

FINITE ELEMENT ANALYSIS OF FLAT SLAB WITH AND WITHOUT OPENING

Seema Rajabhau Ghogare¹, Dr. Ashok Kasnale², Kadlag Viswajeet.³

¹PG Student Dr. D. Y. Patil School of Engineering and Technology, Charholi bk, Lohegaon, Pune India

²Professor, Dr. D. Y. Patil School of Engineering and Technology, Charholi bk, Lohegaon, Pune India

³Assistant Professor, Dr. D. Y. Patil School of Engineering and Technology, Charholi bk, Lohegaon, India

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.

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

1. 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. The main aim of this work is to study the effect of opening in a flat slab and to find the ideal location of opening, ideal shape of opening and reinforcement detailing around the opening. Generally in almost all constructions, flat slab system includes openings. These may be of substantial size, as required by stair-ways and elevators shafts, or they may be of smaller dimensions, like those needed to accommodate heating, plumbing, and ventilating risers, floor and roof drains, and access hatches. To study the behavior of flat slab when opening is present different alternative have been adopted as mentioned in tabulated format. In flat slab construction, openings are introduced for different purposes. Hence a flat slab with openings is another alternative which has been taken to study the optimistic design of flat slabs. Analysis results have been presented later in this chapter in the form of tables and graphs. In second stage, analysis of flat slab with openings has been carried out for following cases: -

1. Flat slab with drop having different diameter of openings.
2. Flat slab with drop having different shape of openings.
3. Flat slab with drop having different arrangement of opening.

2. GENERAL

Aim of this dissertation is to compare the behavior of flat slab with and without openings Aim of this dissertation is to compare the behaviour of flat slab with and without openings. In 2nd Stage we have discuss following points.

- 1- Evaluation of Suitable shape of Opening.
- 2- Evaluation of Suitable Size of Opening.

3. EXAMPLE FRAMES

3.1 Analysis of Flat Slab with openings

3.1.1 Position of openings

To study the behavior of flat slab when opening is present different alternative have been adopted as mentioned in tabulated format. Case-04 Model-03 is considered for analyzing the flat slab with opening. At the initial stage for finding the ideal location of opening the circular openings having diameter 200mm to 800mm are provided at three position i.e. position-A, position-B and position-C are as shown in fig-3.1. Various analysis trials have been performed and investigation has been done to study the nature of tensile stresses and compressive stresses around the opening and deflection at different location of a flat slab. Further the calculated stresses along each strips as per the notations mentioned in table-3.2 and results are presented through table.

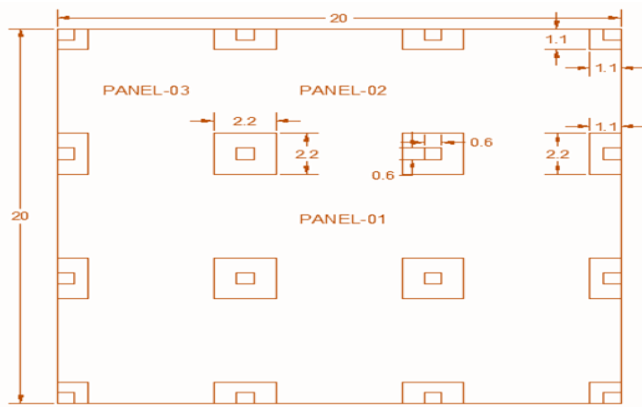


Figure-3.1: Plan View of Flat Slab Showing Different Position of Opening

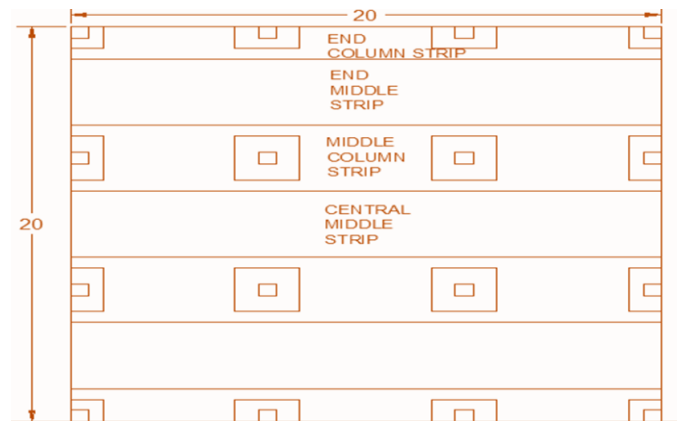


Figure-3.2: Plan View of Flat Slab Showing Different Types of Strips

Table-3.1 gives the description of different types of alternative used for analysis of flat slab with opening.

