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Identification Of Damage Levels Of Residents' Houses Due To Earthquake in Pasaman 2022

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Abstract

The earthquake that occurred in Pasaman on February 25, 2022 has caused considerable losses to local residents. Thousands of buildings have been damaged and collapsed due to the earthquake, especially houses of residents, which in the field investigations are mostly caused by lack of knowledge in building these houses. This study aims to identify the level of damage to houses damaged by the earthquake in Nagari Malampah, Pasaman District, West Suatera. This research method is carried out by direct observation and investigation to the research location, then identifying the level of damage to residents' houses, by taking 10 samples of affected residents' houses. Of the 10 houses, the percentage of damage will be grouped based on the level of Light Damage, Medium Damage, and Heavy Damage, with reference to the Technical Guidelines for the Director General of Human Settlements, SNI 1726-2019 and PU Guidelines. The results of this study indicate that the percentage of the level of damage to houses that are lightly damaged ranges from 7.1% - 26%, the level of moderate damage ranges from 32.5% - 36.09%, and the level of residential buildings that experience severe damage (total collapse). ranged from 50% - 100%.

Keywords: Earthquake, level of damage to buildings, Nagari Malampah, Pasaman, residents' houses.

1. Introduction

The geographical location and position of the West Sumatra region which is between the Subduction Zone of the world's three major plates, namely the Eurasian, Indo-Australian and Philippine Plates and is crossed by the Sumatran Great Fault or Semangko Fault, has put this region in a very serious earthquake threat [1],[2],[3],[4],[5]. Many large destructive earthquakes have occurred in the West Sumatra region, most of which are the result of the collision between these plates and the Mentawai Megathrust [6],[7]. Several earthquakes occurred in West Sumatra, such as the 2004 Tanah Datar earthquake, the 2009 Padang and surrounding earthquakes, the 2010 Mentawai earthquake, the 2010 and 2018 Solok earthquakes, and the last West Pasaman earthquake in early 2022 [8].

Many losses have been caused by the earthquake that occurred in the West Sumatra region. For example, the 30 September 2019 earthquake has caused more than a thousand fatalities, 1200 people were injured, and more than 100 thousand buildings were highly, moderately and lightly damaged [9]. The last earthquake in West Sumatra was an earthquake 6.1 on the Richter Scale (SR) that occurred in the Pasaman area, precisely in Nagari Malampah, Tigo Nagari District, Pasaman Regency, on February 25, 2022 ago. Prior to this high earthquake, an earthquake had occurred at 08.35 a.m centered on land at a distance of 18 km Northeast with a depth of 10 km, but did not cause any damage. It was only after that a large earthquake at 08.39 a.m with a magnitude of 6.1 on the Richter scale centered on land at a distance of 17 km Northeast with a depth of 10 km. This last earthquake caused the collapse and damage to buildings and caused flash floods. Besides that, in addition to building damage, this earthquake has also caused the death toll of 18 people [10]. The impact of building damage due to the 2022 Pasaman earthquake can be seen in Table 1.

Table 1. The impact of the 2022 Pasaman earthquake [11]

Wilayah	Rumah Rusak	Meninggal	Luka Berat	Luka Ringan
Kabupaten Pasaman	1.736 unit	9 orang		1 orang
Kabupaten Limapuluh Kota	27 unit	-	-	-
Kota Padang dan Agam	2 unit	-	1 orang	-
Pasaman Barat	4.831 orang	18 orang	46 orang	336 orang

The Meteorology, Climatology and Geophysics Agency (BMKG) has found a new fault segment in West Sumatra. Previously in the Pasaman area, which frequently affected the earthquake in that area were the Ancora and Sianok faults. But now a new fault segment has been found, namely the Talamau fault, as shown in Figure 1. This fault is classified as a right-hand shear fault, which is a characteristic of the seismic mechanism of the Sumatra fault.

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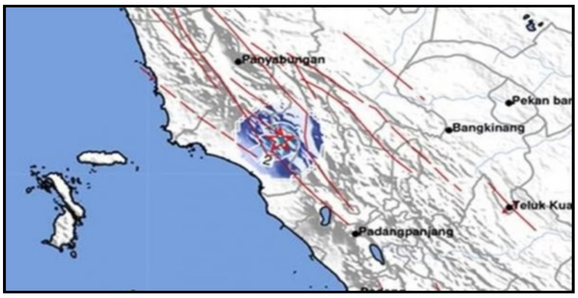

Figure 1. Talamau fault segment

This Post-earthquake damage to buildings in Nagari Malampah, Tigo Nagari District in Pasaman Regency, West Sumatra, was caused by a lack of knowledge about buildings in accordance with the established building planning standards. Most of the people in Pasaman Regency build houses only based on experience, as a result the buildings that are built are not in accordance with standards, so there is a risk of building damage very easily due to the earthquake (Interview with Mr. Kasuman, 2022).

