Article

Residential Building Damages Related to the Geological Bedrock Variations During M_{ww} 5.6 Earthquake in Cianjur, West Java, on November 21, 2022

Andri Wibowo

Universitas Indonesia. Pondok Cina, Beji, Depok City, West Java 16424.
* Correspondence: paleobio2020@gmail.com

Abstract
Recently on the November 4, 2022 at 03:00 PM, a M_{ww} 5.6 earthquake struck Cianjur district of West Java province, Indonesia. To our best knowledge, an earthquake will cause a massive damage to the manmade infrastructure and this responsible for a massive casualty. A building damage is affected by various determinant factors. One of important factors is the geological bedrock variations. Here this research aiming to elaborate the associations of geological bedrocks in Cianjur district with residential building damages caused by recent earthquakes. The results confirm that majority of building damages account for 54.67% of the total building was associated with quaternary volcanic bedrocks. The second massive building damages were observed for Andesitic Dacitic volcanic rocks accounted for 32.07%. To conclude, elaborations of geological bedrock-building damage will contribute to the better planning in the future that can reduce the damages in the urban settings.

Keywords: bedrock; building; damage; earthquake; planning

1. Introduction

1.1 West Java earthquakes

Indonesia is one of the countries in the world that is very vulnerable to earthquakes. For almost a century, the USGS has records of at l more than 150 earthquakes with magnitudes greater than 7 in the period 1901–2019. One of the regions in Indonesia that is very susceptibl earthquakes is West Java. These areas are vulnerable due to the presence of faults combined with soli characteristics and slope. Landslides considered an associate disaster following an earthquake since West Java's topography is dominated by hilly regions with very steep slopes.

In West Java, there are at least three faults that have the potential to cause massive earthquakes (Supendi et al. 2018). Those faults include Cimandiri fault (Setyonegoro et al. 2013, Febriani 2016, Marliyani et al. 2016), the Baribis fault, and the Lembang fault. Cimandiri is an ac fault located in the region of southern Sukabumi, West Java, that extends from Pelabuhan Ratu to Padalarang. While Baribis is located in northern parts, and Lembang in the central parts. (Fitri et al. 2019). To the east of the Cimandiri fault lies the Lembang fault.

Baribis fault is located in the northern part of the West Java area. The fault is the result of the subduction movement of the Indo-Austra plate with the Eurasia plate of about 57 mm per year In Sumatra, the boundary between the two is accommodated by the Sumatran fault. Howe in Java, the movement of the Sunda Megathrust could be transferred to inland faults in Java such as the Cimandiri fault, the Lembang fault, this Baribis fault in Western Java (Simanjorang et al. 2020, Daryono et al. 2021).

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The Lembang fault (Daryono et al. 2019) extended for 24 kilometers. The western part of this fault runs through Paropong district, and the Lembang fault is parallel to the Java subduction zone, which lies 300 km off shore from the southern coast of Java Island. To the west of the Lembang fault lies the Cimandiri fault. The north-facing fault scarp of the Lembang fault has slopes steeper than 40^0. The east-west profile shows that the scrap has a height above the surface of about 300 m (Meilano et al. 2012, Nugraha et al. 2019).

1.2 Residential building susceptibility

Building damage as resulted from earthquake is associated with the geological rock. As a result of the 2016 Kumamoto Earthquake, Japan, most building damage was associated with the liquefaction process (Setiawan et al. 2017). Soil liquefaction that occurred in this area after earthquake was mainly affected by the very loose silt and sand layer at a depth of around 6 m below the ground surface, and the existence of the Kiyama river as well. In Indonesia, ground shaking was also observed following M_w7.5 strike-slip event at shallow depths within Palu Bay and underneath Palu city. This earthquake has triggered the liquefaction of sandy soils that has damaged residential a building at village scales (Goda et al. 2019).

1.3 Cianjur earthquake

On November 21, 2022, at 13:21 WIB (UTC +07:00), a M_{ww} 5.6 earthquake struck near Cianjur in West Java, Indonesia. The earthquake occurred at a depth of 11 km (7 mi), classifying it as a shallow event. It had a strike-slip focal mechanism and is associated with seismic activity on the Cimandiri Fault. The recent earthquake had a greater impact because it ruptured within a few kilometers of the city of Cianjur.

