Seismic Response of Reinforced Concrete Building with Shear Wall

Agus, Taufik Hidayat

Civil Engineering Department, Padang Institute of Technology, Padang, Indonesia
agus@itp.ac.id

Abstract: *Preventing a collapse on the structure of a building has currently been done in a massive effort, particularly in an area with a high intensity of a seismic phenomenon. Theoretically, installing shear walls to the building is one of the prevention efforts toward the structural collapse. Therefore, this study focuses on finding and comparing the seismic response between a reinforced concrete building with and without shear walls. SAP 2000 V14 software with an earthquake load response spectrum by Indonesian SNI-03-1726-2012 standard was employed to run an analysis over those two different buildings. As result, the building with shear wall is significantly able to reduce displacement (drift level) and drift (deviation between levels) so that they do not surpass the required limit performance. In addition, it is also found that the reinforced concrete building with a long plan with shear walls on the edge of the building frame is the most effective effort to prevent the structural collapse; however, it requires a more efficient reinforcement area compared to the building with shear walls on the center side of the building frame and without any shear wall installation.*

Keywords: shear wall, displacement, drift.

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1. Introduction

Nowadays, many prevention efforts toward the structural collapse on a building in a high-earthquake intensity area have been carried out intensively. The efforts are initially done by planning the construction of the building thoroughly and cautiously.The structure system in a building construction covers of a gravity load resist system and a lateral load resist system. A thorough and cautious plan of building construction is made by making prediction over the seismic load in order to build a building that endures the load during the earthquake. One of the solutions to improve building endurance toward earthquake is by installing the shear walls. As Verma S.K.(2014) found in his research that the shear wall installation had successfully reduced deviation between the drift and he also found that the average displacement and installing the shear wall on the inside of the frame was the most effective way. Moreover, another research found that the configuration of the straight-shaped shear wall performed much better than the L (L-Shape) or T (T-Shape) shapes since it created a better displacement and a minimum time period. In addition structural collapse was effectively reduced in any forms of shear wall configurations (Anjali B U, 2017).

The research was aimed to investigate a seismic response of reinforced concrete (RC) building structures using shear walls in several variations compared to the one without shear walls. In addition, investigation

was also focused on comparing the response of various models of reinforced concrete building structures without and with shear walls toward earthquake loads and on analyzing the effectiveness of using shear walls.

2. Literature Review

Stiffness and strength are special feature of the structure related to the level of building services due to earthquakes. Many countries have always improved their seismic standards. In Indonesia, the standard that sets the criteria for planning earthquake resistant buildings is SNI-03-1726-2012.

A building resistance to earthquake depends on the maximum of endurable limit of the building's displacement and the maximum inter-level; therefore, it is important to determine the endurable limit of the building if the earthquake strikes in the construction plan in order to avoid casualties due to the building's collapse.

The displacement limit between levels according to SNI-03-1726 - 2012 article 8 is as follows:

➢ It must not exceed higher than R 0.03 (or 30 mm) of the maximum level, depending on which value is the smallest.

➢ It must not exceed higher than 0.02 times of the maximum level.

SNI-03-1726-2012 arranges classification of an irregular and irregular building, structural ductility, nominal earthquake mitigation, earthquake areas in Indonesia along with earthquake spectrum response in each area, building structure performance, and et cetera.

A concrete structure with open framed reinforcement consists of columns and beams combined with moment-resistant joints. The lateral stiffness of the rigid portal depends on the flexural stiffness of its column, beam and joints. The shear walls are generally joined by portals in reinforced concrete structures with shear walls. A shear wall functions as a stiffener in order to continuously reinforce the building foundation and as a core wall to sustain all buildings designed to endure shear forces and lateral forces due to earthquakes. Shear walls are generally rigid; consequently, the horizontal deformation becomes small (Agus, 2015).

3. Methodology

The building structure used was a 3-story building structure model with a height of 10.81 meters and with a building area of 1042 m². The building is residential (dormitory) building and this building is located in Payakumbuh, Indonesia. The following were some structural data used in modeling the structure of the building.

