

Seismic Response of R/C Buildings with Various Shear Wall Layouts

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ABSTRACT

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Reinforced concrete buildings in seismic-prone regions require effective lateral load-resisting systems to control displacement and prevent structural damage during earthquakes. Shear walls are widely used to enhance structural stiffness and reduce seismic response; however, systematic comparisons of different shear wall layout configurations under identical conditions remain limited. This study evaluates the seismic response of a reinforced concrete building with various shear wall layout configurations based on the Indonesian seismic design standard SNI 1726:2019. Numerical modeling and response spectrum analysis were performed using SAP2000 to assess key seismic performance parameters, including natural vibration period, displacement, and inter-story drift. Several structural models with different shear wall arrangements were analyzed under identical material properties, geometry, and seismic input. The results show that appropriate shear wall placement significantly improves seismic performance, with the most effective configuration achieving a reduction of inter-story drift of more than 30% compared to the structure without shear walls. The novelty of this study lies in the comprehensive and consistent comparison of multiple shear wall layout configurations within a single building model under identical seismic conditions, enabling clearer identification of an optimal configuration that balances seismic performance and architectural functionality.

Keywords: Shear Wall Layout, Seismic Response, Inter-Story Drift, Reinforced Concrete Building, SNI 1726:2019

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1. Introduction

In many countries worldwide, reinforced concrete buildings are widely used for residential, commercial, and public facilities due to their structural efficiency and economic feasibility [1], [2]. In regions with high seismic intensity, substantial efforts have been made to prevent failure of reinforced concrete structures during earthquakes by improving their lateral load-resisting capacity [3], [4]. In general, building structural systems consist of gravity load-resisting systems and lateral load-resisting systems designed to withstand seismic forces [5]. One effective solution for improving seismic resistance and controlling lateral deformation is the installation of shear walls [6], [7].



As vertical structural components, shear walls play a significant role in resisting lateral forces generated by earthquakes and wind loads. These elements are effective in minimizing lateral displacement, reducing inter-story drift, and increasing overall structural stiffness [6], [8]. Agus [9] investigated a three-story reinforced concrete building with a plan dimension of 17.6×59.25 m and demonstrated that appropriate shear wall placement can significantly reduce the natural vibration period, resulting in a first mode shape dominated by translational behavior. Similar findings were reported by Agus [10], who analyzed a multi-story building and concluded that shear walls substantially improve structural performance under seismic loading.

Several studies have examined the influence of shear wall layout on seismic performance. Verma [11] reported that combining shear walls in reinforced concrete frames significantly reduced inter-story drift and average displacement. Widodo et al. [12] investigated five shear wall configurations in a 20-story building and found that combined core and perimeter layouts provided the most effective drift reduction and force distribution. These studies confirm that variations in shear wall placement can lead to different seismic responses, particularly in terms of stiffness, displacement, and torsional behavior.

In Indonesia, seismic design of reinforced concrete buildings must comply with SNI 1726:2019, which classifies structural systems based on their lateral load-resisting mechanisms, including dual systems combining moment-resisting frames and shear walls [13]. According to this standard, controlling displacement and inter-story drift is essential to prevent structural damage and collapse during earthquakes [13], [14]. Kusumastuti and Pribadi [15] emphasized that shear walls serve multiple functions, including increasing stiffness, reducing drift, distributing lateral forces, and protecting non-ductile elements.

Despite extensive research on the application of shear walls in reinforced concrete buildings, most existing studies focus on limited configurations or evaluate seismic performance parameters in isolation. Furthermore, systematic comparisons of multiple shear wall layout configurations within the same building model under identical seismic loading conditions remain limited. The novelty of this study lies in the comprehensive and consistent evaluation of several shear wall layout configurations applied to a single reinforced concrete building model, using uniform material properties, geometric characteristics, and seismic input based on SNI 1726:2019. By simultaneously assessing the effects of different shear wall placements on natural vibration period, displacement, and inter-story drift, this study provides clearer insight into the relationship between shear wall configuration and overall seismic performance, thereby supporting the identification of an optimal layout that balances structural efficiency and architectural functionality.

Based on these considerations, this study aims to evaluate the seismic response of reinforced concrete buildings with various shear wall layout configurations. The analysis focuses on structural stiffness, natural vibration period, displacement, and inter-story drift to identify an optimal shear wall arrangement that satisfies seismic performance requirements while maintaining architectural functionality.