Table-3.2: Different Types of Strips and There Description

Cases	Models	Openings	Description
Case-I	M-1	A-200	Opening Of 200mm Diameter at Position-A
	M-2	A-400	Opening Of 400mm Diameter at Position-A
	M-3	A-600	Opening Of 600mm Diameter at Position-A
	M-4	A-800	Opening Of 800mm Diameter at Position-A
Case-II	M-1	B-200	Opening Of 200mm Diameter at Position-B
	M-2	B-400	Opening Of 400mm Diameter at Position-B
	M-3	B-600	Opening Of 600mm Diameter at Position-B
	M-4	B-800	Opening Of 800mm Diameter at Position-B
Case-III	M-1	C-200	Opening Of 200mm Diameter at Position-C
	M-2	C-400	Opening Of 400mm Diameter at Position-C
	M-3	C-600	Opening Of 600mm Diameter at Position-C
	M-4	C-800	Opening Of 800mm Diameter at Position-C

Table-3.1: different diameter of opening and their position

Plan View of Flat Slab Showing Different Types of Strips is represent in Figure-3.2.

Different Strips	Description
ECS	End Column Strip.
EMS	End Middle Strip.
MCS	Middle Column Strip.
CMS	Central Middle Strip.

a) Case-I Model-1, 2, 3, 4

In this case the flat slab is analyzed when circular opening of diameter 200mm to 800mm is located at position-A

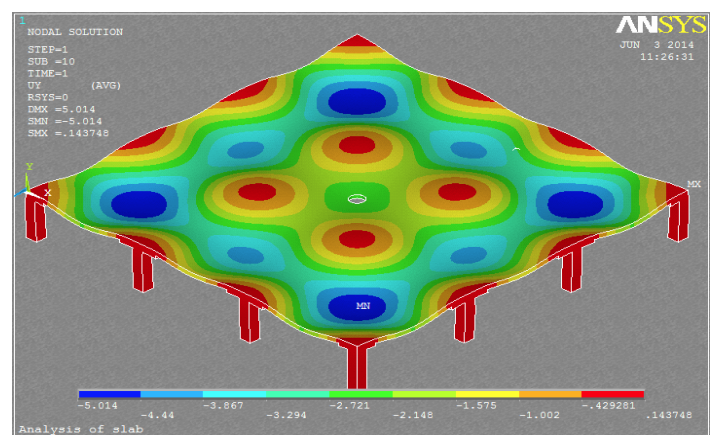


Figure-3.3: Deflected Shape of Flat Slab for Case-I M-4

b) Case-II Model-1, 2, 3, 4

In this case the flat slab is analyzed when circular opening of diameter 200mm to 800mm is located at position-B

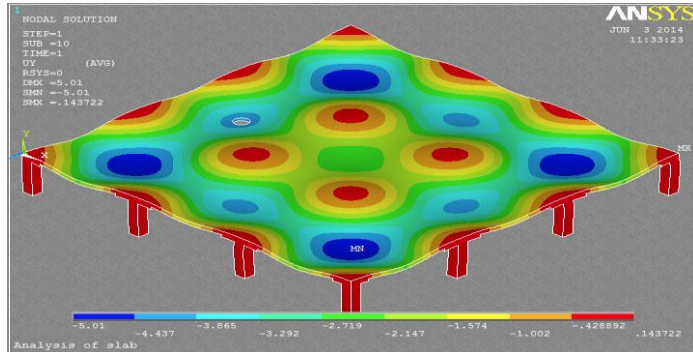


Figure-3.4: Deflected Shape of Flat Slab for Case-II M-4

c) Case-II Model-1, 2, 3, 4

In this case the flat slab is analyzed when circular opening of diameter 200mm to 800mm is located at position-C