Cianjur is very susceptible to the earthquake. A sequence of previous earthquakes proves this. Since 1844, numerous earthquakes have been recorded. In 1910, 1912, 1958, 1982, and 2000, earthquakes caused damage and casualties in the area.

Considering the vulnerability of Cianjur and the fact that it is located near a fault, and at the same time that Cianjur is a populated city, information on how residential building damage was associated with geological rocks is urgently needed. This is very important because it is one of the crucial components of mitigation and planning efforts in the future.

2. Methods

The research frameworks describing methods for this study is available in Figure 1. The method follows Hidayat (2022).

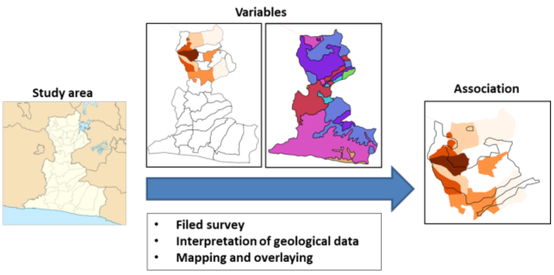

Fig 1 Research frameworks.

2.1. Study area

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The study area was numerous subdistricts within Cianjur (Figure 2), a district located in the West Java province that was struck by an earthquake on November 21, 2022. This district has an area of 3,614 km^2 and a population of 2,244 people. The geocoordinate of Cianjur is 6° 49′ 16″ S and 107° 08′ 24″ E, or 6.8212005° S and 107.1400351° E. Cianjur district was bordered by mountainous areas in the north and lowland and coastal areas in the south.

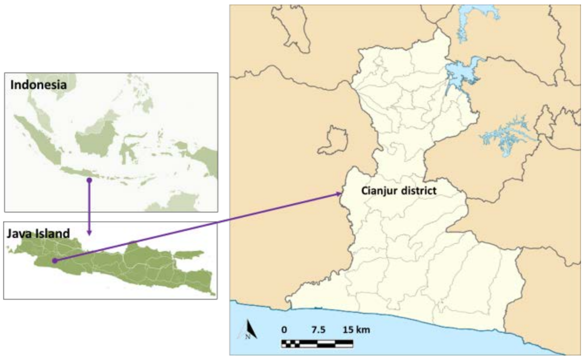

Fig 2 Subdistrict within Cianjur district, West Java, Java island, Indonesia.

2.2. Residential building surveys

The majority of the information needed for this study is the number of damaged residential buildings in the Cianjur subdistrict. This data was collected from primary and secondary sources. The primary data was collected through direct observation. The secondary data came from interviews and literature reviews. Documents that are included in literature reviews are mainly disaster reports containing numbers of casualties and damaged houses. The reports were official documents published and circulated by authorized government agencies. The numbers of damaged residential buildings were recorded and tabulated in a GIS database.

2.3. Geological surveys

The geological data used in this is the geological bedrock. The bedrock data was secondary data provided by a geological agency. The bedrock data described the types of rocks that lie in the Cianjur district. The bedrock data were then recorded and tabulated in a GIS database.

2.4. Mapping and analysis

This study's analysis is primarily based on mapping and overlaying. The data, along with its tabulated data on damaged buildings obtained from surveys, were then visualized and mapped into a vector layer. This vector layer consists of polygons representing surveyed subdistricts of Cianjur district along with their number of damaged houses. The vector layer of damaged houses was then overlaid with a vector layer of mapped geological bedrock. The delineations of damaged house vector layers followed the subdistrict border. While the delineations of geological bedrocks were independent and did not follow the subdistrict borders. It means that one subdistrict can have more than one geological bedrock. Similarly, one geological bedrock can occur in more than one subdistrict. All the mapping and analysis were implemented using the GIS platform.

3. Results and Discussion

3.1. Damaged buildings

Figure 3 depicts the spatial distributions of damaged buildings based on current available data in subdistricts within Cianjur district, West Java, Java island, Indonesia. It is clear that the majority of damaged buildings were concentrated in the district's northern and western parts, which were cut off from the mountainous areas. A high concentration of damaged buildings with a range of 9,705–10,411 houses was also observed in the

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northwest. This area was surrounded by areas that experienced quite high numbers of damaged buildings, ranging from 1,128 to 9,705 houses. The number of damaged buildings was decreasing in the east. Then, the north and west sides experienced more earthquakes in comparison to the south and east sides.

