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Analysis of penel drop-off on shear slip at flat slab in the animal hospital education building of the Faculty of Veterinary Medicine (RSHP-FKH), Udayana University

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ABSTRACT

The Animal Hospital Education of the Faculty of Veterinary Medicine (RSHP-FKH) at Udayana University is located on Sesetan Main Road, Markisa Alley, No. 6, South Denpasar District, Denpasar, Bali. The building structure is planned with a modified flat slab design incorporating drop panels around the column areas. The purpose of this modification is to provide flexibility in spatial arrangement, facilitate the installation of mechanical and electrical systems, and indirectly meet the height requirements specified by the local regulations in Bali. The structural analysis of the Animal Hospital Education building at RSHP-FKH, Udayana University was conducted using the ETABS v.18 software, following the guidelines of the Indonesian National Standard (SNI). The analysis focused on the effect of drop panels on shear slip in the flat slab. The analysis aimed to determine the magnitude of deflection and its corresponding locations in the structure. The results of the analysis provide relevant information regarding the strength and stability of the building structure, ensuring that the RSHP-FKH building at Udayana University meets the established standards.

Keywords: Drop Panel, Flat Slab, Shear Slip, Structural System

1 Introduction

Animal Hospital is one of many healthcare facilities specifically designed to serve the healthcare needs of animals, both in terms of inpatient and outpatient care. The Animal Hospital Education Building of the Faculty of Veterinary Medicine (RSHP-KFH) at Udayana University is one of the largest animal hospitals in Bali and, of course, must have adequate infrastructure to ensure a safe and comfortable environment. The building has 4 floors, each with a height of 3.5 meters, and is located at Sesetan Main Road, Markisa Alley, No. 6, South Denpasar District, Denpasar, Bali.

A flat slab is a floor system that replaces the function of beams along the column lines with floor slabs, while edge beams may or may not be present [1]. By using the flat slab system, the loads on the slabs are directly distributed to the columns. To address this, a thicker slab or drop panel is provided around the column heads, which increases the slab's resistance to withstand punching shear and negative moments at the slab-column connections [2]. The decision to use the flat slab system with drop panels was based on research studies that compared the analysis of flat slabs and flat plates in terms of field moments [3], the influence of stiffness on the difference between flat slabs and conventional slabs [4], the effect of column heads on flat slab systems with drop panels [5], a comparison between two-way slabs with beams and flat slabs [6], the efficiency of flat slab systems with post-tensioning and conventional methods [7], punching shear behavior at column-slab connections [8], reinforcement design comparison between flat slabs and waffle slabs [9], structural modification with flat slabs and shear walls [10], and the application of value engineering by replacing plate designs with flat slab alternatives [11]. Based on the aforementioned studies, an analysis was conducted to examine the behavior of drop panels in relation to punching shear.

2 Data and Methods

Based on the background mentioned, the purpose of this design is to determine the thickness of the slab, magnitude of moments, reinforcement of the slab, and deflection resulting from the behavior of the flat slab with drop panel structural system. The analysis of the flat slab-drop panel design of the Animal Hospital Education Building (RSHP-FKH) at Udayana University was performed using the ETABS V.18 software, considering the deflection requirements stated in SNI 2847-2019 and the structural loading requirements stated in SNI 1727-2020.

To analyze the punching shear in the drop panel, the following steps were taken:

1. Creating a building structure model using the ETABS software, inputting relevant dimensions and geometry.
2. Determining the material properties for the slab and drop panel, including concrete strength and required reinforcement.
3. Establishing the applied loads on the structure, including dead loads, live loads, and other loads according to the applicable standards.
4. Performing structural analysis using ETABS, considering the interaction between the slab, drop panel, and other structural elements.
5. Analyzing the results of the structural analysis, including the magnitude of moments, deflection, and punching shear occurring in the drop panel.
6. Designing the reinforcement for the slab and drop panel based on the analysis results, considering the strength and stability requirements of the structure.

Planning data:

a. Concrete Quality f'c = 25 MPa
b. Drop Panel Thickness = 330 mm
c. Slab Thickness = 230 mm
d. Reinforcement Quality = 420 MPa

Once the structure model is established, the loading process is carried out by applying the relevant loads to the building, such as dead loads, live loads, and seismic loads. The details of the seismic loading process will be explained in more detail during the design phase, considering factors such as seismic zones, soil characteristics, and relevant seismic response spectra.

