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The effect of variation of shear walls placement on the response of building structure using the Direct Displacement-Based Design method

Hanif Satria Aji, Anis Rosyidah*, Jonathan Saputra
Department of Civil Engineering, Politeknik Negeri Jakarta, Indonesia

Abstract
Shear walls' placement in specific positions could develop different structural responses to the building and affect the structure's strength to the received lateral loads. This research aims to find the variations in the shear walls' placement on the structure's response under the Direct Displacement Based Design (DDBD) method. The object of this research is the model of a 10-story reinforced concrete building located in Yogyakarta, Indonesia. Modelling of building structures is carried out in this study with four variations of shear wall placement. First, the walls are located at every building's corner. The shear wall is then positioned in the core of the building, where the apertures have shrunk. Then, the shear wall is located on the edge of the building. Last, the shear wall is located on the edge of the building. ANOVA method is used to analyze the significant difference, i.e., variations in the walls' placement. This research indicates the significant differences in the x-direction shear force and the y-direction moment The shear walls are suggested to be placed according to the building's condition and the earthquake ground site's class to produce an optimal structure to resist earthquake loads.

Keywords:
Direct Displacement Based Design (DDBD);
Shear Wall;
Structural Response;

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Corresponding Author:
Anis Rosyidah
Department of Civil Engineering, Politeknik Negeri Jakarta, Indonesia
Email:
anis.rosyidah@sipil.pnj.ac.id

INTRODUCTION

In designing a building structure, earthquake loads are an absolute requirement to consider so that the building structure does not collapse whenever an earthquake happens. Therefore, it does not cause casualties or material loss, and building occupants' safety can be relatively guaranteed [1][2]. Lateral loads, especially earthquake loads, are more prone to respond in taller buildings.

A particular structural system is needed to withstand earthquake loads and improve buildings' performance. One solution is adding a shear wall [3][4]. However, the beams and columns will be pretty significant when the building is designed without shear walls, and problems will arise at the joints [5]. Furthermore, the presence of the shear wall will affect the building's stiffness so that the lateral forces are not fully borne by the frame structure (columns and beams) [6][7].

In structural engineering, shear walls are structural systems that consist of reinforced concrete slabs (also known as shear panels). It resists the effects of lateral loads acting on a structure. The two results of lateral loads that are commonly designed to be carried by shear walls are wind and earthquake loads [8]. It can be said that shear walls ensure the structure's safety against earthquake loads and other lateral loads. If the primary retaining mechanism (or the only lateral load in a building) is in the wall, then the type of building is called a "shear wall structure" [9]. The use of shear walls can be essential from the economic perspective and the horizontal displacement control. Shear walls are lateral force resisting systems that bear bending moments and shear forces [10].

The properties of shear walls that make a building effective are rigid and robust so that the resulting horizontal deflection is small [11]. Shear walls are usually provided along both the length and width of buildings. Their thickness can be varied from 150mm to 400mm in high-rise buildings [12], but shear walls are relatively thin and experience considerable axial forces, unlike beams. Therefore, shear walls must be designed as axially loaded beams, capable of forming plastic hinges of sufficient rotational capacity, and vertically oriented to carry earthquake loads down to the foundation [13].

From the previous research, there were differences in the placement of shear walls which was considered the most optimum. Some research stated that the ideal placement might occur when the shear walls are placed on the side of the building with the most edges [14][15]. Other research said that the shear walls placed in the L-shaped building corner are considered the most optimum [16]. On the other hand, the shear wall placed in the middle (approaching the center) of the building's mass is considered the most optimum than the other shear walls' placement [3][17].

Based on the background above, this research is conducted to determine the effect of variations in shear walls' placement on the structure's response according to the specified seismic load design. The structural responses that are being studied in this research are axial forces, moments, and shear forces. First, the order is defined as the shear walls' placement in a specific part of a building. Then, the shear wall placement variation is analyzed on the structure's response.

METHOD

Direct Displacement Based Design (DDBD)

The latest concept for the design of earthquake-resistant building structures is the performance-based concept, which directly determines the structure's performance as the main reference in the design of earthquake-resistant buildings. Performance-based design (PBD) has been widely used in structures like buildings and bridges, especially in seismic engineering and structural dynamics [18]. The method used in this research is Direct Displacement Based Design (DDBD). DDBD uses the displacement value as a reference to determine the strength required by the building against the designed earthquake force that is consistent with the given response spectrum reference [19][20].

The DDBD method appears to overcome the weaknesses in the design using the Force Based Design (FBD) method because the FBD method is dependent on the initial stiffness to determine the period and shear forces. In FBD, it is necessary to repeat iterations. Besides that, the determination of the same flexibility and force reduction factor for various structures could be inaccurate [20]. The DDBD method is more effective and efficient in processing than similar methods [21].

