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The effect of shear wall location in resisting earthquake

J Tarigan*[1], J Manggala[1], T Sitorus[1]

[1]Department of Civil Engineering, Faculty of Engineering, Universitas Sumatera Utara

*Email: johannes.tarigan@usu.ac.id

Abstract. Shear wall is one of lateral resisting structure which is used commonly. Shear wall gives high stiffness to the structure so as the structure will be stable. Applying shear wall can effectively reduce the displacement and story-drift of the structure. This will reduce the destruction comes from lateral loads such as an earthquake. Earlier studies showed that shear wall gives different performance based on its position in structures. In this paper, seismic analysis has been performed using response spectrum method for different Model of structures; they are the open frame, the shear wall at core symmetrically, the shear wall at periphery symmetrically, and the shear wall at periphery asymmetrically. The results are observed by comparing the displacement and story-drift. Based on the analysis, the placement of shear wall at the core of structure symmetrically gives the best performance to reduce the displacement and story-drift. It can reduce the displacement up to 61.16% (X-dir) and 70.60% (Y-dir). The placement of shear wall at periphery symmetrically will reduce the displacement up to 53.85% (X-dir) and 47.87% (Y-dir) while the placement of shear wall at periphery asymmetrically reducing the displacement up to 59.42% (X-dir) and 66.99% (Y-dir).

1. Introduction

RC multi-story buildings are designed for resisting both the vertical and horizontal load. A taller structure will undergo the greater lateral load. Every structural Engineer is met with the problem of giving sufficient strength and stability of these tall buildings against lateral load thus the effect of lateral loads like wind load, earthquake load and blast forces are attaining escalating importance. One of the solution to give better stability for the structure is the utilization of shear wall [1].

Shear wall is one of the most commonly used lateral load resisting systems in buildings. Shear wall has high plane stiffness and strength which can be simultaneously resist large horizontal loads and support gravity loads, which significantly reduces the lateral sway of the building and thereby reduces damage to structures and its contents. When the shear wall is strong enough, it will transfer the horizontal load to the next element in the load path below them such as floors, other shear walls, slabs or footings. Shear wall also provides lateral stiffness to prevent the roof or floor above from large lateral sway. When shear wall is stiff enough, they will prevent floor and roof from moving off their supports. Also, buildings that are sufficiently stiff will usually suffer less non structural damage.

Since shear wall carry large horizontal earthquake forces, the overturning effects on it is large. Shear wall in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings. When shear wall are placed in advantageous positions in the building, they can form an efficient lateral force resisting system by reducing lateral displacements under earthquake loads. Therefore it is very necessary to determine effective, efficient and ideal location of shear wall.

Tuppad and Fernandes [2] presented a study of the effect of shear wall placement in the 10-story RC structure at 6 alternative placement. The structure located in India at earthquake zone V. Analysis of earthquake using static equivalent method by ETABS 2015. It is found that the story displacement of the structure without shear wall shows maximum displacement compared to the other Model having shear wall. Placing shear wall near the core of the building was the best location to reduce the story displacement. It also found that by providing shear wall to the high rise building, structural behavior will be affected to a great extent and also the stiffness and the strength of the building will be increased.

Agrawal and Charkha [3] considered 5 different Models of shear wall in 25-story building in India at seismic zone V. Building consists of 7 bays of 7.5M in X- direction and 5 bays of 6.5 M in Y-direction. Earthquake loading calculated using ETABS and applied to the mass centre of the structure. By the results, it is clear that by shifting the shear wall location gave the significant effect on deflection. It is observed that placing shear wall away from centre of gravity resulted in increase in most of the member forces. With the increase in eccentricity, the building shows non-uniform movement of right and left edges of roof due to torsion and induces excessive moment and forces in member.

