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The Performance Of Multi-Storey Buildings Dual Systems With Special Moment Resisting Frames And Intermediate Moment Resisting Frame: A Comparative Study

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Abstract
Special reinforced concrete moment resisting frames are typically used in seismic design for high-rise buildings, but looking at the criteria of SNI 1726-2019 with seismic design category D. Multi-storey building plans can be designed using the dual systems with Special Moment Resisting Frame (SMRF), and Intermediate Moment Resisting Frames (IMRF). This study will compare the predicting efficiency of the dual systems with IMRF to that of the dual systems with SMRF in terms of dimensions, details of reinforcement, and structural performance. The building simulation has a building length and width of 35 x 25 meters, then the height between floors is 4 meters with a building height of 16 meters for Low Rise Building (LRB), 32 meters for Middle Rise Building (MRB), and 48 meters for High Rise Building (HRB). The result of the study shows that the ratio of the longitudinal reinforcement area of the beam elements in the double system of IMRF is not more efficient than the double system of SMRF. Comparison of the area of transverse reinforcement of column elements of IMRF are more efficient than SMRF. Comparison of structural performance of the IMRF system is more efficient than the SMRF System.

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I. Introduction

The Indonesian region is an area that has a high earthquake vulnerability because Indonesia's geographical location is traversed by tectonic plate confluence, this is evidenced by the frequent occurrence of earthquakes in recent years. Natural conditions, especially this earthquake, require the fulfillment of the planning requirements for an earthquake-resistant structural system in every building that is erected, especially for Multi-storey Buildings, so that when the earthquake occurs, the building structure can withstand the risk of earthquake hazard. Failures that occur in a building structural system due to the earthquake are generally caused by a building system that is planned and constructed not in accordance with the level of vulnerability of the local area to earthquakes and inadequate structural planning and reinforcement details used in a structural system. Previous research has compared designs in various regions in Indonesia, it was found that earthquake-prone zones produce more dimensions and reinforcement [1].

For multi-storey buildings, it is usually designed using a structural system, especially using reinforced concrete, namely a moment-resisting frame. Analysis of the structure of hospital buildings in Cirebon City uses a special reinforced concrete moment resisting frames system [2]. In the design of earthquake-resistant multi-storey buildings using reinforced concrete, several requirements need to be considered, such as horizontal and vertical irregularities, adjustments to the vibration period of the structure, earthquake force scale factors, structural stability checks, and other requirements [3].

Earthquake design of high-rise buildings in Manado City with reinforced concrete moment resisting frames system such as structural building for a 4-storey hotel building [4], design for a 3-storey laboratory building [5], planning for an office building 5 floors [6], design for a 4-storey training center building [7], building for a 4-storey parking construction [8], and planning for a 5-storey lecture building [9]. This plan fulfills one of the reinforced concrete moment resisting frame requirements, specifically Strong Column Weak Beam must be fulfilled, where the building is planned to be stiffer columns than beams so that the expected failure occurs in the plastic joints of the beams.

In addition to planning high-rise buildings due to earthquake loads, performance-based planning for high-rise buildings needs to be done. In previous research, in a 10-storey building with Push-over analysis, the Damage Control performance level was obtained with the spectrum capacity ATC-40 method and Life Safety with the FEMA-356 displacement method [10]. In a case study of a high-rise building in Manado City for 12 floors taking into account earthquake loads and wind loads, it has an Immediate Occupancy structural performance level [11]. In evaluating the performance of a 13-storey building due to earthquake loads, the Damage Control performance level was obtained using the spectrum capacity ATC-40 method, and using the Life Safety of FEMA-356 displacement method [12].

Generally, buildings are designed to use a SMRF system. But in accordance with the requirements of SNI 1726-2019 in the city of Manado with seismic design category D, multi-storey building plans can be designed using a double system of intermediate reinforced concrete moment frames by paying attention to the building height limit of 48 meters. In contrast to SMRF, the IMRF system's structure is subjected to higher seismic stress, resulting in the structure's dimensions increasing [13]. As a result, SMRF is more rigid than IMRF. The details of the flexible shear reinforcement in SMRF are more detailed than those in IMRF (14). In fulfilling the requirements by using the intermediate reinforced concrete moment, it is required to use a special structural shear wall. The consequence of adding shear walls to the building makes the structure more rigid [15].

The addition of shear walls also affects the displacement of the structure for the purpose of adding shear walls; for instance, the displacement of shear walls placed diagonally affects a structure less than those placed in the direction of the earthquake load [16]. The location of the shear wall at the mass center of the structure has a smaller deviation than the placement of shear walls outside the building [17].

Fig. 1: Location of Manado City (source: mapcarta.com)

II. Scope and Aim

The scope of this research is to compare the dual systems with SMRF and dual systems with IMRF in Manado City (Figure 1). The limitations of this research problem are as follows: Variations in the number of stories are 4 storey, 8 storey, and 12 storey; The compressive strength used is 30MPa; The reinforcing steel yield strength is 420MPa; The position of the shear walls is made symmetrical on the outside of the building; The building plan is symmetrical; The size of the building is 35 meters x 25 meters with a distance of 5 meters between columns; and The distance between floors is 4 meters.

The aims of this research are as follows:

- To find out the efficient dimensions of the beam, column, shear wall, and slab structures from a comparison of dual systems with SMRF and dual systems with IMRF.
- To find out the efficient reinforcement of beam, column, joint, shear wall, and slab structures from a comparison of dual systems with SMRF and dual systems with IMRF.
- To find out the comparison of building performance from a comparison of dual systems with SMRF and dual systems with IMRF.

III. Methodology

Load combination

Buildings must be built in accordance with SNI 1727:2020 article 2.3.1 so that the design strength will either exceed or be equal to the factored load effect in loading combinations. Furthermore, the Basic Combination with Seismic Load Effects for Strength Design is stated in article 2.3.6 of SNI 1727:2020. If the structure is planned with the effects of earthquake loads, the combination due to seismic loads must be considered as an addition to the basic combination. When the effects of seismic loads are specified, $E = f(E_v, E_h)$ seismic loads must be used: The working loads are used as live loads, dead loads, and seismic loads in accordance with SNI 1727:2020 [18], which addresses Minimum Design Loads and Related Criteria for Buildings and Other Structures [19].

