e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

PUNCHING SHEAR ANALYSIS OF FLAT SLAB WITH DIFFERENT OPENING POSITION

Surjeet Verma*1, Anjali Rai*2

*1M.Tech. Student, Department Of Civil Engineering, Institute Of Engineering And Technology, Lucknow, Uttar Pradesh, India.

*2Assistant Professor, Department Of Civil Engineering, Institute Of Engineering And Technology, Lucknow, Uttar Pradesh, India.

DOI : https://www.doi.org/10.56726/IRJMETS45650

ABSTRACT

Flat slab is a commonly used and competitive structural system where columns directly support the floor slab without the need for beams. Openings in flat slabs can serve architectural purposes, such as accommodating stairways, elevators, and utility systems. However, it is important to note that adding an opening adjacent a column creates a critical location in the structure. This can disrupt the load path and create structural vulnerabilities. One common failure mode for flat slabs is punching shear, where the load is concentrated around the column, leading to brittle failures. To improve the resistance against punching shear, drop panels are often used. These panels increase the slab thickness around the column, specifically in the area with the highest shear stresses. This study analyzes eight different models of flat slabs, divided into two groups: one without drop panels and one with drop panels. the flat slab without drop panel and with drop panel is further divided into the without opening and with opening at different position from column face. the opening dimensions 2.0 x 2.0 m and is square in shape. All models are analyzed using the CSI-SAFE software based on the Indian Standard code for reinforced concrete structures

Keywords: Flat Slab, Opening Adjacent To The Column, Square Opening, Punching Shear, CSI-SAFE Software.

I. INTRODUCTION

Reinforced concrete flat slabs are slabs that are supported directly by concrete columns, without the need for beams. Gurnani (2022) [2] They are commonly used in the construction of high-rise buildings, large supermarkets, shops, underground garages, and bridge decks. Elshafiey (2012) [3] This technique offers several advantages, including architectural flexibility, more open space, lower building heights, simpler formwork, and faster construction. Flat slabs are two-way reinforced concrete slabs that can have Alrousan (2022) [4] Mostofinejad (2020) [5] openings for various purposes such as electricity, air conditioning, water supply, stairways, and elevators. However, Kadam (2019) [6] these openings can disrupt the load path of the structure, leading to unbalanced shear forces and bending moments. Yankelevsky (2021) [7] The connection between the slab and the supporting column is particularly vulnerable to high stresses and can result in punching shear failure. Girish (2018) [8] Anil (2014)[9] This failure mode is critical to consider when designing flat slabs, as it can cause brittle failure and even the progressive collapse of the structure .

Marques (2020) [11] The size and position of an opening greatly impact the punching shear capacity of a structure. If the opening is larger or located near a column, more steel construction is needed. It is important to have an opening in a flat slab, but the most critical location is Adjacent to the column. The punching shear capacity of the flat slab is significantly influenced by the opening near the column. Therefore, it is necessary to thoroughly assess how these openings affect the punching shear behavior of flat slab-column systems. It is essential to investigate punching shear failure for safety reasons and to design with caution. Evaluating the impact of these openings near the column on the punching shear behavior of flat slab-column systems is crucial.

This research uses the CSI-SAFE 16 software to examine the effects of different opening positions in relation to the column face, with or without a drop panel. The study compares Group A and Group B, looking at the impact of openings on the slab specimens. This includes square openings at the column faces, square openings at 0.5 m meter away from the column faces, and square openings at 1.0 m meters away from the column faces. Group A focuses on a slab specimen without a drop panel, while Group B examines a slab specimen with a drop panel.

The objective of this research is-

- To investigate the impact of openings with and without drops on flat slabs
- To investigate the impact of different opening positions on the behavior of flat slabs
- Analysis of a flat slab utilizing various parameters (punching shear deflection).

II. METHODOLOGY

The three-dimensional finite element software SAFE is used to analyze models of flat slabs. The purpose of the analysis is to understand the behavior of flat slabs with openings. The analytical modeling is divided into two groups: Group A represents a flat slab without a drop, and Group B represents a flat slab with a drop. Both groups are further divided into parts based on the presence or absence of openings at different distances from the column face. The openings are located on the column's face, 0.5 m from the column face, and 1.0 m from the column face. The slabs are subjected to finite element analysis to evaluate outcomes such as total deformation, punching shear, and moments. The SAFE software performs a comparative analysis between Groups A and B.