However, the costs incurred in this DDBD method are more expensive because the design results will use more materials [21]. Structures that use the DDBD method are designed with a Single Degree of Freedom (SDOF), representing performance at the maximum displacement response, not by initial characteristics [22]. PBD can also be applied to strengthen existing buildings. The design process begins with the initial design of the building, followed by simulations of the building's performance under a variety of earthquake loads. If the simulation results are still below the minimum parameters specified earlier, a re-design will be carried out to bring the building's performance up to par [23].

The design concept based on displacement Direct Displacement Based Design (DDBD) is generally illustrated in Figure 1.

Analysis of Variance (ANOVA)

Statistics is a form of mathematics that deals with data collection, data analysis, and interpretation of results of data analysis to get information or explanations to develop conclusions and make decisions [24]. For example, one of the statistical methods used to analyze data to prove the research hypothesis by comparing (comparative test) is the Analysis of Variance (ANOVA). ANOVA is a statistical testing method used to compare two or more group data [25][26].

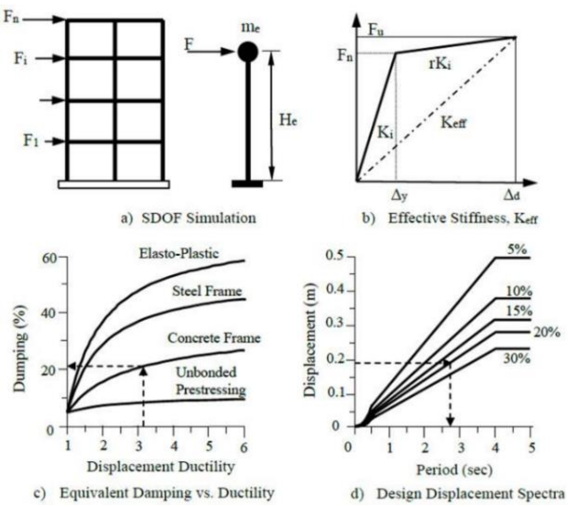


Figure 1. Direct Displacement Based Design Concept [27]

The application of the ANOVA method is intended to produce more accurate conclusions [28]. In addition, an in-depth analysis can be carried out through this ANOVA method, which compares the values and deepens the comparative study of any variations in each sample tested [24].

Research Variable

There are two variables in this research, independent and dependent variables, i.e.:

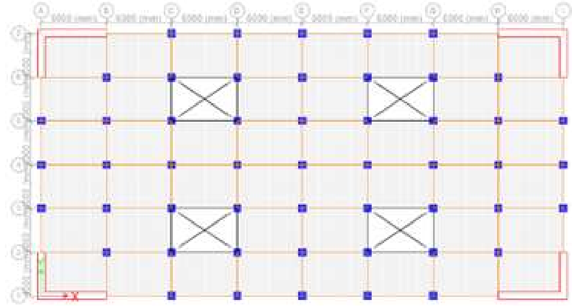
a. The independent variable is the shear walls' placements (four different placements) that are described in Figure 2.
b. The dependent variable is the response of the building structure to each research object. The structural responses are defined as axial forces, moments, and shear forces on shear wall structural elements.

Material

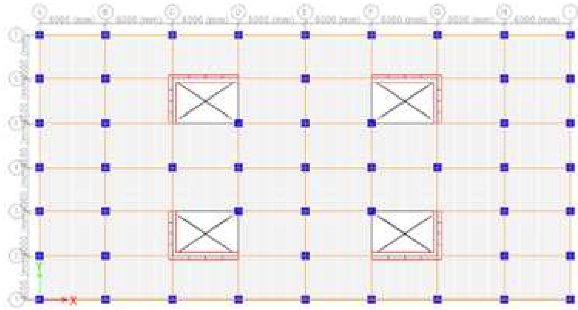
The building is in Yogyakarta with the soft soil site class. The structural system used is the building frame system. The structure used is reinforced concrete with ten floors and four meters for each floor. The building design data in this research will be described in the following points:

a. Building length: 48 meters
b. Building width: 24 meters
c. Floor slab thickness: 0.12 meters
d. Column dimensions 1 (K1) : 0.65 x 0.65 meters (floors 1-4)
e. Column dimensions 2 (K2) : 0.55 x 0.55 meters (floors 5-7)
f. Column dimensions 3 (K3) : 0.50 x 0.50 meters (floors 8-10)
g. Beam dimensions 1 (B1) : 0.40 x 0.60 meters (x-direction)
h. Beam dimensions 2 (B2) : 0.30 x 0.50 meters (y-direction)
i. Shear wall-length x-direction: 6 meters
j. Shear wall-length y-direction: 4 meters
k. Shear wall thickness: 0.65 meters

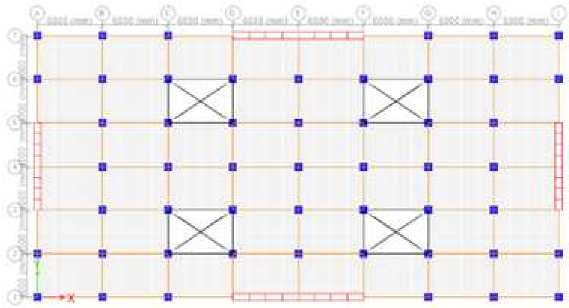
Structural analysis was assisted by using ETABS. In addition, statistical analysis was carried out using SPSS to determine the impact of shear wall placement on structural reaction. The analyzed building structure consists of 4 models, in which the order of shear walls is different.



