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Numerical Analysis of Two Way Slab With Openings

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Abstract

Slabs are the concrete elements used as significant components in building. It is common to have openings in slabs for various operational reasons like electrical, mechanical and plumbing services as a result decreases their capacity to carry loads. Along with this, insufficient data is available for slabs having openings at centre and at eccentric positions to resist applied loads. Moreover, many difficulties were faced analytically while modelling the complex behaviour of RCC slabs in nonlinear zone. Therefore, they require special attention in both analysis and design. This research gives more attention on studying structural behaviour of two-way slab having openings at centre and at eccentric positions along with solid slab. To study this type of behaviour seven different models of square slabs having different shapes of openings like square, rectangular and circular at centre and eccentrically has been generated in ANSYS, which is a FEM based software. All specimens were subjected to load, which was increased from zero to failure load. The effects of opening shape on crack formation were also analysed.

Keywords: Finite Element Analysis, Slab with Opening, Crack Pattern

1. Introduction

Undeniably slabs as a part of structures plays very vital role in transferring load normal to their plane. Mostly concrete slabs are used as floors in different buildings like, industrial, residential and so on. Alones solid slabs, slabs with large openings are also required for fulfilling the purpose of plumbing, for providing pipes for fire protection ,ducts for heat, ventilation and air conditioning, on the other hand big openings has been required for stairs and shafts for elevators which ultimately reduces the maximum load carrying capacity of slabs as compared to solid slabs. The location and sizes of openings as per requirement are predetermined in the early stages of design, for construction of new slabs and then accordingly it can be accommodated.

The problems concerning with design of slab with openings is very complicated; therefore it cannot be solved by analytical method [5], [6], [7], [9]. On the other hand, in the present scenario, it become possible to analyse complicated structures like slab having openings by using powerful computers and advanced softwares which make it possible to create accurate methods by following Finite Element Method [1], [2], [3]. Nowadays many recent types of software are avail in market which really makes research works easy [4], [8], [10]. In this research, commercial software package ANSYS has been used to model various slab models having openings and solid slab without any opening to understand their behaviour by providing various types of openings at centre and at eccentric positions. The main focus of this study is to determine the effect of different shapes of openings at different positions on its stress region and deflection resistance.

2. Material and Methodology

In the present work, ANSYS which is powerful engineering software and is based on finite element method is used for investigation of numerical analysis of seven different slab models shown in table 1. This software has been generated by following recent technology which ultimately helps in solving problems related to linear as well as nonlinear simulations.

2.1 Modelling of Concrete

The different models of concrete slabs has been created by using solid 65 element present in ANSYS software, which has eight nodes and each node has three degrees of freedoms in x, y and z directions with properties of concrete mentioned in tables 2 and 3 [8]. In three orthogonal directions plastic deformation, cracking and crushing is possible by selecting solid 65 elements. A schematic diagram of this element is shown in Fig 1.

2.2 Modelling of steel reinforcement

For providing reinforcement in slab models Link8 element has been used which has a 3D spar element and has twonodes which further have three degrees of freedom inn x, y and z directions along with capability of plastic deformation and properties mentioned in tables 4 and 5 [8]. The diagram of this element is shown in Fig 2.

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Table-1 Description of Slabs

Sr. No	Slab Symbol	Description
1	S1	Solid Slab
2	S2	Slab with square opening (75x75mm) at an eccentricity of 75mm from center of the slab.
3	S3	Slab with rectangular opening(75x150mm) at eccentricity of 75mm from center of the slab
4	S4	Slab with circular opening(diameter 75mm) at eccentricity of 75 mm from center of the slab
5	S5	Slab with square opening (75x75mm) at center of the slab.
6	S6	Slab with rectangular opening (75x150mm) at center of the slab.
7	S7	Slab with circular opening (diameter 75mm) at center of the slab.

