Comparison of thickness shear wall against drift floor using pushover method

Widyasa Dwi Rizky Astre, Irpan Hidayat, Andryan
Civil Engineering Department, Faculty of Engineering, Bina Nusantara University
Jakarta, Indonesia 11480

Corresponding author: widyasa.astre001@binus.ac.id

Abstract. Lateral load or earthquake disaster can damage the structure of a highrise building. Therefore, calculations are needed to avoid massive damage to the structure when an earthquake occurs and give a load to the structure. One of the efforts that is done to resist the earthquake is using shear wall. On this research, there will be a comparison of shear wall thickness that will be used for the building model. Where there is existing model with the shear wall thickness 400 mm, modified model with the shear wall thickness 350 mm and 300 mm, and model without shear wall. Earthquake standards is using SNI 1726-2019, load standards are using SNI 1727-2013, concrete design is using SNI 2847-2019, and for the structure analysis is using ETABS Program. First step is calculating the Demand Capacity Ratio (DCR) of the structure element to determine if the structure needed to be analyse using non-linear static (pushover) or not. And then there will be drift ratio calculation to determine the building performance level using Federal Emergency Management Agency (FEMA) 356 provisions.

Keywords: Shear Wall, thickness, drift floor

1. Background

There are several problems that can damage or cause structure failure to the building structure especially a high-rise building. One of the problems that often occurs especially in Indonesia is earthquake disaster. Massive earthquake load can cause at least damage to the building structure or worse could destroy a building.

Therefore, calculations are needed to be done and calculate all the possibilities that could happen, especially in this case is earthquake load. In civil engineering, especially in high-rise building construction, to anticipate when an earthquake occur is by using shear walls that could reduce the vibration that caused by earthquake load. This shear wall looked like a wall with reinforcement bars and concrete as the cover of the reinforcement bars.

In this research, building modelling will be using ETABS software and will make four of building models with the different on the thickness of the shear wall but the location of the shear wall is still the same. The first model will be using shear wall with the thickness of 400 mm (based on the project design). The second model will not use shear wall. The third model will be using shear wall with the thickness of 350 mm. The fourth model will be using shear wall with the thickness of 300 mm.
Reference [3] conclude that the most effective shear wall shape to resist the lateral load is the I Shape and the wider the dimension will resist load more effective. Reference [4] has analysed a building structure with different thickness and conclude that increase the width of the shear wall will increase the strength of the structure. Reference [10] said that the wider the shear wall thickness been used, the deflection of the structure will be decreased. Reference [11] conclude that the length of flange is not very influential but the width of the shear wall thickness. Reference [17] get a result that the wider the shear wall will increase the displacement on the roof. Reference [18] conclude that the wider the shear wall, then the structure will get stiffer. Reference [19] get a result that the wider the shear wall with the same percentage of reinforcement bars, will get better resist the load. Reference [20] said that the wider the shear wall, the deflection will be decreased.

2. Methodology

First, there will be a study first about the analysis that will be used. The purpose of the study is to master the material that will be used in this research. The next, structural data collection is collected to do the modelling of the Hotel BXC Second Phase is ETABS Program. And then define the materials that will be used on this project. In this research, the model that will be analysed is the existing model with the width of the shear wall is 400 mm, modified model with 350 mm and 300 mm width dimension of shear wall, and the model without using shear wall. And then analyse using linear static and calculate the story drift that will be compared with the rules of SNI 2847:2019. And then the next is calculation of Demand Capacity Ratio to determine if the structure need the continuous analysis, non-linear static analysis or push over analysis. In DCR analysis, the structure elements that will be observed are column, beam, and shear wall. For the beam, DCR calculation is for the moment, torsion, and shear of the beam. And then after the DCR calculation is done, the next is analysis using non-linear static if needed. In non-linear static analysis, FEMA 356 is used as the basis of push over analysis using target displacement method to get the building performance level of the structure. Beside that, calculation of structure ductility is also be done, and this ductility is related to the yield and maximum point of the structure.

![Figure 1. Research Methodology](image)

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3. Analysis

3.1. Existing Model Analysis (SW 400 mm)

In this section, analysis will be done to the existing model and resulted the story drift, demand capacity ratio and push over analysis.

a. Story Drift

After making building model and applied the dead load, live load, and earthquake load, then the next is doing the linear static analysis to get the result of story drift. The story drift that will be calculated is for the X direction and Y direction. And then both directions are compared with the allowed story drift based on SNI 2847-2019. Figure 2 shows the story drift comparison graphic between the X and Y direction and the allowed drift based on SNI.

