

Finite Element Analysis of Flat Slab with and Without Opening

Seema Rajabhau Ghogare.¹, Dr. Ashok Kasnale², Kadlag Viswajeet.³,

PG Student, Dept. of Structure Engineering, Dr. D. Y. Patil School of Engineering and Technology, Charholibk,
Lohegaon, Pune India¹

Professor, Dept. of Structure Engineering, Dr. D. Y. Patil School of Engineering and Technology, Charholibk,
Lohegaon, Pune India²

Assistant Professor, Dept. of Structure Engineering, Dr. D. Y. Patil School of Engineering and Technology,
Charholibk, Lohegaon, Pune India³

ABSTRACT: The purpose of this study was the implementation and verification of a procedure of finite element method to design reinforced concrete flat slab systems based on the results of non-linear finite element analysis. And also to determine what causes in slab when we put the opening in the slab due to various reasons. For many years, researchers have been working toward the successful application of finite element technology to the design of reinforced concrete flat slab systems due to practical restrictions inherent in simplified or approximate design techniques. Despite promising research in this area, only a few practical finite element based design tools have been implemented in standard structural engineering technology. The goal of this study was to develop and validate such a tool.

KEYWORDS: finite element method, reinforced concrete flat slab, direct design, equivalent frame, yield line, and strip design techniques, flat slab with opening.

I. INTRODUCTION

In the present work, analysis of flat slab is performed by using finite element software ANSYS. A flat slab is divided into small rectangular solid element and load is applied on top surface of slab and analysis is performed. In general, thinner slabs not only save on direct material costs for the frame and the supporting foundations but also provide knock-on benefits in terms of reduced height of the structure and lower cladding costs. Various alternatives are tried for optimum design of flat slab to decide the economical depth of slab, depth of drop and its size. By changing the depth of slab, depth of drop resulting deflection patterns, maximum stress concentration area at different locations of flat slab have been observed. Aim of this dissertation is to compare the behavior of flat slab with and without openings. Comprehensive study of punching shear effect on flat slab has been done by providing double drops and column heads of different sizes.

II. RELATED WORK

2.1 Analysis of Flat Slab with single drop

2.2 Analysis of Flat Slab with double drop

2.3 Analysis of Flat Slab with Drop and Column with Column Head

After the analysis of flat slab with single drop and double drop it was observed that punching shear is far more than its permissible limit. Hence flat slab with single drop and column head is adopted as a third alternative.

Cases	Slab Depth In mm	Depth Of Drop In mm	Column Head In mm	
			Depth	Top Width
1.	150	150	600	1800
2.	200	200	600	1800
3.	240	240	600	1800

III. METHODOLOGY

A 3x3 panel single storey flat slab having plan dimension 20mx20m is analyzed using software ANSYS. The center to center distance between columns of flat slab is taken as 6.67m. In first alternative, flat slab without openings various sub-alternatives like slab with different depths and drops of different depths have been tried. In order to understand optimum design of flat slab, the effect of tensile and compressive stresses and also the effect of deflection under the given loadings are studied. An attempt is made to study the punching shear effect on flat slab by providing flat slab with double drops and slab with column head.

3.1 Modeling

The joint is modeled as volume. The dimensions are shown in Table 3.7. The combined volumes created in ANSYS are shown in Fig. 3.18.

Table-3.7: Dimensions for Column, Drop and Slab

Coordinates			X1	X2	Y1	Y2	Z1	Z2
Column in mm		Volume-01	0	0.6	0	3	0	0.6
Drops in mm	At Centre	Volume-02	0	2.2	0	0.12	0	2.2
	At Periphery	Volume-03	0	2.2	0	0.12	0	1.1
	At Corner	Volume-04	0	1.1	0	0.12	0	1.1
Slab in mm		Volume-05	0	20	0	0.24	0	20

