also uses 3 indicators, namely the percentage of the built area, the number of buildings, and the road network. Physical vulnerability assessment indicators produce results in the form of physical vulnerability maps and welding, which uses 3 classes, namely low, medium and high.

The value of physical vulnerability in the Jailolo Subdistrict is strongly influenced by the percentage of built area indicators. Seen in the data on building damage caused by the swarm earthquake in 2015. An area will have a high level of vulnerability if it has a built area with a high percentage value. The second indicator used is data on the number of buildings obtained from image digitization data obtained from Google Earth. And the third indicator is a good road network used as an evacuation route when an earthquake occurs. The opportunity for evacuation to run smoothly is influenced by a good road network.

Based on the results of the scoring of several indicators of physical vulnerability used, then for the category of low vulnerability, there are 10 villages and the category of moderate vulnerability there are 11 villages. While for the high category there are 8 villages or 28%. The level of physical vulnerability in Jailolo sub-district is illustrated as a percentage and can be seen in Figure 4.

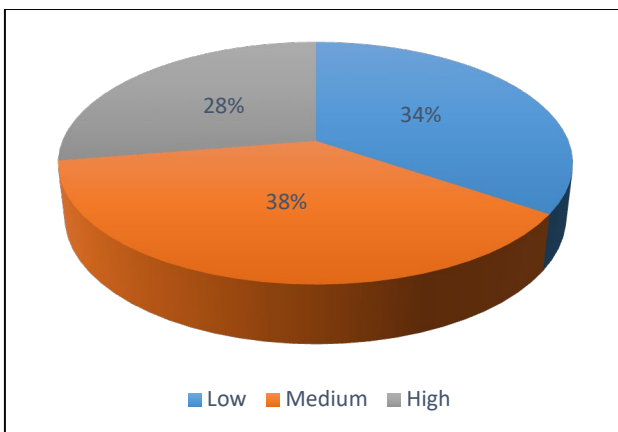


Figure 4. Percentage Diagram of Physical Vulnerability Classes in Jailolo District

The level of physical vulnerability of an area for earthquake disasters is not influenced by topography. This is because the indicators used in determining physical vulnerability only consider the percentage of the area built, the number of buildings and the road network in the village. Then linked to the density of houses, the availability of public facilities and critical facilities. For villages with low physical vulnerability, most are still in the form of gardens and jungles. For example, Idamdehe Village, which has a topography close to Mount Jailolo, is in the category of moderate physical vulnerability and a low percentage of built area.

High levels of physical vulnerability are in the villages of Guaemaadu, Acango, Akediri, Bobanehena, Bobo, Gamtala, Jalan Baru and Tedeng. The level of physical vulnerability of villages in the Jailolo sub-district is shown in Figure 5.

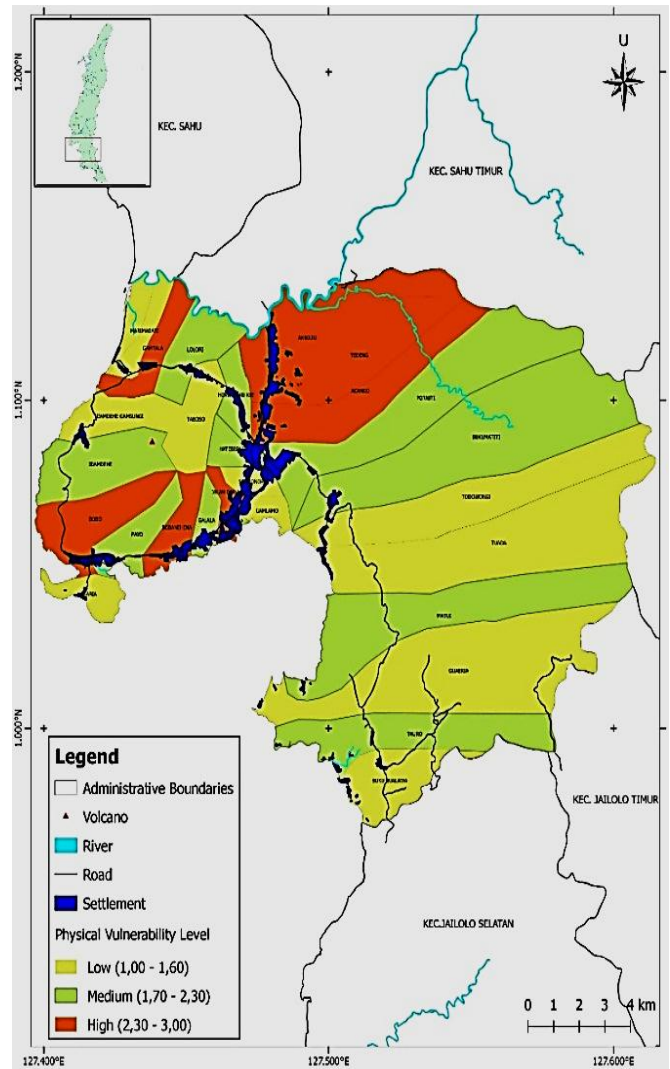


Figure 5. Physical Vulnerability Level in Jailolo District

Table 1. Results of analysis of soil amplification (A_0) values in Jailolo District

