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Behaviour of Flat Slab with Square Opening at Different Position from Column Face

Surjeet Verma [1], Anjali Rai [2],

[1]M. tech. Student, Department of Civil Engineering, Institute of Engineering and Technology, Lucknow, Uttar Pradesh
[2]Assistant Professor, Department of Civil Engineering, Institute of Engineering and Technology,Lucknow, Uttar Pradesh

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Abstract The flat slab system is widely used in the construction industry because of its advantages, such as architectural flexibility, easier form-work, more clear space, and shorter construction time. To accommodate essential public services like electricity, gas pipeline, water supply, computer networking, sewerage, and air conditioning ducts, it is necessary to pass pipes and ducts through the slab. However, these openings disrupt the load path to the column, increasing the effect of critical forces like moments, deflection, and punching shear. This paper presents a numerical analysis and study of different types of flat slabs with different types of columns adjacent to different types of openings. The analysis includes two groups: group A (flat slab with no drop and no column head) and group B (flat slab with drop and with column head). Each group is further divided into five parts with different opening configurations. The study aims to understand the behavior of flat slabs with different opening shapes, locations, and aspect ratios while keeping other parameters constant. The analytical results lead to various conclusions and recommendations

***Key Words*:** Flat slab, opening adjacent to the column, square opening, deflection, CSI-SAFE software

1.INTRODUCTION

A flat slab is a type of slab that directly rests on columns or column heads without the use of primary and secondary beams. It can be constructed quickly without a drop panel, as the formwork is simple. However, a flat slab with a drop panel and column head provides additional stiffness and increases the shear strength of the slab. The absence of a beam allows for more flexibility in the placement of partition walls and horizontal services. This type of slab can also reduce the overall height of the building and lower cladding costs. However, in order to accommodate utilities such as water pipes, gas pipes, electrical lines, and ducts, openings need to be made in the slab. The most common failure observed in flat slabs is shear punching failure, which is a brittle failure that can cause the structure to collapse suddenly. Despite the widespread use of this structural system, the study of shear failure is not well-defined. Codes and standards rely on empirical studies and formulas to explain failure. Therefore, experimental studies are necessary to better understand the issues related to the use of flat slabs. This paper aims to investigate the behavior of different types of flat slabs with various opening shapes, locations, and aspect ratios, and provide recommendations based on the findingsThe aim of this research is to examine the effects of openings with and without drops on flat slabs. Additionally, the research aims to investigate how different opening positions impact the behavior of flat slabs. Furthermore, the research will analyze a flat slab using various parameters, such as punching shear deflection.

2. METHODOLOGY

The SAFE software, a three-dimensional finite element software, is utilized to examine flat slab models. The objective of the analysis is to comprehend the behavior of flat slabs that have openings. The analytical modeling is categorized into two groups: Group A represents a flat slab without a drop, while Group B represents a flat slab with a drop. Both groups are further divided into sections based on the presence or absence of openings at various distances from the column face. These openings are positioned on the column's face, 0.5 m away from the column face, and 1.0 m away from the column face. The slabs undergo finite element analysis to assess outcomes such as total deformation, punching shear, and moments. The SAFE software conducts a comparative analysis between Groups A and B

2.1 Details of Specimen and Material Properties

This analysis involves the utilization of M30 grade concrete and Fe415 grade steel. The columns directly support a slab that is 250 mm thick. The dimensions of the column are assumed to be 0.450 m x 0.450 m, while each panel of the slab measures 6 m x 6 m. The flat slab is designed using the finite element approach with the CSI SAFE2016 software. Several 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 surfaces of the slab have a clear cover that is 15 mm thick

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Table 1 model description

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

2.2Numerical Analysis-

The three-dimensional finite element program SAFE was used to numerically analyze eight flat slab models. The analysis considered 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 were steel grade Fe415 and concrete grade M30. Each of the eight conditions was modeled and examined using the automatic slab mesh option. The minimum reinforcing ratio for cracking, according to IS 456, was 0.12%. The design allowed for easy comparison of punching shear in different scenarios, whether the model included openings or not.The stiffness of the slab specimen is primarily influenced by the concrete section of the slab. When there is an opening present, the stiffness of the slab decreases, resulting in increased deflection in that area. It is clear that as the size of the opening increases, the deflection also increases due to the reduced amount of concrete, which in turn reduces the slab's stiffness.

