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Deflection of flat slab-drop panel in the G2 building at Warmadewa University

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ABSTRACT

To conserve building height, flat slabs are concrete structures that do not employ beams as weight transfer to columns. The flat slab system structure is prone to shear collapse due to the lack of beams. A column head is made to forward the load from the plate to the column so that the shear value in the building is not too high. This is done by expansion at the end of the column or by thickening around the critical circumference of the column and plate meeting. The Warmadewa University G2 Building Planning Analysis is carried out during the planning stage, using a flat slab-drop panel structural system as one of the optional structural systems that can be used to obtain a building height that is in accordance with Bali Provincial Regulation Number 16 of 2009 concerning the regional spatial plan of the Province of Bali. Terompong street No. 24, Sumerta Kelod, East Denpasar sub-district, Denpasar City, Bali, is where the Warmadewa University G2 building will be built. According to the soil data, the building is constructed on a medium soil site class with a building structure risk level IV. The Warmadewa University G2 Building structure was studied using etabs v.18 software in accordance with SNI 2847-2019 requirements for structural concrete for building buildings and loading in accordance with SNI 1727-2020 criteria. The biggest deflection value occurs in the middle lane due to the load from the function room, as determined by the study for the dimensions of the 350mm thick drop panel and 250mm thick slab utilizing a column size of 600 x 600 mm with a span of 8000mm. The inner drop panel experiences the highest lateral loads due to shear failure.

Keywords: *Drop panel, Flat Slab*, SNI 2847:2019

1 Introduction

Warmadewa University (Unwar) is one of the KOPERTIS Region VIII (Bali and Nusa Tenggara) large private universities (PTS). Warmadewa University is expanding with the passing of time. Unwar currently oversees seven faculties, 20 study programs, and 14,221 students. One of the challenges with so many students is the imbalance between the number of students and the number of classes offered.

The increasing number of students at Warmadewa University is not being matched by the availability of classrooms. The scarcity of classrooms has an impact on the teaching and learning process, particularly in terms of managing course schedules and class division for students. This study was undertaken at the planning stage for the future selection of the construction design of the Warmadewa University G2 building. The flat slab-drop panel method is one of the construction methods that can be used because the flat slab structural system provides a more spacious space and can reduce the height of the building structure to comply with Bali Province Regional Regulation Number 16 of 2009 concerning the regional spatial plan of Bali Province. The performance of a structure against the planned load is referred to as structural performance. The soil layer and geological circumstances have a significant impact on the performance of the construction to be built [1].

Previous research [2] examined a 5-story structure with a review of the plate element on the third level using an equivalent frame and direct design technique, in accordance with the loading requirements of SNI-2847-2013 and SNI 1727-2013. The incorporation of drop panels or column heads in the flat slab system allows for a comparison of flat plate and flat slab analysis. According to the analysis, the field moment on the flat plate is bigger than the field moment on the flat slab because the flat plate lacks additional drop panels or column heads, which impacts the computation of plate thickness, plate-beam stiffness, column stiffness, and shear resistance.

A number of structural calculations were performed to determine whether the G2 building's flat slab construction could bear the existing loads. Because the problem's scope is fairly vast, researchers exclusively investigated the reinforcement of the 5th floor flat slab with 1.2D + 1.6L loading. To achieve effective seismic design criteria and construct economical earthquake-resistant structures, solutions that can maintain high strength and stiffness while preventing brace buckling at large deformations are required [3].

Flat slabs are reinforced concrete slabs that are supported by columns plus drop panels, columns plus column heads, or no column heads at all [4]. Turner, a foreign expert, devised a kind of construction that did not use one of the basic components, namely beams, for the first time in 1906. This style of construction, which does not use beams, is known as flat slab [5]. The benefits of a flat slab structure are reduced building height, material savings, ease of access, and mechanical and electrical distribution adaptability [6]. Flat slabs have enough shear strength due to the presence of a drop panel, which is a thickening of the slab at the head of the column, to limit the amount of negative reinforcement in the supporting zone [7]. The lack of resistance to lateral loads, such as those induced by powerful winds and earthquakes, is the weakness of flat slab structures; hence, shear walls must always be installed if utilized in high-level construction. Figure 1 depicts the many varieties of flat slabs [8].

The flat-slab system, as shown in Figure 1, is a special structural form of reinforced concrete construction that possesses major advantages over the conventional moment-resisting frames [9]. Architectural demands for better illumination, lesser fire resistance of sharp corners present in the form of beams & increase in the formwork cost, optimum use of space leads to the new concept in the field of structural engineering as Reinforced concrete flat slabs [10]. The flat slab method has the advantages of reducing floor height, reducing structural loads, avoiding the use of ceilings, simpler reinforcement, and cost-effective scaffolding and formwork installation while creating a building [11]. The punching shear capability of flat slab structures, on the other hand, is uncertain and can sometimes contribute to the structure's gradual failure [12], so its structural performance must be reviewed.