Cross-sectional dimensions

The cross-sectional dimensions are planned with the initial design according to the provisions of concerning Procedures for Structural Concrete Requirements for Buildings and Explanations [20]. Following an analysis to determine the cross-section used, a Push-over method is then performed to find out the building's degree of performance. The imported earthquake load is evaluated in the form of modal loads and expressed as a combination of modal loads using the Push-over method [21]

Building Models

Placement of the shear walls is planned to enable the translation mode to occur in the first and second forms by trial and error from several models of shear wall placement. Placement of shear walls as shown in Figure 2 is possible for the form of the translation mode to occur in the first and second modes then rotation in the third mode. Figures 3 to 5 are 3-dimensional modeling drawings for the LRB, MRB, and HRB models respectively.

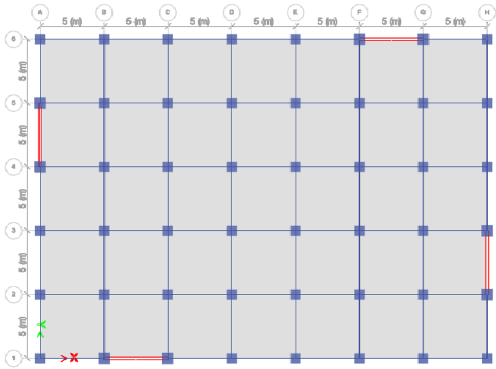


Fig. 2: Plan of modeling the results of trial and error

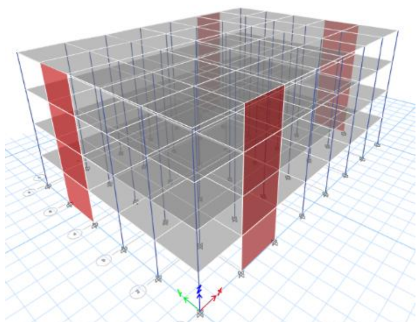


Fig. 3: 3D Modeling of LRB (16 meters)

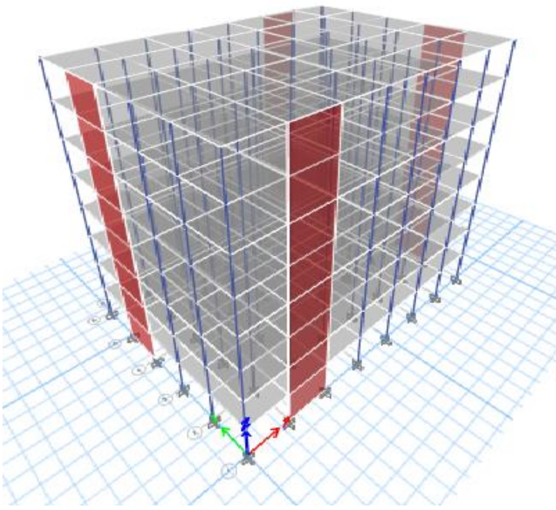


Fig. 4: 3D Modeling of MRB (32 meters)

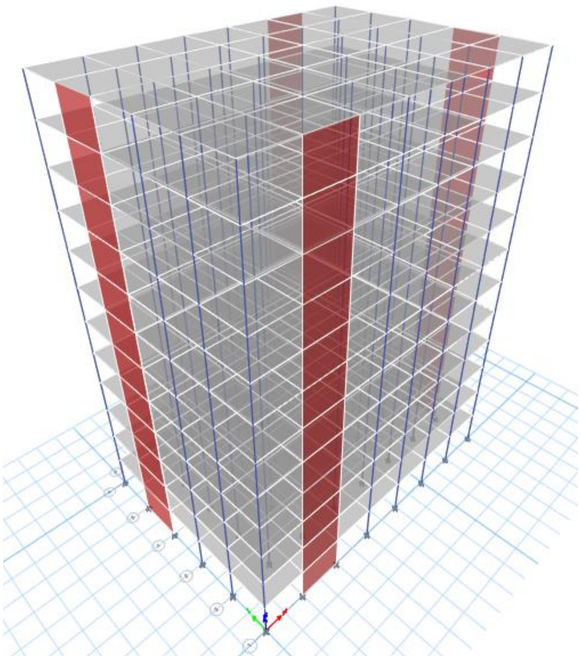


Fig. 5: 3D Modeling of HRB (48 meters)

Research Steps and Flowchart

The research steps and flowchart are shown in Figure 6, and are designated as follows:

- *Data Collection and Modelling on ETABS*
- *Variety check*
- *Double system check*
- *Check deviation between floors and stability of the structure.*
- *Force analysis in each structural element*
- *Structural element design*.
- *Structural system performance analysis*
- *Analysis results*
- *Conclusion*

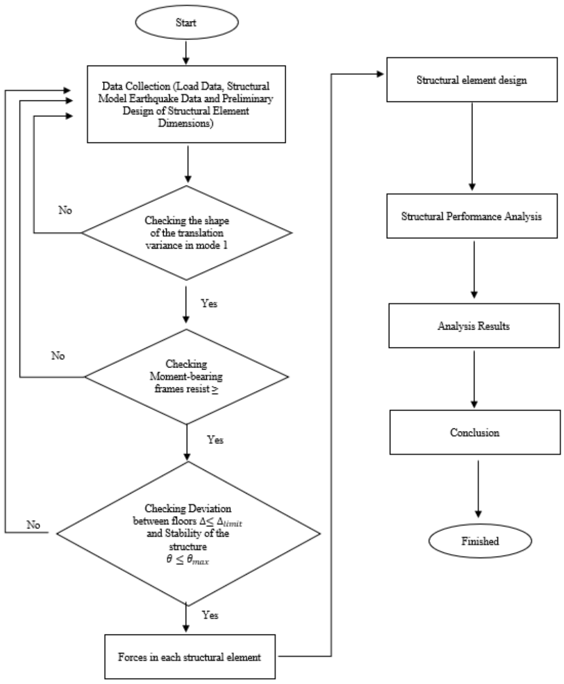


Fig. 6: Flow Chart

IV. Literature review

Earthquake-resistant reinforced concrete structure

An earthquake is one of the frequent natural catastrophes [22]. Indonesia is located between several of the world's tectonic plates causing Indonesia to become an archipelago country that is rich in natural resources and fertile soil. These plates form the geography of Indonesia, which cannot be separated from natural disasters such as earthquakes caused by the tectonic plate. Wood, Steel, and Reinforced concrete are the main elements forming a structural system. Reinforced concrete is concrete reinforced with steel. These two materials work together to withstand the forces acting on a structural system [23].