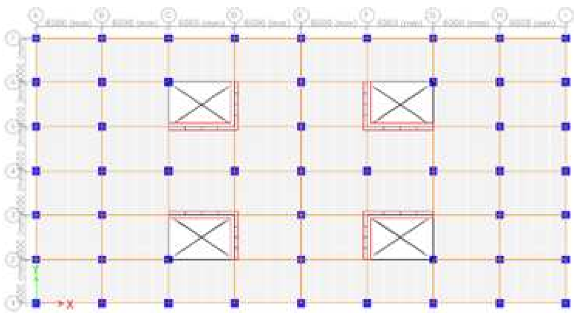
a. Model 1, The location of the shear walls is at the four corners of the building



b. Model 2, The shear wall is in the center of the building, specifically in the corner of the entrance



c. Model 3, The location of the shear wall is on the edge of the building



d. Model 4, The location of the shear wall is the center of the building (close to the center of mass)

Figure 2. Object of research: (a) Model 1, (b) Model 2, (c) Model 3, (d) Model 4.

Working Flow

The working flow of this research is illustrated in Figure 3.

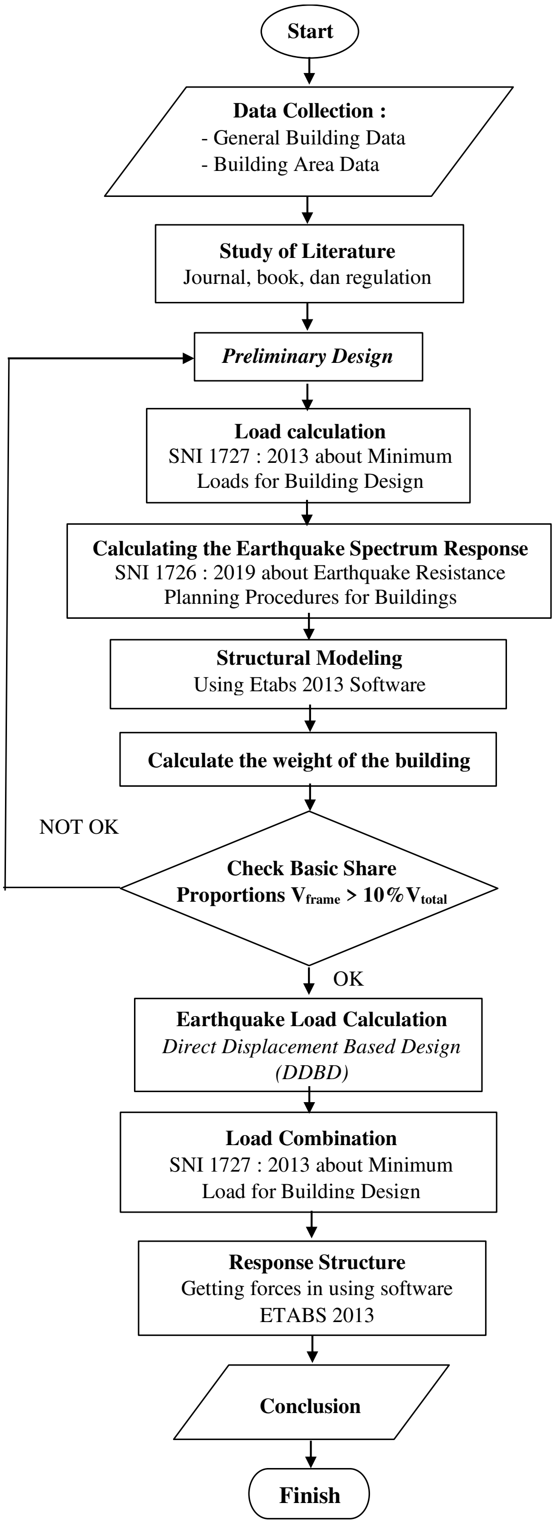


Figure 3. Flow Chart

Preliminary Design

Preliminary design is the initial design of the structural components and materials used to design the structure. This stage includes the initial design of the dimensions of beams, columns, plates, and shear walls based on SNI 2847: 2019 concerning Requirements for Structural Concrete for Buildings.

