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Research Article

Seismic Performance Evaluation of a Five Storey Cancer Hospital Building Using a Special Moment Resisting Frame System

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Abstract

The development of specialized healthcare facilities is essential to improving access to cancer treatment, particularly in regions with limited oncology services. This study presents the structural design and seismic evaluation of a five-storey reinforced concrete cancer hospital building located in Pontianak City, West Kalimantan Province, Indonesia. The project aims to support the provision of safe and reliable healthcare infrastructure while ensuring compliance with national structural and seismic design standards.The structural planning was carried out using primary and secondary data obtained from the project site. The building is designed as a reinforced concrete system consisting of slabs, beams, and columns in accordance with the Indonesian concrete design code SNI 2847:2019. To address seismic demands, the structure adopts a Special Moment Resisting Frame (SMRF) system following the Indonesian seismic standard SNI 1726:2019. A three-dimensional structural model was developed using ETABS v18 software, and response spectrum analysis was applied to evaluate internal forces, inter-storey drift, and overall seismic behavior. The results indicate that the designed beam and column sections satisfy the cross-sectional and detailing requirements of the SMRF system. The strong-column weak-beam mechanism is consistently achieved, supporting ductile structural performance under seismic loading. Structural serviceability under design loads remains within permissible limits. In addition, the foundation system was designed based on cone penetration test data, demonstrating adequate bearing capacity and structural stability. This study provides a practical reference for the seismic-resistant design of hospital buildings in earthquake-prone regions and contributes to the development of resilient healthcare infrastructure in Indonesia.

Keywords: *Seismic Performance; Resisting Frame; Reinforced Concrete; Earthquake Resistant*

How to Cite:

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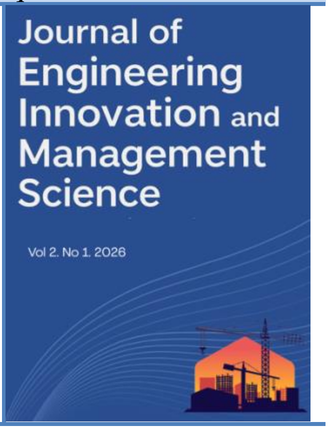

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INTRODUCTION

Healthcare facilities play a critical role in maintaining public safety and social resilience, particularly during natural disasters. Hospitals are classified as essential buildings that must remain operational during and after seismic events (Achour & Miyajima, 2020; Ceferino et al., 2020; Zhai et al., 2022). In seismically active regions, structural failure of hospital buildings can lead to severe humanitarian and economic consequences. Indonesia is located along the Pacific Ring of Fire, making earthquake hazards a major concern for infrastructure development. Several regions in Indonesia, including West Kalimantan, are exposed to moderate seismic risks that require careful structural consideration (Suppasri et al., 2021; Triyanti et al., 2023). Pontianak City, as a growing urban center, demands resilient healthcare infrastructure to support regional medical services. Cancer treatment facilities, in particular, require high levels of structural reliability due to the continuous operation of medical equipment and patient care services. Structural damage in hospital buildings may disrupt medical functions even under moderate ground motions (Ibrahim, 2025; Pei et al., 2023; Zhai et al., 2022). Therefore, seismic-resistant structural design is a fundamental requirement for hospital construction. Ensuring structural safety in healthcare buildings contributes directly to community resilience and disaster preparedness.

Reinforced concrete structures remain the most widely used structural system for multi-storey buildings in Indonesia. Their popularity is attributed to material availability, construction familiarity, and proven structural performance (Ahmed & Arocho, 2020; J. Hu et al., 2020; Rajanayagam et al., 2024). However, reinforced concrete buildings in seismic regions must be designed with adequate ductility to dissipate earthquake energy. Special Moment Resisting Frame (SMRF) systems are specifically developed to provide high ductility through controlled plastic hinge formation (Mokhtari et al., 2022; Shakouri et al., 2021). The SMRF system applies the strong-column weak-beam concept to prevent catastrophic structural collapse (Badal & Sinha, 2024; Ghorbanzadeh & Khoshnoudian, 2022; Nie et al., 2020; Waqas et al., 2024). In Indonesia, the application of SMRF systems is regulated through SNI 1726:2019 for seismic design and SNI 2847:2019 for reinforced concrete structures. These codes adopt performance-based principles aligned with international standards. Proper implementation of these regulations requires detailed structural modeling and analysis. Numerical simulation tools such as ETABS are commonly used to assess seismic responses. Nevertheless, code compliance alone does not always guarantee satisfactory structural performance without thorough evaluation.

