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Effectiveness of building structure reinforcement to withstand earthquake loads with ETABS V.19 application (Case Study of Commercial Building "Butik Tanah Liek Pusako Mande")

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ABSTRACT

This research addresses the vulnerability of commercial buildings to collapse during earthquakes due to inadequate structural design and identifies the structural weaknesses requiring reinforcement. The focus is on the use of steel bracing as a means to strengthen the structure. The specific case study is the commercial building "Butik Tanah Liek Pusako Mande" in Kota Padang. The research aims to determine whether reinforcing the building with additional steel bracing can enhance its stiffness during seismic events and identify the most effective type of steel bracing. The research methodology employs a quantitative descriptive approach, utilizing structural modeling in analysis software such as ETABS. The study involves analyzing displacements in buildings with and without steel bracing to quantify the effectiveness of the reinforcement. The results indicate that structures employing inverted V bracing achieve a maximum displacement of 9.515 mm in the X direction and 2.525 mm in the Y direction, resulting in a 67% reduction in drift for the X direction and 92% for the Y direction. In contrast, structures using X bracing show a maximum displacement of 30.635 mm in the X direction and 32.753 mm in the Y direction, indicating a 26% increase in drift for the X direction and 36% for the Y direction. The study concludes that inverted V bracing is more effective in reducing building drift compared to X bracing. In conclusion, the research findings suggest that commercial building "Butik Tanah Liek Pusako Mande" already possesses a structural stiffness compliant with standards. However, the addition of inverted V bracing proves effective in further reducing story drift, emphasizing its efficacy in enhancing the structural integrity of commercial buildings during seismic events.

Keywords: *Commercial Building; Stell Bracing; Story Drift; ETABS V.19*

INTRODUCTION

Indonesia is located geographically between the continents of Asia and Australia, as well as the Indian Ocean and the Pacific Ocean. Indonesia is also in the Ring of Fire, a region in the Asia-Pacific area known for its active volcanic belts. This positioning places Indonesia at the convergence of three major tectonic plates: the Eurasian plate, the Indo-Australian plate, and the Pacific plate, making it a country prone to high seismic activity and earthquakes.

Padang is one of the areas in Western Sumatra that is vulnerable to earthquake disasters. Earthquake loads can affect buildings on floors because, generally, buildings have large floors and can cause deflection and deformation. The higher a building is, the greater the risk of

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building damage from an earthquake.

An earthquake is a vibration that occurs on the Earth's surface, which can damage the Earth's surface structure and also affect changes in the landscape.[2]. Padang City is an area that frequently experiences earthquakes, one of the largest being in 2009 with a magnitude of 7.6 Richter scale (SR) and in 2007 with a magnitude of 8.4 SR. The earthquake in 2007 marked a 700-year record in the super megathrust cycle of Sumatra and indicated that the 8.4 SR earthquake was the beginning of a failure episode of the Earth's plates in Mentawai. This disaster has garnered significant attention from the Indonesian government. [3]

One consequence of such damage is caused by the selection of irregular structures, such as buildings that lack shear walls on their ground floors (soft story). In this case, the columns on the ground floor have lower stiffness compared to the rest of the structure. As a result, buildings with a soft story experience lateral deformation and higher shear forces on these columns. [4]. One type of soft-story building is a building with an open ground floor, as shown in Figure 1, and commercial buildings with a ground floor used for retail purposes (shops).

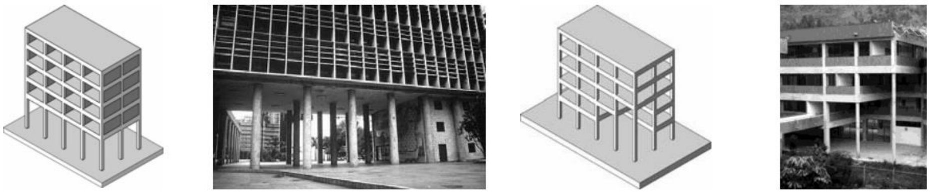

Figure 1: The form of a building with an open ground floor and a soft story.[5]

The commercial building is one of the buildings with a soft story that is vulnerable to collapse during an earthquake. Construction planning at the storehouse also often does not comply with the regulations in force and only uses estimates of the land in the field, which makes these buildings more susceptible to structural failure when an earthquake occurs. That's why it's necessary to do structural reinforcement on the structure of a commercial building.