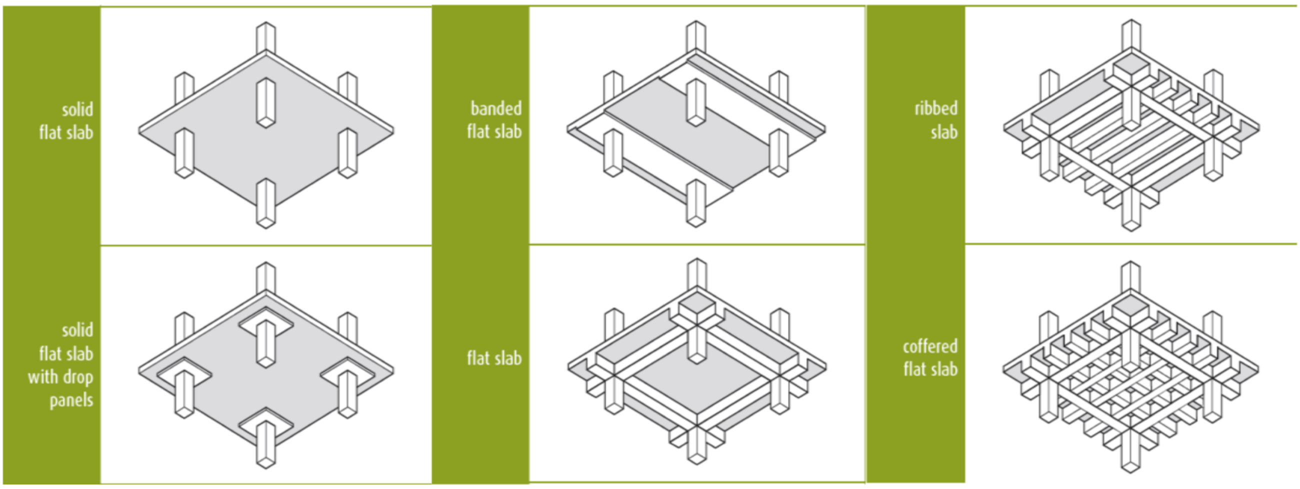

Figure 1. Flat slab type [8]

2 Analysis Methods

Based on the background, the goal of this planning is to establish the amount of moment and deflection that happens as a result of the flat slab-drop panel structural system's behavior. The following is the planning data:

a. Drop Panel Thickness = 350 mm

b. Slab Thickness = 250 mm

c. Reinforcement Quality = 420

d. Concrete Quality = 30 f'c

The flow chart in Figure 2 depicts an analysis of the flat slab-drop panel layout for Warmadewa University's G2 building. The flowchart is described as follows:

a) Enter the measurements of the flat slab and drop panel (b, h, and d) as well as the material quality (f'c and fy).

b) Entering gravity loads, namely dead and live loads, in compliance with SNI requirements: 1727-2020 [13].

