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Seismic Performance of Reinforced Concrete Hotels with Different Shear Wall Configurations

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ABSTRACT

The seismic performance of high-rise reinforced concrete buildings is strongly influenced by the configuration of their lateral force-resisting system. This study evaluates a 15-story reinforced concrete hotel building by comparing five structural configurations: an existing moment-resisting frame, bearing wall, core wall, perimeter shear wall, and combined wall systems. Three-dimensional structural models were developed in SAP2000 and analyzed using Response Spectrum Analysis according to SNI 1726:2019 for Site Class SD and Seismic Design Category D, while reinforced concrete members were designed based on SNI 2847:2019. Structural performance was evaluated using the fundamental natural period, modal mass participation, inter-story drift, story displacement, and dual-system behavior. All modified configurations reduced the natural period, indicating greater structural stiffness than the existing model. The combined wall system exhibited the most balanced seismic performance by satisfying inter-story drift limits in both principal directions while distributing lateral base shear between the moment-resisting frame and shear walls at 60.15%/39.85% in the X-direction and 74.88%/25.12% in the Y-direction. These findings demonstrate that an appropriate shear wall configuration significantly improves the seismic performance of reinforced concrete buildings in seismic regions.

1. Introduction

Rapid urbanization and the increasing concentration of population in metropolitan areas have accelerated the demand for commercial facilities and multi-story reinforced concrete buildings [1], [2], [3]. Meanwhile, the high seismicity of many urban regions, combined with the growing concentration of critical infrastructure, has increased the potential consequences of earthquake events, emphasizing the need for resilient structural systems capable of mitigating seismic risk and enhancing urban resilience [4]. Consequently, vertical development has become an effective solution to accommodate increasing spatial demands while maintaining land-use efficiency. As the number of high-rise reinforced concrete buildings continues to increase, improving their seismic performance has become an essential aspect of



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structural design to ensure safety, serviceability, and structural resilience in earthquake-prone regions [1], [2], [5].

Indonesia is located at the convergence of the Indo-Australian, Eurasian, and Pacific tectonic plates, making it one of the countries with the highest seismic activity in the world [6]. Therefore, multi-story reinforced concrete structures in Indonesia must be designed to resist significant earthquake-induced lateral forces while satisfying current seismic performance requirements [6], [7]. The implementation of SNI 1726:2019, together with SNI 2847:2019, has introduced updated seismic hazard maps, response spectra, and reinforced concrete design provisions that require more reliable structural evaluation procedures [6], [8]. Because earthquake excitation produces dynamic structural responses, dynamic analysis methods are required to accurately evaluate their seismic behavior [7]. Among these methods, Response Spectrum Analysis (RSA) has been widely adopted because it efficiently estimates the maximum seismic response of multi-degree-of-freedom systems through modal superposition using the response spectrum without requiring full nonlinear time-history analysis [9], [10]. Furthermore, RSA has been widely used to estimate displacement, velocity, acceleration, and other dynamic response parameters, making it an efficient and practical tool for seismic evaluation and design [10].

Among the various seismic force-resisting systems, reinforced concrete shear walls have been widely adopted to enhance the lateral stiffness and strength of multi-story buildings [11], [12], [13]. Previous studies have also demonstrated their effectiveness in improving seismic performance because of their high lateral strength, stiffness, and ductility [14], [15], [16], [17], making them one of the most widely adopted lateral force-resisting systems in medium- and high-rise buildings. [5] further explained that shear walls act as the primary vertical force-transferring elements during earthquakes and significantly influence the global seismic response of reinforced concrete buildings. Properly designed shear walls effectively reduce lateral displacement, control inter-story drift, shorten the fundamental natural period, and improve the distribution of seismic forces throughout the structure [11], [12], [13], [14]. Numerous studies have demonstrated that the effectiveness of shear walls is strongly influenced by their configuration, orientation, geometry, and location within the structural plan [12], [13], [15], [16], [17]. Inappropriate placement may produce torsional irregularities and uneven stiffness distribution, whereas an optimized configuration significantly improves structural stability and earthquake resistance [12], [13], [15], [16].

