LOGIC
Journal of Engineering Design and Technology
Vol. 19 No.3 November 2019; p. 162 - 168

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs.pnb.ac.id/index.php/LOGIC

FORCE BASED DESIGN AND DIRECT DISPLACEMENT BASED DESIGN FOR DUAL SYSTEM STRUCTURE

1) Department of Civil Engineering, Politeknik Negeri Jakarta
2) Department of Civil Engineering, Politeknik Negeri Jakarta

Correponding email:
[1]annisaadina06@gmail.com
[2]anis.rosyidah@sipil.pnj.ac.id

Annisaa Dina Puspita D[1], Anis Rosyidah[2]

Abstract. The Force Based Design (FBD) and the Direct Displacement-Based Design (DDBD) are methods for designing seismic-resistant buildings. Building structures designed, are expected to be suitable with the purpose and usefulness of a building. For this reason, this study compares the performance of dual system structures using the DDBD and FBD methods that aim to prove better performance with consideration of safety against users during an earthquake. This research method uses design analysis method to compare the value of the base shear force, reinforcement ratio, and performance level using software for static nonlinear pushover analysis. The results showed the value of the base shear force x direction of the DDBD method was 17.57% smaller than the FBD method, whereas for the y direction the DDBD value was greater than 9.38% of the FBD. The value of the reinforcement ratio of the beam, column and shear wall results is greater DDBD than FBD. The actual drift of the DDBD and FBD methods is slightly different. So that both are at the same level of performance, namely damage control. The performance level has not reached the performance target of life safety design in DDBD, but the structure has met the level performance requirements for offices.

Keywords : Dual System, DDBD, FBD

1. INTRODUCTION

In multi-story building planning, the structure of a building must be able to withstand earthquake forces so as not to cause casualties or material losses. One way to increase stiffness and structural resistance to earthquakes is to use shear walls [1]. Structural models with shear walls are considered more effective in resisting earthquake loads because displacement and force in structural elements are smaller than open frame structures [2]

One of the known methods of designing seismic-resistant buildings is the Force Based Design (FBD) method whose analysis procedures are found in SNI 1726: 2012 [3]. The Force Based Design (FBD) concept does not directly show the performance of the building against the effects of earthquakes. That is because in FBD analysis it is done linearly [4]. Along with the advancement of science and technology, it is known that a new performance-based concept that directly determines the performance of the structure is expected to be achieved when an earthquake occurs [5]. In this concept, one of the methods is Direct Displacement Based Design (DDBD) which uses the displacement value as a reference to determine the strength needed by the building on seismic forces[6] - [7].

In planning the structure of buildings, it is expected that the structures designed can be following the purpose and usefulness of a building[8]. For this reason, this study compares the performance of a dual system structure using the DDBD and FBD methods which aims to prove which methods have better performance with consideration of safety against users when an earthquake occurs.

2. METHODS

This study was conducted through modeling simulation as a 3D portal with software that was given load based on building loads data and seismic loads by the FBD and DDBD methods. The building functions as an office which consist of 10 floors located in Yogyakarta. Building a plan area of 700 m^2 and typical story height of 4 m as shown in **Figure 1.**