The basic structural design concept must meet criteria such as being strong in holding the planned load, fulfilling serviceability, having high durability, compatibility with the surrounding environment, economical and easy to maintain [24]. In the design of earthquake-resistant high-rise buildings with reinforced concrete materials, some special performance needs to be considered, such as horizontal and vertical irregularities that may occur, adjustment of the structure vibration period with the required minimum and maximum periods, the factor of the scale of the earthquake force for the analysis of earthquakes with dynamic forces, checking structural stability and various other requirements according to SNI 1726:2019. High-rise buildings frequently exceed the necessary normal limits, consequently, certain restrictions in the planning process must be made to guarantee the structural reliability of the building.

Structural Analysis Due to Earthquake

Table 1 shows the parameters for determining earthquake loads according to SNI 1726-2019.

Table 1: Parameters According to SNI 1726-2019

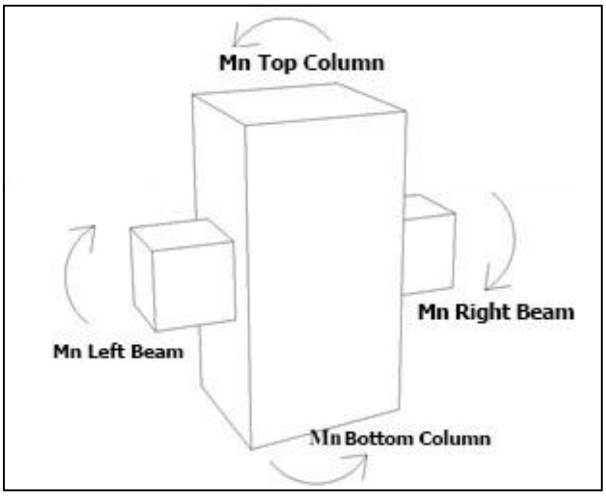
Parameters	SNI 1726-2019	Parameters	SNI 1726-2019
Site Coefficient and Parameters of Spectral Response of Maximum Earthquake Acceleration	article 6.2	Redundancies	article 7.3.4.
Design Spectral Acceleration Parameters	article 6.3.	Selection of Analysis Procedures	table 16.
Seismic Design Category	article 6.5	Determination of Structure Period	table 17 and table 18.
Design Response Spectrum	article 6.4	number of varieties	article 7.9.1.1
Risk Category Structure and Priority Factors	article 4.1.2.	Seismic base shear	article 7.8.1.
Seismic Force Bearing Structure System	table 12.	Style Scaling	article 7.9.1.4.1.
Horizontal Irregularities in the Structure	table 13.	Deviation Limits between story	article 7.12.1
Vertical Irregularities in the Structure	table 14.	P-delta effect	article 7.8.7.

Special Moment Resisting Frame (SMRF) System

In article 18.6.3.2 SNI 2847-2019, the nominal moment of positive beam support must exceed or equal 50% of the negative nominal moment of beam support, and the nominal moment of the positive, and negative field must exceed or equal 25% of the major nominal moment at the support of the beam cross-section. In article R18.7.1 of SNI 2847-2019, the amount of factored axial load acting on a column structure component is limited to not less than $0,1A_g f_c'$.

In article 18.7.2.1 SNI 2847-2019 The geometric requirements must comply with the bearing frame system of SMRF column structure; $b \geq 300\ mm$, and $^b/_h \geq 0{,}4$. Additionally, based on article 18.7.3.2 of SNI 2847-2019, the flexural strength of the SRPMK column must comply with the weak beam-strong column requirements as shown in Figure 7.

Fig. 7: Strong Column-Weak Beam Concept



Article 18.7.4 of SNI 2847-2019 states that the longitudinal reinforcement's area must not exceed less than 1% of the column's cross-sectional area or greater than 6% of the area. Then for columns with circular hoops the minimum amount of longitudinal reinforcement must be 6 bars. Tensile lap joints must comply with the provisions of transverse reinforcement in articles 18.7.5.2 and 18.7.5.3 SNI 2847-2019.

Transverse reinforcement must be placed in column areas that have the potential to create plastic hinges, with the reinforcement's area and spacing governed by the guidelines in SNI 2847-2019's article 18.7.5.1.

Intermediate Moment Resisting Frame (IMRF) System

According to article 18.4.2.2 SNI 2847-2019, the support nominal moment of the beam's positive support must be greater than or equal to 33.33% of the support nominal moment of the beam's negative support, and the nominal moments at the support of the beam's positive and negative fields have to be greater than or equal to 20% of the largest nominal moment at support.

Special Structure of Shear Wall Systems

Shear walls are usually categorized based on their geometry, namely: Flexural wall ratio $h_w/l_w \geq 2$; Squat wall (short wall) ratio $h_w/l_w < 2$; and Coupled shear wall.

Performance Level

Performance level shows the level of damage that occurs to a structure if the planned earthquake load occurs. The maximum structural and non-structural damage caused by the design earthquake load is limited by the level of performance. This performance level is stated according to the criteria for physical damage to the building that occurs.

V. Results and Discussions

Element of Beams

High-Rise Building Model

Comparison of the area dimensions of the beam elements (Ag) for the HRB model can be seen in that the beam dimensions in the Bearing Frame System of SMRF and Bearing Frame System of IMRF obtained the same results as shown in Figure 8.

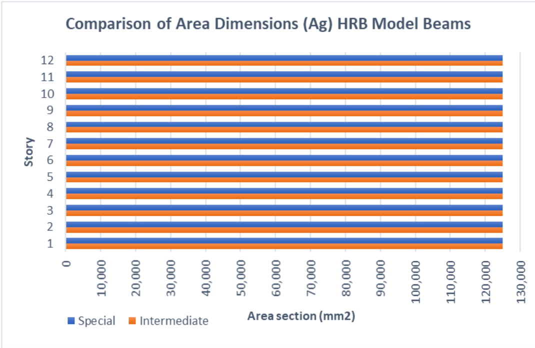


Fig. 8: Comparison of Area Dimensions (Ag) HRB Model Beams

When comparing the area of longitudinal beam reinforcement (As) for the HRB model, the area of longitudinal reinforcement at the Bearing Frame System of IMRF is greater than at the Bearing Frame System of SMRF, as shown in Figure 9.

