INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY: APPLIED BUSINESS AND EDUCATION RESEARCH
2023, Vol. 4, No. 2, 446 – 453
http://dx.doi.org/10.11594/ijmaber.04.02.12

Research Article

Study of Damage to Residential Buildings, Soil Geophysics and The Relationship Between the Epicentrum Distance and the Level of Damage Caused by Earthquake

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Article history:
Submission December 2022
Revised February 2023
Accepted February 2023

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ABSTRACT

The earthquake that occurred on September 26 2019 caused considerable damage to residential buildings in Ambon City, Central Maluku District and West Seram. This research was carried out in the villages of Liang, Tulehu and Waai, Salahutu District, Central Maluku Regency, which experienced the most damage, namely 5,406 houses were lightly damaged, 1,483 were moderately damaged, and 866 were heavily damaged. This study examines the characteristics of residential buildings, and analyzes the relationship between the level of damage to residential buildings and the distance from the epicenter. Coordinates and data on the level of damage to residential buildings (slight, moderate, very heavy) were obtained from BPBD Maluku Province, data on building characteristics including building construction, basic building conditions, building materials, building age were collected through field surveys and interviews with building owners based on damage level data building. The results showed that the level of damage to residential buildings was related to age/length, structure/construction, and materials used for building walls. The damage is even more severe if the building is old (> 20 years), the construction is boneless and unbuttoned (only the bricks are stacked), and the brick material is made of sea sand. Meanwhile, houses built with plastered masonry walls are more resistant to earthquakes. There is a relationship between the level of damage to residential buildings and the epicenter, the closer to the epicenter the damage is more severe, while the farther from the epicenter the level of damage is mild to moderate.

Keywords: *Earthquake on September 26 2019, Epicenter Distance, Damage Residential Building, Salahutu Sub-District*

How to cite:
Sangadji, A. R., Osok, R. M., & Talakua, S. M. (2023). Study of Damage to Residential Buildings, Soil Geophysics and The Relationship Between the Epicentrum Distance and the Level of Damage Caused by Earthquake. *International Journal of Multidisciplinary: Applied Business and Education Research*. *4*(2), 446 – 453. doi: 10.11594/ijmaber.04.02.12

Introduction

The Maluku Islands region is a disaster-prone area with a 2020 Indonesian disaster risk index (IRBI) value of 160.35, which is an area that has a high disaster risk. According to Hamilton, Katili, Cardwell and Isack, McCaffrey and Silver, and Sukamto in Khan (2021) the Maluku sea area and eastern Indonesia generally have different geological and physiographic settings from western Indonesia, and the tectonic framework around the Maluku sea It is the result of the activity of four tectonic plates, namely the Asian Euro plate, the Indo-Australian plate and the Pacific Ocean plate (Markušić et al., 2021;Martin et al., 2019;Jalil et al., 2021). This position places Maluku Province at high risk of earthquakes triggered by impacts on these plates. Earthquake-prone areas in Maluku include the southeastern regions, Ambon Island , Spooky and Hurry (Naik et al., 2019). Meanwhile, the center of the fault is in the Ambon Sea and West Seram (Cilia et al., 2021;Mezősi, 2022).

Based on Indonesian Disaster Data and Information for Maluku Province in 2019, there have been 6 (six) types of disasters that have occurred and have a total of 33 incidents. The Maluku earthquake in September 2019 with a magnitude of 6.5 resulted in 41 deaths and caused a lot of damage to buildings (Kusumawardani et al., 2021). According to Sianipar, et al., (2019) the Thursday, September 26, 2019 earthquake (main earthquake) was followed by thousands of aftershocks, and various series of earthquake events after the September 26, 2019 incident in Ambon City, Central Maluku, and West Seram were caused by deformation rocks with a fault movement mechanism due to a complicated tectonic setting and directly related to the activity of the Banda Api volcano, and the topography of the Maluku Province (Mori et al., 2022;Cipta et al., 2021).

Several studies on the vulnerability of residential buildings have been carried out, namely after the earthquake in Yogyakarta in 2006, and Tasikmalaya and Padang in 2009 by Satyarno, and Saputra, et a and studies of damage to residential buildings due to earthquakes earth in West Palu District, Palu City in 2018 by Rajindra, et al., (2019).