In general, some buildings get impacted by structural failure on the base floor, but the upper level did not suffer significant damage. This explains that commercial buildings belong to the category of soft-story buildings and need to be reinforced on the base floor to reduce the likelihood of structural failure in the building.

Various forms of reinforcement can be implemented on a building, such as adding shear walls, performing load limitations, adding steel bracing, and jacketing some parts of the structure. Each reinforcement of this structure has a variety of advantages and disadvantages in its use. For that, it is necessary to do an analysis when choosing the type of structural reinforcement to be used. One of the structural reinforcements that can be done on a soft-story commercial building is to add steel bracing to the side walls of the building. All types of bracing can be used, including X, K, V-inverted, and diagonal. Adding steel braces in the right position and pattern can strengthen the structure to withstand earthquake loads on the building. One form of steel bracing used for building reinforcements can be seen in Figure 2.

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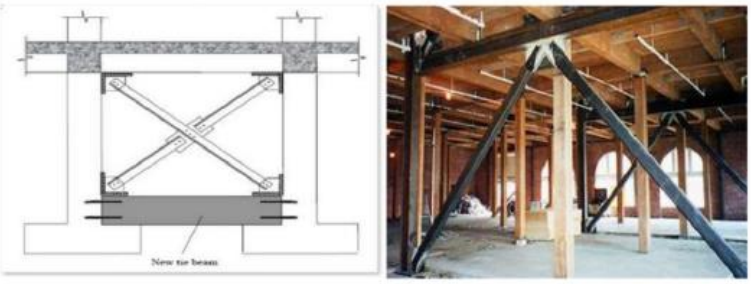

Figure 2: An example of reinforcement of steel bracing.[6]

In this case, research will be based on the need for analysis related to strengthening soft-story building structures to withstand earthquake loads by adding steel bracing to the building walls.

METHOD

The research employs a quantitative descriptive method by utilizing structural modeling in analysis software such as ETABS, followed by analyzing the significant displacement that occurs between soft story buildings without steel bracing reinforcement and those that have been reinforced. The research was carried out on one of the buildings of the commercial building “Butik Tanah Liek Pusako Mande”, which is located in front of the provincial DPRD office, Jl. S. Parman No.225a, North Ulak Karang, Kec. North Padang, Padang City, West Sumatra.0

The data used in this research includes (1) general building data (2) structural data (3) concrete quality data (4) relevant journals. The research instrument uses the hardware used in this research includes a laptop, a rebound hammer test used to determine concrete quality, and a tape measure. Meanwhile, the software used is ETABS 19, which is utilized for building modeling and analyzing story drift in the commercial building.

After obtaining the required data, the data will be analyzed. Structural element loading At this stage, steps are taken to insert structural loads on the building, which will be examined according to the rules in force. The burdens are dead load, live load, and earthquake load. Structural analysis with the ETABS 19 will lead to modal participating mass ratio, story drift, p-delta effect, and checking the contribution of the frame to bear a minimum of 25% of the lateral force. This research will analyze the displacement differences and story drift that occur on a soft-story building, namely a storehouse, which subsequently produces the comparative value of the rigidity that occurs on the commercial building structure.

Story drift can be calculate after calculate different of mass deflection of the building. Calculation of mass deflection using the formula. [1]

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

Keterangan:

C_d = Factor of enlargement of the lateral axis
δ_{xe} = The constriction at the required level-x, determined by elastic analysis
I_e = Earthquake priority factor

After calculate mass deflection, then calculate story drift using the formula.. [1]

$$\Delta x = \delta_{xa} - \delta_{xb} \leq \Delta a$$

$$\Delta x = (\delta_{xea} - \delta_{xeb}) \frac{C_d}{I_e} \leq \Delta a$$

Keterangan:

δ_{xea} = Elastic displacement calculated as a result of an earthquake design strength level at the upper level

δ_{xeb} = Elastic displacement calculated as a result of an earthquake design strength level at the lower level