Specimen Details and Material Properties-

This analysis involves the use of M30 grade concrete and Fe415 grade steel. The columns directly support a 250-mm-thick slab. The dimensions of the column are assumed to be 0.450 m x 0.450 m, while each slab panel measures 6 m x 6 m. The flat slab is designed using the finite element approach with the CSI SAFE2016 software. Various locations near reference column C have a square opening with dimensions of 2 m x 2 m. Group A does not have a drop panel, but Group B has a drop panel with dimensions of 2.00 m × 2.00 m x 0.350 m. The slab is subjected to a dead load of 6.25 KN/m2, a floor finish load of 2 KN/m2, and a live load of 4 KN/m2. Both the top and bottom faces of the slab have a 15 mm thick clear cover.

Table- 1 design input

NO.	Panel parameters	Panel dimensions
1.	Flat Slab Panel	6.00 x 6.00 m
2.	Column Size	0.45 x0.45 m
3.	Flat Slab Thickness	0.250 m
4.	Floor to floor height	3.00 m
5.	Drop Panel	2.0 x 2.0 x0.350 m
6.	Grade of Concrete	M30
7.	Grade of Steel	Fe415
8.	Square Opening	2.00m x 2.00m
9.	Floor Finish	2.00 KN/m2
10.	Live load	4.00 KN/m2

Numerical Analysis-

The numerical analysis of eight flat slab models is conducted using the three-dimensional finite element program SAFE. The analysis includes consideration of long-term cracking in the nonlinear analysis, with creep coefficient and shrinkage strain parameters set at 1.6 and 0.0003, respectively. The material properties used for the analysis are steel grade Fe415 and concrete grade M30. Each of the eight conditions is modeled and examined using the automatic slab mesh option. The minimum reinforcing ratio for cracking, as per IS 456, is 0.12%. The design allows for easy comparison of punching shear in various scenarios, whether the model includes openings or not.

As a result of the opening, the shear stress in the structure increases, leading to an increase in the punching shear ratio. The punching ratio is defined as...

$$\text{Punching Shear Ratio} = \frac{\textit{Maximum Designed Shear Stress}}{\textit{Shear Stress Capacity}}$$

The concrete's ability to withstand shear stress is 1.369 N/mm2 for M30 grade concrete. The shear stress capacity is influenced by the concrete grade and the presence of shear reinforcement. As no shear

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

strengthening measures were taken in any of the models, the shear stress capacity is solely attributed to the concrete.

For, Punching Shear ratio > 1 (Implies the Structure/Model fails in punching)

Punching Shear ratio ≤ 1 (Implies the Structure/Model is safe)

III. MODEL FRAMEWORK AND MODELLING

The finite element method has been employed to model and analyze reinforced concrete flat slab systems. To investigate flat plates with highly unequal or irregular shapes, finite element analysis is commonly utilized. Groups A and B are divided into four sections, with one section having no opening and the other three sections representing openings at different locations, as indicated in.

Table 2. Model specification

Group	Part	Structure of the Opening	Dimensions of the Opening	Place of Opening
Group A	I.	-	No Opening	-
	II.	Square	2 x 2 m	At column face
	III.	Square	2 x 2 m	At 0.5 m away from column face
	IV.	Square	2 x 2 m	At 1.0 m away from column face
Group B	I.	-	No Opening	-
	II.	Square	2 x 2 m	At column face
	III.	Square	2 x 2 m	At 0.5 m away from column face
	IV.	Square	2 x 2 m	At 1.0 m away from column face