Earthquake Response Spectrum

Spectrum response design is based on SNI 1726: 2019 concerning Earthquake Resistance Design Procedures for Buildings. The steps for determining the response spectrum are as follows:

1. Determine the building risk category depending on the function of the building (Table 1 SNI 1726: 2019).
2. Determine the priority factors of the earthquake (Table 2 SNI 1726: 2019).
3. Determine the ground acceleration parameters (Ss, S1) based on the location of the building.
4. Determine the site classification factor (Table 3 SNI 1726: 2019).
5. Determining the Site Coefficient Factor (Fa, Fv) (Table 4 and Table 5 SNI 1726: 2019).
6. Calculate the acceleration response parameters in the 2.0 secs (S_{MS}).
7. Calculate the acceleration response parameters in the 1.0 secs (S_{M1}).
8. Calculate the spectral acceleration parameters in the 0 s period (S_{DS}).
9. Calculate the spectral acceleration parameters in the 1 s period (S_{D1}).
10. Calculate the period of the fundamental vibration of the structure (T0 and TS).
11. Calculate the acceleration spectrum (Sa). It is made in the form of tables and response spectrum graphs.

Structural Modeling

The building structure model is made using ETABS software by entering the structural data that has been determined based on the Preliminary Design. The model is then given a load based on the calculation of the load that has been carried out, including dead load, live load, and earthquake load.

Weight of The Building

After modelling the structure and getting the story force output, the next thing to do is calculate the building weight for each floor. The calculation is then used to determine the effective weight of the building to be designed as 1.0 x Dead Load + 0.5 x Live Load.

Check the Percentage of Force Lateral on the Shear Wall

Building frame systems use a complete three-dimensional space frame to support vertical loads but use either shear walls or braced frames to resist lateral forces [29]. Therefore, it is necessary to check the percentage of column placement and shear wall reactions due to earthquake forces. In addition, it is essential to see the ability of shear walls to absorb lateral loads due to earthquakes. In the frame system of the building, the shear walls carry 90% of the lateral forces, while the shear walls of the frame system carry 10% of the lateral forces [30].

Earthquake Load Calculation DDBD Method for Building Frame System

Design of Proportion of Shear Force on Shear Frame and Wall

The first step in designing using the Direct Displacement Based Design (DDBD) method for a structure with a building frame system is to determine the proportion of shear forces that the frame and shear wall system will accept. The proportion of the shear force on the frame is determined by (1) and (2).

$$V_F = \beta_F \, V_{base} \tag{1}$$

$$V_W = (1 - \beta_F) \, V_{base} \tag{2}$$

Explanation:

V_F = Basic shear force on the frame

V_W = Basic shear forces on shear walls

V_{base} = Total fundamental shear force

β_F = The ratio of the basic shear forces on the frame

Determining Wall Contraflexure Height (HCF)

The wall height under contra flexure conditions is illustrated in Figure 4. The value of H_{CF} will vary according to the magnitude of the basic shear force that the frame can withstand (V_F) against the total shear force (V_{base}).

From Figure 4, the wall inflexion value, H_{CF}, depends on the magnitude of the relative overturning moment value and the proportion f the shear forces that the frame can be old.

$$F_i = \frac{m_i}{\sum m_i H_i} \tag{3}$$

$$M_{OTM}.i = V_i \times H_n \tag{4}$$

Explanation:

F_i = Ratio of the relative force of the i-th floor

m_i = Mass on the sixth floor, a ton

H_i = Total height of the structure of the i-th floor, m

$M_{OTM}.i$ = Total overturning moment of the i-th floor

V_i = Total shear force of the i-th floor

H_n = Height of the structure on two sixth floor

Determining the Shear Wall Yield Displacement Profile

To determine the design displacement profile, the assumption used is that the ultimate strain in the frame will not reach a critical state because the design displacement profile will reach the limit by the material strain in the plastic hinges on the shear wall or by the displacement limit. Displacement will reach its maximum at the contra flexure wall height (H_{CF}). Equations (5) and (6) are used to determine the yield transfer profile of the shear walls.

$Hi \le H_{CF}$

$$\Delta_{ei} = \Delta_{yi} = \varphi_{y,W} \left(\frac{H_i^2}{2} - \frac{H_i^3}{6H_{CF}} \right) \tag{5}$$

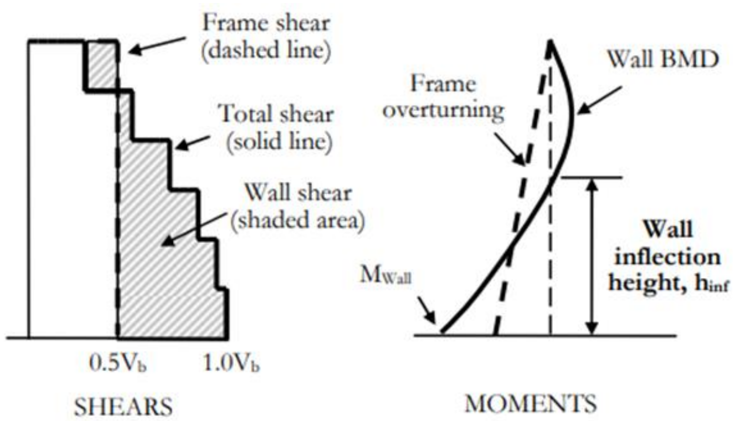


Figure 4. Contra flexure Wall Height Based on the Proportion of the Shear Force and Relative Overturning Moment [23]

