International Science and Engineering Research Journal (ISERJ)
Volume 01 Number 02, 2025, pp. 30 - 37
P-ISSN: xxxx-xxxx E-ISSN: xxxx-xxxxx
Open Access: https://publishing.impola.co.id/index.php/ISERJournal

Analysis of Structural Damage and Disaster Management Resulting from Earthquakes in Cianjur

Sudarno P Tampubolon*

Civil Engineering Study Program, Indonesian Christian University, Indonesia

Keywords:
Cianjur earthquake, mitigation, building reliability, building assessment

ABSTRACT

The earthquake that occurred in the Cianjur area, West Java on Monday 21 November 2022 at 13.21 WIB resulted in 635 fatalities and 56,000 houses that were damaged. Therefore, it is necessary to conduct an assessment and mitigation of the structural damage buildings and the impact of earthquakes. From the results of the assessment carried out in the area where the earthquake occurred, it was found that many houses and public facility buildings still did not meet the requirements for earthquake-resistant buildings, especially in the use of concrete materials, main reinforcement and stirrups in columns, beams, foundations and beam-column joint. The amount of damage to buildings that occurred as a result of the buildings standing did not have a strong column-weak beam planning concept. This can be seen from the inability of the column to withstand/ carry the working load which causes the column to collapse and damage. Therefore, it is very necessary to pay attention to building planning in Disaster Prone Areas (KRB) in accordance with earthquake resistant building regulations SNI 1726:2019 and SNI 2847:2019. In addition, post-disaster management measures should include the assessment of survivors' health conditions (psychological support and trauma healing), the operational control of healthcare services, the treatment of injured victims and the management of fatalities, the prevention of communicable diseases, the provision of adequate nutrition, the strengthening of information systems and coordination mechanisms, the improvement of sanitation facilities (installation and supply of clean water) and latrines, as well as the deployment of medical personnel and logistics assistance need to be improved and coordinated well after the earthquake.

1. INTRODUCTION

On Monday, November 21, 2022, an earthquake with a magnitude of 5.6 on the Richter scale struck Cianjur Regency, West Java, lasting approximately 10 to 15 seconds. The earthquake occurred at coordinates 6.84°S latitude and 107.05°E longitude, with its epicenter located 10 km southwest of Cianjur, without the potential for a tsunami, [1], [2], [3]. Although it did not trigger a tsunami, the earthquake caused significant damage to residential buildings, infrastructure, and other essential facilities in Cianjur and its surrounding areas, resulting in hundreds of casualties and injuries. The tremors were also felt strongly in Jakarta, Depok, Bogor, and South Tangerang. Various public facilities, including government buildings, schools, and places of worship, sustained damage, while many casualties occurred due to buildings collapsing under the earthquake's forces. The earthquake in Cianjur is suspected to have been caused by movement along the Cimandiri Fault. Following the initial powerful earthquake, Cianjur was hit by 21 aftershocks. In addition to structural damage, the earthquake triggered landslides on several key routes in Cipanas, Cianjur Regency, West Java, causing road closures and disrupting traffic access. (https://news.detik.com/berita/d-6501898/kilas-balik-duka-cianjur-diguncang-gempa-dashyat.).

*Corresponding author.
E-mail addresses: sudarno89tampubolon@gmail.com

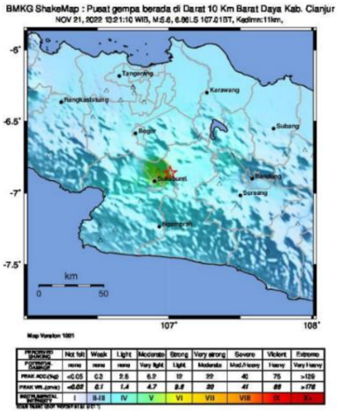

Figure 1: Earthquake Location and Magnitude Source: BMKG

Due to the structural damage caused by the earthquake, it is essential to conduct a thorough assessment of affected buildings to identify the types and extent of damage, including both structural components and utility systems. Post-earthquake, evaluating the reliability of buildings is critical to ensure operational continuity and to prevent accidents resulting from compromised structural integrity. Although a building may appear stable after an earthquake, its structural performance and physical integrity are often significantly reduced. Therefore, rapid post-earthquake assessments are necessary to evaluate and verify the extent of damage sustained by buildings [4][5].

At present, the timing and exact occurrence of earthquakes remain unpredictable. Coupled with the substantial negative impacts they cause-ranging from loss of life to infrastructure damage-disaster mitigation becomes an essential priority. Given the considerable casualties, infrastructure destruction, and the enormous economic burden-often amounting to trillions of rupiah for rehabilitation and reconstruction it is imperative to minimize earthquake-related losses. One critical preventive measure involves assessing the structural reliability of buildings affected by earthquakes. This assessment serves to determine whether damaged structures still comply with earthquake-resistant building standards.

