JURNAL RISET REKAYASA SIPIL
https://jurnal.uns.ac.id/jrrs/about/history
ISSN 2579-7999
JURNAL RISET REKAYASA SIPIL
UNIVERSITAS SEBELAS MARET

SEISMIC PERFORMANCE ANALYSIS OF CIRCULAR-SHAPED BUILDINGS IN PADANG

Hovifah Indra Parawansyah[1], Agustinus Agus Setiawan[1*]

[1]*Program Studi Teknik Sipil, Universitas Pembangunan Jaya, Blok B7/P, Jl. Cendrawasih Raya Bintaro Jaya, Sawah Baru, Kec. Ciputat, Kota Tangerang Selatan, Banten 15413*
Email: agustinus@upj.ac.id

ABSTRACT

Indonesia is a country with high seismic activity due to its location on the convergence of several tectonic plates, making earthquake-resistant structural design a crucial aspect of construction. This study aims to analyze the seismic performance of circular-shaped buildings based on displacement, story drift, and base shear, as well as to calculate the structural work volume. Prior studies rarely examined the seismic performance of circular buildings under Indonesian code, making this study's insights particularly novel and important. ***.*** *The modeling was carried out using Robot Structural Analysis Professional (RSAP 2025) software. The earthquake load analysis was performed using the equivalent static lateral force procedure in accordance with SNI 1726:2019, with the research location in Padang City. The analysis results show that the 8-story building experiences a maximum displacement of 22.56 mm in the X direction and 51.08 mm in the Y direction; the 5-story building has a maximum displacement of 6.33 mm in the X direction and 35.86 mm in the Y direction; and the 3-story building experiences 1.37 mm in the X direction and 7.98 mm in the Y direction. The maximum story drift for the 8-story building is 19.91 mm (X) and 43.34 mm (Y); for the 5-story building, 8.36 mm (X) and 48.51 mm (Y); and for the 3-story building, 2.86 mm (X) and 17.71 mm (Y). The base shear values are 4,950.56 kN for the 8-story building, 4,485.20 kN for the 5-story, and 2,691.12 kN for the 3-story building. The concrete requirement ratio is 0.287 m³/m², and the steel reinforcement requirement ratio is 150.31 kg/m³.*

Kata kunci: *base shear, circular, building, displacement, story drift*

1. INTRODUCTION

Indonesia is classified as a region with a very high level of seismic activity due to its location at the convergence of four major tectonic plates: the Indo-Australian, Eurasian, Pacific, and Caroline-Philippine plates. The interaction among these plates has resulted in the formation of numerous active fault lines that segment the Indonesian archipelago into several distinct regions. Consequently, nearly all areas across Indonesia are exposed to earthquake hazards. Earthquake disasters that have occurred in Indonesia often result in significant loss of life and extensive physical damage. One such event took place on September 28, 2018, in the capital of Central Sulawesi, within the Palu Valley region, with a magnitude of 7.4 on the Richter scale. This natural disaster led to 2,113 confirmed fatalities, 1,309 individuals reported missing, and widespread structural damage (Balitbang PUPR, 2018). Meanwhile, the 2022 Cianjur earthquake, which registered a magnitude of 5.6 on the Richter scale, resulted in 602 fatalities and damage to approximately 67,504 facilities (Akman and Faizal, 2022). Another major seismic event occurred in 2009, affecting the city of Padang with a magnitude of 7.6 Mw, resulting in 1,117 fatalities and damage to approximately 135,448 buildings(Ikhlas et al., 2022).

The high level of seismic activity in Indonesia has led to numerous buildings suffering severe damage. According to statistical data from the National Disaster Management Authority (BNPB) in 2022, a total of 15,951 buildings were reported as heavily damaged. In response to these figures, it is essential to develop buildings with adequate seismic performance. A well-designed structure with reliable performance should be capable of withstanding earthquake-induced forces without collapsing (Murty, C. V. R., Rupen, Goswami., A. R. Vijayanarayanan., 2018).