$H_i > H_{CF}$

$$\Delta_{ei} = \Delta_{yi} = \varphi_{y,W}\left(\frac{H_{CF}.H_i}{2} - \frac{H_{CF}^2}{6}\right) \quad (6)$$

Explanation:
Δ_{yi} = Yield displacement profile, m
Φ_{yW} = Yield curvature at the base of the wall
ε_y = Strain of the reinforcing material at the base of the shear wall (f_{ye}/E)
f_{ye} = Yield strength of reinforcement (1.1fy), MPa
L_w = Shear wall length, m
H_i = Structural height on the i-th floor

Design Displacement Design Profiles

The next step is to determine the design curvature of the shear walls. There are two design conditions:
First, to design on serviceability conditions

$$\phi_s = 0.0175 / l_w \quad (7)$$

Second, to design in a damage control state

$$\phi_s = 0.072 / l_w \quad (8)$$

The length of the plastic hinge in the shear wall is determined by (9) and (10).

$$L_p = k.H_{CF} + 0.1\ l_w + L_{sp} \quad (9)$$
$$L_{sp} = 0.022\ f_{ye}.d_{bi} \quad (10)$$

Explanation:
L_{sp} = The length of penetration of the strain to the foundation (m) whose value depends on the diameter of the shear walls with fye = 1.1 fy
L_p = Plastic hinge length, m
d_{bi} = Shear wall principal reinforcement diameter, mm
k = Constant

$$k = 0.2\ (f_u / f_y - 1) \leq 0.08 \quad (11)$$

The deviation value (drift) at high contra flexure (θCF) is determined by (12).

$$\theta_{CF} = \phi_{yW} H_{CF} / 2 + (\phi_{ls} - \phi_{yW})\ L_p \quad (12)$$

The value of the designed displacement profile is determined by (13) and (14).

If $\theta_{CF} \leq \theta_C$, then,
$$\Delta_{Di} = \Delta_{yi} + (\phi_{ls} - \phi_{yW})\ L_p H_i \quad (13)$$
If $\theta_{CF} > \theta_C$ then,
$$\Delta_{Di} = \Delta_{yi} + (\theta_C - \phi_{yW} H_{CF} / 2)\ H_i \quad (14)$$

Explanation:
Δ_{Di} = Design displacement profile, m
θ_{CF} = Deviation at contra flexure height, H_{CF}
θ_C =Design deviation limit

The deviation value's correction factor at high contra flexure (ω_θ) is determined by (15).

$$\omega_\theta = \left(1 - \frac{(n-5)}{100}\right)\left(\frac{M_{OTM.F}}{M_{OTM}} + 0.25\right) \quad (15)$$

Explanation:
ω_θ = Correction factor
n = Number of floors
$M_{OTM.F}$ = total overturning moment on the frame
M_{OTM} = Total overturning moment at the base of the building

SDOF Displacement Design

The MDOF level displacement design should be converted to an SDOF system where the maximum displacement is the equivalent of the MDOF level displacement design. The value is determined by (16).

$$\Delta_d = \frac{\sum_{i=1}^n (m_i.\Delta_i^2)}{\sum_{i=1}^n (m_i.\Delta_i)} \quad (16)$$

Explanation:
Δ_d = SDOF design maximum displacement, m
m_i = Mass in the i-th grade, tons
Δ_i = Displacement on the i-th fdoublem

High Effective

The effective height of the structure, which is equivalent to the SDOF system, is calculated by (17).

$$H_e = \frac{\sum_{i=1}^n (m_i.\Delta_i.h_i)}{\sum_{i=1}^n (m_i.\Delta_i)} \quad (17)$$

Explanation:
H_e = Effective height of the structure, m

Effective Mass

The effective mass for the SDOF system on the building frame system is calculated by (18).

$$m_e = \frac{\sum_{i=1}^n (m_i.\Delta_i)}{\Delta_d} \quad (18)$$

Explanation:
m_e = Effective mass, ton/g

Equivalent Damping

The equivalent viscous damping value for SDOF systems depends on the structural system's displacement ductility.

1. Calculation for displacement ductility in shear walls.

$$\mu w = \Delta_d / \Delta_{Yw} \quad (19)$$

2. Equivalent viscous attenuation in reinforced concrete shear walls.

$$\xi w = 0.05 + 0.444 \left(\frac{\mu_w - 1}{\mu_w \pi}\right) \quad (20)$$

Explanation:
μw = Shear wall displacement ductility
Δ_{yw} = The displacement of the yield in the shear wall when it reaches the effective height (see (5) and (6))
ξw = The effective attenuation of RC-Wall in the direction under review

Effective Period

The value of the displacement spectra (S_d) is calculated by (21), and the value of the displacement spectra (S_d) at the equivalent viscous damping level must be multiplied by the correction factor for the damping level is calculated by (22).

