Scholars Journal of Engineering and Technology

OPEN ACCESS

Abbreviated Key Title: Sch J Eng Tech
ISSN 2347-9523 (Print) | ISSN 2321-435X (Online)
Journal homepage: https://saspublishers.com

Investigation of the Influence of Drop Panels on Natural Period of Vibration of Flat Slab Building Structures

Samsul Abdul Rahman Sidik Hasibuan[1*]

[1]Department of Civil Engineering, Faculty of Engineering, Universitas Medan Area

DOI: 10.36347/sjet.2024.v12i06.002 | **Received:** 15.05.2024 | **Accepted:** 27.06.2024 | **Published:** 28.06.2024

***Corresponding author:** Samsul Abdul Rahman Sidik Hasibuan
Department of Civil Engineering, Faculty of Engineering, Universitas Medan Area

Abstract **Original Research Article**

Investigation on the influence of drop panels on the natural period of vibration of flat slab building structures has been conducted in this study. Drop panels are structural elements projected beneath slabs around columns to enhance stiffness and structural capacity. Numerical modeling was performed for flat slab building structures with and without drop panels using ETABS software. Modal analysis was employed to determine the natural vibration periods of the structures in their initial modes. The results indicate that the use of drop panels significantly reduces the natural vibration period of the structure. In structures with drop panels, the natural vibration period values for mode 1 and mode 2 were 0.7493 seconds, whereas in structures without drop panels, the natural vibration period values for mode 1 and mode 2 were 0.8380 seconds. The difference of 0.0887 seconds indicates an overall increase in structural stiffness with the presence of drop panels. A lower natural vibration period implies increased resistance of the structure to lateral forces such as seismic. The effectiveness of drop panels in reducing natural vibration periods depends on factors such as drop panel dimensions, structural materials, and applied structural loads. This study contributes to understanding the influence of drop panels on the dynamic behavior of flat slab building structures and provides guidance in designing optimal structures for lateral force resistance.

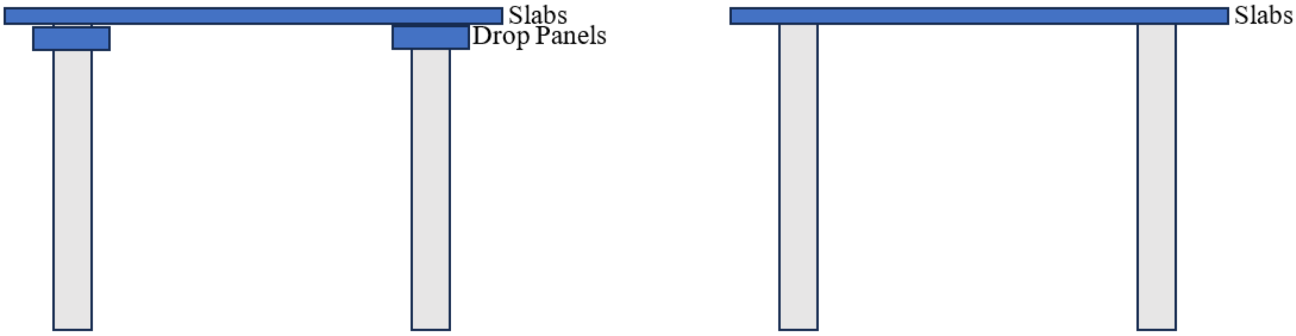
Keywords: Drop Panel, Flat Slab Structure, Natural Period of Vibration, Modal Analysis, Numerical Modeling.

INTRODUCTION

High-rise building construction has become increasingly common in densely populated urban areas (Romanova, 2018; Guan, 2019). One of the structural systems frequently employed in high-rise construction is the flat slab system (Figure 1). This system is known for its ease of design and construction flexibility, where reinforced concrete slabs are directly supported by columns without the need for connecting beams (Pan g *et al.*, 2021; El-Enein *et al.*, 2014). The use of flat slabs allows for a reduction in overall floor height, increased flexibility in spatial layout, and simplification of formwork, thereby reducing construction time and costs (Hawkins *et al.*, 2016; Hewavitharana, 2017). However, this system has several drawbacks, particularly in terms of resistance to dynamic loads such as seismic (Wang & Zhao, 2018). One of the main weaknesses of flat slab systems is the low shear capacity around columns, which can lead to structural failure at critical points. To address this issue, the addition of drop panels is often employed (Sreevalli, 2021; AlHarras, 2015). Drop panels are local reinforcements beneath the slab around columns designed to enhance shear capacity and reduce deflection (Yankelevsky *et al.*, 2021; Kenea & Feyissa, 2022). For non-prestressed slabs without interior beams spanning between supports on all sides that have a maximum span-to-depth ratio of 2, the overall slab thickness must not be less than the limits specified in Table 1 (SNI 2847, 2019). A drop panel used to reduce thickness must meet the minimum requirements outlined in Table 1, including:

1. The drop panel must protrude below the slab by at least one-quarter of the adjacent slab thickness.
2. The drop panel must extend in every direction from the centerline of the support with a column head, used to enlarge the critical shear section at the slab-column joint, which should protrude below the slab and extend horizontally from the column face at a distance at least equal to the column head thickness.

In this paper, building structures with and without drop panels are modeled using ETABS software (Nishanth *et al.*, 2020; Chandravanshi, 2022; Anjaneyulu & Prakash, 2016; Hasibuan *et al.*, 2022). The addition of drop panels is expected to enhance local stiffness around columns and thereby improve the dynamic performance of the building structure. This study aims to evaluate the influence of adding drop panels on the natural vibration period of flat slab building structures using ETABS software. Additionally, the study aims to provide practical recommendations for engineers and designers to enhance the dynamic resistance of buildings with flat slab systems. The natural vibration period is a critical parameter in structural dynamic analysis, representing the time taken by a structure to complete one cycle of natural vibration (Géradin & Rixen, 2014; Myklestad, 2018). A thorough understanding of the natural vibration period is crucial because structures with a period close to the seismic vibration period can undergo resonance, leading to significantly increased seismic response in the structure. Previous studies have shown that the addition of drop panels can increase the strength and stiffness of slabs around columns. Muhammed (2024) found that drop panels can increase shear capacity by up to 30% in reinforced concrete slabs. Additionally, study by Hartawan *et al.,* (2023) indicated that the use of drop panels can reduce slab deflection by up to 20%. However, most of these studies focus on static aspects and load capacities, while the effects on dynamic characteristics, such as natural vibration period, require further investigation. In this context, the use of ETABS software as a numerical analysis tool offers the capability to conduct more in-depth simulations and evaluations of the dynamic response of flat slab structures. ETABS is widely used structural analysis software in the construction industry, capable of static and dynamic analyses, including modal analysis to determine natural vibration periods and mode shapes of structures. Through ETABS, various drop panel configurations can be analyzed to assess their influence on the natural vibration period of flat slab building structures. The scope of this study includes analyzing various drop panel configurations and their effects on the natural vibration period of flat slab building structures. The modeled structure is a multi-story building with a flat slab system, with parameters varied including drop panel thickness and size. Simulations are conducted by modeling buildings with and without drop panels, and comparing the analysis results to evaluate the influence of drop panels on the natural vibration period of structures. This study aims to evaluate the impact of adding drop panels on the natural vibration period of flat slab building structures. The novelty of this study lies in its specific focus on the natural vibration period of flat slab structures with drop panels, utilizing numerical analysis based on ETABS software, which has not been extensively discussed in previous literature. Thus, the findings from this study are expected to make a significant contribution to the design of structures that are more resistant to dynamic loads, particularly in earthquake-prone areas. In conducting this study, the first step involves modeling multi-story building structures with flat slab systems using ETABS. This model encompasses various drop panel configurations to observe their varying effects. Upon completing the model, modal analysis will be conducted to determine the natural vibration period and mode shapes of the structure. Given the critical importance of building resilience to seismic in disaster-prone areas, the outcomes of this study are anticipated to contribute to safer and sustainable development. By utilizing ETABS, this study can provide a deeper and more comprehensive analysis, including simulating structural responses to realistic seismic loads. The results of this study are expected to offer new insights into the role of drop panels in enhancing the dynamic performance of flat slab building structures. Through accurate modeling and detailed analysis using ETABS, this study aims to provide a clearer understanding of how drop panels influence the natural vibration period and dynamic response of such structures. Overall, this study has the potential to make a significant contribution to the field of civil engineering, particularly in the design and analysis of high-rise building structures. By focusing on natural vibration periods and employing advanced analysis software such as ETABS, this study can yield relevant and applicable findings to enhance the safety and efficiency of future buildings.