In the aftermath of an earthquake, sanitation programs and the provision of clean water must be prioritized to ensure access to safe drinking water and sanitation facilities in refugee camps [1], [6]. Additionally, psychological support is vital for survivors experiencing varying degrees of trauma. This includes art therapy and healing activities facilitated by trained professionals (Sadiyah et al., 2023). These efforts also extend to educational and psychological recovery programs in learning tents for early childhood, kindergarten, and primary school students (Sihotang et al., 2023; Willya et al., 2023). Collectively, these interventions aim to support the recovery process and expedite post-disaster rebuilding efforts in Cianjur.

Cianjur has experienced several major earthquakes in the past, underscoring the urgent need to examine the region's seismic characteristics and fault zones. Earthquake impacts can include severe infrastructure damage, loss of life, and disruption of socioeconomic activities (Astuti et al., 2023; Rosalina et al., 2023). Therefore, a comprehensive understanding of the geological factors contributing to seismic activity and accurate risk assessment is crucial. This study aims to analyze structural damage and disaster management resulting from the Cianjur earthquake. Figure 2 illustrates the proposed model for disaster response following the event.

2. METHOD

Data and Methods

On December 12, 2023, the research team from the Civil Engineering Program at UKI conducted direct survey and assessment methods to evaluate building damage in Cikancana Village, Babakan Bandung Hamlet, RT 05/RW 02 and RT 03/RW 01, and Cibeleng Hilir Hamlet, Cikancana Village, Gekbrong District, Cianjur Regency, which is one of the villages that suffered significant damage.

In the context of construction regulations, the Strategic Plan Amendment Document of the Regional Disaster Management Agency (BPBD) of Cianjur Regency for 2016–2021 included a review of the Spatial Planning Policy and the Strategic Environmental Assessment, which stipulated that land use must comply with building codes adapted to the microzonation map (BPBD Cianjur, 2019). Nevertheless, the earthquake event in Cianjur on 21 November 2022 revealed deficiencies in the implementation of these standards, as evidenced by the high number of fatalities resulting from the collapse of structures that did not meet seismic resistance requirements. The consistent enforcement of building codes is considered critical to enhancing the resilience of buildings and public facilities within the affected area. According to data as of 7 December 2022, the provisional damages caused by the Cianjur earthquake were recorded as Figure 2.

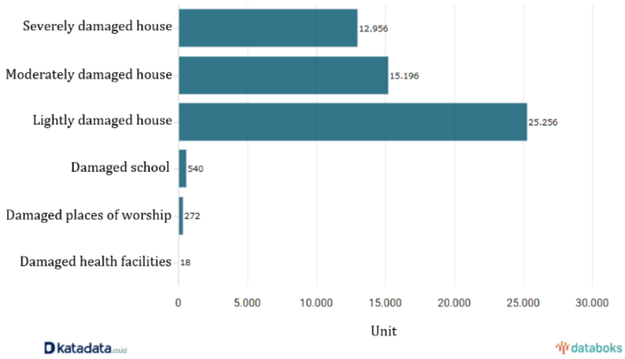

Figure 2: Number of Buildings Damaged Due to the Cianjur Earthquake, [20]

Building inspections were conducted by visiting the sites and directly observing building elements. Data collection involved reviewing buildings and homes, with damage data collected using the following methods:

1. Coordinating with the Faculty of Applied Sciences at Surya Kencana University Cianjur and the National Disaster Management Agency (BNPB) regarding the mapping of earthquake-affected areas in Cianjur.
2. Performing direct assessments of buildings damaged by the earthquake.
3. Inspecting building structures (columns, beams, roofs, and walls) for damage, whether minor, moderate, or severe, to classify the extent of damage.
4. Coordinating with BNPB to verify the buildings assessed in the field, which will then be eligible for material compensation from the central government's Ministry of Social Affairs.
5. Providing education on earthquake-resistant construction to local residents, ensuring they receive guidelines for building earthquake-resistant homes during repairs.

3. RESULT AND DISCUSSION

Result

3.1 Column Structure Failure

From the assessment conducted by the team from the Civil Engineering Program at FT UKI from December 12 to 17, 2022, several images were obtained showing the damage and collapse patterns of various residential buildings and public facilities in Cianjur. Figure 3 below illustrates the failure that occurred in the column structure due to the column's inability to withstand the applied loads and poor design for supporting axial loads and beams. The image shows that the column can no longer properly support the beams and roof framework.