Fig. 9: Comparison of Area of Longitudinal Reinforcement (As) HRB Model Beams

Comparison of the area of the transverse reinforcement beam (Av) for the HRB model shows that the area of the transverse reinforcement in the Bearing Frame System of SMRF and the Bearing Frame System of IMRF obtained the same results as shown in Figure 10.

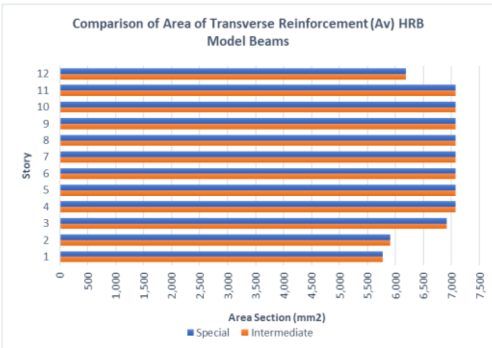


Fig. 10: Comparison of Area of Transverse Reinforcement (Av) HRB Model Beams

Middle-Rise Building Model

Comparison of the area dimensions of the beam elements (Ag) for the MRB model can be seen in that the beam dimensions in the Bearing Frame System of SMRF and Bearing Frame System of IMRF obtained the same results as shown in Figure 11.

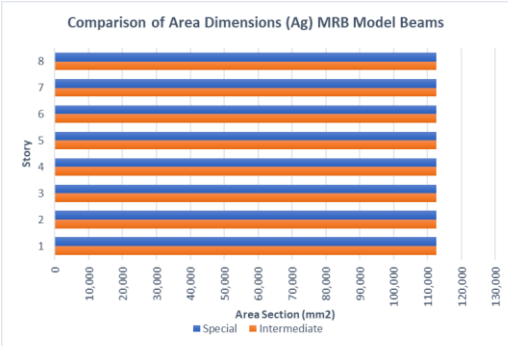


Fig. 11: Comparison of Area Dimensions (Ag) MRB Model Beams

The area of longitudinal reinforcement at the Bearing Frame System of the IMRF is greater than at the Bearing Frame System of the SMRF, as shown in Figure 12 when comparing the area of longitudinal beam reinforcement (As) for the MRB model.

Fig. 12: Comparison of Area of Longitudinal Reinforcement (As) MRB Model Beams

Comparison of the area of the transverse reinforcement beam (Av) for the MRB model shows that the area of the transverse reinforcement in the Bearing Frame System of SMRF and the Bearing Frame System of IMRF obtained the same results as shown in Figure 13.

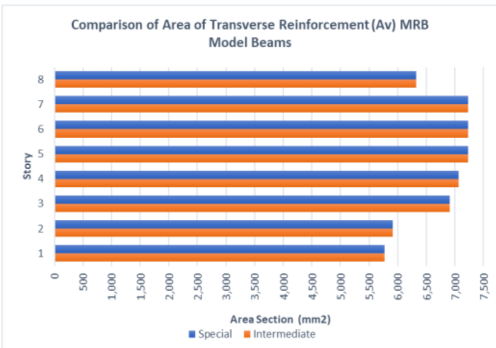


Fig. 13: Comparison of Area of Transverse Reinforcement (Av) MRB Model Beams

Low-Rise Building Model

Comparison of the area dimensions of the beam elements (Ag) for the LRB model can be seen that the beam dimensions in the Bearing Frame System of SMRF and Bearing Frame System of IMRF obtained the same results as shown in Figure 14.

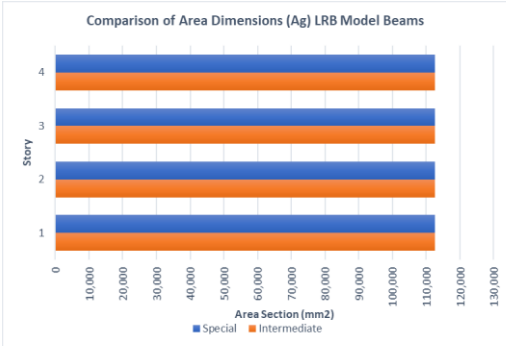


Fig. 14: Comparison of Area Dimensions (Ag) LRB Model Beams

The area of longitudinal reinforcement at the IMRF bearing frame system is greater than at the SMRF bearing frame system, as shown in Figure 15, when the area of longitudinal beam reinforcement (As) for the LRB model is compared.

Fig. 15: Comparison of Area of Longitudinal Reinforcement (As) LRB Model Beams

Comparison of the area of the transverse reinforcement beam (Av) for the MRB model can be seen in that the area of the transverse reinforcement in the Bearing Frame System of SMRF and Bearing Frame System of IMRF obtained the same results as shown in Figure 16.

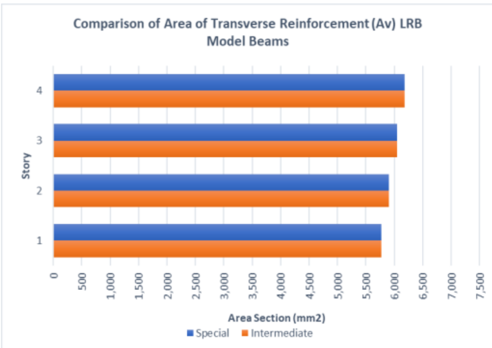


Fig. 16: Comparison of Area of Transverse Reinforcement (Av) LRB Model Beams

Element of Columns
High-Rise Building Model

Comparison of the area of the column element dimensions (Ag) for the HRB model can be seen that the column dimensions in the Bearing Frame System of SMRF and Bearing Frame System of IMRF obtain the same results as shown in Figure 17.

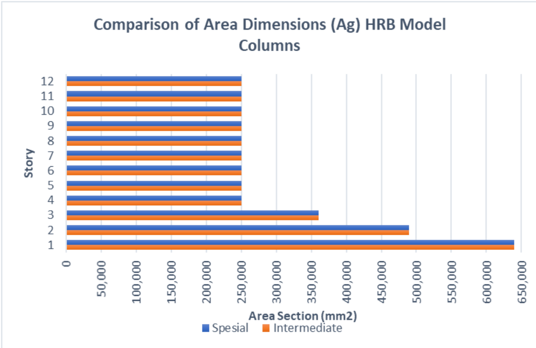


Fig. 17: Comparison of Area Dimensions (Ag) HRB Model Columns

Comparison of the longitudinal column reinforcement area (As) for the HRB model shows that the area of longitudinal reinforcement in the Bearing Frame System of SMRF and Bearing Frame System of IMRF obtained the same results as shown in Figure 18.