a. Flab slabs with drop panels   b. Flab slabs without drop panels

Gambar 1: Flat slabs system

Table 1: Minimum thickness of two-way non-stressed slabs without beams

Ƒy, (MPa) [2]	Without drop [3]			With drop [3]		
	Eksterior Panels		*Interior* Panels	*Eksterior* Panels		*Interior* Panels
	Without edge beams	With edge beams [4]		Without edge beams	With edge beams [4]	
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

Note:
1. ℓn is the clear span length, measured from face to face of supports (mm).
2. For fy values falling between those provided in the Table, the minimum thickness must be calculated using linear interpolation.
3. The drop panel shall comply with b.1) and b.2).
4. Slabs with beams between columns along exterior edges. Exterior panels shall be considered without edge beams if αf is less than 0.8. The value of αf for edge beams shall be calculated according to equations 1 and 2.

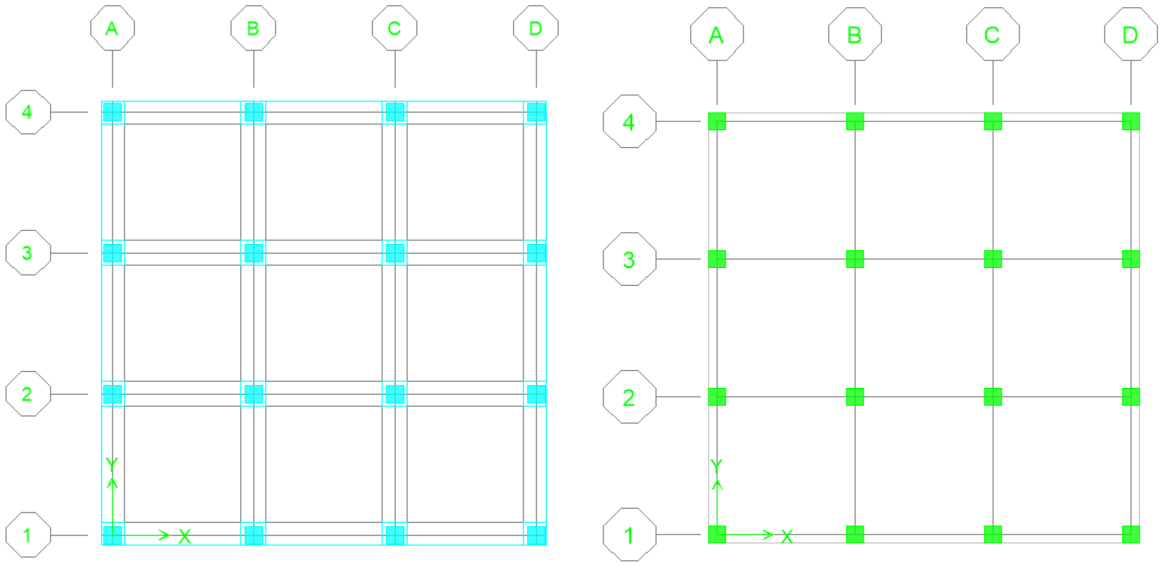
METHODS

This method is designed to evaluate the effect of adding drop panels on the natural vibration period of flat slab building structures using ETABS software. The study includes modeling and modal analysis of a four-story building structure, both with and without drop panels, to understand the impact of drop panel additions on the dynamic characteristics of the structure. The building structure modeled in this study is a four-story building with a flat slab system.

Two structural models were created: one with drop panels and one without drop panels. The floor plan of the structure with drop panels and without drop panels is shown in Figure 2. The building structure used in the modeling has the following data:

1. Columns used are square columns with dimensions of 500 x 500 mm. The selection of square columns is based on the need to provide adequate stiffness and stability to the building structure.
2. The height of the columns between floors is 4 meters. This height was chosen to provide sufficient space on each floor and aligns with multi-story building standards.
3. The assumed number of reinforcements used is 8 bars with a diameter of 22 mm. This selection is based on the need to withstand significant structural loads and ensure sufficient strength in the columns.
4. The length and width between columns are 4 meters, creating a uniform grid structure and facilitating analysis.
5. The number of analyzed levels is 4, representing a medium-rise building commonly found in urban environments.
6. Concrete strength (F'c) and steel strength (F'y) use default values from the ETABS software, considered representative for standard materials in building construction.
7. Based on Table 1, the thickness of the slab used is 135 mm, in accordance with standard recommendations to ensure adequate strength and stiffness.
8. The thickness of the drop panel used is 170 mm, with dimensions of 600 x 600 mm. This drop panel is designed to enhance shear capacity and stiffness around the columns.