Despite the availability of seismic design standards, practical implementation in real projects remains challenging. Many hospital buildings in developing regions are designed primarily to meet minimum code requirements (Borges de Oliveira et al., 2021; Rahman et al., 2021, 2021). Limited documentation of case-based seismic performance evaluations reduces opportunities for knowledge transfer (Işık et al., 2021; Medaa et al., 2025; Pedro et al., 2022). Hospital buildings possess unique functional demands that differentiate them from ordinary structures (Ceferino et al., 2020; Peng et al., 2020; Pilosof, 2021; Zhai et al., 2022). These demands include stricter serviceability limits and higher importance factors. In practice, ensuring compliance with drift limits and ductility requirements requires careful design decisions. Local soil conditions further influence seismic response and foundation performance. Cone penetration testing is often used to assess subsurface conditions for foundation design (Chala & Ray, 2023; Oyeyemi et al., 2020; Stuyts et al., 2024). Integrating superstructure and foundation performance is essential for overall structural reliability. Case studies based on real hospital projects provide valuable insights for structural engineers and policymakers.

Recent studies have extensively examined seismic performance and design strategies for reinforced concrete structures, including healthcare facilities, through various analytical approaches and case studies. Several researchers have evaluated the seismic performance of hospital buildings under different conditions, such as irregular geometries and existing structural deficiencies, as well as vulnerability assessments in diverse seismic regions (Hooda & Derit Singh, 2023; Kuria & Kegyes-Brassai, 2023; Uros et al., 2020). In parallel, other studies have focused on enhancing hospital resilience through advanced systems such as base isolation, damping devices, and retrofit strategies, demonstrating improvements in post-earthquake functionality and structural response (Ding et al., 2025; Ferj & Lopez-Garcia, 2022; Mehrjoo & Aval, 2024). Meanwhile, research on Special Moment Resisting Frame (SMRF) systems has primarily addressed general reinforced concrete buildings, emphasizing collapse behavior, fragility analysis, and performance-based design methodologies (Dilsiz et al., 2022; Malla & Wijeyewickrema, 2022; Padalu & Surana, 2024). However, these studies are largely conducted in generic building contexts and rarely focus specifically on essential healthcare facilities. Moreover, existing literature tends to prioritize advanced nonlinear or optimization-based approaches rather than practical code-based design implementation aligned with national standards. There remains a lack of integrated studies that evaluate SMRF systems specifically for hospital buildings while simultaneously addressing structural performance, serviceability requirements, and foundation capacity using site-specific geotechnical data. In addition, regional case studies from Southeast Asia, particularly Indonesia, are still underrepresented in international publications. Therefore, a comprehensive case-based evaluation that integrates seismic design, code compliance, and geotechnical considerations for hospital buildings using SMRF systems remains insufficiently explored.

This study aims to evaluate the seismic performance of a five-storey reinforced concrete cancer hospital building using a Special Moment Resisting Frame system. The research focuses on assessing structural compliance with Indonesian seismic and concrete design standards. A three-dimensional numerical model is developed to analyze seismic responses under design-level ground motions. The study examines internal forces, inter-storey drift, and overall structural behavior. Particular attention is given to verifying the strong-column weak-beam mechanism. Structural serviceability under hospital loading conditions is also evaluated. The foundation system is assessed based on site-specific cone penetration test data. The study seeks to demonstrate the practical applicability of SMRF systems for hospital buildings. Findings are intended to support engineers in seismic design decision-making. Ultimately, this research contributes to improving the resilience of healthcare infrastructure in earthquake-prone regions.

METHODS

Study Area and Building Description

The study was conducted on a planned cancer hospital building located in Pontianak City, West Kalimantan Province, Indonesia. The site is situated in an urban area with moderate seismic risk according to the Indonesian seismic hazard map. The proposed hospital building consists of five storeys and is classified as an essential healthcare facility. As a hospital structure, the building is assigned a higher importance factor to ensure operational continuity during seismic events. The structural system is designed using reinforced concrete as the primary construction material. The building layout accommodates functional hospital requirements, including serviceability and safety considerations. Structural elements include floor slabs, beams, columns, and foundation systems. The geometric configuration and storey heights were defined based on architectural planning data. Local soil conditions were evaluated to support foundation design. This project represents a realistic case study for seismic-resistant hospital structures.

Data Collection and Design Standards

Both primary and secondary data were used in this study. Primary data include site investigation results obtained from cone penetration tests (CPT) conducted at the project location. Secondary data consist of architectural drawings, material specifications, and design parameters. Structural design and analysis were performed in accordance with Indonesian national standards. Reinforced concrete elements were designed based on SNI 2847:2019. Seismic loading and analysis procedures followed SNI 1726:2019 for building and non-building structures. Gravity loads were determined according to SNI 1727:2019. Hospital-specific functional requirements were considered during serviceability evaluation. These standards are aligned with internationally recognized seismic design principles. Compliance with code provisions formed the basis of the analytical framework.