2.1. Flat slab

Two-way flat slabs are structural slabs that experience deflection in two perpendicular directions, where the flexural reinforcement is provided in both directions that are perpendicular to each other. Two-way flat slabs can be categorized into three types: slabs with supporting beams, flat slabs, and flat plates. Flat slabs are slabs directly supported by columns without the presence of beams [12]. The design of the thickness of flat slabs is determined based on [13]. For non-prestressed slabs without the use of interior beams that cross between supports on all sides, with a maximum long-span to short-span ratio of 2, the minimum thickness of the slab must meet the following limits and should not be less than the specified values:

1. Without drop panels 125mm
2. With drop panels 100mm

2.2. Drop panel

Drop panel is an additional plate in the column area, where the thickening of this plate serves to reduce the potential punching shear stress that may occur in the column area against the slab. This thickening also helps to increase the resisting moment in the area where significant negative moments occur [14]. The design of drop panels is regulated in [13] and is as follows:

1. Thickness of the drop panel

$$h_{drop\ panel} \geq \frac{1}{4} h\ plate \quad (2)$$

2. Dimensions of the drop panel

Width of the drop panel in the X-axis direction

$$L_{drop\ panel} \geq \frac{1}{6} L_x \quad (3)$$

Width of the drop panel in the Y-axis direction

$$L_{drop\ panel} \geq \frac{1}{6} L_y \quad (4)$$

2.3. Shear strength of the slab

Two-way slabs must have sufficient shear strength in each design strip in one direction (assuming the slab behaves as a wide short beam) and must also have sufficient shear strength in both directions at each column. Two-way shear strength is a critical aspect of the strength of two-way slabs. To determine the two-way shear strength, the minimum value from the following equations is considered:

$$V_{c1} = 0{,}33 \cdot \lambda \cdot \sqrt{f'_c} \cdot b_o \cdot d \quad (5)$$

$$V_{c2} = 0{,}17 \cdot \left(1 + \frac{2}{\beta}\right) \cdot \lambda \cdot \sqrt{f'_c} \cdot b_o \cdot d \quad (6)$$

$$V_{c3} = 0{,}083 \cdot \left(2 + \frac{a_s \cdot d}{b_o}\right) \cdot \lambda \cdot \sqrt{f'_c} \cdot b_o \cdot d \quad (7)$$

The critical section perimeter can be calculated based on the area of the drop panel, as follows:

1. For interior column

$$b_o = 2(B + d) + 2(H + d) \quad (8)$$

2. For corner column

$$b_o = (0{,}5d + B) + 2(0{,}5H + d) \quad (9)$$

3. For edge column

$$b_o = 2(0{,}5d + H) + 2(d + B) \quad (10)$$

Where:

$a_s = 40$ (interior column)
$a_s = 30$ (corner column)
$a_s = 20$ (edge column)

Description:
V_c = Nominal shear strength provided by concrete
f'_c = Concrete strength (MPa)
b_0 = Critical section perimeter
d = Effective thickness of the slab
B = Critical section width
β = Ratio of column width to column length

2.4. Punching shear control.

The condition for the nominal two-way shear strength of the slab to satisfy is that ($\emptyset V_c$) must be greater than the factored shear force (V_u) to ensure that the slab does not experience two-way shear failure.

Condition: $\emptyset V_c \geq V_u$ dengan $\emptyset = 0{,}75$

2.5. Reinforcement design for flexural behavior of flat slab with the addition of drop panel.

In the existing literature [13], the reinforcement design for flat slab with the addition of drop panel is determined similarly to the reinforcement design for concrete slabs, which is as follows:

$$M_n = A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right) \quad (11)$$

$$\emptyset M_n \geq M_u \quad (12)$$

Where:
M_n = Nominal moment
M_u = Ultimate moment
$\emptyset$ = Reduction factor (0,75-0,80)

3 Results and Discussion

3.1 Two-Way Shear Analysis

An experiment was conducted on the interior drop panel with a drop panel thickness of 330 mm and a slab with a thickness of 230 mm on the fourth floor, with a span in the x-direction of 2800 mm and the y-direction of 2800 mm. The ultimate shear value obtained was 1123.97 kN.

