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Structural Performance of a 10-Story Building Using Seismo Struct Software

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ABSTRACT

The building is a high-rise building with a complex structure that requires special attention in structural design and evaluation. This research focuses on evaluating the structural performance of a 10-story building using SeismoStruct software. The aim of the research is to assess the ability of buildings to withstand earthquake loads. This evaluation was conducted based on ASCE 41-17 for Basic Performance Objectives for Existing Buildings (BPOE), which includes various risk categories and structural and nonstructural performance criteria, using the ASCE 41-17 standard published by the American Society of Civil Engineers to regulate seismic evaluations. and repairs to existing buildings. ASCE 41-17 is a standard published by the American Society of Civil Engineers governing seismic evaluation and repair evaluation of existing buildings. The evaluation process is based on secondary data in the form of asbuilt-drawing which is used as 3D structural modeling in the SeismoStruct program. The modeling stage involves creating a 3D model, determining reinforced concrete materials, cross-sectional design of structural elements, and non-linear static analysis. The evaluation results show that the target displacement in the building can be achieved well when facing BSE-1E and BSE-2E spectral earthquakes. Recommendations include regular maintenance and regular monitoring to ensure safe future performance of the structure

INTRODUCTION

High-rise buildings, for example, are complex structures that require special attention in terms of design and structural evaluation. In recent decades, Indonesia has experienced rapid growth in infrastructure development, including high-rise buildings. However, the main challenge faced is ensuring that these buildings can withstand significant seismic loads, so structural planning for seismic loads plays a crucial role, given that parts of Indonesia are located in high-intensity earthquake zones; this planning aims to prevent building collapse and reduce the risk of loss of life among occupants during an earthquake (Masbudi et al., 2015). To ensure infrastructure meets applicable standards, numerous factors must be considered. These standards also apply to older buildings that remain in operation today. These older buildings are referred to as existing structures—that is, buildings that have been standing for some time (I. Wijaya et al., 2023). According to Arifin (2015), such buildings often face high seismic risks. Therefore, measures must be taken to ensure the building's structural safety while maintaining its existing functions.

Technological advancements play a crucial role in the planning and analysis of building structural performance. The availability of structural modeling software has reduced the complexity of modeling tasks that were previously difficult to perform using conventional methods (Asmara et al., 2021). Consequently, this study focuses on evaluating the structural performance of a 10-story building using SeismoStruct software. This software enables realistic simulations of a building's structural behavior during an earthquake, providing a clear picture of how the structure will respond to such loads.

Over time, not only has construction work continued to evolve, but regulations are also routinely updated. By studying cases that occur in the construction industry, design codes are continuously reviewed and updated to ensure human safety from disasters. In developed countries such as the United States, updates to regulations and technology occur rapidly (U. Wijaya et al., 2020). In this case, the evaluation was conducted in accordance with ASCE 41-17 Basic Performance Objectives for Existing Buildings (BPOEB), which covers various risk categories and structural and nonstruktural performance criteria. "ASCE 41-17 is a standard issued by the American Society of Civil Engineers to govern seismic evaluation and retrofitting of existing buildings. (Adhitama et al., 2022)

Seismic evaluation is defined as an accepted process or methodology for evaluating deficiencies in a building that cause it to fail to meet the selected Performance Objectives ("Seism. Eval. Retrofit Exist. Build.," 2023)

Although several studies have examined seismic performance and structural safety of reinforced concrete buildings in Indonesia, most of them still emphasize code-based design verification, linear structural analysis, or general checks of drift and internal forces using commonly applied structural software. Limited attention has been given to the performance-based seismic evaluation of existing high-rise buildings by integrating nonlinear structural modeling, component-level damage identification, and performance objectives based on ASCE 41-17. This creates a research gap, particularly in understanding how an existing ten-story reinforced concrete building responds to seismic demand when assessed not only from global structural behavior but also from the potential deficiencies of individual structural components.

Another gap lies in the limited application of SeismoStruct for evaluating existing high-rise buildings in the Indonesian seismic context. Previous studies have generally focused on design compliance or comparison of structural analysis results, while fewer studies have investigated how nonlinear seismic response can be used to interpret expected performance levels, damage progression, and vulnerable structural zones. Therefore, a more detailed performance-based assessment is required to bridge the gap between conventional structural analysis and practical seismic safety evaluation of existing buildings.

