OPEN ACCESS

POTENSI

Jurnal Proyek Teknik Sipil
Journal of Civil Engineering Project
Vol 8 (1), 2025, 17-25.
E-ISSN: 2654-4482
https://ejournal2.undip.ac.id/index.php/potensi

A Comparative Study of Flat Slab and Waffle Slab Structure for Efficiency of Convention Building Slab System

Efendi[a], Andri Irfan Rifai[a], Amanatullah Savitri[a*]

[a] *Faculty of Civil Engineering & Planning, Batam International University, Indonesia*

Corresponding Author:
Email: amanatullah@uib.ac.id

Keywords:
Flat Slab, Waffle Slab, Effectiveness

Received :
Revised :
Accepted :

Abstract: *In the world of construction, aesthetic has become an important factor that must be considered. The aesthetic elements consist of wholeness, prominence and balance. However, aesthetic values can be influenced by several factors, namely economic, social, cultural, technological, ergonomic and psychological factors and this cause that in commercial development or the building that use slab system for foundation is used greatly affects it in terms of aesthetics and also cost effectiveness Despite the importance of aesthetics, structural efficiency in terms of material usage and deflection remains a key consideration in slab selection. The author's purpose of doing this research is to analyse the efficiency of volume in concrete and deflection between Flat Slab system and Waffle slab system. This research uses a case study at the Pasir Putih Convention, Batam, Indonesia. The analysis is done with ETABS software based on the local standards or known as Indonesia National Standard (abbreviated SNI). The choice of a slab system in a development is very important, especially if the building or construction is categorized as commercial structure. Based on the data obtained by researchers in terms of economics and deflection, Waffle Slab System is the right option, meanwhile in terms of ease construction Waffle Slab System will be the secondary choice than Flat Slab, Since Flat Slab is more ease of framework installation than Waffle Slab.*

1. INTRODUCTION

Indonesia has entered an era where every region in Indonesia must pay attention to the development and construction method. The development mentioned here stand for development of the infrastructure sector. The infrastructure built in Indonesia has increased from year to year. Infrastructure built such as offices, malls, schools, housing, hotels, and others. The development carried out requires the availability of sufficient land, but the current development is oriented in a vertical direction by making it multilevel to minimize land use. Multi-storey buildings were built to overcome the density of land which the land availability have been decreasing from year to year (Egan & Leo, 2018).

In the world of construction, aesthetic values must be considered along with the times. The definition of aesthetics is basically related to several issues such as, beauty, art, expression, form, and aesthetic experience. In general, aesthetics can also be classified into two, namely natural aesthetics and artificial aesthetics. Where in works of art and architecture, there are three most basic aesthetic elements, namely wholeness, prominence, and balance. But aesthetic values have problems that are influenced by several factors, namely economic, social, cultural, technological, ergonomic, and psychological factors (Utomo, 2010). So that in commercial construction or building the used of slab system has greatly affects in terms of cost and aesthetics.

The Design of structures for buildings and bridges is maily concerned with the provision and support of load-bearing horizontal surfaces. Except in some long-span structures, these floor or decks are usually made of reiforced concrete, for no other material provides a better combination of low cost, high strength, and resistance to corrosion abrasion and fire (Johnson, 2018; Johnson, 2018). In construction of high-rise building, used of materials & volume of concrete in an element's structures, slab is the most dominance.

Slab is a horizontal structural element that support both dead and live loads and transmit them to the vertical frame of the structural system. Slab is also a plane (surface) structure (flat or curved) whose thickness is much smaller than the other dimensions. Meanwhile reinforced concrete slab means a thin structure made of reinforced concrete with a horizontal direction, and the loads acting perpendicular to the structure. The thickness of this plane slab is relatively very small when compared to the long span / width of the slab. This concrete slab is very rigid, and the direction of transfer loading is horizontal, so that in buildings, this slab functions as a secondary structure and can also function as a diaphragm that helps channel lateral forces due to earthquakes that might affect to the main structure frame. The addition of drop panels is an effort to overcome the shear stress (punching shear), besides that it can also be added with edge beams or column capital. Drop panels are placed above the column which aims to distribute the load that occurs on the slab and transfer to the column so that there is a thickening of the slab in that area. Flat slab construction with drop panels is a unique system that can provide load-bearing strength and save time of the construction process, which will be faster than conventional slabs (Sidjabat, Ginting, & Marbun, 2021).