Recent studies have shown that the seismic performance of reinforced concrete buildings depends not only on the presence of shear walls but also on the interaction between the lateral force-resisting system and the global dynamic characteristics of the structure [13], [14], [18], [19]. Various analytical approaches, including response spectrum analysis, nonlinear analysis, and advanced numerical procedures, have been successfully applied to evaluate structural responses such as natural period, inter-story drift, displacement, and lateral force distribution [9], [18], [19]. These studies consistently demonstrate that an appropriate structural configuration improves stiffness, reduces structural deformation, and enhances the overall seismic performance of reinforced concrete buildings [13], [14], [18], [19].

Although considerable progress has been achieved in evaluating reinforced concrete shear wall systems, previous studies primarily focused on individual wall behavior, wall orientation, wall shape, retrofit strategies, or numerical modeling techniques [13], [14], [15], [18], [20], [21]. Comprehensive investigations comparing multiple shear wall configurations under identical structural geometry, material properties, loading conditions, and seismic design criteria remain relatively limited, particularly for medium- to high-rise reinforced concrete buildings designed according to the latest Indonesian seismic provisions [14], [18], [19], [21]. Furthermore, integrated evaluations considering modal mass participation, fundamental natural period, inter-story drift, and dual structural system behavior within a unified analytical framework are still scarce. Therefore, a comprehensive comparative study is required to determine the most effective shear wall configuration for improving the seismic performance of reinforced concrete buildings subjected to response spectrum analysis [9], [14], [15], [19], [20], [21].

To address these research gaps, this study evaluates the seismic performance of a 15-story reinforced concrete hotel building by comparing five structural configurations, namely the existing moment-resisting frame system, bearing wall system, core wall system, perimeter shear wall system, and combined wall system. The building was modeled as a three-dimensional reinforced concrete structure and analyzed using SAP2000 based on the Response Spectrum Analysis method in accordance with SNI 1726:2019. The design and evaluation of reinforced concrete members followed SNI 2847:2019, while gravity loading was assigned according to SNI 1727:2020. The structural performance

of each configuration was evaluated by comparing the fundamental natural period, modal mass participation ratio, inter-story drift, and dual structural system behavior, which are widely recognized as key indicators in seismic performance assessment [9], [18], [19], [22]. Unlike previous studies that primarily focused on individual shear wall arrangements or a limited number of structural configurations, this study provides a comprehensive comparative evaluation of five shear wall configurations under identical geometric, material, loading, and seismic design conditions. Furthermore, the study integrates stiffness, drift performance, and dual-system load-sharing behavior to identify the optimum shear wall configuration, thereby offering a more comprehensive basis for the seismic design and retrofit of reinforced concrete hotel buildings in earthquake-prone regions of Indonesia.

2. Research Method

2.1 Research Framework

This study employed a quantitative comparative approach to evaluate the seismic performance of different shear wall configurations in a 15-story reinforced concrete hotel building. The selected building served as the case study. The research framework is presented in Figure 1. Initially, structural data, including geometry, material properties, member dimensions, and design loads, were collected to develop a three-dimensional model in SAP2000.

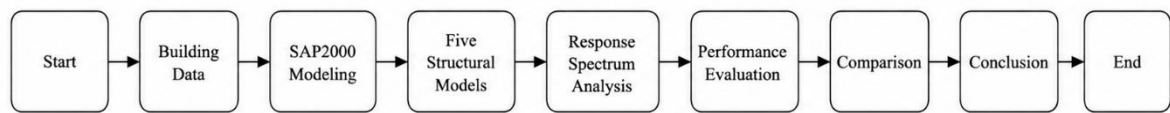


Figure 1. Research framework.

Five structural models were subsequently established to investigate the influence of shear wall configuration on the seismic response of the building. The first model represents the existing moment-resisting frame system without additional shear walls, whereas the other four models represent bearing wall, core wall, perimeter shear wall, and combined wall systems. To ensure an objective comparison, all models were developed with identical building geometry, material properties, loading conditions, and analysis procedures, with the shear wall configuration as the only variable.

