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EFFECT OF EARTHQUAKE FORCES ON COLUMNS WITH DIFFERENT STRENGTHENING USING SAP2000 SOFTWARE

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ABSTRACT

Indonesia is an area that has quite a high frequency and strength of earthquakes because it is at the meeting point of four tectonic plates, namely the Eurasian plate, the Indo-Australian plate, the Pacific plate and the Philippine Sea plate. Earthquake-resistant buildings are an alternative to minimize the impact of earthquake forces that occur. One design that needs to be analyzed is that there are openings in the building wall structure that cause the columns not to bend properly when receiving lateral forces, so they have the potential to fail. A collapsing column will cause the load of the building floor above it to collapse. Through this research, the influence of the frequency of earthquake forces, the influence of earthquake forces on the deviation between floors, and the location of the collapse in building models A (without walls) and B (with walls) will be identified. The method used is dynamic load analysis in SAP2000 based on spectrum response. Based on the results of the SAP2000 analysis, it can be seen that the deviation value between floors is smaller in building model B (with walls), thus indicating *short column* with lower heights absorb more energy and have stiffer properties. The location of the collapse is not visible in the SAP2000 analysis, but the largest deformation occurs in the beam for both building models.

Say Key**:** Earthquake, SAP2000, *Short-column*, Beams, Deviations between floors

1. INTRODUCTION

Indonesia is at the junction of four tectonic plates, namely the Eurasian, Indo-Australian, Pacific and Philippine Sea plates, so it has quite high earthquake frequency and strength. The effects of the earthquake caused various damages to public facilities and even casualties (Utami & Warastuti, 2017). Earthquake-resistant building design is an alternative in minimizing the impact of earthquake forces, namely that the building does not collapse or at least is able to provide sufficient duration for evacuation before building failure occurs. The main structure of the building must have strong strength to accept the earthquake forces on the structural elements, namely columns, foundations, beams and floor plates. The loads borne by the building on the floor structure above will be distributed to the beams first and to the foundation through the intermediary columns, but on the ground floor the loads will be distributed from the slab to the sloof to the foundation. (Latip, 2018)

One of the reasons why a building does not qualify as an earthquake-resistant building is that there are openings in a building such as glass to add aesthetic value and ventilation space. This situation causes the column to not be able to bend properly when receiving the lateral force of an earthquake because the infill wall as a support is stiff (Ramin & Mehrabpour, 2014). Columns can experience potential failure and cause load distribution from a floor to the foundation to not occur so that the floor of the building above that is supported can

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collapse.

Therefore, through this research, the influence of earthquake forces on the building model, deviations between floors, and the location of the collapse in columns with different reinforcement from the building model will be analyzed. The problem limitation in this research is using SAP2000 with types *student version*.

2. REVIEW BIBLIOGRAPHY

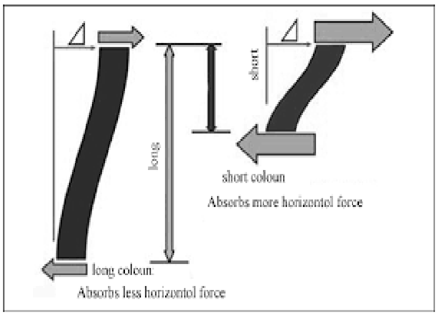
2.1 Column Classification Based on Slenderness

Based on slenderness, columns can be classified into two, namely long columns and short columns. Long columns have a ratio of the effective length of the column to the smallest dimension of the column, which exceeds the value 12 ($\frac{l_{eff}}{d} > 12$). Meanwhile, short columns have the smallest effective length to dimension ratio of columns below 12 ($\frac{l_{eff}}{d} < 12$) (Santhanu Bhanja, 2024). Long columns fail due to buckling, but short columns fail by experiencing destruction due to direct pressure that exceeds the compressive capacity of the column.

