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Comparative Analysis of Set-Back Field Jumps In Multi-Storey Building Structures Due To Earthquake Load

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Abstract: The magnitude of the influence of a building that has a set-back jumping plane out due to an earthquake depends on various things, one of which is the percentage of the jumping plane out in the building itself. The purpose of this study is to determine what percentage of set-back field jumps are safe in multi-storey building structures when given earthquake loads, evaluate the behavior of building structures when viewed based on displacement and drift ratio and evaluate the effect of the elevation height of the set-back field jumps on building safety.In this study, the building is modeled as high as 7 floors and 6 floors with elevation heights of 28 m and 24 m using the SAP 2000 program which is also used to analyze earthquake forces with the variational response spectrum method. The modeling studied was 8 modeling, namely at a height of 7 floors (building structure with set-back out 50%, 30%, 20% and 10%) and at a height of 6 floors (building structure with set-back out 50%, 30%, 20% and 10%). Based on the results of the research that has been done, the percentage of safe set-back exit plane jumps in the 7-storey high-rise building structure is in the modeling with a 10% set-back exit because the displacement value is below the allowable limit. As for the 20% and 30% set-back modeling, the displacement value of the top floor exceeds the allowable limit value. However, if the number of floors in the set-back section is reduced by 1 floor (to 6 floors) the structure is safe for every percentage of modeling.

Keywords: *Set-back; displacement; drift ratio*

1. Introduction

In structural planning in earthquake-prone areas, to reduce the risk of earthquakes to multi-storey buildings, earthquake-resistant structural design is required, where the structure is expected not to experience structural damage during an earthquake [1]. Structures must be designed to be able to bear earthquake forces or horizontal forces, the magnitude of which varies from region to region depending on local geographical conditions. Regular building planning is preferred because it has a center of mass and a center of rigidity that coincide. However, following the development of the needs of building functions and architectural designs, many irregular buildings with varied models whose configurations often cause vertical and horizontal irregularities in the structure [2] [3].

Based on observations, when an earthquake takes place, it will cause ground movement due to the deviation of irregular multi-storey buildings [4], such as buildings with set-backs, which is a condition where there is a protrusion or jump in the face plane of a multi-storey building. The magnitude of the effect due to earthquakes depends on various things, one of which is the magnitude of the plane jump in the building itself. So it is necessary to conduct research on what percentage of the set-back exit plane jump is safe in multi-storey buildings due to earthquakes [5].

2. Research Methods

The research location is in Sorong City, Southwest Papua at the coordinates of Latitude: 0º52′58.52″S, Longitude: 131º16′42.96″E, following the location map in this study [6]. The planning data used are as follows:

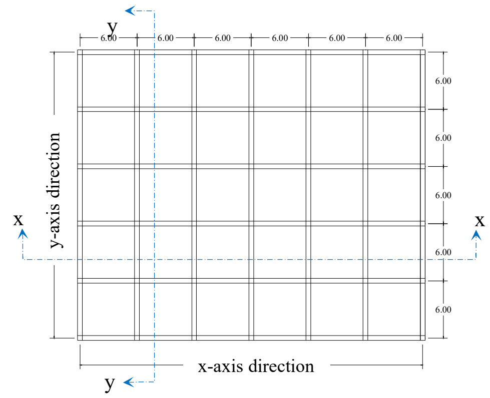

Fig. 1. Ground Floor Plan

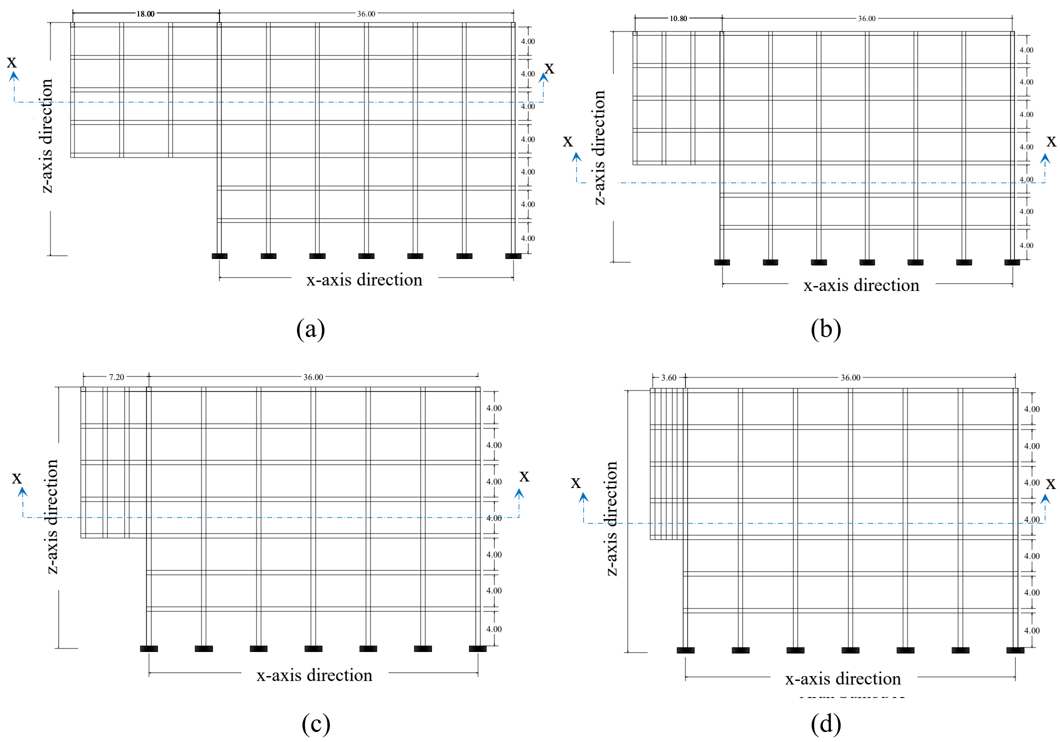

Fig. 2. X-Direction Cutout at 7 Floors, (a) Model A, (b) Model B, (c) Model C and (d) Model D