Column size K1, K3 = 30/40 cm   Column size K2 = 30/30 cm

Beam size B1, B2, B3, B4 = 25/40 cm   Beam size B5 = 30/50 cm

Plate thickness = 13 cm   Shear wall thickness = 25 cm

Concrete quality = K350   Steel Quality = 400 MPa

The analysis was based on Indonesian standard of SNI 03-1726-2012; Planning Procedures for Earthquake Resistance for Buildings and Non-Buildings, and SNI -03-2847-2002: Procedures for Calculating Concrete Structures for Buildings.

The SAP 2000 V 14 program was employed to build the building model referred to the drawing schema so that it represented the real condition in the field. Modeling was made in the form of 3-dimensional figures in order to obtain the best result.

The dead load (DL), additional dead load (SDL), live load (LL), lateral earthquake load (EL) were analyzed in reinforced concrete buildings. Each loading was labeled as a different load case with several loading combinations as set in the current standard. The earthquake load is in the form of a spectrum response according to the location of the building and the local soil condition.
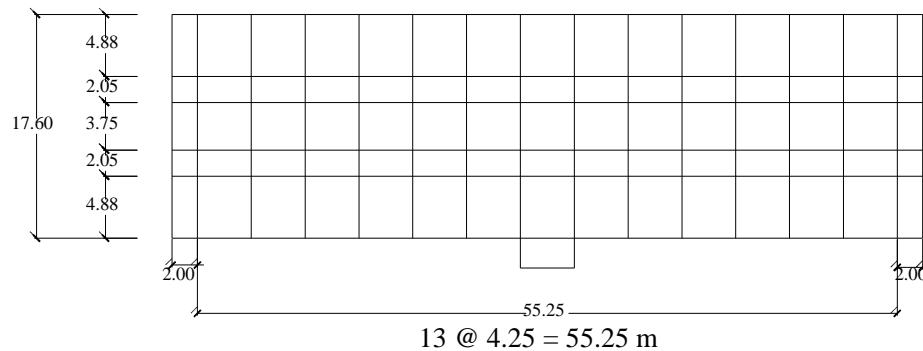

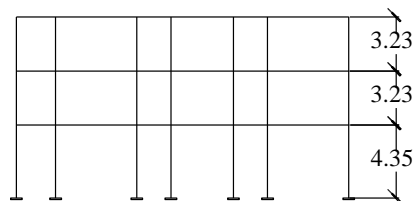Figure 1. Plan of the building without shear wall (model 1)
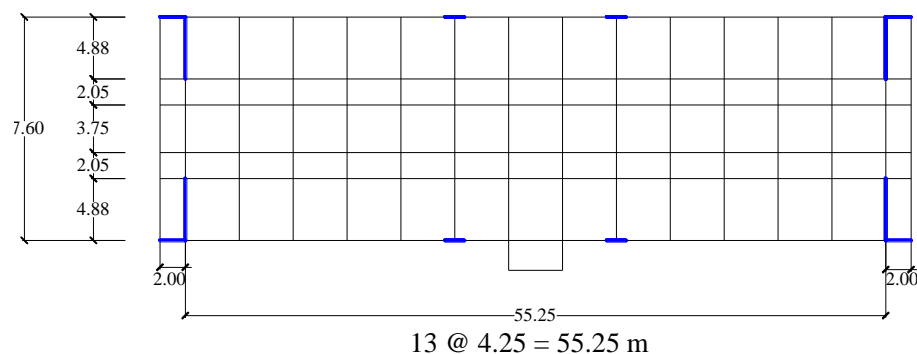

Figure 2. Cross section of the building

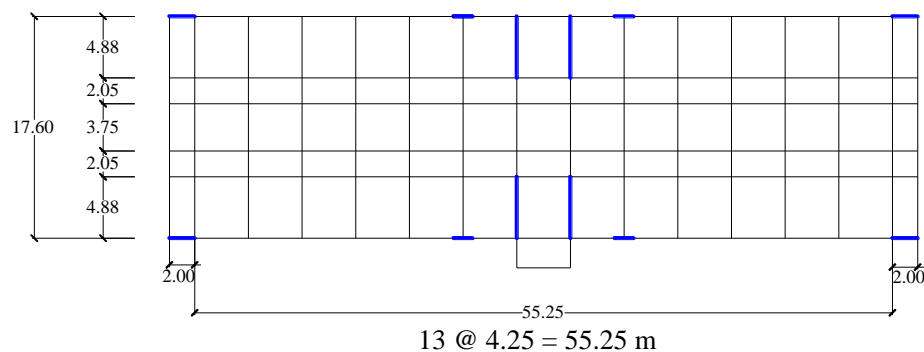Figure 3. Plan of the building with shear wall (model 2)