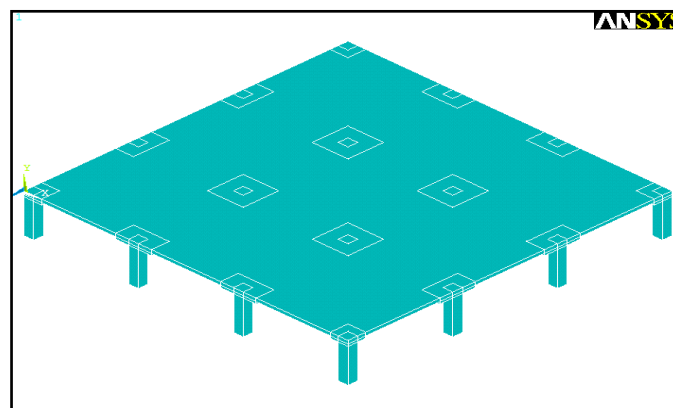


Figure-3.18: Volumes Created in ANSYS for the Control

3.2 Meshing

To obtain good results from the Solid65 element, the use of a rectangular mesh is recommended (Wolanski, 2004; Kachlakev et al., 2001). Therefore, the mesh is set up such that square or rectangular elements are created. The overall mesh of the flat slab created in ANSYS is shown in Fig. 3.19 and Fig. 3.20 the necessary element divisions are noted.

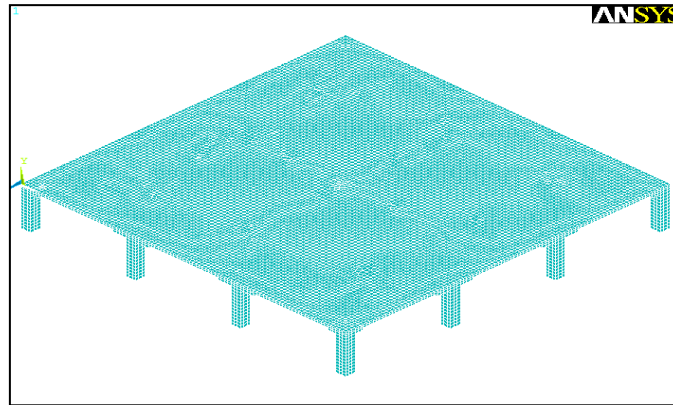


Figure-3.19: Mesh Created In ANSYS for the Flat Slab

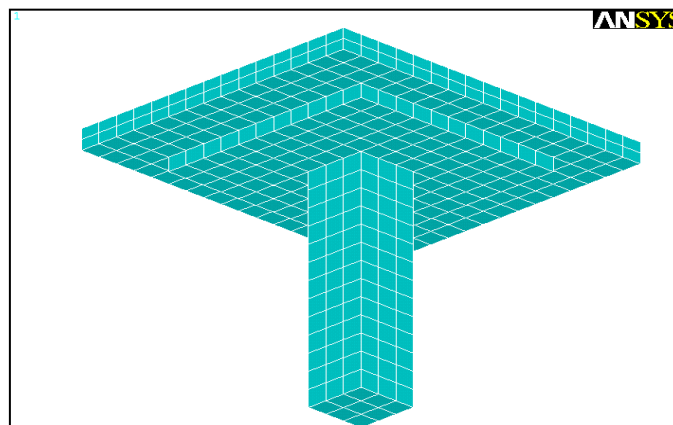


Figure-3.20: Mesh Created In ANSYS for the Column Slab Connection

3.3 Loads and Boundary Conditions

Displacement boundary conditions are needed to constrain the model to get a unique solution. To achieve this, the translations at the nodes (UX, UY and UZ) are given constant values of 0. The support conditions at the bottom of the column are shown in Fig. 3.22. The pressure P is applied on top area of the slab. Fig. 3.23 illustrates the applied loading.