Each structural model was analyzed using the Response Spectrum Analysis (RSA) method in accordance with SNI 1726:2019. The design response spectrum was established for Malang, East Java, considering Site Class SD (medium soil) and Seismic Design Category (SDC) D, with spectral response acceleration parameters of $S_s = 0.8599$ g, $S_1 = 0.4026$ g, $S_{DS} = 0.66$ g, and $S_{D1} = 0.51$ g. The building was designed as a dual structural system consisting of a Special Moment Resisting Frame (SMRF) and reinforced concrete shear walls. The seismic performance of each structural model was evaluated by comparing the fundamental natural period, modal mass participation ratio, inter-story drift, story displacement, and dual-system behaviour. Finally, the analytical results of the five structural models were compared to identify the shear wall configuration that provides the optimum seismic performance for the reinforced concrete hotel building.

2.2 Existing Data

The case study considered in this research is an existing 15-story reinforced concrete hotel building located in Malang, East Java, Indonesia. The building was selected because its structural system represents a typical medium- to high-rise reinforced concrete building commonly constructed in seismically active regions of Indonesia. Owing to the high seismicity of the region, the building provides an appropriate case for evaluating the influence of different shear wall configurations on seismic performance.

The structural models were developed in SAP2000 using the previously defined seismic and loading parameters. To ensure an objective comparison, the building geometry, material properties, member dimensions, and loading conditions were kept identical for all models. The only variable considered in the analysis was the shear wall configuration, allowing its influence on the seismic performance of the reinforced concrete hotel building to be evaluated systematically. The general characteristics of the investigated building are summarized in Table 1.

Table 1. Building Information

Parameter	Description
Building Name	Existing 15-story reinforced concrete hotel building
Location	Malang, East Java, Indonesia
Area	490 m ²
Building Function	Hotel
Number of Stories	15
Structural Material	Reinforced Concrete
Structural System	Dual System (SMRF + Reinforced Concrete Shear Walls)
Column Dimensions	600 x 1000 mm
Beam Dimensions	500 x 800 mm
Floor Slab Thickness	125 mm
Structural Wall Thickness	400 mm
Structural Analysis Software	SAP2000
Seismic Analysis Method	Response Spectrum Analysis
Site Class	SD (Medium Soil)
Risk Category	II
Ss	0.8599 g
S1	0.4026 g
SDS	0.66 g
SD1	0.51 g
Response Modification Factor, R	6.5
Importance Factor, Ie	1.0
Deflection Amplification Factor, Cd	2.5
Overstrength Factor, Ω_o	5.0
Seismic Design Standard	SNI 1726:2019
Concrete Design Standard	SNI 2847:2019
Gravity Load Standard	SNI 1727:2020

2.3 Material Properties

The reinforced concrete building was modeled using the material properties specified in the original structural design. Concrete and reinforcing steel properties were assigned in accordance with SNI 2847:2019, while the seismic loading criteria and gravity loads were defined based on SNI 1726:2019 and SNI 1727:2020, respectively. The concrete compressive strength (f_c') was specified as 40 MPa for columns and structural walls from the basement to Level 3, 35 MPa for columns and structural walls from Level 4 to Level 8, and 30 MPa for beams, stairs, and floor slabs. High-strength deformed reinforcing steel (BjTS) with a yield strength (f_y) of 420 MPa and an ultimate strength (f_u) of 545 MPa was adopted for the primary reinforcement, including longitudinal bars and seismic transverse reinforcement, in accordance with SNI 2847:2019. The material properties implemented in the structural model are summarized in Table 2.

Table 2. Material Properties Used in the Structural Model

Material	Structural Element	Property	Value
Concrete	Columns	Compressive strength, f_c'	40 MPa
Concrete	Beams	Compressive strength, f_c'	35 MPa
Concrete	Structural Walls	Compressive strength, f_c'	35 MPa
Concrete	Floor Slabs	Compressive strength, f_c'	35 MPa
Reinforcing Steel (BjTS)	Flexural Reinforcement	Yield strength, f_y	420 MPa
		Ultimate strength, f_u	545 MPa

Material	Structural Element	Property	Value
Reinforcing Steel (BjTP)	Shear Reinforcement	Yield strength, f_y	280 MPa
		Ultimate strength, f_u	405 MPa
Reinforcing Steel (BjTS)	Torsional Reinforcement	Yield strength, f_y	420 MPa
		Ultimate strength, f_u	545 MPa

2.4 Structural Modelling

. Three-dimensional structural models were developed using SAP2000. The building geometry, member dimensions, material properties, floor elevations, and loading conditions were maintained consistently for all structural models. The only variable modified in this study was the configuration of the shear wall system.