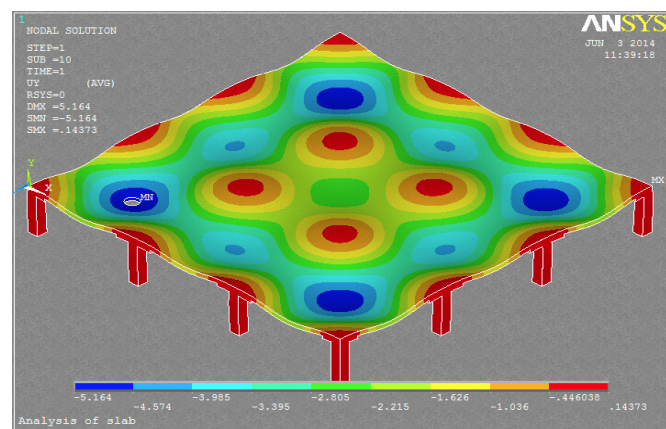


Figure-3.5: Deflected Shape of Flat Slab for Case-III M-4

3.1.2 Shape of Opening

To study ideal shape of opening a single panel has been considered and analyzed for different shapes of openings. In the initial stage a circular opening of area 1 m² is provided at the center of panel as shown in figure-3.6. Comparison has been made between square and circular opening having same area. Results are presented through tabulated and graphical format.

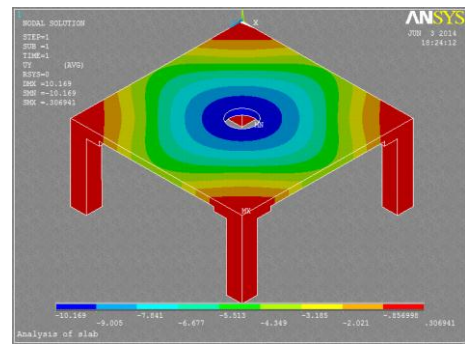


Figure-3.6: Deflected Shape of Single Panel with Circular Opening

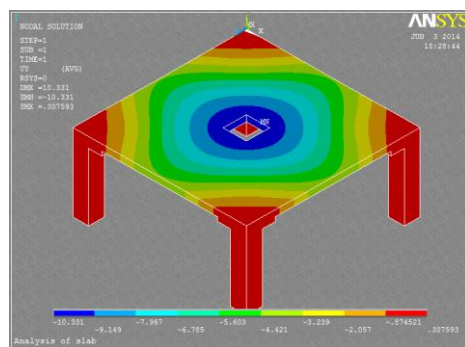


Figure-3.7: Deflected Shape of Single Panel with Square Opening

4. 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.

Parameters needed to define the material models for the control specimen are listed in Table 4.1 Note that there are multiple parts of the material model for each element.

Table-4.1: Material Models for the Flat Slab Model

Material Model Number	Element Type	Material Properties
1 Solid186		Linear Isotropic
	EX	22360.68 Mpa
	PRXY	0.2
		Multilinear Isotropic

		Strain	stress (Mpa)
	Point 1	0.0005	11.18
	Point 2	0.001	17.03
	Point 3	0.0015	19.59
	Point 4	0.002	20
	Concrete		
	ShrCf-Op	0.6	
	ShrCf-Cl	0.9	
	UnCrcksSt	2.77	
	UnCrusSt	-20	
	BiCrusSt	-24	
	HydrPress	0	
	HydrBICrusSt	-29	
	HydrUnCrusSt	-34.5	
	TenCrFac	-0.15	
2 Link180	Linear Isotropic		
	EX	2.00E+05	
	PRXY	0.3	
	Bilinear Isotropic		
	Yield stress	460 Mpa	
	Tangent Modulus	0	

	At Corner	Volu me-04	0	1.1	0	0.1	0	1.1
Slab in mm		Volu me-05	0	20	0	0.2	0	20

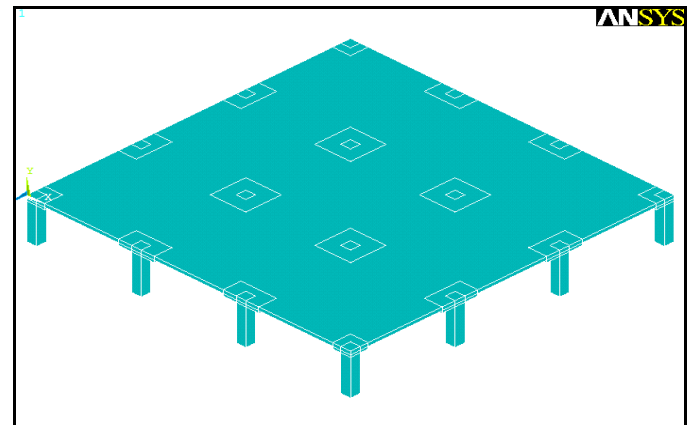


Figure-4.1: Volumes Created in ANSYS for the Control

4.2 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. 4.2 and Fig. 4.3 the necessary element divisions are noted.