There are several kinds of slab system, namely flat plate system, waffle slab system, flat slab system, and conventional plate system. Each Slab system has its own advantages and disadvantages. Which is considering in the economics, in terms of construction & aesthetic. The selection of these various plate systems is based on the purpose of the designed structure. The function of the plate system in the building structure is as a diaphragm that transmits loads. Much research had been done on the comparison of the three slab systems, but specifically for this journal's research theme has never been done (Rupidara, Cornelis, & Sir, 2022).

Most of the high-rise building construction uses a slab and beam system, but in terms of efficiency due to limited of availability land, especially in term for the interior of the building purposed, the flat slab system is more effective in reducing the height and time of construction work and is widely used in terms of architecture. As explained above, a flat slab is a reinforced concrete slab construction system without beams which is often used as a high-rise building slab choice, such as offices, residences, or other industrial facilities, which doesn't have high intensity. In the process of working on flat slabs, high-strength concrete is usually used, and slab formwork can be used evenly throughout. Behind these advantages, there are also disadvantages contained in the plate of flat slab, such as, the planned building has a limited span capability that relatively short. (Primakov & Leo, 2019).

Among the various slab systems, the waffle slab system is still rarely used. Waffle slabs are usually used in special projects that require large spaces with a small number of columns and rooms, yet the floor slabs have small deflections and small vibration frequencies. Usually used in the construction of airports, bridges, parking buildings, as well as commercial and industrial buildings, libraries or art galleries that prioritize the aesthetic value of building ceilings. So that most preferable long span slab for a Building is Waffle Slab (Malviya & Tiwari, 2021). However, they have limitations in terms of span length and deflection control. On the other hand, Waffle Slabs provide structural efficiency, especially for large-span applications, minimizing deflections and enhancing load distribution. Despite their advantages, Waffle Slabs are less commonly used due to their complex formwork and higher construction costs.

This study aims to determine the most efficient slab system for commercial buildings by analyzing the volume of concrete usage and deflection performance. Using the Pasir Putih Convention Centre in Batam as a case study, a comparative analysis is conducted between Flat Slab and Waffle Slab systems utilizing ETABS software. The results of this study are expected to assist engineers and architects in optimizing slab selection to enhance structural efficiency while maintaining construction feasibility

2. DATA DAN METHOD

This research has use the commercial structure concept design of convention centre that located in Pasir Putih, Batam-Indonesia shown in figure 1 as a study case for this research's object. Pasir Putih is a well-known place in Batam for residential area, however these days, commercial structure are developing in that area. Hence this research has chosen one of the developing structure for this research's object. The structures are modelled in 3-Dimensional as commercial structure by using the ETABS software. In the present work, reinforced concrete frame of double storey building situated in Indonesia had been designed to follow Indonesian National Standard (abbreviated SNI) during the research progress. Design have also been considered toward dead load and live load that happened. The calculation data is collected with quantities method. This research is only for a comparative purpose between the concrete's volume and deflection of flab slab and waffle slab design.. Figure1 shows the Convention Centre at Pasir Putih as a reference to this research.