2.2 Short Column

The impact of *short column* will occur when the columns in a reinforced concrete building frame are restricted in their movement by certain obstacles. Barriers can be in the form of bricks that fill part of the height of the column. Among other things, barriers can be in the form of columns on the ground floor that are shorter than others due to differences in ground elevation. (Sivanantham & Pradeep, 2017),

Short column causes the lateral force that occurs on the column to become greater during an earthquake. The illustration can be seen in Figure 2.8, long and short columns will move in the same direction and magnitude of force when an earthquake occurs, but *short column* absorbs more energy than a long column. This situation is caused by the ductility of *short column* This will be reduced due to the nature of stiffness *short column* higher (Sivanantham & Pradeep, 2017). The nature of ductility allows columns to be able to deform, namely change shape or shift post-elastic position in order to maintain sufficient strength and stiffness so that they are still able to support the building. (Nuraga et al., 2021a). As the ductility of the column decreases, the column will not be able to deform properly after the elastic phase, especially when it receives significant earthquake forces. This resulted in *short column* receive greater bending moments and shear forces when an earthquake occurs.



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Picture 2.1 Comparison between *long column* And *short column*

2.3 Earthquake Force

Earthquakes are a natural phenomenon that occurs due to the release of energy from elastic strains in lithospheric rocks because the rocks in the earthquake source area are unable to withstand the relative motion forces between rock blocks, resulting in friction and deformation. (Zebua, 2018). Deformation that exceeds the elasticity and stretch of the lithospheric rocks, also known as plates, causes the rocks to fracture. After breaking, the rock returns to its original shape by moving to a more stable position using potential energy. Elastic energy occurs during this transfer process which propagates to the earth's surface in the form of seismic waves that vibrate horizontally, vertically, and horizontally and vertically. Lateral loads can cause shifts in the building which are distributed at each level of the structure (IMANI dkk., 2024).

The spectrum response curve created based on SNI 1726-2019 is the response of a structure to earthquake seismic wave vibrations in a certain period and region. The indicators obtained are based on the S value$_S$, S_1, site class, truss system and T_L which is mapped and produces calculations in accordance with SNI 1726-2019 and produces graphs in accordance with Figure 2.2.

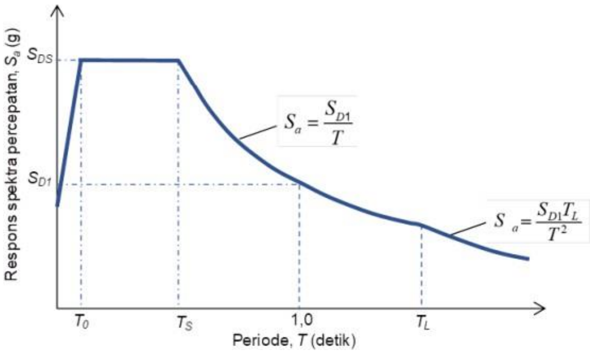

Figure 2.2 Image of acceleration spectral response

2.4 Deviations Between Levels

Deviation is the relative lateral displacement of two adjacent building levels or horizontal deviation (Hidayah & Mughni, 2018). The calculation of the deviation between floors in the design is obtained through the difference in deviation at the center of mass above and below the level under consideration (SNI 1726-2019. The center of mass which has a non-aligned position in the vertical direction can be determined through a vertical projection of the center of mass of the level above. If design stresses are permitted, then Δ is calculated using seismic forces.

Center of mass deviation δ_x on certain floors can be obtained based on equation 1. C_d is a factor in increasing the lateral deviation δ_{car} is the calculated elastic displacement due to the design earthquake force. Whereas, I_{and} is the value of the earthquake priority factor.

$$\delta_x = \frac{C_d \cdot \delta_{car}}{I_{and}}$$

2.5 SAP2000

SAP2000 is software that functions in modeling and calculating the strength of the structure. The elements used are elements *frame* for structural, namely beams and columns, meanwhile, for floor plate elements, the element type is used *shell (Yusmar et al., 2019)*. Among them, there are two analysis methods for earthquakes, namely equivalent static lateral force and dynamic earthquake load analysis. The equivalent static lateral force in SAP2000 is an analysis method to simplify complex earthquake forces into lateral forces that are easier to calculate in building modeling (Imani et al., 2024). Meanwhile, dynamic earthquake load analysis is able to obtain the value of the division of storey shear forces due to ground movements caused by earthquake forces by entering the spectrum response value as a load in accordance with SNI 1726-2019. The results obtained are *displacement, drift,* And *base shear* from the building level (Sagita et al., 2019).

