Comparative Analysis of Special Moment Bearing Frame System with Modified Structure Planning Using Double System on Bluecross Medika International Beauty Clinic Building

Anggik Ayu Trisnawati[1], I. Ketut Yasa Bagiarta[1], Putu Aryastana[1,2*]

[1]Department of Civil Engineering, Warmadewa University, Denpasar, Bali, Indonesia

[2]Master of Infrastructure and Environmental Engineering, Warmadewa University, Denpasar, Bali, Indonesia

***Corresponding Author**

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ABSTRACT

In line with the developments that occur, many high-rise buildings are increasingly being built. An important consideration in the planning of multi-storey buildings is the earthquake force, so it is necessary to choose a good structural system in overcoming these problems. The special moment-bearing frame system is one of the structural systems that is often chosen. In addition, the moment-bearing frame system is often combined with shear walls (Double System), As shear walls enhance earthquake resistance. The purpose of this research is to compare the planning of SMRFS (Special moment resisting frame system) and Dual System structures and compare the efficiency of the behavior of these structures. The comparison of SRPMK and Dual System planning lies in the parameters used in earthquake loading, where the value of (R) = 8, (Ω0) = 3, (Cd) = 5.5 for SRPMK and (R) = 7, (Ω0) = 2.5, (Cd) = 5.5 for Dual System. The x-direction SRMPK structure is 25,463 mm and the y-direction is 22,905 mm, for the dual system the x-direction is 16,507 mm and the y-direction is 20,508 mm. The use of dual system structures is more efficient because the resulting displacement value is smaller than SRPMK. The deviation values of the two structures meet the criteria for deviation requirements, and the use of dual systems is better at accepting earthquake loads than SRPMK. By comparing the SMRFS and the dual system, we can find out the right decision in choosing the most appropriate structural system, resulting in a safe, reliable and efficient building.

Keywords: Special Moment Bearing Frame System, Double System, Earthquake Load.

INTRODUCTION

Bali is a densely populated area and one of the tourist destinations. This causes Bali to experience rapid population and economic development resulting in limited land. So that the construction of multi-storey buildings to solve the problem [1].

Bluecross Medika International Beauty Clinic is a high-rise building that has a function as a health facility and medical services and care for people in need. In the planning of high-rise building construction, there are things that must be considered, namely the earthquake force that occurs [1]. The taller the building, the more vulnerable it is to lateral forces [2], especially earthquake forces. Therefore, in earthquake-prone areas such as Indonesia, comprehensive planning of earthquake-resistant building designs is necessary [3][4][5][6].

One alternative to improve structural performance in resisting earthquake forces when planning earthquake-resistant high-rise buildings is to use shear walls [7]. Shear wall placement location affects the behavior of high-rise building structures [8]. To meet the required horizontal load, shear walls can be placed appropriately and strategically [4] [9][10][11].

Construction planning for multi-storey buildings must consider design procedures that refer to the SNI 2847: 2019 standard which regulates structural requirements for building-buildings [12], SNI 1726: 2019 which

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regulates the procedures for earthquake resistance planning for building and non-building structures [13] and SNI 1727:2020 for minimum design loads and related Criteria for buildings and other structures [14].

Shear walls are also designed to minimize damage to non-structural parts [15][16]. SMRFS and shear walls can be combined in structural planning which is often referred to as a dual system [17]. Where two structures with different properties and behaviors are combined and produce a strong structure.

Based on the explanation above, this research is intended to find out how the comparison of planning parameters, structural behavior (displacement and deviation between floors) between the special moment bearing frame system (SMRFS) and dual system.

Theoretical Foundation

Previous studies related to the comparison of SMRFS and dual-system structures found that the addition of shear wall elements affects the robustness of the structural system, where lateral forces due to earthquakes are resisted by shear walls [18]. Analysis result belongs to [11] Placement of shear retaining walls in the center of the building or in the core area of the building has better seismic response, as it effectively attracts lateral loads and reduces vibration response [19]. Research shows that the most effective configuration for shear walls in an 8-story building is to place them around the perimeter and corners of the building. This increases stiffness, reduces torsional effects, and does not disrupt the interior layout of the building.