1) Spectra Displacement (Sd) Value

$$S_d = \frac{T^2}{4\pi^2} S_a.(g) \quad (21)$$

2) Correction factor for the attenuation level of Spectra Displacement stand (Sd)

$$R_\xi = \left[\frac{0.02 + \xi}{0.07}\right]^{1/2} \quad (22)$$

Explanation:
S_d = *Spectra displacement,* m
S_a = *Spectra acceleration,* g
g = Acceleration due to gravity (9.81 m/s2)
R_ξ = The displacement spectra correction factor at the damping level
T = Fundamental period of vibration, Seconds

The value of the effective period of the SDOF system at the peak displacement response with the inelastic damping of the system is calculated by converting the design response spectrum to a displacement spectra graph (S_d) with the correction to the equivalent viscous damping level. On the displacement spectra graph, the designed displacement value (Δd) is drawn so that the value of the system's effective period can be known. For more details, the conversion of the design spectrum response curve to displacement spectra can be seen in Figure 5.

Effective Stiffness

The value of effective stiffness depends on the effective mass and the effective period. It is calculated by (23).

$$K_e = \frac{4.\pi^2.m^e}{T_e^2} \quad (23)$$

Basic Shear Force

After the effective stiffness value is calculated, the value of the basic design shear force is calculated by (24).

$$V_{base} = K_e \times \Delta_d \quad (24)$$

RESULTS AND DISCUSSION

Earthquake Load Analysis with DDBD Method in Building Frame System

Table 1 shows the base-shear force output ratio results for each model's frame and shear walls. Based on Table 1, the base shear force ratio's value on the frame in each model has met the building frame system's requirements, where the proportion value of the base shear force on the structure must be more than 10%. The building frame system requirement is that the shear walls withstand 90% of the lateral forces, while for the frame system, they resist 10% of the lateral forces [30].

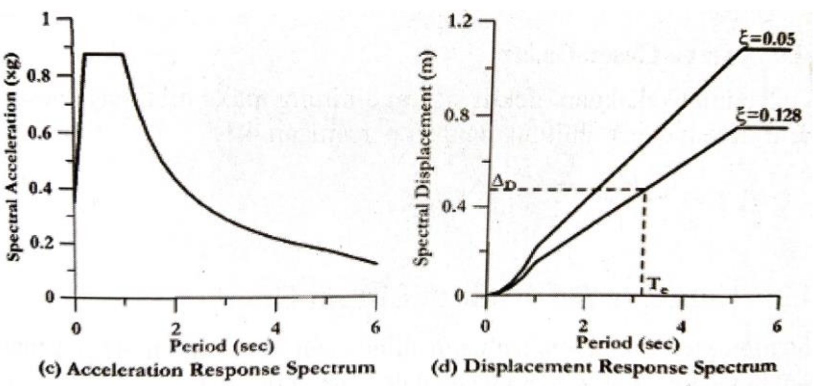


Figure 5. Response Spectrum Design and Spectra Displacement [23]

Table 1. The ratio of shear force on the frame and shear wall

Object of research	Total Base Shear Force on The Frame (kN)	Entire Base Shear Force on Shear Wall (kN)	Base Shear Force Ratio on the frame (%)
Model 1	1443.08	6606.11	17.93%
Model 2	1429.70	6920.07	17.12%
Model 3	1406.70	7889.29	15.13%
Model 4	1427.77	6907.85	17.13%

Table 2. Earthquake Load Distribution for Each Floor DDBD Method.

Level	Model 1		Model 2	
	Fx (kN)	Fy (kN)	Fx (kN)	Fy (kN)
10	3480.60	3777.04	3676.01	3778.52
9	2277.70	2485.41	2405.72	2486.65
8	1998.74	2167.15	2110.64	2167.51
7	1755.46	1888.15	1853.38	1887.85
6	1476.35	1572.32	1558.40	1571.57
5	1203.12	1266.07	1269.76	1265.06
4	979.56	1016.07	1033.64	1014.92
3	713.19	727.10	752.43	726.04
2	459.65	459.02	484.87	458.19
1	221.18	215.44	233.28	214.97
0	0	0	0	0
Total	12792.50	14083.45	14008.34	14026.95

Level	Model 3		Model 4	
	Fx (kN)	Fy (kN)	Fx (kN)	Fy (kN)
10	3813.99	3769.59	3718.43	3774.10
9	2496.32	2481.28	2433.48	2483.74
8	2189.19	2161.38	2135.00	2164.98
7	1921.58	1881.27	1874.77	1885.65
6	1615.13	1565.07	1576.39	1569.74
5	1315.50	1259.00	1284.42	1263.59
4	1070.50	1009.39	1045.57	1013.75
3	779.00	721.58	761.12	725.20
2	501.82	455.04	490.47	457.66
1	241.36	213.33	235.97	214.72
0	0	0	0	0
Total	14368.35	13992.40	14022.62	14032.03

Earthquake Load Distribution with DDBD Method

From the calculation of earthquake loads using the Direct Displacement Based Design (DDBD) method, the distribution of earthquake loads in the x- and y-directions on each floor in each building model is obtained in Table 2.

