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RESEARCH ARTICLE

Analysis The Effect Of Column Height Variation On The Perfomance Of Increased Building Structure

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Abstract

Indonesia is a country with a high earthquake risk. Thus, Indonesia often experiences earthquakes and the consequences of these earthquake waves cause damage to buildings ranging from light damage to heavy damage. Dealing with the case, it is necessary to plan and implement earthquake-resistant building structures, especially in high-rise buildings. Another factor that needs to be considered is the function of the room which affects the column height when the column height is different and it causes uneven stiffness from the ground floor to the top.

The aim of this study was to find out the effect of variations in column height on the performance of multi-storey building structures in terms of shear forces, floor drift and buckling load (Pc). The method used in this study was the response spectrum method. The spectrum response is the maximum response of a Single Degree of Freedom (SDOF) structural system, both acceleration, velocity and displacement due to the structure being loaded by a certain external force. Before carrying out the analysis using the response spectrum method, a structural model was undertaken by varying the column height on the 1st floor into 3 variations.

Dealing with the results of the analysis on the building structure model with varying column height on the 1st floor, it indicated that the higher the column the maximum base shear force value increases. The higher the 1st floor column, the maximum floor deviation value increases. The higher the column the value of the column slenderness ratio increases and the Euler buckling load decreases.

Keywords: column, earthquake, shear force, floor drift, buckling

1. Introduction

Indonesia is a country with a high risk of earthquakes, because Indonesia is at the confluence of three world tectonic plates, namely the Indian-Australian plate, the Pacific plate, and the Eurasian plate. In addition, Indonesia is also part of the Pacific Ring of Fire, which is the path of active earthquakes in the world (Dept. PU, 2014).

Earthquake forces in the vertical and horizontal directions will burden the points on the mass of the structure. The impact of the earthquake caused damage to different buildings, ranging from light damage to heavy damage.

To prevent damage to buildings that cause material losses and casualties, it is necessary to plan and implement earthquake-resistant building structures, especially in high-rise buildings. In the planning of building structures based on the stiffness of a building. The stiffness of the structure can be measured by the magnitude of the deviation between floors, the smaller the deviation between floors, the stiffer the building will be (Hartoyo, 2010).

In planning the structure of the building, it is also necessary to pay attention to the function of the room, due to the main cause of the function of the building itself is the building and it must be strong and safe without reducing the function of the room.

The function of the room can cause different story heights or column heights. Especially at the lower levels of buildings, such as parking lots, lobbies and others which have different column heights, causing an uneven distribution of stiffness throughout the building vertically (Siajaya, 2018).

Based on the above background, this research was carried out structural analysis with various variations of the first floor column height in the building structure model to determine the effect of column height on structural performance in terms of the amount of shear and displacement that occurs in the building structure and buckling load/critical load (pc) in column.

2. Literature Review

Previous Studies Apriani. 2017 *"Analysis of the Effect of Column Span Variations on Building Structure Performance"*, The purpose of this study was to analyze the effect of column span variations on structural performance, in order to obtain the most optimal column spans. In order to obtain the optimal span, this paper will examine the correlation between the span on the stiffness of the building structure and the strength of the structure. The research method is a simulation using the help of the finite element method program on a 3-storey reinforced building (12 meters) with a horizontal span of 20 meters. The results of the study show that from the structural stiffness factor, the most optimal scheme in terms of stiffness can be obtained, namely the shortest span scheme (scheme 1) with spans of 4m-4m-4m-4m-4m. In terms of structural strength, the shortest span scheme (scheme 1) has the highest optimization/dimensional reduction percentage compared to the other two schemes. In terms of structural strength, scheme 1 has the smallest moment among the other schemes.