3. RESEARCH FRAMEWORK

The use of the finite element method has been applied to simulate and study reinforced concrete flat slab systems. To examine flat plates with varying or irregular shapes, finite element analysis is commonly used. Groups A and B are divided into four sections, with one section having no opening and the other three sections representing openings at different positions, as specified in the text

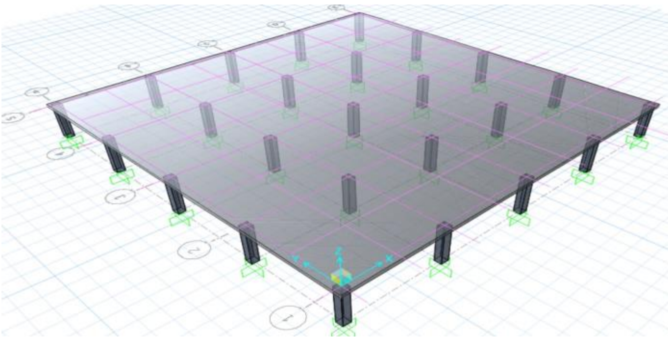

Fig-1. flat slab without a drop with isometric view

Table no-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

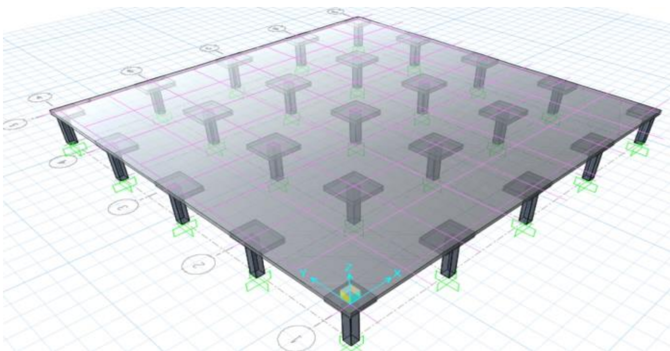

Fig-2. flat slab with a drop with in an isometric view

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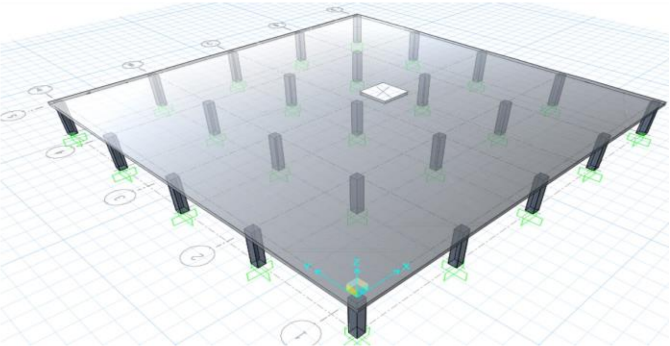

Fig-3 flat slab without a drop with opening at 1.0 m from column face in an isometric view

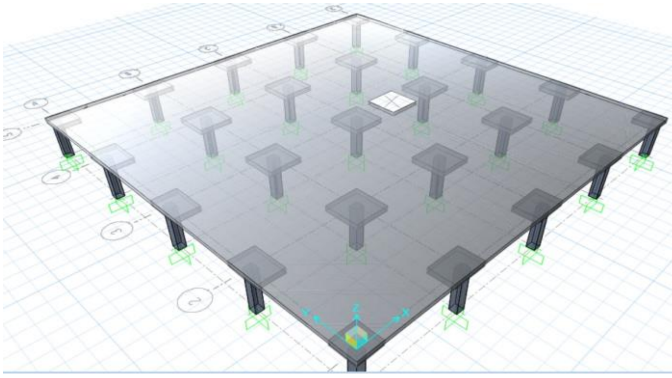

Fig-4 flat slab with a drop with opening at 1.0m from column face in an isometric view

4.RESULT AND DISCUSSION

A hole formed in a flat slab will also effect the deflection, but an opening placed at the face of a column will significantly affect it. The deflection value for the slabs in Groups A and B is largest when the aperture is placed at the column face as opposed to another location in the slab. When a drop panel is provided, the deflection value is less than when one is not.