The five analytical models considered in this study consist of the existing moment-resisting frame system (Model 1), bearing wall system (Model 2), core wall system (Model 3), perimeter shear wall system (Model 4), and combined wall system (Model 5). The three-dimensional configurations of these analytical models are presented in Figure 2.

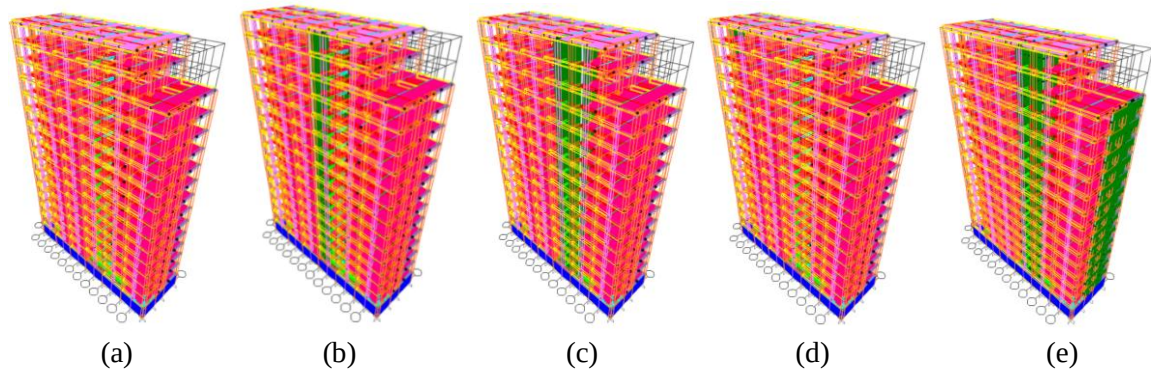


Figure 2. Three-dimensional structural models with different shear wall configurations: (a) Bare Frame, (b) Bearing wall, (c) Core wall, (d) perimeter shear wall, and (e) Combined wall.

This modelling strategy allows a direct comparison of the seismic response produced by each structural configuration while eliminating the influence of other structural variables.

2.5 Seismic Analysis Procedure

Seismic performance was evaluated using the Response Spectrum Analysis (RSA) method. The response spectrum was generated based on the seismic hazard parameters specified in SNI 1726:2019 for Site Class SD. The structural response was assessed through the fundamental natural period, modal mass participation ratio, inter-story drift, story displacement, base shear distribution, and dual-system behavior. To ensure adequate modal participation, the cumulative modal mass participation ratio was verified to satisfy the minimum requirements specified in the seismic design code before evaluating the structural responses.

2.6 Performance Evaluation Parameters

The seismic performance of each structural model was evaluated based on the following parameters:

1. Fundamental natural period.
2. Inter-story drift.
3. Base shear distribution.
4. Dual structural system behaviour.
5. Modal mass participation ratio.

The inter-story drift was assessed by comparing the calculated drift with the allowable drift limits specified in SNI 1726:2019. In addition, the contribution of the moment-resisting frame and shear wall systems in resisting lateral forces was evaluated to verify compliance with the dual structural system requirements.

3. Results and Discussions

3.1 Modal Mass Participation Ratio

The cumulative modal participation ratio in both the X- and Y- directions exceeded **90%** for all five structural models, indicating that the selected vibration modes adequately represented the dynamic characteristics of the structure. Consequently, the calculated structural responses, including the fundamental natural period, story displacement, inter-story drift, and lateral force distribution, were considered sufficiently accurate for comparative evaluation.

No significant difference in cumulative modal participation was observed among the five structural configurations because each model possessed the same overall geometry, mass distribution, and loading conditions. The modification was limited to the shear wall configuration, which primarily influenced the structural stiffness rather than the participating mass. Therefore, all structural models satisfied the modal participation requirements and were considered suitable for subsequent seismic performance evaluation.

The results indicate that the addition and modification of shear wall configurations did not affect the total participating mass of the building but mainly altered its lateral stiffness. Similar observations have been reported in previous studies, where changes in shear wall arrangement primarily influenced structural rigidity, vibration characteristics, and lateral deformation without significantly changing the modal mass participation ratio. These findings demonstrate that the comparison among the five structural models was conducted under equivalent dynamic conditions, ensuring that differences observed in subsequent analyses originated from variations in structural stiffness rather than insufficient modal representation.