The novelty of this study is the application of SeismoStruct-based nonlinear structural evaluation to assess the seismic performance of a ten-story existing building using the Basic Performance Objectives for Existing Buildings under ASCE 41-17. Unlike studies that only determine whether a structure satisfies basic design requirements, this study evaluates the building response through performance indicators, identifies potential structural deficiencies, and provides a clearer interpretation of the expected damage condition under seismic loading. The contribution of this study is expected to support engineers and decision-makers in developing more reliable assessment procedures for existing high-rise buildings in earthquake-prone areas of Indonesia.

The objective of this study is to assess the building's ability to withstand seismic loads and to identify potential deficiencies or damage. The results of this study are expected to provide new insights into the structural performance of high-rise buildings in Indonesia. Additionally, the results are expected to serve as a reference for practitioners and researchers in the fields of civil and structural engineering, particularly in the context of earthquake-resistant building design and evaluation. Thus, this study has the potential to make a significant contribution to enhancing the safety and efficiency of high-rise buildings in Indonesia.

This study also has strong relevance to previous research conducted in this field. However, this study offers originality in terms of the use of SeismoStruct software for evaluating the structural performance of buildings. Thus, this study contributes not only to the advancement of scientific knowledge but also to professional practice in the fields of civil and structural engineering. This demonstrates how research focused on the application of technology can help address real-world challenges in civil and structural engineering.

METHODS

This study was conducted using a case study of an existing 10-story hotel building located in Manado, North Sulawesi, Indonesia. The research employed a quantitative approach because the analysis produced numerical outputs related to structural response, including base shear, roof displacement, inter-story drift, plastic hinge formation, and structural performance level. The main secondary data used in this study were as-built drawings, including architectural plans, structural plans, column schedules, beam schedules, slab thickness, reinforcement details, and material specifications. These data were used to develop a three-dimensional structural model in SeismoStruct.

The research was carried out through document review, structural modeling, nonlinear static pushover analysis, and performance evaluation. The document review was conducted to identify the geometry, structural configuration, member dimensions, material properties, and reinforcement detailing of the existing building. The structural model was then developed in SeismoStruct by representing beams and columns as frame elements, while floor slabs were assumed to act as diaphragms that distribute lateral loads to the vertical structural elements. The foundation condition was idealized as a fixed-base support, assuming that the interaction between the soil and foundation did not significantly alter the global lateral response of the building. This assumption was adopted because the main focus of the study was the seismic performance evaluation of the superstructure.

Structural Modeling Parameters

The structural model was developed based on the actual geometry and structural dimensions obtained from the as-built drawings. The building consists of 10 stories, with each floor modeled according to its actual elevation and plan configuration. The main structural components included reinforced concrete columns, beams, and floor slabs. The material properties were defined based on the available project data. Concrete compressive strength, reinforcement yield strength, modulus of elasticity, unit weight, and nonlinear material behavior were assigned to the model to

represent the expected response of reinforced concrete members under increasing lateral load.

The nonlinear behavior of reinforced concrete members was modeled using force-based or displacement-based frame elements available in SeismoStruct. Plasticity was represented through distributed inelasticity along the member length, allowing the model to capture the progressive development of damage in beams and columns. Each structural element was assigned appropriate cross-sectional properties, reinforcement arrangement, and material constitutive models. Concrete behavior was modeled to account for nonlinear compression response, while reinforcing steel was modeled to represent yielding behavior under tensile and compressive stress. P-delta effects were included in the analysis to consider the influence of axial load and lateral displacement on the global stability of the structure.

The main parameters used in the structural model are summarized as follows:

Table 1. Structural Modeling Parameters

Parameter	Description
Building function	Existing hotel building
Location	Manado, North Sulawesi, Indonesia
Number of stories	10 stories
Structural system	Reinforced concrete moment-resisting frame
Modeling software	SeismoStruct
Main structural elements	Columns, beams, and floor slabs
Data source	As-built drawings and structural documents
Support condition	Fixed-base assumption
Slab idealization	Floor diaphragm for lateral load distribution
Nonlinear modeling approach	Nonlinear frame element with distributed plasticity
Material model	Nonlinear concrete and reinforcing steel models
Geometric nonlinearity	P-delta effect considered
Analysis type	Nonlinear static pushover analysis
Performance reference	ASCE 41-17 performance-based seismic evaluation
Main output parameters	Base shear, roof displacement, inter-story drift, capacity curve, and damage mechanism

Pushover Analysis Procedure

The seismic performance of the building was evaluated using nonlinear static pushover analysis. Pushover analysis was selected because it can describe the progressive behavior of a structure from the elastic stage to nonlinear response and potential failure mechanisms. In this method, the structure is subjected to monotonically increasing lateral loads until the target displacement is reached or until the model indicates significant loss of lateral resistance.