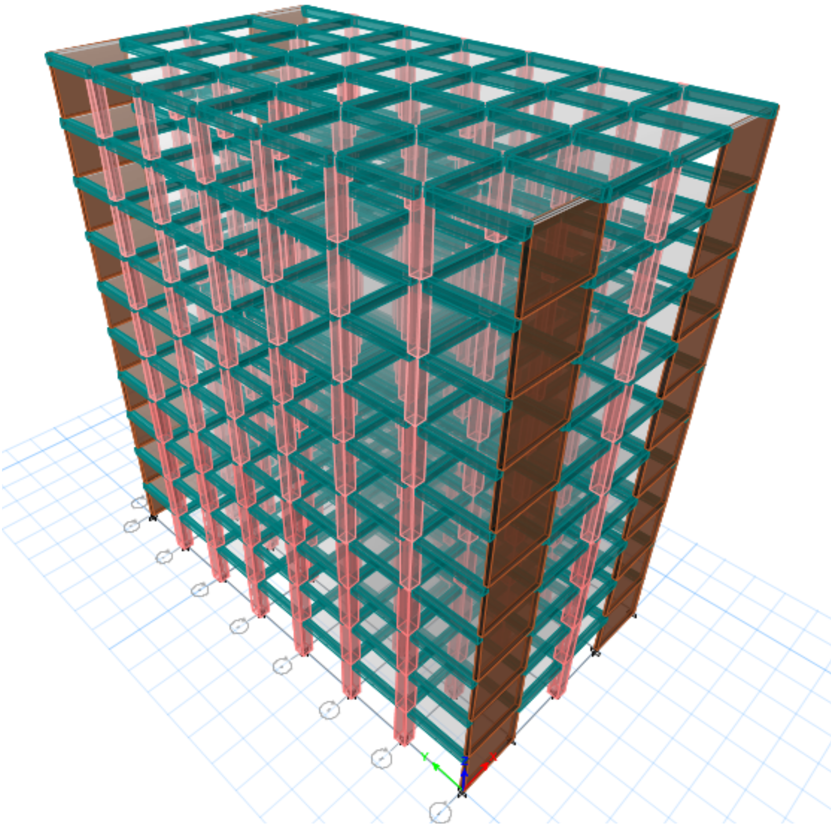


Figure 1. 3D Modeling of Dual System Structure

The method of study is focused on comparing the values of base shear, seismic loads distribution, reinforcement, and performance levels with the DDBD and FBD methods on dual system structures. Structural performance analysis used is static nonlinear pushover analysis. Flow chart the research method is illustrated in **Figure 2.**

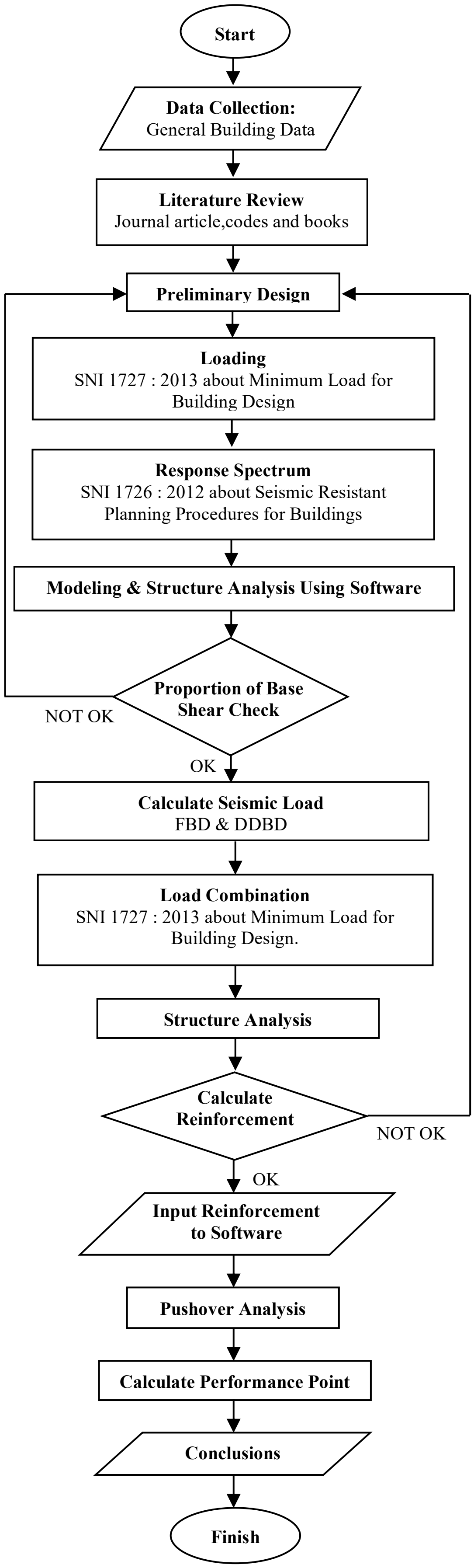


Figure 2. Flow Chart

3. RESULTS AND DISCUSSION

3.1 Base Shear Force

From the calculation of the base shear force with the DDBD and FBD methods, the value of the base shear force is obtained.