This research will examine the damage to residential buildings due to the September 26 2019 earthquake, specifically related to building conditions such as building structure/construction, basic building conditions, building materials, building age which is based on data on the level of damage to residential buildings (houses) (Watkinson & Hall, 2019;Contreras et al., 2021). Furthermore, the level of damage to residential buildings will also be assessed based on the geophysical conditions of the area, namely geological, soil and topographical conditions (Pranantyo et al., 2022;Hébert et al., 2020). It is hoped that the results of this study will provide an overview of the condition of residential houses that are vulnerable to damage due to earthquakes and also provide direction for models of earthquake resistant building structures, especially residential buildings that are in accordance with the local geophysical conditions (specific local).

Methods

The research was carried out in the villages of Liang, Tulehu and Waai village, Salahutu District, Central Maluku Regency, which are villages with a high number of damaged dwellings (Cilia et al., 2021). Collecting data on damage to residential buildings using the *stratified purposive sampling method*, namely observing and measuring damage to residential buildings at all levels of damage (light, moderate and severe) at the location of the earthquake disaster that has been determined through the Decree of the Central Maluku Regent. Building damage indicators collected include (a) building type (permanent (100% concrete), semi-permanent (50% concrete, 50% other materials), (b) building structure (type of roof, wall system/forming system, foundation system including depth of foundation), (c) building materials (type of wood, iron, cement, mixture of wall and foundation materials), (d) age of the building (year built) (Triantafyllou et al., 2019). Data collection on building damage indicators was carried out through direct field observations, and interviews with owners The geophysical conditions of the observed land included geology, topography and soil.To analyze the effect of epicenter distance on the level of damage to buildings, epicenter coordinates from the Maluku Province BMKG were used, while the coordinates of each house affected by the earthquake were measured according to the level of damage in the villages of Liang, Waai and Tulehu in the field.Data analysis includes the characteristics of damage to residential buildings based on the level of damage.To analyze the effect of epise distance ntrum to the level of damage to buildings residence using the Chi-square method (X2) and analysis of the influence/relationship between variables using the Pearson correlation coefficient (Pearson Chi-Square) (Chian et al., 2019). To analyze the regression between the distance from the epicenter to the level of damage to the building , a regression analysis is carried out with the following equation:

$Y_i = \beta_o + \beta_1 X_{ij} + \varepsilon_i$,

Y_i = dependent variable, namely the level of damage to buildings,

X_{ij} = Independent variable, namely: Epicenter distance.

β_1 = regression coefficient

β_o = intercept coefficient

ε_i = error

$_i$ = 1)

In this study using quantitative data analysis methods, namely by processing and interpret data in the form of numbers or that are systematic. This type of analysis uses percentage analysis using formulas

$$P = \frac{f}{N} \times 100\%$$

P : Percentage (%) searched

f : The number of respondents' answers

N : The total number of respondents

The numbers entered in the formula above are data obtained from the results of the respondents' answers and identification of the questions/criteria posed.