Limbongan 2016. *"Analysis of Flat Column Reinforced Concrete Structures in Multi-storey Buildings"*. Planning or design is a very decisive factor to ensure the strength and safety of a building structure, buildings with large loads also require large supporting structures, so that they are able to withstand the existing loads. Columns with large enough dimensions will have an impact on the size of the room which is getting smaller. This can cause the function of the room to be disrupted. Meanwhile, if the column is too small, the size of the room becomes larger, but it is not necessarily strong enough to withstand the existing load. From the results of the model analysis with variations in thickness, namely 15cm, 20cm, and 25cm, as well as variations in the height of each floor, namely 3m, 3.2m, and 3.5m, it shows that a wall thickness of 15cm has an optimal floor height which is small compared to a wall thickness of 25cm which has a floor height which is larger, but from some considerations 20cm thick is considered an economical option

Ridwan, 2014. *"Evaluation on the Behavior of Five-Story Building Structures Using Short Columns Due to Earthquake Loads"*. Evaluating the behavior of a five-storey reinforced concrete building structure with short columns using a two-dimensional portal model to determine the deformation values that occur along the height of the building. This modeling is carried out with four types of short column positions which will be analyzed with the SAP 2000 program which is designed according to SNI 03-2874-2002 and SNI 03-1726-2012 regulations.

3. Theoritical Basis

3.1 Analysis Procedure

In accordance with SNI-1726-2012, the analytical procedures that may be used must be based on the seismic design category and structural characteristics. As for the irregular configuration of the building structure, it can be divided into horizontal and vertical irregularities. Horizontal structural irregularities (clause 7.3.2.1) consist of torsional irregularities, excessive torsion, interior angles, diaphragm discontinuities, transverse displacements to the plane and nonparallel systems.

Vertical structural irregularities (clause 7.3.2.2) consist of soft story stiffness irregularities, excessive soft story stiffness, weight (mass), vertical geometry, plane direction discontinuities in vertical lateral force resisting element irregularities, discontinuities in story lateral strength irregularities and discontinuities in irregularities excessive level lateral strength.

According to the source SNI_1726-2012, In general, structural analysis of earthquake loads is divided into two types, namely static analysis and dynamic analysis. Each type of analysis has its own advantages and disadvantages which can be seen in **Table 1.**

Table 1. Priority Factor of Earthquake

Category	Priority Factor of Earthquake
I or II	1,00
III	1,25
IV	1,50

Spectrum Response Method

Spectrum response is an approach concept used for building planning purposes. The definition of spectral response is the maximum response of a Single Degree of Freedom (SDOF) structural system, both acceleration, velocity and displacement due to the structure being loaded by a certain external force. According to SNI 1726-2012, the design spectral response must first be made based on existing data.

Intersection between ramps

Dealing with SNI 1726-2012 article 7.8.6, the deviation between floors is only one performance, namely at the ultimate limit performance. The determination of the design story drift (Δ) shall be calculated as the difference in deflection at the center of mass of the upper and lower floors under consideration.

The deflection of the center of mass at Level x (δx) (mm) must be determined according to the following equation:

$$\delta_x = \frac{C_d \delta_{xe}}{I_e}$$

Where:
Cd : deflection magnification factor
δxe : deflection at the location required in this article determined by elastic analysis
Ie : priority factor

4. Research Method

This research is a literature study, where literature study is a method used to collect data or sources related to the topic raised in a study. Such as journals and books related to earthquake planning using the response spectrum method. The reference books used include, among others, Procedures for Planning Earthquake Resistance for Building and Non-Building Structures SNI 1726:2012, Minimum Load Regulations for the Design of Buildings and other Structures SNI 1727:2013, Requirements for structural concrete for buildings SNI 2847:2013.

The analysis used was dynamic analysis with response spectrum method. After the data was collected, the data will then be analyzed.

Calculating loading. Loading calculations were undertaken in accordance with the supporting data. Calculate the loads acting on the structure in the form of dead loads, live loads. The dead load was calculated based on the existing modeling where the self-load in the program was included in the dead load case, while the additional dead load that cannot be modeled in the program was in the super dead load case. The calculation of self-weight in the program for dead was 1, while super dead was 0, where the load for dead has been calculated automatically by the program, while for super dead loads the load needs to be entered manually according to existing data.