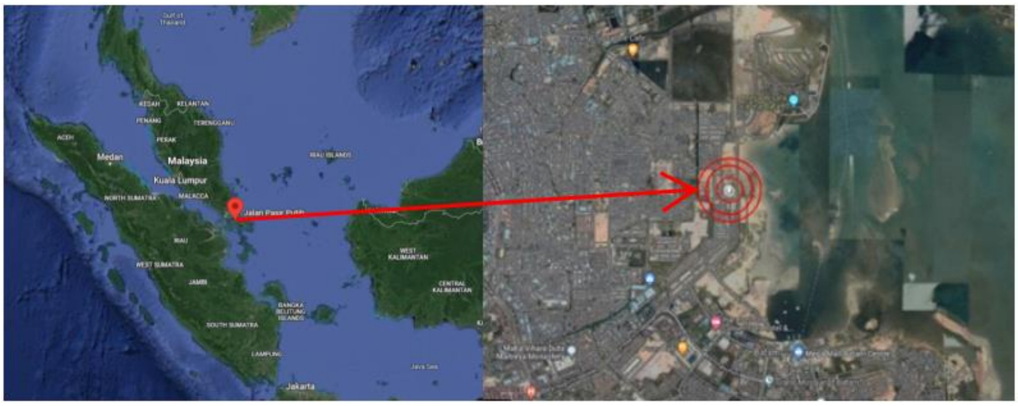

Figure 1. Location of case study

Concept of Architecture's Design

Below is an architectural design concept of this research's object, convention centre that located on Pasir Putih, Batam-Indonesia, based on the location above. This concept design of this convention centre is a commercial project with a site area of 19,154 m2 as shown in figure 2. This design concept is in the form of self-service and retail with a very futuristic building facade. This design concept is located near the Mondial and Ocarina schools which are very easy to reach by the public and has a total parking area of 442 vehicles consisting of 210 car parking units and 232 motorcycle parking units.

Figure 2. Concept design of the convention centre

This concept design of this convention centre is a commercial project with a building area of 4,240 m2. The concept design plan on the first floor is in the form of a ballroom which has a floor area of 2,840 m2, which there are a management room, toilet, prayer room, warehouse, and lounge area. The function of the building as a retail shopping centre with a total of 81 retail stands as shown in figure 3. The interior design concept of this supermarket and retail with a futuristic concept design.

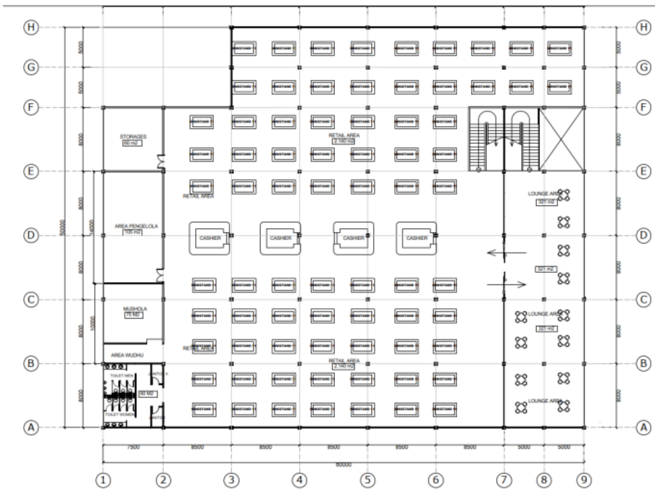

Figure 3. Concept design of first floor plan

Design Criteria of Structure's

Below are the structure details as per shown in Table 1, material specifications, and loading that use for this research's analysis with the help of ETABS Software in purpose to compare between the concrete's volume and deflection of flab slab and waffle slab design.

Table 1. Criteria of Structure's

No	Description	Criteria Design	
		Flat Slab	Waffle Slab
I	Structure Details		
1	Plan Dimension	40 m x 25 m	40 m x 25 m
2	Height of the Floor	3.5m	3.5 m
II	Material Properties		
1	Concrete Grade	25 Mpa	25 Mpa
2	Density of Concrete	25 kN/m^3	25 kN/m^3
3	Grade of Steel	500 Mpa	500 Mpa
4	Modulus of Elasticity	25 kN/m^3	25 kN/m^3
III	Section Properties		
1	Beam/Rib Width	-	200 mm
2	Slab Thickness	275 mm	125 mm
3	Drop Panel Thickness	400 mm	375 mm
4	Panel Size	1450mm x 1450mm	2650 mm x 2650 mm
5	Spacing Beam/Rib	-	750 mm
IV	Gravity Loads		
1	Dead Load (Floor)	1.5 kN/m^2	1.5 kN/m^2

Step of Modelling ETABS

Below are the steps to do the modelling with ETABS software to check for the comparison of flat slab and waffle slab's concrete volume and deflection.