2.1. Earthquake Events

Large earthquake events can damage and even collapse buildings. Earthquakes are natural vibrations that occur in the earth's rocks and spread to the ground surface in the form of seismic vibrations and can affect the foundation and structure of the building above it [12],[13]. Earthquakes cannot be predicted both when the magnitude is precise, but the estimated location can be predicted. Earthquakes are natural events that occur due to the influence of the earth's plates colliding with each other. An earthquake event can become an earthquake disaster if the environment and people in the area affected by the event suffer losses due to the event [14]. Directly, earthquakes do not cause death to humans. However, the impact of an earthquake that can collapse and damage buildings such as residents' houses, facilities and infrastructure buildings, as well as office buildings, which has an impact on death, that's when the earthquake is said to have resulted in fatalities [15]. Many buildings and houses of residents are prone to earthquake disasters. As a result, many of these buildings were destroyed and damaged by the earthquake [16]. In general, damage to buildings due to earthquakes can be divided into, heavily damaged buildings, moderately damaged buildings and lightly damaged buildings. Severe damage such as plaster on the walls being removed, brick walls cracked or broken, damaged ceilings, and building collapses. While minor damage is damage that occurs to building structural elements, such as cracks in the columns, plates or beams, detachment of the concrete cover of beams and columns or rupture of the head or bottom of the column. Earthquakes cannot be avoided, but we can reduce the adverse effects caused by earthquakes by planning and building earthquake-resistant buildings or strengthening the buildings to be built. Currently, technology and findings from research on earthquake construction design have been widely developed, where efforts have begun to develop to prevent and reduce the impact of this earthquake, either directly or indirectly. Generally, the loss of life and property loss caused by the earthquake occurred due to the damage or collapse of simple (non-engineered) buildings. These buildings are usually owned by residents, such as houses, schools, houses of worship and others which are usually built by residents without the help of structural experts. When the earthquake occurred, most of the buildings were heavily damaged, slightly damaged, although some did not collapse. Earthquakes can cause danger and disaster as a result of the damage or collapse of buildings and other man-made structures. Until now humans have not been able to do much to prevent earthquakes. However, humans can reduce the adverse effects caused by earthquakes by planning and building earthquake-resistant buildings or strengthening artificial structures. There are 2 types of earthquake-resistant buildings, namely (1) conventional earthquake-resistant buildings that rely on the strength of the building materials, namely elastic (rigid) and ductile (ductile) properties, rigid properties are owned by materials from concrete and masonry, while clay properties are owned by metal, wood and bamboo, (2) buildings with base insulators. Base insulator is a material made of rubber and mild steel which is placed between the foundation (sub-structure) and sloof/column (super structure) which functions to reduce/reduce earthquake energy/acceleration of the subgrade to the building so that the destructive nature of the earthquake can be minimized [17].

2.2. Types of Structures and Failures in Buildings

Figure 2. Damage to buildings due to the 2022 Pasaman earthquake

Structures can be grouped into non-engineered and engineered structures. Non-engineered structures are simple buildings designed without structural experts, while engineered structures are structures that are well planned by a planning consultant or structural expert. Structural damage due to earthquake can be divided into non-structural damage and structural damage. Non-structural damage is damage that occurs in non-structural parts of the building, such as detached wall plaster, cracked or broken brick walls and damaged ceilings. Structural damage is damage that occurs to the main elements of the building structure, such as cracks in the columns, plates or beams, the detachment of the concrete cover of the beam/column or the breaking of the head or bottom of the column. This structural damage can be seen in Figure 2, where it can be seen that there is poor reinforcement detailing.

2.3. Classification of Damage to Building Structural Elements

The types of damage to structural elements due to earthquakes can be grouped as in the following description.

1. Connection Failure

Connection failure causes the beam-column connection system to be vulnerable to repeated seismic loads. This failure will cause a large shear stress in the joint and can cause shear failure. Besides, the wall automatically collapses because the wall is not designed for earthquake loads. Joint failures are generally caused by factors such as tight reinforcement spacing.