Structural Modeling and Seismic Analysis

A three-dimensional structural model of the hospital building was developed using ETABS v18 software. Beams, columns, and slabs were modeled as reinforced concrete frame and shell elements. Material properties were assigned based on specified concrete strength and reinforcement grades. The Special Moment Resisting Frame system was implemented through appropriate member sizing and detailing assumptions. Seismic analysis was carried out using the response spectrum method. The design response spectrum was defined according to site-specific seismic parameters provided in SNI 1726:2019. Load combinations incorporated gravity and seismic effects. Structural responses such as internal forces and inter-storey drift were extracted from the analysis results. Model verification was performed to ensure numerical stability and consistency.

Structural Performance Evaluation

Structural performance was evaluated by examining strength, ductility, and serviceability criteria. Beam and column capacities were checked against factored internal forces. The strong-column weak-beam requirement was verified at beam–column joints throughout the structure. Inter-storey drift ratios were assessed to confirm compliance with allowable limits for hospital buildings. Reinforcement detailing was evaluated to ensure ductile behavior under seismic loading. Serviceability performance was examined under design gravity loads. Foundation capacity was assessed based on CPT-derived soil parameters. Bearing capacity and structural stability were evaluated for safety. The combined assessment provided an integrated evaluation of superstructure and foundation performance. All evaluation procedures adhered to the applicable design standards.

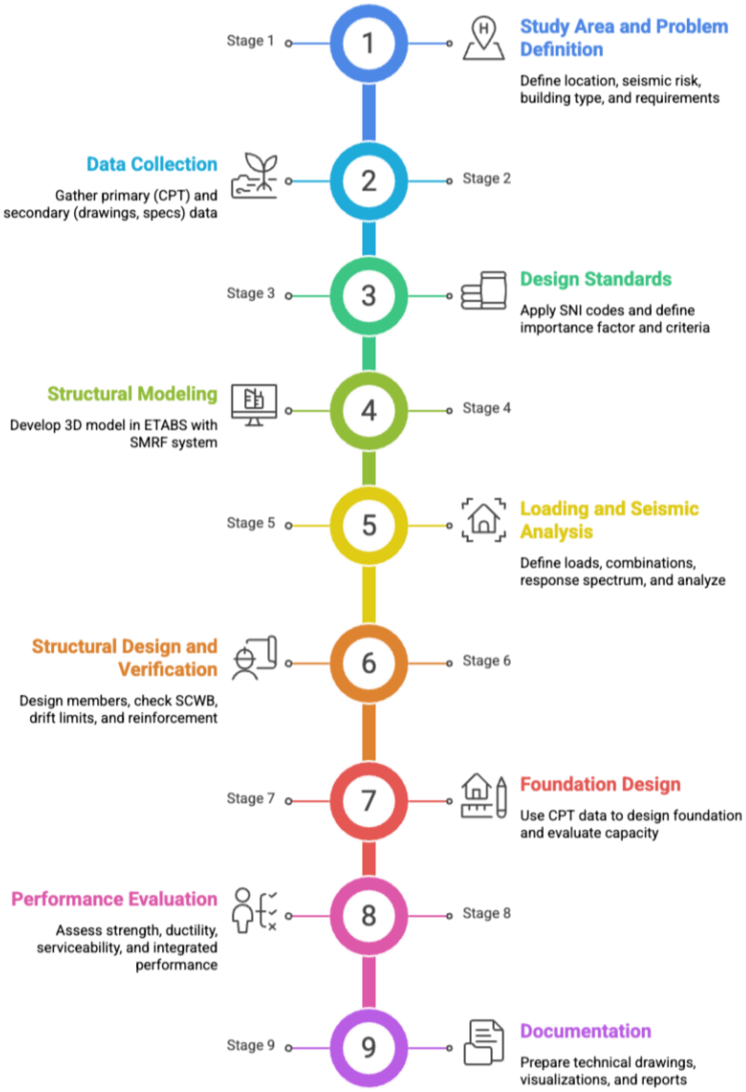


Figure 1. Research method flow

Figure 1. Presents the sequential research methodology employed in this study for the structural design and seismic performance evaluation of a cancer hospital building, consisting of nine systematically interconnected stages. The process begins with the identification of the study area and problem definition, where the project location, seismic risk level, building classification as an essential facility, and functional requirements are established. This is followed by data collection,

which involves the acquisition of primary data through cone penetration testing (CPT) and secondary data including architectural drawings and material specifications. The third stage focuses on determining the applicable design standards, specifically the Indonesian codes governing reinforced concrete structures, seismic loading, and structural performance criteria. Subsequently, a three-dimensional structural model is developed using ETABS software, incorporating the Special Moment Resisting Frame (SMRF) system to represent the building's lateral force-resisting mechanism. In the next stage, structural loading and seismic analysis are conducted using response spectrum methods to evaluate internal forces and inter-storey drift behavior. The structural design and verification stage includes the assessment of member capacities, reinforcement detailing, and compliance with the strong-column weak-beam principle. Foundation design is then performed based on CPT-derived soil parameters to ensure adequate bearing capacity and stability. Structural performance is further evaluated in terms of strength, ductility, and serviceability, followed by the final stage of documentation, which includes the preparation of technical drawings, three-dimensional visualizations, and analytical reports to support comprehensive engineering evaluation.