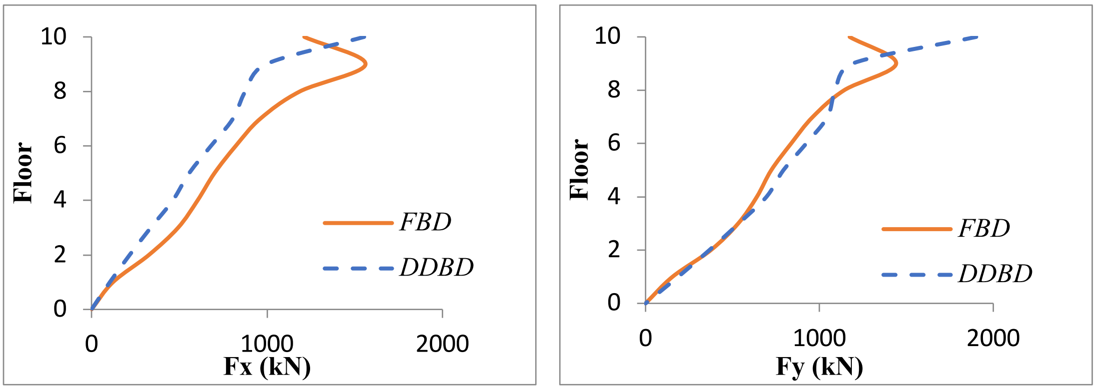
Table 1. Base Shear Force

Dir	Base Shear Force (kN)		% Base Shear Force to FBD	
	FBD	DDBD	FBD	DDBD
X	7992,34	6588,38	100,00	82,43
Y	7984,60	8733,19	100,00	109,38

Based on **Table. 1**, the value of base shear force x-direction in a structure designed using the DDBD method is 17.57% smaller than the value of the base shear force in structure designed using the FBD method. Whereas in the y-direction, the base shear force of the DDBD method is 9.38% greater than the base shear force of the FBD method**.**

3.2 Seismic Load Distribution

The distribution of seismic loads on each floor based on DDBD and FBD calculations is shown in **Figure 3.**



(a) Seismic Load Distribution Dir-X (b) Seismic Load Distribution Dir-Y

Figure 3. Seismic Load Distribution

Based on **Figure 3.**, the seismic load DDBD method value increases from floor 1 to floor 10. So that the most significant seismic load DDBD method is on the 10th floor, 1553,388 kN for the x-direction and 1901,57 kN for the y-direction. That is because, in the DDBD method, seismic loads are designed based on displacement of structural plans. So the seismic load value each floor increases to the top floor following the increase in design displacement. As for the FBD method, seismic load increases from floor 1 to floor nine then becomes smaller on the 10th floor. On the 9th floor, the value of seismic load in x-direction is 1561,329 kN and 1441,205 kN in y-direction. Then on the 10th floor, the value of the seismic load in x-direction becomes 1212,651 kN and in y-direction becomes 1173,847 kN. That is because, in the FBD method, seismic loads are designed based on building loads so that the seismic load on the 10th floor is smaller than the previous floor. Whereas in the DDBD method, seismic loads are designed based on displacement. The most significant design displacement is on the 10th floor, so the highest seismic load value is on the 10th floor [9].

3.3 Reinforcement ratio

Reinforcement requirements are calculated based on results of structural analysis using software with the FBD and DDBD methods, as shown below.

Table 2. Beam Reinforcement

Dir	As (mm²)		The ratio of As to FBD	
	FBD	DDBD	FBD	DDBD
x - x	2551,76	2551,76	1,00	1,00
y - y	3118,82	3402,34	1,00	1,09

Based on **Table 2**. Percentage of beam reinforcement in y-direction DDBD method is 0.09% greater than the FBD method. The reinforcement area with FBD method is 3118.82 $mm^{2,}$ and DDBD method is 3402.34 mm^2. Whereas in the x-direction, reinforcement area with the FBD and DDBD methods are same 2551.76 mm^2.

In the column structure element, the percentage of DDBD method reinforcement is also higher than the FBD method for columns K1, K2, and K3. The difference in the percentage of reinforcement column K1 in **Table 3**. is 0.09% with the area of reinforcement FBD method is 16725.84 $mm^{2,}$ and DDBD method is 18246.37 mm^2. Column reinforcement K2 method FBD is 13684.78 $mm^{2,}$ and DDBD method is 15205.31 mm^2 with a difference of 0.11%. Also, reinforcement of K3 column FBD method 10643.72 mm^2 and DDBD method 12164.25 mm^2 with a difference of 0.14%.