A. Working Load

SNI 1727:2020 has regulated the minimum loading for building planning, where the loading value is influenced by the function of the space and the building itself. Some types of loads received in buildings are:

1. Dead Load

Dead load is the weight of all installed building components including walls, floor coverings, roofs, ceilings, finishes and all architectural aspects that are integral to the building [14].

2. Live Load

Live load is the weight that is not fixed or moving that comes from the use and occupants of buildings or other structures that are not included in construction loads or dead loads [14].

3. Earthquake Load

Based on SNI 1726:2019 concerning the planning of earthquake-resistant building structures, the earthquake load comes from the movement of the soil layer both horizontally and vertically. It is necessary to analyze the earthquake force based on the dynamic analysis of the earthquake load so that the building can withstand the earthquake load that occurs [13].

B. Earthquake Resistant Structural System

In planning earthquake-resistant structures, there are requirements for the type of structure and Ceismic Design Category (CDC). This category is found in SNI 1726:2019, which is related to the consideration of earthquake hazard level, soil characteristics, occupancy capacity, and function [13]. In the elemental part of the structural frame system used, there are several levels of ordinary, intermediate, and special, which means that the detail requirements and design capacity against structural damage increase at each level according to the expected strength.

Structures with KDS D, E and F are potentially exposed to strong ground vibrations. Based on existing regulations, the seismic load-bearing concrete structural systems applicable to these KDS are SRPMK, special structural walls or a combination of both.

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SNI 2847:2019 defines a wall as either a retaining wall or a shear wall. This retaining wall can be interpreted as a wall that supports vertical loads that exceed a certain threshold value [12]. Shear walls are defined as walls, bearing or non-bearing, that are planned to resist earthquake loads that affect the wall plane. A dual-system structure consists of a combination of SMRFS and shear walls [20]. Which is a frame structure capable of withstanding a minimum seismic load of 25% [12].

C. Deviation Between Floor

Drift is lateral movement, which is usually referred to as displacement. Inter-level deviation is a significant parameter to identify the magnitude of, in order to obtain in planning how flexible or rigid the construction structure is. For seismic force-resisting systems consisting of moment frames in structures planned according to seismic design categories D, E, or F, the design inter-storey deviation is (Δ) cannot be greater than $\Delta a/\rho$ for the entire floor [13]. The calculation uses the following equation:

$$\delta_x = \frac{C_d \delta_{xe}}{I_e}$$

$$\Delta_{\text{ijin}} = \frac{\Delta_a}{\rho}$$

Description:

$cd = Lateral\ deviation\ magnification\ factor.$

$\delta xe = Deviation\ at\ x - level$

$Ie = Earthquake\ primacy\ factor.$

$\Delta a = Deviation\ between\ permission\ levels.$

$hsx = The\ height\ of\ the\ level\ below\ the\ x - level.$

$\rho = Redundancy\ factor.$

RESEARCH METHODS

D. Buiding Data

Table I is general planning data containing building functions, soil data at the planning location, concrete quality and reinforcing steel quality used. This data is used in the process of taking planning parameters in the standards used.

Table I General Planning Data

No.	Data	Description
1.	Building Function Type	Hospital
2.	Planning Location	Sanur Lot H3A, Sanur Kaja, South Denpasar District, Denpasar City, Bali Province
3.	Total Level	5 Level
4.	Building Structure	Reinforced Concrete
5.	Concrete Quality (fc)	30 Mpa.
6.	Quality of stirrup reinforcement (fy)	420 Mpa.
7.	Quality of Main Reinforcement (fy)	420 Mpa.
8.	Ground Data	Soil search results found the depth of hard soil at 7.2 meter. With average conus resistance at 210 kg/cm^2 and the number of sticky barriers at 610 kg/cm.

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E. Research Flow Chart

Figure 1 shows the flow chart of the research to be carried out, the flow chart illustrates the systematic planning of the steps that must be passed from the initial stage to the final stage of the research which results in research conclusions.