3. RESEARCH METHODOLOGY

3.1 Research flow

The research flow begins with determining the research topic followed by literature study. Then, the specifications for building models A and B were determined. The building model was tested on an earthquake table, then testing and modeling analysis of the building model was carried out using SAP2000. The results of the earthquake force influence test on the SAP2000 analysis and vibration table test will be calculated and discussed and a final conclusion made based on the results of the discussion.

3.2 Dimensions

The dimensions in the study are on a scale of 1:10 compared to the original conditions for building models A and B. The building dimensions are 40 x 30 cm with column sizes of 4.5 cm x 4.5 cm and beams of 2.5 x 4 cm. The height between floors is 35 cm with a distance between column axles of 35.5 cm (x direction) and 25.5 cm (y direction). The thickness of the floor slab is 1.2 cm with a reinforcement diameter of 1 mm every 2.4 cm in the x and y directions. The concrete cover on beams, columns and foundations is 0.25 cm thick. Meanwhile, the main beam and column reinforcement is 4 D1.6 mm and the foundation reinforcement is D 1.6 mm with a distance of 1 cm. In stirrup reinforcement, beam reinforcement has a diameter of 0.8 mm every 1 cm and column reinforcement uses a diameter of 0.9 mm every 1 cm. In building model B on the 2nd floor, a wall structure with a height of 17.5 cm will be provided

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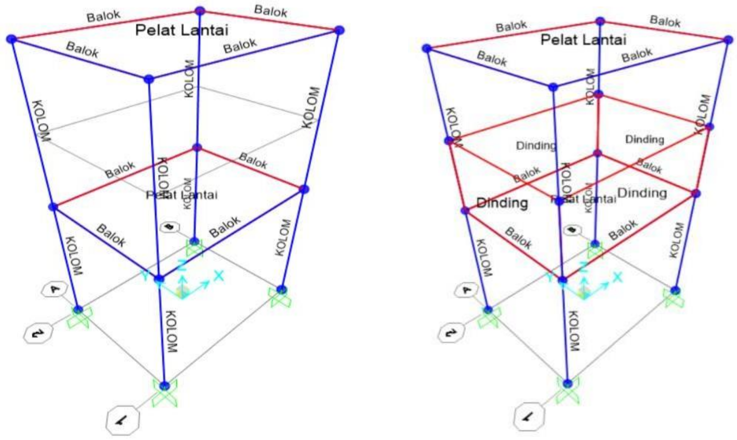

Figure 3.1 Building models (A) and (B)

3.3 SAP2000 Analysis

The analysis used in SAP2000 for this research is dynamic earthquake load analysis which uses structural loads and spectrum response loads. The analysis will be carried out on 10 cities with different spectrum response values in accordance with SNI 1726-2019. The results of the dynamic earthquake load analysis obtained are *displacement* which will be calculated through equation 1 ($\delta_x = \frac{C_d.\delta_{car}}{I_{and}}$) to obtain *drift* or the deviation between levels of a certain floor in the building with a time period of 10 seconds. The site class used is SE. C grade*d* which is used is 5.5 by considering the building as special moment bearing concrete (SNI 1726-2019). Value I_{and} is 1 because the building is category 2 as housing (SNI 1726-2019). Based on *drift* that occurs in the building, the influence of the earthquake forces that occur on the building columns will be analyzed. The earthquake load which is the spectrum response in the analysis is shown in the graph in Figure 3.2. The earthquake load analyzed in SAP2000 will have an increasing frequency and acceleration starting from the city of Banjarmasin to Mataram.

