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COMPARISON STUDY OF DESIGN SHEARWALL VARIATIONS PLACEMENT ON MOMENT FRAME SYSTEM AND DUAL SYSTEMS FOR REINFORCED CONCRETE BUILDINGS IN SEISMIC DESIGN CATEGORY ZONE D

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ABSTRACT

As a country that continues to develop, the construction of high-rise buildings is inevitable, given the many capacities and functions of these buildings. However, considering that Indonesia is located between 4 main active plates of the world, so it is an area that is prone to earthquakes. As a result of this earthquake, it is necessary to design a structure that is stronger and more rigid in order to be able to withstand earthquake vibrations for a long time as much as possible.

This research consists of designing the superstructure of a building in the seismic zone D by comparing the value of the drift ratio, displacement, and the amount of reinforcement towards variation structure model that occurs due to the response spectrum of earthquake load. The analytical method used is the response spectrum analysis method modelled on 3 building structure models.

Based on the result of the design analysis carried out on all models, the dimension for beam with all models are 35 x 45 cm and 25 x 35, the column dimensions are 50 x 50 cm, the floor slab thickness is 125 mm and the shear wall thickness is 30 cm. The results for the model that has shear walls, decreased in the amount of reinforcement up to 14% in the column and 10% in the beam and decreased to 3% in the column and 6% in the beam for the bending moment. For the maximum drift ratio value, which is 10.26% in the x-direction of the shear wall structure model 2 and 6.81% in the y-direction shear wall structure model 3 and the smallest displacement value due to the load response spectrum on the placement of the shear wall is model 3, then the recommended model for structural planning in the seismic zone D is model 3.

Keywords : momen frame system, dual system, seismic zone D, reinforcement, drift ratio, displacement

1. INTRODUCTION

The increasing number of people who live or live temporarily, it is undeniable that the need for houses or residences continues to increase for these people. Therefore, high-rise buildings are needed as an alternative solution so that the use of development land becomes more efficient.

This research was conducted in an earthquake area with seismic design category D, so Yogyakarta was chosen due to an increase in seismic activity. This study aims to compare the size of the structural elements as well as the values of drift ratio and displacement in buildings. In this study, several variations of the placement of shear walls will also be given, it is the Core wall variation and the L-shape variation, to find out which variations in the placement of shear walls contribute the most to buildings with a dual system.

As for the limitations of the problem of this study, as follows:

1. The design of structural elements refers to the Procedures for Concrete Structures for Buildings (SNI 2847:2019).
2. For analysis of dead loads, live loads, and earthquake loads according to the Minimum Load for the Design of Buildings and Other Structures (SNI 1727:2013).
3. For analysis of earthquake resistance planning, refer to the Procedures for Planning Earthquake Resistance for Buildings (SNI 1726:2019).
4. Structural analysis is carried out with an analysis software program.
5. The planning review is only carried out on the superstructure.
6. Does not take into account the volume and budget plan.

2. THEORITICAL STUDY

High-Rise Building Structure System

The selection of the structural system of a building is very important so that the building is strong enough to withstand the planned load so that the building becomes safe and comfortable. Based on SNI 1726:2019, there are several types of structural systems for tall buildings including:

1. Moment-resisting frame system
   The moment-resisting frame system is a space frame system in which the structural components of beams, columns and their joints resist the forces acting through bending, shear and axial action (Iswandi, 2014).
2. Dual System
   According to SNI 1726:2019 article 3.51.3, a dual system is a structural system with a complete space frame to carry gravity loads, while resistance to earthquakes is provided by a combination of a moment frame system and shear walls or by a combination of a moment frame system and bracing frame.

Shear Wall Placement System

Based on its location and function, shear walls can be classified into 3 types namely:

1. *Bearing wall*, is a shear wall which also supports most of the gravity load. These walls also use adjacent partition walls.
2. *Frame wall*, is a shear wall that resists lateral loads, where the gravity load comes from the reinforced concrete frame. These walls were built between the rows of columns.

3. *Core wall*, is a shear wall located within a central core area within a building that normally contains a staircase or elevator shaft. Walls located in the central core area have a dual function and are considered to be the most economical option.