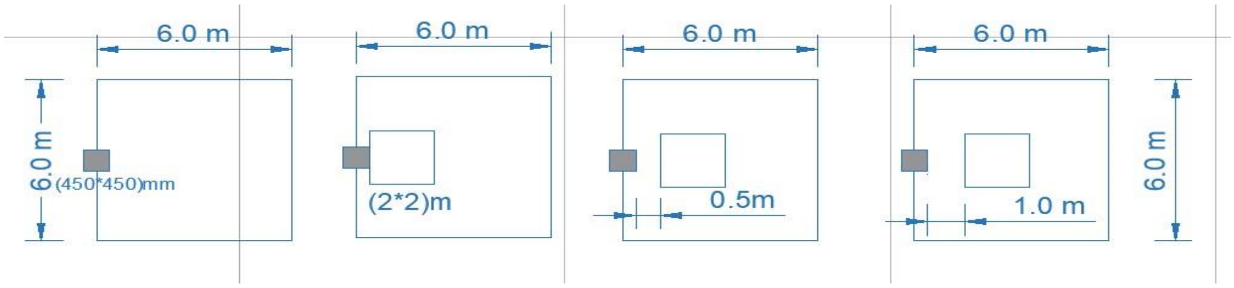

Fig-1 flat slab with several opening positions and no drop

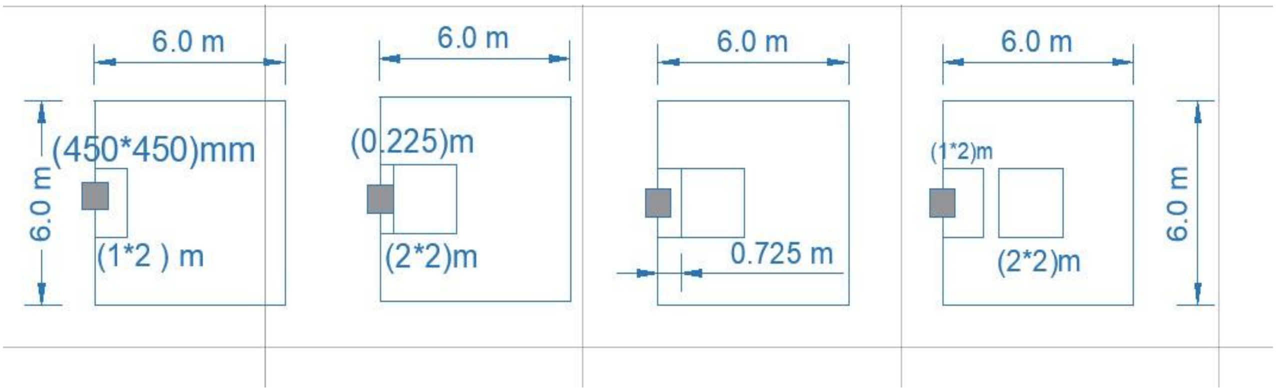

Fig-2 flat slab with several opening positions and with drop

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

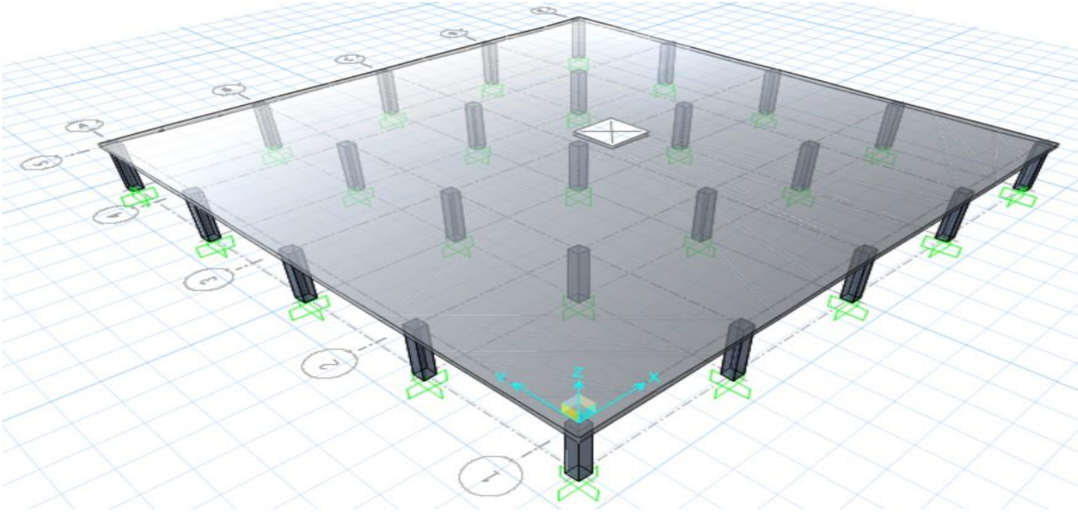

Fig-3 flat slab without a drop with opening at 0.5 m from column face in an isometric view