Δx = Story drift on the level-x

Δa = Story drift permission level

RESULTS AND DISCUSSION

Modal Participating Mass Ratio

Based on the ETABS output, different results were obtained for the mass participation ratio in each structural system. In the structural modeling without bracing, mode 1 = 0.575 (Translation UY), mode 2 = 0.586 (Translation UX), and mode 3 = 0.816 (Rotation RZ). In the structural modeling using inverted V bracing, mode 1 = 0.795 (Translation UX), mode 2 = 0.909 (Translation UY), and mode 3 = 0.791 (Rotation RZ). In the structural modeling using X bracing, mode 1 = 0.554 (Translation UX), mode 2 = 0.478 (Translation UY), and mode 3 = 0.415 (Rotation RZ).

Story drift

Story drift is an important consideration in the planning and design of buildings to ensure that they can be used efficiently, safely, and for their intended purpose. The calculation of the story drift of the commercial building is as follows:

Table 1. Story Drift Modeling Without Bracing

Story	***h***	***Inelastic Drift***		***Drift Limit***	***Cek***
		Δ_X	***Δ_Y***		
	(mm)	**(mm)**	**(mm)**	**(mm)**	
2	3750	24.310	24.002	57.692	OK
1	3750	28.677	30.239	57.692	OK
Base	0	0	0	0	OK