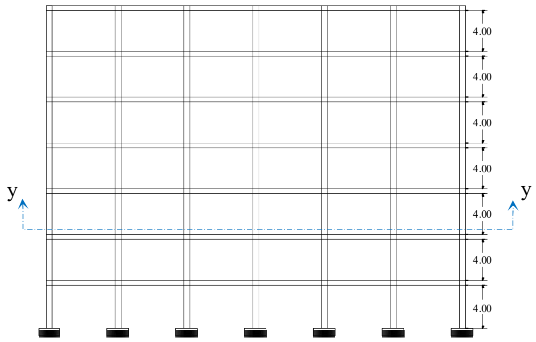

Fig. 3. Y-Direction Cutout at 7 Floors for Models A,B,C and D

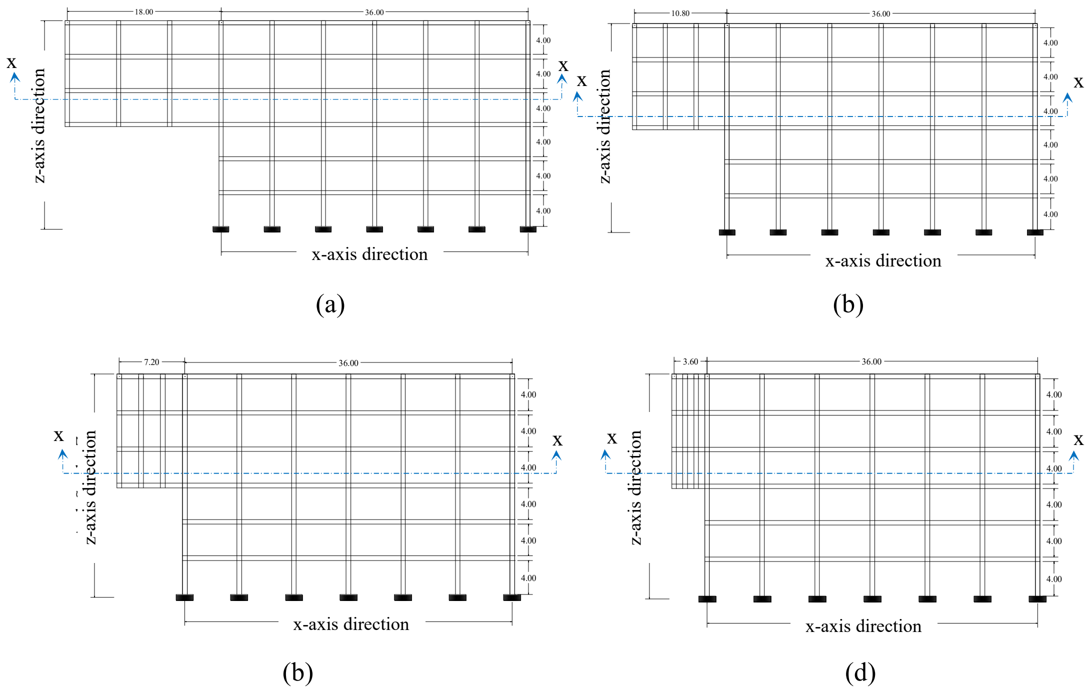

Fig. 4. X-Direction Cutout at 6 Floors, (a) Model 1, (b) Model 2, (c) Model 3 and (d) Model 4

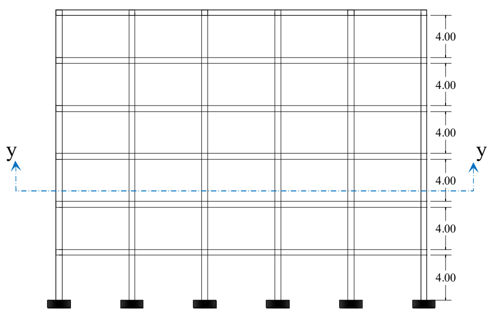

Fig. 5. Y-Direction Cut at 6 Floors for Models 1, 2, 3 and 4

The structural system to be used in this research is the Special Moment Bearing Frame System (SMBFS) [7]. Where the function of the building structure used in this study functions as an office building. The *concrete quality* (*f'c*) used is 30 Mpa and the *steel quality* (*Fy*) used is 410 Mpa and 240 Mpa. With the dimensions of beams, columns and plates (*preliminary design*) and the type of soil (*site classification*) in this study is soft soil [8].

3. Results and Discussion

3.1 Analysis of Loadings

1. Dead Load of the structure
   The dead load of the structure will be calculated using the SAP 2000 application
2. Additional dead load
   Floor plate = 60,63 kg/m^2
   Roof plate = 43,63 kg/m^2
   Beams (walls) = 1.000 kg/m^2
3. Live load
   Building live load = 250 kg/m^2
4. Earthquake load
   Building Risk Category = II
   Primacy Factor (I) = 1,00
   S_S = 1,39
   S_1 = 0,56
   Site class = SE
   Fa = 0,9
   Fv = 2,4

3.2 *Displacement*

The displacement value obtained from the analysis of the spectrum response method is taken based on the joint at the center of mass from the top level to the lowest level of the structure. Displacement or displacement and deviation between floors or drift ratio are determined based on the provisions in SNI 1726-2019 article 7.8.6 [9] with the following equation:

$$\delta x = \frac{C_d \delta_{xe}}{I_e} \quad (1)$$

Explanation:
Cd = Amplification factor of deflection
δ_{xe} = Deflection at locations required by this article determined by elastic analysis elastic analysis
I_e = Earthquake primacy factor

For the $\Delta_{allowable}$ value is determined based on the risk category and the planned building structure [10-12], in this study the $\Delta_{allowable}$ value is obtained by the following equation:

$$0{,}025hx \quad (2)$$

The calculation of the $\Delta_{allowable}$ value in this study is as follows:
$\Delta_{allowable} = 0{,}025hx$
$= 0{,}025 \times 4$ m
$= 0{,}1000$ m

