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Comparative analysis of the behavior of drop panel-slab system and beam-slab system using spectrum response method

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ABSTRACT

The height of a building is influenced by the needs of the room. The height of a building can be reduced by planning the structural system to be used. The use of a structural system in a building will affect the behavior of the structure when given an earthquake load. The drop-panel slab is a structural system where the slab is directly connected to the column without resting on the beam. In this system, the load received by the floor slab is directly distributed to the column. The advantage of the drop-panel slab system is easier installation of formwork and reinforcement. In addition, the drop-panel slab system will reduce the clear height of the room because there are no beams protruding under the slab. However, the drop-panel slab system has disadvantages such as limited slab span and weak in resisting shear forces. While the slab-beam system is a structural system where the slab will rest on the beam to distribute the load. The slab-beam system has advantages such as a longer span and better strength to withstand shear because there are beams as components that resist shear forces. A comparison of the behavior of the beam-slab and drop panel -slab system will be analyzed using the spectrum response method ETABS V.22 software to determine the value of the structure vibration period, base shear, the story drift, and the deflection value that occurs on the floor slab. The slab-beam structural system demonstrates a higher fundamental period in the x-direction and a lower period in the y-direction when compared with the slab-drop panel system. The value of the base shear force on the beams is also smaller than in the panel drop-drop system due to the smaller effective weight of the building as well. Likewise, the story drift that occurred in the smaller slab-beam system was 17,39% in the x-direction and 20,50% in the y-direction compared to the slab-drop panel system. This shows that the slab-beam system can be more reliable in reducing the story drift value due to earthquake loads. The value of the deflection of the floor slab calculated on the floor that experienced the greatest moment showed that the system of slabs experienced an instantaneous deflection of 10.58 mm, 26.84% bigger than the drop panel-slab system that experienced an instantaneous deflection of 7,74 mm. So that the service ability of the slab-drop panel system is better than the slab-beam system.

Keywords: beam-slab; drop panel-slab; spectrum response

1 Introduction

The need for space in a building adds complexity and innovation in planning. In order for space needs to be met in accordance with the structure and architecture, planning is needed that can accommodate each area based on its function. The method to design these needs is to utilize the slab-drop panel as a slab system for the floor. The slab-drop panel system is a two-way floor slab system that does not utilize beams as a focus [1], [2].

In the absence of beams, a slab-drop panel system will reduce the height of the room. This will be beneficial if the room requires a large enough net height without increasing the floor to floor height [3]. This system will also facilitate the implementation of tasks in the field due to more practical formwork installation, easier casting, and simple reinforcement arrangement [4], [5]. With these advantages, the slab-drop panel system will reduce costs in the implementation of the project. On the other hand, a slab system with conventional beams requires more complicated formwork planning due to the difference in the height of the slabs and beams. In addition, the arrangement of the reinforcement will be complex because it requires reinforcement of the beams on the slab using conventional beams. Even so, this system also has drawbacks such as the limitation of the slab

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range, where generally the range on the slab-drop panel system is between 6-9 meters [6]. The shear strength of the slab-drop panel is also not as large as the shear strength of the slabs that use conventional beams [7]. In contrast, a slab system with a traditional beam can withstand a greater shear force and has a longer range.

With previous research on the panel-drop panel system and the tablet-beam system, this research will make a comparison of the behavior and serviceability performance of the building structure between these two types of systems, namely the panel slab-drop system and the slab system equipped with beams, using the Spectrum Response method in accordance with SNI 1726-2019. Comparative analysis of behavior will include aspects such as vibration periods, base shear forces, story drift, as well as slab deflection. The author uses the ETABS V22 software to then analyze the results obtained from thesoftware.

2 Data and Methods

2.1 Methods

This study utilizes a literature review as a source of research data and conducts simulations using ETABS V22 software to analyze the structure through the spectrum response method in accordance with [8], [9], [10]. The research flow diagram can be seen in **Figure 1**.