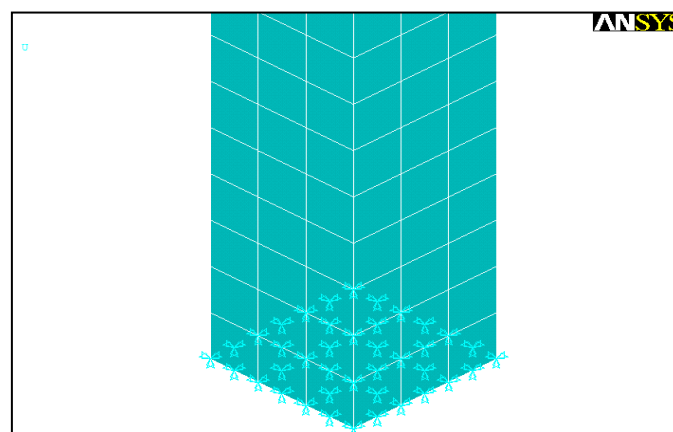


Figure-3.22: Boundary Conditions for the Control Flat Slab

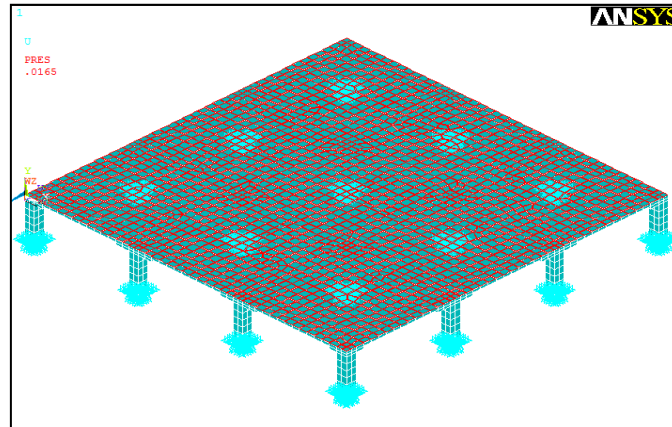


Figure-3.23: Loading Conditions for the Flat Slab

IV. RESULTS AND DISCUSSION

The flat slab with single drop having different thickness and depth of drop are analyzed using ANSYS. Results are presented in tabular as well as in graphical format.

4.1 Analysis of Flat Slab with single drop

4.1.1 Deflection and Stresses

Analysis results like maximum deflection, compressive stress, tensile stress and punching shear (shear stress in xy direction) are presented in tabulated as well as in graphical format.