Table 3. Column Reinforcement

Type	Load	As (mm²)	The ratio of As to FBD
K1 (1000 x 1000)	FBD	16725,84	1,00
	DDBD	18246,37	1,09
K2 (900 x 900)	FBD	13684,78	1,00
	DDBD	15205,31	1,11
K3 (800 x 800)	FBD	10643,72	1,00
	DDBD	12164,25	1,14

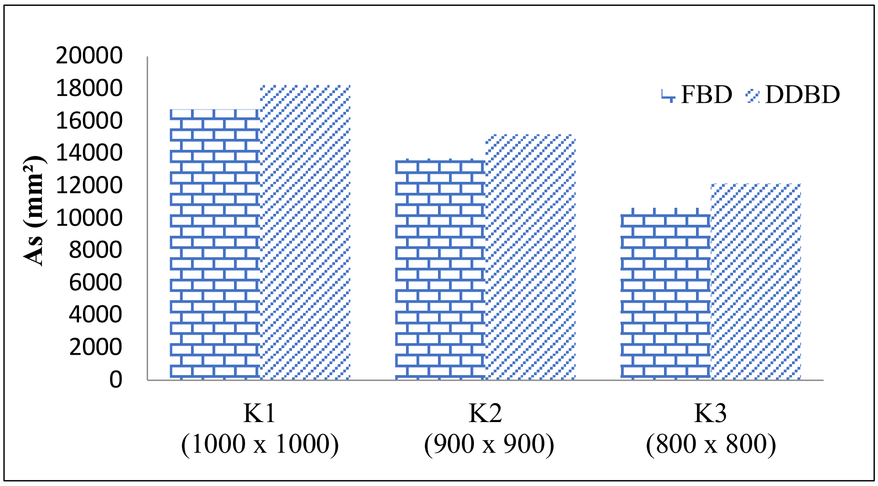


Figure 4. Diagram of Column Reinforcement

As for the shear wall reinforcement requirements, which are tabulated in **Table 4.** The DDBD method is 0.091% greater than the FBD method. The area of reinforcement by the FBD method is 21598,449 $mm^{2,}$ and the DDBD method is 23561,945 mm^2.

Tabel 4. Shear Wall Reinforcement

Load	As (mm2)	The ratio of As to FBD
FBD	21598.449	1,000
DDBD	23561.945	1,091

Overall, the structural reinforcement with the DDBD method is more because, in its design, base shear force of the DDBD method is higher than the FBD method, so the moments that occur in the DDBD method structure planning are of greater value than the FBD method[10].

3.4 Structure Performance

Determination of the performance level of the dual system building structure by the FBD and DDBD methods is tabulated in **Table 5.**

Table 5. Performance Level

Dir	Parameter	Result of Pushover Analysis			
		FEMA -356		FEMA -440	
		FBD	DDBD	FBD	DDBD
x-x	Performance Point, Δm (m)	0,4167	0,4202	0,4387	0,4431
	Drift Actual (Δm/Ttot)	0,0104	0,0105	0,0110	0,0111
	Level (ATC – 40)	Damage Control	Damage Control	Damage Control	Damage Control
y-y	Performance Point, Δm (m)	0,5043	0,5184	0,4886	0,4906
	Drift Actual (Δm/Ttot)	0,0126	0,0130	0,0122	0,0123
	Level (ATC – 40)	Damage Control	Damage Control	Damage Control	Damage Control

Based on **Table 5.** it can be seen that each direction in the FEMA - 356 (displacement coefficient) method and FEMA - 440 (equivalent linearization) produces performance point value of FBD method as a whole at the level of damage control performance[11]-[12]. The performance level, according to ATC - 40, 1996 is a transition between Immediate Occupancy and Life Safety [13]. Buildings are still able to withstand earthquakes that occur with minimal risk of casualties[14].

For the performance level of DDBD method, the overall performance point value is also at the damage control. The value of the performance point has not yet reached the target level of design performance, namely life safety, but is at a safer level than the design level [15].