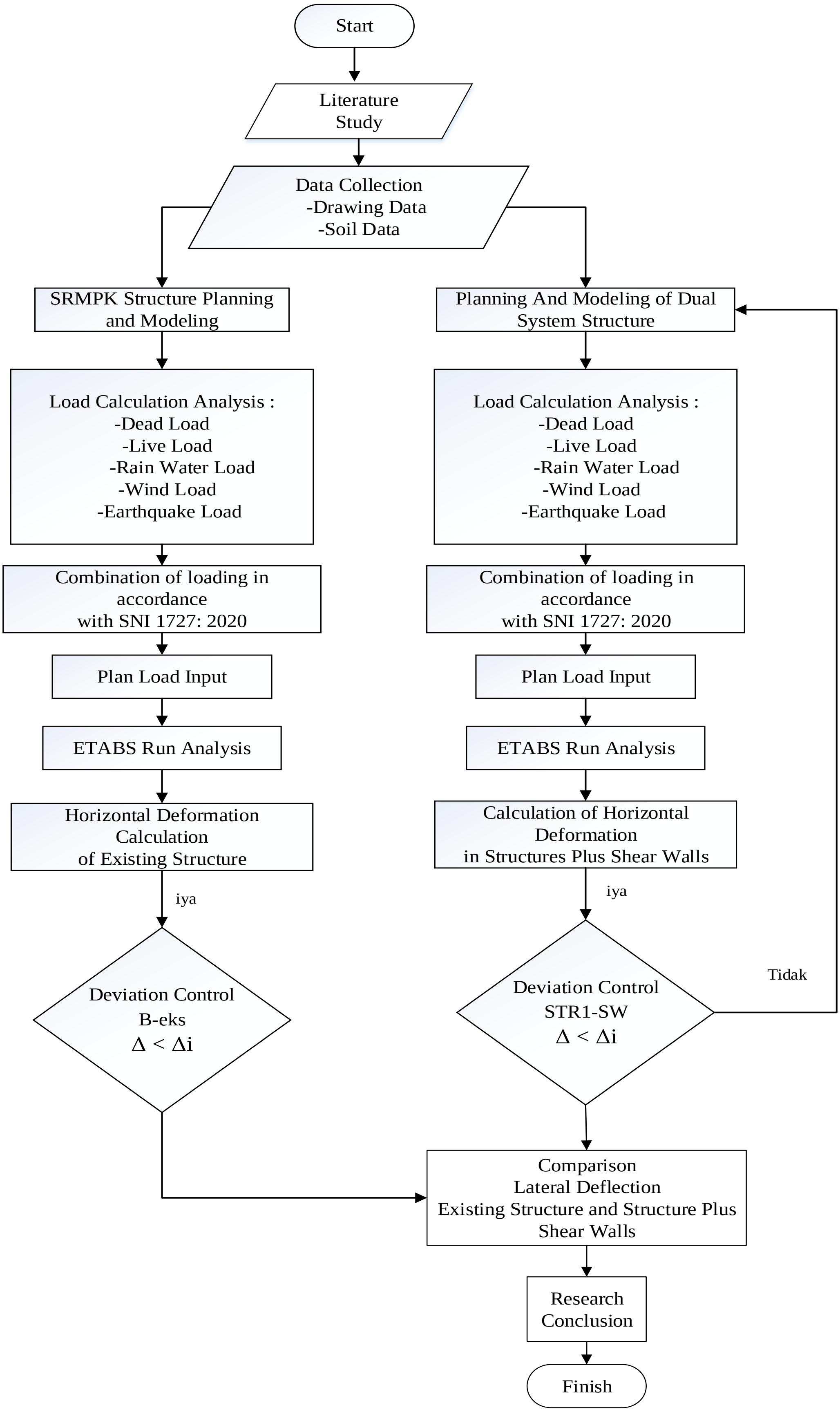

Figure 1 Research Flow Chart

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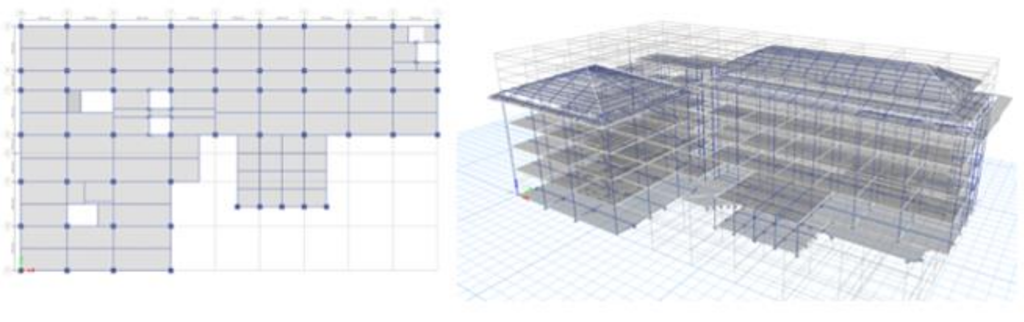
F. Planning Data

The dimensional data of the structural components used in modeling the SMRFS and Dual System structures are shown in Table II. Contains information on width and height of beam and column elements, thickness of shear walls and floor slabs used.

Table II Dimensional Data of Structural Components

No.	Component structure	Code	Dimensions of SMRFS (mm)	Dual System Dimensions (mm)
1.	Column	K1	700x700	600x600
		K2	600x600	500x500
		KAA	450x450	400x400
		KL	500x500	400x400
2.	Blocks	B1	300 x 650	300 x 450
		BA1	300 x 650	250 x 350
		B2	300 x 700	350 x 500
		BA2	300 x 700	300 x 450
		B3	400 x 650	300 x 450
		B4	300 x 500	200 x 300
		B5	400 x 700	400 x 700
		BA3	250 x 500	250 x 500
		B6	500 x 1100	400 x 750
		B7	500 x 700	400 x 700
		TB	250 X 900	250 x 900
3.	Plates.	S1	250	250
		S2	130	130
		S3	130	130
		S4	150	150
		S5	150	150
		S6	140	140
4.	Shear Wall	DG	-	200

Figure 2 is the result of drawing the SMRFS structure in ETABS software based on the dimensions of the structure that has been determined. Figure (a) shows the plan form of the planned SMRFS structure and (b) is the result of the planned SMRFS 3D model.