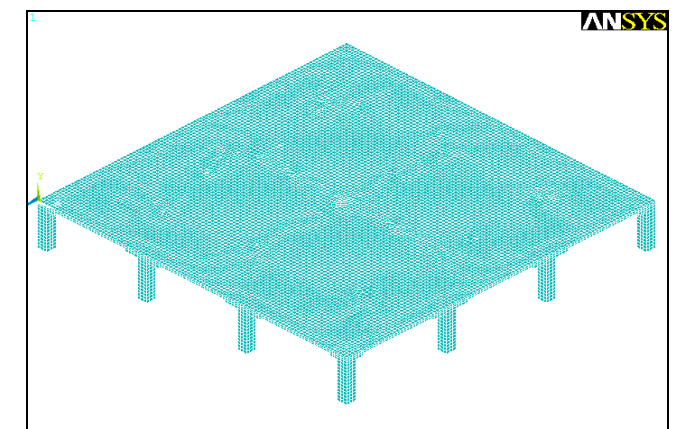


Figure4.2: Mesh Created In ANSYS for the Flat Slab

4.1 Modeling

The joint is modeled as volume. The dimensions are shown in Table 4.2. The combined volumes created in ANSYS are shown in Fig. 4.1.

Table-4.2: Dimensions for Column, Drop and Slab

Coordinates			X1	X2	Y1	Y2	Z1	Z2
Column in mm		Volu me-01	0	0.6	0	3	0	0.6
Drops in mm	At Centre	Volu me-02	0	2.2	0	0.1	0	2.2
	At Periphery	Volu me-03	0	2.2	0	0.1	0	1.1

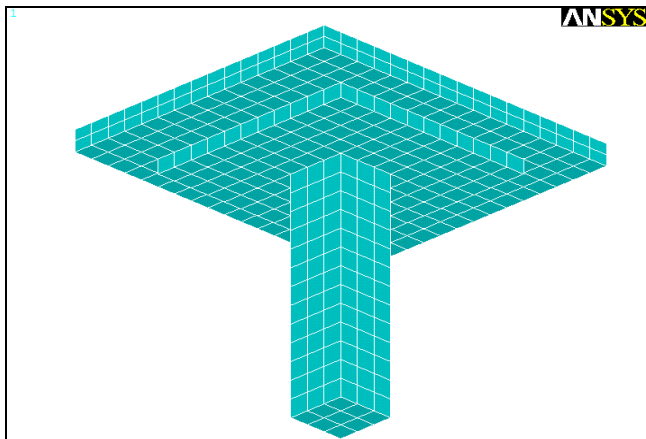


Figure-4.3 Mesh Created In ANSYS for the Column Slab Connection

4.3 Analysis Type

For the purpose of this model, the Static analysis type is utilized. The Restart command is utilized to restart an analysis after the initial run or load step has been completed.

The Sol'n Controls command dictates the use of a linear or non-linear solution for the finite element model. Typical commands utilized in a nonlinear static analysis are shown in Table below.4.3

Analysis Options	Large Displacement
Calculate Prestress Effects	No
Time at End of Load step	0.0165
Automatic Time Stepping	On
Number of Sub steps	10
Max no. of Sub steps	10
Min no. of Sub steps	10
Write Items to Results	File All Solution items
Frequency	Write Every Sub step

5. RESULTS AND DISCUSSION

The flat slab with different position of opening and differ shape of openings are analyzed using ANSYS. Results are presented in tabular as well as in graphical format.