Table 1. Comparison of 7-Story Modeling Displacement Values

Floor plate	Hx (m)	50%		30%		20%		10%		$\Delta_{allowable}$ (m)
		δx (m)	δy (m)	δx (m)	δy (m)	δx (m)	δy (m)	δx (m)	δy (m)	
Roof plate	4	0,117	0,128	0,105	0,108	0,101	0,069	0,097	0,065	0,1000
7	4	0,105	0,121	0,096	0,104	0,093	0,065	0,090	0,062	0,1000
6	4	0,091	0,112	0,085	0,099	0,082	0,058	0,079	0,056	0,1000
5	4	0,075	0,101	0,071	0,090	0,069	0,049	0,067	0,048	0,1000
4	4	0,057	0,087	0,055	0,080	0,053	0,038	0,052	0,037	0,1000
3	4	0,036	0,058	0,035	0,053	0,034	0,025	0,034	0,024	0,1000
2	4	0,015	0,024	0,015	0,021	0,014	0,011	0,014	0,010	0,1000
Ground floor	0	0	0	0	0	0	0	0	0	0

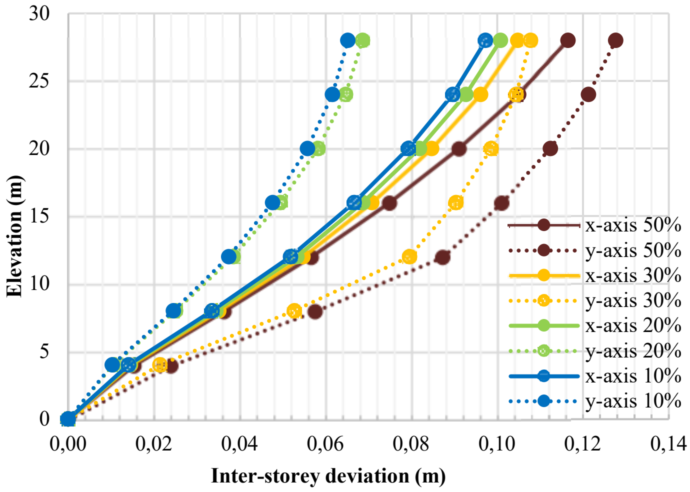

Fig. 6. Comparison Chart of Displacement Value of 7-Story Modeling

From the displacement values in Table 1, it can be seen that for modeling the building structure set-back out with 7 floors that do not exceed the allowable limit and will not experience collapse are at 10% set-back modeling. In the 20% set-back modeling there is still one *upper floor* (*roof plate*) whose value exceeds the allowable limit in the *x-axis* direction by 0.101 m. As for the 30% set-back modeling, there are two top floors whose displacement values still exceed the allowable limits in both the *x-axis* direction and the *y-axis* direction [13-14].

Table 2. Comparison Table of Displacement Values of 6-Story Modeling

Floor plate	Hx (m)	50%		30%		20%		10%		Δ Ijin (m)
		δx (m)	δy (m)	δx (m)	δy (m)	δx (m)	δy (m)	δx (m)	δy (m)	
Roof plate	4	0,078	0,098	0,088	0,093	0,086	0,093	0,084	0,096	0,1000
6	4	0,069	0,093	0,079	0,089	0,078	0,090	0,076	0,092	0,1000
5	4	0,057	0,086	0,067	0,083	0,066	0,083	0,065	0,085	0,1000
4	4	0,044	0,076	0,053	0,074	0,053	0,074	0,052	0,075	0,1000
3	4	0,028	0,051	0,034	0,049	0,034	0,050	0,034	0,050	0,1000
2	4	0,012	0,021	0,014	0,020	0,014	0,020	0,014	0,021	0,1000
Ground floor	0	0	0	0	0	0	0	0	0	0