Table-2 Properties of concrete prior to initial yield surface

Material	Material model	Modulus of elasticity (kN/m^2)	Poisons ratio
Concrete	Linear elastic	2.236e7	0.12

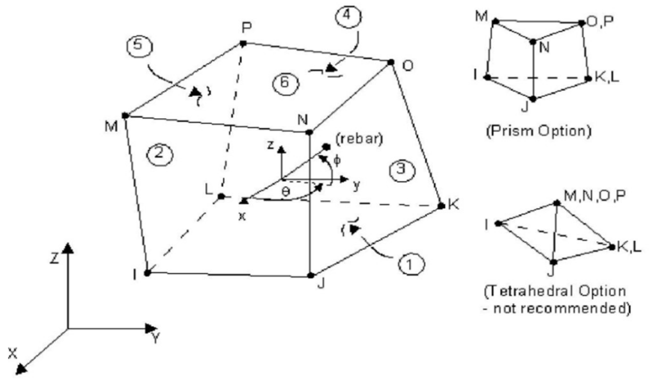

Fig. 1 Solid 65 element

Table-3 Parameters of concrete beyond initial yield surface

Open shear transfer coefficient	0.4
Closed shear transfer coefficient	1
Uniaxial cracking stress	1.98
Uniaxial crushing stress	-1

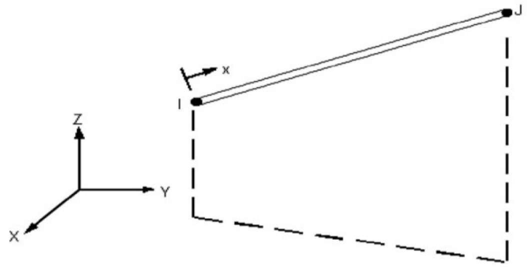

Fig. 2 Link 180-3-D spar

Table-4 Properties of reinforcement within link 180 element

Material	Material model	Modulus of elasticity (kN/m2)	Poisons ratio
Structural Steel	Linear elastic	2e8	0.3

Table-5. Parameters of steel beyond initial yield surface

Yield strength (Mpa)	415
Tangent Modulus	0

2.3 Meshing

The slab models are meshed in square and rectangular elements (shown in figures 3-9) as these options are avail in solid65 element [8]. For meshing the slabs volume mapped command was used. The meshing was done by giving the appropriate element divisions, which further helps in assigning proper length and width of appropriate divisions.