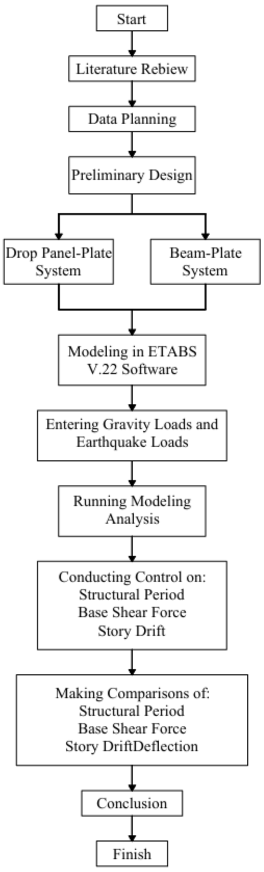

Figure 1. Research Flow Diagram

2.2 Drop Panel

Drop panel is the thickening of the slab around the column on the slab-drop panel system [2]. Drop panels are used to withstand the punching shear and negative moments on the slab in the area near the column [11], [12]. The dimensional requirement of the drop panel is that the drop panel must overhang under the slab at least 1/4 the thickness of the adjacent slab and must be extended in all directions from the midpoint of the pile, with a distance of no more than 1/6 of its span length [8].

2.3 Two-Way Slab

A two-way slab is a slab that is supported by a concentrator on all four sides and also flexes in both directions that are perpendicular to each other [13]. The ratio between the long and short sides that are perpendicular to each other does not exceed 2 [14]. On a two-way slab, the reinforcement is carried out in both directions according to the moment that arises in each direction. The minimum thickness of the two-way slab is determined by **Table 1**.

Table 1. Minimum thickness of two-way slab slabs

αfm	**Minimum h, mm**		
$\alpha fm \leq 0.2$			(a)
$0.2 \leq \alpha fm \leq 2.0$	Largest of:	$\dfrac{\ln\left(0{,}8 + \frac{fy}{1400}\right)}{36 + 5\beta(\alpha fm - 0{,}2)}$	(b)
		125	(c)
$\alpha fm > 2.0$	Largest of:	$\dfrac{\ln\left(0{,}8 + \frac{fy}{1400}\right)}{36 + 9\beta}$	(d)

Where:

αfm : Average value of αf for all beams located along the slab edge.

Ln : Effective longitudinal span measured at the interface between supports or beams (mm).

β : Ratio of the longer clear span to the shorter clear span in a two-way slab.

fy : Yield strength of the reinforcement (MPa).

2.4 Beam-Slab System

This slab system uses beams as a concentrator. The load on the slab will be channeled to the beam and then channeled back to the column. Compared with slab drop-drop panel systems, conventional slabs have several advantages, including:

a. The span of the sponge is longer.
b. The existence of a beam as a horizontal element that can withstand greater lateral forces.
c. Some of the disadvantages of using conventional slabs with beams:
d. The height between the floors is reduced due to the presence of beams under the slab.
e. Installation of formwork is more complicated due to the different heights of the slabs and beams.
f. Greater casting volume due to the presence of beams.

2.5 Drop Panel-Slab System

A slab with a drop panel (flat slab) is a two-way slab that does not use a beam where the load of the slab will be directly received by the column [13], [15]. In the flat slab system, a drop panel or column head is required to withstand the shear force. With the thickening of the slabs in the column area or the enlargement of the column head, the slab-drop panels will be able to withstand greater loads [14].

The planning of the thickness of the panel-drop panel is regulated based on [8] the determination of slab thickness is seen from the use of drop panels and the presence or absence of edge blocks. The minimum thickness of the slab-drop panel is determined by **Table 2.**

Table 2. Minimum Slab Thickness on Slab Drop Panel System

fy, mpa	No drop panel			With drop panel		
	Panel exterior		Panel Interior	Panel exterior		Panel Interior
	No edge beams	With edge beams		No edge beams	With edge beams	
280	ln/33	ln/36	ln/36	ln/36	ln/40	ln/40
420	ln/30	ln/33	ln/33	ln/33	ln/36	ln/36
520	ln/28	ln/31	ln/31	ln/31	ln/34	ln/34

There are several advantages in the use of the panel slab-drop system such as ease in assembling formwork, easier assembly of slab reinforcement, larger net height of the room so that the height of the building can be reduced [4], [5]. In addition, in the panel-drop system there are several disadvantages such as low earthquake force resisting strength due to not using beams and the presence of pons shear force that occurs on the floor slab due to shear forces and unbalanced moments[16], [17], [18] .