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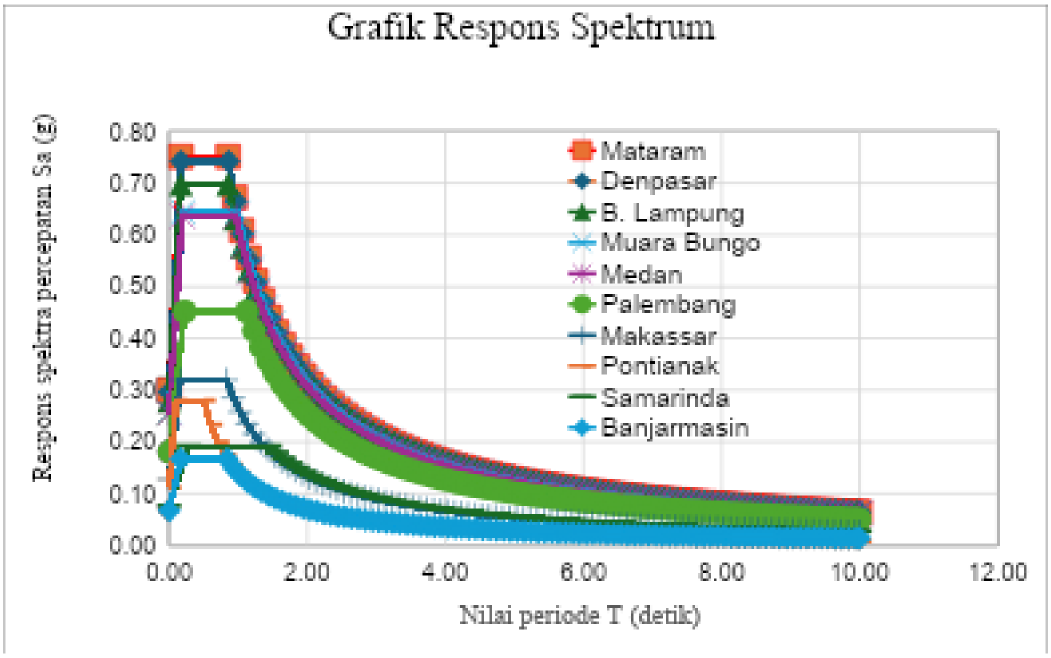

Figure 3.2 Spectrum response graph

4. ANALYSIS AND DISCUSSION

4.1 Effect of Frequency on Building Models

The results of the analysis in SAP2000 obtained the displacement value for each *joint* in building models A and B for 10 cities (Banjarmasin, Samarinda, Pontianak, Makassar, Palembang, Medan, Muara Bungo, Bandar Lampung, Denpasar, and Mataram) according to the labels shown in Figure 4.1. The deviation value between levels in building models A and B is obtained by adding up the difference between the joints on the 2nd floor and the 1st floor and multiplying it by the Cd value, namely 5.5, then dividing by Ie, namely 1, to obtain the calculation results in accordance with Table 4.1.

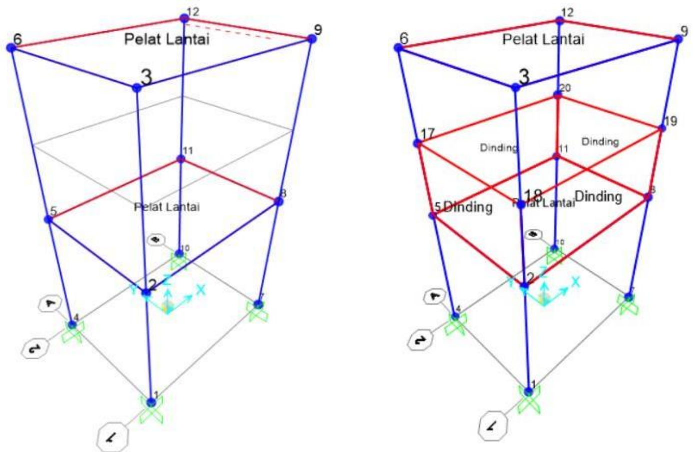

Figure 4.1 Labels *joint* in building models (A) and (B)

Table 4.1 Deviation values between floors in building models A and B from analysis *SAP2000*

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City	Building Model A		Building Model B	
	δx (mm)	δy (mm)	δx (mm)	δy (mm)
Banjarmasin	0,05585	0,04743	0,00202	0,00281
Samarinda	0,05957	0,05080	0,00223	0,00310
Pontianak	0,10589	0,08939	0,00364	0,00507
Makassar	0,10736	0,09116	0,00388	0,00540
Palembang	0,14538	0,12373	0,00536	0,00744
While	0,20908	0,17773	0,00763	0,01060
Bungo Estuary	0,21016	0,17873	0,00770	0,01069
Bandar Lampung	0,22980	0,19534	0,00839	0,01165
Denpasar	0,24907	0,21151	0,00902	0,01252
Mataram	0,24896	0,21310	0,00912	0,01267

Through these results, the deviation values between levels in the four columns of the building on the 2nd floor in building model A or building model B are the same at similar elevation heights. This is influenced by the displacement value *joint* when receiving earthquake forces with a certain frequency and acceleration for building models A and B are the same at similar elevations.