![Figure 2. Existing Model Story Drift Graphic (SW 400 mm)](image)

b. Demand Capacity Ratio

DCR calculation are divide into three structure elements, that are column, beam, and shear wall. And then, for the column element, there will be calculation that are moment, torsion, and shear. The purpose of DCR calculation is to determine if the structure needed the pushover analysis or not. If the value of DCR more than 1.0, then the structure must be analysed using push over analysis.

- Column DCR

Figure 3 shows the recapitulation of Column DCR.

![Figure 3. Column DCR Calculation Result](image)

- Beam DCR

Figure 4, Figure 5, and Figure 6 show the recapitulation results of beam DCR moment, shear and torsion, respectively.
Figure 4. Beam Moment DCR Calculation

Figure 5. Beam Torsion DCR Calculation

Figure 6. Beam Shear DCR Calculation Result

- Shear Wall DCR
  Figure 7 shows the recapitulation result of Shear Wall DCR calculation.

Figure 7. Shear Wall DCR Calculation Result

From the DCR recapitulation above, there are some structure elements that have DCR value more than 1.0, which means that the building structure must be analyse using non-linear static or pushover analysis.

c. Non-Linear Static Analysis
After DCR calculation, there are some structure elements that has DCR value more than 1.0. Therefore, the building structure needs to be analysed using pushover analysis or non-linear static analysis. The result of the pushover analysis is used to calculate the structure ductility and determine the building performance level. Figure 8 dan Figure 9 show the result of pushover analysis.
Structure Ductility
Calculation of structure ductility related to the yield point and the maximum point. Tabel 1 presents the structure ductility of the existing model. Where Fully Elastic is below 1.0, Ductile Partially is from 1.0 until 5.3, and Fully Ductile is more than 5.3.

| Direction | δ_m  | δ_y  | μ   | Structure Ductility |
|-----------|------|------|-----|---------------------|
| X         | 385.72 | 92.23 | 4.2 | Ductile Partially   |
| Y         | 467.76 | 141.86 | 3.3 | Ductile Partially   |

Building Performance Level
Building performance level is done within two ways, first is totally and the second is totally inelastic. The different is on the calculation. Tabel 2 presents the result of building performance level calculation. The result is then being classified to the ATC 40 classification.

| Description            | Drift Ratio | Building Performance Level |
|------------------------|-------------|-----------------------------|
| Totally                | X           | 0.551%                      | Immediate Occupancy      |
| Totally                | Y           | 0.669%                      | Immediate Occupancy      |
| Totally Inelastic      | X           | 0.5508%                     | Damage Control           |
| Totally Inelastic      | Y           | 0.668%                      | Damage Control           |

3.2. Model Without Shear Wall Analysis
In this section, the analysis will be done to determine the story drift of the model without shear wall to compare with the story drift of the existing model to find out if the use of shear wall can decrease the story drift of the building. After modelling the model without shear wall, then the next is analysed to determine the story drift and will be compared to the allowed story drift based on SNI 2847-2019. Figure 10 shows the graphic of the story drift.

Figure 10. Model Without Shear Wall Story Drift Graphic
It can be seen that, there are 7 floors that are not qualified to the SNI 2847:2019 rules.
3.3. Model SW 350 mm Analysis
In this section, story drift will be determined using linear static analysis and determine the building performance level that will analysed using pushover analysis.

a. Story Drift
After modelling the building with the width dimension of 350 mm and applied the dead load, live load, and earthquake load, then next is doing the linear static analysis to determine the story drift that will be compared with the allowed story drift based on SNI 2847-2019. Figure 11 shows the story drift graphic.

![Figure 11. Model SW 350 mm Story Drift Graphic](image)

The story drift of the SW 350 model is still qualified to the allowed story drift based on SNI 2847-2019.

b. Non-Linear Static Analysis
The result of the non-linear static analysis is used to calculate the structure ductility and building performance level. Figure 12 and Figure 13 shows the structure ductility and building performance level of the model SW 350 mm.

![Figure 12. SW 350 mm X Direction Pushover](image)

![Figure 13. SW 350 mm Y Direction Pushover](image)

- Structure Ductility
  Structure ductility is related to the yield point and the maximum point of the structure. Table 3 presents the structure ductility of the building. Where Fully Elastic is below 1.0, Ductile Partially is from 1.0 until 5.3, and Fully Ductile is more than 5.3.

| Direction | \( \delta_m \) | \( \delta_y \) | \( \mu \) | Structure Ductility |
|-----------|----------------|----------------|-------|-------------------|
| X         | 387.55         | 101.91         | 3.8   | Ductile Partially |
| Y         | 469.30         | 140.40         | 3.3   | Ductile Partially |