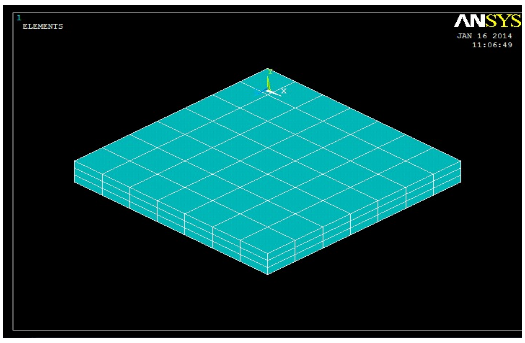

Fig. 3 Model showing meshing of solid slab

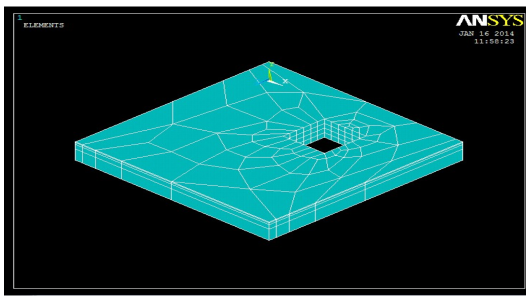

Fig. 4 Model showing meshing of slab with eccentric square opening

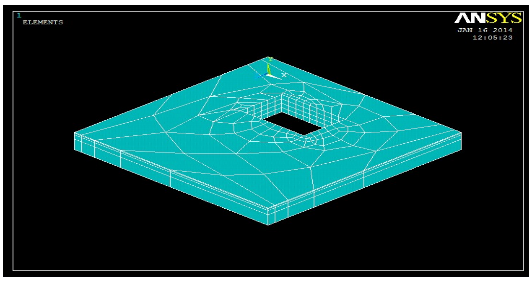

Fig. 5 Model showing meshing of slab with eccentric square opening

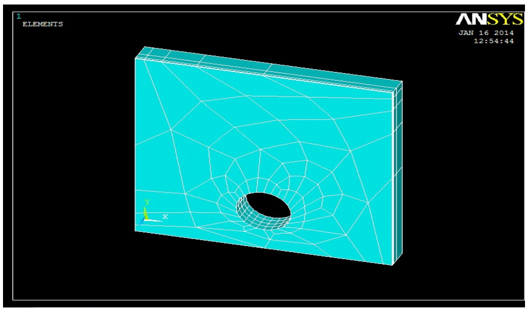

Fig. 6 Model showing meshing of slab with eccentric circular opening

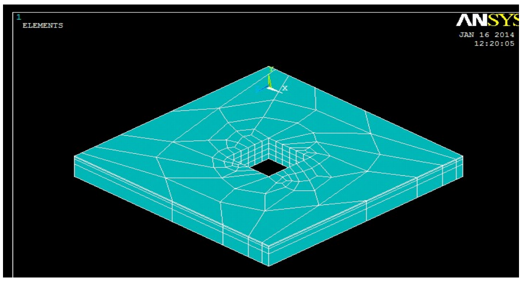

Fig. 7. Model showing meshing of slab with square opening at centre

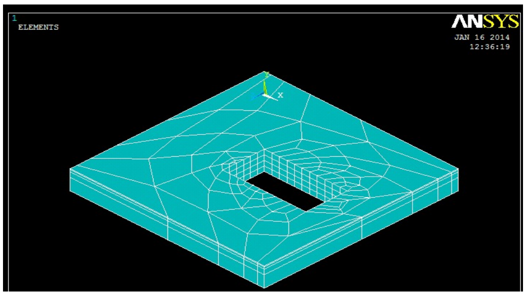

Fig. 8 Model showing meshing of slab with rectangular opening at centre

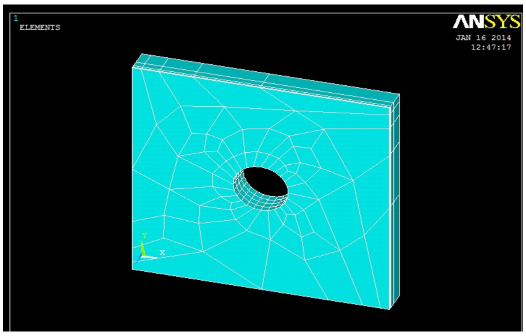

Fig. 9 Model showing meshing of slab with circular opening at centre

3. Results and Discussion

In the present work, slab without opening and with opening of rectangular, circular and square openings at different positions are being analysed and studied. The variation in deflection due to different openings in slab center and at eccentricity for different loads is compared with load deflection variation of solid slab is graphically shown in figures 10-12.