2.6 Dynamic Analysis (Spectrum Response)

Dynamic analysis for earthquake-resistant structure planning is carried out on buildings that are very tall or have multiple levels, are irregular, and buildings that require high precision. The strength of a building's structure is something that cannot be ignored to avoid building collapse due to earthquakes [19]. The response spectrum can be seen as an improvement compared to linear static analysis. One of the main differences between the linear static method and the response spectrum is the effect of gravity and its spread along with the height of the structure being analyzed. In the response spectrum, a response with many degrees of freedom is displayed as a modal response [20].

Response spectrum is a linear analysis method for solving dynamic equations caused by earthquakes [21]. The characteristics of the earthquake and the dynamic properties of the building will affect the response spectrum [22]. The magnitude of the base shear force and story drift can be generated from the linear analysis of the dynamic response spectrum [23].

2.7 Structure Vibration Period

Period is the time to reach a single vibration. While resonance is a state at the frequency of the structure that is equal to the frequency due to external loads. Fundamental periods need to be obtained to avoid resonance in the structure. The distribution of stiffness and mass of the structure will affect the fundamental vibration period [24]. Based on [10] the fundamental period of the approach (Ta) must be determined from the following equations:

$$\mathrm{Ta} = \mathrm{Ct} \times \mathrm{hn}^{x} \tag{1}$$

Information:
hn : height of the structure
Ct : structure type approach parameters

2.8 Base Shear

The base shear force is the lateral force that appears at the basic level [22]. The determination of the base shear force in each lateral direction is generally based on elastic response spectrum analysis [25]. The presence of shear forces on structural elements can produce bending moments . The base shear force is determined based on [10] using the formula:

$$\mathrm{V} = \mathrm{Cs} \times \mathrm{W} \tag{2}$$

Information:
Cs : the specified seismic response coefficient.
W : effective seismic weight.

To get the value of Cs using the equation:

$$\mathrm{Cs} = \frac{S_{DS}}{\left(\frac{R}{Ie}\right)} \tag{3}$$

Information:
SDS : design spectral response acceleration parameters within a period range short.
R : the response modification coefficient.
Ie : earthquake priority factor.

The value does not need to exceed the max Cs, namely:

For $T \leq TL$

$$\mathrm{Cs} = \frac{S_{D1}}{T \times \left(\frac{R}{Ie}\right)} \tag{4}$$

For $T > TL$

$$\mathrm{Csmax} = \frac{S_{D1} \times TL}{T^2 \times \left(\frac{R}{Ie}\right)} \tag{5}$$

Cs must be no less than:

$$\text{Csmin} = 0{,}044 \times S_{DS} \times \text{Ie} \geq 0{,}01 \quad (6)$$

If $S_1 \geq 0.6g$, then Cs should be no less than:

$$\text{Csmin} = \frac{0{,}5 \times S_1}{\left(\frac{R}{Ie}\right)} \quad (7)$$

2.9 Story drift

The displacement is described by the total overall lateral displacement at the top of the structure and the displacement between floors which is defined as the relative lateral displacement that occurs between two adjacent building stories [26]. Based on [10], in determining the story drift between the design floors (δ) must be calculated as the difference in story drift at the center of mass above and below at the level under review [27]. The story drift of the center of mass at the x-level (δx) in mm is determined using the formula:

$$\delta x = \frac{Cd \times \delta xe}{Ie} \quad (8)$$

Information:
Cd : Lateral story drift enlargement factor
δxe : Story drift at the required x-level
Ie : Earthquake priority factor

2.10 Deflection

In addition to safety through design capabilities, deflection control is a key element to ensure comfort, stability and structural integrity [5], [28]. Deflection occurs due to the presence of vertical loads acting on the elements resulting in a change in shape in the vertical direction [29].

The deflection in structural elements is affected by the stiffness of the elements, the magnitude of the force, and the dimensions or thickness of the elements [29]. Permit limits are needed on deflection to avoid a decline in the ability to serve the structure.