1. Determining the Structural Model

   In determining the model structure, ETABS software already provides various kinds of models, alternatively, we can also create our own model by use grid, by selecting the file-new menu, and followed up with the option of grid only

2. Determining Materials and Material Values

   If done with the modeling structures, next is entering the stage of determining the material. Firstly, select the material type, input the name for this material type, and check the value of material which have been input automatically

3. Creating the Section Profile Properties of Slab

   After determining the materials, next is entering the stage of making the profile section that will be used. Choose the slab material from the list provided. Provide name for the profile have been created, lastly input the slab type, depth, thickness, and others needed

4. Assigned Materials to the Shells

   Now is assigning properties to the specified member. Choose from the list in "shell assignment – slab section" and assign the correct shells.

5. Define the Load Case

   After doing the profile properties section for each member, then determining the load case contained in the model from the list of load case. Fill up the name for the load case and specify the factor used.

6. Input the Loading to the Elements/Members

   Next also required to ensure the load input is correct according to the existing standards and criteria based. Select the "Assign" Panel, load type, and the load pattern. Lastly, fill up the value and direction of the loading.

7. Define the Load Combination

   After inputting the loads according to the Indonesian National Standard, following up is determining the load combination which also according to the Indonesian National Standard.

8. Run Analysis Design & Print the Output

   Finally, the model will enter the last stage, which named as running analysis toward the models, if the results of the model structure had already matched the Indonesian National Standard, means this model is ready to be used, so afterward is to print the required output.

3. RESULTS AND DISCUSSION

ETABS Modelling Slab

Below are the 2-Dimension modelling figure of Flat slab and waffle slab system for the first floor of Convention Centre in Pasir Putih with Software ETABS 19.0.1 ® based on the data in table 2.

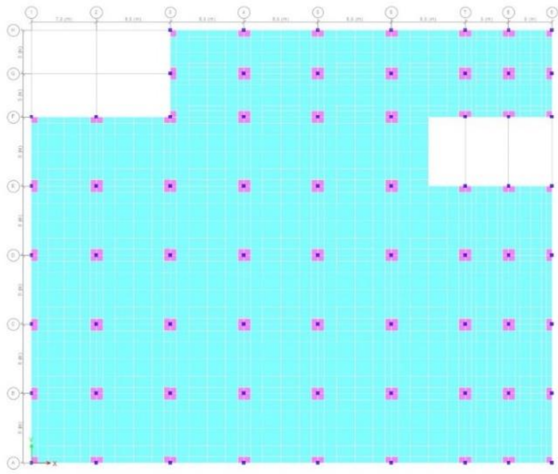

Figure 4. First floor's plan view with flat slab design

The following Figures 4 are showing the 2-Dimension building models for the Flat slab. The structure is modeled based on the structure details, material specifications, section properties, loading and based on the SNI.

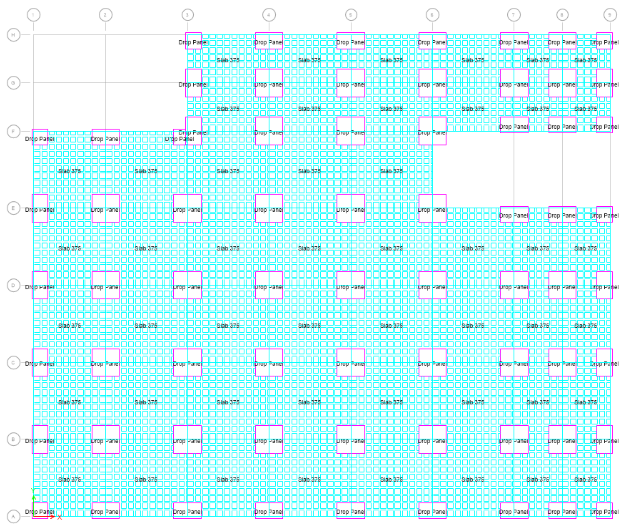

Figure 5. First Floor's plan view with waffle slab design

The following Figures 5 are showing the 2-Dimension building models for the Flat slab. The structure are modeled based on the structure details, material specifications, section properties, loading and based on the SNI.

Calculation for Concrete's Volume

The purpose of this calculation is to compare flat slab and waffle slab design from the effectiveness purpose. Below is the calculation for the concrete's volume between flat slab and waffle slab.