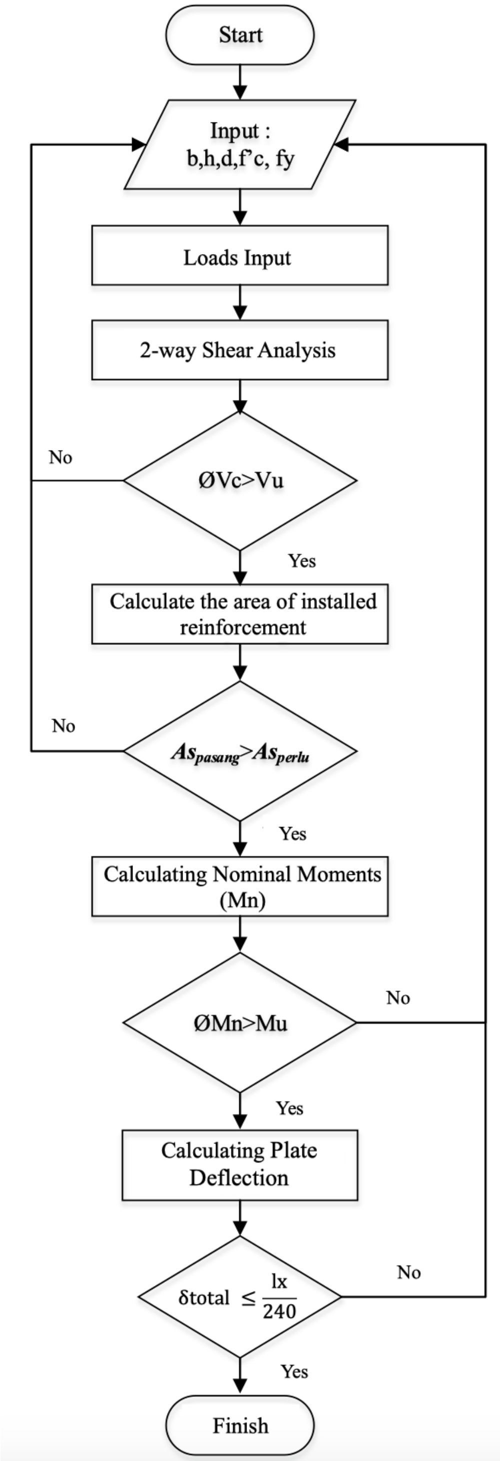

Figure 2. Flowchart of flat slab-drop panel planning for building G2

c) Comparing the pons shear to the requirements of SNI 2847-2019 [14], if the shear value exceeds the limit, return to dimension input.

d) Then compute the installed reinforcement, with the condition that the installed reinforcement must be greater than the necessary reinforcement, if the value does not meet, the reinforcement's quality can be increased.

e) If it does not satisfy the requirements, control between the nominal moment and the ultimate moment, and then return to entering the dimensions and material quality.

f) Once the nominal moment is controlled, continue to compute the slab's deflection in accordance with SNI 2847-2019. If it does not meet, return to inputting the slab dimensions, but if it meets the computation of the flat slab, the drop panel is finished.

2.1 Column Heading

The column head on a flat slab is also known as a drop panel (as shown in Figure 3), and it is an enlargement at the top of the column or at the meeting of the column and slab to obtain the length of the circumference of the column so that the pons shear caused by the load of the floor slab structure is continuous to the column and to increase the thickness of the meeting of the column and slab due to the reduction of the critical section near the column [13].

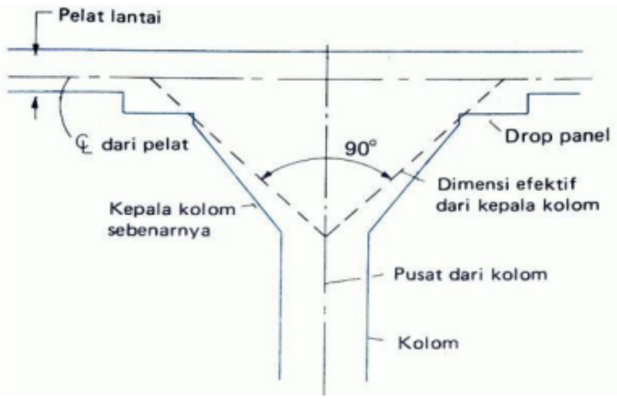

Figure 3. Flat slab construction with drop panels and column heads in the field [13]

2.2 Thickness Restrictions and Prerequisites

According to SNI 2847:2019 (page 134), the minimum thickness for non-stressed slabs without interior beams that span between supports on all sides and have a long span to short span ratio of not more than 2 shall comply with the provisions of Table 1 and Table 2.

2.3 Slab Deflection

A change in the shape of the slab structure produced by gravity loads is referred to as deflection or deflection of the floor slab. The stiffness of the structure, the type of support installed, and the type of load applied to the structure are all factors that might influence the amount of the deflection value on the floor slab [14].

The computed deflections shall not exceed the permitted deflection limits specified in Table 3 and Table 4 of SNI 2847-2019.

Table 1. Minimum thickness of non-stressed two-way plates without interior beams [14]

Fy	Without Drop Panel		
	Panel Eksterior		Panel Interior
	Without Edge Beams	With Edge Beams	
280	ℓn/33	ℓn/36	ℓn/36
420	ℓn/30	ℓn/33	ℓn/33
520	ℓn/28	ℓn/31	ℓn/31

Table 2. Non-prestressed two-way slab minimum thickness without interior beams [14]

Fy	Without Drop Panel		
	Panel Eksterior		Panel Interior
	Without Edge Beams	With Edge Beams	
280	ℓn/36	ℓn/40	ℓn/40
420	ℓn/33	ℓn/36	ℓn/36
520	ℓn/31	ℓn/34	ℓn/34

Table 3. Calculate the Maximum Permitted Deflection [14]

Structure component type	Conditions		Deflection limit
Flat roof	Not bearing or not joined with nonstructural parts that may deform owing to high deflections.		ℓ/180
Floor			ℓ/360
Roof or floor	carrying or attached to nonstructural elements	Large deflections may cause harm.	ℓ/480
		Large deflections will not harm it.	ℓ/240

Table 4. Calculation of the Maximum Permit Deflection (Continued) [14]

Structure component type	Calculated deflection	Deflection limit
Flat roof	Deflection at the instant of maximal Lr and R	ℓ/180
Floor	L-induced instantaneous deflection	ℓ/360
Roof or floor	The portion of total deflection that happens after the installation of nonstructural elements, i.e., the sum of all fixed load long-term deflection and live load instantaneous deflection	ℓ/480 ℓ/240

3 Results and Discussion

3.1 Analysis of Pons Shear

Experiments on an edge drop panel with a 350 mm thick drop panel and a 250 mm thick slab on a 7x8 meter span yielded a shear value of 492.736 kN.