Deflection for Group A slab –

The group A minimum deflection is achieved in the event that no opening is supplied. and the highest value attained when the column face is equipped with an opening

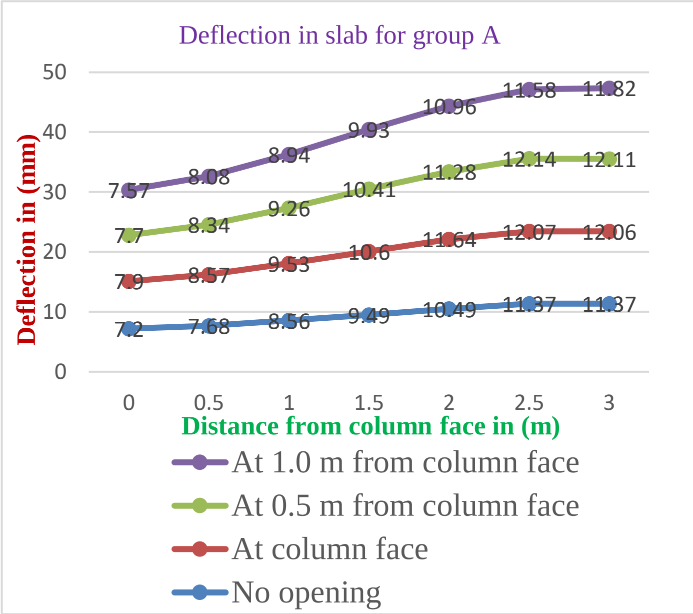

Fig.5. Deflection value for group A

Deflection for Group B slab

In the event that no opening is given, group B's minimal deflection is determined. and the highest value that results from providing an aperture at the column face

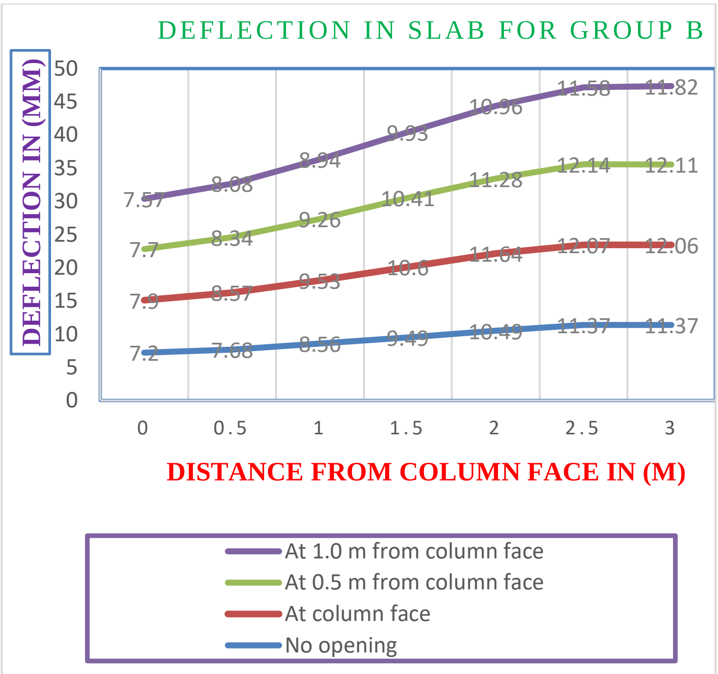

Fig.6. Deflection value for group B

5. CONCLUSIONS

This paper discusses a numerical investigation conducted on a flat slab with an opening positioned at different distances from the column face in two separate groups. The results were obtained for each scenario without the presence of shear reinforcement, enabling the examination and comparison of how the size and location of the opening affect the flat slab. Based on the analysis of the numerical findings and subsequent discussions, the following conclusions have been drawn

I. When an opening is present, the slab's stiffness is decreased, increasing the slab's deflection.
II. The opening at the column face exhibited the largest deflection when compared to the no opening, the opening at 0.5 m from the column face, and the opening at 1.0 m from the column face in both groups.
III. The slab without a drop and an opening at the column face has a 38.523% higher deflection than the slab with a drop panel and an opening at the column face.

According to the previously referenced study, in order to prevent the structure from being punched to failure, shear strengthening must be given. This can be done using stud rails, column drops, column heads, shear reinforcement, or a combination of these.

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