The process of modeling the structure in the ETABS software begins with defining the material and structural element properties. Concrete and steel materials are defined according to the specified strengths. After completing the structural modeling, the next step is modal analysis. Modal analysis aims to determine the natural vibration periods and mode shapes of the structure. In this analysis, the structure is virtually vibrated to identify its natural vibration characteristics. The results of modal analysis provide information on natural vibration periods, which are crucial for evaluating the dynamic response of the structure to seismic loads. The steps of modeling and analysis using ETABS software are presented in a flowchart in Figure 3. This flowchart explains the stages from material definition, structural element modeling, addition of drop panels, to modal analysis. By following the established procedures, this study is expected to yield valid and reliable results in evaluating the influence of drop panels on the natural vibration periods of flat slab building structures.



a. **Flab slabs with drop panels** b. **Flab slabs without drop panels**

Figure 2: Grid configuration in building structure with and without drop panels

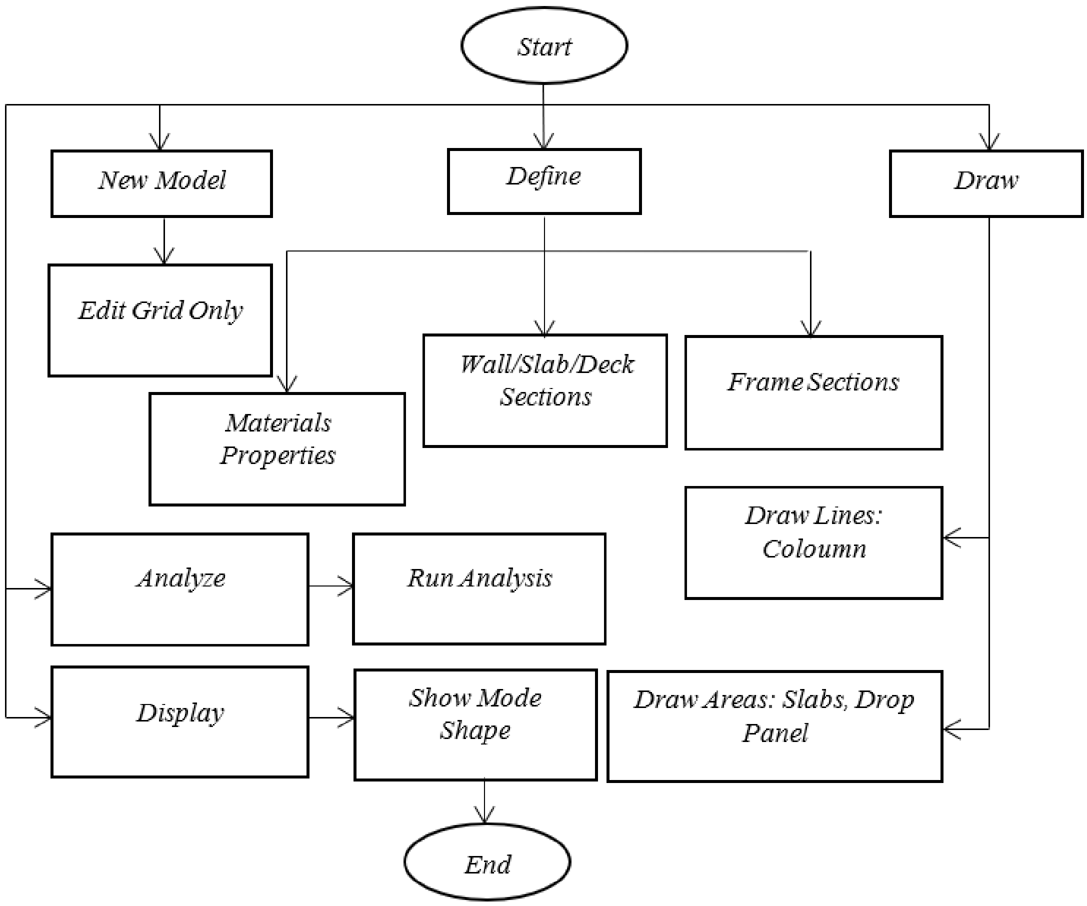
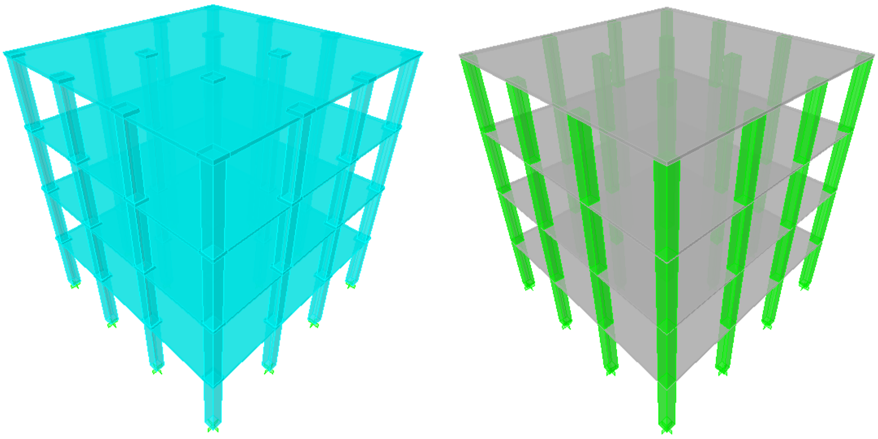