The Fx value represents the x-direction distribution of shear forces for each level, while the Fy value represents the y-direction distribution for each floor. Based on Table 2, the largest earthquake load occurs on the 10th floor in all models. Due to the Direct Displacement-Based Design (DDBD) method, the earthquake load is designed by emphasizing the displacement value as an initial guideline to obtain the building's strengths against the design earthquake load. In calculating the earthquake load using the DDBD method, the most significant displacement occurs on the 10th floor of each model. It means that the displacement is directly proportional to the results of the earthquake load using the DDBD method so that the most extensive earthquake load distribution occurs on the 10th floor [30].

Response Structure

In this research, the structural response consists of the internal forces in the shear walls, including the axial force value, the x-direction shear force, the y-direction shear force, the x-direction moment, and the y-direction moment.

Response Structure

In this research, the structural response consists of the internal forces in the shear walls, including the axial force value, the x-direction shear force, the y-direction shear force, the x-direction moment, and the y-direction moment. The selection of shear wall elements for the structure under review means that the shear walls are designed to be a single unit that can behave like columns and beams that can accept axial and bending loads. The results of the structural response analysis for each model are described as follows.

Axial Force

The structural analysis results using ETABS obtained axial force in all models presented in Table 3.

Table 3. Result of Axial Force on Shear walls in All Models

Level	Axial Force			
	Model 1 (kN)	Model 2 (kN)	Model 3 (kN)	Model 4 (kN)
10	1466.77	1688.17	1595.23	1699.59
9	2189.95	2621.25	2261.19	2649.46
8	2428.69	2963.42	2515.30	3010.22
7	2942.51	3165.13	4220.53	3183.72
6	5034.47	4757.34	6420.91	4769.64
5	7666.42	7217.43	9053.62	7180.05
4	10446.59	9883.72	11865.32	9842.83
3	13831.41	13154.34	15099.59	13110.59
2	17749.47	16986.70	18721.98	16942.36
1	21324.10	20524.66	22144.44	20480.52

The first step is determining the result of this axial force, i.e., internal force output on the shear wall from ETABS 2013 software, then searching for the maximum on each floor in all models.

Based on Table 3, all models' axial forces arising on the shear walls have different values. The most significant axial force arising on the shear wall occurs on the 1st floor for each model. It happens because the shear wall on the first floor resists all the loads from the floor above.

Shear Force

The structural analysis results using ETABS obtained shear force in all models presented in Table 4. Therefore, the first step is determining the result of this shear force, i.e., internal force output on the shear wall from ETABS 2013 software. Then, the stage is searching for the maximum on each floor in all models.

Based on Table 5, the most significant shear force value occurs in the y-direction because the shear wall in the y-direction is shorter than the shear wall in the x-direction, so the shorter span is usually dominant, causing a greater shear force.

Table 4. x-Direction Shear Force on Shear Wall in All Models

Level	x-Direction Shear Force			
	Model 1 (kN)	Model 2 (kN)	Model 3 (kN)	Model 4 (kN)
10	96.43	244.41	118.44	269.57
9	89.84	215.11	104.28	231.01
8	107.70	240.96	119.00	254.47
7	107.63	250.37	115.97	263.84
6	130.66	287.70	123.32	299.05
5	177.97	324.65	135.24	333.04
4	145.03	299.26	108.29	307.57
3	182.93	346.20	121.75	352.99
2	183.32	329.02	80.60	332.98
1	441.72	439.74	171.32	439.31

Table 5. y-Direction Shear Force on Shear Walls in All Models

Level	y-Direction Shear Force			
	Model 1 (kN)	Model 2 (kN)	Model 3 (kN)	Model 4 (kN)
10	779.52	760.87	629.17	768.70
9	466.93	488.13	798.87	492.69
8	983.05	1074.44	1355.80	1085.43
7	1262.94	1395.76	1680.47	1409.11
6	1773.35	1908.46	2173.63	1926.53
5	2279.84	2415.80	2639.56	2438.81
4	2327.30	2501.45	2743.13	2524.29
3	2909.09	3070.08	3229.11	3098.42
2	3337.47	3502.15	3625.89	3535.12
1	3275.78	3443.53	3626.74	3478.93

Moment

The structural analysis results using ETABS were obtained moment in all models presented in Table 6. Therefore, the first step is determining the result of this moment, i.e., internal force output on the shear wall from ETABS 2013 software, and then searching for the maximum on each floor in all models.

Based on Table 7, the shear walls occur on each model's 1st floor, The magnitude of the moment on the shear wall is influenced by the loads acting on the building, including dead loads, live loads, and earthquake loads. The dead load and live load in all buildings are designed the same, but the earthquake load design using the Direct Displacement-Based Design (DDBD) method shows different results, In the Direct Displacement-Based Design (DDBD) method, earthquake loads are designed to be located at the center of the building mass so that structural elements close to the center of the building mass will have a considerable moment value.