5.1 Analysis of Flat Slab with openings at different position.

5.1.1 Deflection and Stresses

Figure-5.1 represent the deflected shape of flat slab for circular opening of diameter 800mm which is located at position-A

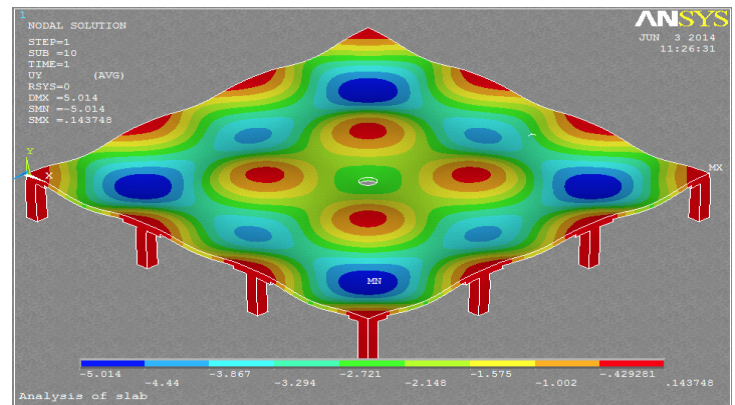


Figure-5.1: Deflected Shape of Flat Slab for Case-I M-4

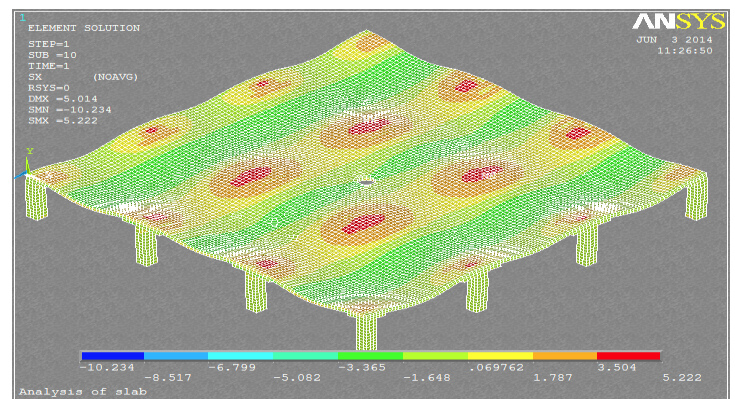
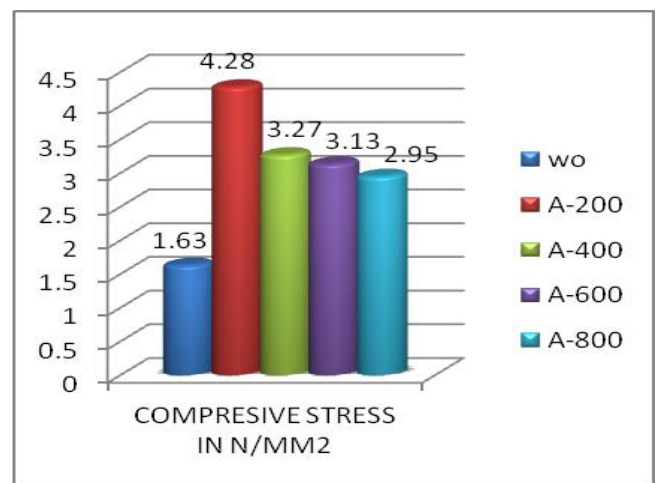
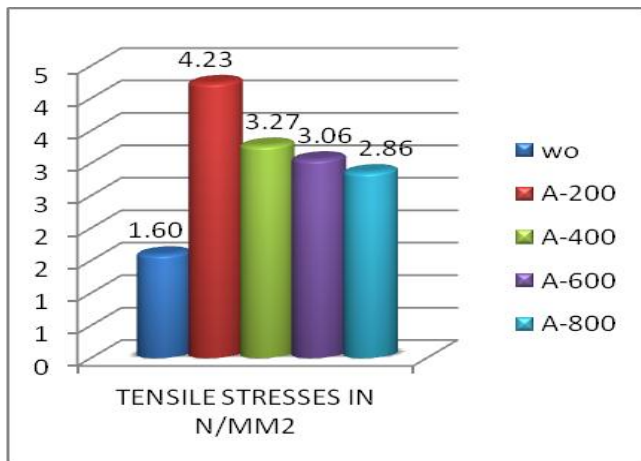


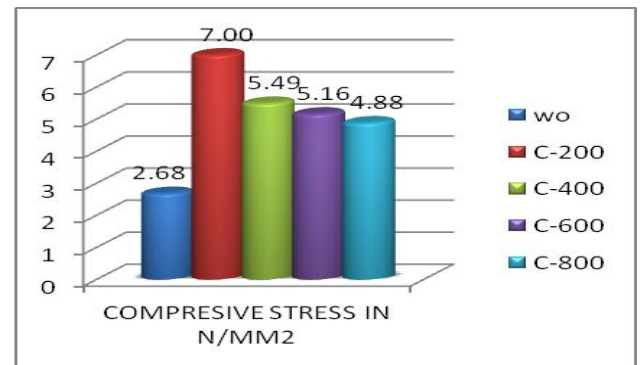
Figure-5.2: X-Directional Stress of Flat Slab for A-800