The design of earthquake-resistant structures has evolved from a force-based design approach to a performance-based design methodology. Structural design practices in Indonesia are generally governed by the SNI 1726:2019 code, which is adapted from ASCE 7-16 and tailored to the country's seismic conditions, replacing the previous SNI 1726:2012. One of the notable changes introduced in SNI 1726:2019 involves the seismic loading provisions, particularly regarding the dynamic base shear limit. While the 2012 version allowed it to be 85% of the equivalent static force, the 2019 revision requires it to match 100% of the static base shear force (Sucipto and Sutjipto, 2022).

Corresponding Author
E-mail Address : agustinus@upj.ac.id

The structural design in accordance with SNI 1726:2019 serves as a preventive measure to minimize potential damage. This effort includes conducting research on earthquake-resistant buildings in compliance with seismic design standards. One of the critical considerations in designing structures capable of withstanding seismic forces is the selection of the basic geometric configuration of the structure.

The selection of the fundamental configuration for multistory buildings must be capable of resisting both dynamic loads, such as seismic forces, and static loads, including self-weight and live loads (Mackenzie Davis, 2024). The architectural configuration of a building significantly influences the distribution of seismic loads and the structural behavior of the system. Rectangular-shaped buildings are the most commonly adopted basic forms. However, with the advancement of modern architectural design, non-rectangular shapes such as circular, trapezoidal, and other geometries are becoming increasingly prevalent. In particular, circular buildings, with their symmetrical and continuous geometry, are theoretically capable of achieving a more uniform stress distribution, thereby potentially enhancing their performance under seismic loading (Jiwane & Mahalle, 2024). Circular buildings exhibit distinct advantages in seismic resilience, such as uniform stress distribution and enhanced torsional resistance, stemming from their symmetric geometry (Bramhane et al., 2025). Another finding, according to Hasan et al. (2020), is that circular structures exhibit inferior seismic performance compared to square structures, demonstrating greater story displacement and drift, as well as reduced resistance to base overturning moments and lateral loads from wind and earthquakes. Tarigan et al. (2024) found that symmetrical (regular) buildings resist seismic loads more effectively, as their uniform mass distribution leads to lower forces (base shear, story shear, and torsion).

Earthquake-prone cities in Indonesia, such as Padang, serve as appropriate locations for conducting this research. Evaluating the seismic performance of non-rectangular buildings is essential to identify potential structural vulnerabilities and enhance building safety in high-risk seismic zones. A comparative study on the seismic performance of circular and rectangular-shaped buildings was conducted by Pritesh (2024), employing STAAD Pro to analyze a 15-story structure with a floor area of 750 m². The findings indicated that circular buildings exhibited superior structural performance under seismic conditions, demonstrating greater resistance to lateral forces and resulting in lower maximum displacements.

The author observes a limited number of studies focusing on the seismic performance analysis of circular-shaped buildings. This research is expected to serve as a reference for designers in evaluating the seismic behavior of circular buildings, particularly in earthquake-prone areas such as Padang City. The structural design process in this study employs Robot Structural Analysis Professional (RSAP) software. The design adheres to the provisions of SNI 1726:2019, which outlines the Seismic Resistance Design Guidelines for Building and Non-Building Structures. Additionally, material quantity analysis is incorporated as an initial step towards implementing Building Information Modeling (BIM), specifically for structural works

2. RESEARCH METHOD

The research methodology in this study involves several stages, including structural data collection, data processing, and analysis, in order to obtain meaningful results. This study utilizes Robot Structural Analysis Professional (RSAP) software to evaluate the seismic performance of a circular building based on the SNI 1726:2019 standard, which provides guidelines for earthquake-resistant design of buildings and non-building structures. The outcomes of this research include displacement, interstory drift, and base shear values from each building model, as well as the estimated volume of structural work derived from the modeling process.

Research location and duration

The object of this study is the seismic performance of circular-shaped buildings. The variables in this study were the number of levels taken from each model, specifically 3, 5, and 8 stories. The selected case study location is Padang City, an area known for its high seismic risk. This research focuses on evaluating the seismic performance of circular buildings through 3D modeling using Robot Structural Analysis Professional (RSAP), in accordance with SNI 1726:2019, which outlines the procedures for earthquake-resistant design of buildings and non-building structures. Following the seismic analysis, the study also examines the output in terms of structural work volume, based on the developed building model.