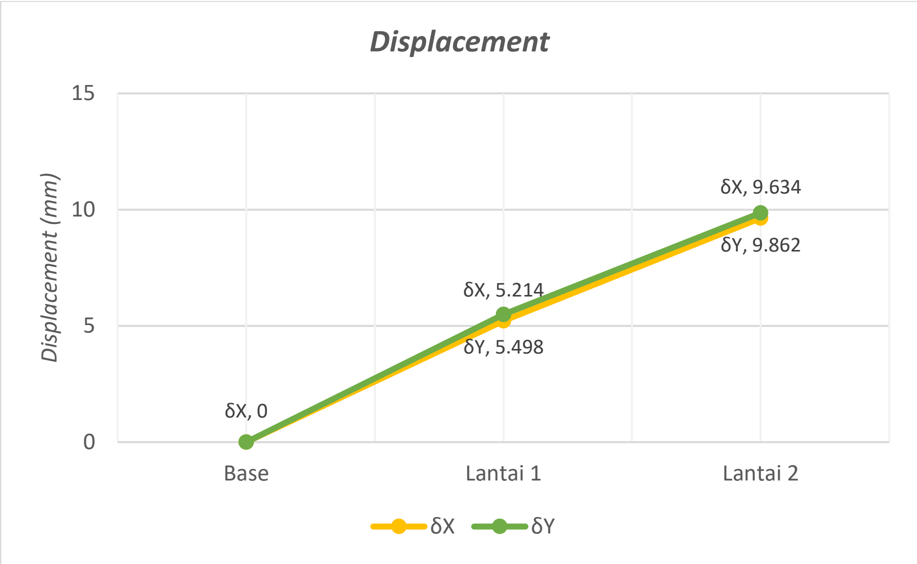

Figure 3. Graphic Displacement Modeling Without Bracing

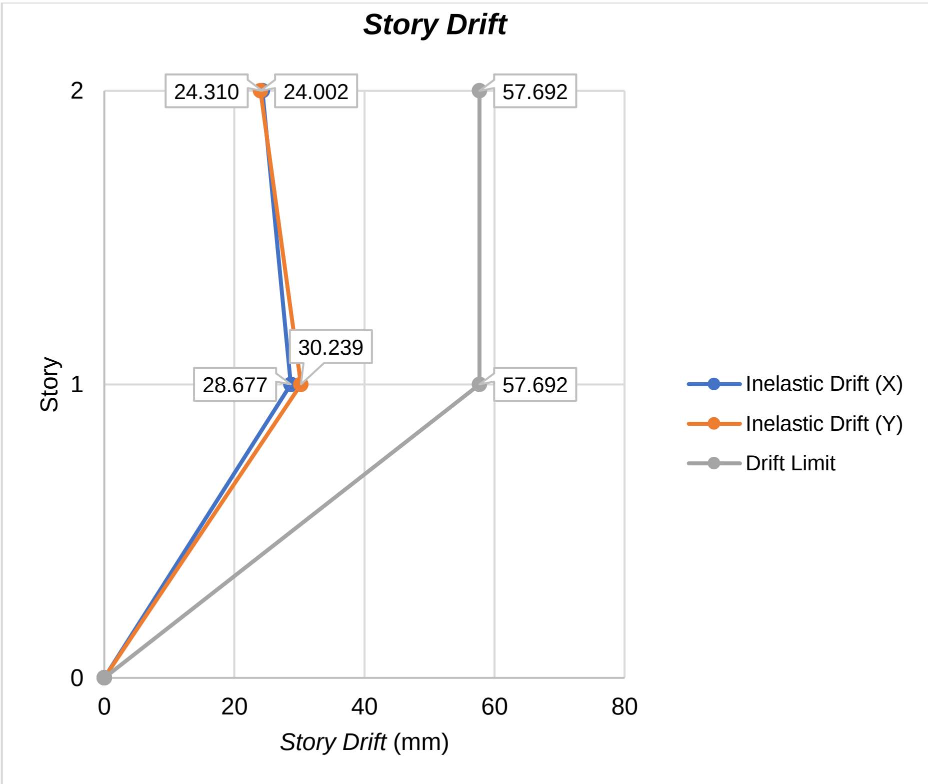

Figure 4. Graphic Story Drift Modeling Without Bracing

Table 2. Story Drift Modeling With Inverted Bracing V

Story	***h***	***Inelastic Drift***		***Drift Limit***	***Cek***
		Δ_X	Δ_Y		
	(mm)	**(mm)**	**(mm)**	**(mm)**	
2	3750	7.875	1.680	57.692	OK
1	3750	9.515	2.525	57.692	OK