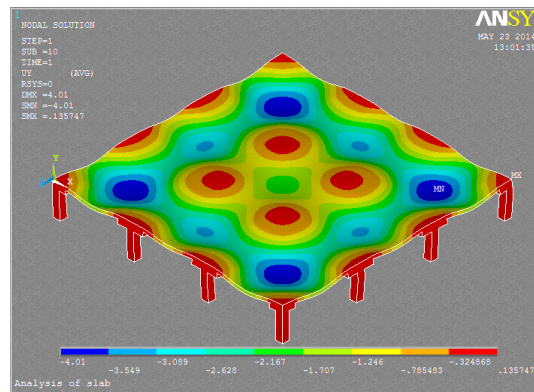


Figure-4.13: Deflected Shape of Flat Slab for Case-03 Model-05

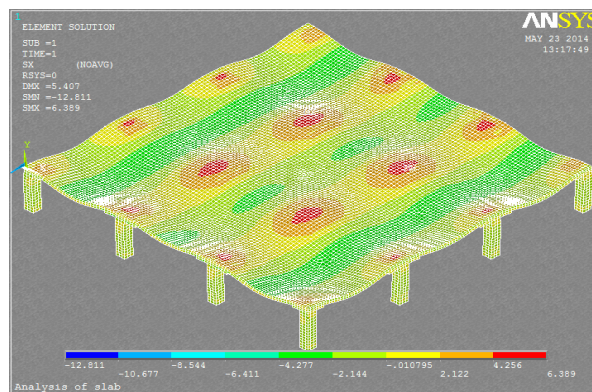


Figure-4.14: stresses in x-direction of Flat Slab for Case-03 Model-05

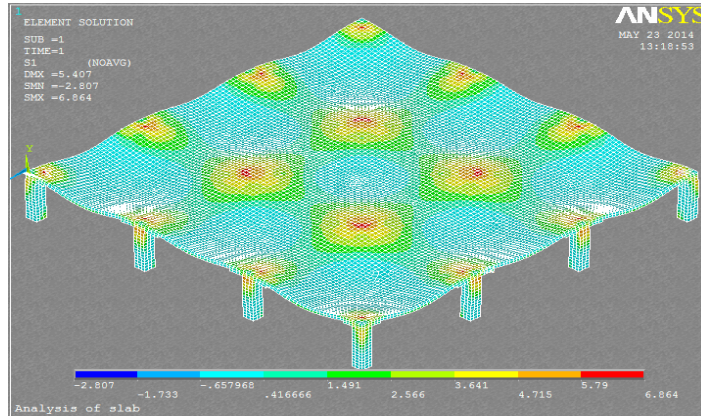


Figure-4.15: First Principle Stresses (σ_x) Of Flat Slab for Case-03 Model-5

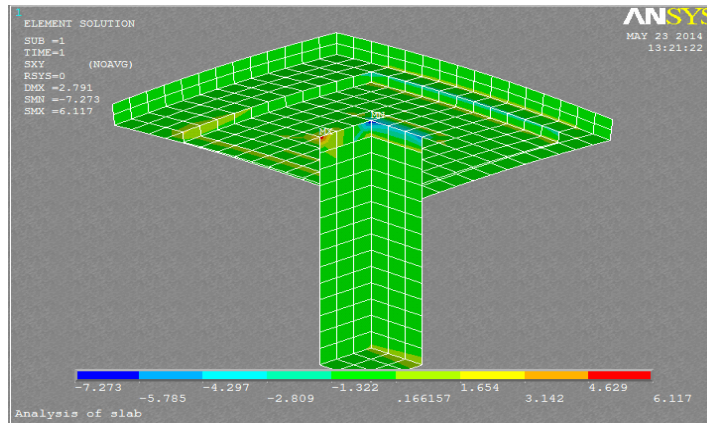
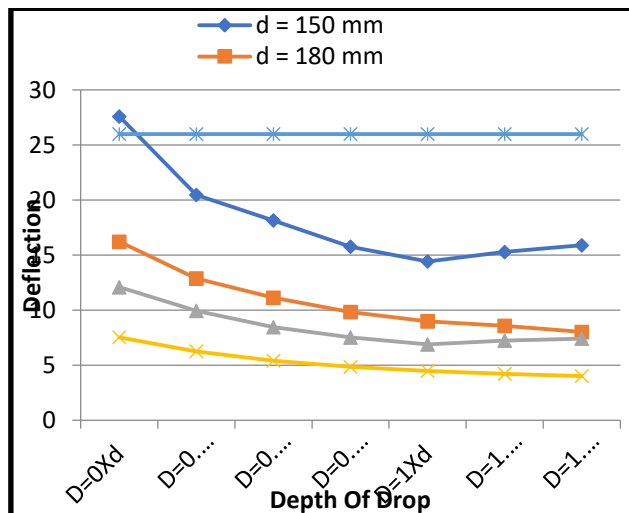


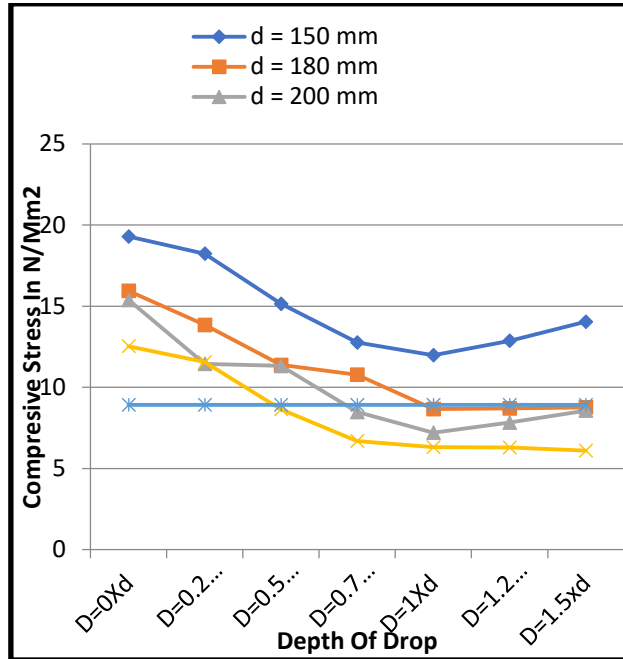
Figure-4.16: shear Stresses (τ_{xy}) Of Flat Slab for Case-04 Model-3

Graph-4.5 shows the variation of maximum deflection of flat slab for different alternatives along with its permissible limit