The pushover analysis was performed in two principal horizontal directions, namely the X-direction and Y-direction, to evaluate the structural response along both main axes of the building. The lateral load pattern was applied incrementally to the structural model. The roof level was selected as the control node because it represents the global lateral displacement of the building. During the analysis, the

relationship between base shear and roof displacement was recorded to generate the capacity curve of the structure.

The pushover analysis procedure consisted of the following steps:

1. Developing a three-dimensional model of the 10-story building based on as-built drawings.
2. Defining material properties for concrete and reinforcing steel according to the available structural data.
3. Assigning cross-sectional dimensions and reinforcement details to columns and beams.
4. Applying gravity loads, including dead loads and live loads, to represent the initial load condition of the structure.
5. Defining mass source and lateral load patterns for seismic pushover analysis.
6. Applying incremental lateral loads in the X-direction and Y-direction.
7. Selecting the roof level as the control node for displacement monitoring.
8. Running nonlinear static pushover analysis until the target displacement or structural instability condition was reached.
9. Generating the capacity curve in the form of base shear versus roof displacement.

Evaluating the structural performance level based on displacement demand, inter-story drift, and damage distribution.

Load Application and Lateral Load Pattern

Gravity loads were applied before the pushover analysis to represent the actual loading condition of the building. The gravity load consisted of dead load, additional dead load, and a portion of live load based on the building function. After the gravity load stage was completed, lateral loads were applied incrementally to simulate seismic demand.

The lateral load pattern was assigned based on the vertical distribution of seismic forces along the height of the building. This approach allows the model to capture the dominant mode response of the structure under earthquake excitation. The analysis was conducted separately for the X and Y directions to identify the direction that produces greater displacement demand, higher inter-story drift, and more critical damage concentration.

RESULTS AND DISCUSSION

Performance Evaluation Criteria

The structural performance was evaluated using the performance-based seismic assessment concept. The main evaluation parameters included base shear capacity, roof displacement, inter-story drift ratio, and the distribution of nonlinear damage in structural elements. The resulting capacity curve was used to identify the transition from elastic response to nonlinear behavior. The performance level of the building was then interpreted based on the extent of structural deformation and damage.

The expected performance levels were classified into Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP). Immediate Occupancy indicates that the structure experiences minor damage and can still be used after an earthquake with limited repair. Life Safety indicates that structural damage occurs, but the risk of collapse remains low and life safety is generally maintained. Collapse Prevention indicates that the structure is near its ultimate deformation capacity, with significant damage and limited residual strength.

The evaluation focused on identifying whether the building satisfies the intended performance objective under seismic loading. Particular attention was given to story drift concentration, potential soft-story behavior, excessive roof displacement, and the sequence of nonlinear damage formation in beams and columns. These indicators were used to determine the vulnerability of the existing 10-story building and to provide recommendations for further structural assessment or retrofitting if required.

The study was conducted using a case study of a 10-story building, specifically a hotel located in Manado, North Sulawesi. This research employed a quantitative method as it generated numerical data—specifically, the results of the building's structural analysis using the SeismoStruct program. The secondary data used in this study consists of as-built

drawings, which were utilized to model the 3D structure in the SeismoStruct program. These as-built drawings cover all major structural elements, and this study also involves a document review approach. The step-by-step approach related to the SeismoStruct software modeling, which will be used to perform simulations and structural analysis of the 10-story building, is outlined as follows:

Standard values are used for material properties. These material values may be assumed unless otherwise specified in construction documents or test results. Some required standard material values include concrete compressive strength (f'c), yield stress (fy), modulus of elasticity (E), and effective prestressing force (Fpe) (Faldi et al., 2023).