Figure 3: Column Structure Failure Unable to Support Beam and Roof Framework

3.2 Beam Structure Failure

In addition to the column failures, several structural failures in the beams were also identified. Figure 4. below shows the structural failure in the beam due to the inadequate connection between the beam and the column.

Figure 4: Beam Structure Failure Due to Poor Design for Load Bearing

3.3 Collapse of Building Walls

Structural damage was also found in the installation of house walls, where bricks or concrete blocks were not anchored during installation. This can be seen in Figure 6 below, where the house wall collapsed due to the lack of anchors to bind the bricks or concrete blocks used.

Figure 5: Photo of Wall Collapse Due to Poor Design and Lack of Anchors/ Reinforcement in the Columns to Bind the Wall

3.4 Roof Structure Failure

Structural failures were also found in the roof structure. The assessment revealed that the connections in the roof trusses were inadequate, resulting in many roof joint failures, as shown in Figure 6.

Figure 6: Failure of Connections in the Wooden Roof Frame

3.5 Foundation Structure Failure

Cianjur Regency is highly susceptible to earthquakes due to the influence of potential faults that cause ground movements. These ground movements are expected to lead to surface fault hazards and collateral hazards such as ground cracks, subsidence, landslides, and even liquefaction. These issues can potentially reduce the bearing capacity of foundations to support loads. Ground movement can also cause foundation shifting or overturning. Foundations are a critical part of the substructure that must be carefully analyzed and installed in the field. Structural failure of the foundation can result in the collapse of the building, causing columns and beams to fail. Post-earthquake inspections in Cianjur revealed that foundation installations lacked attention to detail in joint connections and reinforcement placement, as shown in Figure 7.

Figure 7: Foundation Structure Failure in Supporting Axial and Vertical Loads

3.6 Rebar Hook Failure

Failures in rebar hooks are commonly encountered in the field due to a lack of understanding of the use of hooks or stirrups in reinforcement. Proper bending details for rebar/ hooks are crucial to anticipate collapse patterns (shear force/axial force) in beam and column structures [7]. SNI-2847-2019 specifies standard hook types, including 90˚ hooks, 180˚ hooks, stirrup hooks, and tie reinforcement hooks with < 135˚. Figure 10 shows the use of rebar hooks that do not comply with these standards.

Figure 8: Failure in Rebar Hook Installation in Columns

3.7 Hazard, Vulnerability, and Capacity in Relation to Earthquake Disaster Risk in Cianjur

Vulnerability is defined as a combination of physical, social, and psychological conditions that influence the level of disaster risk. In Cianjur, psychological vulnerability to seismic events remains high, as reflected by the significant casualties and structural damages. The region's response capacity is considered inadequate, evidenced by the limited availability of medical supplies and emergency equipment. Given its high seismic potential and elevated vulnerability, coupled with insufficient response capacity, Cianjur is classified as a high-risk earthquake-prone area [8].

3.8 Earthquake Disaster Mitigation

Disaster mitigation refers to a series of measures that aim to reduce the impact of natural disasters, both in the form of casualties and property losses (BNPB, 2010). In the Cianjur area, earthquake mitigation efforts are carried out through several main strategies, namely the identification of earthquake-prone areas based on seismic maps, the construction of houses with earthquake-resistant construction designs in accordance with SNI 03-1726-2019**,** and the evaluation and renovation of buildings that have not met resilience standards. Other measures include securing furniture so that it does not collapse during earthquakes, providing evacuation maps in vulnerable areas, and establishing community-based organizations to improve preparedness and public education related to earthquake risks. Emergency measures implemented include sheltering under a sturdy table, getting out of the elevator immediately after stopping, staying away from outdoor buildings, leaving bridges to the safe side, and avoiding coastal areas in anticipation of tsunamis. Motorists are urged to stop their vehicles and move to the nearest evacuation location Post-disaster management includes evaluation of victims' health conditions (Psychology Healing, trauma healing),[9], [10], [11], [12] operational control of health services, handling of wounded and corpses, prevention of infectious diseases, meeting nutritional needs, strengthening information and coordination systems, Sanitation (Installation/Procurement of Clean Water) and MCK [13] , as well as the delivery of medical and logistical assistance from various regions.[14]

Discussion

Column structure failure occurs when columns are unable to withstand loads (especially bending forces), leading to structural failure and column collapse. Therefore, it is crucial to pay attention to the details of stirrup and main bar reinforcement in column design [15] . Field inspections revealed that the concept of strong column-weak beam design has not yet been implemented, and improper column reinforcement according to standards has resulted in numerous building collapses and failures, [16], [17], [18].