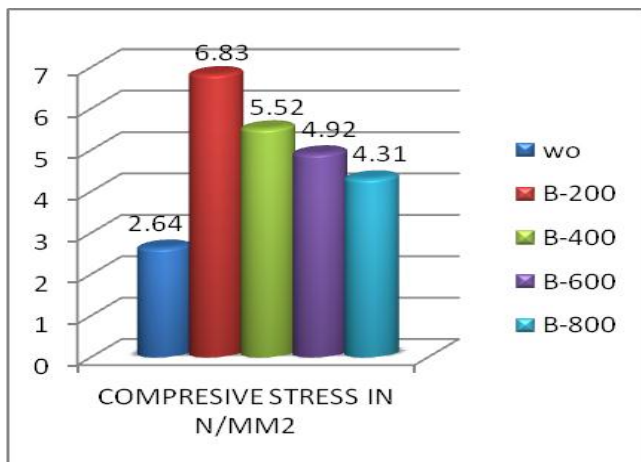
Graph-5.1: Compressive Stress around Opening for Case-01 M1, M2, M3 and M4



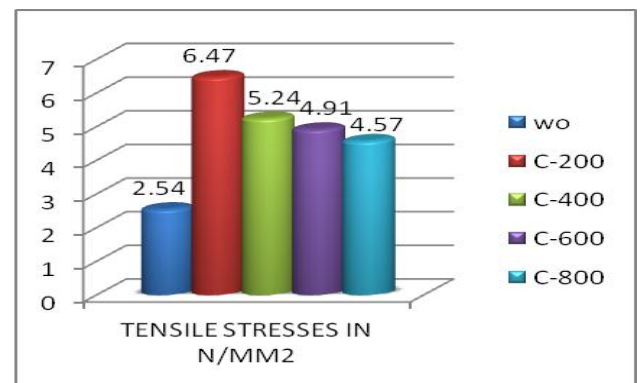
Graph -5.2: Tensile Stress around Opening for Case-01 M1, M2, M3 and M4



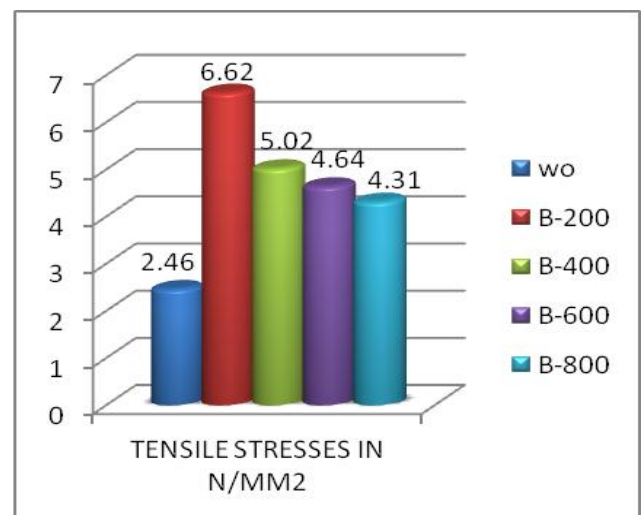
Graph -5.5: Compressive Stress around Opening for Case-01 M1, M2, M3 and M4



Graph -5.3: compressive Stress around Opening for Case-02 M1, M2, M3 and M4



Graph -5.6: Compressive Stress around Opening for Case-01 M1, M2, M3 and M4



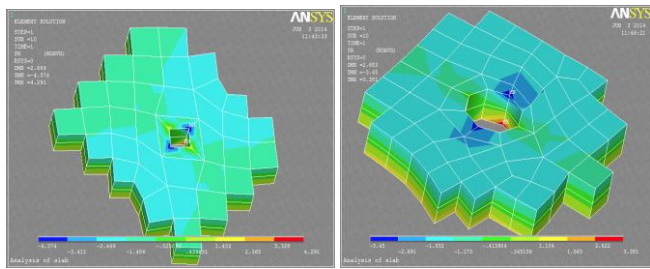
Graph -5.4: compressive Stress around Opening for Case-02 M1, M2, M3 and M4