Table 3. Cumulative Modal Mass Participation Ratio

Model	SUM UX	SUM UY	Status
Existing	0.90	0.90	OK
Bearing Wall	0.90	0.90	OK
Core Wall	0.90	0.90	OK
Perimeter Shear Wall	0.90	0.90	OK
Combined Wall	0.90	0.90	OK

3.2 Fundamental Natural Period

The fundamental natural period is one of the primary dynamic characteristics used to evaluate the global stiffness of a structure. In general, structures with higher stiffness exhibit shorter vibration periods, whereas more flexible structures produce longer vibration periods. Therefore, comparing the fundamental natural period among different structural configurations provides an effective measure of the influence of shear wall placement on seismic performance.

The analytical results indicate that the existing structural model exhibited the longest fundamental natural period of 2.517 s, reflecting the lowest lateral stiffness among the five investigated configurations. The introduction of shear walls reduced the vibration period in all modified models, indicating an increase in structural stiffness. Compared with the existing model, the bearing wall system produced the greatest reduction in the fundamental period to 2.026 s (19.5%), followed by the combined wall system (2.050 s, 18.6%), the core wall system (2.158 s, 14.3%), and the perimeter shear wall system (2.271 s, 9.8%). These results confirm that incorporating shear walls effectively enhanced the lateral

stiffness of the reinforced concrete building, with the bearing wall and combined wall configurations providing the greatest improvement in structural rigidity.

Among the investigated configurations, the bearing wall system exhibited the shortest fundamental natural period, corresponding to the greatest increase in lateral stiffness, followed closely by the combined wall system. However, the optimum seismic performance cannot be determined solely from structural stiffness, since increasing stiffness also influences the distribution of seismic forces throughout the structural system. Therefore, additional performance indicators, including inter-story drift, story displacement, and dual-system behavior, were evaluated to provide a comprehensive assessment of the seismic performance of each structural configuration.

The observed reduction in the natural period agrees with previous studies, which reported that the incorporation of reinforced concrete shear walls increases global stiffness and reduces structural flexibility under seismic loading. The effectiveness of shear walls is strongly influenced by their configuration and location within the structural plan. Properly positioned shear walls improve lateral load transfer and reduce structural deformation, whereas inappropriate arrangements may produce less efficient structural behaviour despite increasing stiffness. Similar observations have been reported by Abate et al. (2023), Simon et al. (2023), Hidayatullah and Walujodjati (2025), and Al Agha and Umamaheswari (2021), who demonstrated that shear wall configuration plays a significant role in controlling the dynamic characteristics of reinforced concrete buildings.

Although the bearing wall system produced the shortest vibration period, the final assessment of structural performance should consider additional seismic response parameters rather than relying solely on structural stiffness. Therefore, the subsequent discussion evaluates the inter-story drift performance of each structural configuration to identify the most balanced seismic behaviour. The Fundamental Natural Period of Each Structural Model are summarized in Figure 3.