Based on the studies above, this paper discussed the effect of shear wall location in 4-story building in Pekanbaru. It will analyze 4 Models of structure by shifting the location of shear wall. The objectives of this study is to analyze the effect of shear wall to the structure and find the optimum location of shear wall to reduce the lateral displacement of structure. The result will be displayed in term of natural period, displacement, and story-drift.

2. Modelling and method

For the analysis purpose, the Model of RC structure (G+4) story and 79.85 m x19.85 m plan area has selected which is located in Pekanbaru. The ground to the (G+3) story height is 4 m and the roof height is 9 m. The grade of the concrete used is M20 and for the structural steel is Fe 400. Building description is shown in Table 1.

Table 1. Building description

Particular	RC Structure
Number of Story	G+4
Height	3 m (Ground to G+3) 9 m (G+4)
Grade of Concrete	M20
Grade of Steel	Fe 400
Shear Wall Thickness	0.3 m
Seismic Design Category	D (as per SNI 1726:2012)
Type of Soil	Medium Soil
Importance Factor, I_e	1.25

Structure Model can be seen in Figure 1. Model 1 is RC structure without shear wall. Shear wall the added to the structure in various location as shown in Figure 2. In Model 2, shear wall located near the core of the structure symmetrically, for Model 3 shear wall located at the peripheral of the structure symmetrically and for Model 4 shear wall located at outer location of structure asymmetrically.

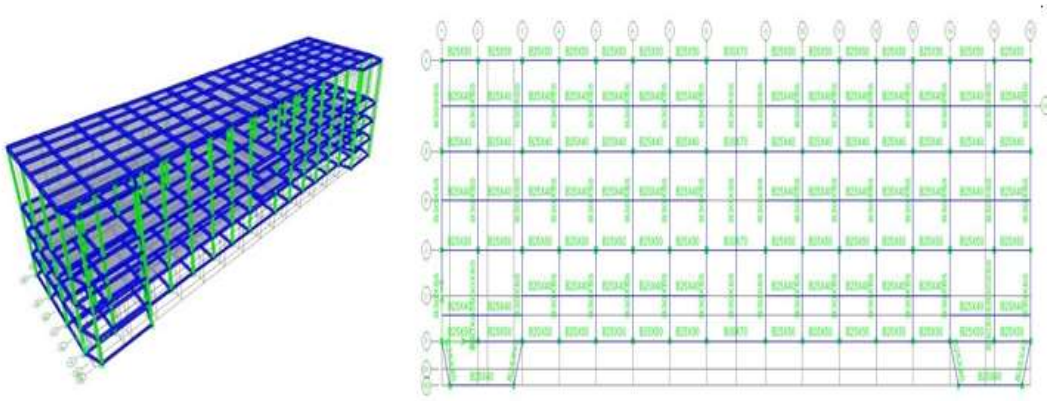

Figure 1. Structure Model 1 (without shear wall)

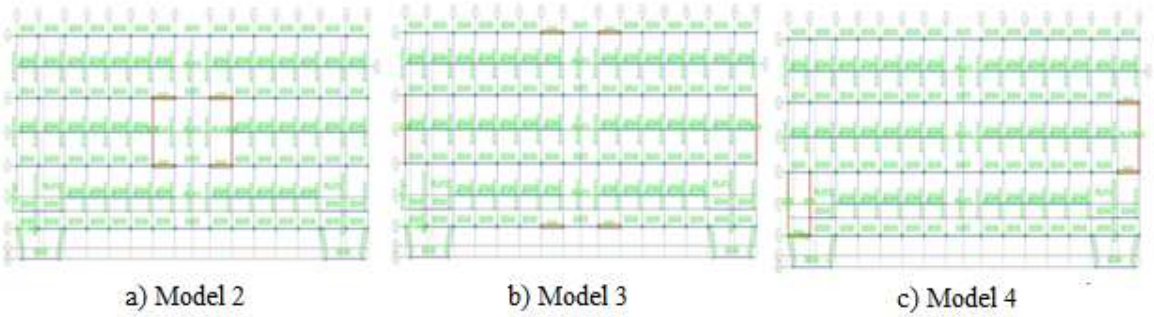

Figure 2. Structures with shear wall; a) Model 2 structure (shear wall at core symmetrically), b) Model 3 structure (shear wall at peripheral symmetrically), and c) Model 4 structure (Shear wall at peripheral asymmetrically)