This research references several key Indonesian National Standards (SNI) to ensure accurate and earthquake-resistant design and analysis. Specifically, the standards used include SNI 1726:2019, which governs the Procedures for Earthquake Resistance Design of Buildings and Non-Building Structures; SNI 1727:2020, which establishes the Minimum Load Requirements for the Design of Buildings and Other Structures; and SNI 2847:2019, which contains the Structural Concrete Requirements for Building Design. By applying these three standards, the research ensures

Jurnal Riset Rekayasa Sipil Universitas Sebelas Maret
ISSN: 2579-7999
Vol. 9 No. 2, Maret 2026

that the structural models being tested meet the minimum safety, loading, and structural concrete material detailing criteria in line with the latest civil engineering practices in Indonesia.

The concrete strength used for the column, beam, slab, and shear wall elements is f'_c=30 MPa, while the reinforcing steel yield strength is 300 MPa for plain reinforcing steel and 420 MPa for deformed reinforcing steel. Meanwhile, in the modeling, several beam sizes were taken, namely B1 (250×500 mm), B2 (200×350 mm), B3 (200×400 mm), B4 (300×550 mm), and BA (150×300 mm). The column size was uniformly set at 600×600 mm, while the slab thickness was taken as 150 mm, and the shear wall thickness as 300 mm.

Figure 1 shows the floor plan of the building model, while Figures 2, 3, and 4 respectively show the 3-dimensional visualizations for the 8-story, 5-story, and 3-story models.