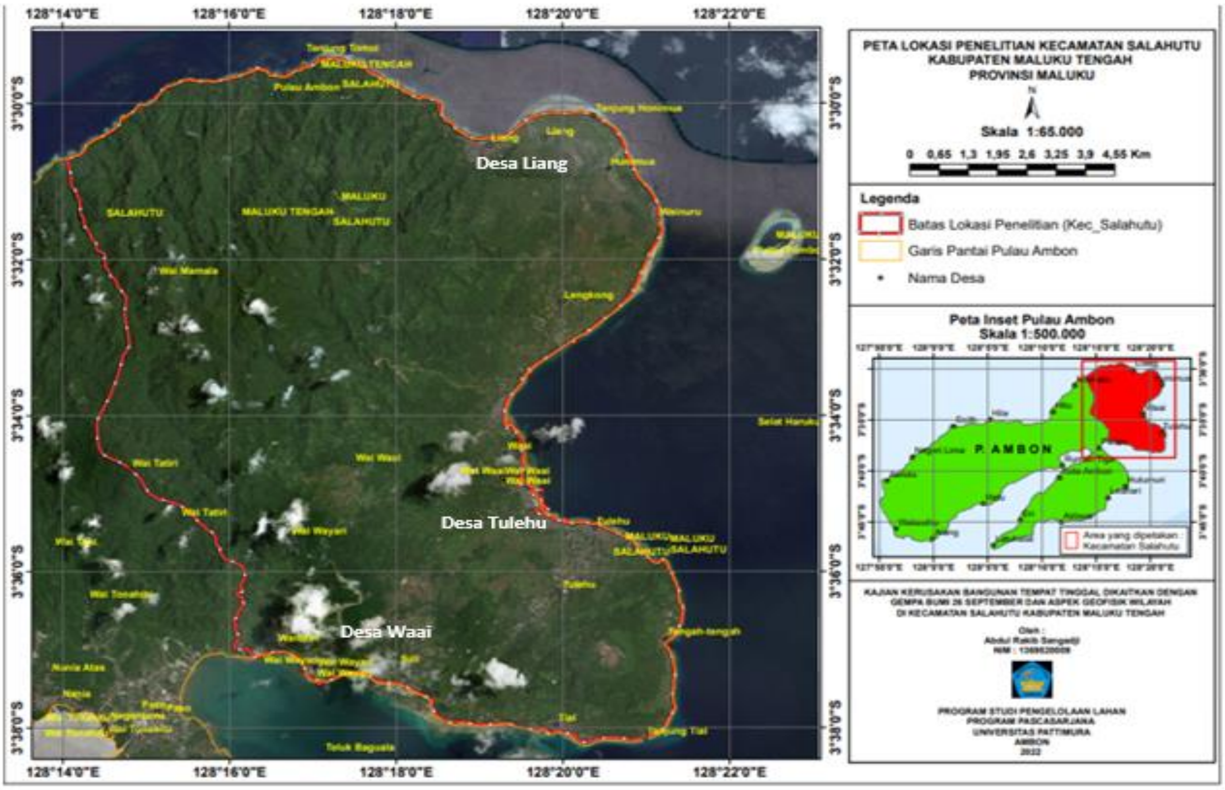

Figure 1. Research location

Results and Discussion

Geophysical Characteristics

Table 1. Geophysics of the area to the level of damage to buildings due to the earthquake

No	Village	Building damage rate	Number of buildings	Topography	elevation (m asl)	Geology	Land Association
1	Liang	Light	11	Flat	27	Limestone	Rensina
		Currently	16	Flat	9	Ambon Volcano	Cambisol
		Heavy	33	Flat	14	Limestone	Cambisol
2	Wow	Light	16	Flat	17	Limestone	Rensina
		Currently	23	Flat	17	Limestone	Rensina
		Heavy	21	Flat	15	Limestone	Rensina
3	Tulehu	Light	33	Flat	14	volcanic alluvium and rock	Alluvial, Cambisol
		Currently	21	Flat	9	Ambon Volcano	Cambisol
		Heavy	6	(Sloping)	27	Ambon Volcano	Cambisol

Based on the results of regional geophysical analysis of the level of damage to houses at the study site (Table 1) it can be seen that the level of light damage in Liang village light damage generally occurs in flat topography, elevation 27m above sea level, limestone geology and resinous soil. Moderate damage was found in flat topography, elevation 9m above sea level, Ambon volcanic rock geology and cambisol soil (Mori et al., 2022). While heavy damage generally occurs in flat topography, elevation 14m above sea level, limestone geology and resinous soil (Jena et al., 2021). Waai Village, the level of light to heavy damage was found in flat topography, elevation of around 17m above sea level, geology of limestone and resinous soil. Tulehu Village with mild damage generally occurs in flat topography, elevation 14m above sea level, alluvium geology and Ambon volcanic rock and cambisol soil (Pribadi et al., 2021). Meanwhile, moderate and severe damage occurred in flat topography, elevation 9 – 27m above sea level, Ambon volcanic rock geology and cambisol soil. Rensina soil formed on limestone is soil with a shallow solum (<40cm) so that when an earthquake occurs the soil conditions affect the building above it, while cambisol soil is a developing soil so it has unstable soil properties (Mezősi, 2022). When an earthquake occurs, unstable ground will easily vibrate and cause damage to buildings.