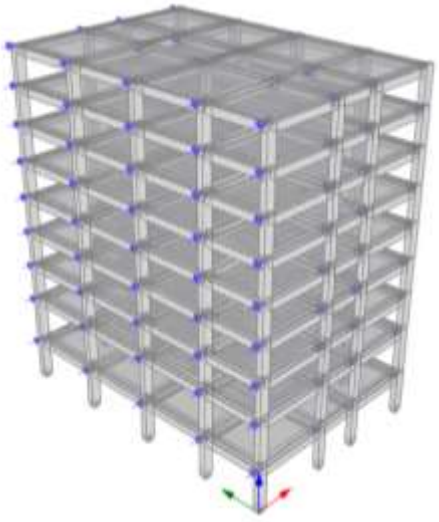
a. Concrete Grade : - Structural Beams, f'c 25 MPa
- Structural Columns, f'c 25 MPa
- Floor Slabs, f'c 25 MPa

b. Reinforcing Steel Grade : Yield strength of steel, fy 420 MPa, fy 280 MPa

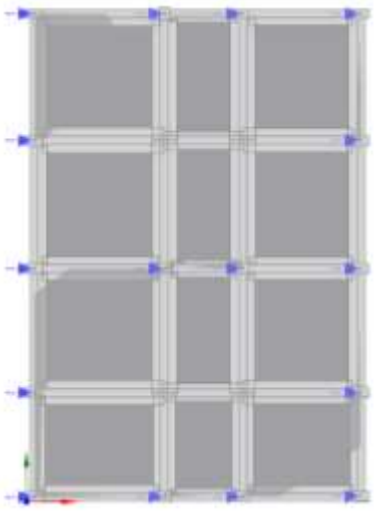
3.3 Structural Modeling

The main structural modeling was performed using SeismoStruct software and referenced as-built drawings that depict the actual condition of the building on-site after completion, including all changes that occurred during the construction process. Three-dimensional modeling of the building structure was successfully performed based on the contractor's as-built documents and other supporting data to analyze the structural compliance obtained after conducting a running analysis on the model that aligns with the design data (Muhammad Hilmi et al., 2021). The building's substructure or foundation was modeled using fixed supports. Gravity loads on the structure consist of two types of loads, namely dead loads and live loads.

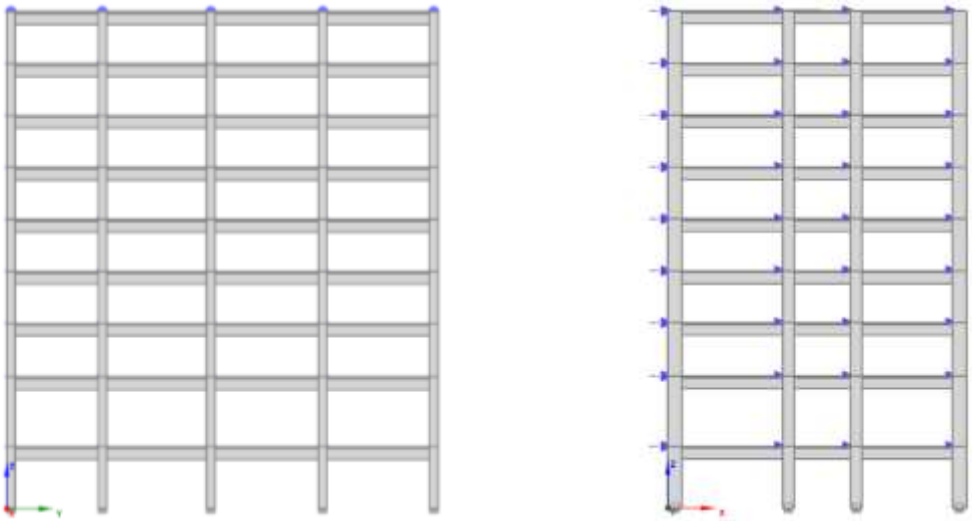
Dead loads result from the materials used in the structure, while live loads include all loads arising from the occupancy or use of the building, including loads from movable objects. The results of the building structure modeling are shown in Figure 1, which presents a 3D perspective of the structure, a top view of the structure, a structural portal in the x-direction, and a structural portal in the y-direction.