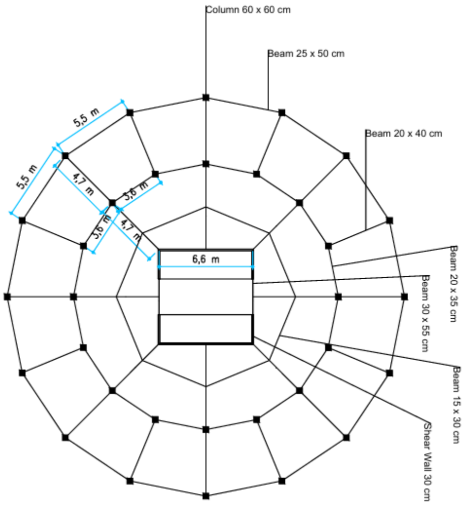

Figure 1. Building plan

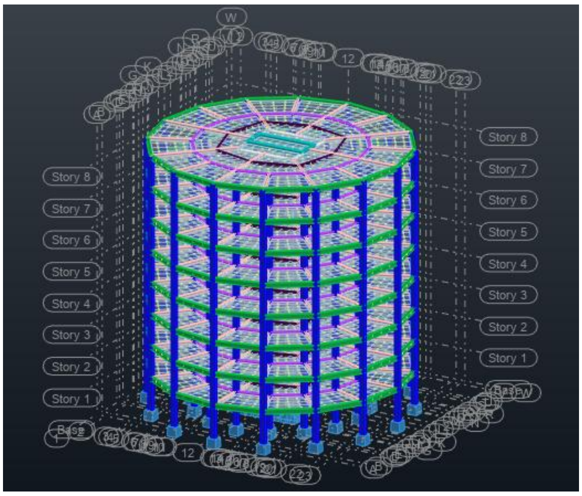

Figure 2. 8-story floor plan

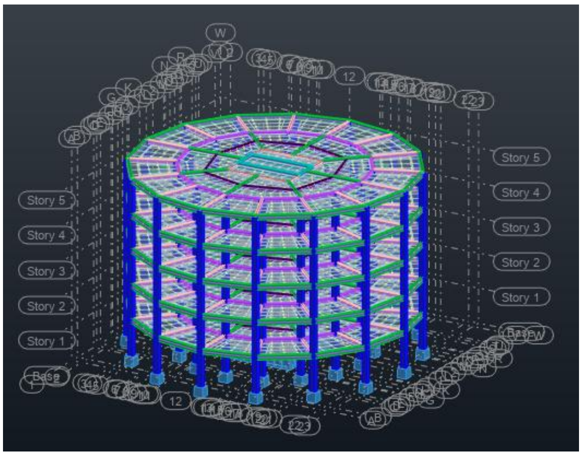

Figure 3. 5-story floor plan

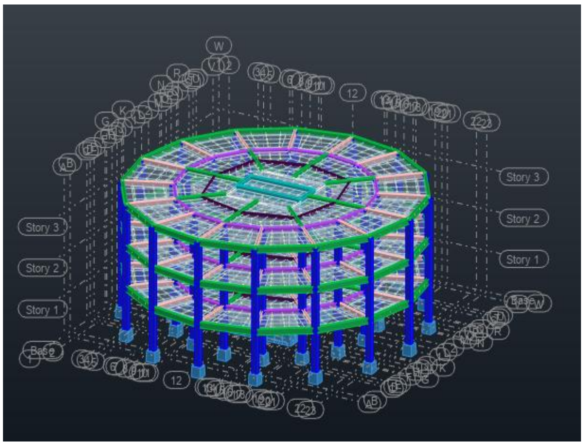

Figure 4. 3-story floor plan

Loadings

The applied loads on the structure, including Dead Load (DL), Superimposed Dead Load (SIDL), and Live Load (LL), are defined bellow :

- Dead Load (DL)
  In the analysis using Robot Structural Analysis Professional, these loads are defined by assigning structural elements such as beams, columns, slabs, and shear walls to the Dead Load (DL) type.
- Superimposed Dead Load (SIDL)
  Floors 1–7 = 1.3 kN/m²
  Roof = 0.48 kN/m²
- Live Load (LL)

Floors 1–7 = 2.40 kN/m²
Roof = 1 kN/m²

- Earthquake Load (E)
  This research performed the earthquake load analysis using the response spectrum method. For the soft soil site conditions in Padang city, based on SNI Earthquake Standard 1727:2019 and using values of S_s=1.1245 and S_1 =0.5737, the resulting response spectrum graph is shown in Figure 5.

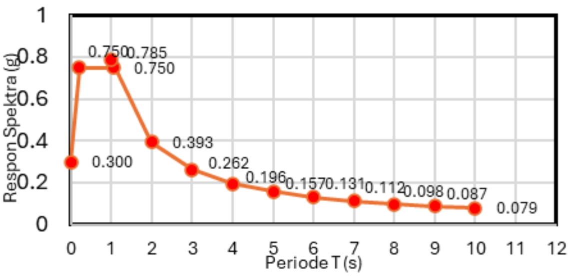

Figure 5. Spectrum response in Padang

Time Period

The structure is classified as Risk Category II, resulting in an Earthquake Importance Factor (I_e) = 1. The design incorporates the following seismic response modification parameters: Response Modification Factor (R) = 7,0, Overstrength Factor (Ω_0) = 2.5, and Deflection Amplification Factor (C_d) = 5.5. Given that the seismic design parameter S_{D1} is greater than 0.4, the Limiting Coefficient (C_u) is set at 1.4. The structural analysis uses the Approximate Period parameters, C_t = 0.0488 and x = 0.750 to estimate the Fundamental Periods (T_a) = $C_t h_n^x$. The Maximum Periods (T_{max}) for the 3-story, 5-story, and 8-story models, are 0,644 s, 1,148 s and 2,114 s respectively.

Modal Mass Participation Summary

The modal mass participation ratios for all three building models (8-story, 5-story, and 3-story) successfully met the minimum code requirement of 90% (0.9). Specifically, the 8-story model achieved a maximum sum of UX of 0.9513 and UY of 0.9629; the 5-story model showed UX of 0.9300 and UY of 0.9615; and the 3-story model demonstrated UX of 0.9645 and UY of 0.9521. Since all calculated values exceed 0.9 in both the X and Y directions, the models are considered structurally adequate for seismic analysis using the response spectrum method.