Table 2. Comparative of calculation of slab's volume

No	Description	Area						Total
		1	2	Void	3	4	5	
I	**Flat Slab**							
a.	Slab Thickness (m)	0,275	0,275	0,275	-	-	-	
b.	Slab Width (m)	40,000	16,000	8,000	-	-	-	
c.	Slab Length (m)	44,000	40,000	14,250	-	-	-	

d.	Volume of Slab (m^3)	484,000	176,000	31,350	-	-	-	628,650
II.	Waffle Slab							
a.	Rib Width (m)	0,200	0,200	-	0,200	0,200	0,200	
b.	Slab Thickness (m)	0,125	0,125	-	0,125	0,125	0,125	
c.	Overall Depth (m)	0,375	0.,375	-	0,375	0,375	0,375	
d.	Volume of Rib (m^3)	2,800	4,000	-	4,250	3,800	3,350	
e.	Volume of Slab (m^3)	3,125	5,000	-	8,500	7,500	5,312	
f.	Overall Volume (m^3)	23.700	90,000	-	318,750	56,500	69,300	558,250

Based on Table 2 regarding total volume of concrete that are required for the waffle slab design of Convention Centre in Pasir Putih's, the result for first floor is 558,25 m^3 approximate, meanwhile if using flat slab than the concrete required is 628.65 m^3. From total of using concrete volume aspect, Waffle slab requires 12% less concrete than flab slab design. This is indicating better material efficiency and potential cost savings in terms of concrete usage. However, in the other aspect of nominal Area of Reinforcement area required is approximately same.

Analysis Deflection on Flat Slab and Waffle Slab

The purpose of analysing the deflection is to compare the effectiveness of using flat slab and waffle slab for a structure design. Below are the results of comparing and analysing with the help of ETABS 19.0.1® software and based on structure data above.

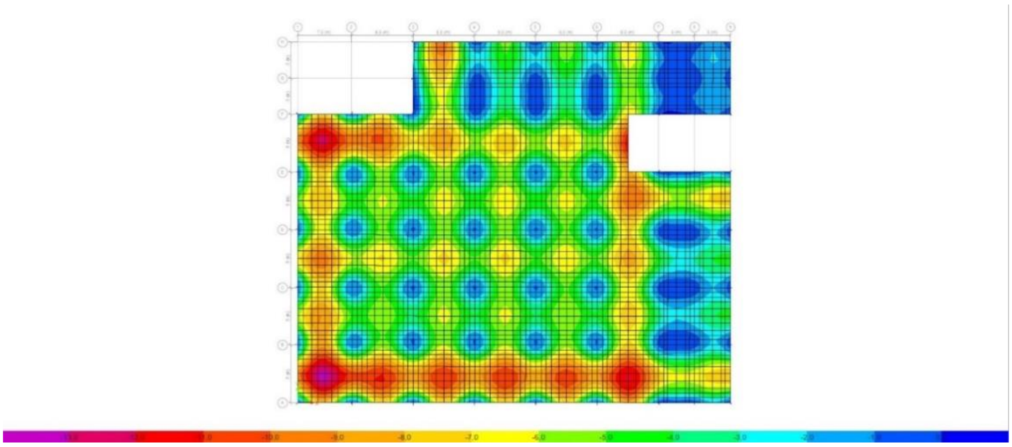

Figure 6. Deflection Result of First Floor Flat Slab design

The above figure 6 is the flat slab output, which is modelled based on the design criteria above, in this model there are various colors stating the amount of deflection that occurs due to the inputted loads. Where if the contour's color is increasingly towards purple color, this indicates that the deflection occurs here is getting bigger and reaching the maximum deflection occurs, which is 13.0 mm, while if the contour's color moving towards blue color, than this indicates the deflection that is happening is getting smaller reaching minimum amount which is 0 mm. so that based on the data released through the ETABS software the maximum deflection of the flat slab is 13.0mm.