2. Plastic Joint Failure

Damage to the plastic hinges on the column is caused by the diameter and distance of the shear reinforcement which has poor concrete quality and does not meet the requirements of earthquake-resistant buildings. The distance between the shear reinforcement is very large, so that when an earthquake occurs, the column is not strong enough to withstand cyclic loads.

3. Failure of Column Bonding to Foundation

Most of the non-structural buildings were not built by construction experts and did not pay attention to the risk of damage in the event of an earthquake.

4. Less Concrete Mix to the Foundation

The composition of concrete that does not meet the specified standards and requirements, will usually result in damage and failure of the concrete used.

5. Wall Damage

Damage to walls after an earthquake is very common in large and small earthquakes. Damage to walls generally occurs in the column area that touches the wall and the area around windows and door frames.

2.4. Classification of Structural Damage According to the Technical Guidelines for Cipta Karya

Formula The classification of the level of building damage is calculated based on the following equation [18]:

$$\text{Level of Demage}\,(\%) = \frac{QD}{DT} \times 100\% \qquad (1)$$

where DT is the number and or total area of the damaged area and QD is the number and or area of the damaged part. The percentage indicator for the classification of the level of damage is determined with the following provisions:

1. Damage level < 30%, then the damage classification is at the Light Damage level,
2. the damage level is between 30% - 45%, then the damage classification is at the Medium Damage level, and
3. damage level > 45% - 100%, then the damage classification is at the Heavy Damage level.

The classification of structural damage according to the Technical Guidelines of Cipta Karya can be grouped as follows.

1. *Low Damage*. The building is said to be low damaged if there is damage to non-structural elements such as fine cracks in stucco, falling stucco fragments, with architectural repair actions without vacating the building. Other forms of damage such as, small cracks (gap width between 0.075 to 0.6 cm) on the wall, falling plaster, covering a large area, damage to the chimney, lisplang, the ability of the structure to bear the load is not much reduced and is fit for function/habitability. Actions that need to be taken are architectural repairs so that the durability of the building is maintained. Repairs with minor damage to structures can be carried out without emptying the building.
2. *Moderate Damage*. A building is said to be moderately damaged if the following things occur in the building such as large cracks (gap width greater than 0.6 cm) in the walls, cracks spread widely in many places, such as in load-bearing walls, columns, sloping chimneys and collapse. Besides, the ability of the structure to bear the load has been reduced in part and the building is still feasible.
3. *Highly Damage.* Highly damage to building structures due to earthquakes such as load-bearing walls split and collapsed, buildings separated due to failure of binding elements, about 50% of the main elements were damaged and the buildings were unfit for habitation.

Damages in simple buildings usually occur in foundation and column connections, column connections with beams, masonry walls and roof structural systems. Most of the time, to deal with damage such as the above conditions, residents usually decide to immediately tear down the building. This is a mistake that often occurs, because not all buildings damaged by the earthquake must be torn down. Further evaluation is needed to decide whether the building can be repaired only on damaged building elements or must be reconstructed by tearing it down first [15]. Many studies have been developed related to the identification of building damages and their evaluation due to earthquakes. Several related studies have been carried out as described below. Research by Saputra (2019) which aims to evaluate the damage to simple buildings caused by the earthquake in South Helmahera. The results of this study concluded that the criteria for house damage with the category of minor damage was 39.67%, and severe damage was 48.00% [19]. Jafar (2021) conducted a study on the comparison of actual and predicted damage to unreinforced walls due to earthquakes, which aims to classify buildings based on structural components and elevation ranges. The results of his research explain that the average damage (MDR) for the actual damage to the URML building is 20.40%, while the estimated damage is 11.66% [20]. Research by Bawono (2016) on the Vulnerability of Residential Residential Buildings in Bantul in Nine Hamlets. The method used to evaluate the damage is the Fuzzy Analythic Hierarchy Process (FAHP) method. The results of this study concluded that there were 199 houses completely damaged, 429 heavily damaged, and 218 houses lightly damaged. In general, the level of damage in the studied area is at a moderate level of vulnerability [21]. Subsequent research by Kusumaningrum (2017), which aims to identify the level of damage to residents' houses due to the Yogayakrat earthquake in May 2006 and the West Sumatra earthquake in September 2009. The research method used is interview technique with quantitative analysis. The subjects of this study were employees of BPBD Bogor Regency, Bandung Regency, Tasikmalaya Regency, Yogyakarta Province, Banyumas Regency and surveyors Rekompak. The results of his research concluded that the group of houses with minor damage <30% which was marked by architectural damage and the building was still standing. The moderate damaged category is indicated by the building still standing, a small part of the structural components being damaged, with a percentage of around 30%-70%. Meanwhile, the houses that suffered heavy damage, which was marked by the collapsed buildings, were more than 70% [13]. The research that will be carried out is to evaluate and identify the level of damage to residents' houses due to the earthquake that occurred on February 25, 2022 in the Pasaman area. The research method used is direct observation to the research location to collect primary data. Data analysis was carried out with a quantitative approach.