3D Structural Perspective



Top View of the Structure



X-Axis Structure Portal Y-Axis Structure Portal

Figure 1. Structural Modeling in SeismoStruct Software

Structural Analysis

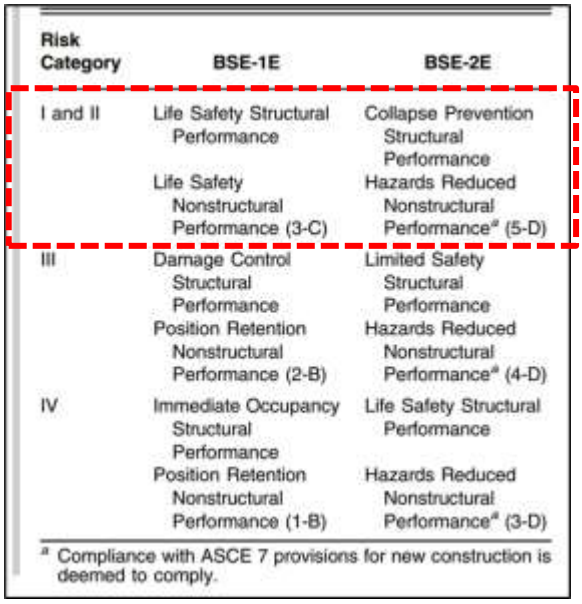
The structural analysis was performed using SeismoStruct software in accordance with SNI 2847:2019, which specifies the requirements for structural concrete in buildings, and SNI 1726:2019, which specifies the procedures for seismic design of building and non-building structures. This building was designed with structural principles that can withstand lateral loads, particularly during earthquakes. Its seismic design follows the Special Moment-Resisting Frame System (SRPMK) to reduce the risk of collapse or structural failure in areas with Seismic Risk Category II, as shown in Figure 2. For seismic retrofitting purposes, two earthquake levels are used: an earthquake with a 5% probability of occurrence in 50 years (referred to as BSE-2E) and an earthquake with a 20% probability of occurrence in 50 years (referred to as BSE-1E). These two earthquake levels are defined by ASCE 41-17 as earthquakes that refer to the Basic Performance Objective for Existing Buildings (BPOE) (Nugroho, 2022). The risk categories for building and non-building structures are listed in Table 3 of SNI 1726 (2019). The effect of the design earthquake on the structure must be accounted for by multiplying the earthquake importance factor (Ie). The earthquake importance factor, Ie, and risk categories for non-building structures are based on the hazard level associated with their contents and functions (Rifai et al., 2022).

Table 3 – Risk categories of buildings and nonbuilding structures for seismic loads

Occupancy type	Risk category
Buildings and nonbuilding structures that pose a low risk to human life in the event of failure, including, but not limited to, the following: - Agricultural, plantation, livestock, and fishery facilities - Temporary facilities - Storage warehouses - Guard houses and other small structures	I
All buildings and other structures, except those included in risk categories I, III, and IV, including, but not limited to: - Residential buildings - Shop houses and office houses - Markets - Office buildings - Apartment buildings / flats - Shopping centers / malls - Industrial buildings - Manufacturing facilities - Factories	II

Figure 2. Risk Categories Based on SNI 1726-2019

According to SNI 1726-2019 in Figure 2, the hotel building falls under Risk Category II, where Risk Category II in ASCE 41-17 refers to two earthquake levels. First, the BSE-1E earthquake with a 225-year return period and a 20% exceedance probability over 50 years, which targets structural performance in accordance with Life Safety limits. Second, the BSE-2E earthquake with a return period of 975 years and a 5% exceedance probability over 50 years, which targets structural performance in accordance with Collapse Prevention limits; this can be seen in Figure 3.



Risk Category	BSE-1E	BSE-2E
I and II	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Collapse Prevention Structural Performance Hazards Reduced Nonstructural Performance[a] (5-D)
III	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Limited Safety Structural Performance Hazards Reduced Nonstructural Performance[a] (4-D)
IV	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Life Safety Structural Performance Hazards Reduced Nonstructural Performance[a] (3-D)

[a] Compliance with ASCE 7 provisions for new construction is deemed to comply.

Figure 3. Building Performance Targets Based

on Basic Performance Objectives for Existing Buildings (TKDBGE) in ASCE 41-17

Displacement Target

The displacement target is the displacement goal that the structure must achieve when subjected to the BSE-1E and BSE-2E spectral response demands (Adhitama et al., 2022). To calculate the displacement target, the results of the displacement target calculation are plotted on the pushover curve obtained from the nonlinear static analysis. This aims to understand the overall structural condition when the displacement target aligns with the earthquake being analyzed. The capacity curve is a graph comparing base shear with displacement. The capacity curve is used to evaluate the displacement target based on ASCE 17 and then assessed against performance levels/acceptance criteria (Parinduri et al., 2022). The pushover curve graph with plots of the target for each seismic hazard level can be seen in Figure 4. The pushover curve for the Building indicates that the structure can still withstand lateral forces until it reaches the predetermined displacement target. This applies both to the BSE-1E seismic hazard, which has a return period of 225 years with a 20% probability of exceedance in 50 years and targets structural performance in accordance with Life Safety limits, and to the BSE-2E seismic hazard, which has a return period of 975 years with a 5% exceedance probability over 50 years and targets structural performance in accordance with Collapse Prevention limits.