Calculating the design spectrum response. Calculating the design spectrum response to obtain a response spectrum curve that refers to the site coefficients and the maximum earthquake acceleration spectral response parameters that are considered the target risk. Analyzing a structural model with a spectrum response to obtain a spectrum response curve according to the earthquake area analyzed with the help of the program. The data needed in the spectrum response analysis are the function of the building, the location of the building to the earthquake area, the type of soil and the type of structure.

Research Stage

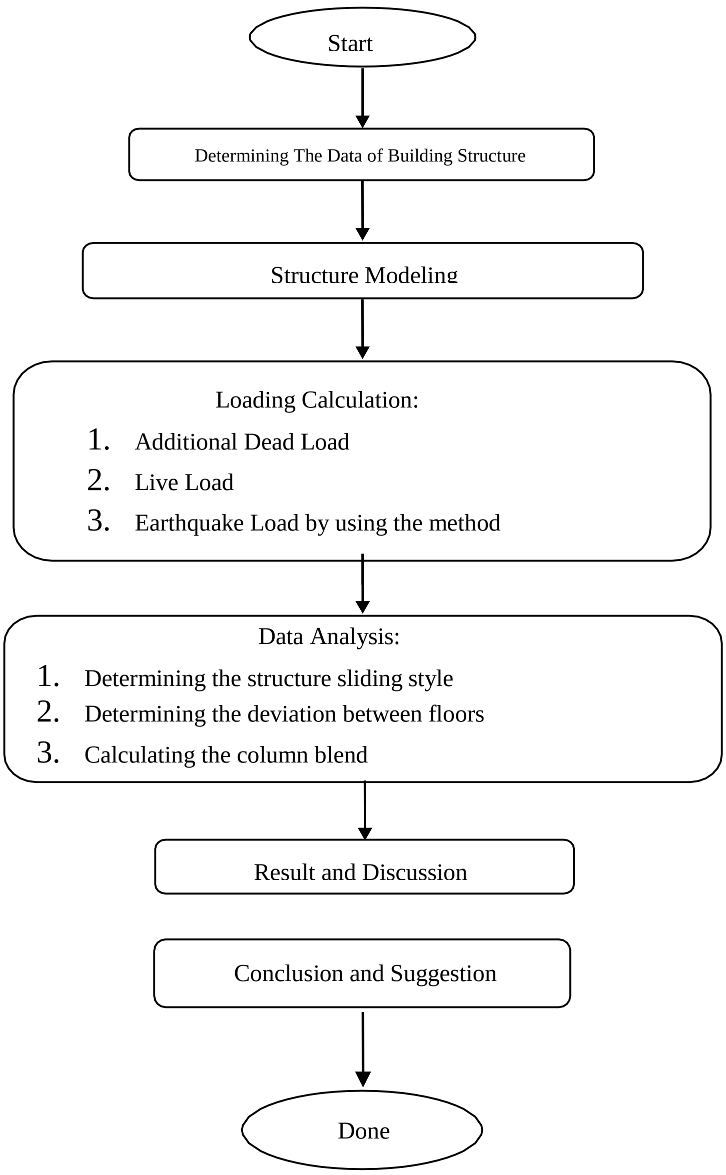

Fig 1. Research Flow

5. Finding

5.1 Level of Sliding Style

Dealing with the results of the structural analysis carried out using the response spectrum method, the story shear due to the maximum loading combination was obtained.
Based on Table 2, it can be seen that the maximum shear force on the 1st floor due to the combined load in the X direction is increasing. The shear force that occurs is in model 1 (3m) of 3,080.24 kN, model 2 (4m) of 3,094.62 kN, and model 3 (5m) of 3,099.65 kN.