2. Methodology

This study employed an engineering-based analytical and numerical simulation approach to evaluate the seismic response of reinforced concrete buildings with different shear wall layout configurations. The object of analysis is a three-story reinforced concrete building with a total height of 11.3 m, where each floor has an area of 665.55 m² ($38.25 \text{ m} \times 17.4 \text{ m}$). The building functions as a residential dormitory and is assumed to be located in a seismic-prone region of Indonesia.

Structural modeling was performed using SAP2000 v14 to represent the actual geometry, material properties, and boundary conditions of the building based on design drawings and Indonesian standards. A three-dimensional structural model was developed to capture the spatial behavior of the structure under seismic loading. The building plan configuration without shear walls is illustrated in Figure 1, while its corresponding three-dimensional model is shown in Figure 2. This configuration represents Model 1, which serves as the baseline reference for evaluating the effectiveness of shear wall implementation.

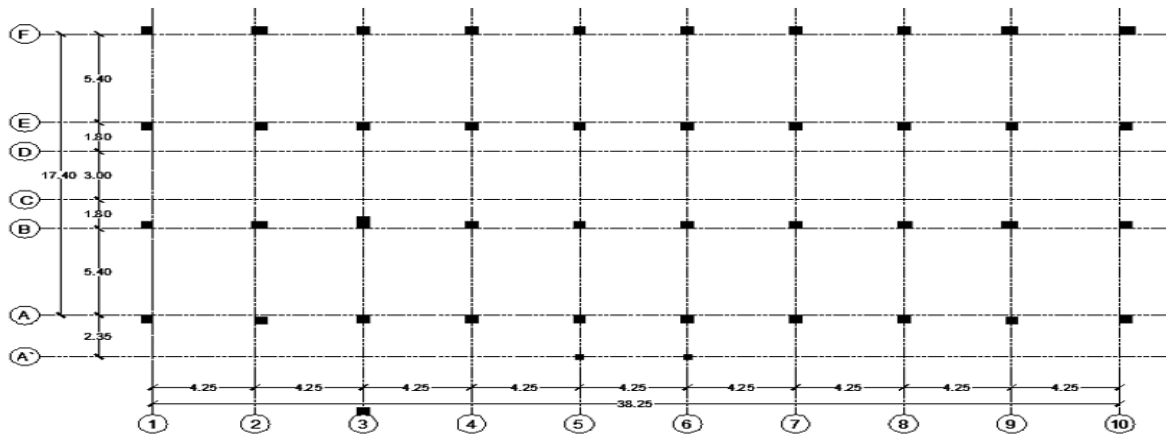


Figure 1. Plan of the building without shear wall (model 1)