3. METHOD

This research method uses a dynamic analysis method, namely the response spectrum method. The following are the stages of the research:

1. Preliminaries literature
   Collecting references and references related to the final project such as SNI 1726:2019, SNI 1727:2013, SNI 2847:2019 and PPPURG 1989.
2. Planning data
   The data needed to assist in the analysis of this structure are as follows:
   - Building function : Hotel (residential)
   - Building location : Yogyakarta
   - Soil type : Medium soil
   - number of storeys : 10 storeys
   - Height of 1st storey : 4,5 m
   - Height of each storey : 3,2 m
   - Concrete grade (*fc'*) : 30 Mpa
   - Grade of steel reinforcement (*fy*) : 400 Mpa
   - Grade of steel shear reinforcement (*fy*) : 240 Ma
3. Structure models
   The structure is modelled with 3 variations where model 1 is SMRF without shearwall, model 2 is a dual system with shearwall L-shaped variation, and model 3 is a dual system with core wall variation.

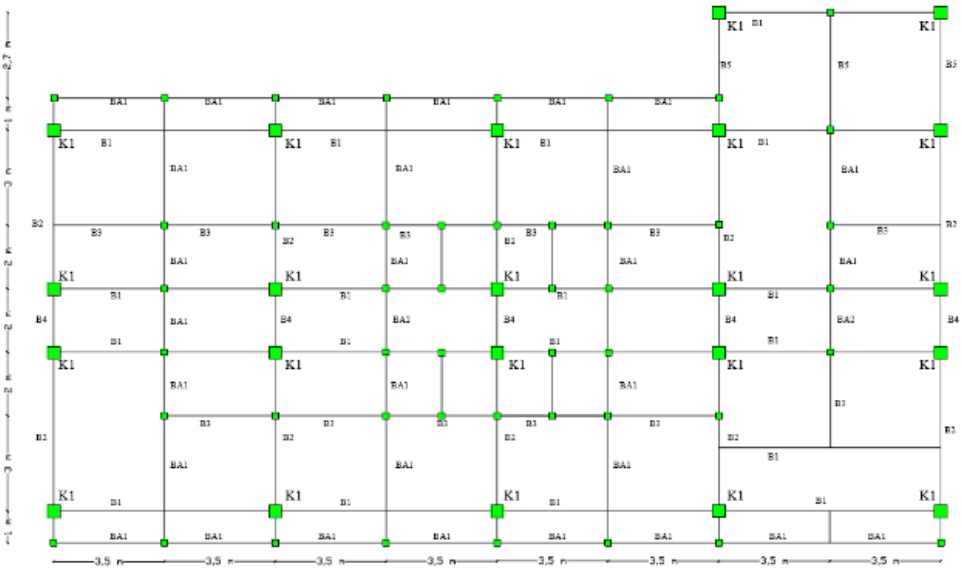

Figure 1. Model 1 without shearwall (M1)

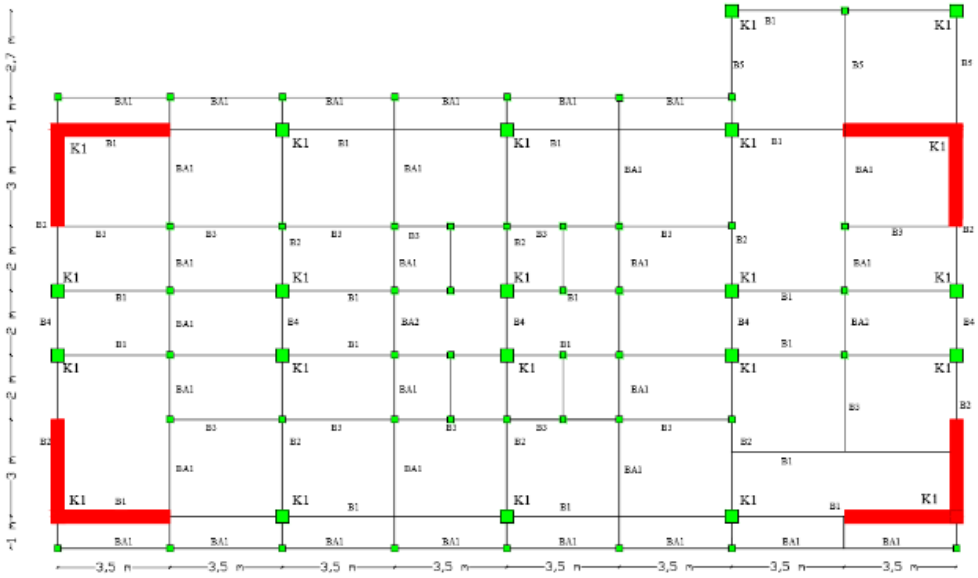

Figure 2. Model 2 dual system L-shaped (M2)