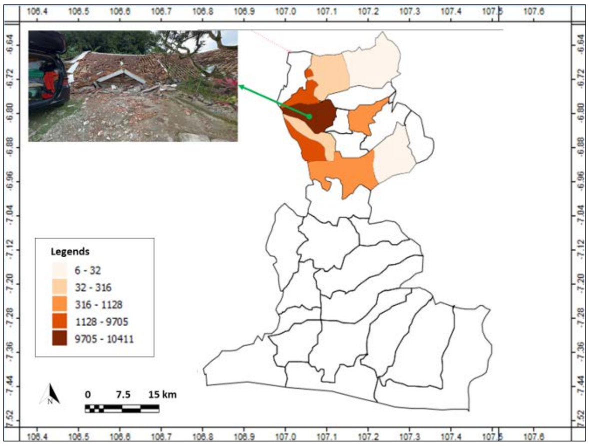

Fig 3 Damaged residential buildings in subdistricts within Cianjur district, West Java, Java island, Indonesia (Insert photo: damaged house).

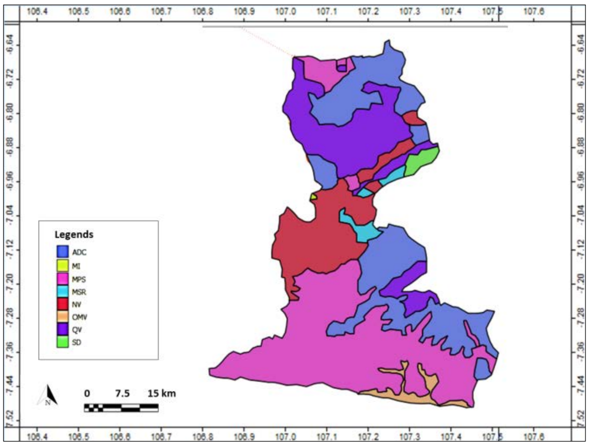

Fig 4 Geological bedrocks in subdistricts within Cianjur district, West Java, Java island, Indonesia (ADC: Andesitic Dacitic, MI: Miocene Intrusive, MPS: Miocene Pliocene Sediment, MSR: Miocene Sedimentary Rocks, NV: Neogene Volcanic, OMV: Oligo-Miocene Volcanic, QV: Quarternary Volcanic, SD: Superficial Deposits).

3.2. Geological bedrocks

Geological bedrock in Cianjur, where the earthquake was present, varied (Figure 4). At least there were eight types of geological bedrock. The bedrocks in the north were different from the bedrocks in the central and southern parts. The northern parts, where the most damaged buildings were recorded, were dominated by quarternary volcanic bedrocks. This bedrock covers almost 7 subdistricts that have high numbers of damaged houses (Figure 5). The northern parts were bordered by Andesitic Dacitic bedrocks. In contrast, the central parts of Cianjur were dominated by Neogene volcanic bedrocks. Miocene-Pliocene sediments dominated the lowland southern parts of Cianjur. The results (Figure 6) confirm that majority of building damages account for 54.67% of the total building was associated with quaternary volcanic bedrocks. The second massive building damages were observed for Andesitic Dacitic volcanic rocks accounted for 32.07%.

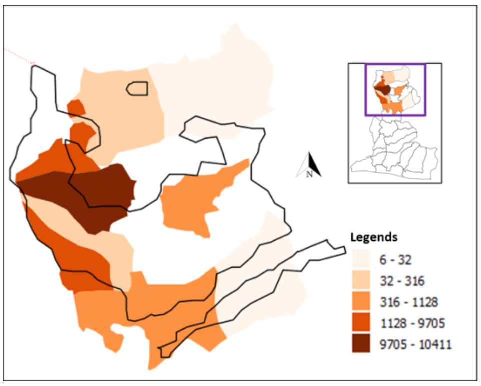

Fig 5 Overlaid of Quarternary Volcanic geological bedrocks with damaged houses in subdistricts within Cianjur district, West Java, Java island, Indonesia.