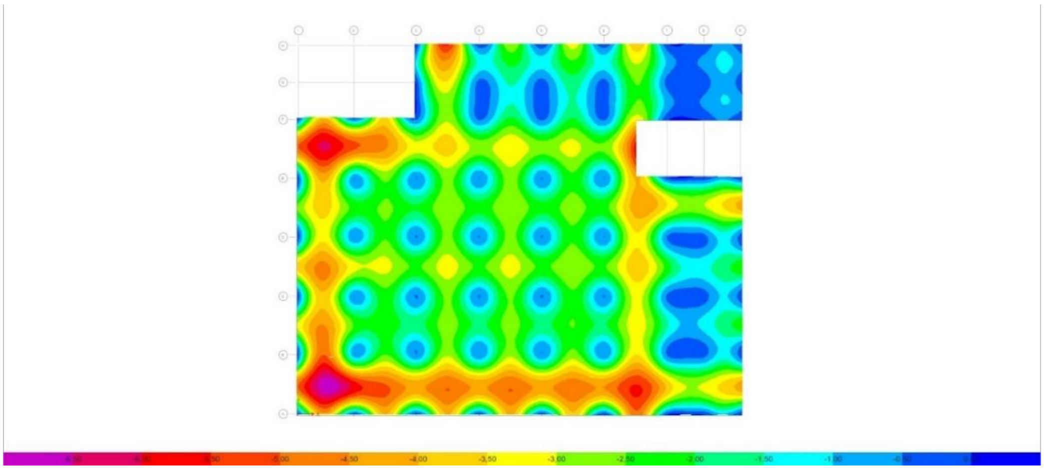

Figure 7. Deflection Result of First Floor Waffle Slab design

The above figure 7 is the output of the waffle slab, which is modelled based on the design criteria, in this model there are various colors stating the amount of deflection that occurs due to the inputted loads. Where if the contour's color is increasingly towards purple color, this indicates that the deflection occurs here is getting bigger and reaching the maximum deflection occurs, which is 6.5mm while if the contour's color moving towards blue color, than this indicates the deflection that is happening is getting smaller reaching minimum amount which is 0 mm. so that based on the data released through the ETABS software the maximum deflection of the waffle slab reaches 6.5mm.

Based on the output result from ETABS 19.0.1. Software, flab slab has a maximum of 13.0mm deflection. However, waffle slab only has a maximum of 6.5mm deflection. Both slab design has met the requirement of SNI. Both slab design has met the requirement of SNI which based on SNI 2847:2013; Table 9.5(b) indicate that deflection limit must be less than L/240. The longest slab of this commercial project is 8.5m, so the allowable maximum deflection limit for this project is 35.41 mm. But flat slab maximum deflection that happened is 100% higher than waffle slab deflection, which is only 6.5 mm. This indicates that the waffle slab provides better structural stiffness and reduces the risk of excessive deformation, which can enhance serviceability and long-term performance. The lower deflection in the waffle slab may also contribute to better occupant comfort by minimizing floor vibrations and potential cracking issues.

4. CONCLUSION

Based on the result of analysing and comparing effectiveness of flat slab and waffle slab design, with ETABS 19.0.1. Software for Commercial Concept Design at Pasir Putih, Waffle slab is more effective than Flat slab in terms of concrete volume and deflection happened. From total of using concrete volume aspect, waffle with used of 12% less concrete than Flab slab, Flat slab maximum deflection happened is 100% higher than waffle slab deflection, which only 6.5mm for waffle slab. Hence, from this research, the conclusion is waffle slab is more effective than flat slab, so waffle slab is a better option in terms of effectiveness volume concrete deflection for slab, meanwhile in ease construction Waffle Slab System will be the secondary choice than Flat Slab, Since Flat Slab is more ease of framework installation than Waffle Slab.

UCAPAN TERIMA KASIH

Terima kasih kepada dosen pembimbing yang telah membantu penyelesaian penelitian dan artikel ini.

REFERENCES

Afshari, H., Hare, W., & Tesfamariam, S. (2019). Constrained multi-objective optimization algorithms: Review and comparison with application in reinforced concrete structures. Applied Soft Computing, 83.

Al-Bayati, A. F., Leong, L. T., & Clark, L. A. (2018). Eccentric Punching Shear of Waffle Slab. ACI Structural Journal, 115.