RESULT AND DISCUSSIONS

Structural Modeling and Load Response

The three-dimensional structural model of the five-storey cancer hospital building was successfully developed using ETABS v18, representing reinforced concrete slabs, beams, and columns configured within a Special Moment Resisting Frame (SMRF) system. The geometric configuration of the building, including storey height, span arrangement, and structural layout, was defined based on architectural planning data and implemented in the modeling environment. As illustrated in Figure 4.1, the structural geometry reflects a regular configuration, which is essential for achieving uniform load distribution and minimizing torsional irregularities.

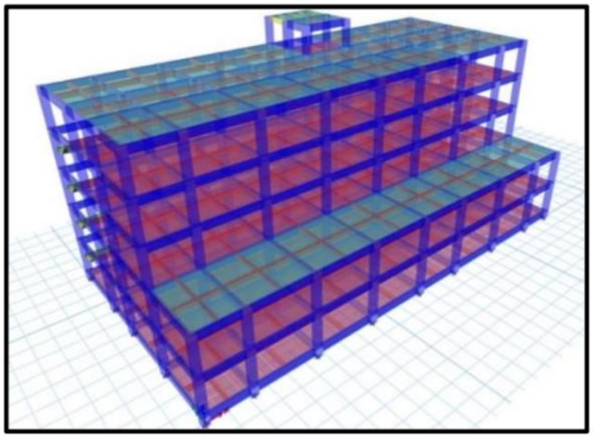
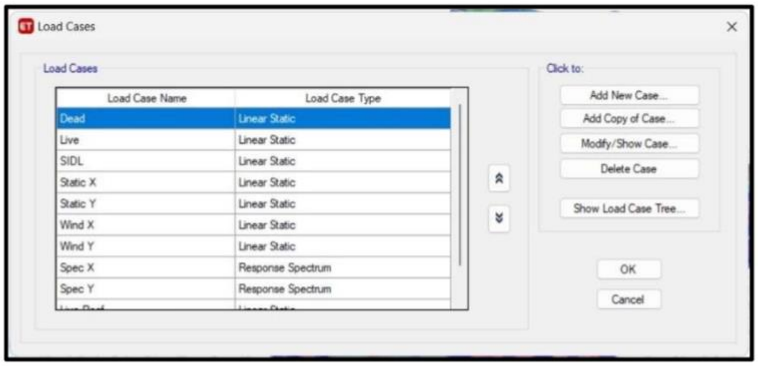


Figure 1. Design Geometry

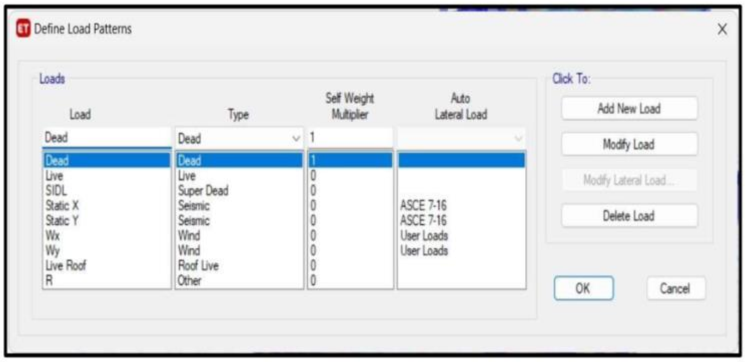
Load definitions were systematically introduced through load cases and load patterns, as shown in Figures 4.2 and 4.3, ensuring accurate representation of gravity and lateral loads. The applied loads include dead loads, live loads, and seismic loads, combined using prescribed load combinations in accordance with SNI 1727:2019 and SNI 1726:2019. The seismic demand was defined using a response spectrum curve derived from site-specific parameters, as presented in Figure 4.4, which incorporates the seismic design coefficient (SDS = 0.28) and other relevant parameters.



Load Cases

Load Case Name	Load Case Type
Dead	Linear Static
Live	Linear Static
SIDL	Linear Static
Static X	Linear Static
Static Y	Linear Static
Wind X	Linear Static
Wind Y	Linear Static
Spec X	Response Spectrum
Spec Y	Response Spectrum

