The Effect of Shear Wall Configuration on Seismic Performance in the Hotel Building

by Cindrawaty Lesmana

MATEC Web of Conferences **159**, 02074 (2018) https://doi.org/10.1051/matecconf/201815902074
IJCAET & ISAMPE 2017

The Effect of Shear Wall Configuration on Seismic Performance in the Hotel Building

Daud Rahmat Wiyono[1,a], Roi Milyardi[1] and Cindrawaty Lesmana[1]

[1]*Department of Civil Engineering, Universitas Kristen Maranatha, 40164 Bandung, Indonesia*

Abstract. Earthquake effects on the buildings must be evaluated within the current standard provision. The shape of building gives a unique seismic performance on the structure. In typical hotel building, the lobby area in the first floor usually has some slender columns due to the needs of higher clearance to give a widely space area. The slender columns in the big hall tends to create asymmetric building and torsional behaviour on seismic performance. This behaviour is one of the most frequent source of structural damage and failure. One of the solution is to add shear wall in elevator area. The purpose of this paper is to seek the effect of shear wall configuration in elevator area on the seismic performance through numerical analysis. There are some requirements for structural analysis under seismic load, such as: time period, modal analysis, story drift, and other details. In building with dual system, story shear in frame at each level must carry over 25 % of total story shear at that level. In this study, an eleven-storey hotel building located in Tanjung Pinang City, Indonesia was evaluated due to gravity and seismic load. For the building, the requirements of the time period from the standard are 1.21 sec (minimum) and 1.70 sec (maximum). As results, two-sided shear wall in X direction and two-sided shear wall in Y direction is recommended because it has the best seismic performance, time period below the minimum, story drift below allowable, the dynamic lateral load has meet minimum requirement (85% Static Load), and frame structure has carry more than 25% lateral load in dual system building.

1 Introduction

The earthquake resistant buildings design codes help the designer to improve the behaviour of structures to withstand the earthquake effects without significant loss. Seismic load on the building must be evaluated within the unique standard provision that particular to the country. The shape of building gives a unique seismic performance on the structure. In public buildings, such as: hotel, mall, apartment, the needs of higher clearance in the entrance are common to be found to give a widely space area sensation for the user. This widely space usually includes several slender columns in the lobby area at the first floor. The slender columns in the big hall tends to create asymmetric building and torsional behaviour on seismic performance. This behaviour is one of the most frequent source of structural damage and failure [1]. One of the solution is to add shear wall in elevator area. The configuration of shear wall must be analysed in accordance some requirements for structural analysis under seismic load in earthquake resistant buildings design code, such as: time period, modal analysis,

[a] Corresponding author: daud.rw@eng.maranatha.edu; hwiesiong1@gmail.com

story drift and dynamic lateral force must be larger than 85% static lateral force. In dual system, story shear in frame at each level must carry over 25 % of total story shear at that level. In this paper, the hotel building is analysed based on the requirements for structural analysis under seismic load that referred to Indonesian earthquake resistant buildings design code (SNI 1726:2012).

2 Seismic Calculation

The seismic load was calculated based on Indonesian earthquake resistant buildings design code, SNI 1726:2012, The requirements for structural analysis under seismic load included time period, modal analysis, story drift, dynamic lateral force that must be larger than 85% static lateral force ($V_d \leq 85\% V_s$) in dynamic analysis, and story shear in frame at each level must carry over 25 % of total story shear at that level in dual system [2].

The time period of the building must be met the requirement on SNI 1726:2012 Section 7.8.2. The minimum time period ($T_{a\ min}$) can be calculated as:

$$T_{a\ min} = C_t \,.\, h_n^{\ x} \quad (1)$$

where h_n is the height of building, C_t and x is period parameter based on building system (for dual system: $C_t = 0.0488$ and $x = 0.75$).
The time period should less than:

$$T_{a\ max} = C_u \,.\, T_{a\ min} \quad (2)$$

where $T_{a\ max}$ is the maximum time period, and C_u is maximum period parameter based on SNI 1726:2012.