a). SMRFS Model Plan b). 3D SMRFS Model

Figure 2 SMRFS Structure Results in ETABS Software

Figure 3 is the result of depicting the Dual System structure in ETABS software based on the predetermined structural dimensions. Figure (a) shows the plan form of the planned dual system structure and (b) is the result of the 3D model of the planned dual system.

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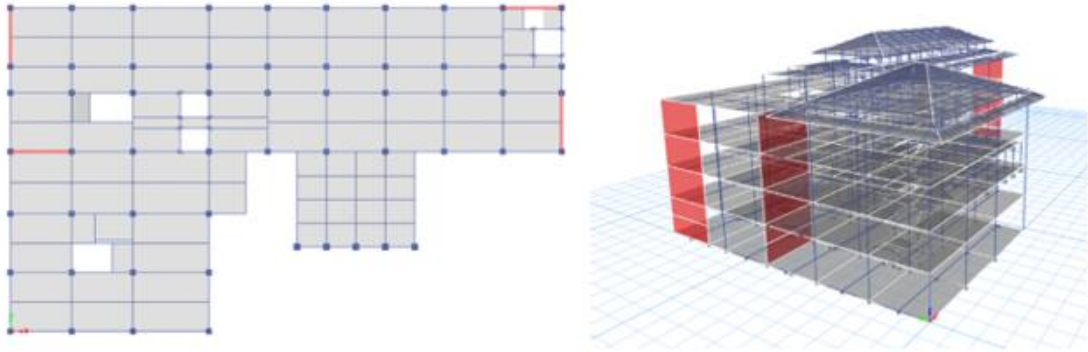

a). Dual System Model Floor Plan   b). 3D Dual System Model

Figure 3 Results of Dual System Structure Drawing in ETABS Software

G. Structure Loading

Table III contains details of the dead load adjusting to the provisions stipulated in SNI 1727: 2020 [14]. The dead loads listed in this table include the fixed weight of the building's structural components, including the value of other structural material components such as walls, floor coverings, mechanical electrical and plumbing dam used in the design and analysis of the structure in order to ensure that the building has the stability to withstand loads throughout its lifetime.