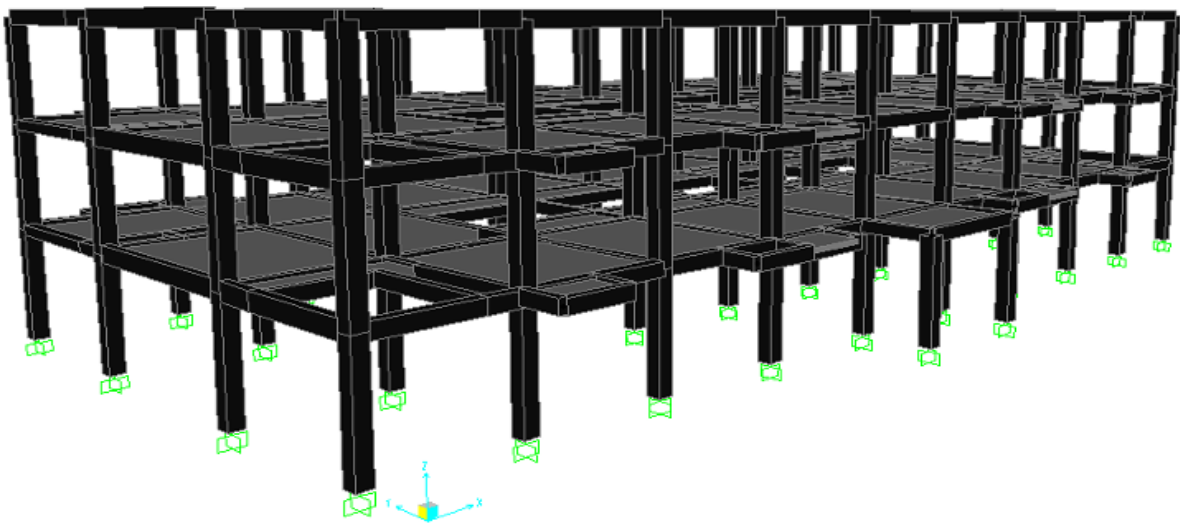


Figure 2. 3-D of the building building without shear wall (model 1)

To investigate the influence of shear wall placement on seismic performance, three additional structural models were developed by introducing shear walls with different layout configurations. Model 2 incorporates shear walls arranged in an L-shaped and core configuration, as shown in the plan view in Figure 3 and the three-dimensional representation in Figure 4. This configuration was designed to enhance structural stiffness while maintaining architectural flexibility.

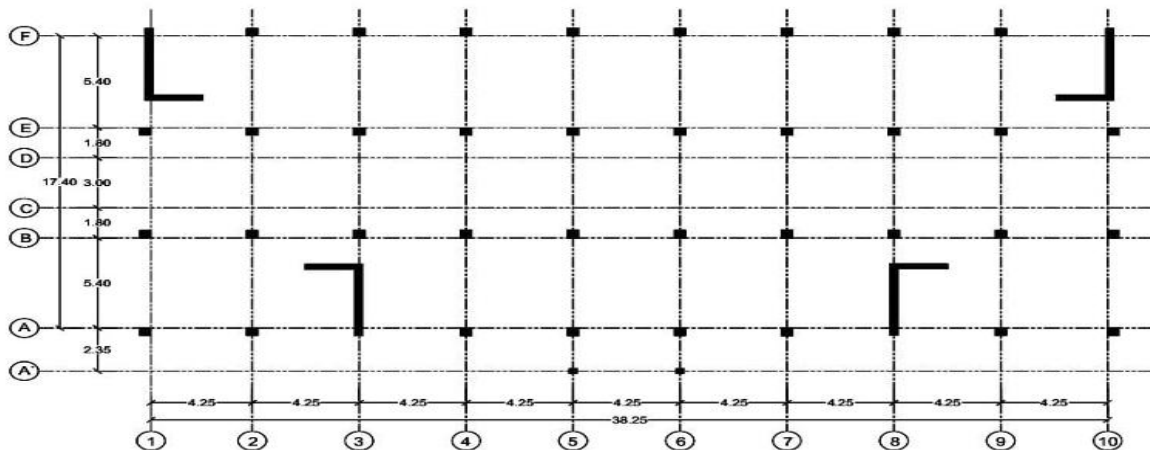


Figure 3. Plan of the building with shear wall (model 2)

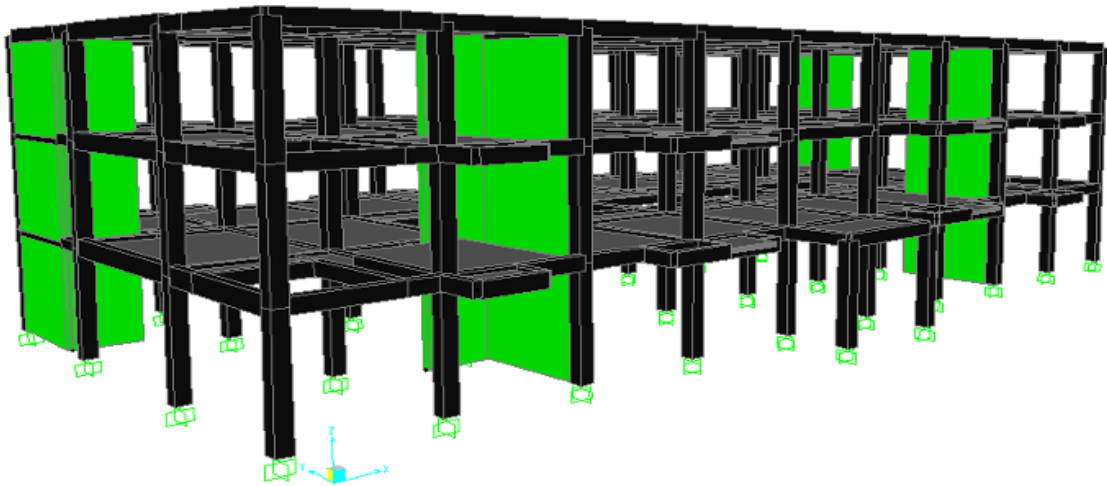


Figure 4. 3-D of the building building with shear wall (model 2)