Figure 3: Steps of modeling and analysis with ETABS software

RESULTS AND DISCUSSION

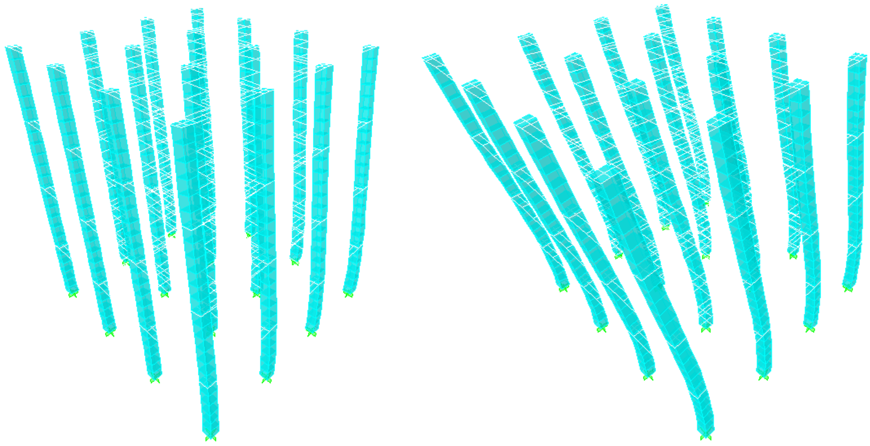
Results

The results of modeling the building structure with and without drop panels using ETABS software are shown in Figure 4. Subsequently, modal analysis was performed by executing the "run analysis" command and selecting the "show mode shape" option to obtain outputs such as mode shapes or natural periods of vibration for the building structure with and without drop panels, as depicted in Figures 5 and 6.



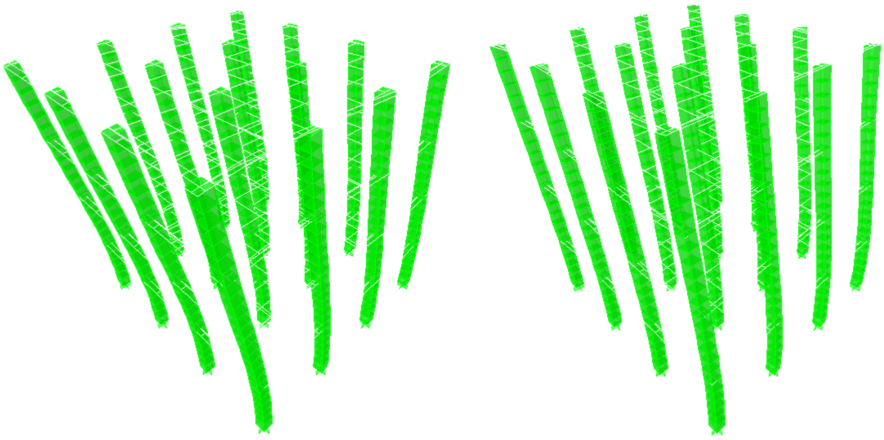
a. **Flab slabs with drop panels** b. **Flab slabs without drop panels**