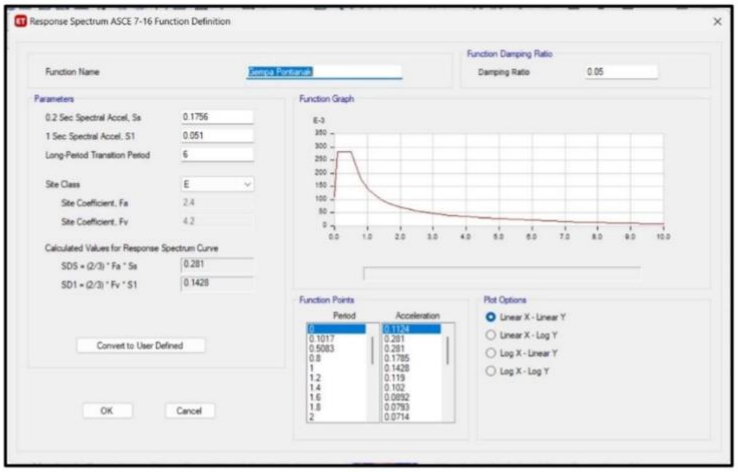
Figure 2. Data Load Case



Loads

Load	Type	Self Weight Multiplier	Auto Lateral Load
Dead	Dead	1	
Dead	Dead	1	
Live	Live	0	
SIDL	Super Dead	0	
Static X	Seismic	0	ASCE 7-16
Static Y	Seismic	0	ASCE 7-16
Wx	Wind	0	User Loads
Wy	Wind	0	User Loads
Live Roof	Roof Live	0	
R	Other	0	

Figure 3. Data Load Patterns



Function Name: Gempa Pontianak

Function Damping Ratio
Damping Ratio: 0.05

Parameters
0.2 Sec Spectral Accel, Ss: 0.1756
1 Sec Spectral Accel, S1: 0.051
Long-Period Transition Period: 6
Site Class: E
Site Coefficient, Fa: 2.4
Site Coefficient, Fv: 4.2

Calculated Values for Response Spectrum Curve
SDS = (2/3) * Fa * Ss: 0.281
SD1 = (2/3) * Fv * S1: 0.1428

Function Points

Period	Acceleration
0	0.1124
0.1017	0.281
0.5083	0.281
0.8	0.1785
1	0.1428
1.2	0.119
1.4	0.102
1.6	0.0892
1.8	0.0793
2	0.0714

Plot Options
● Linear X - Linear Y
○ Linear X - Log Y
○ Log X - Linear Y
○ Log X - Log Y

Figure 4. Respon Spektrum

The structural model demonstrated stable numerical behavior under all loading conditions, with no convergence issues observed during analysis. Internal force distributions, including bending moments, shear forces, and axial loads, were obtained for all structural elements. The global structural response indicates that lateral seismic loads are effectively resisted by the SMRF system.

The absence of significant irregularities suggests that the structure exhibits a balanced stiffness distribution, ensuring uniform load transfer across storeys. These results confirm the adequacy of the modeling approach and provide a reliable basis for further structural evaluation.

Seismic Response and Inter-Storey Drift

The seismic performance of the structure was evaluated using response spectrum analysis based on site-specific seismic parameters. The response spectrum curve applied in the analysis, as shown in Figure 4.4, represents the dynamic characteristics of ground motion at the study location and serves as the primary input for seismic loading.mThe fundamental period of the building obtained from the analysis falls within the allowable range specified by SNI 1726:2019, indicating that the structure has appropriate dynamic properties for a mid-rise reinforced concrete building. The distribution of lateral forces along the height of the structure follows the expected pattern, with increasing displacement toward the upper storeys.

Inter-storey drift ratios were calculated for each floor level under design earthquake conditions. The results show that the maximum drift values remain below the permissible limits for essential buildings such as hospitals. The drift distribution is relatively uniform across all storeys, indicating consistent lateral stiffness and the absence of soft-storey behavior. No excessive deformation concentration was identified at any level, suggesting that the structural system effectively controls lateral displacement. These findings demonstrate that the SMRF system provides sufficient flexibility to absorb seismic energy while maintaining structural integrity and serviceability. The controlled drift behavior is particularly important for hospital buildings, where excessive deformation could disrupt medical equipment and critical operations. Therefore, the structure meets the required performance criteria under design-level seismic loading.

Beam and Column Capacity Verification

The structural capacity of beams and columns was evaluated based on factored internal forces obtained from seismic load combinations. The design process follows the strength design approach, where the nominal capacity of structural elements must exceed the required demand. The dimensions of structural members used in the design are presented in Figures 4.5 and 4.6, which illustrate column sections of 60 × 60 cm and beam sections of 35 × 70 cm. These dimensions were selected to ensure adequate strength and stiffness while satisfying the requirements of the SMRF system.