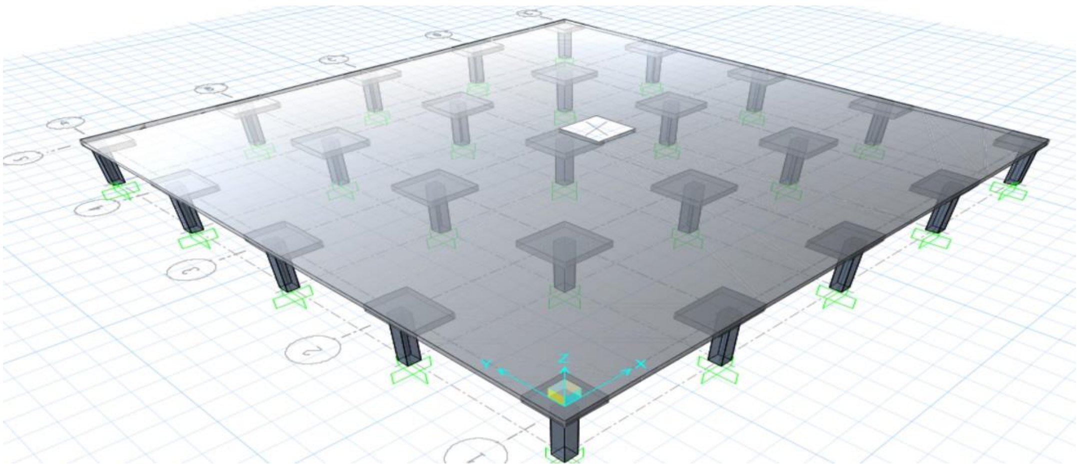

Fig-4 flat slab with a drop with opening at 0.5 m from column face in an isometric view

IV. RESULT AND DISCUSSION

The presence of an opening adjacent to the column disrupts the load path of the structure. This opening has a significant impact on the punching shear behavior of the structure. The punching shear perimeter, which is located at a distance of d/2 from the column face (where d is the depth of the slab), is affected by the presence of the opening. The opening creates a discontinuity in the punching shear perimeter, leading to a decrease in punching strength. The size and location of the opening next to the column directly affect the punching shear perimeter and, consequently, the shear strength of the member. The decrease in punching shear perimeter results in an increase in the design punching shear. To evaluate the maximum/designed shear stress, finite element-based software CSI SAFE was used, and the results are presented in Table 3.

From the result, it can be noted that the punching shear ratio value of Group A exceeds more than one, but when we can provide a drop panel, then the punching shear ratio value is not exceeded more than one Which is safe against punching shear. when we can provide a drop, then the punching shear perimeter increases, which can minimize the value of punching shear ratio, and the slab is safe in punching.

Table no.3 Punching shear value

Group	Case	Place of Opening	Perimeter of a punching shear	At column C punching shear ratio
Group A	i.	No opening	2.69 m	0.739
	ii.	At column face	1.49 m	1.75
	iii.	At 0.5 m away from	1.82	1.31

		column face		
	iv.	At 1.0 m away from column face	2.12	0.99
Group B	i.	No opening	3.09 m	0.45
	ii.	At column face	1.72 m	1.01
	iii.	At 0.5 m away from column face	2.09	0.78
	iv.	At 1.0 m away from column face	2.70	0.50