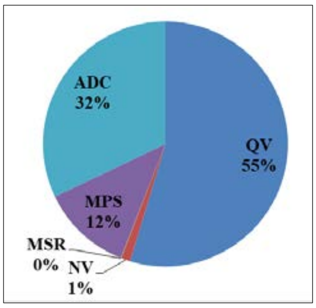

Fig 6 Compositions of damaged houses in every geological bedrocks (ADC: Andesitic Dacitic, MPS: Miocene Pliocene Sediment, MSR: Miocene Sedimentary Rocks, NV: Neogene Volcanic, QV: Quarternary Volcanic) in subdistricts within Cianjur district, West Java, Java island, Indonesia**.**

Discussion

This research is the first to elaborate on the association between geological rocks and building damage due to the earthquake. This information is crucial considering that understanding the scale and distribution of building damage along with its confounding factors will guide the improvement of disaster management (Bhattacharjee et al. 2021). The results obtained in this study highlighted the association of geological rocks with the damaged houses as a proxy for earthquake disaster, which was corroborated with the previous researches.

The variations in geological characteristics are determinant factors that regulate and differentiate the magnitude of earthquakes in certain locations. As observed and learned from the previous earthquake in Palu (Hidayat 2022), the geological and topographic conditions of the Palu area really control the distribution of damage caused by earthquakes. In valleys, which consist of soft sediments, there is an increase in earthquake vibrations, which results in increased levels of damage. Strengthening earthquakes or earthquake vibrations due to geological conditions has an important impact on the level of damage to buildings that occurs.

The geological rocks characterized by the deposits of the Holocene age are more susceptible to earthquakes. The rock formations generally consist of material that has not undergone compacting and is therefore loose. The rock structure generally consists of sand at the top, silt at the middle, and clay at the bottom. In this study, it was clearly observed that most damaged buildings were recorded in the volcanic bedrock. Aside from volcanic rocks, Andesitic Dacitic rocks have also contributed to a significant number of damaged buildings.

The characteristics of volcanic rocks are related to the number of damaged buildings associated with the types of volcanic rocks. Volcanic soil is known for being problematic and hazardous because of its peculiar behavior (Sumartini et al. 2018). It is ejected from volcanic activity and has unique properties in its mineral content, chemical content, porosity, fabric, interlocking between grains, and cementation process. The results of this can be seen in Japan, one of the countries that has similarities to Indonesia due to its geological characteristics and location, which is also located in the Ring of Fire. A large number of earthquake-induced building damages have been reported in specific volcanic rocks (Miyagi et al. 2011, Kayen et al. 2016, Hazarika et al. 2018), which is comparable to the result obtained in Cianjur.

Despite the fact that this study is the first to elaborate on the links between earthquake-induced building damage and geological bedrock, there is still room for improvement. First, this study excludes a possible landslide as another factor that could cause and contribute to residential building damage; in the future, it is recommended to distinguish whether the building was damaged by ground shaking or struck by a landslide. Another important variable that is overlooked in this study is the characteristics of the building itself. The number of floors, the shape of the building, building style, ground foundation condition, seismic design, and the quality of the building's construction, including the material properties, are all factors to consider (Jin et al 2020).

Conclusions

To our best knowledge, a systematic analysis elaborating on the association of bedrock with damaged buildings has not been implemented so far. Finally, this study assessed and confirmed that variations in bedrock differentiate the magnitude of an earthquake represented by numbers. Quaternary volcanic bedrocks are most responsible for the most damaged buildings. High numbers of damaged buildings within volcanic bedrock were also related to the areas of this bedrock that cover almost 7 subdistricts.

References

Bhattacharjee G, Soden R, Barns K, Loos S, Lallemant D. 2021. Factors affecting earthquake responders' building damage information needs and use. Earthquake Spectra. 38. 875529302110302. 10.1177/87552930211030297.

Daryono MR, Natawidjaja DH, Sapiie B, Cummins P, 2019. Earthquake Geology of The Lembang Fault, West Java, Indonesia, Tectonophysics. 751: 180-191.

Daryono MR, Natawidjaja DH, Puji AR, Aribowo S. 2021. Fault rupture in Baribis Fault possibly related to the 1847 major earthquake event in the Cirebon area. The 3rd Southeast Asian Conference on Geophysics. 10.1088/1755-1315/873/1/012052

Febriani F. 2016. Seismicity around the Cimandiri fault zone, West Java, Indonesia. AIP Conference Proceedings. 1711. 070003. 10.1063/1.4941644.

Fitri IH, Setyadji AB, Meilano I, Susilo. 2019. Analysis of Cimandiri fault mechanism type based on strain pattern from gps observations in the year 2010 – 2017. 2018 IEEE Asia-Pacific Conference on Geoscience, Electronics and Remote Sensing Technology (AGERS).