4. CONCLUSION

Based on the analysis and discussion in the previous, conclusions can be drawn, including:

1. The base shear force of the DDBD and FBD methods is close to the difference of 17.57% for the x-direction and 9.38% for the y-direction.
2. The reinforcement ratio of the DDBD method is more than the FBD method, with a small difference.
3. The difference between performance points between FBD and DDBD is minimal. Overall both are at the same level of performance, namely damage control so that the structure meets the building level performance requirements for offices.
4. Structural planning in this study for the same level of performance results, the DDBD method is more wasteful compared to the FBD method seen from the calculation of reinforcement needs.

5. ACKNOWLEDGEMENT

The authors would like to thank the P3M of Politeknik Negeri Jakarta for the fund provided by the BTAM program

6. REFERENCES

[1] Baehaki, Soelarso, and N. Fitria, "Analisis Perilaku Struktur Pada Sistem Ganda Apartemen 9 Lantai Menggunakan Metode Time History Analysis Sesuai Peraturan SNI 1726 : 2012," *J. Fondasi*, vol. 7, no. 1, 2018.

[2] A. H. Luih, K. Agusta, I. Muljati, and B. Lumantarna, "Evaluasi Kinerja Direct-Displacement Based Design Pada Perencanaan Bangunan Dengan Ketidakberaturan Tingkat Lunak," pp. 1–7, 2012.

[3] F. Perdana and Faimun, "Final Project (Rc14-1501) Application Of Direct Displacement Based Design For Dual System Building" 2015.

[4] E. Adel, Z. AbdelHamd, and E. Ahmed, "Comparison between Force Based Design and Direct Displacement Based Design for Reinforced Concrete Frame or Walled Structures," *Second Eur. Conf. Earthq. Enginering Seismol.*, 2014.

[5] N. Rianto and E. Leo, "Perencanaan Struktur Dengan Metode Ddbd Beserta Tingkat Kinerjanya Dan Idealisasinya Terhadap SNI 1726 : 2012," *J. Mirta Tek. Sipil*, vol. 1, no. 1, pp. 139–148, 2018.

[6] Tavio and U. Wijaya, *Desain Rekayasa Gempa Berbasis Kinerja (Performance Based Design)*, 2nd ed. Yogyakarta: ANDI, 2018.

[7] G. M. Calvi, M. J. N. Priestley, and M. J. Kowalsky, "Displacement-Based Seismic Design of Structures," 2007.

[8] S. Pangemanan and H. G. Mantiri, "Analisis Pushover Perilaku Seismik Struktur Bangunan Bertingkat : Studi Kasus Bangunan Ruko," *Pros. Simp. II*, vol. 40, no. September, pp. 978–979, 2017.

[9] R. Parulian Purba, Z. Djauhari, and R. Suryanita, "Kinerja Struktur Gedung Beraturan Dual System (Concrete Frame-Rc Wall Structures) Menggunakan Metode Direct Displacement Based Design Dan Capacity Spectrum Method," *Jom FTEKNIK*, vol. 3, no. 2, p. 1, 2016.

[10] F. Asisi, K. Willyanto, and I. Muljati, "Perbandingan Kinerja Bangunan Yang Didesain Dengan Force-Based Design Dan Direct Displacement-Based Design Menggunakan Sni Gempa 2012," *J. Dimens. Pratama Tek. Sipil*, vol. 4, no. 1, pp. 1–8, 2015.

[11] "Prestandard And Commentary For The Seismic Rehabilitation Of Buildings," *FEMA 356*, 2000.

[12] "Improvement Of Nonlinear Static Seismic Analysis Procedures," *FEMA 440*, 2005.

[13] ATC-40, *Seismic Evaluation and Retrofit of Concrete Buildings*. California, 1996.

[14] A. Y. Prakosa and A. Wibowo, "Desain Rekayasa Gempa Berbasis Kinerja Dengan Metode Direct Displacement Based Design (DDBD) (Performance Based Seismic Design using Direct-Displacement Method)," pp. 1–9, 2018.

[15] A. Alfianto, "Pemikul Momen Khusus Performance Based Design Dengan Pembebanan Gempa Menggunakan Sni 03-1726-20Xx Dan Beban."