3. RESULTS AND DISCUSSIONS

Displacement

The analysis using RSAP yielded the following maximum displacement values for the three models. The 8-story model experienced the largest displacements, reaching 22.56 mm in the X-direction and 51.08 mm in the Y-direction. The 5-story model showed smaller displacements, with a maximum of 6.33 mm in the X-direction and 35.86 mm in the Y-direction. Finally, the 3-story model recorded the smallest displacements, measuring 1.37 mm in the X-direction and 7.98 mm in the Y-direction. These results consistently show that maximum displacement increases with the number of stories, and displacements in the Y-direction were significantly larger than those in the X-direction across all models. Figure 6 shows the displacement of the 3 models. Based on the displacement graphs in the structural design for earthquake-resistant multi-story buildings, the displacement in the Y-direction consistently exceeds that in the X-direction across all three structures. This indicates lower stiffness in the Y-direction, likely due to differences in structural configuration or the lateral load-resisting system between the two directions. This difference is attributed to the fact that the X-direction is supported by two shear walls (each 6.6 m long) to carry the lateral earthquake load, whereas the Y-direction is supported by only four shear walls, each just 2 m long. This phenomenon is consistent with the findings of research conducted by Pratama et al. (2025) and Jiwane (2024).

Base Shear

According to SNI 1726:2019 - Procedures for Earthquake Resistance Design of Buildings and Non-Building Structures. Article 7.8.1, the seismic base shear force (V) in a specified direction must be determined using the following equation:

$$V = C_s \times W \tag{1}$$

Jurnal Riset Rekayasa Sipil *Universitas Sebelas Maret*
ISSN: 2579-7999
Vol. 9 No. 2, Maret 2026 *109-111*

The total base shear for the 8-story model was found to be 4,950.6 kN, the 5-story model yielded 4,485.2 kN, while the 3-story model exhibited a base shear of 2,691.1 kN.
After the seismic base shear force has been determined, the next step is to distribute this force across each story level of the building in the form of lateral seismic forces (F_x), with the magnitude for each level calculated using the following formula

$$F_x = C_{vx}V \tag{2}$$

Story Drift
The analysis of all three building models showed that the maximum story drift remained within the allowable limit of 53.85 mm, confirming the structural safety criteria were met. The 8-story model recorded maximum story drifts of 19.91 mm in the X-direction and 43.34 mm in the Y-direction. The 5-story model exhibited maximum drifts of 8.36 mm (X-direction) and 48.51 mm (Y-direction). Finally, the 3-story model had the smallest drifts, with a maximum of 2.86 mm (X-direction) and 17.71 mm (Y-direction). Notably, the Y-direction drift consistently proved to be the more critical value across all models. Figure 7 shows the story drift results from each model in X and Y-direction.

The analysis results of the three buildings indicate that story drift values increase with the number of floors. As concluded from the findings, the pattern of story drift shows a relatively progressive rise from the lower to the mid-level floors, then tends to decrease toward the upper stories, particularly in the 5- and 8-story buildings. This reduction can be attributed to changes in vibration modes and a more uniform stiffness distribution in the upper levels, which leads to smaller relative inter-story deformations. These findings are consistent with the study conducted by (Chaitanya and Jagarapu, 2020).