Table 2. shear force in the X direction

	Model 1		**Model 2**		**Model 3**	
Floor	**Fx (kN)**	**Vx (kN)**	**Fx (kN)**	**Vx (kN)**	**Fx (kN)**	**Vx (kN)**
Floor 5	947,07	947,07	911,54	911,54	861,81	861,81
Floor 4	837,06	1.784,13	826,34	1.737,88	834,93	1.696,74
Floor 3	600,08	2.384,21	574,43	2.312,31	560,42	2.257,16
Floor 2	473,24	2.857,45	468,78	2.781,09	465,78	2.722,94
Floor 1	222,79	3.080,24	313,53	3.094,62	376,71	3.099,65

Dealing with Table 3, it can be seen that the maximum shear force on the 1st floor due to the combined load in the Y direction is increasing. The shear force that occurs in model 1 (3m) is 3,080.45 kN, model 2 (4m) is 3,099.15 kN, and model 3 (5m) is 3,107.13 kN. It can be seen that the maximum shear force on the 1st floor due to the combined load on the X direction increases. The shear force that occurs is in model 1 (3m) of 3,080.24 kN, model 2 (4m) of 3,094.62 kN, and model 3 (5m) of 3,099.65 kN.

Table 3. shear force in the X direction

Floor	Model 1 Fy (kN)	Model 1 Vy (kN)	Model 2 Fy (kN)	Model 2 Vy (kN)	Model 3 Fy (kN)	Model 3 Vy (kN)
Floor 5	918,16	918,16	882,53	882,53	832,34	832,34
Floor 4	858,02	1.776,18	845,41	1.727,94	849,71	1.682,05
Floor 3	618,40	2.394,58	595,09	2.323,03	582,78	2.264,83
Floor 2	472,29	2.866,87	472,35	2.795,38	473,43	2.738,26
Floor 1	213,58	3.080,45	303,77	3.099,15	368,87	3.107,13

5.2 Dealing with the results of the analysis of building structures using the response spectrum method, the maximum deviation of the structure due to the maximum loading combination is obtained according to SNI 1726-2012.

Based on the data in Table 4 and Figure 2, it can be seen that the maximum deviation in the X direction on the 5th floor due to the increasing influence of variations in the height of the first floor columns. The biggest maximum deviation in the X direction occurs in the model 3 structure (5m high) of 85.828 mm.

Based on the data in Table 4 and Figure 2. it can be seen that the maximum deviation in the Y direction on the 5th floor due to the increasing influence of variations in the first floor column height. The biggest maximum deviation in the Y direction occurs in the model 3 structure (5m high) of 77.681 mm.

Table 5. maximum deviation

Floor	Deviation (mm) Model 1 Direction X	Model 1 Direction Y	Model 2 Direction X	Model 2 Direction Y	Model 3 Direction X	Model 3 Direction Y
Floor 5	71,483	64,464	77,463	69,962	85,828	77,681
Floor 4	62,195	56,467	68,526	62,272	77,193	70,266
Floor 3	47,140	43,037	53,932	49,267	62,949	57,607
Floor 2	27,280	25,079	34,248	31,504	43,325	39,954
Floor 1	7,337	6,799	12,891	12,007	20,596	19,293