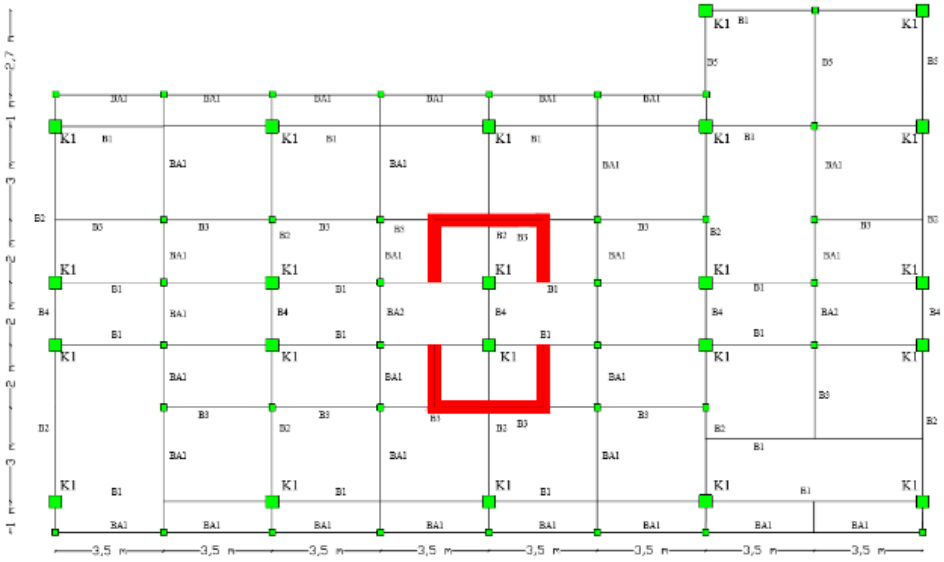

Figure 3. Model 3 dual system core wall (M3)

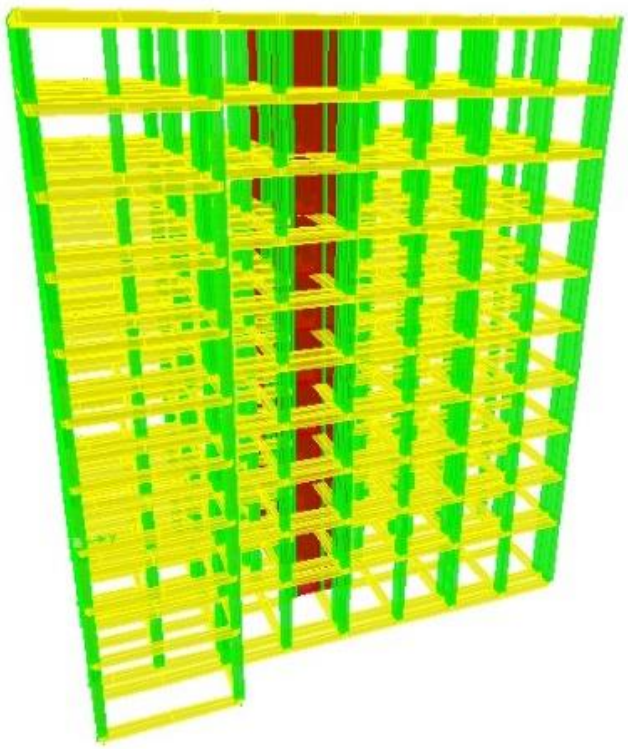

Figure 4. 3d structure modelling

4. Preliminary design
   At this stage, a preliminary design is carried out, which is an assessment of the components of the building's structural elements. The assessment of the structural components of the building includes the assessment of beams, columns, slabs and shear walls in accordance with the applicable code, namely SNI 2847:2019.
5. Design variables
   The design variable in this study is the use of the structural system which will be analyzed using different shearwall placement conditions in the structural system.
6. Structure loads
   Calculation of the loading of the building structure will be analyzed using an analysis software program, load inputs are in the form of dead loads, live loads, earthquake loads, and wind loads which will produce vertical forces, horizontal forces and moments.
7. Structure analysis
   Structural analysis in building planning in this study aims to determine the value of internal forces that occur due to working loads including dead loads, live loads, wind loads and earthquake loads.
8. Design control
   After analyzing the structure, design control is carried out on each model by controlling the dimensions of the structural elements including cross sections of beams, columns, slabs and shear walls.
9. Reinforcement design
   The value of the internal force obtained from the results of the analysis of the structure that has been modelled and the design control has been carried out will be

used to carry out an analysis of the calculation of the amount of reinforcement required.