2.1 Lateral loading

Lateral loading consist of earthquake loading which has been calculated by program and using the response spectrum analysis. Earthquake analysis completed by using the rules in code SNI 1726: 2012 (based of IBC 2009) [4, 5, 6]. By inputted the spectral response curve, program will calculate the earthquake load. For Pekanbaru, the value of acceleration response, S_s = 0.435 and S_1 = 0.273, then the spectral response curve can be seen in Figure 3.

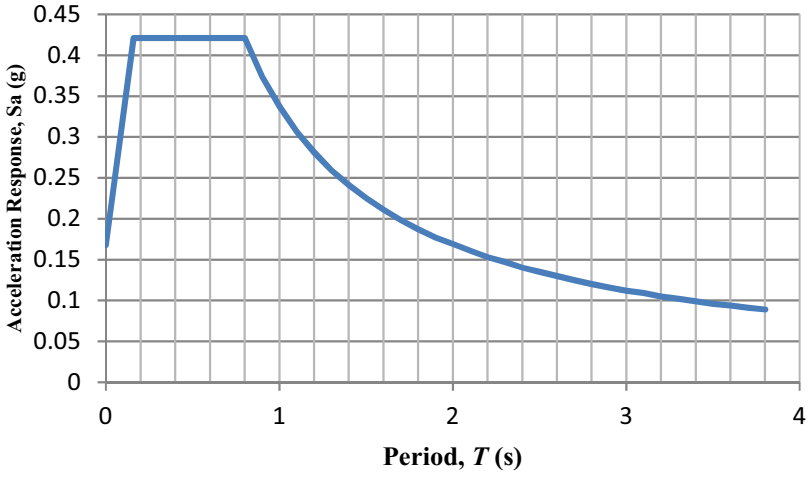

Figure 3. Spectral response design for Pekanbaru

3. Results and discussion

Result obtained from the analysis are recorded in tabular and graphic form for the 4 Model of structures for comparison of maximum natural period, displacement, and story-drift.

3.1 Maximum natural period

The natural period of all Model structures as shown in Table 2.

Table 2. Natural period of structures

Model	Tmax	Reduction Percentage (%)
1	1.690	-
2	0.669	60.41
3	0.751	55.55
4	0.694	58.90

It has been found that the maximum natural period is in Model 1 structure without shear wall. Shear wall gives high stiffness to the structure that can reduce the period of structure. It has been found that the Model 2, Model 3, and Model 4 shows the shorter natural period of structures compared to the Model 1. Model 2 shows the shortest period among the other Models.

3.2 Displacement

Lateral displacement of all Model structures as shown in Table 3 and Figure 4.

Table 3. Lateral displacement of structures

Story	X-Direction				Y-Direction			
	Model 1 mm	Model 2 mm	Model 3 mm	Model 4 mm	Model 1 mm	Model 2 mm	Model 3 mm	Model 4 mm
Roof	229.68	89.2	106	93.2	221.76	65.2	115.6	73.2
Story 3	113.96	44.8	49.6	46	103.84	32.8	54.4	42
Story 2	79.64	26	27.2	26.4	72.6	19.6	30.8	26.8
Story 1	35.2	9.6	9.2	9.6	32.56	7.6	11.2	11.2