Examine 2-way shear

$$\emptyset V_c > V_u$$
$$990.31\ kN > 492.736 kN$$
(**OK**)

The actual shear value resulting from the analysis is 492.736 kN, while the shear permitted by concrete is 990.31 kN, this means that the results of the flat slab structure design are safe from pons shear.

3.2 Reinforcement of Flat Slabs

The moments at the column lane (Figure 4) and the center lane (Figure 5) and and summarized in Table 5, may be observed in the figure from the loading of 1.2D+1.6 L, with the moment at the column lane being bigger than the moment at the center lane.

Table 5. Plate Moment Recapitulation Due to 1.2D+1.6L Factored Load

Lane	Section	Mu kN.m/m
Lane in the X-Direction Column	Pedestal	145.9
	Field	44.8
Column lane oriented in the Y direction	Pedestal	168.2
	Field	43.0
X direction in the center lane	Pedestal	27.7
	Field	36.4
Center lane in the Y direction	Pedestal	24.1
	Field	38.4

The reinforcement for the plate is obtained after studying the findings of the moment due to the 1.2D + 1.6L load with etabs v.18: (as shown in Table 6).

Table 6. Flat Slab Reinforcement Recapitulation

Lane	Section	Rebar
Lane in the X-Direction Column	Pedestal	D13-150mm D13-150mm
	Field	D13-100mm
Column lane oriented in the Y direction	Pedestal	D13-150mm D13-150mm
	Field	D13-100mm
X direction in the center lane	Pedestal	D13-100mm
	Field	D13-150mm
Center lane in the Y direction	Pedestal	D13-100mm
	Field	D13-150mm

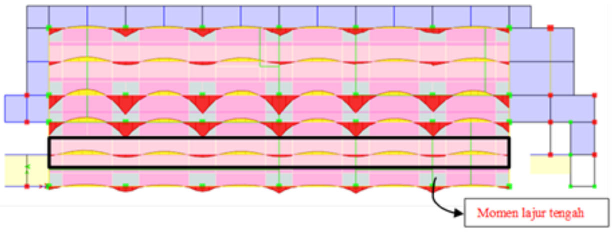

Figure 4. X-Direction Strip Moment

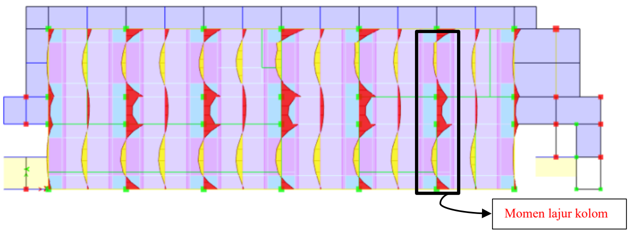

Figure 5. X-Direction Strip Moment

3.3 Control of Plate Deflection

The allowable deflection can be determined as follows:

$$L_{allow} = \frac{L}{240} = \frac{8000}{240} = 33{,}33\ mm$$

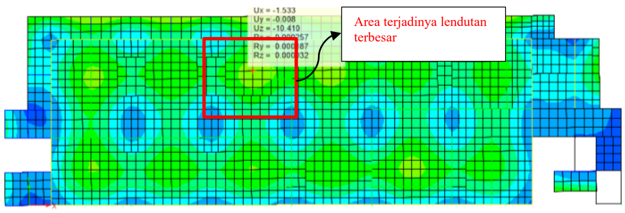

Figure 6. Deflection occurs

According to Etabs V.18 software [17], the deflection obtained on the longest span plate of 8000 mm is 10,410 mm, which is due to the evenly distributed live and dead loads on the building space functions as well as the thickening at the end of the column, which causes the deflection that occurs to be relatively small or far from the allowable deflection.

Eligibility:

$$L_{allow} > L$$
$$33{,}33\ mm > 10{,}410 mm$$
(OK)

4 Conclusion

After evaluating the structure of the calculation process on the planning of the flat slab-drop panel system of the Warmadewa University G2 Building using etabs v.18 software, the following conclusions may be drawn:

a. According to the analytical results, the plate dimension thickness is 250 mm, with a 100 mm thickening for the drop panel. For the greatest lateral load on the inner drop panel.
b. As a result of the evenly distributed gravity load in the plate area, the maximum deflection value of 10.410 is obtained at the longest column span of 8000mm, which is impacted by the load function space.

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