10. Conclusion

    The results of the analysis of the moment-resisting frame structure system and the dual system with shear wall variations will have differences in the percentage distribution of the lateral force carried so that the conclusions can be drawn about the more optimal structural system.

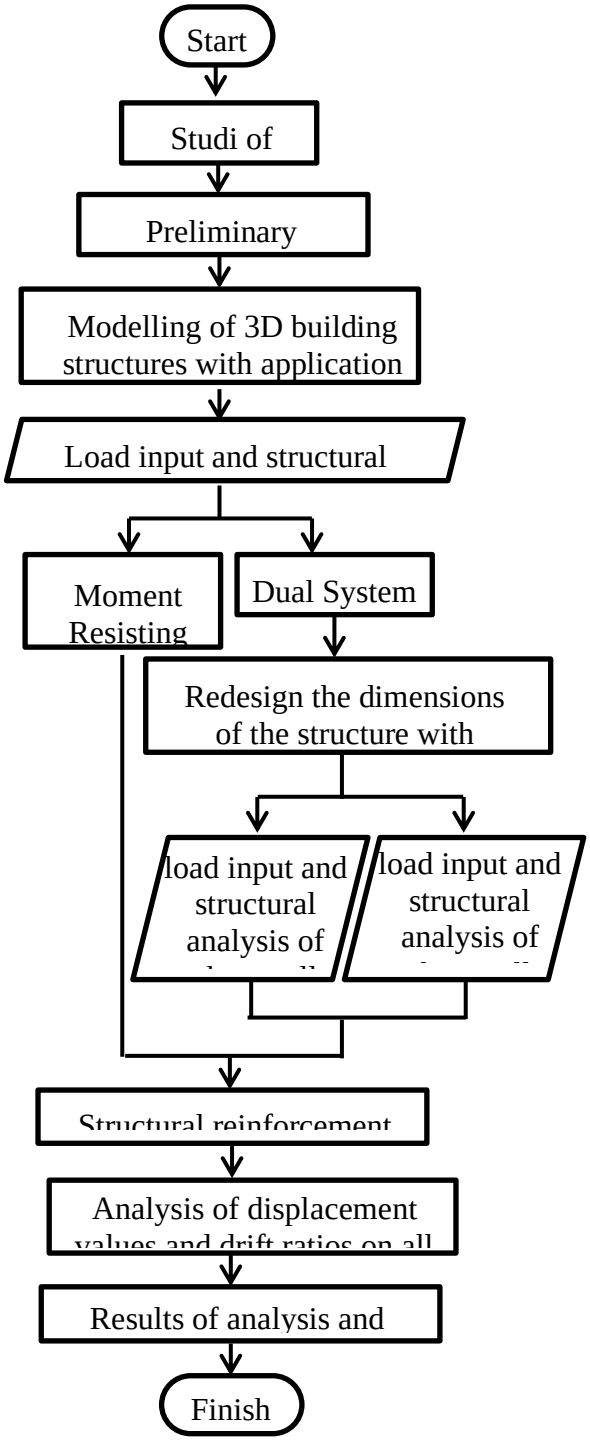

Figure 5. Planning flow chart

4. RESULTS AND DISCUSSION

Preliminary Design

In planning the building structure, it is necessary to carry out preliminary design for the dimensions of beams, columns, floor slabs, and shear walls for all structural models. The dimensions of the structural element plan can be seen in table 1.

Table 1. Preliminary design of structural elements

Structure Elements	Dimensions (mm)
B1 (L = 7000 mm)	350/450
B2 (L = 5000 mm)	250/350
B3 (L = 3500 mm)	250/350
B4 (L = 2000 mm)	250/350
B5 (L = 3700 mm)	250/350
Column Floors 1 – 10	500/500
Floor Slab 1 – Deck	125
Shear Wall	300

Internal Force Recapitulation and Structural Element Reinforcement

The structural dimensions obtained from the preliminary design were then analyzed using the help of a structure software program.