Table 6. Moment x-Direction on Shear Walls in All Models

Level	Moment of x-Direction			
	Model 1 (kNm)	Model 2 (kNm)	Model 3 (kNm)	Model 4 (kNm)
10	1779.06	1710.97	1012.10	1738.72
9	2592.05	3011.72	1727.26	3034.28
8	2476.54	2852.96	1883.14	2877.69
7	2123.06	2272.28	2677.38	2245.80
6	4434.47	4075.96	4439.27	4121.98
5	7559.93	7175.30	6701.17	7256.79
4	10458.57	10130.68	8777.08	10245.99
3	14501.69	14225.43	11555.12	14391.70
2	19310.27	19179.30	14917.17	19408.85
1	26800.22	26933.87	19403.60	27243.25

Table 7. Moment y-Direction on Shear Walls in All Models

Level	Moment of y-Direction			
	Model 1 (kNm)	Model 2 (kNm)	Model 3 (kNm)	Model 4 (kNm)
10	199.02	441.00	323.16	476.48
9	256.27	411.95	266.85	434.69
8	239.61	432.29	278.84	451.43
7	192.78	417.03	250.57	436.13
6	200.77	431.04	251.15	447.54
5	335.93	470.70	340.39	479.34
4	334.83	461.45	338.35	469.15
3	465.31	558.43	427.29	562.52
2	552.56	591.61	415.12	593.63
1	1182.64	1162.64	853.95	1161.97

Effect of Shear Wall Placement Variations

Testing the effect of shear wall placement used is Analysis of Variance (ANOVA), where the structural responses that have been obtained in all models will be compared to find the effect of shear wall placement. The specific requirement met in comparative analysis is the homogeneity test of variance [26][28].

Homogeneity Test of Variance

The homogeneity test of variance is one of the terms for comparative analysis, The purpose of this test is to determine whether a data variance from two or more groups is homogeneous (identical) or heterogeneous (different) [26][28]. This test can be done with Levene's homogeneity of variance tests. According to Levene's homogeneity of variance test, if the significance value is more than 0.05, the diversity of two or more population groups is homogeneous (the same). For example, the following are the results of the variance homogeneity test in all models presented in Table 8.

Based on Table 8, the significance value of the structural response in all models is more than 0.05 (>0.05), so the diversity of the internal forces in all models is homogeneous (the same) so that the requirements for the Analysis of Variance (ANOVA) test are fulfilled.

Hypothesis Testing

Hypothesis testing is done to prove the research hypothesis. The hypothesis in this research is comparative: a provisional estimate or answer to the structural response calculation results to determine the effect of the four research variables,

a. Initial hypothesis (H_0): There is no significant difference in the calculated response structure analysis between the research objects,
b. Research hypothesis (H_1): There is a significant difference in calculating the response structure analysis between the research objects,

The results of hypothesis testing with Analysis of Variance (ANOVA) using SPSS in all models are presented in Table 9.

Table 8. Homogeneity Test Results of Structural Response Variance in All Models

Structural Response	Sig.
Axial Force	0.964
X Direction Shear Force	0.153
Y Direction Shear Force	0.996
Moment of X Direction	0.754
Moment of Y Direction	0.700

Table 9. Recapitulation of Structural Response Results with ANOVA

Structural Response	Recapitulation of Structural Response Results with ANOVA
	Sig.
Axial Force	0.987
X Direction Shear Force	0.000
Y Direction Shear Force	0.996
Moment of X Direction	0.754
Moment of Y Direction	0.022

Table 9 shows that the x-direction shear-force significance value is 0.000, and the y-direction moment significance value is 0.022 after completing the Analysis of Variance (ANOVA) test on all models. This value is less than 0.05 (<0.05), which is a requirement for the Analysis of Variance (ANOVA) test so that the hypothesis decision is accepted. It means a difference in placing the shear wall on the shear force resulting in the x-direction and the moment in the y-direction. The axial force's significance value is 0.987, the shear-force significance value of the y-direction is 0.996, and the moment significance value of the x-direction is 0.754. This value is more than 0.05 (>0.05), so the rejected hypothesis decision. There is no difference in the effect of the shear walls' placement on the value of axial force, shear force in the y-direction, and moment in the x-direction,

The significance value that meets the requirements of Analysis of Variance (ANOVA) is only 2 out of 5, namely the x-direction shear force and the y-direction moment of the structural response under review so that the Initial Hypothesis (H_0) presented is accepted and the Research Hypothesis (H_1) is rejected.

CONCLUSION

Based on the results and discussion that has been obtained, it can be concluded that from the results of the ANOVA test to get the effect of comparison, the significance value that meets the requirements is only two of the five structural responses reviewed. Therefore, it is the x-direction shear force and the y-direction moment, so the Initial Hypothesis (H_0) is accepted. There is no significant difference in the effect of shear wall placement on the structural response of the four 10-story building models. Therefore, it is suggested for the further study to place the shear walls according to the building's regular or irregular conditions, the earthquake ground location's class, and the seismic design category to produce an optimal structure to resist earthquake loads.

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