Characteristics of the building and the level of damage

The results of field studies and interviews obtained damage to residential buildings (houses) in the three study location villages including minor damage such as cracked walls/floors of houses (vertical, horizontal, irregular), moderate damage covering house walls, cracks, ceilings fell, the roof fell, and the level of damage was severe, such as walls collapsing to the heaviest house collapsing (Dollet & Guéguen, 2022). Based on the results of data analysis, the characteristics of buildings and the level of damage to buildings can be classified as follows:

a. Light damage was mostly found in buildings with button structures, with bamboo matting walls, tin roofs, sand building materials (generally beach sand) and pressed bricks.

Figure 2. Example of a button house with walls of woven bamboo and plastered with cement so that the bonding power is strong and the house does not collapse or crack easily

b. Medium-severe damage was found in houses without bones and sloofs, buildings that did not use binding frames and joints between the timbers that were not fastened or walls with unreinforced concrete (only stacked and plastered bricks) so that the buildings were fragile and easily collapsed when there was a shock. Earthquake (Cipta et al., 2021).

Analysis of the Effect of Epicenter Distance on the Level of Damage to Buildings

Based on the crosstabulation results, as presented in Table 4.22, it shows that the *expected count* between each class, the distance from the epicenter to the level of damage to the building, is 20, in other words, there are no cells that have an expected frequency <5 (Table 4.23). This means that the assumption of using Chi{X2}-squared in this study meets the requirements. Furthermore, the results in the table also show that at a distance of epicenter 1 (17,000-20,000 m) the level of damage to light buildings was 18.3%, on the other hand, the level of damage to heavy buildings was 55.0%. In class 2 epicenter distance (20,000-25,100 m) the level of damage to light buildings was 28.3%, on the other hand, the level of damage to medium buildings was 36.7%. In class 3 epicenter distance (25,100-27,600 m) the level of damage to heavy buildings was 10.0%, on the other hand, the level of damage to light buildings was 53.3%.

Table 2. Crosstabulation Results Analysis of the Effect of Epicenter Distance Against the Level of Damage to Buildings in the Salahutu District

			Building Damage Rate			**Total**
			1(Light)	**3(Currently)**	**5(Heavy)**	
Epicenter-trumpet distance class (km)	1 (17,000-20,000m)	Count	11	16	33	60
		Expected Count	20	20	20	60
		% within Klas_JE	18.3%	26.7%	55.0%	100.0 %
	2 (20,000-25,100m)	Count	17	22	21	60
		Expected Count	20	20	20	60
		% within Klas_JE	28.3%	36.7%	35.0%	100.0 %
	3 (25100-27600 m)	Count	32	22	6	60
		Expected Count	20	20	20	60
		% within Klas_JE	53.3%	36.7%	10.0%	100.0 %
Total		Count	60	60	60	180

		Building Damage Rate			Total
		1(Light)	3(Currently)	5(Heavy)	
	Expected Count	60	60	60	180
	% within Klas_JE	33.3%	33.3%	33.3%	100.0 %

Source: Analysis results, 2022

Based on the results of the Chi-square Test (Table 3), it was found that the Asymp. Sig (2-sides) on the Pearson Chi-Squre is 0.000, where this value is smaller than the value α = 0.05, which means that there is a relationship between the distance of the epicenter and the level of damage to houses due to the earthquake. This shows that the distance from the epicenter has a significant effect on the damage to houses at the 95% confidence level, where the position of residential housing in the research location that is closer to the epicenter will experience more severe damage, when compared to the position of residential housing that is far from the epicenter with the level of damage mild to moderate.

Table 3. Chi-square Test Results Effect of Epicenter Distance Against the Level of Damage to Buildings in the Salahutu District

	Value	Df	asymp. Sig. (2-sided)
Pearson Chi-Square	31,200 [a]	4	,000*
N of Valid Cases	180		
a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 20,00.			

Source: Results of analysis, 2022

Considering that the data for variable Y is categorical, this regression analysis is only focused on trend analysis or the direction of the relationship between variables X and Y. The results of the regression analysis (Figure 3) show that the regression coefficient B1 is -0.0002, which means that the distance from the epicenter to the level of damage to houses has a negatively significant trend. This can be explained that the closer the distance of the house to the epicenter, the more severe the level of damage to the building during the earthquake, conversely the farther the distance of the house from the epicenter, the lower the level of damage at the 95% confidence level.