Diana, W. (2011). Metode Beam on Elastic Foundation (BoEF) dan Finite Element Method (FEM). Semesta Teknika, 14(1), 94-100.

Giri, M., & Jamle, S. (2019). An Approach to Lessen the Stresses in Flat Slab for Earthquake Zone IV. International Journal of Advanced Engineering Research and Science ISSN: 2349-6495 (P), 2456-1908 (O)), 6(6),., 216-224.

Johnson, R. P. (2018). Composite Structures of Steel and Concrete: beams, slabs, columns and frames for building. John Wiley & Sons Ltd.

Lapi, M., Ramos, A. P., & Orlando, M. (2019). Flat slab strengthening techniques against punching-shear. Engineering Structures, 160-180.

Lee, T. U. (2022). Optimizing load locations and directions in structural design. Finite Elements in Analysis and Design, 209.

Lionardo, L., & Sari, Y. A. (2022). DESIGN COMPARISON OF STRUCTURAL ELEMENTS BETWEEN CONVENTIONAL SLAB AND RIBBED SLAB ON OPTIMIZATION CONCRETE VOLUME EFFECIENCY. CoMBInES.

Malviya, S., & Tiwari, M. V. (2021). Comparative Study of Seismic Behaviour of Multi-Storey Buildings with Flat Slab, Waffle Slab, Ribbed Slab &Slab with Secondary Beam. Journal of Xi'an University of Architecture & Technology, 14.

Malviya, S., & Tiwari, M. V. (2021). Comparative Study of Seismic Behaviour of Multi-Storey Buildings with Flat Slab, Waffle Slab, Ribbed Slab &Slab with Secondary Beam. Journal of Xi an University of Architecture & Technology, 14.

Nuh, S. M. (2018). Analysis of the Influence of Project Implementation Methods for Time and Cost Efficiency of High-rise Building Work in Pontianak City. JeLAST: Jurnal PWK, Laut, Sipil, Tambang,, 5(3).

Olawale, S. O., Akintunde, O. P., Afolabi, M. O., & Tijani, M. A. (2020). Design Optimization of Reinforced Concrete Waffle Slab Using Genetic Algorithm. Journal of Soft Computing in Civil Engineering, 4(2), 46-62.

Pethe, M. D., & Khedikar. (2022). A Comparative Study of Conventional Slab, Flat Slab and Waffle Slab by using Finite Element Method. International Journal for Research in Applied Science & Engineering Technology (IJRASET), 14.

Primakov, A., & Leo, E. (2019). Efficiency Study of Flat Slab Systems Using Post-Tension and Conventional Methods . JMTS: Jurnal Mitra Teknik Sipil, 2(1), 133-142.

Rupidara, Y. A., Cornelis, R., & Sir, T. M. (2022). Comparative Analysis of Seismic Performance of Building Structures with Conventional Plates, Waffle Slab, dan Flat Slab. Jurnal Forum Teknik Sipil (J-ForTekS) Vol. 2 (1), 80-91.

Sacramento, P., Picanco, M., & Oliveira, D. (2018). Reinforced concrete ribbed slabs with wide-beam. Lajes nervuradas de concreto armado com viga-faixa.

Shirin, K. P., & George, B. M. (2022). Comparative Analysis and Seismic Performance Improvement of RCC Post Tensioned Flat Slab with Steel Composite PT Flat Slab System using ETABS. International Journal Of Engineering Research & Technology (IJERT) ICART (Volume 10 – Issue 06), 190-196.

Sitole, A., Guha, S., & Shekhawat, S. S. (2018). Conversion of MDOF System Into SDOF System of RC Waffle Slab Structure by Using N2 Method. International Research Journal of Engineering and Technology (IRJET), 5.

Taha, B. O. (2020). Aspect Ratio Consideration in Flat Plate Concrete Slab Deflection. Zanco Journal of Pure and Applied Sciences, 62-77. Utomo, T. P. (2010).

Youlanda, N. A., & Winaya, A. (2016). Comparative study of two-way ribbed slab (waffle slab) and conventional slab. Jurnal Iptek, 20(1), 25-36.