- Building Performance Level
  Building performance level is done within two ways, first is totally and the second is totally inelastic. The different is on the calculation. Table 4 presents the result of building performance level calculation. The result then being classified to the ATC 40 classification.
Table 4. SW 350 mm Building Performance Level

| Description          | Direction | Drift Ratio | Building Performance Level |
|----------------------|-----------|-------------|----------------------------|
| Totally Inelastic    | X         | 0.553%      | Damage Control             |
| Totally Inelastic    | Y         | 0.667%      | Damage Control             |

3.4. Model SW 300 mm Analysis

In this section, story drift will be determined using linear static analysis and determine the building performance level that will analysed using pushover analysis.

a. Story Drift

After modelling the building with the width dimension of 300 mm and applied the dead load, live load, and earthquake load, then next is doing the linear static analysis to determine the story drift that will be compared with the allowed story drift based on SNI 2847:2019. Figure 14 shows the story drift graphic.

![Figure 14. Model SW 300 mm Story Drift Graphic](image)

The story drift of the SW 300 model is still qualified to the allowed story drift based on SNI 2847-2019.

b. Non-Linear Static Analysis

The result of the non-linear static analysis is used to calculate the structure ductility and building performance level. Figure 15 and Figure 16 show the structure ductility and building performance level of the model SW 300 mm.

![Figure 15. Model SW 300 mm X Direction Pushover](image)

![Figure 16. Model SW 300 mm Y Direction Pushover](image)

- Structure Ductility

Structure ductility is related to the yield point and the maximum point of the structure. Table 5 presents the structure ductility of the building. Where Fully Elastic is below 1.0, Ductile Partially is from 1.0 until 5.3, and Fully Ductile is more than 5.3.
Building Performance Level

Building performance level is done within two ways, first is totally and the second is totally inelastic. The different is on the calculation. Table 6 presents the result of building performance level calculation. The result then being classified to the ATC 40 classification.

### Table 6. Model SW 300 mm Building Performance Level

| Description               | Direction | Drift Ratio | Building Performance Level |
|---------------------------|-----------|-------------|----------------------------|
| Totally                   | X         | 0.554%      | Immediate Occupancy        |
| Totally                   | Y         | 0.671%      | Immediate Occupancy        |
| Totally Inelastic         | X         | 0.553%      | Damage Control             |
| Totally Inelastic         | Y         | 0.667%      | Damage Control             |

#### 3.5. Comparison of Thickness Shear Wall

These are the comparison of base shear of the earthquake, story drift, structure ductility, and building performance level from each of the models. For the base shear and story drift, all models will be compared to each other. Meanwhile for the structure ductility and building performance level, only the model with shear wall will be compared.

- **Base Shear Comparison**

  Figure 17 shows the result of base shear comparison between all models.

  ![Figure 17. Base Shear Comparison](image)

  From Figure 17, the thinner the dimension of shear wall, the base shear will be decreased. It is related to the weight of the structure.

- **Story Drift Comparison**

  Figure 18 and Figure 19 show the comparison of the story drift between all models.

  ![Figure 18. Story Drift X Direction Comparison](image)

  ![Figure 19. Story Drift Y Direction Comparison](image)
The model using shear wall with the thickness of 400, 350, and 300 mm are still qualified based on the SNI 2847-2019. But for the model without shear wall, there are 7 floors that is not qualified or exceed the allowed story drift based on SNI. Therefore, using shear wall can decrease the story drift of the structure.

c. Structure Ductility Comparison
Figure 20 shows the comparison graphic between the models using shear wall.

![Structure Ductility Comparison](image)

*Figure 20. Structure Ductility Comparison*

It can be seen that the thinner the shear wall dimension, then the structure ductility is also decreased. It is related to the endurance of the structure from the yield point to the maximum point.

d. Building Performance Level Comparison
These are the comparison of building performance level of the structure.

![Total Drift Ratio Comparison](image)
![Inelastic Drift Ratio Comparison](image)

*Figure 21. Total Drift Ratio Comparison*  
*Figure 22. Inelastic Drift Ratio Comparison*

From both graphics above, there are two different building performance level that are immediate occupancy and damage control. In this case, take the weakest building performance level. But from the drift ratio comparison, can be seen that the thinner the shear wall, will get more drift ratio.

4. Conclusion
According to the analysis result, the conclusions can be drawn as follow
a. The thinner the dimension of shear wall the lesser base shear when an earthquake occur. This can be happened because the decrease of the weight of structure.

b. The use of shear wall can decrease the story drift of the structure because of an earthquake load.

c. The thinner the dimension of shear wall the lesser the structure ductility. This can be happened because of the endurance of the structure from the yield point to the maximum point.

d. The thinner the shear wall the more drift ratio will resulted.

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