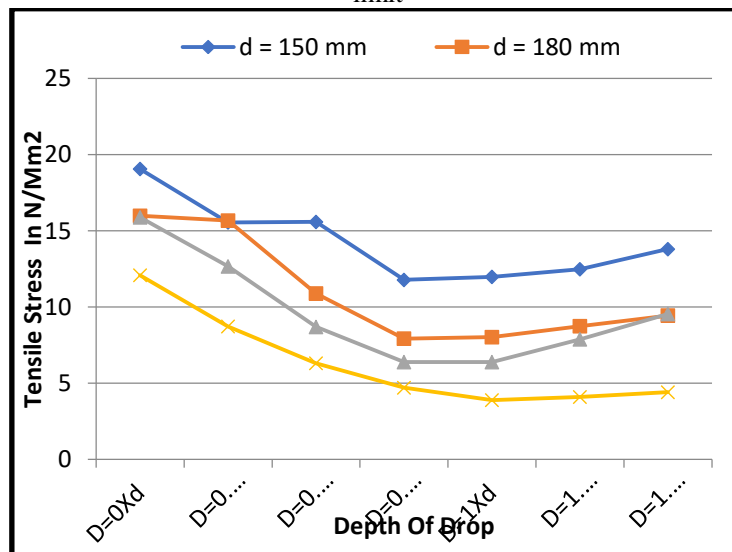
Graph-4.5: Maximum Deflection of Flat Slab for Different Cases

Graph-4.6 shows the variation of maximum compressive stress in flat slab for different alternatives along with its permissible limit



Graph-4.6: Maximum Compressive Stress of Flat Slab for Different Cases

Graph-4.7 shows the variation of maximum tensile stress in flat slab for different alternatives along with its permissible limit

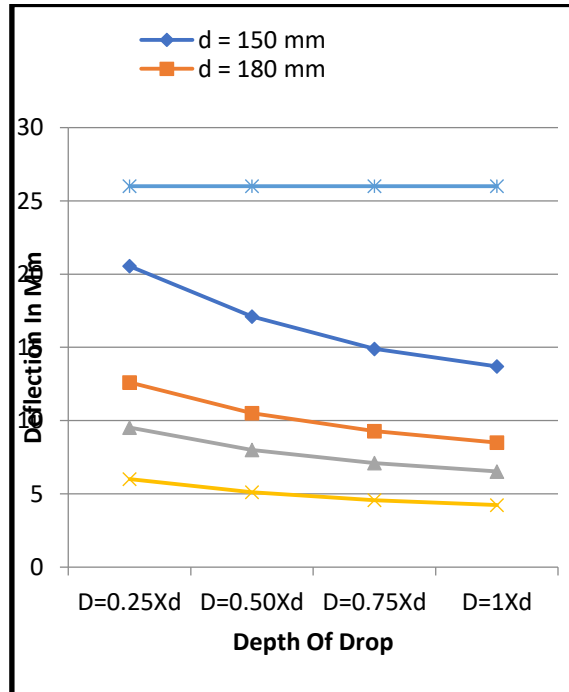


Graph-4.7: Maximum Tensile Stress of Flat Slab for Different Cases



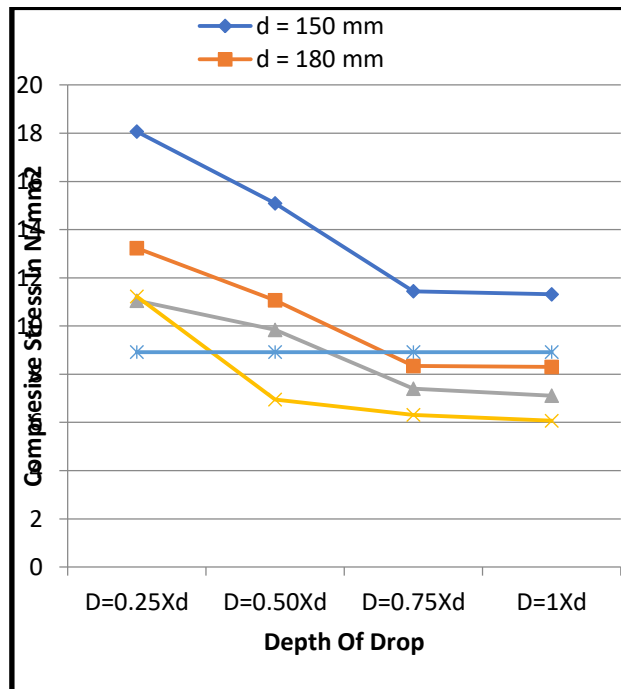
4.2 Analysis of Flat Slab with double drop