The modal results of the building must be met the requirement of SNI 1726:2012 Section 7.7.3., which the first mode and the second mode are not allowed to control by rotation, hence, the modes should be in two directions of the orthogonal floor plan. The rotation control is allowed for the third mode and so on.

The story drift of the building should meet the requirement on SNI 1726:2012 Section 7.8.6. The story drift of the building (δ_x) is defined as a difference of deflection in floor centre mass in each level, which should be met as follows:

$$\delta_x = \frac{C_d \times \delta_{xe}}{I_e} \quad (3)$$

where C_d is amplification factor for deflection, δ_{xe} is deflection at center mass, and I_e is seismic importance factor based on building function.

The story drift maximum requirement (δ_a) for dual system and importance factor (I_e) = I or II is defined as follows:

$$\delta_a = 0.020\ h_{sx} \quad (4)$$

where h_{sx} is the story height.

In dynamic analysis, the minimum dynamic lateral force should be more that 85% of the static lateral force ($V_d \geq 0.85\ V_s$), which is specified on SNI 1726:2012 Section 7.9.4.1. Special requirement from SNI 1726:2012 Section 7.2.2 for dual system is the story shear from the frame elements at each level must carry over 25 % of total story shear at that level.

3 Detail of Buildings

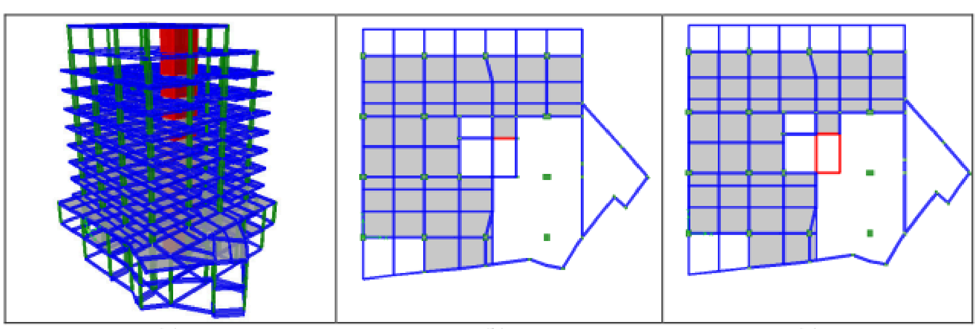
Eleven-storey Reinforced Concrete building is considered for the study. The function of the building is for hotel which located in Tanjung Pinang City, Indonesia. The structures are treated as a discrete system having lumped masses at each floor level. The loads considered on each floor are the permanent loads consisting of all the dead loads on each floor, weight of one-half of the columns and walls above and below the floor, and an appropriate portion of the live load that always act on the structure [3]. Geometrical detail of the building is illustrated in Fig. 1. In total, nine proposed configurations for the shear wall in elevator area are evaluated. Furthermore, the numerical simulation using ETABS [4] is created to obtain the seismic performance of the building.

Figure 1. Building plan.

The seismic load is included to the model based on the local provision standard [5] which the seismic coefficients for the Tanjung Pinang City are S_S=0.061 and S_1= 0.088. All the dimension of the structural elements meets the requirement on the ACI building code [6] and Indonesian Building Code for Reinforced Concrete Structure (SNI 2847:2013) [7]. In average, the column dimension were 400 mm x 600 mm to 600 mm x 800 mm and the beam dimension was 300 mm x 500 mm.

4 Analysis and Results

The analysis of the hotel buildings was carried out using ETABS. Fig. 2(a) shows the 3D model of the hotel building. Fig. 2(b) illustrated one of the configuration of the shear wall from the total of nine proposed evaluated configurations for the shear wall in elevator area. Fig. 2(c) showed the plan view of the best configuration of the shear wall.