Frame Section Property Data

General Data

Property Name: 1-K 60x60

Material: Beton Fc' 30 Mpa

Shape

Section Shape: Concrete Rectangular

Section Property Source

Source: User Defined

Section Dimensions

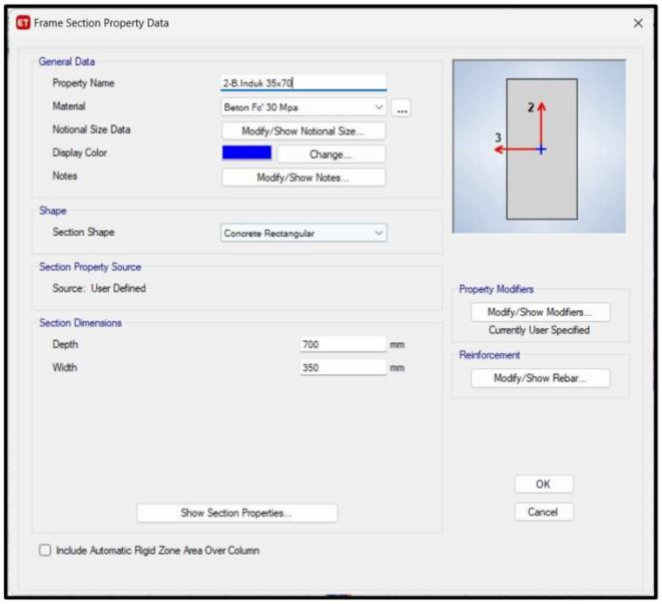
Depth: 600 mm

Width: 600 mm

Property Modifiers: Currently User Specified

☐ Include Automatic Rigid Zone Area Over Column

Figure 5. Column dimension input: 60 cm × 60 cm


Frame Section Property Data

General Data

Property Name: 2-B.Induk 35x70

Material: Beton Fc' 30 Mpa

Shape

Section Shape: Concrete Rectangular

Section Property Source

Source: User Defined

Section Dimensions

Depth: 700 mm

Width: 350 mm

Property Modifiers: Currently User Specified

☐ Include Automatic Rigid Zone Area Over Column

Figure 6. Column dimension input: 35 cm × 70 cm

Beam elements demonstrate sufficient flexural and shear capacity under combined loading conditions. Reinforcement detailing meets the minimum and maximum reinforcement ratios specified in the design code, ensuring both strength and ductility. Column elements exhibit adequate axial and flexural capacity, confirming their ability to resist combined loading effects. A key requirement of the SMRF system, the strong-column weak-beam (SCWB) mechanism, was verified at beam–column joints. The ratio of column moment capacity to beam moment capacity satisfies the prescribed criteria, ensuring that plastic hinges are more likely to form in beams rather than columns. This behavior promotes ductile structural performance and prevents sudden collapse during seismic events. Overall, the capacity verification results confirm that all structural elements meet code requirements and provide sufficient safety margins against failure.

Foundation Performance

The foundation system was designed based on geotechnical data obtained from cone penetration tests (CPT) conducted at the project site. The soil bearing capacity was evaluated to ensure that it exceeds the applied loads from the superstructure. The analysis results indicate that the foundation system provides sufficient bearing capacity and stability under combined loading conditions. The applied axial loads are lower than the allowable soil capacity, ensuring safety against bearing failure. Settlement analysis shows that both total and differential settlements are within acceptable limits, maintaining structural integrity and serviceability. The integration of superstructure and foundation design ensures that load transfer is efficient and continuous. The foundation system is capable of supporting the structural loads without excessive deformation or instability. This confirms that the substructure design is consistent with the overall structural performance requirements. In addition, the use of CPT data enhances the reliability of the foundation design by incorporating site-specific soil conditions. This approach ensures that the foundation system is tailored to local geotechnical characteristics, improving the overall resilience of the structure.

Design Output and Visualization

The final design outputs include detailed two-dimensional working drawings produced using AutoCAD and three-dimensional structural visualizations developed using SketchUp. These outputs provide a comprehensive representation of the structural system and facilitate practical implementation. The generated drawings include detailed reinforcement layouts, member dimensions, and connection details, ensuring constructability and compliance with design standards. The 3D visualization supports a better understanding of the structural configuration and spatial relationships between elements. These outputs confirm that the proposed design is not only analytically sound but also practically feasible for construction. The integration of analytical results with design documentation ensures a complete and reliable engineering solution.

Discussion

The results of this study demonstrate that the application of a Special Moment Resisting Frame (SMRF) system provides adequate seismic performance for hospital buildings in moderate seismic regions. The structural model exhibited stable behavior under combined loading conditions, indicating the reliability of the modeling approach (Dinh et al., 2020; Li, 2021; Yue et al., 2023). This finding is consistent with previous studies that highlight the importance of reinforced concrete frame systems in resisting seismic loads effectively. Nonlinear analysis studies on hospital buildings have shown that structural systems with proper design can achieve acceptable performance levels such as Immediate Occupancy under seismic conditions (Ferj & Lopez-Garcia, 2022; Gabbianelli et al., 2020; Ibrahim, 2025; Kuria & Kegyes-Brassai, 2023; Singh & Palissery, 2024; Uros et al., 2020). The observed uniform load distribution across storeys further supports the effectiveness of regular structural configurations. Similar results have been reported in studies where regular building geometry reduces the likelihood of torsional irregularities and improves global structural response. The absence of instability in the present study confirms that the selected modeling parameters are appropriate. Moreover, the use of numerical simulation tools aligns with widely accepted practices in structural engineering research. Previous research has demonstrated that such tools are essential for accurately predicting structural behavior under seismic loading. Therefore, the findings reinforce the validity of simulation-based structural evaluation methods.