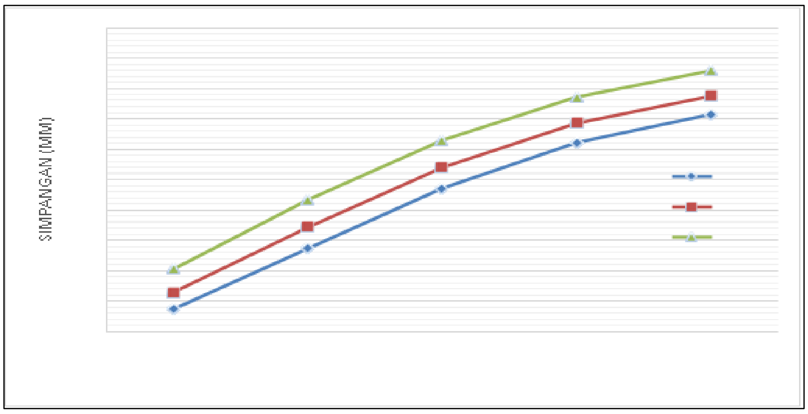

Fig 2. maximum deviation in the X direction

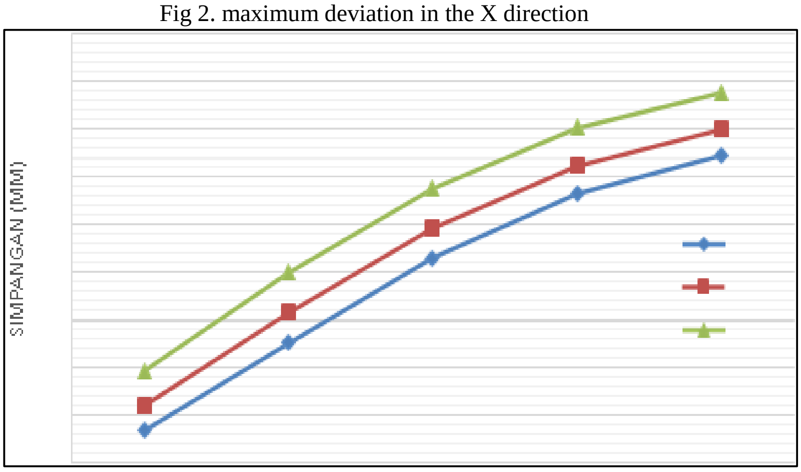

Fig 3. maximum deviation in the Y direction

5.3 Deviation between the floor

According to SNI 1726-2012, the deviation between floors (Δ) is the difference between the maximum deviation between the floor and the floor below it. The drift between floors should not exceed the allowable drift (Δa = 0.015 x hsx), hsx is the floor height.

Based on Table 5 and Figure 4 it can be seen that the deviation between floors in the X direction on the 1st floor is increasing. The largest deviation between floors occurs in the model 3 structure (5m high) of 75.518 mm, does not meet the allowable deviation limit

Table 6. Deviation between the floor in the x direction

Floor	Model 1 (Δ) (mm)	Model 1 (Δα) (mm)	Model 1 Ket	Model 2 (Δ) (mm)	Model 2 (Δα) (mm)	Model 2 Ket	Model 3 (Δ) (mm)	Model 3 (Δα) (mm)	Model 3 Ket
Floor 5	34,055	60	M	32,768	60	M	31,664	60	M
Floor 4	55,201	60	M	53,512	60	M	52,228	60	M
Floor 3	72,821	60	TM	72,173	60	TM	71,954	60	TM
Floor 2	73,125	60	TM	78,309	60	TM	83,340	60	TM
Floor 1	26,902	45	M	47,268	60	M	75,518	75	TM

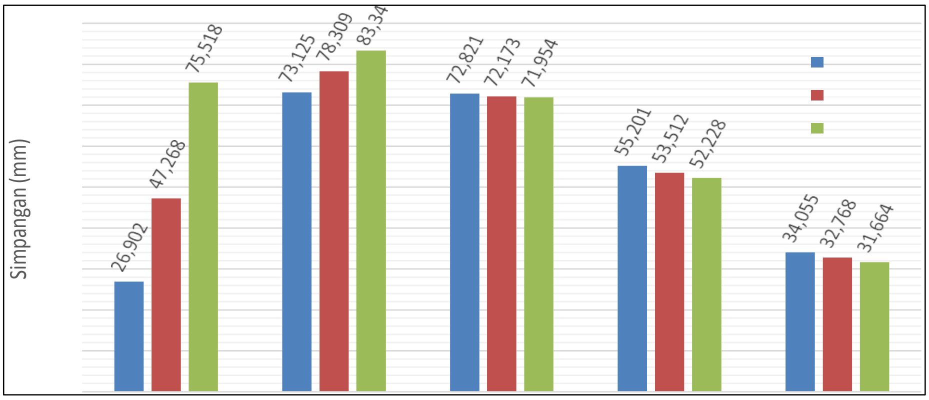

Fig 4. Deviation between the floor in the x direction

In accordance with Table 6 and Figure 5 above, it can be seen that the deviation between floors in the Y direction on the 1st floor is increasing. The largest drift between floors have occurred in the model 3 structure (height 5m) of 70.74 mm, it still meets the permissible drift limit