Fig. 18: Comparison of Area of Longitudinal

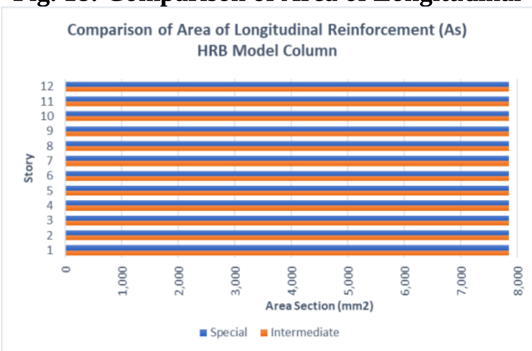
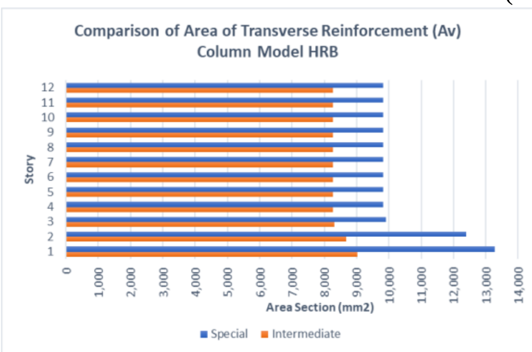


Fig. 19: Comparison of Area of Transverse

Reinforcement (As) HRB Model Column Reinforcement (Av) Column Model HRB



Comparison of the transverse column reinforcement area (Av) for the HRB model displays that the longitudinal reinforcement area in the Bearing Frame System of IMRF is smaller than in the Bearing Frame System of SMRF as shown in Figure 19. This is because the Bearing Frame System of SMRF requires restraints so in the area of plastic joints is necessary to add transverse reinforcement.

Middle-Rise Building Model

Comparison of the area of the column element dimensions (Ag) for the MRB model displays that the column dimensions in the Bearing Frame System of SMRF and Bearing Frame System of IMRF obtain the same results as shown in Figure 20.

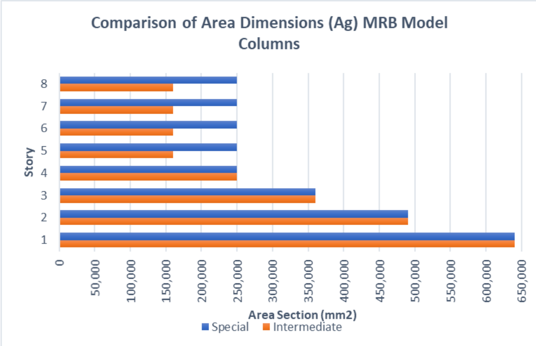


Fig.20: Comparison of Area Dimensions (Ag) MRB Model Columns

Comparison of the longitudinal column reinforcement area (As) for the MRB model shows that the area of longitudinal reinforcement in Bearing Frame System of SMRF and Bearing Frame System of IMRF obtained the same results as shown in Figure 21.

Fig. 21: Comparison of Area of Longitudinal

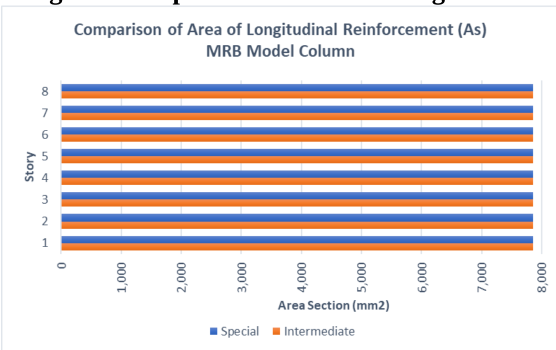
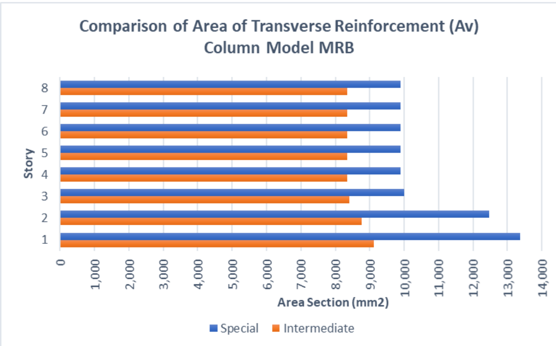


Fig. 22: Comparison of Area of Transverse Reinforcement (As) MRB Model Column Reinforcement (Av) Column Model MRB



Comparison of the transverse column reinforcement area (Av) for the MRB model displays that the area of longitudinal reinforcement in the Bearing Frame System of IMRF is smaller than in the Bearing Frame System of SMRF as shown in Figure 22. This is because the Bearing Frame System of SMRF requires restraints so in the area of plastic joints is necessary to add transverse reinforcement.

Low-Rise Building Model

Comparison of the area of the column element dimensions (Ag) for the LRB model can be seen that the column dimensions in the Bearing Frame System of SMRF and Bearing Frame System of IMRF obtain the same results as shown in Figure 23.

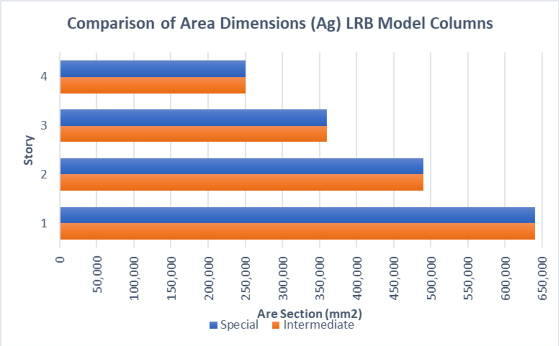


Fig. 23: Comparison of Area Dimensions (Ag) LRB Model Columns

Comparison of the longitudinal column reinforcement area (As) for the MRB model displays that the longitudinal reinforcement area in the Bearing Frame System of SMRF and Bearing Frame System of IMRF obtained the same results as shown in Figure 24.