The seismic response analysis reveals that the inter-storey drift values remain within allowable limits, indicating satisfactory serviceability performance. This result is particularly important for hospital buildings, where operational continuity must be maintained during and after seismic events. The controlled drift behavior observed in this study is consistent with findings from previous research, which emphasize that limiting lateral displacement is critical to maintaining structural integrity (Abdullah & Wallace, 2021; Huang et al., 2022; Zhou et al., 2025). Studies using time-history and pushover analysis have shown that increased building height often leads to higher displacement demands (Georgiou et al., 2023; He et al., 2023; Kuria & Kegyes-Brassai, 2023; Pinzón et al., 2023). The present study demonstrates that a mid-rise structure can effectively control drift when designed using SMRF principles. The uniform drift distribution also indicates that stiffness is well distributed throughout the structure (H.-S. Hu et al., 2020; Wu et al., 2021; You et al., 2023). This behavior reduces the risk of soft-storey mechanisms, which are commonly associated with structural failure. Comparative studies have shown that irregular buildings exhibit significantly higher drift ratios and are more vulnerable to seismic damage. The absence of such irregularities in this study contributes to improved seismic performance. Therefore, the results highlight the importance of regular structural configuration in earthquake-resistant design.

The verification of beam and column capacity confirms that the structure satisfies the strong-column weak-beam (SCWB) criterion, which is essential for ductile performance. This mechanism ensures that plastic hinges form in beams rather than columns, thereby preventing catastrophic collapse (Abdulsalam & Chaudhary, 2021; Arowojolu & Ibrahim, 2020). The findings are consistent with previous studies that demonstrate the importance of SCWB in achieving controlled inelastic behavior. Previous analyses have shown that plastic hinge formation typically initiates in beams before columns in properly designed moment-resisting frames. The reinforcement detailing adopted in this study further supports the development of ductility under seismic loading. Prior research on SMRF systems indicates that appropriate detailing significantly enhances energy dissipation capacity (Chen et al., 2023; Hadinejad et al., 2025). In addition, studies on structural strengthening techniques have demonstrated similar improvements in seismic performance through increased stiffness and deformation control. The present study achieves comparable performance without additional strengthening systems. This highlights the effectiveness of code-compliant design in ensuring structural safety. Therefore, the results confirm that SMRF systems are suitable for essential buildings requiring high reliability.

The foundation performance evaluation indicates that the use of CPT-based soil data provides a reliable basis for designing safe and stable foundation systems. The results show that the foundation capacity exceeds the applied structural loads, ensuring safety against bearing failure. This finding aligns with previous studies emphasizing the importance of integrating geotechnical data into structural design. In many existing studies, soil structure interaction is often simplified or neglected, which may affect the accuracy of structural predictions. However, research has shown that soil conditions can significantly influence seismic response, particularly in soft or variable soils. The present study addresses this issue by incorporating site-specific CPT data into the design process. This approach improves the accuracy and reliability of the foundation design. Furthermore, the acceptable settlement values indicate that the structure can maintain serviceability under operational conditions. Previous research also highlights that foundation inadequacy can lead to structural damage and service disruption. Therefore, the integration of superstructure and substructure analysis represents a significant strength of this research.

Overall, this study contributes to the existing body of knowledge by providing a comprehensive evaluation of hospital building performance using a code-based SMRF design approach. Unlike many previous studies that focus on nonlinear or advanced analytical methods, this research emphasizes practical implementation based on national standards. This approach is particularly relevant for developing countries where design practices are often guided by code compliance. Comparative studies have shown that performance-based design methods offer detailed insights but may not always be practical for routine engineering applications. The present study demonstrates that code-based design can achieve satisfactory performance when properly implemented. In addition, the integration of structural, seismic, and geotechnical analysis provides a holistic evaluation of building performance. This integrated approach is rarely addressed in previous studies, which often treat these aspects separately. The findings also highlight the importance of consistent application of design standards. Furthermore, the study contributes regional insights from Indonesia, which remain underrepresented in international literature. Therefore, this research provides both theoretical and practical contributions to earthquake-resistant structural design.