3 Results and Discussion

The structure uses reinforced concrete material with the following parameters:

1. Building type : Office Building
2. Location of the building : Banda Aceh
3. Number of floors : 5 floors
4. Height of each floor : 3.5 meters
5. Building size : 18 x 24 meters
6. Building height : 17.50 meters
7. Concrete quality (fc') : 35 MPa
8. Steel quality (fy) : 450 MPa
9. Building risk categories : II (Office building)
10. Earthquake priority factors : 1,0
11. Site classification : SE (soft soil)

In addition, there is dimensional data of elements used for modeling in software. The data can be seen in **Table 3.**

Table 3. Structural Element Data

Structural Element Data		
	Model 1	**Model 2**
Column	600 x 600	900 x 900
Beam	300 x 600	-
Floor Slabs	150	170
Drop panel	-	(t = 160 mm)

3.1 Structural Modeling

Model 1 and model 2 structural modeling using ETABS V.22 software. The results of the 3D modeling of model 1 can be seen in **Figure 2.**

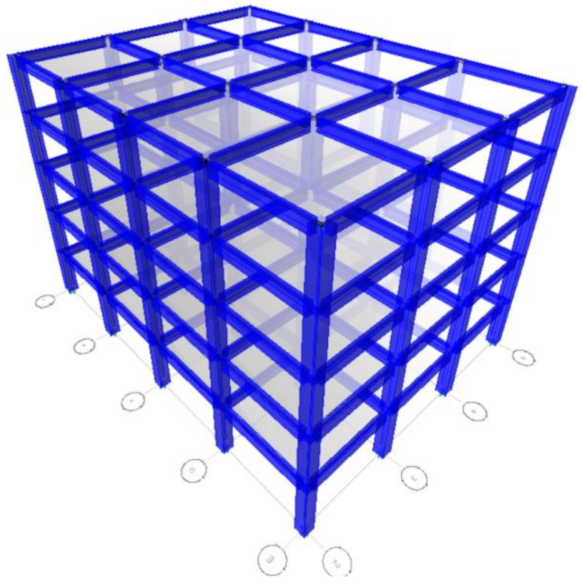

Figure 2. 3D modeling model 1

The 3D modeling model 2 in the ETABS V.22 software can be seen in **Figure 3.**

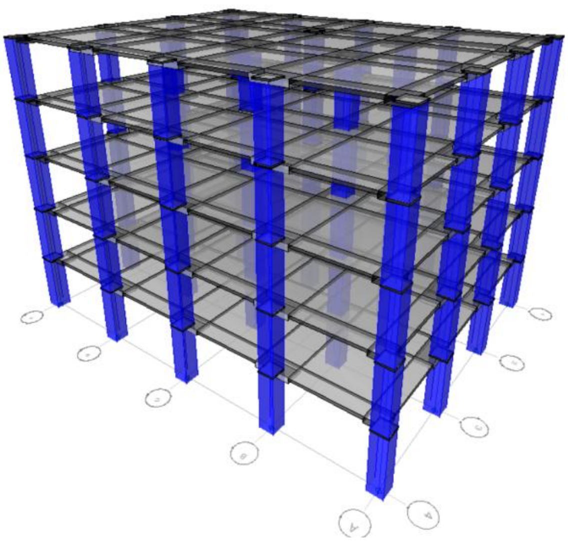

Figure 3. 3D modeling of model 2

3.2 Structure Period

A comparison of the structure vibration period taken from the results of the analysis on both model 1 and model 2 is shown in **Figure 4.**

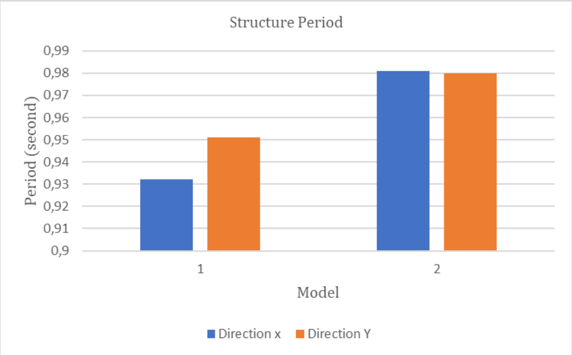

Figure 4. Comparison of X-Directional and Y-Directional Structure Periods

From the results of the analysis, the period in model 1 for the x direction is 0.932 seconds with the y direction period is 0.951 seconds. Meanwhile, in model 2, the period obtained from the results of the analysis x directions was 0.8981 seconds with the y direction is 0,980 seconds. The value also supported [30].