Beams are a key structural component of buildings and require careful design and planning. Beam design must adhere to established rules and standards to prevent and anticipate failures [19]. A proper understanding of good and correct building design principles is essential when designing structural elements. Many field cases reveal discrepancies between the design concept and actual construction, which can lead to critical structural issues. According to SNI 2847-2019, detailed reinforcement must be accurately designed to mitigate shear failures in the structure. Figure 12 below illustrates the detailing of reinforcement in beams and exterior columns. To prevent collapse of walls, anchors/ reinforcements should be installed every 6 layers of bricks to secure the bond between the wall and column structure.

4. CONCLUSION

From the survey and direct assessment conducted on building damage Cianjur Regency, the following structural damage was observed Strong column-weak beam concept has not been applied in the construction of houses. This is evident from columns that are not designed to withstand axial forces, resulting in many columns being broken and damaged. The column reinforcement does not meet SNI 2847-2019 standards. Beam structures were not designed to resist bending moments and shear forces. This is observed from shear reinforcements lacking 90˚ and 135˚ hooks, leading to beam cracking and failure. Beam-column connections were poorly designed. This is evident from numerous joints being damaged and broken, causing floor slabs to collapse. Foundation reinforcement details were not properly installed according to standards, causing the foundation to be unable to support the forces transferred from the columns. Walls and roofs experienced cracking and damage due to the lack of anchors in the walls and improper detailing and construction of the truss connections, leading to many truss connections breaking.

In addition, need to be improved and coordinated well after post-disaster management measures should include the assessment of survivors' health conditions (psychological support and trauma healing), the operational control of healthcare services, the treatment of injured victims and the management of fatalities, the prevention of communicable diseases, the provision of adequate nutrition, the strengthening of information systems and coordination mechanisms, the improvement of sanitation facilities (installation and supply of clean water) and latrines, as well as the deployment of medical personnel and logistics assistance.

5. REFERENCES

[1] Elferida Sormin, Ulinata, Sudarno P. Tampubolon, and Haposan Sahala Raja Sinaga, "Strengthening Communities of Earthquake Victims through a Sanitation Program (Installation/Clean Water Supply and Portable MCK in Kampung Tugu Rw 3 Cibeureum Village, Cugenang, Cianjur)," Asian Journal of Community Services, vol. 2, no. 1, 2023, doi: 10.55927/ajcs.v2i1.2570.

[2] L. E. Hutabarat, "Tinjauan Geologis Gempa Cianjur November 2022," Jurnal Rekayasa Teknik Sipil dan Lingkungan, Program Studi Sipil, Universitas Kristen Indonesia, Jakarta, vol. 4, no. 1, 2023.

[3] S. Mokodenseho, Hasrullah, M. Mokodompit, J. Salinsehe, and N. Paputungan, "Analisis Geologis Gempa di Cianjur : Karakteristik Seismik, Zona Patahan, dan Peran Geologi dalam Penilaian Risiko Gempa," Jurnal Geosains West Science, vol. 1, no. 02, 2023, doi: 10.58812/jgws.v1i02.420.

[4] T. Zubaidah et al., "Investigasi Tingkat Kerawanan Gedung Dalam Rangka Implementasi Mitigasi Gempa Bumi di Fakultas Teknik Universitas Mataram," Jurnal Gema Ngabdi, vol. 3, no. 3, 2021, doi: 10.29303/jgn.v3i3.160.

[5] S. Samsunan and D. Febrianti, "Analisa Tingkat Kerusakan Struktur Kolom Terkena Tsunami," Jurnal Teknik Sipil dan Teknologi Konstruksi, vol. 4, no. 1, 2018, doi: 10.35308/jts-utu.v4i1.591.

[6] V. M. Zakhra, Y. Styawan, E. I. Fattah, and A. Farduwin, "ANALISIS GEMPA CIANJUR 2022 DENGAN PENDEKATAN SPASIAL TEMPORAL a-VALUE DAN b-VALUE," JGE (Jurnal Geofisika Eksplorasi), vol. 9, no. 3, 2023, doi: 10.23960/jge.v9i3.318.

[7] S. P. Tampubolon, "Analisis Kekuatan Geser Pada Hubungan Balok-Kolom Interior Beton Bertulang," JCEBT (Journal of Civil Engineering Building and Transportation), vol. 5, no. 1, pp. 56–63, 2021, doi: 10.31289/jcebt.v5i1.3731.

[8] S. Mokodenseho, Hasrullah, M. Mokodompit, J. Salinsehe, and N. Paputungan, "Analisis Geologis Gempa di Cianjur : Karakteristik Seismik, Zona Patahan, dan Peran Geologi dalam Penilaian Risiko Gempa," Jurnal Geosains West Science, vol. 1, no. 02, 2023, doi: 10.58812/jgws.v1i02.420.