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Base	0	0.000	0.000	0.000	OK

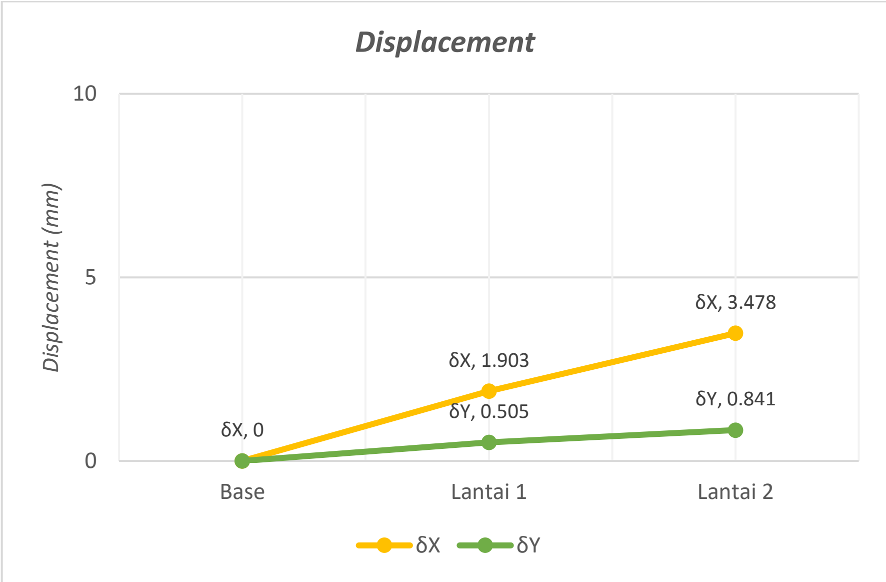

Figure 5. Graphic Displacement Modeling With Inverted Bracing V

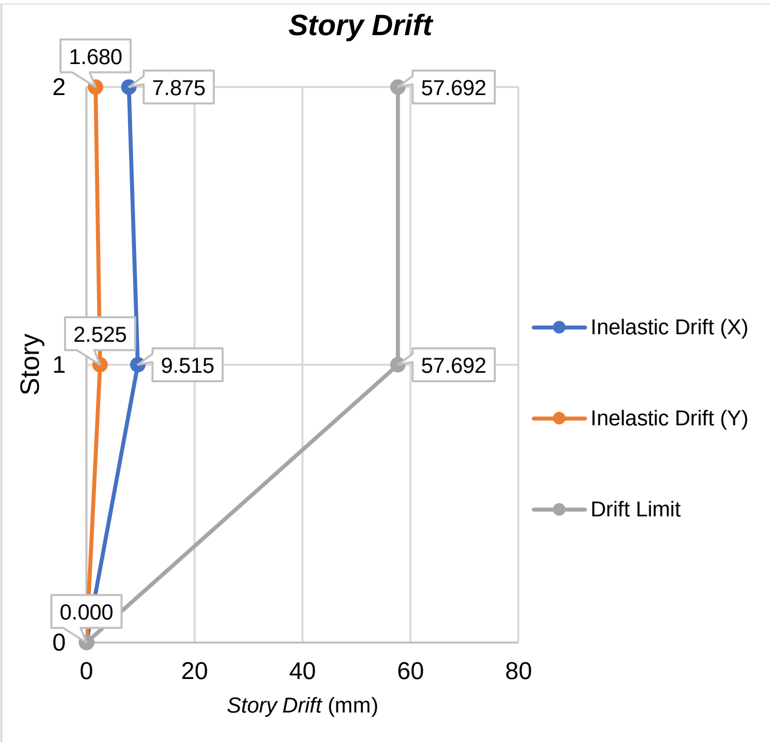

Figure 6. Story Drift Graphics Modeling With Inverted Bracing V

Table 3. Story Drift Modelling with *Bracing* X

Story	***h***	***Inelastic Drift***		***Drift Limit***	***Cek***
		Δ Δ_X	Δ_Y		
	(mm)	**(mm)**	**(mm)**	**(mm)**	
2	3750	30.635	32.753	57.692	OK