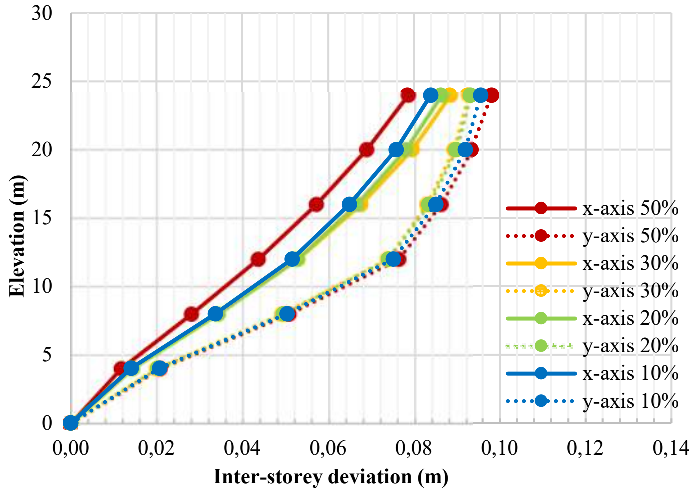

Fig. 7. Comparison Chart of 6-Story Modeling Displacement Values

From the displacement values in Table 2, it can be seen that for set-back exit modeling with 6 floors, all percentages are below the allowable limit so that the structure will not collapse. So it can be seen that in addition to the percentage of set-back exit column length, the floor height of the set-back section also has a very large influence on the displacement value in each modeling [15].

3.3 *Drift ratio*

The level drift ratio is the percentage comparison of the difference in displacement between levels and floor height [16]. The value of the drift ratio can be calculated with the following equation:

$$DR = \frac{\delta_{2-}\delta_1}{h_x} \times 100\% \quad (3)$$

Explanation:
DR = Drift ratio
δ = Deflection or Displacement
hx = Height of Portal Structure

Table 3. Comparison of Drift Ratio Values of 7-Story Modeling

Floor plate	Hx	50% DR (%)		30% DR (%)		20% DR (%)		10% DR (%)	
	(m)	x	y	x	y	x	y	x	y
Roof plate	4	0,288	0,158	0,217	0,083	0,201	0,099	0,191	0,090
7	4	0,350	0,223	0,285	0,145	0,271	0,159	0,258	0,146
6	4	0,405	0,288	0,349	0,206	0,330	0,221	0,316	0,204
5	4	0,455	0,343	0,401	0,270	0,385	0,274	0,370	0,254
4	4	0,508	0,743	0,491	0,670	0,472	0,336	0,457	0,324
3	4	0,525	0,840	0,514	0,783	0,501	0,363	0,488	0,355
2	4	0,383	0,598	0,363	0,535	0,359	0,263	0,351	0,257
Ground Floor	0	0	0	0	0	0	0	0	0

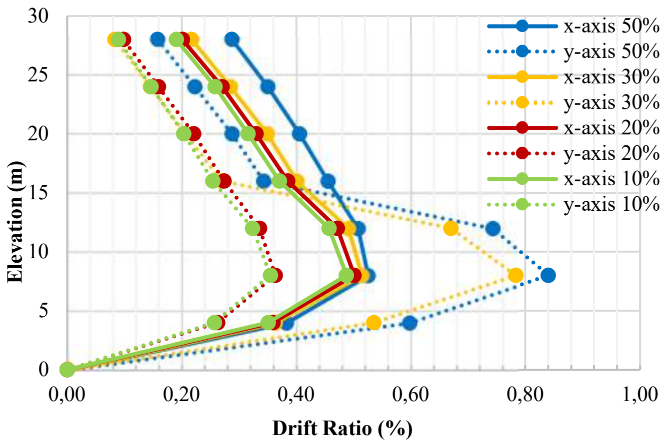

Fig. 8. Comparison Chart of Drift ratio Value of 7-Story Modeling

From Table 3 it can be seen that the largest drift ratio value is in Model A set-back 50% which is large in the *x-axis* direction is 0.525% and the *y-axis* direction is 0.840%. Meanwhile, the smallest drift ratio value is in Model D set-back 10% in the *x-axis* direction of 0.191% and the smallest in the *y-axis* direction in Model B set-back 30% of 0.083% [17].