Point	Latitude (dec)	Longitude (dec)	Soil Amplification (A_0)	Category	Zone
D6	1,1087	127,4541	4,67	Medium	2
C7	1,0917	127,4132	5,38		
D1	1,0608	127,4676	7,22	High	3
B1	1,0538	127,4474	7,5		
D2	1,0514	127,4243	7,77		
E7	0,9741	127,5139	7,82		
E9	0,991	127,498	7,88		
B3	1,0556	127,4458	8,54		
D3	1,0638	127,4066	8,76		
B4	1,0531	127,4483	8,8		
E8	0,9841	127,5063	8,95		
E6	1,0203	127,497	9,31		
D8	1,0699	127,4719	9,49		
E2	1,0725	127,4674	9,56		
E3	1,083	127,4722	9,61		
B2	1,0552	127,4486	9,75		
B5	1,0503	127,4442	9,79		
C8	1,0931	127,4134	10,1		
C9	1,0895	127,4123	10,7		
E5	1,0455	127,5091	11,1		
E1	1,0668	127,4662	11,21		
C1	1,0972	127,4172	11,54		
H4	1,0608	127,4556	11,96		
C2	1,0874	127,4152	12,27		
D11	1,0633	127,5005	12,43		
D5	1,1066	127,43	13,04		
C10	1,0874	127,4108	13,11		
H5	1,0419	127,4073	13,31		
D9	1,024	127,5208	14,13		
C5	1,0886	127,4136	14,90		
D7	1,0879	127,4729	15,05		
C4	1,0856	127,4152	15,14		
G1	1,1006	127,5036	15,26		
H3	1,0669	127,4596	15,28		
H6	1,0527	127,4438	15,93		
C3	1,0865	127,4147	17,78		
E4	1,0560	127,4992	18,24		
D4	1,0803	127,4052	26,49		
C6	1,0902	127,4141	32,32		
D10	1,0478	127,5165	50,98		

b. Microtremor Data

Microtremor data analyzed using the HVSR method aims to determine local geological characteristics. The resulting value is the value of natural frequency and soil amplification (A_0), where this value is closely related to physical parameters below the surface (Herak, 2008). Soil amplification is affected by the wave velocity and is a large magnitude of earthquake amplification. The greater the wave speed, the smaller the amplification value obtained. Soil amplification value describes the level of rock density, the higher the amplification value, the layer density will decrease or soft. This is caused by differences in wave propagation parameters in the bedrock and sediments that are increasingly large so that it will cause amplification of earthquake waves or amplification when an earthquake occurs (Hardaningrum, O, et al, 2016). From the results obtained, the value of soil amplification (A_0) at 40 points in Jailolo District ranged from 4.67 - 50.98 (Figure 6).

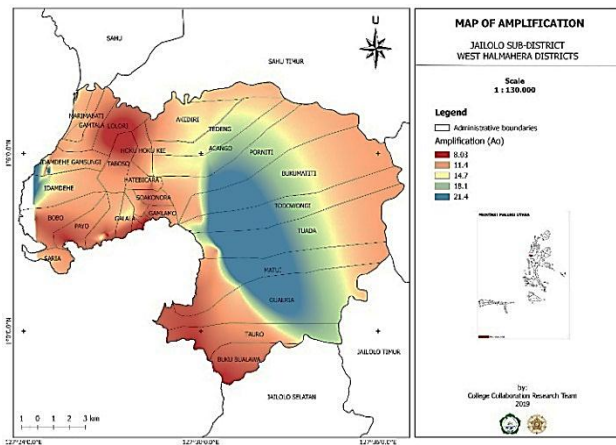


Figure 6. Amplification values in Jailolo District

The amplification value and included in the very high category are located in the villages of Idamdehe, Idamdehe Gamsungi, Acango, Porniti, Bukumatiti, Guaeria, Matui, Tuada, and Todowangi. Where the village is included in zone 4 and shows a high level of risk of damage. The results of the data analysis of the amplification factor value (A_0) at the measurement point can be seen in Table 1.

IV. CONCLUSION

1. The level of physical vulnerability in Jailolo District is 28% of villages with a high level of physical vulnerability.
2. The value of land amplification (A_0) in the Jailolo District ranges from 4.67 - 50.98 and the category is very high located in the villages of Idamdehe, Idamdehe Gamsungi, Acango, Porniti, Bukumatiti, Guaeria, Matui, Tuada, and Todowangi.
3. Villages that are categorized as high physical vulnerability and high amplification value are Acango Village with a physical vulnerability index value of 2.6 and an amplification value of 15.26.

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