2. Research Method

This research is an observational study with direct survey actions to the field or to the research study area, namely to areas directly affected by the Pasaman earthquake on February 25, 2022, precisely in Nagari Malampah, Tigo Nagari District, Pasaman Regency, West Sumatra Province. The research area can be seen on the administrative map of Pasaman Regency in Figure 3. The research data needed are in the form of primary and secondary data.

Observations to research study locations through survey activities were carried out to collect primary data in the form of documentation of the condition of residents' houses that were damaged, either heavily damaged, moderately damaged or lightly damaged, where this data will later be planned to identify and classify the level of building damage. Other primary data is data in the form of interviews with victims whose houses collapsed or were damaged. The data from this interview are used to make recommendations for building improvements that are evaluated. Furthermore, secondary data was collected from related parties such as the administrative map of the Pasaman Regency, texts in the form of reference standards used such as the SNI-1726-2012 Manuscript on Earthquake Resistant Building Resilience [22], as well as the Technical Guidelines of Ditjen Cipta Karya PU 2006. This study uses a quantitative-qualitative approach with an analytical method that refers to SNI-1726: 2012, and Technical Guidelines of Ditjen Cipta Karya PU 2006. Data analysis to classify types of damage to residential buildings refers to SNI-1726-2012, while to classify the level of damage and analysis of recommendations for repairs to these damages was made based on Technical Guidelines of Dirjen Cipta Karya 2006.

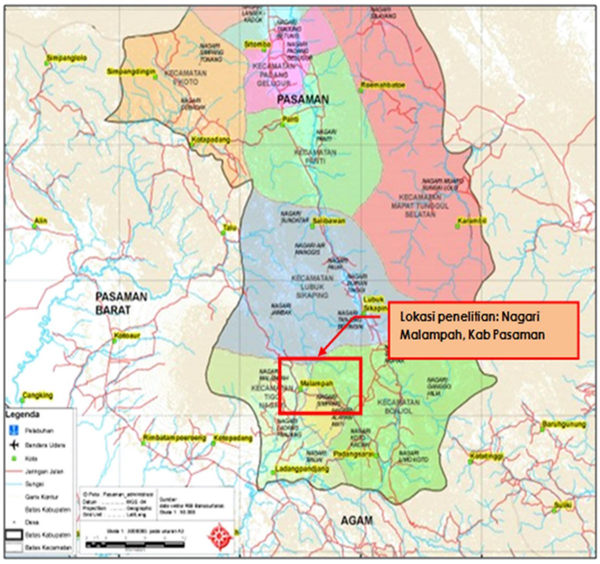

Figure 3. Damage to buildings due to the 2022 Pasaman earthquake

3. Result and Discussion

3.1. Identification of Types of Damage to Residents' Houses

From the survey and analysis that has been carried out, it can be classified some building damage from residents' houses, both totally damaged or lightly damaged and moderately damaged. The types and identification of damage to residential buildings due to the 2022 Pasaman earthquake are as follows:

1. Damage to the walls of the house, which is shown from the front view (Figure 4),
2. damage to the wall and column structure, which is shown from the side view (Figure 5),
3. buildings that are damaged on the walls. The wall suffered from cracks and also the plaster of the damaged wall was quite extensive and fell due to the energy of the earthquake waves (Figure 5),
4. buildings damaged by the earthquake occurred on the columns, truss, and walls (Figure 6),
5. building damage that occurred in the column, cracked and collapsed walls (Figure 6), and
6. buildings that were damaged by earthquakes in all building structures, damage to walls, floors, roofs, window frames, doors, and houses did not use a column structure, only using wooden beams as support poles. Under these conditions, the building becomes uninhabitable and cannot be repaired, because the structure has been completely damaged, so the building must be rebuilt by following the applicable standard procedures (Figure 7).