Graph-4.24 shows the variation of maximum deflection of flat slab for different alternatives along with its permissible limit



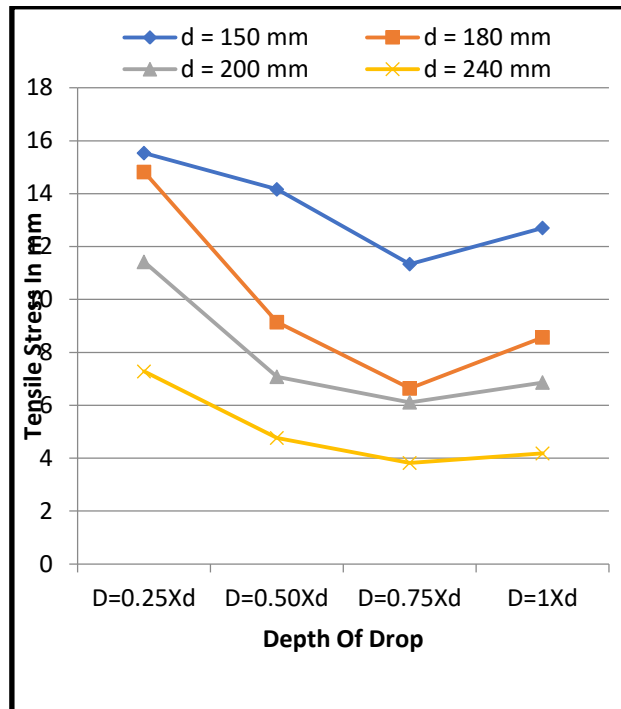
Graph-4.24: Maximum Deflection of Flat Slab for Different Cases

Graph-4.25 shows the variation of maximum compressive stress in flat slab for different alternatives along with its permissible limit



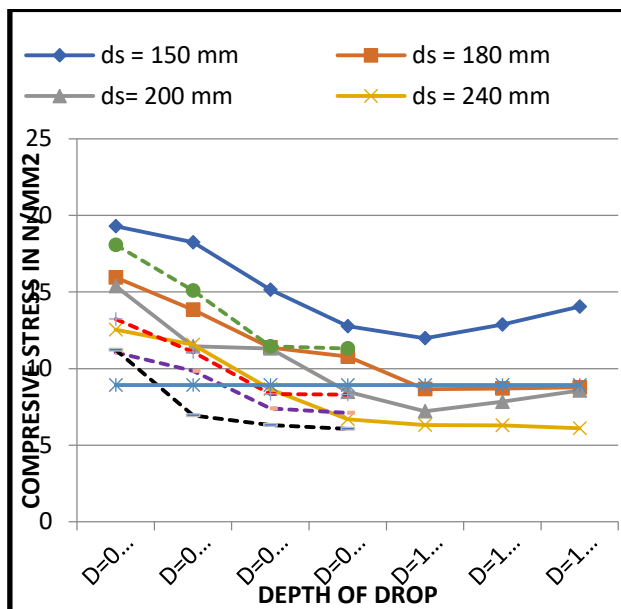
Graph-4.25: Maximum Compressive Stress of Flat Slab for Different Cases

Graph-4.26 shows the variation of maximum tensile stress in flat slab for different alternatives along with its permissible limit



Graph-4.26: Maximum Tensile Stress of Flat Slab for Different Cases

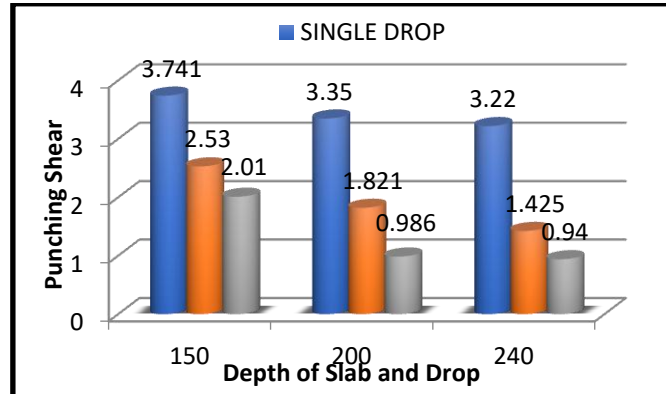
Graph-4.36 shows the variation of maximum compressive stress in flat slab with single drop and double drop for different alternatives along with its permissible limit. ds and dd indicates single drop and double drop.