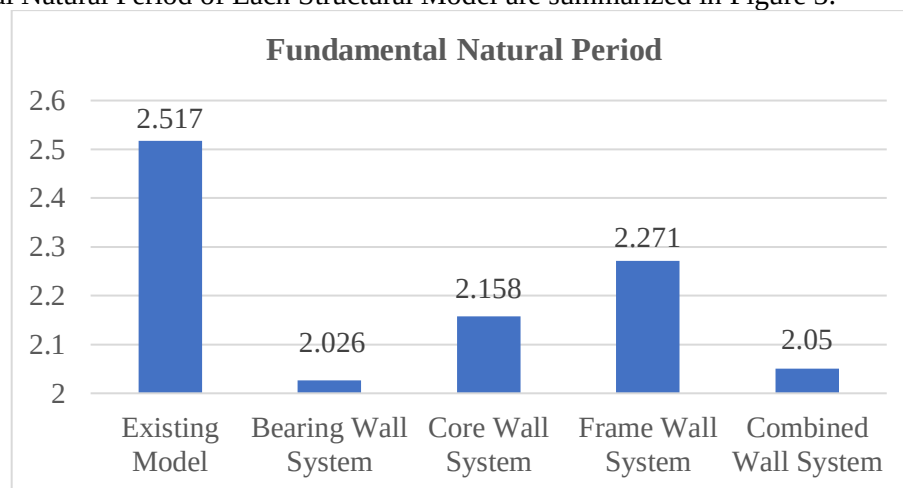


Figure 3. Fundamental Natural Period of Each Structural Model

3.3 Inter-story Drift Evaluation

Inter-story drift is one of the most important parameters in evaluating the seismic performance of buildings because it reflects the deformation capacity of the structural system under earthquake loading. Excessive inter-story drift may cause structural and non-structural damage even when the overall strength of the building remains adequate. Therefore, the calculated drift values of all structural models were compared with the allowable drift limits specified in SNI 1726:2019

3.3.1 Inter-story Drift in the X-Direction

The inter-story drift results in the X-direction are presented in Table 4. All five structural models satisfied the allowable drift limits at every story level. The existing and bearing wall systems exhibited comparable maximum drift values (101.404 mm and 101.596 mm, respectively), whereas the combined wall system produced the smallest maximum inter-story drift (84.799 mm). In contrast, the core wall and perimeter shear wall systems exhibited larger maximum drift values of 120.049 mm and 108.862 mm, respectively.

Although the bearing wall system provided the greatest increase in structural stiffness, as indicated by the shortest fundamental natural period, it did not produce the lowest maximum inter-story drift in the X-direction. Instead, the combined wall system demonstrated the most effective drift control

while maintaining a balanced structural response. This result indicates that increasing structural stiffness alone does not necessarily minimize lateral deformation, since the seismic response is also influenced by the distribution and interaction of the shear walls with the moment-resisting frame.

These findings are consistent with previous studies reporting that the effectiveness of shear walls depends not only on their stiffness but also on their configuration and location within the structural system. Properly distributed shear walls improve lateral load transfer and deformation control, resulting in more balanced seismic performance. Similar observations have been reported by Simon et al. (2023), Hidayatullah and Walujodjati (2025), Abate et al. (2023), and Al Agha and Umamaheswari (2021).

Table 4. Maximum Inter-story Drift in the X-Direction

Structural Model	Maximum Inter-story Drift X (mm)
Existing Model (Model 1)	101.404
Bearing Wall System (Model 2)	101.596
Core Wall System (Model 3)	120.049
Perimeter shear wall System (Model 4)	108.862
Combined Wall System (Model 5)	84.799

3.3.2 Inter-story Drift in the Y-Direction

The inter-story drift results in the Y-direction revealed more pronounced differences among the five structural configurations. The existing model and the bearing wall system exceeded the allowable drift limits at several story levels, indicating that these configurations were unable to provide sufficient lateral stiffness in the Y-direction. Similarly, the core wall system exceeded the allowable drift limit at the upper stories, although it satisfied the code requirements for the remaining story levels.

In contrast, both the perimeter shear wall system and the combined wall system satisfied the allowable inter-story drift limits throughout the building height. These configurations provided a more uniform stiffness distribution in both principal directions, resulting in improved control of lateral deformation under earthquake loading.

The comparison demonstrates that structural performance should not be evaluated solely based on stiffness in one principal direction. Although the bearing wall system exhibited the shortest fundamental natural period and the smallest drift in the X-direction, its poor drift performance in the Y-direction indicates that high stiffness alone does not guarantee balanced seismic behaviour. Conversely, the combined wall system consistently satisfied the drift requirements in both directions, indicating a more reliable seismic performance.

The superior performance of the combined wall system can be attributed to its ability to distribute lateral stiffness more uniformly throughout the structural plan. This configuration reduced torsional effects and improved the interaction between the moment-resisting frame and the shear walls, resulting in better deformation control under bidirectional seismic loading. Similar observations have been reported in recent studies, which concluded that balanced shear wall arrangements generally provide more stable seismic responses than configurations relying on a single dominant structural element.