Figure 4. Damage to the wall

Table 2. Identification of level of damage

No	Elements of structure	Number of damage	Level of Damage (%)
1	wall (Figure 4)	Number coloumn (DT) = 105 cm^2 Damage element (QD) = 24,5 cm^2	Level = 24,5/105*100%=24,5% < 30% → **Low damage**
2	Wall & coloumn (Figure 5)	Total wall area (LT) = 126 cm^2 Damage element (QD) = 19,8 cm^2	Level=19,8/126*100%=15,7% < 30% → **Low damage**
3	Coloumn & ring beam (Figure 5)	Numbercoloumn+ring beam=10+4=14 Number coloumn +ring beam damage = 1	Level = 1/14*100% = 7,1% < 30% → **Low damage**
4	Element wall (Figure 4)	Total wall area = 133 m^2 Damage element = 35 m^2	Level = 35/133*100% = 26% < 30% → **Low damage**
5	Wall element (Figure 5)	Total wall area = 162 cm^2 Damage element = 52 cm^2	Level = 52/162*100 = 32,5% → **Moderete damage**
6	Wall element (Figure 6)	Total wall area = 176 cm^2 Damage element = 60 cm^2	Level = 60/176*100 = 34,09% → **Moderete damage**
7	Wall element (Figure 7)	Total wall area = 119 cm^2 Damage element = 80 cm^2	Level = 80/119*100 = 67,22% > 65% → **High damage**
8	door, sill, window (Figure 7)	Number of door = 6 total number sill + window = 14 cm^2 Number of door, sill, number of damage = 11	Level = 11/14*100 = 78,6% > 65% → **High damage**
9	Floor (Gambar 8)	Total area floor =72 cm^2 Damage floor area = 36 cm^2	Level = 36/72*100 = 50% > 50% → **High damage**
10	Penutup atap (Gambar 10)	Total area = 144 cm^2 Damage element = 144 cm^2	Level = 144/144*100 = 100% > 65% → **High damage**
11	Rangka atap (Gambar 8)	Total area = 144 cm^2 Damage element = 144 cm^2	Level = 144/144*100 = 100% > 65% → **High damage**

Figure 5. Damage to walls and column structures

Figure 6. Damage to columns, walls cracked and collapsed

Figure 7. Total damage to the house

3.2. Classification and Types of Damage to Residents' Houses

The The calculation of the grouping of building damage level criteria is calculated based on Equation (1), and refers to documentation data and pictures of damaged house buildings in accordance with the explanation of the types of damage described in the description above. The level of damage from the analysis that has been carried out is shown in Table 2 above.

4. Conclusion

From the research and analysis that has been carried out, it can be concluded that the percentage of building damage criteria for Light Damage level ranges from 7.1%-26%, Moderate Damage level ranges from 32.5%- 36.09%, while the level of Severely Damaged buildings (total collapse) ranged from 50%- 100%.

References

[1] H. S. Naryanto, "Analisis Potensi Kegempaan dan Tsunami di Kawasan Pantai Barat Lampung Kaitannya dengan Mitigasi dan Penataan Kawasan," J. Sains dan Teknol. Indones., vol. 10, no. 2, pp. 71–77, 2008.

[2] I. Sugiyarto, R. Irawan, and D. Rosiyadi, "Pengelompokan Dampak Gempa Bumi Dan Kerusakan Pada Wilayah Berpotensi Gempa Di Provinsi Sumatra Barat," J. Students‘ Res. Comput. Sci., vol. 2, no. 2, pp. 211–222, 2021, doi: 10.31599/jsrcs.v2i2.850.

[3] R. Kurniawan, A. Mahtarami, and R. Rakhmawati, "GEMPA: Game Edukasi sebagai Media Sosialisasi Mitigasi Bencana Gempa Bumi bagi Anak Autis," J. Pendidik. dan Pembelajaran Univ. Negeri Malang, vol. 6, no. 1, pp. 115–120, 2017, [Online]. Available: http://studentjournal.petra.ac.id/index.php/desain-interior/article/view/2146.

[4] Supartoyo; and E. K. Abdurachman, "Kejadian gempabumi merusak di indonesia tahun 2007," Badan Meteorol. Klimatologi dan Geofis., pp. 32–43, 2007.

[5] T. K. Wibawa and A. Zakariya, "Mitigasi Gempa Bumi Menggunakan Detektor Gempa Sederhana Sistem Relay dengan Mengacu Prinsip Struktur Dinamik," ....., pp. 1–10, 2006.

[6] R. Imani, "Seismic Pattern Based on Analysis of Fractal Variations Before the 2009 Sumatra Earthquake With Zmap Software," J. Islam. Sci. Technol., vol. 4, no. 1, 2019.