Table 7. Deviation between the floor in the Y direction

Floor	Model 1 (Δ) (mm)	Model 1 (Δα) (mm)	Model 1 Desc	Model 2 (Δ) (mm)	Model 2 (Δα) (mm)	Model 2 Desc	Model 3 (Δ) (mm)	Model 3 (Δα) (mm)	Model 3 Desc
Floor 5	29,322	60	M	28,197	60	M	27,188	60	M
Floor 4	49,242	60	M	47,682	60	M	46,415	60	M
Floor 3	65,847	60	TM	65,132	60	TM	64,728	60	TM
Floor 2	67,025	60	TM	71,489	60	TM	75,759	60	TM
Floor 1	24,931	45	M	44,026	60	M	70,740	75	M

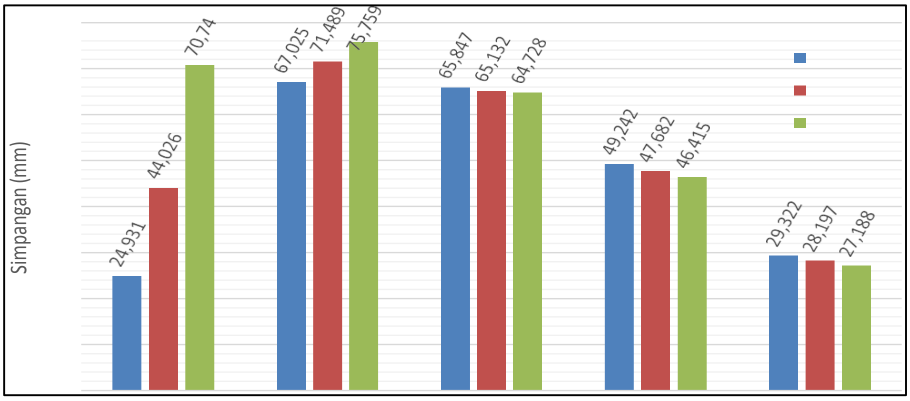

Fig 5. Deviation between the floor in the Y direction

5.4 Column bay inspection results

The results of checking the slenderness ratio and column buckling load can be seen in Table 7.

Based on the table above, it can be seen that the columns in Model 1, Model 2, and Model 3 are slender columns because the column slenderness ratio klu/r > 22. or the critical load is getting smaller. The value of the slenderness ratio (λ) is in Model 1 (height 3m) is 35.911, Model 2 (height 4m) is 45.640, and Model 3 (height 5m) is 55.345.

Table 8. Test result of column buckling

Model	Column Height (m)	k	$\lambda = \frac{kl_u}{r} < 22$	Buckling Load (Pc) (kN)
Model 1	3	2,38	35,911	15239,327
Model 2	4	2,21	45,640	9435,479
Model 3	5	2,11	55,345	6417,182

6. Conclusion

1. Dealing with the results of the analysis, it indicated that the higher the floor column 1, the shear force value that occured increases. The maximum shear force occured in model 3 of 3,107.13 kN in the Y direction.
2. The result of the analysis showed that the higher the 1st floor column, the deviation between floors was increasing. The biggest deviation between floors occurred in model 3 (height 5m) in the X direction of 75.518 mm, not meeting the permissible deviation limit.
3. The results of the buckling examination on the first floor column, it indicated that the columns in model 1 (height 3m), model 2 (height 4m), and model 3 (height 5m) include slender columns and experience buckling. The higher the value of the column, the slenderness ratio of the column increases. The biggest slenderness ratio occurs in model 3 of 55.345 and buckling load (Pc) of 6417.182 kN

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