Based on Table 4.1, the greater the frequency or magnitude of the earthquake force applied to the building model from the spectrum response value, the greater the deviation value between floors. This means that the greater the earthquake force on a building, the greater the displacement that a building model will experience. Apart from that, it can be seen that the deviation value between floors in building model A is greater than in building model B in each city. This indicates that the displacement occurs greater in building model A than in building model B with the same frequency and magnitude of earthquake forces.

In addition, the presence of retaining walls causes the effective length to be shorter. Based on the slenderness of the column, a lower effective length causes greater lateral forces during an earthquake because the ductility of the column is reduced and it has higher stiffness. The reduced ductility characteristic of the deformation that occurs when moving the location to maintain sufficient strength and stiffness to support the building also becomes smaller as seen from the deviation value between the levels of the building model. Through the results obtained in this research, it can be identified that the lower the altitude The effective length of the column, the smaller the displacement it will experience and the more susceptible it will be to earthquake forces to collapse.

4.2 Location of Collapse in Building Model

Based on the analysis results in SAP2000, it can be seen that structural elements will experience deformation when they receive earthquake forces for 10 seconds. All spectrum response analyzes in 10 cities (Banjarmasin, Samarinda, Pontianak, Makassar, Palembang, Medan, Muara Bungo, Bandar Lampung, Denpasar, and Mataram) produce the same deformation occurring in building models A and B. In the SAP2000 analysis, it is not visible deformation that occurs in the building model causes the building model to collapse at a certain frequency,

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but only the structural elements that experience the greatest deformation are visible. Based on Figures 4.2 and 4.3, it can be seen that the structural elements that experience the greatest deformation are the beams.

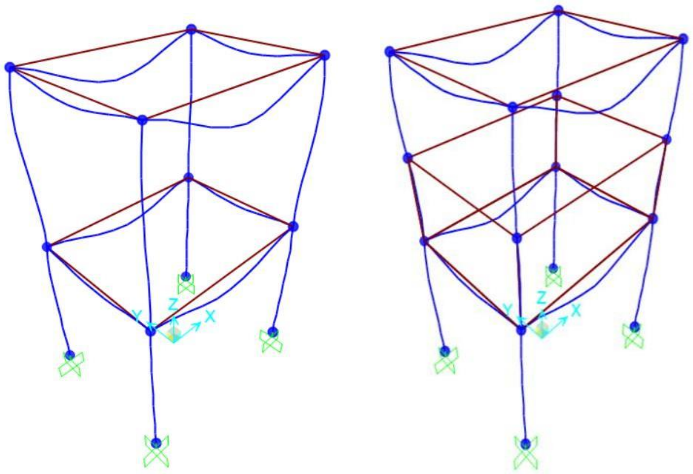

Figure 4.2. Deformation of structural elements of building models (A) and (B)

The deformation that occurs in the beam is based on the results of the SAP2000 analysis in accordance with the design of the building which is a special moment-bearing frame system with special characteristics. *strong column-weak beam*. This means that the beam that will be made is weak and experiences the greatest deformation when it receives external loads such as earthquake loads.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Based on the results and discussion in this research, it can be concluded that:

1. The greater the frequency or magnitude of the earthquake force applied to the column, the greater the displacement value, namely the deviation between levels.
2. The lower the effective column length, the more difficult it is to experience deformation or displacement, indicating that the stiffness of the column increases and its ductility decreases.
3. In the SAP2000 analysis, no collapse was seen, only the largest deformation occurred in the beams for building models A and B. This is in accordance with the design that uses a special moment-resisting frame system, namely *strong column-weak beam* that is, the beam will be weaker than the column.

5.2 Suggestion

Suggestions for further research are to use *software* SAP2000 which has more complete features and specifications compared to *student version*.

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