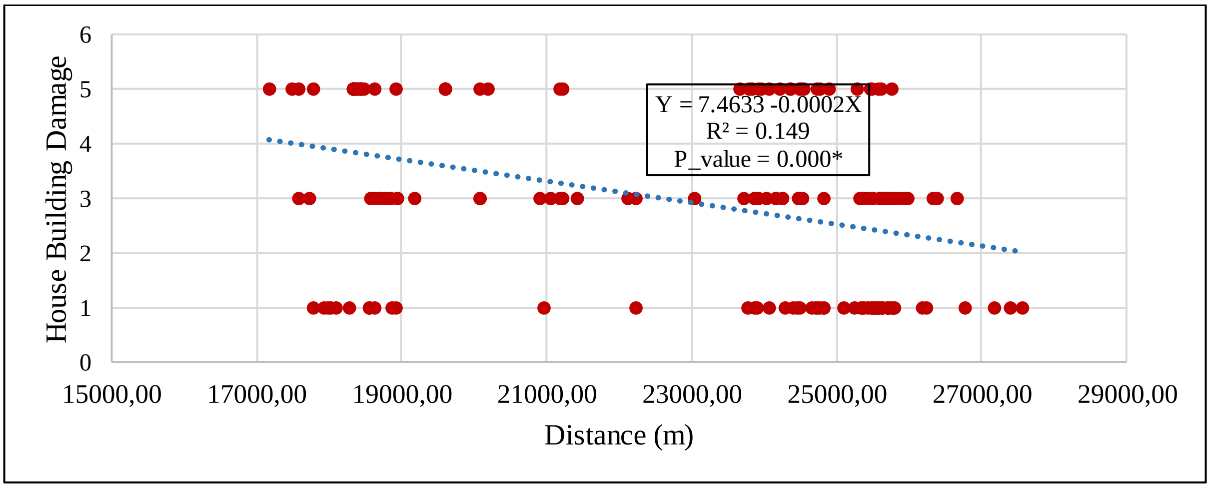

Figure 3. Graph of the Relationship between Epicenter Distance and the Level of Damage to Houses Due to the Earthquake in Salahutu District

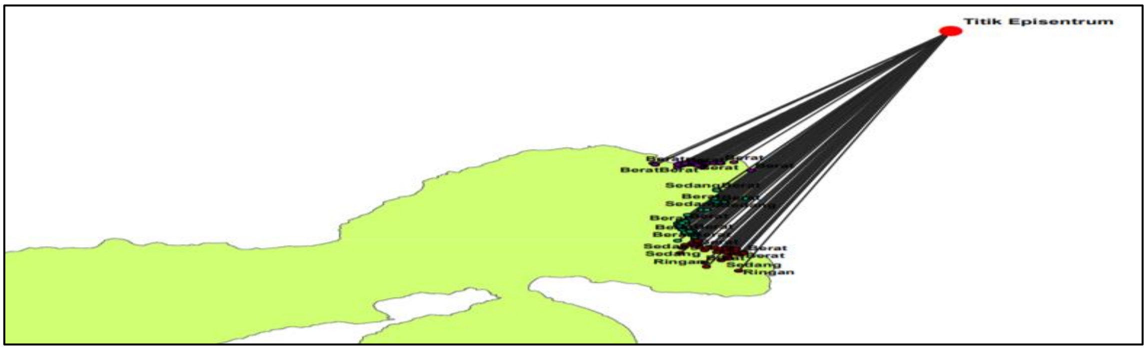

Figure 4. Map of the distance between the epicenter and the locations affected by the September 26 2019 earthquake

Conclusion

Based on the results of a study on the impact of damage to residential buildings due to the September 126 2022 earthquake, several conclusions can be drawn, namely that light damage generally occurs in flat topography, elevation <30m, geology of limestone and resinous soils. Meanwhile, moderate to severe damage was found in flat topography, elevation <30m, geology of Ambon volcanic rock and cambisol soil. Rensina and cambisol soils are developing soils so they have unstable soil properties. When an earthquake occurs, unstable ground will easily vibrate and cause damage to buildings.

Damage to residential buildings (houses) in the three study location villages is directly related to the structure and type of building construction , and the materials used.

The distance from the eficenter has a significant effect on the level of damage to the house with a value of 000. Asymp. Sig. (2-sided) , and the results of the regression analysis have a regression coefficient B1 value of -0.0002, which means that the distance between the epicenter and the level of damage to house buildings shows a negatively significant trend.

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