Check Two-Way Shear.

$$\emptyset V_c > V_u$$

$$1348{,}4 \text{ kN} > 1123{,}93 \text{kN}$$

(OK)

Table 1. Summary of Drop Panel Shear Calculation

Column Location	f'c	b_o (mm)	a_s	V_u (kN)	$\emptyset V_c$ (kN)	Desc.
Interior K1	25	3608	40	1123,97	1348,44	OK
Interior K2	25	3408	40	1125,58	1273,65	OK
Edge	25	2404	30	615,50	898,43	OK
Corner	25	1502	20	333,74	561,33	OK

3.2 Reinforcement of Flat Slab

Based on the analysis using ETABS v.18 software, the ultimate moment values per floor for the load combination 1.2D+1.6L are obtained for the column strip and middle strip as follows:

Table 2. Summary of Drop Panel Shear Calculation

Strip	Part	2nd floor M_u kN.m	3rd floor M_u kN.m	4th floor M_u kN.m
Column lane-x	End	154,60	151,00	170,90
	Mid	44,70	36,50	51,30
Column lane-y	End	125,20	120,00	133,50
	Mid	28,40	27,60	33,30
Middle lane-x	End	47,50	59,20	41,70
	Mid	33,70	34,90	42,50
Middle lane-y	End	12,70	13,10	20,20
	Mid	22,20	26,70	33,90

After analyzing the moment values resulting from the 1.2D+1.6L load combination using ETABS v.18, the reinforcement for the slab is obtained as follows:

Table 3. Recapitulation of Reinforcement for Flat Slab on Floors 2, 3, and 4.

Strip	Part	Reinforcement Bars	Reinforcement Bars'
Column lane-x	End	D13-200 D16-200	D13-100
	Mid	D13-100	D13-200
Column lane-y	End	D13-200 D16-200	D13-100
	Mid	D13-100	D13-200
Middle lane-x	End	D13-100	D13-200
	Mid	D13-100	D13-200
Middle lane-y	End	D13-100	D13-200
	Mid	D13-100	D13-200

3.3 Drawing of the design

Here are the results of the detailed reinforcement design drawing located on the flat slab and drop panel, as follows:

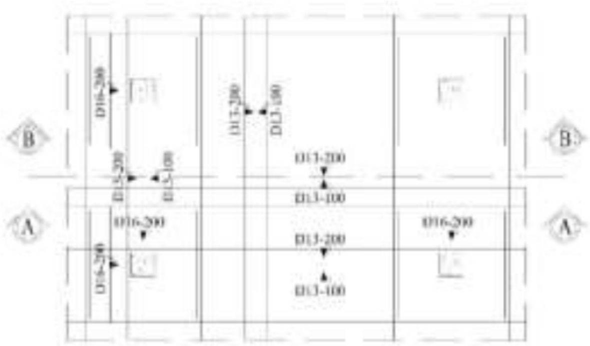

Figure 1. Reinforcement Plan of Flat Slab and Drop Panel on 2nd floor

In Figure 1, the reinforcement plan for the flat slab and drop panel shows the use of D13 and D16 reinforcing bars, with the spacing ranging from 100 mm to 200 mm.

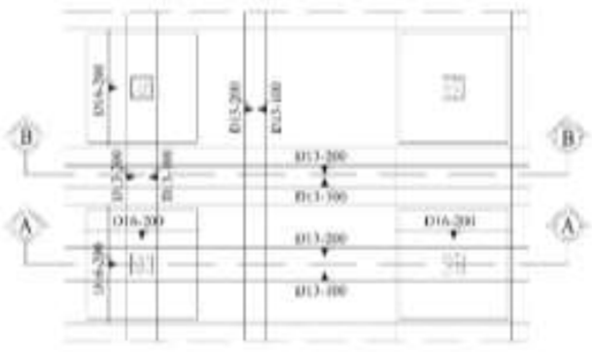

Figure 2. Reinforcement Plan of Flat Slab and Drop Panel on 3rd floor

In Figure 2, the reinforcement plan for the flat slab and drop panel shows the use of D13 and D16 reinforcing bars, with the spacing ranging from 100 mm to 200 mm.

Figure 3. Reinforcement Plan for Flat Slab and Drop Panel on Floor 4th floor

In Figure 3, the reinforcement plan for flat slab and drop panel is depicted. The reinforcement bars used are of sizes D13 and D16, with the spacing of reinforcement ranging from 100 mm to 200 mm.

4 Conclusion

Based on the results and discussions above, several conclusions can be drawn, including the following:

1. The thickness of the flat slab used is 230 mm.
2. The dimensions of the drop panel obtained are 2800 mm x 2800 mm, with a thickening in the drop panel area of 330 mm.
3. The planned flat slab with the addition of drop panels in the column end area meets the safety requirements against shear forces at each column location (interior K1, interior K2, sides, and corners).
4. The planned flat slab with the addition of drop panels meets the safety requirements against bending, with reinforcement used for the second floor ranging from size D13 and D16, with an average spacing of 100 mm-200 mm (according to Table 3). For the third floor, reinforcement ranging from size D13 and D16, with an average spacing of 100 mm-200 mm (according to Table 4), and for the fourth floor, reinforcement ranging from size D13 and D16, with an average spacing of 100 mm-200 mm (according to Table 5).