Table III Dead Load

No.	Name	Weight
1.	Spesi	63 kg/m^2
2.	Floor Cover	18 kg/m^2
3.	Plafond Gypsum	21,5 kg/m^2
4.	MEP	25 kg/m^2
5.	Wall	60 kg/m^2

Table IV contains details of the live load adjusting the provisions in SNI 1727: 2020 [14]. The live loads contained in this table include temporary loads caused by human activity, tools and other movable items that may change during the use of the building. The magnitude of the load used adjusts to the function of the room being used. Live loads are required to ensure the building remains stable, safe and comfortable for the occupants during the building's use.

Table IV Live Load

No.	Name	Weight
1.	Patient Room	195.78 kg/m^2
2.	Surgery Room	292.65 kg/m^2
3.	Doctor's Room	195.78 kg/m^2
4.	Waiting Room	488.44 kg/m^2
5.	Laboratory	292.65 kg/m^2
6.	Corridor	390.55 kg/m^2

RESULT AND DISCUSSION

H. Earthquake Load

Table V contains the values of the layers and the amount of N SPT, so that the average N value of 27.72 shows that the soil site class is in Medium Soil.

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Table V Average N SPT Value

No.	Layer i	Thickness of Layer, in (m)	N value (SPT)	di/Ni
1.	1	2	7	0.286
2.	2	2	15	0.133
3.	3	2	27	0.074
4.	4	2	29	0,068
5.	5	2	30	0,066
6.	6	2	31	0,064
7.	7	2	33	0,060
8.	8	2	42	0,047
9.	9	2	45	0,044
10.	10	2	50	0,04
11.	11	2	50	0,04
12.	12	2	50	0,04
13.	13	2	50	0,04
14.	14	2	50	0,04
15.	15	2	50	0,04
	$\sum di =$	30	$\sum \frac{di}{Ni} =$	1,082

Based on the results of the analysis, Table VI is the coefficient presented for earthquake loading on soft soil in accordance with [13] SNI 1726:2019 which contains the design spectra response coefficient in accordance with the risk of hospital buildings with category IV.

Table VI Earthquake Loading Coefficient

No.	Coefficient	Value
1.	Ss	0.96
2.	$S1$	0.39
3.	Fa	1.11
4.	Fv	1.90
5.	SDs	0.71
6.	$SD1$	0.50
7.	To	0.14 second
8.	Ts	0.7 second
9.	TL	12 second

Figure 4 shows the results of the spectrum response design period diagram at the planning location with the site class on soft soil. The response spectrum diagram is obtained from the relationship between the vibration period (T) and the earthquake acceleration (Sa).

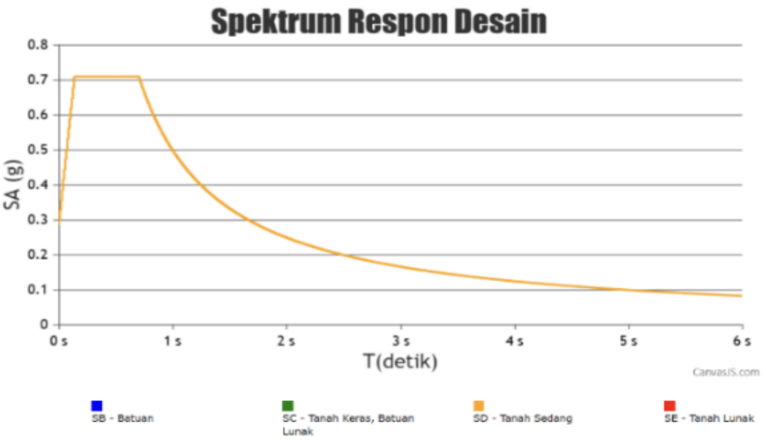

Figure 4 Design Response Spectrum

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Table VII is the structural ductility factor based on the seismic force-resisting frame system used in the planning. There are over-strength factors, deflection magnification factors, and response modification factors for SMRFS and multiple system structural types.