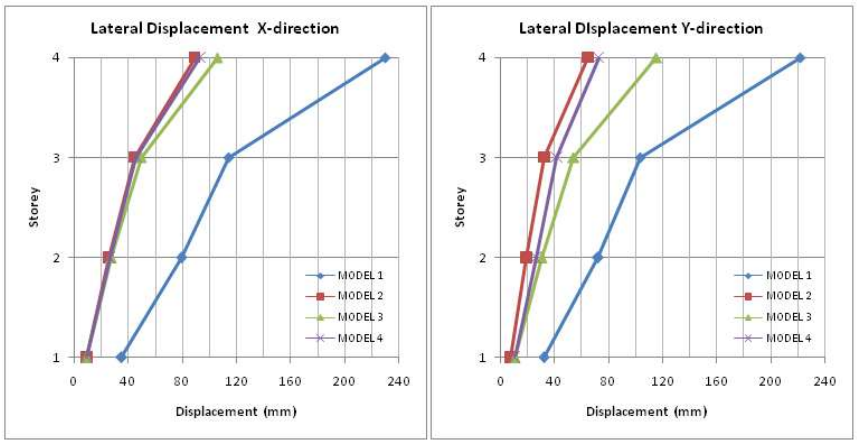

Figure 4. Comparison of displacement structures

From the above results it can be observed that the maximum displacement occurred in Model 1 structures. Shear wall can reduces lateral displacement of structures as it can see in Model that uses shear wall. The maximum reduction of displacement is obtained for Model 2 structure.

3.3 Story-drift

Story-drift of all Model structures as shown in Table 4.

Table 4. Story-drift of structures

Story	X-Direction				Y-Direction				Allowable Drift
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	
	mm	mm	mm	mm	mm	mm	mm	mm	mm
Roof	115.72	44.4	56.4	47.2	117.92	32.4	61.2	31.2	103.85
Story 3	34.32	18.8	22.4	19.6	31.24	13.2	23.6	15.2	46.15
Story 2	44.44	16.4	18	16.8	40.04	12	19.6	15.6	46.15
Story 1	35.2	9.6	9.2	9.6	32.56	7.6	11.2	11.2	46.15

From the above result it can be found that the maximum story-drift occurred in Model 1 structure. It is found that the drift in the roof even higher than the allowable drift which is permitted by SNI 1726:2012 (Figure 5). Utilization of shear wall reduces story-drift below the allowable drift. It is found that Model 2 structure gives the optimum performance to reduce the story-drift.

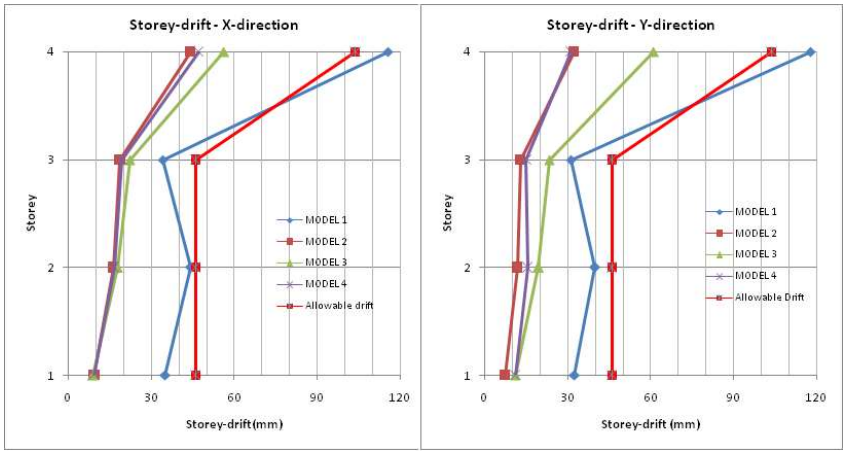

Figure 5. Comparison of story-drift structures

4. Conclusions

Based on this study, it has been observed that the utilization of shear wall can contribute in increasing stiffness of structure. It reduces the natural period of structure, lateral displacement and story-drift significantly. Position of shear wall need to be considered carefully because it gives difference performance to resisting earthquake load. In this investigation, it is found that the optimum location for the structure is Model 2 structure (shear wall at the core symmetrically).

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