Figure 4. Plan of the building with shear wall (model 3)

4. Analysis and discussion

Natural vibration period

The fundamental natural vibration period and vibration pattern were analyzed. Article 5.6 of SNI-03-1726-2012 determines the limitation of the maximum value of fundamental natural vibration period in order to prevent building structures becoming too flexible and rotating. It is known that the rotation in the mode shape number one and two should occur. The following are the results of the analysis of the natural vibration period of each building model in the mode shape 1 and 2 in the form of tables and figures.

Table 1. Natural Vibration Period of the building

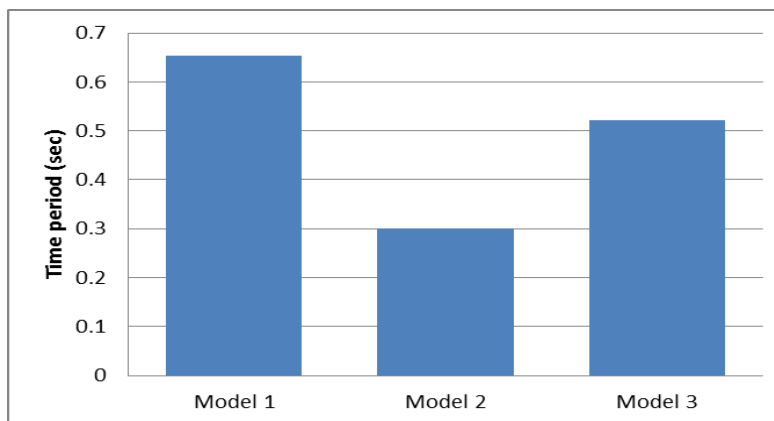| Model	Mode Shape	Period (Seconds)	remarks	The maximum fundamental natural vibration period based on SNI-176- 2012 Max (detik) (SNI-1726-2002)	Control
Model 1	1	0,6537	Rotation-X	$T < \zeta \times n$	Not Ok
	2	0,5524	Rotation-Y	$\zeta = 0.17$	Not Ok
Model 2	1	0,3012	Translation-X	$n = 3$ (number of floors)	Ok
	2	0,1558	Translation-Y	$T = 0.17 \times 3 = \mathbf{0.51}$	Ok
Model 3	1	0,5225	Rotation-X		Not Ok
	2	0,4649	Translation-Y		Ok

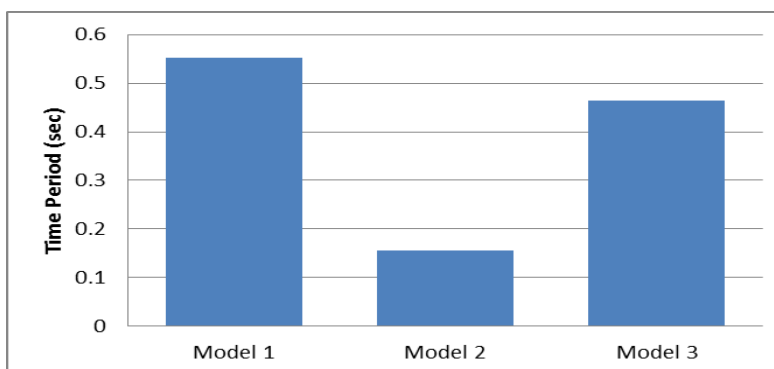Figure 5. Natural vibration period of mode shape 1