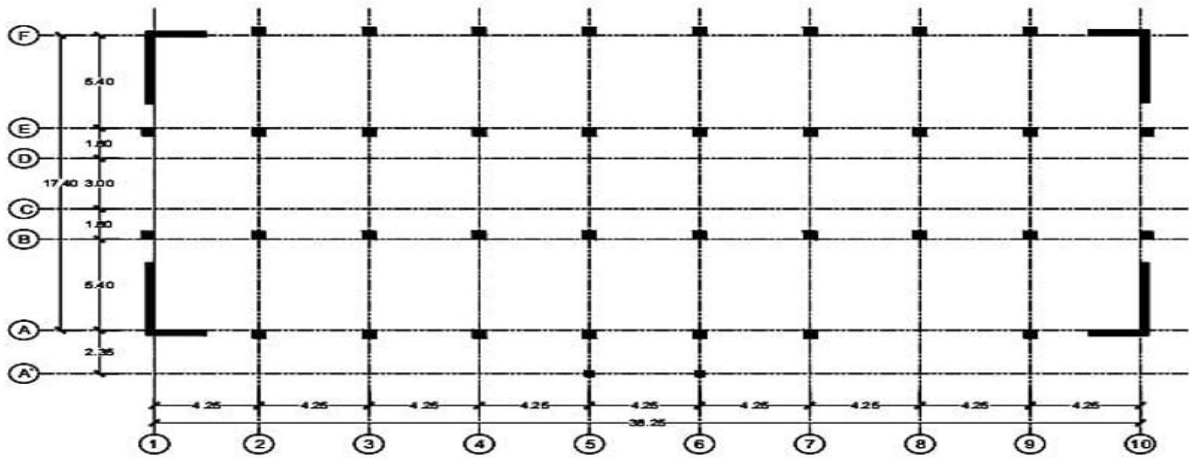


Figure 5. Plan of the building with shear wall (model 3)



Figure 6. 3-D of the building building with shear wall (model 3)

Model 3 applies shear walls along the building perimeter to maximize lateral load resistance. The plan view and three-dimensional representation of this configuration are presented in Figures 5 and 6, respectively. This model aims to evaluate the effectiveness of perimeter shear walls in reducing displacement and inter-story drift by increasing global structural stiffness. Model 4 adopts an alternative shear wall arrangement with asymmetric placement to assess its influence on torsional behavior and overall seismic response. The plan view and three-dimensional model of this configuration are illustrated in Figures 7 and 8. This variation allows evaluation of how non-uniform shear wall distribution affects mode shape characteristics and lateral deformation.