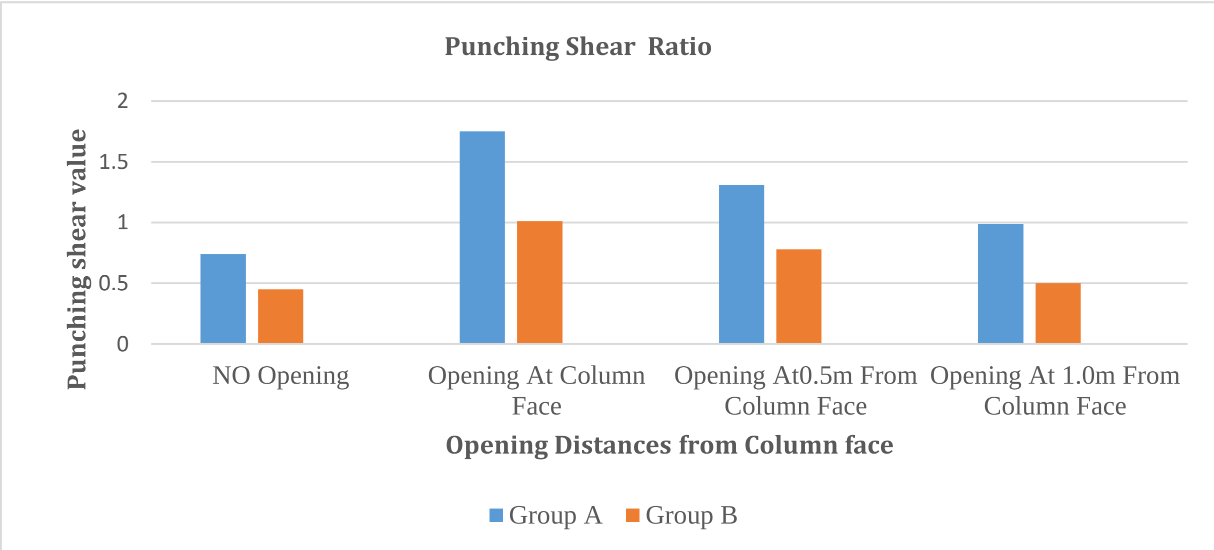

Fig.5. Value of punching shear

V. CONCLUSION

This document presents a numerical study of a flat slab with an opening located at various positions from the column face in two different groups. The outcomes are obtained for each case without the inclusion of shear reinforcement, allowing for the examination and comparison of the impact of the opening's size and location on the flat slab. Through the analysis of the numerical results and subsequent discussions, the following conclusions have been drawn.

- The flat slab without an opening has a greater punching shear capacity compared to the flat slab with an opening.
- for group A the punching shear ratio is minimum in the case when the opening is provided adjacent to the column face because the punching shear perimeter is reduced by 44.60% as compare to without opening
- According to the the results, adjacent openings parallel to the column face are more effective than openings located at different locations parallel to the column face
- When the opening is given adjacent to the column, a flat slab with drop has a punching shear value that is 42.28% lower than one without the drop.

From the study mentioned above, it is also stated that shear strengthening must be provided, either through shear reinforcement, stud rails, column heads, column drops, or a combination of these, in order to prevent punching failure of the structure.

VI. REFERENCE

[1] Jaicky Gurnani, Dr. Prabhakar Chapre, (2022), "Software Based investigation of effect on deflection and moment for flat slab with different opening shapes and positions", JOURNAL OF ALGEBRAIC STATISTICS, 1131-1142

[2] Eslam Hatem El-Mawsly , Khaled Farouk Omar El-Kashif , Ashraf Adel Shawky (2022) , Hany Ahmed Abdalla (2022), "Experimental and numerical investigation on strengthening of RC flat slabs with central opening", Case Studies in Construction Materials, https://doi.org/10.1016/j.cscm.2022.e00974

[3] T. F. EL-Shafiey, M. Hussein, M. A. Abdel-Aziz (2012**)** "Behaviour Of Flat Slabs With Openings Adjacent To Columns,". [Online]. Available: https://www.researchgate.net/publication/278830722

[4] R. Z. Alrousan and B. R. Alnemrawi, (2022), "Punching shear behavior of FRP reinforced concrete slabs under different opening configurations and loading conditions," Case Studies in Construction Materials, vol. 17, Dec. 2022, doi: 10.1016/j.cscm.2022.e01508.

[5] D. Mostofinejad, N. Jafarian, A. Naderi, A. Mostofinejad, and M. Salehi, (2020) "Effects of openings on the punching shear strength of reinforced concrete slabs," Structures, vol. 25, pp. 760–773, Jun. 2020, doi: 10.1016/j.istruc.2020.03.061.

[6] K. N. Kadam and S. Ingole (2019), "Punching Shear Distribution of Flat Slab with Opening Adjacent to Column," 2019, pp. 447–454. doi: 10.1007/978-981-13-6148-7_44.

[7] D. Z. Yankelevsky, Y. S. Karinski, A. Brodsky, and V. R. Feldgun,(2021), "Dynamic punching shear of impacting RC flat slabs with drop panels," Engineering Failure Analysis, vol. 129, Nov. 2021, doi: s10.1016/j.engfailanal.2021.105682.

[8] N. Girish and N. Lingeshwaran,(2018) "A Comparative Study of Flat Slabs Using Different Shear Reinforcement Parameters," International Journal of Engineering & Technology, vol. 7, no. 2.20, p. 321, Apr. 2018, doi: 10.14419/ijet.v7i2.20.16725.

[9] Ö. Anil, T. Kina, and V. Salmani (2014), "Effect of opening size and location on punching shear behaviour of two-way RC slabs," Magazine of Concrete Research, vol. 66, no. 18, pp. 955–966, 2014, doi: 10.1680/macr.14.00042.

[10] S. Garg, V. Agrawal, and R. Nagar (2021), "Sustainability assessment of methods to prevent progressive collapse of RC flat slab buildings," in Procedia CIRP, Elsevier B.V., 2021, pp. 25–30. doi: 10.1016/j.procir.2020.12.003.

[11] D. Zakaria, A. Deifalla, E. Mousa, and A. A. Elrahman,(2023) "Two-way shear full behavior of reinforced concrete flat slabs under membrane tensile forces," Case Studies in Construction Materials, Jul. 2023, doi: 10.1016/j.cscm.2023.e01912.