Table VII Ductility Factor of Structural System

No.	Parameter	SMRFS	Dual System
1.	(R)	8	7
2.	(Ω0)	3	2.5
3.	(Cd)	5.5	5.5

Table VIII shows the effective weight of the building per floor, this weight is obtained from the building's own weight, dead weight and live load acting together on the planned building structural components.

Table VIII Effective Building Weight

No.	Lantai	SMRFS (kg)	DUAL SYSTEM (kg)
1.	Roof	10792.54	10779.21
2.	Roof Top	1207731.71	1090685.12
3.	Third	1778030.85	1628391.61
4.	Second	1827152.86	1673874.10
5.	First	1902714.39	1752380.53
6.	Ground	2070850.34	2044152.20
7.	TOTAL	8797272.72	8200262.80

Table IX is the result of the earthquake load analysis that contains the seismic response coefficient of earthquake load, earthquake static load, dynamic earthquake force scale and earthquake scale magnification to produce the dynamic earthquake load value (V dynamic) ≥ static earthquake (V static).

Table IX Static and Dynamic Earthquakes

No.	Parameter Lateral	SMRFS	Dual System
1.	Cs	0.1341	0.1533
2.	Vx static	8666.61 kN	10612.93 kN
3.	Vy static	8169,29 kN	10224.50 kN
4.	Initial Scale	1.838,75 mm/s^2	2.101.43 mm/s^2
5.	Magnification Scale	3313.50 mm/s^2	3639.78 mm/s^2
6.	Vx dynamic	8666.62 kN	10614.50 kN
7.	Vy dynamic	8169.33 kN	10224.55 kN

I. Dual System Checking

Based on the standards used, the frame structure in the dual system must be able to withstand at least 25% of the acting earthquake force. Table X results of shear force analysis obtained at the model platform.

Tabel X Dual System Requirements

No.	Shear Force	X-direction	Y-direction
1.	Dual System	9071.22	6589.19
2.	Shear Wall	6019.49	4578.66
3.	Percentage of Shear Walls (<75%)	66.36%	69.49%
4.	Frame Percentage (>25%)	33.64%	30.51%

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J. Inter-Storey Deviation

Based on the results of the analysis, it is found that the diplascement that occurs in the existing x direction is 25,463 mm and the y direction is 22,905 mm. While the existing structure that is added to the shear wall at the edge of the building in the x direction is 10.035 mm and in the y direction is 17.82 mm. Which is where the existing structure added by the shear wall is stiffer and more effective in supporting the shear force so that it can experience a decrease in deviation of 39% in the x direction and 78% in the y direction compared to the existing structure. Furthermore, the analysis results obtained that the displacement that occurs in the modified structure in the x direction is 16.507 mm and the y direction is 20.508 mm. Which is where the modified structure has an increase in deviation from the existing deviation added to the shear wall at the edge of the building due to the reduction of several structural elements that have been modified where the deviation results obtained do not exceed the specified building permit limit.