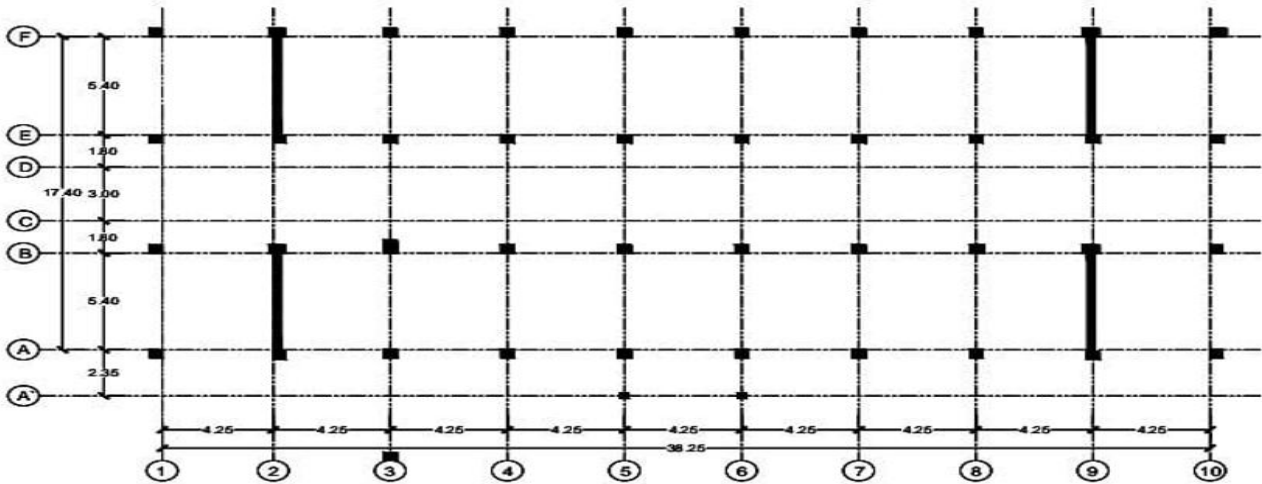


Figure 7. Plan of the building with shear wall (model 4)

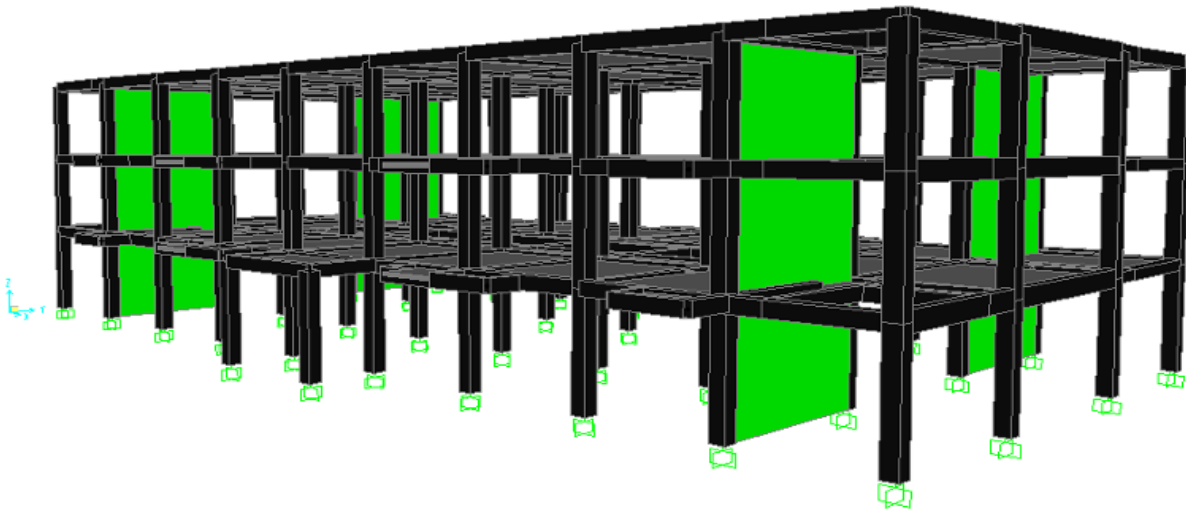


Figure 8. 3-D of the building building with shear wall (model 4)

Material properties and structural dimensions were defined in accordance with Indonesian design standards, including SNI 1726:2019 for seismic design, SNI 1727:2020 for minimum design loads, and SNI 2847:2019 for reinforced concrete structures. Columns, beams, slabs, and shear walls were modeled using the dimensions and material strengths specified in the structural design data.

Structural Properties:

Column K1: 45/45 cm

Beams G1.1, G2.1, G2.2: 25/45 cm

Beam B3.1: 20/40 cm

Slab thickness: 15 cm

Steel yield strength, f_y : 400 Mpa

Column K2 (entrance, 1st floor): 30/30 cm

Beam G4.1: 35/45 cm

Shear wall thickness: 30 cm

Concrete strength, f_c' : 25 MPa

Seismic loading was applied using response spectrum analysis based on SNI 1726:2019. Load cases included dead load (DL), live load (LL), and earthquake load (EL), with load combinations defined according to the applicable design codes. The response spectrum was developed based on site-specific seismic parameters and soil conditions to accurately represent the earthquake demand.