5.1.2 Stresses along each strips

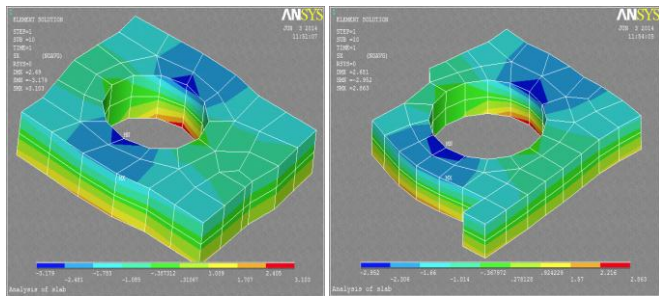
The effect of opening on each strip i.e. column strip and middle strip is observed by examining the stresses along end column strip, end middle strip, middle column strip and central middle strip. Results for Stresses along each strip in the presence of opening are compared with the stresses along each strip in the absence of opening. The detailed overviews of comparison of stresses along each strip for flat slab with opening and without opening are represented in tabulated and graphical format.

5.1.2.1 Case-I Model-1, 2, 3, 4

In this case, flat slab having circular opening of diameter 200mm located at position-A is analyzed. Figure-5.3 (a), (b), (c), (d) represents the stress concentration around the openings for respective diameters of opening i.e. opening of 200mm to 800mm.



(a) Case-I, M-1 (b) Case-I, M-2



(c) Case-I, M-3 (d) Case-I, M-4

Figure-5.3: Stress around the Opening for Various Diameter of Opening

5.2 Shape of Opening

To study ideal shape of opening a single panel has been considered and analyzed for different shapes of openings. In the initial stage a circular opening of area 1 m² is provided at the center of panel as shown in figure-5.4. Comparison has been made between square and circular opening having same area. Results are presented through tabulated and graphical format.

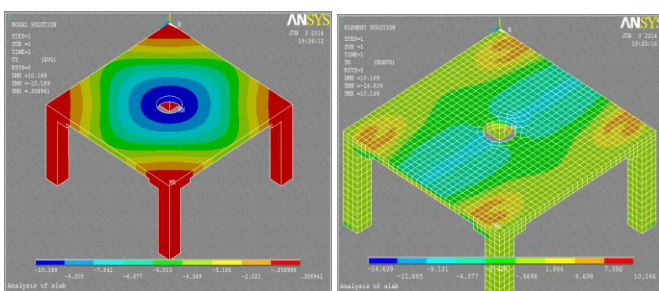


Fig-5.4.: Deflected Shape of Single Panel with Circular Opening.

Fig-5.5.: X-Directional stresses for Single Panel with Circular Opening

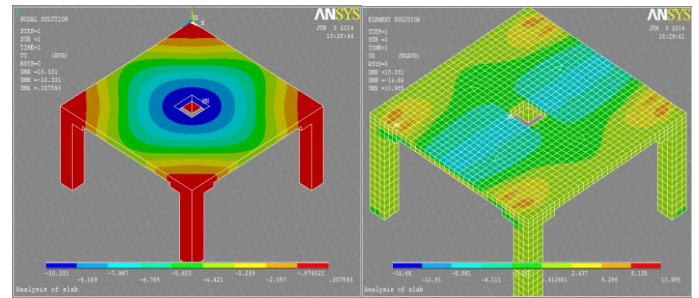


Fig-5.6.: Deflected Shape of Single Panel with Square Opening.

Fig-5.7.: X-Directional stresses for Single Panel with Square Opening

6. CONCLUSIONS

Few prominent conclusions for flat slab without openings are as follows:

1. The presence of openings in flat slab decreases the strength and rigidity of the flat slabs depending on the size, shapes, and location of these opening.
2. The stress around the openings decreases as the diameter of opening increases.
3. The stress increases at the position which is close to the openings and decreases in the position which is far from openings and continues in decreasing order.
4. The stresses along each strip are not affected by the different diameters of opening.
5. The deflection and tensile stress values of flat slab with square openings are higher than those of flat slab with circular openings having area of circular opening equal to the area of rectangular opening.
6. The most suitable shape of opening in the flat slab is of circular shape and the most preferable location is away from the corner supports.
7. Existence of openings in flat slabs of small thickness affects their behavior more than those of big thickness

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