3.3 Base Shear

The comparison of the base shear forces of the building taken from the results of dynamic analysis on both model 1 and model 2 is shown in the following **Figure 5.**

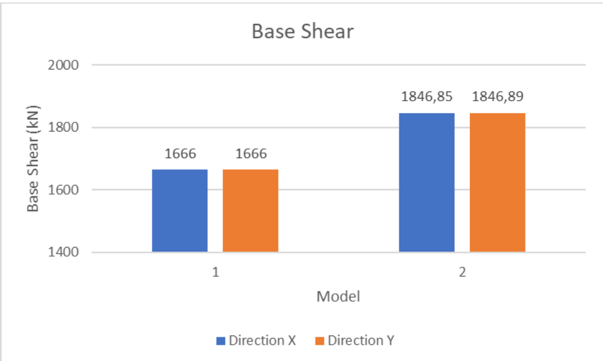

Figure 5. Base Shear Force of X-Direction and Y-Direction Buildings

The base shear value was obtained through spectrum response analysis, where the value of the dynamic base shear force for the x direction model was 1666 kN and for the y direction was 1666 kN, these results were obtained from the scaled dynamic base shear values. As for the 2nd model, the base shear force in the x direction is 1846,85 kN and for the y direction is 1846.89 kN. The value also supported [30], [31].

3.4 Story Drift

Comparison of the story drift between floors between model 1 (beam-slab) and model 2 (drop panel-slab) due to dynamic earthquake load taken from the story drift value at the center of mass. A comparison of the story drift values between the slab-beam system and the slab-drop panel in the x-direction can be seen in **Figure 6.**

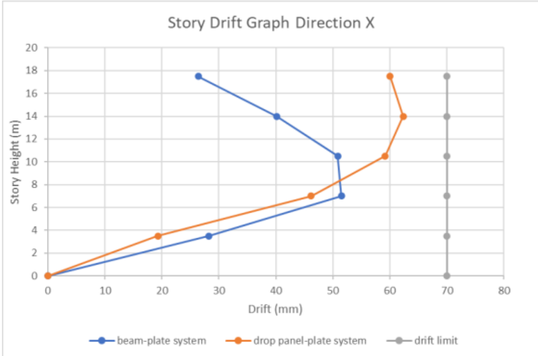

Figure 6. Comparison of Crossroads Between X-Directions Floors

A comparison of the story drift values between the slab-beam system and the slab-drop panel in the x-direction can be seen in **Figure 7**.

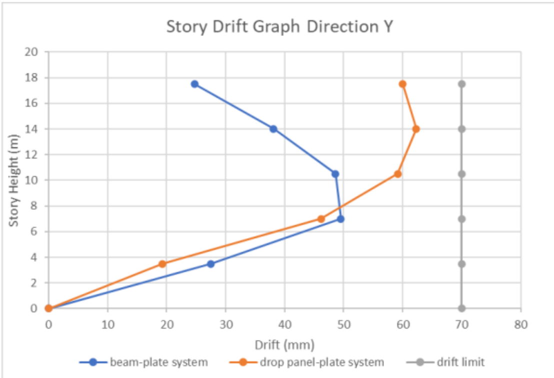

Figure 7. Comparison of Intersections Between Floors in the Y-Direction

From **Figure 6** and **Figure 7** the maximum story drift value on the slab-beam system (model 1) for the x direction is 51.49 mm and for the y direction is 49.52 mm. Meanwhile, in the slab-drop panel system (model 2), the maximum story drift value for the x direction is 62.33 mm and for the y direction is 62.29 mm. The value also supported [31], [32]. The story drift value on both structural systems is below the predefined permissible story drift value.

3.5 Deflection of Slabs

The deflection ratio obtained from the two models uses the deflection value on one of the slabs with the maximum moment value. A comparison of the deflection of the floor slabs in the two models can be seen in **Figure 8**.