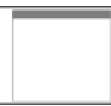
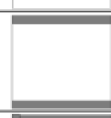
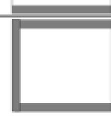
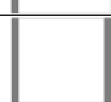
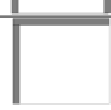
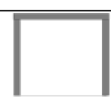
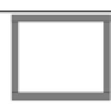


(a) (b) (c)

Figure 2. Hotel building model: (a) 3 d image (b) shearwall one sided X direction (c) shear wall two sided X and two sided Y direction.

There were 9 cases of different configuration of shear wall shown in Table 1. The minimum time period ($T_{a\ min}$) of building requirement was $T_{a\ min} = C_t \ . \ h_n^x$ = 0.0466 x 37.4$^{0.9}$ = 1.21 second and the maximum time period ($T_{a\ max}$) of building was $T_{a\ max} = C_u \ . \ T_{a\ min}$ = 1.61 x 1.21 = 1.95 second. In the result, two-sided shear wall in X direction and two-sided shear wall in Y direction was satisfied the period requirement and direction control from the early mode which the configuration has translational direction control in first and second mode.

Table 1. Time period and direction of mode in some configuration shear wall placement.

No.	**Case**		**Period***	**Direction in Mode 1, 2, and 3 respectively**
1	No Shear wall		1.76	Translational Y, Rotational Z, Translational X
2	One Sided Shear wall in X-Direction		1.74	Translational Y, Rotational Z, Translational X
3	Two Sided Shear wall in X-Direction		1.72	Translational Y, Rotational Z, Translational X
4	Two Sided Shear wall in X-Direction and one side in Y-Direction		1.6	Rotational Z, Translational X, Translational Y
5	One Sided Shear wall in Y-Direction		1.13	Rotational Z, Translational X, Translational Y
6	Two Sided Shear wall in Y-Direction		1.66	Rotational Z, Translational X, Translational Y
7	One Sided Shear wall in X-Direction and one sided in Y-Direction		1.64	Rotational Z, Translational X, Translational Y
8	Two Sided Shear wall in Y-Direction and one sided in X-Direction		1.65	Rotational Z, Translational X, Translational Y
9	Two Sided Shear wall in X-Direction and Two Sided Shear wall in Y-Direction		1.63	Translational Y, Translational X, Rotational Z

Note: * maximum period

Furthermore, the dynamic lateral force was analyzed only on building model in case 9 which had meet all requirements of the time period and mode direction control. Both lateral force in X-direction (Fig. 2) and lateral force in Y-direction met the dynamic lateral force requirement ($V_d \geq 0.85. V_s$). The maximum story drift for the building model in case 9 was 13.23 mm (X-direction) and 18.11 mm (Y-direction) which satisfied the requirement of the allowable story drift 76 mm in the top story as shown in Table 2.

Table 2. Story Drift Analysis for building model case 9.

Storey	Story	X Direction	Y Direction

	Height (mm)	Story Drift δ_x (mm)	Allowable Story Drift δ_a (mm)	$\delta_x < \delta_a$	Story Drift δ_y (mm)	Allowable Story Drift δ_a (mm)	$\delta_x < \delta_a$
Story 11	3800	13.23	76	OK	18.11	76	OK
Story 10	3200	9.48	64	OK	4.97	64	OK
Story 9	3200	10.41	64	OK	7.39	64	OK
Story 8	3200	10.96	64	OK	9.80	64	OK
Story 7	3200	11.37	64	OK	10.57	64	OK
Story 6	3200	11.49	64	OK	10.94	64	OK
Story 5	3200	11.14	64	OK	10.94	64	OK
Story 4	3200	10.25	64	OK	11.08	64	OK
Story 3	3200	8.63	64	OK	9.55	64	OK
Story 2	4000	6.91	80	OK	7.74	80	OK
Story 1	4000	0	80	OK	0	80	OK

In Table 3, the story shear for frame and shear wall elements were presented. From the standard, frame at each level has to carry over 25 % of total lateral force in each level. The results showed 49.76% story shear in X-direction and 31.57% story shear in Y-direction were carried out by the frame that met the requirement for dual system building.

