Effects of opening dimension in shear wall on the behavior of high-rise building structure due to earthquake load

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Abstract. The aim of this study is to analyze the effects of opening dimension in shear wall on the behavior of high-rise building structure due to earthquake load. The 20-story building prototype with shear wall placement as core wall with various sizes of opening are analyzed with the help of software MIDAS GEN, using equivalent lateral force and response spectrum method in X and Y direction. The shape of opening is square with width vary from 0.8 m – 1.3 m and height set at 2.2 m. This analysis will discuss structure’s natural time period, core wall distribution between shear wall and frame, lateral deflection, and story drift. The results show that the greater the opening will increase the natural time period by 1.72% and 1.67%, increase lateral deflection by 21.7932% and 23.5964%, and increase story drift by 24.6910% and 29.077% in each direction.

1. Introduction

Indonesia is a country where is located between 4 world’s active tectonic plates. These plates are pacific plate, Indo-Australia plate, Eurasia plate, and Philippine plate. Indonesia included in pacific ring of fire. Hence, Indonesia is often hit by earthquake with small to large intensity. This earthquake resulted damage and collapse to buildings and public infrastructures. In this modern era, high-rise building structure becomes more popular. The growth in high-rise building construction has been largely used for commercial or residential purposes due to rapid growth of urban population and limited space.

High-rise building is affected by lateral forces due to wind or earthquake action so that become important role in the structural design. In general, stiffness and stability become important in design. There are two ways to satisfy this requirement which are to increase the dimension of structure element or change the form of structure into more rigid and stable to confine the deformation and increase stability. For building taller than 10 stories, frame action obtained by the interaction of slabs and columns is not adequate to give lateral stiffness [3]. This will make structure become uneconomical because of large size of structural elements are required. This condition can be improved by placing shear wall because its effectiveness to retain stability and increase lateral stiffness of structure. In several cases, high-rise building designed as frame structure with shear wall effectively resists lateral forces [2]. Such structure is called dual system.

Shear wall often has an opening to be provided due to functional requirements such as elevator’s door, window, or ducting. The opening is located in each floor which dividing wall into two segments connected by coupling beam. Opening in shear wall will decrease lateral stiffness and structure’s performance. Hence, it’s become important to consider the effects of the opening in structural design. This study was conducted to investigate the effects of opening dimension on the behavior of high-rise
building structure due to earthquake load. The 20-story building with shear wall placement as core wall with various sizes of opening are analyzed with the help of software MIDAS GEN, using equivalent lateral force and response spectrum method. There were 7 models prototype building with variations of opening dimensions.

2. Methods

2.1. Structure Modeling
The building prototype that will be analyzed is a 20-story office building with shear wall placement as core wall. The building plan view, isometric view, and elevation view are displayed on Figure 1, Figure 2, and Figure 3.

![Building plan view](image1)

**Figure 1. Building plan view**

![Building isometric view](image2)

**Figure 2. Building isometric view**

![Building elevation view](image3)

**Figure 3. Building elevation view**

The properties of each elements are presented in Table 1. The figures are collected from preliminary design which has been done before.
Table 1. Structure element properties

| Parameter     | Length (cm) | Width (cm) | Height/thickness (cm) | Compressive strength (Mpa) |
|---------------|-------------|------------|-----------------------|----------------------------|
| Slab          | -           | -          | 20                    | 30                         |
| Edge beam     | -           | 25         | 50                    | 30                         |
| Middle beam   | -           | 30         | 60                    | 30                         |
| Edge column   | -           | 50         | 80                    | 35                         |
| Middle column | -           | 70         | 70                    | 35                         |
| Core Wall     | -           | -          | 25                    | 35                         |

2.2. Shear wall opening modeling
The opening used in this study is an elevator door with two doors in the same side. The opening models are presented in Table 2 and displayed in Figure 4.

Table 2. Opening models in core wall

| Parameter | Width, B (m) | Height, H (m) |
|-----------|--------------|---------------|
| Model 1   | 0            | 0             |
| Model 2   | 0.8          | 2.2           |
| Model 3   | 0.9          | 2.2           |
| Model 4   | 1            | 2.2           |
| Model 5   | 1.1          | 2.2           |
| Model 6   | 1.2          | 2.2           |
| Model 7   | 1.3          | 2.2           |

Figure 4. Opening model parameter

2.3. Seismic analysis method
The seismic analysis methods used in this study are lateral equivalent force and response spectrum method. From [1], the dynamic earthquake force should be bigger than 85% static earthquake force. If dynamic earthquake force less than 85% static earthquake force, the dynamic force will be scaled up to level the static force. After the scale up process is done, the next step is to analyze structure behavior due to earthquake force.

3. Results

3.1. Natural time period
The natural time periods of structure are displayed in Figure 4 and Figure 5.
Figure 5. Structure natural time period in X direction

Figure 6. Structure natural time period in Y direction

Figure 5 and Figure 6 show that the natural period time increased as the greater the opening. The peak natural time period in X direction is 1.3981 s and the peak natural time period in Y direction is 1.3859 s. Both peak natural time period found in model 7. Based on program, the first mode shape of structure is translation X, the second mode shape is translation Y, and the third mode shape is rotation Z.

3.2. Lateral deflection

The structure’s lateral deflection displayed in Figure 6 and Figure 7.
Figure 8. Lateral deflection with core wall opening perpendicular to earthquake force

Figure 7 and Figure 8 show that lateral deflection increased as the greater the opening. From figure 7, the peak lateral deflection parallel to earthquake force is 515.7768 mm in X direction and 523.4130 in Y direction. From Figure 8, the peak lateral deflection perpendicular to earthquake force is 423.7943 mm in X direction and 418.8151 in Y direction. All the peak lateral deflection found in model 7. These figures show that the earthquake force parallel to opening direction is more decisive than earthquake force perpendicular to opening direction.

3.3. Story drift

The structure’s lateral story drift displayed in Figure 8 and Figure 9.

Figure 9. Story drift with core wall opening parallel to earthquake force
Figure 10. Story drift with core wall opening perpendicular to earthquake force

Figure 9 and Figure 10 show that story drift increased as the greater the opening. From figure 9, the maximum drift parallel to earthquake force is 35.2913 mm in X direction and 35.9491 mm in Y direction. From Figure 10, the maximum drift perpendicular to earthquake force is 28.4554 mm in X direction and 27.9631 in Y direction. All the maximum story drift found in model 7. These figures show that the earthquake force parallel to opening direction is more decisive in determined story drift than earthquake force perpendicular to opening direction.

4. Conclusion
Based on analysis data, the following conclusion in this study are drawn:

- Natural time period of structure increased as greater the opening with maximum value is 1.3981 s in X direction and 1.3859 in Y direction.
- The lateral deflection increased as greater the opening. The earthquake force parallel to opening direction is more decisive in determined lateral deflection than earthquake force perpendicular to opening direction.
- The story drift increased as greater the opening. The earthquake force parallel to opening direction is more decisive in determined story drift than earthquake force perpendicular to opening direction.

References
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