1	3750	7.849	1.804	57.692	OK
Base	0	0.000	0.000	0.000	OK

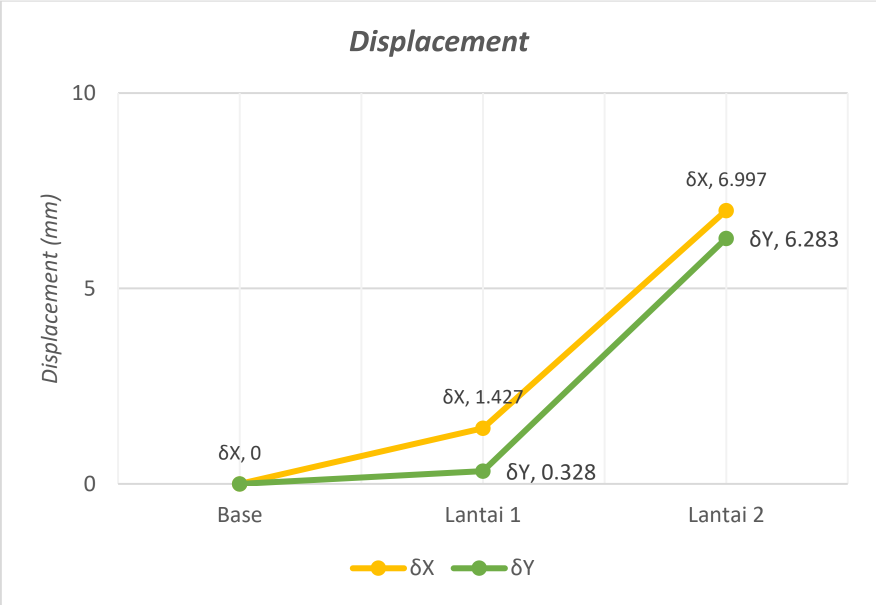

Figure 7. Graphic Displacement Modeling Using X Bracing

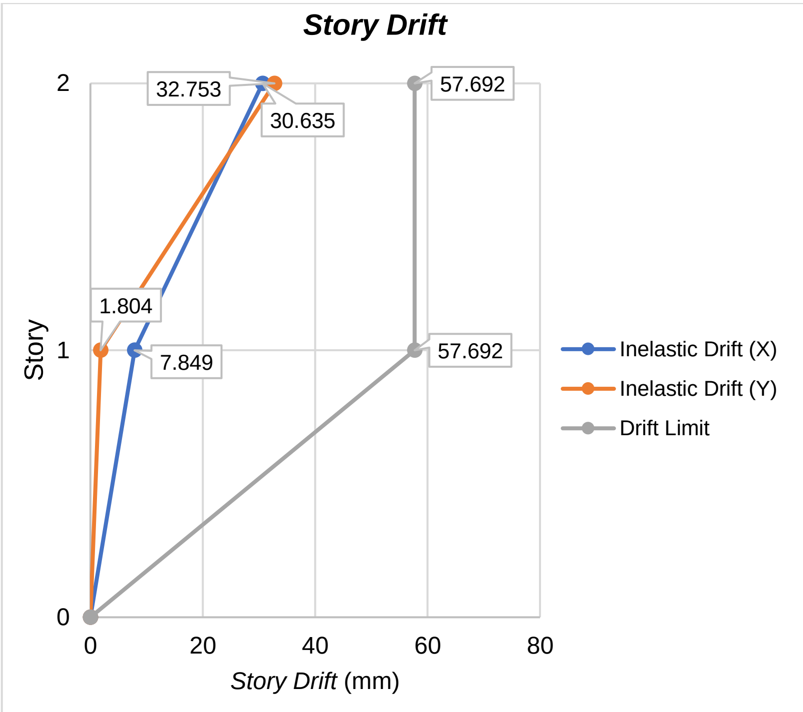

Figure 8. Story Drift Graphics Modeling Using X Bracing

Based on the results of the interstory drift calculation, the addition of inverted V bracing elements can reduce interstory drift by 67% in the X direction and 92% in the Y direction.

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Meanwhile, with the addition of X bracing, it can increase interstory drift by 26% in the X direction and 36% in the Y direction

P-Delta Effect

P-Delta effect assessment on the stage house design is adjusted to the ground site class, according to the graph results, showing that the θ values obtained in the x and y directions do not exceed the structural stability limit (θmax) of 0.09. This indicates that P-Delta impact calculation is not necessary, and the structure is still in stable condition.

The Contribution Of The Frame To Bear A Minimum Of 25% Of The Lateral Force

On a moment-bearing frame system (SRPM) in a building with a dual system is required to bear an earthquake loads of at least 25% of the total seismic loads. The process of calculating the contribution verification frame of the dual system structure is described as follows:

Table 4. Frame Contribution Verification to Earthquake Force

Element	Earthquake Force (kN)		Percentage	
	X	Y	X	Y
All Element	289.24	297.07	100%	100%
Bracing	150.89	151.70	50.60%	51.07%
Frame	147.34	145.37	49.40%	48.93

Based on the check of the frame's contribution in resisting the force of the quake, a 49, 40% contribution value of x and 48.93% on the y. therefore, frame contributions are valued as adequate because more than 25% of the output is resisting the magnitude of the quake.

Discussion

Commercial building modeling without bracing reinforcement gets results that story drift does not go past current standards. This is because the commercial building has a concrete quality high enough that the structure can support the loads without overstepping the predetermined permit limit.

The addition of steel bracing itself may reduce or add a cross-section of the building structure. The structure that USES bracing inverted v provides a maximum cross value of 9,515 mm on x and 2,525 mm on y, suggests that the use of bracing inverted v provides a 67% drift value for x and 92% for y, while the grid using bracing x makes a maximum junction of 30,635 mm on x and 32,753 mm on y, This suggests that the bracing x use of the structure provides a 26% increase in drift value for the x and the 36% for the y.

From story drift calculations it can be seen that bracing inverted v is very effective for use on the ruko building to reduce story drift on the building. Because the drift generated in bracing inverted v is significantly reduced compared to a structure without bracing.

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CONCLUSION

Based on the results of the research carried out in the analysis of structural responses, displacement, and basic sliding styles of the structure modeling and comparing the story drift that occurred on each structure, it was concluded that the building already had structural rigidity that matches the standard. However, the use of V-inverted bracing on ruko buildings is effective enough to reduce the story drift on the structure of this ruko building.

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