Figure 6. Natural vibration period of mode shape 2

Displacement

From the results of structural analysis, the analysis of the maximum displacement data of each structure can be defined in the following figures.
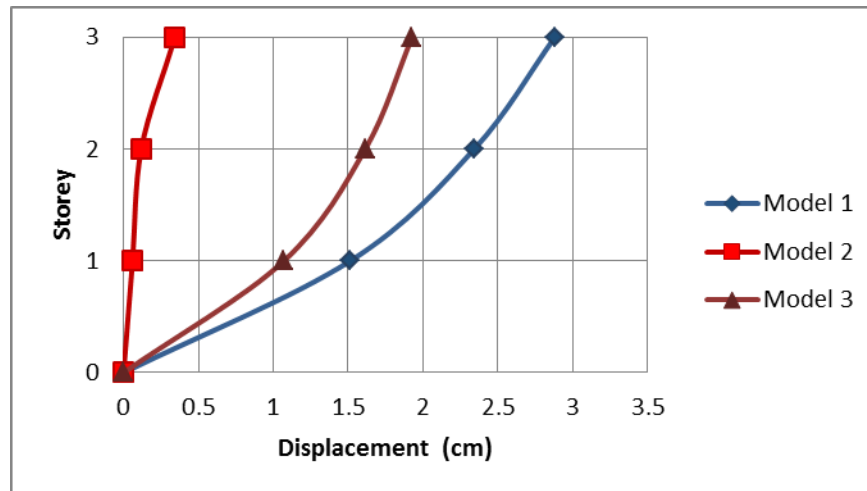

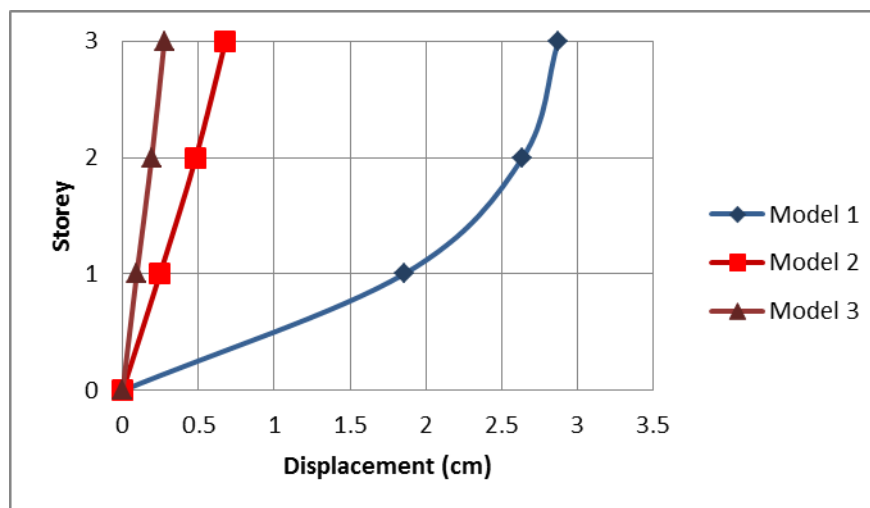Figure 7. Displacement of x direction (transverse)

Figure 8. Displacement of y direction (lengthwise)

Story Drift

The value of displacement between the building mass levels due to the earthquake in the direction of x and y based on SNI-03-1726-2012 can be seen in the following table.

Table 2 . Displacement among levels based SNI-03-1726-2012

Model-1.

Storey	Displacement x (m)	Height (m)	Drift - x (m)	Direction - x (m) $\Delta x = (Dx).Cd / Ie$	$\Delta a = 0,025\ H/\rho$	$\Delta x \leq \Delta a$
3	0,02880	3,23	0,00538	0,029590	0,06212	OK
2	0,02342	3,23	0,00827	0,045485	0,06212	OK
1	0,1515	4,35	0,01515	0,083325	0,08365	OK
	Displacement y	Height	Drift - y	Direction - y		

Storey	(m)	(m)	(m)	(m) $\Delta y = (Dy).Cd / Ie$	$\Delta a = 0,025\ H/\rho$	$\Delta y \leq \Delta a$
3	0,02873	3,23	0,00234	0,01287	0,06212	OK
2	0,02639	3,23	0,00783	0,043065	0,06212	OK
1	0,01856	4,35	0,01856	0,10208	0,08365	NOT OK

Model-2.