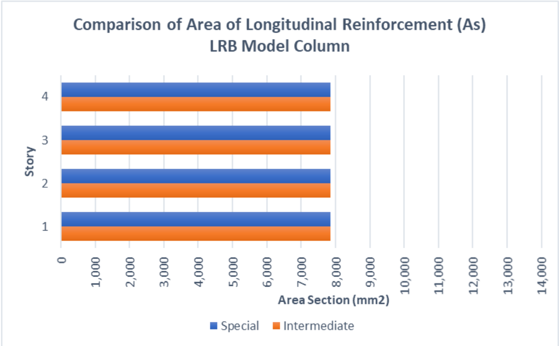


Fig. 24: Comparison of Area of Longitudinal

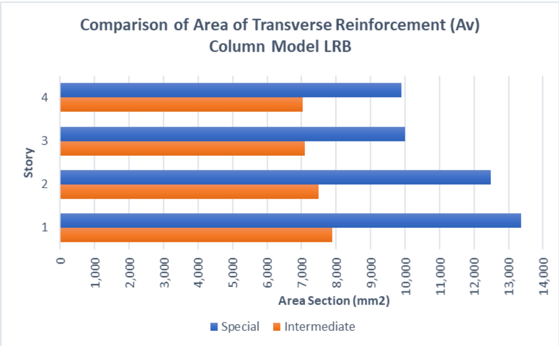


Fig. 25: Comparison of Area of Transverse Reinforcement (As) LRB Model Column Reinforcement (Av) Column Model MRB

Comparison of the transverse column reinforcement area (Av) for the Middle-Rise Building model shows that the longitudinal reinforcement area in the Bearing Frame System of IMRF is smaller than in the Bearing Frame System of SMRF as shown in Figure 25. This is because the Bearing Frame System of SMRF requires restraints so in the area of plastic joints is necessary to add transverse reinforcement.

Element of Beam-Column Joint
High-Rise Building Model

Comparison of the area of joint reinforcement (Asj) for the HRB model displays that the area of joint reinforcement in the Bearing Frame System of IMRF is smaller than in the Bearing Frame System of SMRF as shown in Figure 26. This is because the Bearing Frame System of SMRF requires restraints so the joint area needs to be added reinforcement.

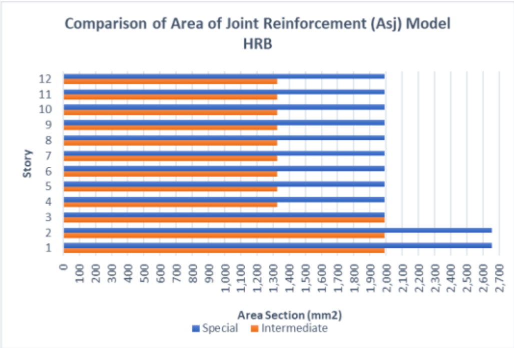


Fig. 26: Comparison of Area of Joint Reinforcement (Asj) Model HRB

Middle Rise Building Model

Comparison of the area of joint reinforcement (Asj) for the MRB model shows that the joint reinforcement area in the Bearing Frame System of IMRF is smaller than in the Bearing Frame System of SMRF as shown in Figure 27. This is because the Bearing Frame System of SMRF requires restraints so that the joint area needs to be added reinforcement.

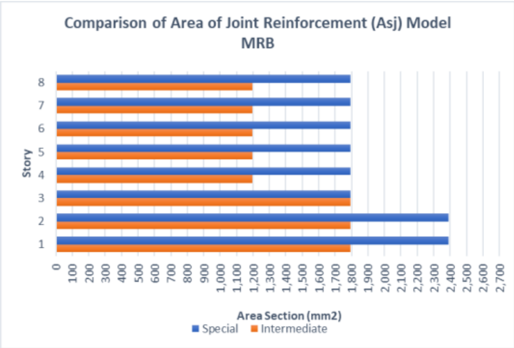


Fig. 27: Comparison of Area of Joint Reinforcement (Asj) Model MRB

Low-Rise Building Model

Comparison of the area of joint reinforcement (Asj) for the LRB model displays that the joint reinforcement area in the Bearing Frame System of IMRF is smaller than in the Bearing Frame System of SMRF as shown in Figure 28. This is because the Bearing Frame System of SMRF requires restraints so the joint area needs to be added reinforcement.

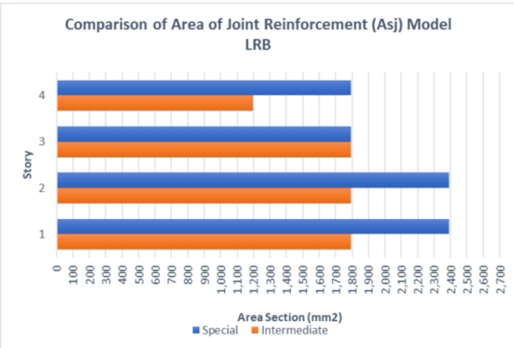


Fig. 28: Comparison of Area of Joint Reinforcement (Asj) Model LRB

Element of Shear Wall

Shear wall Dimension

The shear wall dimensions used are 250 mm thick for the HRB model and 200 mm for the Middle Rise Building and Low-Rise Building models

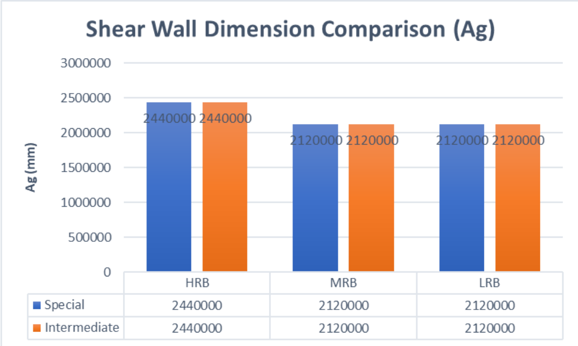


Fig. 29: Shear Wall Dimension Comparison

Shear Wall Special Boundary Element

Figure 30 explains the comparison of special boundary elements with displacement-based methods and strength-based method.

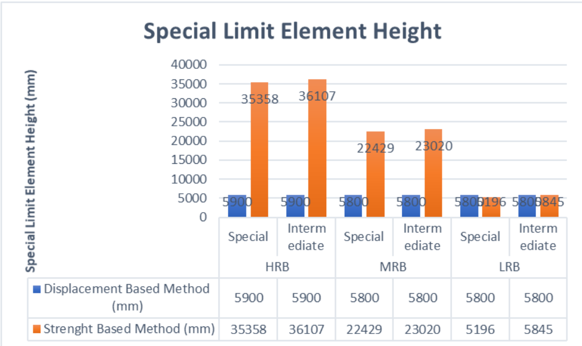


Fig. 30: Special Limit Element Height

Element of Slabs

The Bearing Frame System of SMRF and the Bearing Frame System of IMRF obtain the same results for the thickness and reinforcement of the plate elements because the internal forces obtained and the design method are the same.