Table 2. Comparison of beam moment values

Structure System	Bending Moment (kN.m)			
	B1		B2	
	Support	Midspan	Support	Midspan
Model 1 (SMRF)	263,22	177,74	173,55	120,03
Model 2 (Shearwall L-Shaped)	258,34	154,67	151,56	99,96
Model 3 (Shearwall Core wall)	253,58	143,15	141,28	90,25

Table 2. Comparison of beam moment values (continued)

Structure System	Bending Moment (kN.m)			
	B3		B4	
	Support	Midspan	Support	Midspan
Model 1 (SMRF)	24,60	18,64	6,09	3,36
Model 2 (Shearwall L-Shaped)	23,03	20,07	6,30	3,22
Model 3 (Shearwall Core wall)	15,62	16,69	3,29	1,54

Table 2. Comparison of beam moment values (continued)

Structure System	Bending Moment (kN.m)		Total	
	B5			
	Support	Midspan	(kN.m)	(%)
Model 1 (SMRF)	65,07	34,93	887,22	37
Model 2 (Shearwall L-Shaped)	54,32	32,80	768,21	32
Model 3 (Shearwall Core wall)	46,32	28,11	739,81	31

Table 3. Comparison of column moment values

Structure System	Bending Moment	
	kN.m	%
Model 1 (SMRF)	370,07	35
Model 2 (Shearwall L-Shaped)	340,36	33
Model 3 (Shearwall Core wall)	339,12	32

Then, for planning the reinforcement in the beam using size D22 for main reinforcement and D10 for shear reinforcement.

Table 4. Comparison of the amount of beam reinforcement

Structure System	Beam Code			
	B1		B2	
	Support	Midspan	Support	Midspan
Model 1 (SMRF)	9D22	6D22	8D22	6D22
Model 2 (Shearwall L-Shaped)	9D22	5D22	8D22	5D22
Model 3 (Shearwall Core wall)	9D22	5D22	8D22	5D22

Table 4. Comparison of the amount of beam reinforcement (continued)

Structure System	Beam Code			
	B3		B4	
	Support	Midspan	Support	Midspan
Model 1 (SMRF)	4D22	4D22	4D22	4D22
Model 2 (Shearwall L-Shaped)	4D22	4D22	4D22	4D22
Model 3 (Shearwall Core wall)	4D22	4D22	4D22	4D22

Table 4. Comparison of the amount of beam reinforcement (continued)

Structure System	Beam Code		Total	
	B5			
	Support	Midspan	Pieces	(%)
Model 1 (SMRF)	4D22	4D22	53	40
Model 2 (Shearwall L-Shaped)	4D22	4D22	51	30
Model 3 (Shearwall Core wall)	4D22	4D22	51	30

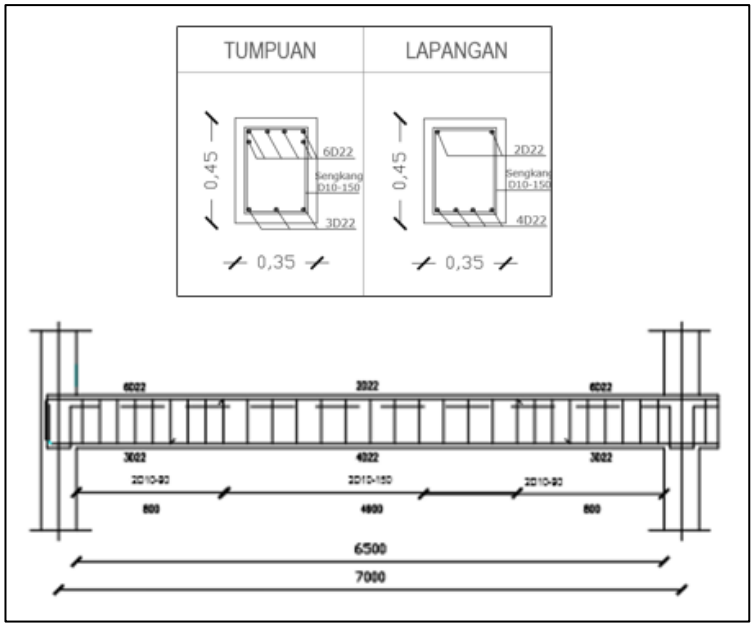

Figure 6. Beam reinforcement details

From what is shown in table 4, it can be seen from the results on the beams that there is a 10% reduction in the amount of reinforcement in the structural model using shear walls. Furthermore, for column planning, D22 reinforcement is also used for main reinforcement and D10 reinforcement for shear reinforcement.