Figure 4: Building structure modeling results



a. **Mode 1** b. **Mode 2**

Figure 5: Results of the natural period of vibration of the flat slab building structure with drop panels



a. **Mode 1** b. **Mode 2**

Figure 6: Results of the natural period of vibration of the flat slab building structure without drop panels

DISCUSSION

Based on the analysis conducted, it was found that the use of drop panels in flat slab building structures significantly affects the natural vibration period of the structure. In modes 1 and 2, buildings with drop panels exhibited lower natural vibration periods compared to those without drop panels. Specifically, for structures with drop panels, the natural vibration period values for modes 1 and 2 were 0.7493 seconds. Meanwhile, for structures without drop panels, the natural vibration period values for modes 1 and 2 were 0.8380 seconds. This difference of 0.0887 seconds indicates that drop panels can effectively reduce the natural vibration period of the structure, particularly in the initial modes. The lower natural vibration period in structures with drop panels suggests an overall increase in structural stiffness.

This aligns with previous studies conducted by Momeni *et al.*, (2021) and Koh *et al.*, (2021), where drop panels positioned under slab around columns enhance the joint strength between the slab and column, thereby increasing the stiffness of the slab in that area. With drop panels, the structural stiffness increases, resulting in shorter natural vibration periods. The reduction in natural vibration periods in structures with drop panels has significant implications for seismic structural response. Structures with shorter natural vibration periods tend to withstand lateral forces such as seismic better, experiencing smaller displacements and deformations during seismic vibrations. This is due to the higher structural stiffness, enabling the structure to absorb and dissipate seismic energy more effectively. However, it is important to note that the effectiveness of drop panels in reducing natural vibration periods and enhancing structural stiffness depends on other factors such as drop panel dimensions, structural materials, and applied structural loads. Larger drop panel dimensions lead to greater stiffness enhancements. Similarly, the use of stiffer structural materials, such as high-strength concrete, increases the effectiveness of drop panels in enhancing structural stiffness. In addition to their influence on natural vibration periods, drop panels can also alter the deformation patterns and mode shapes of the structure in specific modes. Further analysis is required to evaluate the effect of drop panels on the mode shapes of the structure, particularly in modes that significantly contribute to seismic response. By understanding the influence of drop panels on natural vibration periods and mode shapes, engineers can design flat slab building structures that are safer and more resilient to seismic. Optimal design of drop panel dimensions and configurations can be implemented to achieve desired natural vibration periods and minimize structural deformations and displacements under lateral seismic forces.

CONCLUSION

This study investigated the effect of drop panel usage on the natural vibration period of flat slab building structures through modeling and numerical analysis using ETABS software. Modal analysis results demonstrated that drop panels significantly reduce the natural vibration period of the structure, particularly in modes 1 and 2. For buildings with drop panels, the natural vibration period values for modes 1 and 2 were 0.7493 seconds. In contrast, for buildings without drop panels, the natural vibration period values for modes 1 and 2 were 0.8380 seconds. This difference of 0.0887 seconds indicates that drop panels effectively reduce the natural vibration period of the structure in initial modes. Key findings from this study include:

1. Drop panels placed under the slab around columns enhance the overall structural stiffness, thereby reducing the natural vibration period.
2. The lower natural vibration period in structures with drop panels implies increased resilience against lateral forces such as seismic, resulting in smaller displacements and deformations during vibrations.
3. The effectiveness of drop panels in reducing natural vibration periods and enhancing structural stiffness depends on factors like drop panel dimensions, structural materials, and applied loads.

Thus, this study provides insights that the use of drop panels in flat slab building structures can be an effective solution to enhance stiffness and resilience against lateral forces, especially when designed with optimal dimensions and configurations. The findings of this study can serve as a reference for engineers in designing safe, efficient, and earthquake-resistant flat slab building structures.