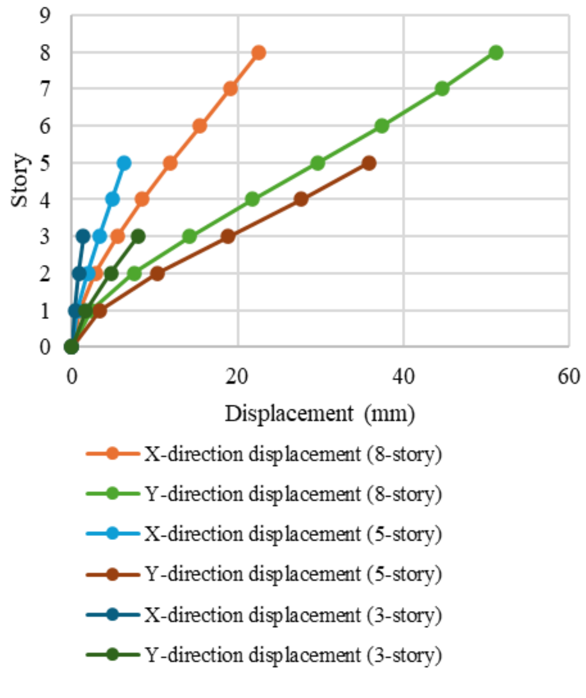

Figure 6. Displacement of 3. 5 and 8 story building models

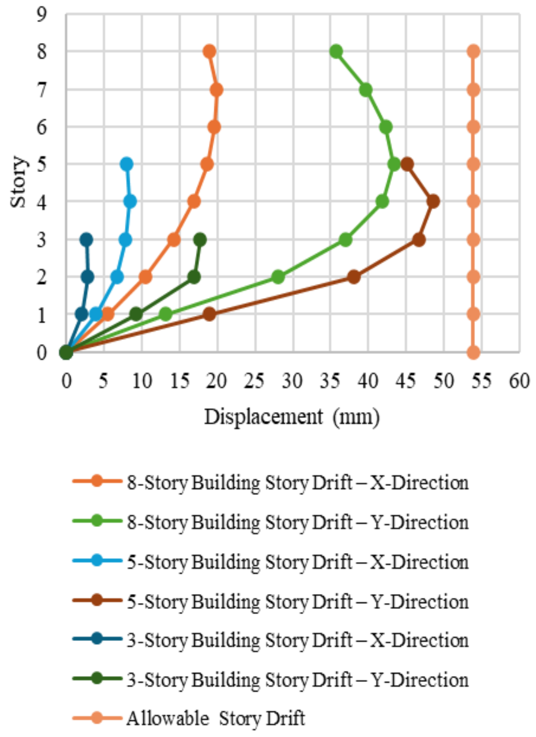

Figure 7. Story drift of 3, 5 and 8 story building models

Structural Work Volume
Once the serviceability requirements of the structure have been satisfied, the subsequent analysis focuses on the necessary concrete and steel reinforcement quantities per square meter of floor area. The material volume calculations were conducted using data outputted by the RSAP program. Based on the calculated concrete volume requirements, it was found that the total volume of concrete increases in line with the number of building stories. The 8-story building requires a concrete volume of 1,411.79 m³, the 5-story building requires 879.81 m³, and the 3-story building requires 527.91 m³. These requirements cover the primary structural elements. Therefore, the concrete demand ratio is 0.287 m³/m².

The study conducted by Sutanto et al. (2016) on an apartment construction project found that the concrete requirement per square meter ranged from 0.3041 to 0.5891 m^3/m^2. Meanwhile, for a hotel project, the concrete demand ratio was reported to range from 0.3041 to 0.4818 m^3/m^2. In the present study, the circular-shaped building design resulted in a total concrete demand ratio of 0.287 m^3/m^2, indicating that the planned structure falls within the average range of concrete demand ratios typically observed in building construction projects.
Based on the findings of (Sutanto et al., 2016), the reinforcement demand ratio for apartment projects ranges between 141.3624–165.6701 kg/m^3, while for hotel projects, the estimated reinforcement requirement falls within the range of 141.1236–156.2936 kg/m^3. According to the calculation results in this study, the modeled building design yields a reinforcement demand ratio of 150.31 kg/m^3, indicating that the structural design falls within the average range of reinforcement demand ratios typically observed in building construction projects.

4. CONCLUSIONS

The analysis of the three building models (3, 5, and 8 stories) consistently shows inferior structural performance in the Y-direction, characterized by greater displacement and story drift compared to the X-direction. This directional weakness is attributed to an imbalance in the lateral load-resisting system, specifically the shorter and less effective shear walls in the Y-direction, which leads to lower stiffness. The study found that both displacement and story drift increase with the number of stories, with drift generally progressing more sharply in the lower-to-mid levels before decreasing at the top stories due to changes in vibration modes. Structurally, the required average concrete and steel ratios (at 0,287 m^2 and 150,31 kg/m^3, respectively) fall within typical industry limits. Importantly, this study highlights that circular-shaped buildings, designed under SNI 1726:2019, demonstrate comparable seismic performance with reduced material usage, establishing them as viable alternatives for earthquake-prone cities. Future work should focus on experimental validation, analysis of other irregular shapes, and BIM-based seismic optimization.

DAFTAR PUSTAKA

Akman, A., Faizal, N., 2022. Buku Penanganan Gempa Cianjur 2022. Kementerian Pekerjaan Umum Dan Perumahan Rakyat 1–124.