[7] H. Murtianto, "Potensi Kerusakan Gempa Bumi Akibat Pergerakan Patahan Sumatera Di Sumatera Barat Dan Sekitarnya," J. Geogr. Gea, vol. 10, no. 1, 2016, doi: 10.17509/gea.v10i1.1667.

[8] E. Tanjung, "10 Kali Gempa Dahsyat yang Pernah Mengguncang Sumatera Barat Sejak Tahun 1835," https://www.suara.com, 2022..

[9] W. Setyonegoro, "Gempabumi Padang 30 September 2009 dan Potensi Tsunaminya," Bul. Meteorol. Klimatologi dan Geofis., vol. 7, no. 3, pp. 163–171, 2013, [Online]. Available: https://www.academia.edu/7677524/GEMPABUMI_PADANG_30_SEPTEMBER_2009_DAN_POTENSI_TSUNAMINYA_Wiko_Setyonegoro_163_GEMPABUMI_PADANG_30_SEPTEMBER_2009_DAN_POTENSI_TSUNAMINYA.

[10] D. Prastiwi, "Gempa Hari Ini Jumat 25 Februari 2022, Terjadi Tujuh Kali di Indonesia," https://www.liputan6.com, 2022. .

[11] H. D. Situmorang, "1.765 Rumah Rusak Akibat Gempa Sumbar," https://www.beritasatu.com, 2022.

[12] R. I. Imani, S. Anita, S. O. Laurency, and F. Rozi, "Asesmen, Perkuatan Dan Perbaikan Bangunan Non-Engineered Perumahan Mekar Melati Kelurahan Lubuk Minturun Kota Padang Pascagempa 2009," Constr. Mater. J., vol. 2, no. 1, pp. 23–32, 2020, doi: 10.32722/cmj.v2i1.2754.

[13] E. Kusumaningrum, "Evaluasi Kriteria Kerusakan Bangunan Rumah Tinggal Sederhana Akibat Gempa Bumi," Universitas Islam Indonesia Yogyakarta, 2017.

[14] G. Zuccaro, F. L. Perelli, D. De Gregorio, and F. Cacace, "Empirical vulnerability curves for Italian mansory buildings: evolution of vulnerability model from the DPM to curves as a function of accelertion," Bull. Earthq. Eng., vol. 19, no. 8, pp. 3077–3097, 2021, doi: 10.1007/s10518-020-00954-5.

[15] B. Hadibroto and S. Ronitua, "Perbaikan Dan Perkuatan Bangunan Sederhana Akibat Gempa," Educ. Build., vol. 4, no. 1, pp. 46–55, 2018, doi: 10.24114/eb.v4i1.10044.

[16] N. Mamat, M. F. Othman, and M. F. M. Yakub, "In uence of Control Strategy in Risk Mitigation of Building Damage Due to Earthquake Influence Of Control Strategy in Risk Mitigation of Building," Res. Sq., vol. 2, pp. 0–18, 2021.

[17] M. Maeda, H. Al-Washali, and K. Matsukawa, "An overview of post earthquake damage and residual capacity evaluation for reinforced concrete buildings in Japan," in COMPDYN Proceedings, 2019, vol. 1, pp. 930–943, doi: 10.7712/120119.6969.19228.

[18] D. J. C. K. D. P. Umum, "Manual Book Pedoman Teknis Perbaikan Bangunan Sederhana Yang Rusak Akibat Gempa Bumi," 2005, p. 99.

[19] Jafar, Sarwidi, M. Teguh, and F. Nugraheni, "Perbandingan Kerusakan Aktual Dan Prakiraan Pada Bangunan Tembok Tanpa Perkuatan Akibat Gempa," J. Tek., vol. 26, no. 1, 2021, doi: 10.20885/teknisia.vol26.iss1.art5.

[20] A. S. Bawono, "Studi Kerentanan Bangunan Akibat Gempa : Studi Kasus Perumahan Di Bantul," Semesta Tek., vol. 19, no. 1, pp. 90–97, 2016.

[21] M. T. Y. Saputra, "Evaluasi Kerusakan Bangunan Sederhana Akibat Gempa Bumi di Halmahera Selatan," J. Sci. Eng., vol. 4, no. 2, pp. 130–137, 2021, [Online]. Available: http://ejournal.unkhair.ac.id/index.php/josae.

[22] Badan Standardisasi Nasional, Tata Cara Perencanaan Ketahanan Gempa Untuk Struktur Bangunan Gedung dan Non Gedung, no. 8. 2019, p. 254.