Table 5. Comparison of the amount of column reinforcement

Structure System	Reinforcement Amount			
	Main reinf.	Shear reinf. of the plastic hinge region	Shear reinf. outside the plastic hinge region	(%)
Model 1 (SMRF)	12D22	4 legged D10 - 125	4 legged D10 – 150	43
Model 2 (Shearwall L-Shaped)	8D22	4 legged D10 - 125	4 legged D10 – 150	29
Model 3 (Shearwall Core wall)	8D22	4 legged D10 - 125	4 legged D10 – 150	28

There was a 14% reduction in the amount of reinforcement required for columns using a dual system compared to models without shear walls.

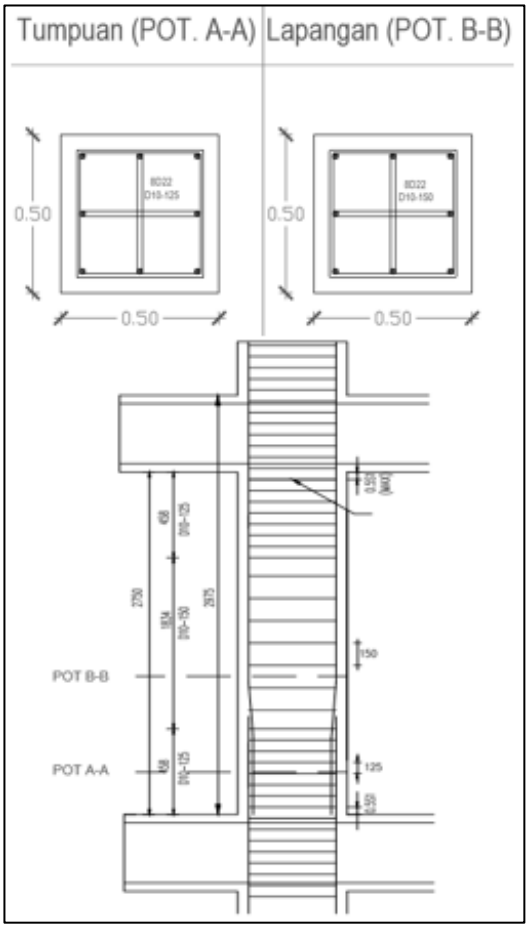

Figure 7. Column reinforcement details

The slab thickness used is 125 mm and the slab reinforcement is shown in table 6.

Table 6. Floor slab reinforcement

Floor	Reinforcement used			
	X direction		Y direction	
	Support	Midspan	Support	Midspan
Base Floor	ϕ16-200	ϕ13-300	ϕ16-200	ϕ13-300
Floor 1-9	ϕ16-450	ϕ13-450	ϕ16-450	ϕ13-450
Deck	ϕ16-250	ϕ13-450	ϕ16-250	ϕ13-450

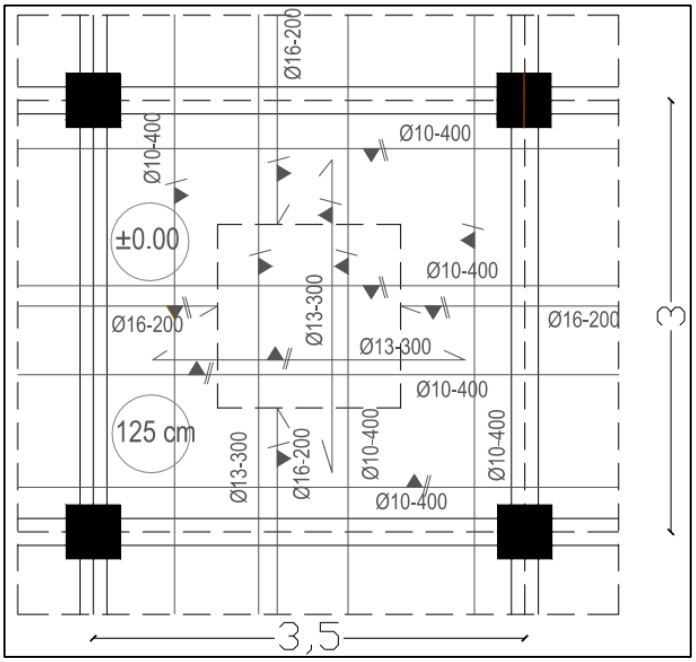

Figure 8. Floor slab reinforcement details

The shear wall thickness used is 350 mm and the shear wall reinforcement is shown in table 7.