Balitbang PUPR, 2018. Kajian Gempa Palu Provinsi Sulawesi Tengah 28 September 2018 (M7.4), Pusat Litbang Perumahan dan Pemukiman, Balitbang PUPR Pusat.

Bramhane, S.S., Padmawar, K., 2025. Seismic Analysis of Circular Building and Rectangular Building. International Journal Of Recent Trends In Multidisciplinary Research, Vol. 5, No. 3, pp 66 – 72. https://www.doi.org/10.59256/ijrtmr.20250503007

Chaitanya, D., Jagarapu, K., 2020. Effect Of Change Of Storey Drift And Storey Height In Multi Storey Building With Varying Seismic Zones.

Fathurrachman, M. P., Satyarno, I., Sulistyo, D. (2024). Modeling's effect of irregular building structure with vegetated roof on seismic evaluation per ASCE 41-17. *Semesta Teknika*, *27*(2), 173–182. https://doi.org/10.18196/st.v27i2.22775

Febriana, L. N., Yamin, A. F. M., & Irwan, I. (2024). Analysis and design of irregular structure using building information modelling integration: Case study: Laboratory Tower. *E3S Web of Conferences*, *517*, 05023. https://doi.org/10.1051/e3sconf/202451705023

Hasan, Md Mehedi, Jamil, M., Mahbub-ul-alam, Md., 2020. Structural floor shape efficiency of circular and square high rise structure towards lateral loadings. World Journal of Advanced Research and Reviews. 8. 116-122. 10.30574/wjarr.2020.8.1.0364.

Ikhlas, M.Z., Husnita, L., Zulfa, Z., 2022. Memori Kolektif Masyarakat Dalam Peristiwa Gempa 2009 Di Kota Padang (Studi Kasus Kecamatan Padang Barat). Puteri Hijau : Jurnal Pendidikan Sejarah 7, 85. https://doi.org/10.24114/ph.v7i1.34595

Jaberi, V., Jaberi, M., & Asghari, A. (2024). A new performance-based seismic design method using endurance time analysis for linked column frame system and a comparison of structural systems and seismic analysis methods. *The Structural Design o[1]f Tall and Special Buildings*, *33*(6), e2100.

Jiwane, P., Mahalle, G., 2024. Comparative Seismic Analysis of Circular and Rectangular Building Structures. International Research Journal of Engineering and Technology 362–373.

Mackenzie Davis, D.C., 2024. Structural Efficiency of Circular and Rectangular Structures A Comprehensive Study, in: Introduction to Environmental Engineering (McGraw-Hill Series in Civil and Environmental Engineering). pp. 374–386.

Murty, C. V. R., Rupen, Goswami., A. R. Vijayanarayanan., V.V.Mehta., 2018. Some Concepts in earthquake behavior of buildings 268.

Nastri, E., & Pisapia, A. (2025). Performance-based seismic design (Editorial for Special Issue). *Applied Sciences*, *15*(5), 2254. https://doi.org/10.3390/app15052254

Pratama, A.I., Teguh, M., 2025. Structural Response of Irregular Buildings : Influence of Geometry and Shear Wall Configurations 27, 22–31.

Sucipto, S., Sutjipto, S., 2022. Dampak Perubahan SNI 1726 Dan SNI 2847 Pada Perencanaan Gedung Studi Kasus 4 Lantai. Prosiding Seminar Intelektual Muda #7, Sains, Teknologi dan Kultur Dalam Peningkatan Kualitas Hidup dan Peradaban 112–116.

Sutanto, I., Andi, A., Arijanto, L., 2016. Rasio Kebutuhan Beton, Besi Tulangan, Dan Bekisting Untuk Pekerjaan Struktur Pada Proyek Apartemen & Hotel. Dimensi Utama Teknik Sipil 3, 23–30. https://doi.org/10.9744/duts.3.1.23-30

Tarigan, J., Nursyamsi, & Alfitra, T. M. R. (2024). Seismic Performance Analysis of Regular and Irregular Buildings Based on SNI 1726:2019 Standards. *International Journal of Architecture and Urbanism*, *8*(3), 463–478. https://doi.org/10.32734/ijau.v8i3.18258