Table 5. Maximum Inter-story Drift in the Y-Direction

Structural Model	Maximum Inter-story Drift Y (mm)
Existing Model (Model 1)	229.009
Bearing Wall System (Model 2)	1538.521
Core Wall System (Model 3)	428.020
Perimeter Shear Wall System (Model 4)	81.791
Combined Wall System (Model 5)	91.196

3.3 Dual Structural System Evaluation

The dual structural system was evaluated to determine the contribution of the moment-resisting frame (MRF) and the shear wall system in resisting earthquake-induced lateral forces. According to SNI 1726:2019, a dual structural system requires the moment-resisting frame to independently resist at least 25% of the design seismic forces, while the remaining lateral loads may be resisted by the shear wall system. Therefore, evaluating the proportion of lateral force carried by each structural component is essential to verify the effectiveness of the structural configuration.

Table 6 summarizes the contribution of the shear wall and moment-resisting frame systems for the five investigated structural configurations. As expected, the existing structural model relied entirely

on the moment-resisting frame system, resulting in 100% lateral force resistance by the frame in both principal directions. The introduction of shear walls redistributed the lateral load between the frame and the shear wall system, thereby improving the structural response under seismic loading.

The bearing wall system (Model 2) transferred approximately 20.49% and 8.81% of the lateral resistance to the shear walls in the X- and Y-directions, respectively. Consequently, the moment-resisting frame remained the dominant lateral force-resisting component. Similarly, the core wall system (Model 3) showed relatively limited shear wall participation, with contributions of 22.71% in the X-direction and 3.95% in the Y-direction.

A more balanced distribution was observed in the perimeter shear wall system (Model 4) and the combined wall system (Model 5). Model 4 exhibited shear wall contributions of 29.54% and 25.13% in the X- and Y-directions, respectively, while Model 5 achieved the highest shear wall participation, reaching 39.85% in the X-direction and 25.12% in the Y-direction. Despite the increased contribution of the shear walls, the moment-resisting frame continued to resist more than 60% of the lateral loads in all modified models, thereby satisfying the minimum frame contribution required for a dual structural system.

The results indicate that increasing the contribution of shear walls does not eliminate the structural role of the moment-resisting frame but instead promotes a more efficient distribution of lateral forces between the two systems. The combined wall system demonstrated the most balanced interaction between structural stiffness and load-sharing capability, which explains its favourable performance in the inter-story drift evaluation. Although the bearing wall system provided the greatest increase in stiffness, its shear wall contribution remained relatively low in the Y-direction, resulting in less balanced seismic behaviour.

The balanced load-sharing observed in the combined wall configuration indicates a more effective utilization of both structural components. The shear walls provide additional lateral stiffness and reduce structural deformation, while the moment-resisting frame maintains structural redundancy and ductility under severe earthquake loading. Similar observations have been reported in previous studies, which concluded that appropriately configured dual systems generally exhibit superior seismic performance compared with structures dominated by either the frame or the shear wall system alone.

Table 6. Dual Structural System Evaluation

Model	Shear Wall X	Shear Wall Y	MRF X	MRF Y
Existing	0.00%	0.00%	100.00%	100.00%
Bearing Wall	20.49%	8.81%	79.51%	91.19%
Core Wall	22.71%	3.95%	77.29%	96.05%
Perimeter Shear Wall	29.54%	25.13%	70.46%	74.87%
Combined Wall	39.85%	25.12%	60.15%	74.88%

3.4 Overall Comparative Discussion

The comparative evaluation of the five structural configurations demonstrates that the incorporation of shear walls significantly improved the seismic performance of the reinforced concrete building compared with the existing moment-resisting frame system. Although all modified configurations increased the global lateral stiffness and reduced the fundamental natural period, the degree of improvement varied depending on the location and arrangement of the shear walls.

The bearing wall system exhibited the highest structural stiffness, as indicated by the shortest fundamental natural period and the smallest inter-story drift in the X-direction. However, its seismic performance in the Y-direction remained unsatisfactory because several stories exceeded the allowable drift limits. This finding indicates that increasing stiffness in one principal direction alone is insufficient to ensure balanced structural performance under bidirectional earthquake loading.

The core wall system improved the global structural response compared with the existing model, although its effectiveness was limited by the concentration of lateral stiffness around the building core. Consequently, excessive deformation remained at the upper stories in the Y-direction, indicating that the stiffness distribution was not sufficiently uniform throughout the structural plan.