Structural Performance Level

Figure 31 to Figure 34 is a comparison of displacement and Max Total Drift in each of the HRB, MRB and LRB models in the X and Y directions.

Fig. 31: Displacement X

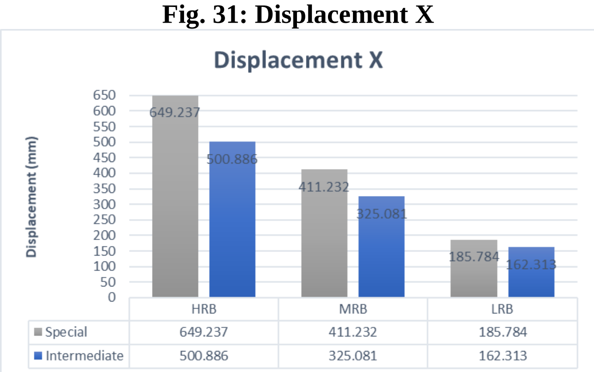


Fig. 32: Maximum Total Drift X

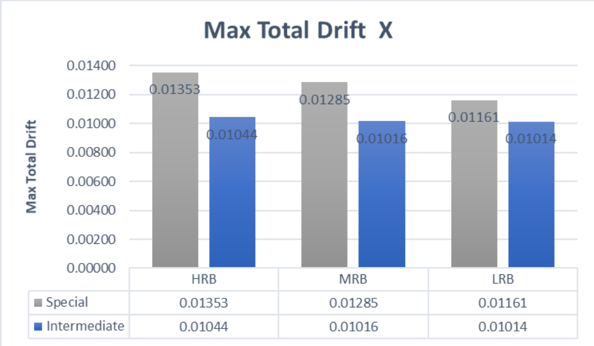


Fig. 33: Displacement Y

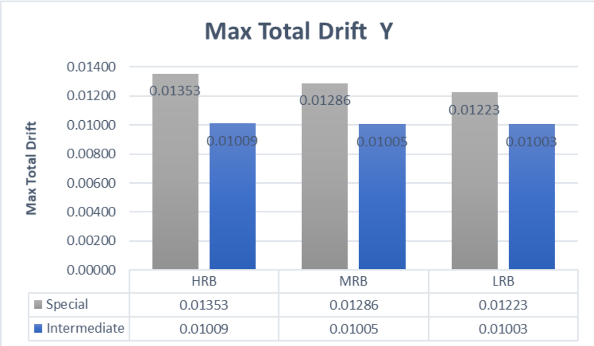
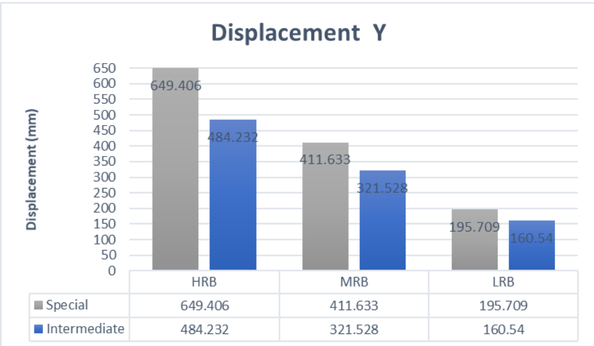


Fig. 34: Maximum Total Drift Y



Efficiency of dimensions and reinforcement of beams

From Figure 35, it can be seen that in comparison of the longitudinal reinforcement beams in the dual systems with IMRF, it is not more efficient than the dual systems with SMRF, whereas in the HRB, MRB, and LRB models the efficiency levels are -13.33%, -12.95 respectively % and -5.00%. This also means that the taller the building, the longitudinal reinforcement of the beams of the dual systems with IMRF is less efficient than the dual systems with SMRF. The result of a negative efficiency value means that the dual systems with SMRF are more efficient than the dual systems with IMRF. Figure 35 shows that there is no difference between the dual systems with SMRF and the dual systems with IMRF in the comparison of the Beam Dimension Area and Transverse Reinforcement Area.

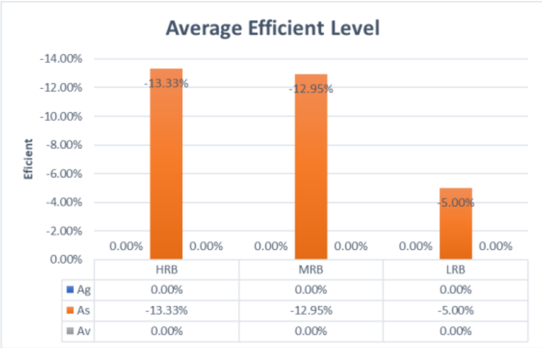


Fig. 35: Comparison of Efficiency of Beam Elements

Efficiency of dimensions and reinforcement of columns

From Figure 36 it can be seen that in comparison of the transverse reinforcement column in the dual systems with IMRF is more efficient than the dual systems with SMRF, where in the HRB, MRB, and LRB models the efficiency levels are 18.35%, 19.47%, and 34.68% respectively. This also means that the higher the building, the efficiency of the transverse beam reinforcement decreases.

From these data, it is clear that there is no difference between dual systems with SMRF and dual systems with IMRF in the comparison of the Longitudinal Reinforcement Area. Then in the comparison of the Middle-Rise Building model the column dimensions of the dual systems with IMRF experience efficiency of 18% compared to the dual systems with SMRF due to the Strong Column Weak Beam requirements where in the dual systems with IMRF on the 5th to 8th story the column dimensions are smaller than the dual systems with SMRF.

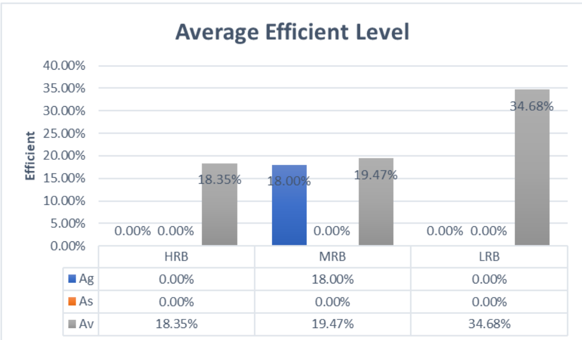


Fig. 36: Comparison of Efficiency of Column Elements

Efficiency of dimensions and reinforcement of Beam-Column Joint

From Figure 37 it can be seen that the dual systems with IMRF are more efficient than the dual systems with SMRF, where in the HRB, MRB, and LRB models the efficiency levels are 29.16%, 27.08%, and 20.83% respectively. This also means that the taller the building, the lower the efficiency level of the joint elements.