BIBLIOGRAPHY

1. AlHarras, O. (2015). Seismic behaviour and nonlinear modeling of reinforced concrete flat slab-column connections (Doctoral dissertation, University of British Columbia).
2. Anjaneyulu, B., & Prakash, K. J. (2016). Analysis and design of flat slab by using Etabs software. International Journal of Science Engineering and Advance Technology, 4(2), 105-112.
3. Chandravanshi, C. K. (2022). Seismic Analysis of building Structures with different Slab arrangements by using ETABS Software. International Journal of Civil Engineering Applications Research, 3(1), 15-19.
4. El-Enein, H. A., Azimi, H., Sennah, K., & Ghrib, F. (2014). Flexural strengthening of reinforced concrete slab–column connection using CFRP sheets. Construction and Building Materials, 57, 126-137.
5. Géradin, M., & Rixen, D. J. (2014). Mechanical vibrations: theory and application to structural dynamics. John Wiley & Sons.
6. Guan, C. (2019). Spatial distribution of high-rise buildings and its relationship to public transit development in Shanghai. Transport Policy, 81, 371-380.
7. Hartawan, I. M. N., Indra, M. N. P., Sinarta, I. N. S. I. N., Erick, T. I. W. G., & Ellsa, S. I. P. (2023). Deflection of Flat Slab-Drop Panel in The G2 Building at Warmadewa University. Journal of Infrastructure Planning and Engineering (JIPE), 2(2), 27-32.
8. Hasibuan, S. A. R. S., Anisa, Y., Asmi, F., Ridwan, A., & Salam, R. (2022). KONTRIBUSI DROP PANEL PADA STRUKTUR GEDUNG TIPE FLAT SLAB. JOURNAL OF CIVIL ENGINEERING BUILDING AND TRANSPORTATION, 6(2), 97-103.
9. Hawkins, W. J., Herrmann, M., Ibell, T. J., Kromoser, B., Michaelski, A., Orr, J. J. & West, M. (2016). Flexible formwork technologies–a state of the art review. Structural Concrete, 17(6), 911-935.

10. Hewavitharana, N. (2017). Cost comparison between conventional and flat slab structures (Doctoral dissertation).
11. Kenea, G., & Feyissa, A. (2022). Cyclic Behavior of Reinforced Concrete Slab-Column Connection Using Numerical Simulation. Advances in Civil Engineering, 2022(1), 2814715.
12. Muhammed, T. A. (2024). Ultra-high-performance fiber-reinforced concrete flat slabs' punching shear resistance as a function of drop panel thickness. Passer Journal of Basic and Applied Sciences, 6(Special Issue), 513-522.
13. Myklestad, N. O. (2018). Fundamentals of vibration analysis. Courier Dover Publications.
14. Nishanth, C. L., Swaroop, Y. S., Jagarapu, D. C. K., & Jogi, P. K. (2020). Analysis and design of commercial building with different slab arrangements using ETABS. Materials Today: Proceedings, 33, 700-704.
15. Pang, B., Wang, F., Yang, J., Nyunn, S., & Azim, I. (2021, October). Performance of slabs in reinforced concrete structures to resist progressive collapse. In Structures (Vol. 33, pp. 4843-4856). Elsevier.
16. Romanova, E. (2018). Increase in population density and aggravation of social and psychological problems in areas with high-rise construction. In E3S Web of Conferences (Vol. 33, p. 03061). EDP Sciences.
17. SNI 2847:2019. Persyaratan Beton Struktural untuk Bangunan Gedung. Badan Standardisasi Nasional, Jakarta.
18. Sreevalli, I. Y. (2021). A review on progressive collapse of reinforced concrete flat slab structures. Civil Engineering Infrastructures Journal, 54(1), 181-194.
19. Wang, J., & Zhao, H. (2018). High performance damage-resistant seismic resistant structural systems for sustainable and resilient city: a review. Shock and Vibration, 2018(1), 8703697.
20. Yankelevsky, D. Z., Karinski, Y. S., Brodsky, A., & Feldgun, V. R. (2021). Dynamic punching shear of impacting RC flat slabs with drop panels. Engineering Failure Analysis, 129, 105682.