Table 4. Comparison of 6-Story Modeling Drift Ratio Values

Floor plate	Hx	50% DR (%)		30% DR (%)		20% DR (%)		10% DR (%)	
	(m)	x	y	x	y	x	y	x	y
Roof plate	4	0,242	0,118	0,223	0,087	0,211	0,083	0,201	0,089
6	4	0,293	0,182	0,298	0,156	0,284	0,158	0,271	0,171
5	4	0,338	0,246	0,366	0,231	0,349	0,235	0,334	0,250
4	4	0,389	0,637	0,466	0,613	0,459	0,613	0,448	0,618
3	4	0,408	0,751	0,499	0,727	0,498	0,733	0,490	0,743
2	4	0,292	0,517	0,356	0,500	0,357	0,507	0,352	0,517
Ground Floor	0	0	0	0	0	0	0	0	0

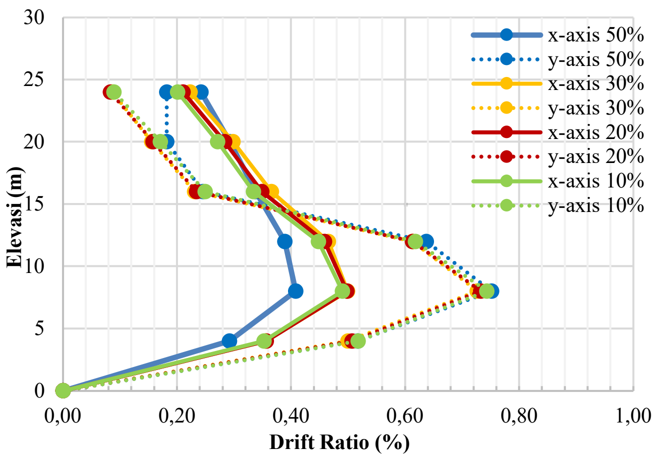

Fig. 9. Comparison Chart of Drift Ratio Value of 6-Story Modeling

From Table 4, it can be seen that the largest drift ratio value for the 6-story modeling is in Model 2 set-back 30% which is large in the *x-axis* direction of 0.499% while the largest *y-axis* direction is in Model 1 set-back 50% of 0.751%. For the smallest drift ratio value, the *x-axis* direction is in Model 4 set-back 10% at 0.201% and the smallest *y-axis* direction is in Model 3 set-back 20% at 0.083%.

4. Conclusion

In terms of displacement values, the percentage of set-back exit plane jumps that are safe in 7-storey high-rise building structures are modeled with 10% set-back exit. Meanwhile, if the number of floors in the set-back section is reduced by 1 floor, for each percentage of set-back exit plane jumps, it shows that the multi-storey building structure is safe.

The behavior of the set-back building structure at each percentage of the outgoing plane jump is reviewed based on the largest displacement and drift ratio values. The largest displacement value modeling with 7 floors is in Model A set-back 50% in the *x-axis* direction of 0.117 m and the *y-axis* direction of 0.128 m. The largest displacement value of modeling with 6 floors in the *x-axis* direction is in Model 1 set-back 30% by 0.088 m and the largest in the *y-axis* direction in Model 1 set-back 50% by 0.098m. The largest drift ratio value for modeling with 7 floors is in Model A set-back 50% in the *x-axis* direction of 0.525% and the *y-axis* direction of 0.840%. Meanwhile, the largest drift ratio value for modeling with 6 floors in the *x-axis* direction is in Model 2 set-back 30% at 0.499% and the largest in the *y-axis* direction in Model 1 set-back 50% at 0.751%.

Judging from the displacement allowable limit value in the 7-story and 6-story modeling, it can be seen that the elevation height of the set-back stepping plane on structural safety is very influential. Because the lower the elevation of the set-back plane, the load carried by the structure will be smaller so that the structure will be more secure.

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