Fig. 37: Comparison of Efficiency of Join Elements

Efficiency of dimensions and reinforcement of Shear Wall

Figure 38 can be seen that the dual systems with IMRF are not more efficient than the dual systems with SMRF, where in the HRB, MRB, and LRB models the efficiency levels are -2.12%, -2.63% and -0.78%

respectively. The result of a negative efficiency value means that dual systems with SMRF is more efficient than dual systems with IMRF.

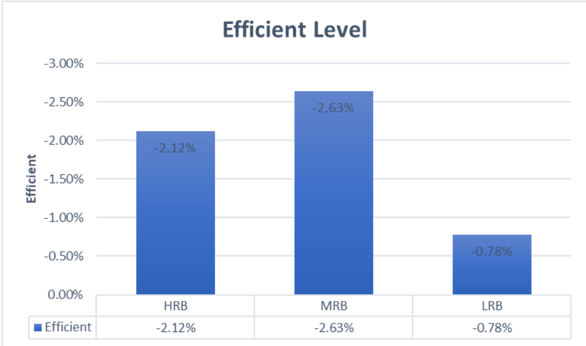


Fig. 38: Comparison of Efficiency of Shear Wall Elements

Performance Comparison of structural systems

From Figure 39, it displays that at the X-Y direction performance efficiency of the dual systems with IMRF is more efficient than the dual systems with SMRF, whereas in the X direction the HRB, MRB, and LRB models have an efficiency level of 22.85%, 20.95% and 12.63% respectively, and in the Y direction the HRB, MRB, and LRB models have efficiency levels of 25.43%, 21.89% and 17.97% respectively. This means that the higher the building, the lower the level of efficiency in structural performance.

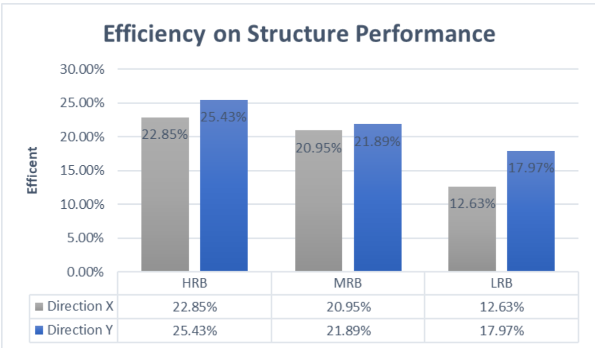


Fig. 39: Efficiency on Structure Performance

Performance evaluation of the Bearing Frame Systems of the SMRF and the IMRF

Table 2, it displays that in the beam and shear wall elements, the dual systems with SMRF are more efficient than the dual systems with IMRF. Then the Column and Joint elements as well as the Structural Performance of the dual systems with IMRF is more efficient than the dual systems with SMRF. Additionally, from the data in Table 2, the result is that the dual systems with IMRF are more efficient than the dual systems with SMRF. It is because the percentage efficiency level of the dual systems with IMRF to the dual systems with SMRF is greater than the efficiency level of SMRF to IMRF.

Table 2: The Comparison of Efficiency of Each Element and Structural Performance

Model			HRB	MRB	LRB
Average Efficient Level	Beam	Ag	0.00%	0.00%	0.00%
		As	- 13.33%	- 12.95%	-5.00%
		Av	0.00%	0.00%	0.00%
	Column	Ag	0.00%	18.00%	0.00%
		As	0.00%	0.00%	0.00%
		Av	18.35%	19.47%	34.68%
	Joint		29.16%	27.08%	20.83%
	Shear Wall		-2.12%	-2.63%	-0.78%
	Slab		0.00%	0.00%	0.00%
	Performance	X	22.85%	20.95%	12.63%
		Y	25.43%	21.89%	17.97%

VI. Conclusion

1. Comparison of the dimensions of the beam elements, shear wall thickness, and plate thickness show that the dual systems with IMRF are not more efficient than the dual systems with SMRF because it has the same dimensions in the HRB, MRB, and LRB models.
2. The comparison of the column element dimensions of the dual systems with IMRF is more efficient than the dual systems with SMRF where the efficiency rate of the Middle Rise Building model is 18.00%. Whereas in the HRB and LRB models, the efficiency level is 0%.
3. Comparison of the longitudinal reinforcement area of the beam elements dual systems with IMRF is not more efficient than dual systems with SMRF with efficiency levels respectively in the HRB, MRB, and LRB models are -13.33%, -12.95% and -5.00%. Then the comparison of the transverse reinforcement of the beam elements dual systems with IMRF is not more efficient than dual systems with SMRF, because it has the same reinforcement area in the HRB, MRB, and LRB models.
4. Comparison of the area of transverse reinforcement of the column elements dual systems with IMRF is more efficient than dual systems with SMRF with efficiency levels respectively in the HRB, MRB, and LRB models are 18.35%, 19.47%, and 34.68 %. Then the comparison of the longitudinal reinforcement of the column elements of the dual systems with IMRF is not more efficient than the dual systems with SMRF because it has the same reinforcement area in the HRB, MRB, and LRB models.
5. Comparison of the area of joint element reinforcement of the dual systems with IMRF is more efficient than the dual systems with SMRF with the respective efficiency rates in the HRB, MRB, and LRB models being 29.16%, 27.08%, and 20.83%.
6. Comparison of the reinforcement of the shear wall elements of the dual systems with IMRF is not more efficient than the dual systems with SMRF with the respective efficiency levels in the HRB, MRB, and LRB models being -2.12%, -2.63%, and - 0.78%.
7. Comparison of plate element reinforcement in the dual systems with IMRF is not more efficient than the dual systems with SMRF, because it has the same reinforcement area in the HRB, MRB, and LRB models.
8. Comparison of Structural Performance in the dual systems with IMRF is more efficient than the dual systems with SMRF with the respective efficiency levels in the HRB, MRB, and LRB models being 22.85%, 20.95%, and 12.63% in the X direction, and 25.43%, 21.89% and 17.97% in the Y direction.
9. The dual systems with IMRF are more efficient than the dual systems with SMRF.

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