Implication

The findings of this study provide several important implications for structural engineering practice, healthcare infrastructure planning, and seismic risk mitigation, particularly in developing regions. The successful implementation of a Special Moment Resisting Frame (SMRF) system demonstrates that code-based design approaches can achieve adequate structural performance for essential facilities such as hospital buildings. This suggests that adherence to national standards, when supported by rigorous modeling and verification, is sufficient to ensure both strength and ductility requirements under seismic loading. The controlled inter-storey drift observed in this study indicates that serviceability criteria for hospital functionality can be maintained during earthquake events, which is critical for operational continuity. Furthermore, the verification of the strong-column weak-beam mechanism highlights the importance of proper capacity design in preventing brittle failure and enhancing structural resilience. The integration of structural analysis with site-specific geotechnical data through cone penetration testing reinforces the necessity of considering soil conditions in foundation design. This approach ensures that both superstructure and substructure perform cohesively under combined loading conditions. From a practical perspective, the study provides a reference framework that can be applied by engineers in similar seismic regions for designing reliable healthcare facilities. The results also emphasize that regular structural configurations contribute significantly to improving seismic performance by reducing irregularities and deformation concentrations. In terms of policy, the study supports the enforcement of seismic design codes for essential buildings to ensure public safety. Additionally, the integration of analytical results with detailed design outputs enhances constructability and implementation feasibility. Overall, this research contributes to bridging the gap between theoretical design provisions and real-world engineering applications, promoting the development of resilient and sustainable healthcare infrastructure in earthquake-prone areas.

Limitation and Suggestion for Further Research

This study has several limitations that should be acknowledged to provide context for the interpretation of the findings and to guide future research directions. First, the analysis is based on a single case study of a five-storey hospital building, which may limit the generalizability of the results to other building types, heights, or seismic zones. Second, the seismic evaluation was conducted using response spectrum analysis, which assumes linear elastic behavior and does not fully capture nonlinear inelastic responses that may occur during strong earthquakes. Third, the modeling approach did not explicitly incorporate detailed soil structure interaction effects, although site-specific geotechnical data were considered in foundation design. Fourth, material properties were assumed based on standard design values without accounting for potential variability in construction quality or long-term degradation. Fifth, the study focuses primarily on structural components and does not include non-structural elements, which are critical for hospital functionality during seismic events. Sixth, uncertainties related to construction tolerances and modeling assumptions were not explicitly quantified in the analysis. Future research is recommended to extend this work by incorporating nonlinear time-history analysis to better capture inelastic structural behavior under severe seismic loading. Additionally, comparative studies involving alternative structural systems, such as dual systems or base isolation, would provide broader insights into optimal design strategies for hospital buildings. Further investigations should also consider detailed soil–structure interaction modeling to improve the accuracy of seismic response predictions. Multi-case studies across different regions and soil conditions are needed to enhance the general applicability of the findings. Finally, future research should integrate the performance of non-structural components and building functionality to provide a more comprehensive assessment of hospital resilience.

CONCLUSION

This study presents a comprehensive structural design and seismic performance evaluation of a five-storey reinforced concrete cancer hospital building using a Special Moment Resisting Frame

(SMRF) system in Pontianak, Indonesia. The results demonstrate that the structural configuration satisfies the requirements of strength, ductility, and serviceability as specified in the applicable Indonesian design standards. The three-dimensional modeling and analysis conducted using ETABS confirm that the building exhibits stable structural behavior under combined gravity and seismic loading. The inter-storey drift values were found to be within allowable limits, indicating that the structure can maintain functional performance during seismic events. The verification of the strong-column weak-beam mechanism confirms that the structure is capable of achieving ductile behavior and controlled energy dissipation. Beam and column capacity checks further indicate that all structural elements meet the required safety margins. The integration of site-specific geotechnical data through cone penetration testing ensures that the foundation system provides adequate bearing capacity and stability. The results also highlight the importance of regular structural configuration in minimizing irregularities and improving seismic response. The study demonstrates that a code-based SMRF design approach can effectively deliver reliable performance for essential healthcare facilities. In addition, the integration of structural and geotechnical considerations provides a holistic evaluation of building performance. The design outputs, including detailed drawings and 3D models, confirm the feasibility of practical implementation. Overall, this research contributes to advancing the application of seismic-resistant design principles for hospital buildings in earthquake-prone regions.

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Randy Setiawan (Corresponding Author) was responsible for the conceptualization of the study, development of the research framework, and overall supervision of the structural design and seismic analysis. He coordinated the research activities, ensured compliance with applicable design standards, and led the integration of analytical results into the manuscript. Nafis Shaifullah contributed to data collection, structural modeling, and numerical analysis using ETABS software. He was involved in the evaluation of seismic responses, including internal force distribution and inter-storey drift assessment. SY. M. Miqdad Al Qadrie participated in the structural design calculations of reinforced concrete elements, including beams, columns, and foundations. He also contributed to the verification of the strong-column weak-beam criteria and assisted in interpreting the structural performance results. Tegar Setyanugraha supported the preparation of technical drawings and visualization of the structural system, including 2D and 3D representations. He assisted in compiling design documentation and contributed to the refinement of figures and technical descriptions within the manuscript.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. All contributions were conducted independently and without any financial, commercial, or institutional influence that could be perceived as a potential conflict. The research was carried out solely for academic and professional purposes.

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