[9] I. A. Soenandi, P. Peranginangin, M. Silalahi, Y. Y. Mokorowu, and M. Ginting, "Pemulihan Kesehatan Dan Fasilitas Pendidikan Pasca Gempa Cianjur Di Wilayah Cugenang," Jurdimas (Jurnal Pengabdian Kepada Masyarakat) Royal, vol. 6, no. 3, 2023, doi: 10.33330/jurdimas.v6i3.2274.

[10] M. Suara et al., "Penanganan Dampak H + 14 Pasca Bencana Gempa Bumi dengan Masalah Kesehatan di Desa Mangun Kerta Kecamatan Cugenang Kabupaten Cianjur," Jurnal Kreativitas Pengabdian Kepada Masyarakat (PKM), vol. 6, no. 4, 2023, doi: 10.33024/jkpm.v6i4.8946.

[11] S. H. Widiastuti, H. K. Siregar, S. M. Pangaribuan, and L. Siringoringo, "PENDAMPINGAN TROUMA HEALING PADA MASYARAKAT YANG TERDAMPAK BENCANA GEMPA BUMI DI KABUPATEN CIANJUR, JAWA BARAT," JMM (Jurnal Masyarakat Mandiri), vol. 7, no. 2, 2023, doi: 10.31764/jmm.v7i2.13143.

[12] A. Septian, E. Komala, A. Rahadian, Y. Suryani, D. Azkia, and E. S. Karnia, "Implementasi Trauma Healing dan Sekolah Alam Pasca Gempa Bagi Anak-anak di Cianjur," Jurnal Pengabdian Sains dan Humaniora, vol. 2, no. 2, 2023, doi: 10.32938/jpsh.2.2.2023.107-115.

[13] Elferida Sormin, Ulinata, Sudarno P. Tampubolon, and Haposan Sahala Raja Sinaga, "Strengthening Communities of Earthquake Victims through a Sanitation Program (Installation/Clean Water Supply and Portable MCK in Kampung Tugu Rw 3 Cibeureum Village, Cugenang, Cianjur)," Asian Journal of Community Services, vol. 2, no. 1, 2023, doi: 10.55927/ajcs.v2i1.2570.

[14] M. A. Kurniayanti, "Peran tenaga kesehatan dalam penanganan manajemen bencana," JURNAL ILMIAH KESEHATAN MEDIA HUSADA, vol. 1, no. 1, 2021.

[15] S. Tampubolon, "Analisis Kekuatan Geser Pada Hubungan Balok-Kolom Interior Beton Bertulang," JOURNAL OF CIVIL ENGINEERING BUILDING AND TRANSPORTATION, 2021, doi: 10.31289/jcebt.v5i1.3731.

[16] H. LE, S. P, and T. S, "Peningkatan Kesadaran Masyarakat terhadap Kerusakan Bangunan dan Lingkungan Pasca Gempa, Tsunami dan Likuifaksi di Palu Sulawesi Tengah," JURNAL ComunitÃ Servizio : Jurnal Terkait Kegiatan Pengabdian kepada Masyarakat, terkhusus bidang Teknologi, Kewirausahaan dan Sosial Kemasyarakatan, 2019, doi: 10.33541/cs.v1i2.1290.

[17] S. P. Tampubolon, I. P. E. Sarassantika, and I. W. G. Suarjana, "Analisis Kerusakan Struktur Bangunan dan Manajemen Bencana Akibat Gempa Bumi, Tsunami, dan Likuifaksi di Palu," Bentang : Jurnal Teoritis dan Terapan Bidang Rekayasa Sipil, vol. 10, no. 2, 2022, doi: 10.33558/bentang.v10i2.3263.

[18] T. Winarsih, "Asesmen Kekuatan Struktur Bangunan Gedung, Studi Kasus Gedung Bangunan Gawat Darurat Rumah Sakit Umum Daerah," 2010.

[19] S. P. Tampubolon, "Analisa Perbandingan Hasil Pengujian Laboratorium dan Simulasi Pada Balok Beton Bertulang," PADURAKSA: Jurnal Teknik Sipil Universitas Warmadewa, vol. 10, no. 1, pp. 195–210, 2021, doi: 10.22225/pd.10.1.2632.195-210.

[20] Arifa SH. Analisis Pengambilan Kebijakan Mitigasi Bencana Gempabumi Kabupaten Cianjur November 2022. Jurnal Planoearth. 2025 Apr 13;9(2):64-9.