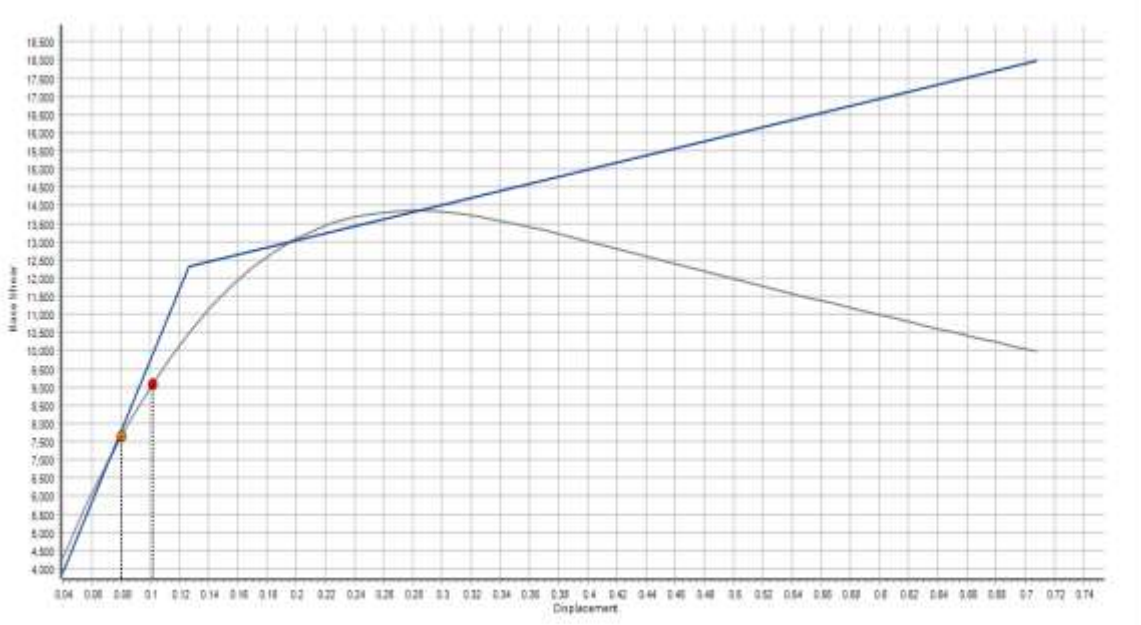


Figure 4. Displacement Target on the Pushover Curve of the Hotel Building

CONCLUSION

Based on the evaluation results, the displacement target for the 10-story hotel building is successfully achieved under the BSE-1E and BSE-2E spectral earthquake responses. The pushover curve indicates that the structure is still able to resist lateral forces up to the specified displacement target. This finding suggests that the existing structural system has adequate seismic capacity within the evaluated performance objective. In general, the building demonstrates acceptable structural behavior under the applied nonlinear static analysis, although continued structural monitoring remains necessary to ensure long-term safety.

To maintain the safety and performance of the structure in the future, periodic maintenance, regular structural monitoring, and re-evaluation are recommended, especially when there are changes in building function, occupancy load, structural modification, or surrounding environmental conditions. These measures are important to ensure that the structure continues to perform properly and remains safe for long-term use.

However, this study has several limitations. First, the analysis was conducted based on secondary data obtained from as-built drawings, so the actual material condition, reinforcement quality, and possible deterioration of structural elements were not directly verified through field testing. Second, the evaluation was limited to nonlinear static pushover analysis, which does not fully represent the dynamic behavior of the building under real earthquake ground motions. Third, the foundation system and soil-structure interaction were not modeled in detail, even though these aspects may influence the seismic response of high-rise buildings. Fourth, nonstructural components, architectural elements, and building utilities were not included in the performance evaluation.