References

[1] M. C. Munawar, "Kajian Struktur Bangunan Gedung Politeknik Perkapalan Its Dengan Sistem Plat Dan Balok Biasa Konvensional Dibandingan Sistem," *Jurnal Teknik SIpil Untag Surabaya,* pp. 83-92, 2014.

[2] V. E. Sakul, "Perencanaan bangunan bertingkat banyak menggunakan Sistem Flat Slab dengan Drop Panel," *Jurnal Sipil Samratulangi Mando,* pp. 1703-1710, 2019.

[3] F. N. Constantine, "Studi Perbandingan Analisis Flat Slab Dan Flat Plate," *Jurnal Sipil Statik,* pp. 1397-1406, 2019.

[4] K. Anwar, "Analisis Perbandingan Flat Slab dan Pelat Konvensional Terhadap Pengaruh Kekakuan Struktur Gedung Jogja Apartel," 2021.

[5] D. R. Gea, "Analisis Pengaruh Penggunaan Column Head Pada Sistem Flat Slab Dengan Drop Panel," *JMTS: Jurnal Mitra Teknik Sipil,* p. 2847, 2019.

[6] M. I. Syamsi, "Perbandingan Analisis Two Way Slab With Beam dengan Flat Slab (Studi Kasus: Coal Yard PLTU Kalimantan Barat)," *Semesta Teknika,* pp. 168-175, 2016.

[7] A. Primakov, "Kajian Efisiensi Sistem Flat Slab Dengan Metode Post-Tension Dan Konvensional," *JMTS: Jurnal Mitra Teknik Sipil,* p. 133, 2019.

[8] M. Zardi, "Perilaku Punching Shear Pada Hubungan Kolom Bulat Dengan Flat Slab Akibat Beban Tekan Aksial," *Jurnal Teknik Sipil Unaya,* pp. 1-14, 2019.

[9] A. M. Kusnita, "Komparasi Desain Penulangan Flat Slab Dan Waffle Slab Pada Struktur Bangunan Bertingkat," pp. 1-187, 1997.

[10] F. A. A. Dian, "Desain Modifikasi Struktur Gedung Apartemen One East Surabaya Menggunakan Struktur Flat Slab Dengan Penambahan Shear Wall," *Jurnal Teknik ITS,* 2019.

[11] M. W. Ramadhan, "Penerapan Rekayasa Nilai Perkejaan Pelat Lantai Pada Proyek Pembangunan Hotel Batiqa Pekanbaru," *Jurnal Rekayasa dan Manajemen Konstruksi,* pp. 1-10, 2020.

[12] Nawy, Beton Bertulang Suatu Pendekatan Dasar, 1998.

[13] SNI 2847:2019 Persyaratan beton struktural untuk bangunan gedung, Indonesia: Badan Standarisasi Nasional, 2019.

[14] Apriyani, Kalimantan Timur Dengan Menggunakan Metode Flat Slab dan Drop Panel, Kalimantan Timur: Jurnal Teknik, 1945.

[15] I. N. Sinarta and I. M. B. Pinandika, "Comparison Of Pushover Method And Direct Displacement Method In Earthquake Load Analysis With Performance-Based Design Concepts," *Ukarst : Universitas Kadiri Riset Teknik Sipil.,* vol. 4, p. 3, 2020.

[16] I. W. M. Andreasnata, I. N. Sinarta, N. K. Armaeni1, I. Sarassantika, D. T. Trung, C. B. Casita, R. Sulaksitaningrum and S. Tampubolon, "Column structure strengtheningwith FRP (Fiber Reinforced Polymer) due to storyaddition," *Journal Of Infrastructure Planning and Engineering (JIPE),* vol. 1, p. 1, 2022.

[17] K. Anwar, "Analisis Perbandingan Flat Slab dan Pelat Konvensional Terhadap Pengaruh Kekakuan Struktur Gedung Jogja Apartel," *Program Studi Teknik Sipil Fakultas Teknik Sipil Dan Perencanaan Universitas Islam Indonesia,* p. 16, 2021.

[18] S. Desiyani, "Analisis Perilaku Sistem Flat Slab-Drop Panel Dengan Balok Semu Terhadap Gaya Lateral Pada Struktur Basement," *Program Studi Pendidikan Teknik Bangunan Fakultas Teknik Universitas Negeri Jakarta,* p. 18, 2018.