Table 7. Shear wall reinforcement

Structure System	Main reinf.	Shear reinf.
Model 2 (Shearwall L-Shaped)	36D22	2 legged D13 - 250
Model 3 (Shearwall Core wall)	36D22	2 legged D13 - 250

Shear wall reinforcement obtained the following results:

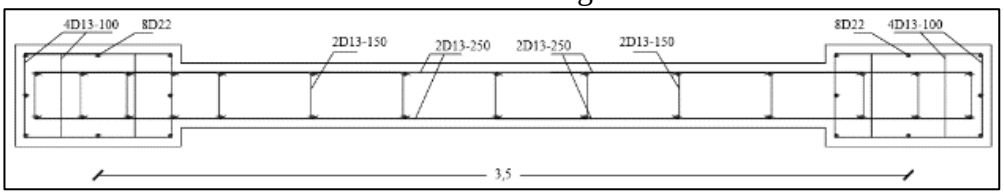

Figure 9. Shear wall reinforcement details

Drift Ratio

The results of the drift ratio due to the earthquake load response spectrum can be seen in table 8 below.

Table 8. Comparison of drift ratio in structural models

Storey	Percentage Comparison of Drift Ratio					
	Model 1 (SMRF)		Model 2 (Shearwall L)		Model 3 (Shearwall Core)	
	Δx (mm)	Δy (mm)	Δx (mm)	Δy (mm)	Δx (mm)	Δy (mm)
10	2,67	1,66	1,71	2,57	2,50	1,34
9	3,93	2,74	3,88	3,41	3,45	2,30
8	5,25	3,92	5,22	3,50	4,69	3,39
7	6,43	4,93	6,21	4,37	5,89	4,41
6	7,53	5,87	6,83	5,89	7,03	5,36
5	8,60	6,72	8,39	6,53	8,14	6,29
4	9,56	7,55	8,93	7,37	9,13	7,18
3	10,43	8,36	10,02	7,96	9,99	8,04
2	11,27	9,47	9,19	8,56	10,81	9,11
1	13,27	12,67	10,46	10,06	12,67	12,12
∑	78,94	63,89	70,84	60,22	74,30	59,54
% drift ratio	19,36	15,67	17,37	14,77	18,22	14,60
% Decreased in drift ratio			10,26	5,74	5,88	6,81

Displacement

The displacement values obtained due to the dynamic earthquake response spectrum which were analyzed using the help of structural software are presented in tabular form which can be seen in table 9.

Table 9. Displacement values in the structure model

Storey	Displacement (mm)					
	Model 1 (SMRF)		Model 2 (Shearwall L)		Model 3 (Shearwall Core)	
	Δx	Δy	Δx	Δy	Δx	Δy
10	78,94	63,89	70,84	60,22	74,3	59,54
9	76,27	62,23	69,13	57,65	71,8	58,2
8	72,34	59,49	65,25	54,24	68,35	55,9
7	67,09	55,57	60,03	50,74	63,66	52,51
6	60,66	50,64	53,82	46,37	57,77	48,1
5	53,13	44,77	46,99	40,48	50,74	42,74
4	44,53	38,05	38,6	33,95	42,6	36,45
3	34,97	30,5	29,67	26,58	33,47	29,27
2	24,54	22,14	19,65	18,62	23,48	21,23
1	13,27	12,67	10,46	10,06	12,67	12,12
∑	525,74	439,95	464,44	398,91	498,84	416,06
% Comparison	19,16	16,03	16,93	14,54	18,18	15,16

5. CONCLUSION

Conclusion

In the design of reinforced concrete buildings in the seismic design category D with variations in the location of the shear walls in the dual system, several conclusions can be drawn based on the results of the structural analysis as follows:

1. For the planning moment-resisting frame system on beam B1 obtained with dimensions of 35 cm x 45 cm, while for beams B2, B3, B4, B5 obtained dimensions of 25 x 35 cm and planning on columns obtained K1 column dimensions of 50 x 50 cm and thickness on a 125 mm floor slab. Whereas the dual planning system on beam B1 obtained with the same dimensions of 35 cm x 45 cm, while beams B2, B3, B4, B5 obtained dimensions of 25 x 35 cm and K1 column dimensions of 50 x 50 cm, floor slab thickness of 125 mm and with a shear wall thickness of 35 cm.
2. For the reinforcement moment-resisting frame system on beams B1, B2, B3, B4, and B5 use reinforcement D22 for main reinforcement and D10 for shear reinforcement while for column K1 also uses main reinforcement D22 and D10 for shear reinforcement and reinforcement on slabs using Ø16 for support reinforcement, Ø13 for midspan reinforcement and Ø10 for shrinkage reinforcement. In the dual system also use reinforcement D22 for the main reinforcement and D10 for shear reinforcement in beams B1, B2, B3, B4, and B5 while for the main reinforcement column D22 is used and D10 in shear reinforcement and reinforcement is used for shearwall D22 for the main reinforcement and D13 for shear reinforcement. The size of the reinforcement used by the moment-resisting frame system and the dual system is almost the same, however the amount of reinforcement is different.
3. From the results of structural analysis in model 1, model 2 and model 3 by providing variations in the location of the shear walls, it can be concluded that model 3 is the recommended structural model because it has a high stiffness value with a smaller displacement value and drift ratio value than the other model. Comparison of the results of reducing the value of the drift ratio is as follows:
    a. The biggest decrease in the value of the drift ratio obtained in each shear wall model is 10.26% in the x direction in the shearwall structure model 2 and 6.81% in the y direction, namely in the shearwall structure model 3.
    b. The smallest decrease in the drift ratio value obtained in each shear wall model is 5.74% in the y direction, namely in the shearwall structure model 2 and 5.88% in the x direction in the shearwall structure model 3.

Suggestions

Some suggestions that can be given as development in further research:

1. In future studies, several variations of the placement of shear walls can be used which are even more varied by taking into account the geometric shape of the building structure.
2. Can use other types of analysis, for example, time history analysis according to SNI 1726: 2019 codes.
3. Using a structure with an irregular building plan.
4. Using newer load codes.

For further research, the placement of shear walls is more focused on long spans.

REFERENCES

Aisyah G.N, 2015, Dinding Geser, (Online),(https://www.scribd.com/doc/279381633/Dinding-Geser. Diakses 2 Juni 2021).

Badan Standarisasi Nasional, 2019. *Tata Cara Perencanaan Ketahanan Gempa untuk Struktur Bangunan Gedung da Non Gedung SNI 1726-2019*. Jakarta : Standar Nasional Indonesia.

Badan Standarisasi Nasional, 2013. *Beban minimum untuk perancangan bangunan gedung dan struktur lain SNI 03-1727-2013*. Jakarta : Standar Nasional Indonesia.

Badan Standarisasi Nasional, 2019. *Persyaratan Beton Struktural untuk Bangunan Gedung SNI 2847-2019*. Jakarta : Standar Nasional Indonesia.

Günel, Mehmet H, & Hüseyin Emre Ilgin. 2014. *Tall Buildings: Structural Systems and Aerodynamic Form*. Routledge: New York.

Imran, Iswandi., Fajar Hendrik, 2014. Perencanaan Dasar Struktur Beton Bertulang. Bandung : ITB.

Imran, Iswandi., Fajar Hendrik, 2014. Perencanaan Lanjut Struktur Beton Bertulang. Bandung : ITB.

McCormac, Jack C. 2003. *Desain Beton Bertulang Edisi Kelima Jilid 2*. Erlangga. Jakarta.

Nishar N.U, dkk, 2015, Sistem Struktur Penahan Gaya Lateral: *Dual System Shear Wall-Rigid Frame*. (https://www.slideshare.net/DeboraElluisaa/kelompok-2-teknik-sipil-2012-b-sistem-ganda. Diakses 14 Juni 2021).

Nugroho F. 2017. Pengaruh Dinding Geser Terhadap Perencanaan Kolom dan Balok Bangunan Gedung Beton Bertulang, Vol.19, Padang.

Poulos, Harry G. 2017. *Tall Building Foundation Design.* Taylor & Francis: Boca Raton.

Schodek, Daniel L., & Martin Bechthold. 2014. *Structures: Seventh Edition*. Pearson Education: United States.

Schueller W., 1989, Struktur Bangunan Bertingkat Tinggi, Eresco, Bandung.

Taranath, Ph.D., P.E., S.E., Bungale S. 2017. *Tall Building Design: Steel, Concrete, and Composite System.* CRC Press: Boca Roton.

Widodo. 2001. *Respons Dinamik Struktur Elastik*. UII Press. Yogyakarta.