Storey	Displacement x (m)	Height (m)	Drift - x (m)	Direction - x (m) $\Delta x = (Dx).Cd / Ie$	$\Delta a = 0,025\ H/\rho$	$\Delta x \leq \Delta a$
3	0,00343	3,23	0,00225	0,01238	0,06212	OK
2	0,00118	3,23	0,00058	0,00319	0,06212	OK
1	0,00060	4,35	0,00060	0,00330	0,08365	OK

Storey	Displacement y (m)	Height (m)	Drift - y (m)	Direction - y (m) $\Delta y = (Dy).Cd / Ie$	$\Delta a = 0,025\ H/\rho$	$\Delta y \leq \Delta a$
3	0,00679	3,23	0,00196	0,01078	0,06212	OK
2	0,00483	3,23	0,00237	0,01304	0,06212	OK
1	0,00246	4,35	0,00246	0,01353	0,08365	OK

Model 3.

Storey	Displacement x (m)	Height (m)	Drift - x (m)	Direction - x (m) $\Delta x = (Dx).Cd / Ie$	$\Delta a = 0,025\ H/\rho$	$\Delta x \leq \Delta a$
3	0,01927	3,23	0,00313	0,017215	0,06212	OK
2	0,01614	3,23	0,00543	0,029865	0,06212	OK
1	0,01071	4,35	0,01071	0,058905	0,08365	OK

Storey	Displacement y (m)	Height (m)	Drift - y (m)	Direction - y (m) $\Delta y = (Dy).Cd / Ie$	$\Delta a = 0,025\ H/\rho$	$\Delta y \leq \Delta a$
3	0,00275	3,23	0,00083	0,004565	0,06212	OK
2	0,00192	3,23	0,00099	0,005445	0,06212	OK
1	0,00093	4,35	0,00093	0,005115	0,08365	OK

As presented in the table above, the displacement value between x and y has fulfilled the required standard. Therefore, it reveales that the evaluated RC building resist the seismic load.

Maximum moment (M max)

One of the results of the analysis obtained is the maximum moment of the column of model 1, 2 and 3 as shown in the following table

Table 3. Maximum moment table (M max) in the column of models 1, 2 and 3

Lantai	Model 1	Model 2	Model 3
	Max. Momen Kn/m	Max. Momen Kn/m	Max. Momen Kn/m
3rd storey	60,99	28,52	29,02
2nd storey storey orestorey	77,43	42,64	53,79
1st storey	95,49	73,15	76,69

Discussion

Despite of the best result, there were still some building model either with or without shear walls that had not fulfilled the requirement determined in accordance with SNI-03-1726-2002 regulations from their dynamic characteristics.

Moreover, the variant pattern of the first vibration in the first building model (without the shear walls rotated toward x and y direction and it had period of 0.6537 and 0.5524 seconds. On the other hand, the second one (shear wall on the edge) on the variant pattern of the first vibration rotated to x direction only having the period of 0.3102 seconds and the second variant pattern moving horizontally (translation) to y direction had the period of 0.1558 seconds. Meanwhile, the third one (shear wall in the middle) in the variant pattern of the first vibration rotated to x direction while in the second variant pattern rotated to y direction with the period of 0.3187 seconds. Thus, it was concluded that the second model's natural vibration period did not exceed the standard limit (0.51) so that it had met the standard of SNI 03-1726-2012.

The drift values of both x and y direction (1.515 cm) on the three-story building on model 1 (without the shear wall) had surpassed the required standard of x direction value of 1,3 cm. Based on the maximum moment value of the column, the most effective number of column reinforcement is in model 2 (shear wall on the edge) with a smaller number of reinforcement compared to models 1 and 3 . The results of this study was in line with previous studies which stated that the accurate position of the shear wall would strengthen the building effectively and efficiently during an earthquake. (Mahdi Hosseini, 2014).

5. Conclusion

Based on the results of comparative analysis of the performance between the reinforced concrete building in open frame without and with the shear walls in restraining the seismic load, it can be summarized as follows:

1. The shear wall installation on a building structure with a long plan is able to enhance the stiffness of the building structure. Installing the shear wall in the proper position of the building occasionally can minimize the natural vibration period of the building so that the first variety (mode) of the building is dominated by translasi.

2. The addition of shear walls to the building structure can significantly reduce displacement (drift) and drift (deviation between levels) and it would not surpass the required limit performance.

3. The structure of reinforced concrete buildings using shear walls produces internal forces, including moments which are smaller than the open frame structure building models. The amount of reinforcement can be moderated by the smaller element moment of the building.

6. References

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