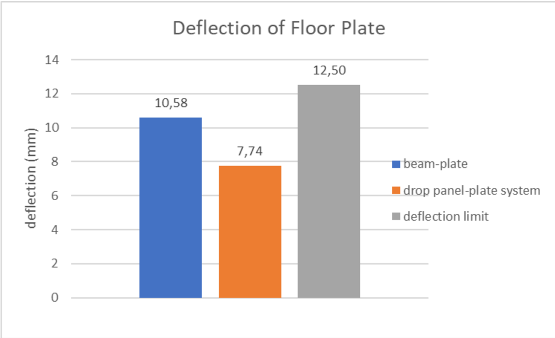

Figure 8. Comparison of Floor Slab Deflection Values (mm)

From **Figure 8**, the instantaneous deflection value of the floor slab on model 1 is 10.58 mm, while the instantaneous deflection value of the floor slab on model 2 is 7.74 mm. The deflection value on both models is lower than the maximum deflection allowed for the slab. The value also supported [29].

Meanwhile, in the calculation on the software, the deflection value in model 1 is 10.729 mm, which is shown in **Figure 9**.

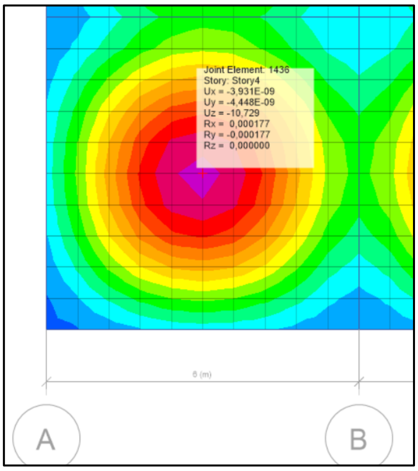

Figure 9. Floor Slab Deflection Value Model 1 ETABS V.22 Analysis Results

In model 2, the deflection value produced by the ETABS V.22 software is 8.929 mm, which is shown in **Figure 10**.

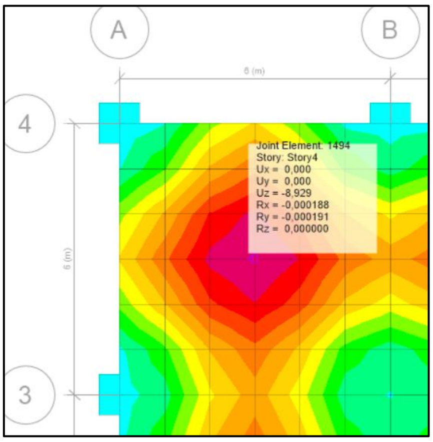

Figure 10. Floor Slab Deflection Value Model 1 ETABS V.22 Analysis Results

4 Conclusion

Based on the analysis that has been carried out, a comparison is made between the beam-slab system (model 1) and the drop panel-slab system (model 2). From the analysis of the two structural systems, conclusions were obtained, including:

1. The value of the structure vibrating period for both systems is 0.932 seconds in the x direction for model 1 (beam-slab system) and 0.951 seconds in the y direction. In model 2 (drop panel-slab system), the value of the vibrating period obtained for x directions is 0.981 seconds and 0,980 seconds in the y direction. Thus, the slab-beam system is able to withstand earthquake forces more effectively compared to the slab-drop panel system.
2. The base shear value in the slab-beam system (model 1) is 1666 kN in the x direction and 1666 kN in the y direction. Meanwhile, in the panel-drop system, the base shear value is 1846.85 kN in the x direction and 1846.89 kN in the y direction. This factor is influenced by the effective weight of both structures. The effective weight of the structure in the slab-drop system is lighter compared to the slab-drop panel system due to the larger dimensions of the structural elements in the drop panel-slab system.
3. From the comparison of the story drift values between the floors in the two structural systems, the difference in story drift values was 17,39% in the x-direction and 20,50% in the y-direction, where the slab-beam system showed a lower story drift value than the slab-drop panel system. Thus, it can be concluded that the slab-beam system (model 1) is more effective in reducing displacement than the panel-drop system.
4. From the deflection calculation in the two structural systems, a difference in deflection value of 26,84% was obtained, where the slab-beam system (model 1) had a bigger deflection value of the floor slab. From this, it can be concluded that the serviceability of the drop panel-slab system is superior to that of the beam-slab.

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