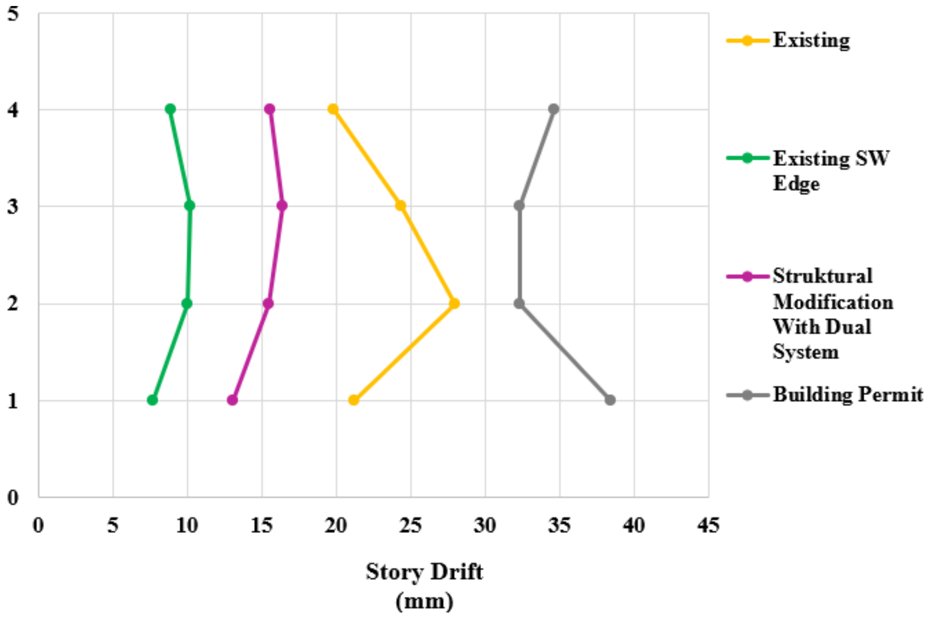

Figure 5 Combined X-Direction Deviation

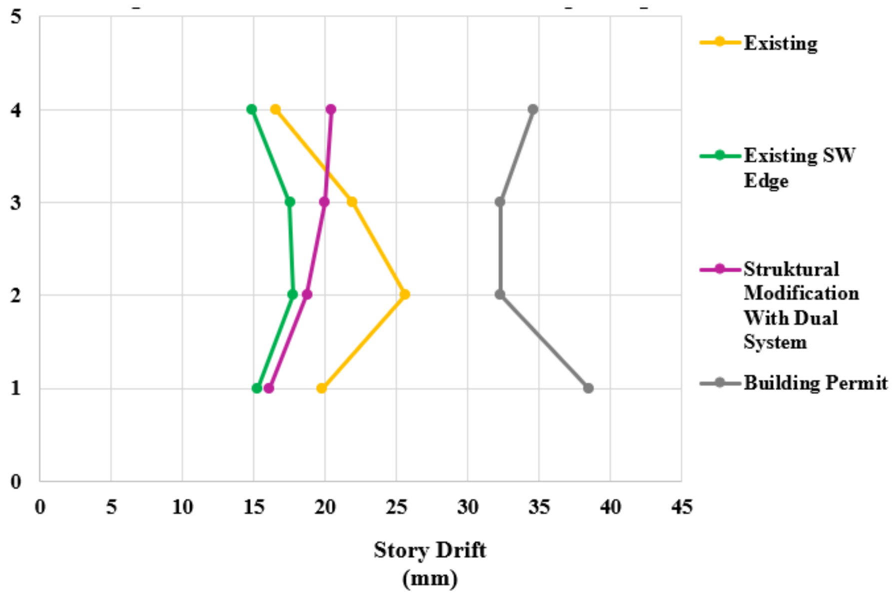

Figure 6 Combined Y-Direction Deviation

CONCLUSIONS

Based on the results of the study, it is concluded that the difference in parameters is earthquake loading, where the value of (R) = 8, (Ω0)= 3, (Cd) = 5,5 for SMRFS and (R) = 7, (Ω0) = 2,5, (Cd) = 5,5 for Dual System. The

SRPMK and Dual System structural models meet the requirements of inter-storey deviation values. The results of the comparison between SMRFS (Special Moment Resisting Frame System) and the dual system allow us to determine the right decision in choosing the most appropriate structural system, resulting in a safe, reliable and efficient building.

SUGGESTIONS

The need for further analysis with varying shear wall placements in order to obtain the results of the analysis of the structural behavior of the use of shear walls in a dual system that is more varied and effective in planning.

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