Table 3. Dual System Base Shear Analysis for building model case 9.

Spectrum Response	X-Direction		Y-Direction	
	Frame	Shear Wall	Frame	Shear Wall
Reaction Force (Kg)	8502.68	8584.18	3352.14	7265.80
Total Force (Kg)	17086.86		10617.94	
Percentage (%)	49.76%	50.24%	31.57%	68.43%

Lateral force in X-direction taken 50,24% by shear wall and distributed in each level that show in Fig. 3. In Y-direction, 68.43% lateral force taken and distributed in each level by shear wall (Fig. 4). Both figures show that frame can resist 25% shear force at each level. Fig. 5 and Fig. 6 present the comparison of lateral force that taken by frame system in hotel building have compared by different lateral load, 25% earthquake lateral load and 100% earthquake lateral load in each direction. The lateral force that taken by frame system in 25% earthquake lateral load is smaller than lateral force that taken in 100% of combination of the dual system earthquake lateral force in each direction. So, the lateral force taken by frame system with 100% earthquake lateral load of the dual system is used for further load design concrete reinforcement.

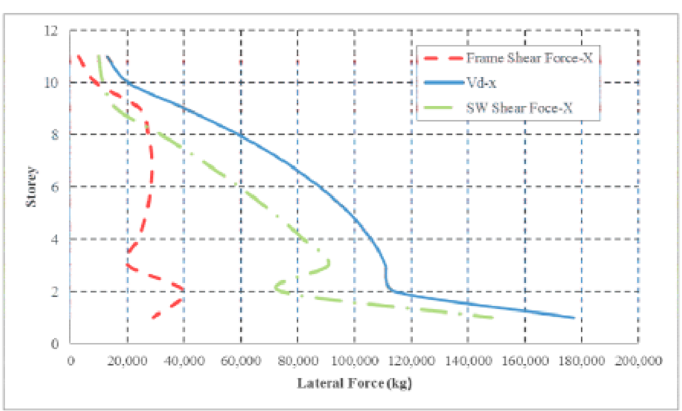


Figure 3. Dual system lateral force analysis in X-direction for building model case 9.

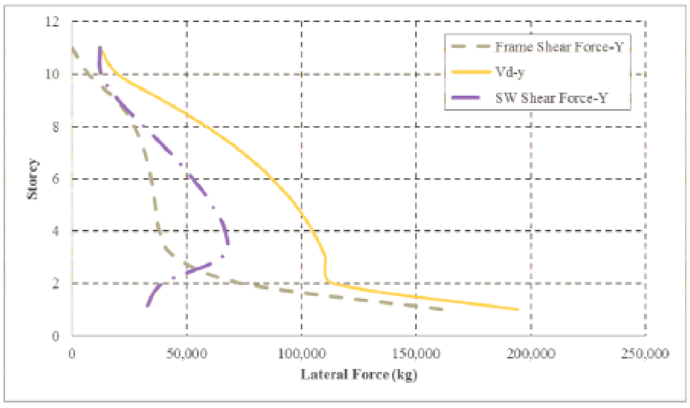


Figure 4. Dual system lateral force analysis in Y-direction for building model case 9.

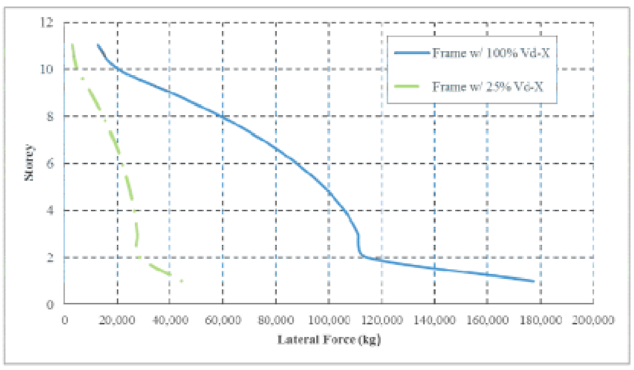


Figure 5. Comparison 25% to 100% Vd that taken by frame system in X-Direction for building model case 9.