3. Results and Discussion

Natural period and Mode Shape

Control of the natural vibration period is necessary to prevent excessive flexibility and torsional behavior. The first and second mode shapes are required to be dominated by translational motion. Figure 9 and Table 1 present comparisons of natural periods and mode shapes for each model.

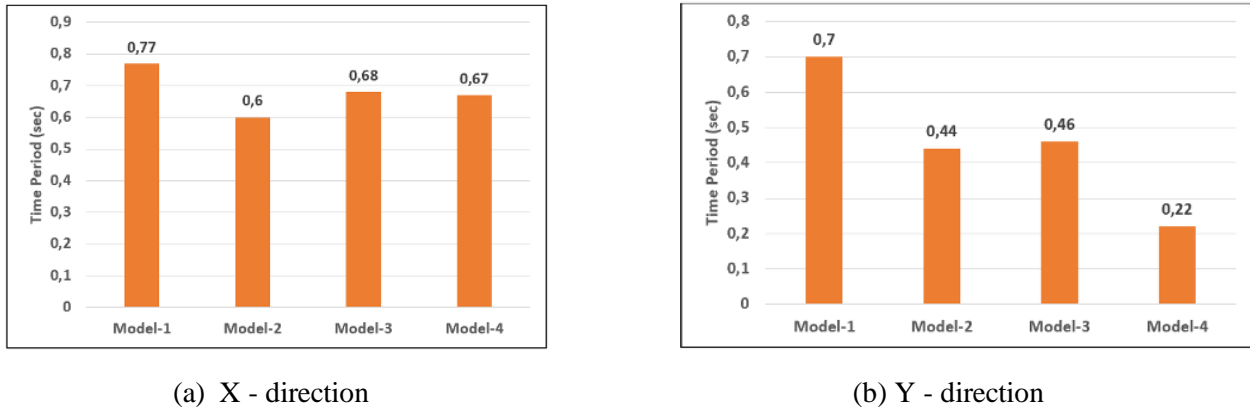


Figure 9. Comparison of the fundamental natural vibration periods for all structural models

Table 1. Characteristics of the first and second mode shapes for all structural models.

Output Case	StepNum	UX (Unitless)	UY (Unitless)	RZ (Unitless)	Check
Modeshape model 1	1	0,000	0,849	0,47296	Translation in Y-direction
Modeshape model 1	2	0,405	0,000	0,38488	Combined translation and torsion
Modeshape model 2	1	0,860	0,000	0,16	Translation in X-direction
Modeshape model 2	2	0,000	0,830	0,44	Translation in Y-direction
Modeshape model 3	1	0,860	0,000	0,2	Translation in X-direction
Modeshape model 3	2	0,000	0,820	0,45	Translation in Y-direction
Modeshape model 4	1	0,860	0,000	0,16	Translation in X-direction
Modeshape model 4	2	0,000	0,760	0,42	Combined translation and torsion

Based on the mode shape analysis as in Table 1 above, Models 1 and 4 show that rotation occurs, while Models 2 and 3 are dominated by translational modes. The reduction in natural vibration period reflects an increase in global structural stiffness, which subsequently influences the dominant mode shape characteristics of the building.

Displacement

Maximum displacement results for each structural model are presented in the following Figures 10. The lateral displacement response of the structure was evaluated to assess the effectiveness of different shear wall layout configurations in controlling global deformation under seismic loading. The results show that the baseline model without shear walls exhibits the largest displacement, indicating relatively low lateral stiffness. In contrast, all models incorporating shear walls demonstrate a significant reduction in displacement, confirming the contribution of shear walls to increased structural rigidity. Among the evaluated configurations, the perimeter shear wall arrangement (Model 3) results in the smallest displacement values due to its higher stiffness

contribution along the building edges. This reduction in displacement is consistent with the observed decrease in natural vibration period and the improved translational mode shape behavior discussed earlier. This displacement reduction directly influences inter-story drift performance