The perimeter shear wall system demonstrated better seismic performance by satisfying the allowable inter-story drift limits in both principal directions while providing a more balanced distribution of lateral stiffness. Nevertheless, the combined wall system exhibited the most favourable overall structural behaviour. This configuration maintained acceptable inter-story drift throughout the

building height, achieved substantial reductions in the fundamental natural period, and produced the most balanced interaction between the shear wall system and the moment-resisting frame.

The dual structural system evaluation further supports this conclusion. Although the combined wall system increased the contribution of the shear walls to approximately 39.85% in the X-direction and 25.12% in the Y-direction, the moment-resisting frame continued to resist 60.15% and 74.88% of the lateral forces in the respective directions. These values comfortably exceed the minimum requirement of 25% of the total design base shear specified by SNI 1726:2019 for dual structural systems, confirming that the moment-resisting frame remained the primary lateral force-resisting component while the shear walls provided substantial additional stiffness and strength. This balanced load-sharing mechanism demonstrates the effective interaction between the two structural components in resisting earthquake loads.

Overall, the results indicate that the seismic performance of reinforced concrete buildings depends not only on increasing structural stiffness but also on achieving an appropriate balance between stiffness, deformation control, and lateral force distribution. These findings are consistent with previous studies, which reported that optimized shear wall configurations provide superior seismic performance by reducing structural deformation while maintaining efficient load transfer and structural redundancy. Therefore, among the five investigated configurations, the combined wall system is considered the most effective structural alternative for improving the seismic performance of medium- to high-rise reinforced concrete buildings.

4. Conclusion and Suggestion

4.1 Conclusion

This study comparatively evaluated the seismic performance of a 15-story reinforced concrete hotel building using five structural configurations: an existing moment-resisting frame system, a bearing wall system, a core wall system, a perimeter shear wall system, and a combined wall system. The response spectrum analysis was performed in accordance with SNI 1726:2019. The comparative analysis demonstrated that incorporating shear walls significantly improved the seismic performance of the building by increasing lateral stiffness and reducing structural deformation compared with the existing structural system.

Among the investigated configurations, the bearing wall system produced the shortest fundamental natural period, indicating the greatest increase in structural stiffness. However, this configuration did not consistently satisfy the inter-story drift requirements in both principal directions. The core wall system provided a moderate improvement in structural stiffness and drift control compared with the existing model, whereas the perimeter shear wall system exhibited further improvement in drift performance. Overall, the combined wall system demonstrated the most balanced structural behaviour by satisfying the allowable inter-story drift limits, maintaining a substantial reduction in the fundamental natural period, and achieving an effective distribution of lateral resistance between the moment-resisting frame and the shear wall system.

The dual structural system evaluation confirmed that all modified configurations satisfied the minimum frame contribution required by SNI 1726:2019, with the combined wall system exhibiting the highest shear wall contribution while maintaining adequate participation of the moment-resisting frame. These findings indicate that the optimum seismic performance of reinforced concrete buildings is achieved not solely by maximizing structural stiffness but by establishing a balanced interaction between stiffness, deformation control, and lateral load distribution.

This study is subject to several limitations. The evaluation was limited to linear elastic response spectrum analysis of a single 15-story reinforced concrete hotel building with regular structural geometry. In addition, the comparison focused exclusively on the influence of shear wall configuration, while other parameters, such as building height, structural irregularities, wall thickness, and nonlinear material behaviour, were not considered. Therefore, the conclusions should be interpreted within the scope of the investigated structural model and analysis assumptions.

The results of this study provide practical guidance for selecting shear wall configurations in medium- to high-rise reinforced concrete buildings located in earthquake-prone regions. Future research is recommended to investigate nonlinear seismic behaviour using time-history or pushover analysis and to evaluate the influence of different building heights, structural irregularities, and shear wall dimensions on structural performance.

4.2 Suggestion

Future research is recommended to extend the present work by performing nonlinear pushover and nonlinear time-history analyses to evaluate the inelastic seismic behaviour of reinforced concrete buildings with different shear wall configurations. Additional investigations involving buildings with various heights, structural irregularities, and alternative shear wall layouts are also encouraged to verify the applicability of the proposed configuration. Furthermore, incorporating soil–structure interaction, performance-based seismic design, and optimization techniques may provide a more comprehensive understanding of the relationship between shear wall configuration and seismic performance.

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