Further research is recommended to conduct a more comprehensive seismic performance assessment using nonlinear time-history analysis with selected ground motion records that represent the seismic characteristics of Manado and North Sulawesi. Future studies should also include field investigation, material testing, reinforcement verification, and structural health monitoring to obtain more accurate input parameters for numerical modeling. In addition, the influence of soil-structure interaction, foundation flexibility, and nonstructural component performance should be evaluated to provide a more complete understanding of building safety. Comparative studies using different software, seismic codes, and retrofit alternatives are also

recommended to support more reliable decision-making for existing high-rise buildings in earthquake-prone areas.

REFERENCES

Adhitama, Y. A., Supriyadi, B., & Suhendro, B. (2022). Evaluasi Seismik Gedung Bertingkat Eksisting Menggunakan Prosedur ASCE 41-17. Jurnal Riset Rekayasa Sipil, 6(1), 1.

Arifin, Z., Suyadi, & Sebayang, S. (2015). Analisis Struktur Gedung POP Hotel Terhadap Beban Gempa Dengan Metode Pushover Analysis. Jrsdd, 3(3), 427–440.

Asmara, K. B., Isneini, M., & D.W.S.B.U, C. N. (2021). Evaluasi Kinerja Struktur Bangunan Tinggi dengan Analisis Pushover Menggunakan Aplikasi Pemodelan Struktur (Studi Kasus: The Venetian Tower). Jurnal Rekayasa Sipil dan Desain, 9(1), 177–188.

Badan Standardisasi Nasional. (2019). Persyaratan Beton Struktural untuk Bangunan Gedung dan Penjelasan (SNI 2847:2019).

Badan Standardisasi Nasional. (2019). Tata Cara Perencanaan Ketahanan Gempa Untuk Struktur Bangunan Gedung dan Non Gedung (SNI 1726-2019).

Badan Standarisasi Nasional (2020) Beban Desain Minimum dan Kriteria Terkait untuk Bangunan Gedung dan Struktur Lain (SNI 1727:2020).

Faldi, R., Wardi, S., Sonata, H., Sipil, T., Teknik, F., & Padang, I. T. (2023). TEKNOLOGI PADANG TERHADAP GEMPA BUMI MENGGUNAKAN METODE EVALUASI TIER 1 BERDASARKAN RSNI (ASCE 41-17). 1.

Masbudi, Purwanto, E., & Supriyadi, A. (2015). Evaluasi Kinerja Struktur Gedung Dengan Analisis Pusover (Studi Kasus: Gedung Bedah Sentral Terpadu Rumah Sakit Bethesda Yogyakarta). e-Jurnal : Materiks Teknik Sipil, 40, 1056–1062.

Muhammad Hilmi, Erizal, & Febrita, J. (2021). Analisis Kinerja Struktur pada Bangunan Bertingkat dengan Metode Analisis Respon Spektrum Berdasarkan SNI 1726:2019. Jurnal Teknik Sipil dan Lingkungan, 6(3), 143–158.

Nugroho, W. O. (2022). Kebutuhan dan Strategi Rehabilitasi Seismik Gedung Beton Eksisting di Indonesia. Conference: Seminar HAKI , November.

Parinduri, A. S., Afifuddin, M., & Putra, R. (2022). Evaluasi Kinerja Struktur Beton Bertulang dengan Pushover Analysis Berdasarkan ASCE 41-17 (Studi kasus : Gedung Ikatan Alumni Universitas Syiah Kuala). Journal of The Civil Engineering Student, 4(2), 204–210.

Rifai, M., Alami, F., Isneini, M., & Helmi, M. (2022). Evaluasi Kinerja Struktur Gedung Bertingkat Dengan Analisis Time History (Studi Kasus : Rumah Sakit Umum Muhammadiyah Metro). Jrsdd, 10(1), 99–114.

Seismic Evaluation and Retrofit of Existing Buildings. (2023). In Seismic Evaluation and Retrofit of Existing Buildings. American Society of Civil Engineers.

Wijaya, I., Wibawa, I. M. S., & ... (2023). Evaluasi Kelaikan Struktur Beton Bertulang Bangunan Showroom Suzuki di Jalan Imam Bonjol Denpasar. Jurnal Ilmiah Teknik …, 3(2).

Wijaya, U., Putra, I. G. E. A., & Tavio. (2020). Assessment and evaluation procedure of existing industrial building structure based on ASCE 41-17. Journal of Physics: Conference Series, 1477(5).