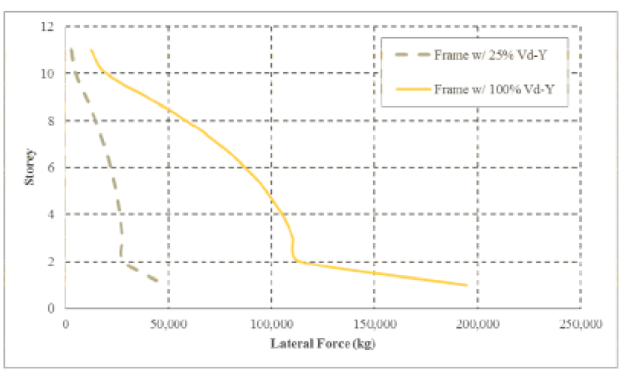


Figure 6. Comparison 25% to 100% Vd that taken by frame system in Y-direction for building model case 9.

5 Conclusion

Two-sided shear wall in X direction and two-sided shear wall in Y direction is recommended because it has the best seismic performance, time period below the minimum, story drift can be accepted, the dynamic lateral load has met minimum requirement (85% Static Load), and frame structure has carry more than 25% lateral load in dual system building.

References

[1] S. G. Maske and D. P. S. Pajgade, *Torsional Behaviour of Asymmetrical Buildings*. Int. J. Mod. Eng. Res., **3**(2), 1146–1149 (2013)
[2] P. W. Somers, Reinforced Concrete, *FEMA P-752 CD, NEHRP*, (2009)
[3] A. S. C. E. Institute, Minimum Design Loads for Buildings and Other Structures. *ASCE 7 – 05*, (2005)
[4] Computers and Structures Inc., Concrete Shearwall Design Manual. *CSI ETABS*, (University Avenue Berkeley, California, 2007)
[5] Badan Standarisasi Nasional, Tata cara perencanaan ketahanan gempa untuk struktur bangunan gedung dan non gedung. *SNI 1726:2012,* (Badan Standarisasi Nasional (BSN), Indonesia, 2012)
[6] PCI, Building Code of Requirements for Structural Concrete (ACI 318-08) and Commentary. *ACI 318-08*, (2008)
[7] Badan Standarisasi Nasional, "Persyaratan beton struktural untuk bangunan gedung. *SNI 2847:2013*, (Badan Standarisasi Nasional (BSN), Indonesia, 2013)

The Effect of Shear Wall Configuration on Seismic Performance in the Hotel Building

ORIGINALITY REPORT

11%	9%	9%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to University of Greenwich Student Paper	3%
2	lib.unnes.ac.id Internet Source	2%
3	Patrick Höschele, Stefan Smit, Ernst Tomasch, Martin Östling, Krystoffer Mroz, Corina Klug. "Generic Crash Pulses Representing Future Accident Scenarios of Highly Automated Vehicles", SAE International Journal of Transportation Safety, 2022 Publication	1%
4	www.proquest.com Internet Source	1%
5	www.iosrjen.org Internet Source	1%
6	eprints.ums.ac.id Internet Source	<1%
7	jurnal.ugj.ac.id Internet Source	<1%
8	jurnal.untan.ac.id Internet Source	<1%
9	www.gulfoodmanufacturing.com Internet Source	<1%
10	"Advances in Construction Management", Springer Science and Business Media LLC, 2025 Publication	<1%

11	Bungale S. Taranath. "Reinforced Concrete Design of Tall Buildings", CRC Press, 2019 Publication	<1%
12	Yang, W.M.. "A levitation force and magnetic field distribution measurement system in three dimensions", Physica C: Superconductivity and its applications, 20061001 Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		

The Effect of Shear Wall Configuration on Seismic Performance in the Hotel Building

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7