Graph-4.36: Comparison of compressive stress for single and double drop

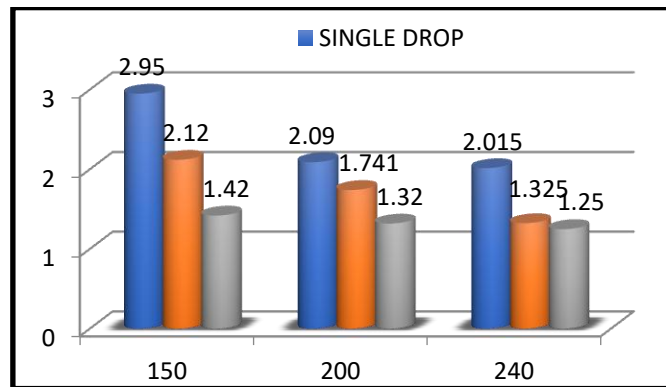
4.3 Analysis of Flat Slab with Drop and Column with Column Head

The variation of punching shear at drop for different method i.e. for single drop, double drop and for column head is represented in graph-4.37.



Graph-4.37: Comparison of Punching Shear at Drop for Flat Slab with Various Alternatives

The variation of punching shear at slab for different method i.e. for single drop, double drop and for column head is represented in graph-4.38.



Graph-4.38: Comparison of Punching Shear at Drop for Flat Slab with Various Alternatives

V. CONCLUSIONS

Following table gives general idea about safe depth of slab along with thickness of drop that can be adopted in flat slab from compressive stress point of view.

Table 4.41 Summary of Safe Depth of Slab and Drops

Model	Depth Of Slab	Depth Of Drop	Remark (Compressive Stress)	
			Single Drop	Double Drop
1	150 mm	D=0Xd	X	X
		D=0.25Xd	X	X
		D=0.50Xd	X	X
		D=0.75Xd	X	X
		D=1Xd	X	X
		D=1.25xd	X	-
		D=1.5xd	X	-
2	180 mm	D=0Xd	X	X
		D=0.25Xd	X	X
		D=0.50Xd	X	X
		D=0.75Xd	X	✓



		D=1Xd	✓	✓
		D=1.25xd	✓	-
		D=1.5xd	✓	-
3	200 mm	D=0Xd	X	X
		D=0.25Xd	X	X
		D=0.50Xd	X	✓
		D=0.75Xd	✓	✓
		D=1Xd	✓	✓
		D=1.25xd	✓	-
		D=1.5xd	✓	-
4	240 mm	D=0Xd	X	X
		D=0.25Xd	X	X
		D=0.50Xd	✓	✓
		D=0.75Xd	✓	✓
		D=1Xd	✓	✓
		D=1.25xd	✓	-
		D=1.5xd	✓	-

Detailed discussions are briefly given after individual analysis cases. Few prominent conclusions for flat slab without openings are as follows:

1. In case of flat slab with single drop for slab thickness 180mm suitable depth of drop is equal to the effective depth of slab.
2. Similarly for slab thicknesses 200mm and 240mm the suitable depth of drop is 0.75 and 0.5 times the effective depth of slab respectively.
3. For flat slab having depth of drop up to 0.75 times the effective depth of slab the compressive stress and tensile stress decreases gradually. But beyond the drop thickness 0.75 to 1.5 times effective depth of slab the trend of both stresses was almost linear.
4. As the depth of drop is increased the stiffness at that region is also increased hence as a result negative bending moment is increased and positive bending moment is decreased.
5. Approximately the size of drop can be calculated as $Lx/3$ however finite element method shows compressive stress can also be kept within permissible limit with the ratio $Lx/3.67$.
6. In case of flat slab with single drop for slab thickness 180mm, 200mm and 240mm the suitable depth of drop should be 0.7, 0.6 and 0.3 times the effective depth of slab respectively.
7. Because of significant change in stiffness from column face to the face of drop a large stress concentration is observed near column face. Hence column face is the most critical section from punching shear point of view.
8. For flat slab with column head punching shear value is far less than flat slab with single and double drop.

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