Goda K, Mori N, Yasuda T, Prasetyo A, Muhammad A, Tsujio D. 2019. Cascading Geological Hazards and Risks of the 2018 Sulawesi Indonesia Earthquake and Sensitivity Analysis of Tsunami Inundation Simulations. Front. Earth Sci. 7:261. 10.3389/feart.2019.00261

Hazarika H, Kokusho T, Kayen RE, Dashti S, Fukuoka H, Ishizawa T, Kochi Y, Matsumoto D, Hirose T, Furuichi H, Fujishiro T, Okamoto K, Tajiri M, Fukuda M. 2018. Geotechnical damage due to the 2016 Kumamoto Earthquake and future challenges. Lowland Technology International, Special Issue on the 2016 Kumamoto Earthquake and Geodisasters. 19 (3): 189-204.

Hidayat R. 2022. Correlation of geological conditions and levels of damage in Palu earthquake. First International Conference of Construction, Infrastructure, and Materials. 10.1088/1757-899X/650/1/012022

Jin K, Lee J, Lee KS. 2020. Earthquake damage and related factors associated with the 2016 ML = 5.8 Gyeongju earthquake, southeast Korea. Geosci J 24, 141–157. 10.1007/s12303-019-0024-9

Kayen R, Dashti S, Kokusho T, Hazarika H, Franke K, Oettle N, Wham B, Calderon JR, Briggs D, Guillies S, Cheng K, Tanoue Y, Takematsu K, Matsumoto D, Morinaga T, Furuichi H, Kitano Y, Tajiri M, Chaudhary B, Nishimura K, Chu C. 2016. Geotechnical aspects of the 2016 MW 6.2, MW 6.0, and MW 7.0 Kumamoto Earthquakes. GEER Report, University of Berkeley

Marliyani GI, Arrowsmith JR, Whipple KX. 2016 Characterization of slow slip rate faults in humid areas: Cimandiri Fault zone, Indonesia, Journal of Geophysical Research: Earth Surface. 121. 2287-2308.

Meilano I, Abidin H, Andreas H, Gumelar I, Sarsito D, Hanifa N, Harjono H, Kato T, Kimata F, Fukuda Y. 2012. Slip rate estimation of the Lembang fault West Java from from geodetic observation,. Journal of Disaster Research. 7.

Miyagi T, Higaki D, Yagi H, Yoshida S, Chiba N, Umemura J. Satoh G, 2011. Reconnaissance report on landslide disaster in Northeast following the M 9 Tohoku Earthquake. Landslides. 8 (3): 339-342.

Nugraha A, Supendi P, Prabowo B, Rosalia S, Erlangga, Husni Y, Widiyantoro S, Puspito N, Priyono A. 2019. The Recent small earthquakes around Lembang fault, West Java, Bandung, Indonesia. Journal of Physics: Conference Series. 1204. 012083. 10.1088/1742-6596/1204/1/012083.

Setiawan H, Serikawa ., Nakamura M. 2017. Structural damage to houses and buildings induced by liquefaction in the 2016 Kumamoto Earthquake, Japan. Geoenviron Disasters 4, 13 ().10.1186/s40677-017-0077-x.

Setyonegoro W, Nugraha J, Shahzad S, Adi Martha A, Pakpahan S, Yusuf M. 2013. Quantitative interpretation of cimandiri fault structure using gravity method (interpretasi kuantitatif struktur sesar cimandiri dengan metode gravitasi). Prosiding BMKG Tahun 2012. 141-148.

Simanjorang RG, Rosid MS, Sembiring AS, Daryono, Heryandoko N. 2020. Cimandiri Fault identification using earthquake tomography double-difference method. Journal of Physics: Conference Series; Bristol 1494(1). 10.1088/1742-6596/1494/1/012044.

Sumartini W, Hazarika H, Kokusho T, Ishibashi S, Matsumoto D, Chaudhary B. 2018. Deformation and failure characteristics of Volcanic soil at landslides site due to the 2016 Kumamoto Earthquake. Lowland Technology International. 19. 237-244.

Supendi P, Nugraha D, Puspito NT, Widiyantoro S, Daryono. 2018. Identifcation of active faults in West Java, Indonesia, based on earthquake hypocenter determination, relocation, and focal mechanism analysis. Geoscience Letters 5(1).