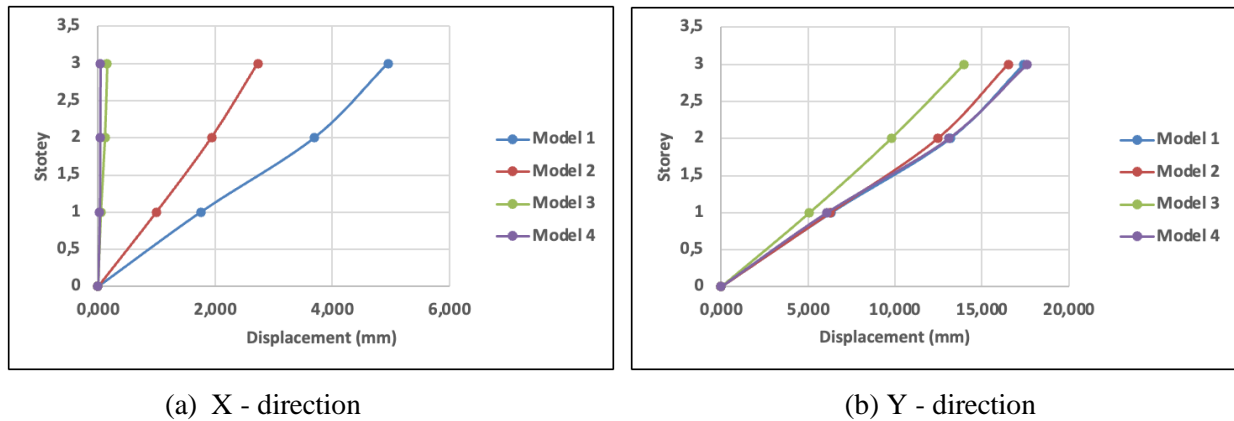


Figure 10. Displacement results for each structural model

Story Drift

Inter-story drift values under seismic loading in both X and Y directions, based on SNI 1726:2019, are shown in Tables 2 and 3.

Table 2. Story drift in x direction base on SNI-1726-2019

Storey	Model 1 Δx (mm)	Model 2 Δx (mm)	Model 3 Δx (mm)	Model 4 Δx (mm)	Permitted Drift Δa (mm)
3	6,914	4,365	0,224	0,029	65,385
2	10,697	5,180	0,392	0,025	65,385
1	9,637	5,482	0,270	0,166	69,231

Table 3. Story drift in y direction base on SNI-1726-2019

Storey	Model 1 Δx (mm)	Model 2 Δx (mm)	Model 3 Δx (mm)	Model 4 Δx (mm)	Permitted Drift Δa (mm)
3	23,265	22,220	23,057	24,777	65,385
2	37,673	33,988	25,857	38,608	65,385
1	34,830	34,586	27,971	33,462	69,231

The results demonstrate that all structural models satisfy the allowable inter-story drift limits specified in SNI 1726:2019, indicating adequate seismic performance. The significant reduction in inter-story drift observed in Models 2 and 3 confirms the effectiveness of shear wall systems in controlling relative floor deformation, which is a critical indicator of seismic safety and serviceability.

Overall, the incorporation of shear walls significantly enhances seismic performance. Among the four evaluated models, Model 3 exhibited the smallest displacement and inter-story drift ratios, fully complying with the requirements of SNI 1726:2019. This confirms the effectiveness of its shear wall layout in improving structural stability. These findings are consistent with the results reported in [16], which indicate that shear walls placed along building edges and aligned with structural axes can maximize ductility and lateral resistance.

Although Model 3 achieved the best numerical performance, Model 2 was identified as the most suitable configuration for practical implementation, as it provides a balanced combination of seismic effectiveness and architectural flexibility. From an application perspective, Model 2 offers improved constructability and functional adaptability, particularly for buildings requiring façade openings and circulation spaces. This observation supports previous studies showing that optimal shear wall placement can achieve effective and efficient seismic performance while accommodating architectural constraints.

4. Conclusions

This study evaluated the seismic response of a reinforced concrete building with various shear wall layout configurations using response spectrum analysis based on SNI 1726:2019. The results demonstrate that shear wall placement significantly influences structural stiffness, natural vibration period, displacement, and inter-story drift. Among the evaluated configurations, the perimeter shear wall arrangement (Model 3) exhibited the best numerical performance in terms of displacement and drift reduction. However, the combined core and L-shaped configuration (Model 2) was identified as the most suitable solution for practical implementation, as it provides a balanced combination of seismic performance and architectural flexibility. These findings highlight the importance of considering both structural efficiency and functional requirements in the design of shear wall systems for earthquake-resistant buildings.

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