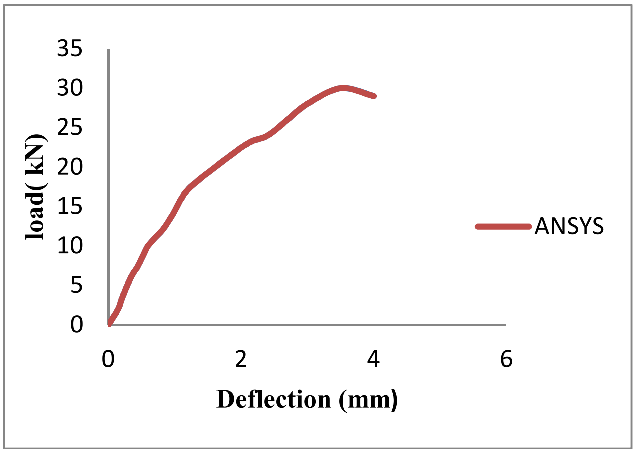

Fig. 10 Load deflection curve of Solid Slab

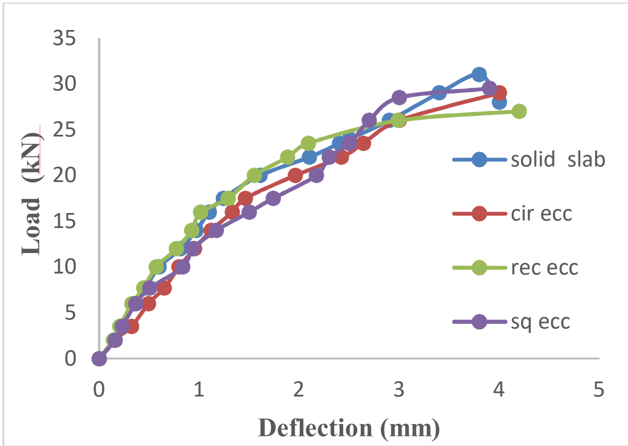

Fig. 11 Load deflection curve of solid slab and openings at eccentricity positions

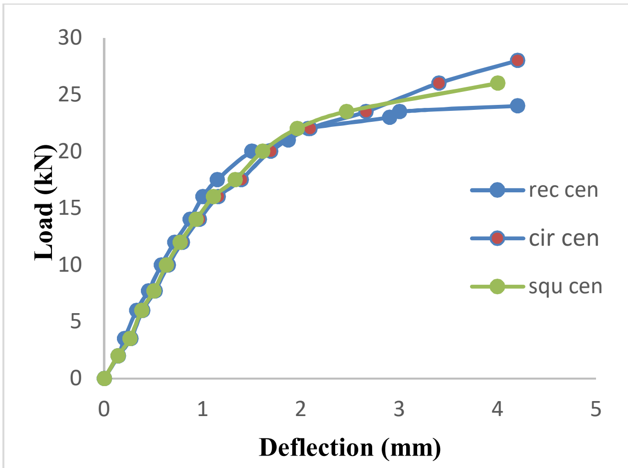

Fig. 12. Load deflection graph of different shapes of openings at centre

From the graph it is clear that deflection is more in case of slab with opening and load carried by slab with opening is less as compared to solid slab. Along with this it has been analysed that slabs having eccentric openings carry more load as compared to slabs having openings at centre. Crack pattern at ultimate load for different slabs are shown in figures 13-16. Crack pattern of ANSYS modelled slabs shows good agreement with experimental results.

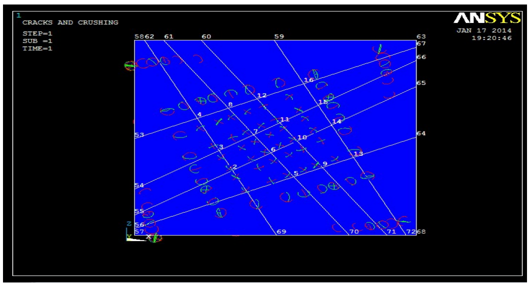

Fig. 13 Crack pattern of solid slab at maximum load

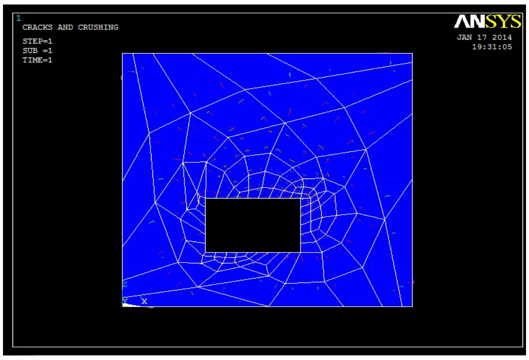

Fig. 14 Crack pattern of slab having rectangular opening at eccentricity

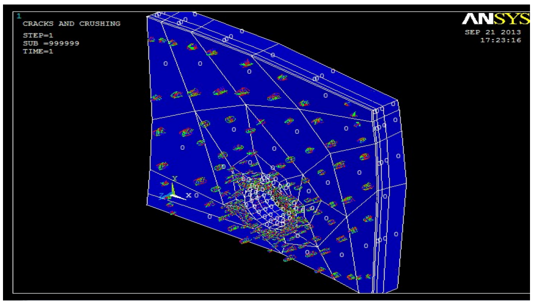

Fig. 15 Crack pattern of slab having circular opening at eccentric position

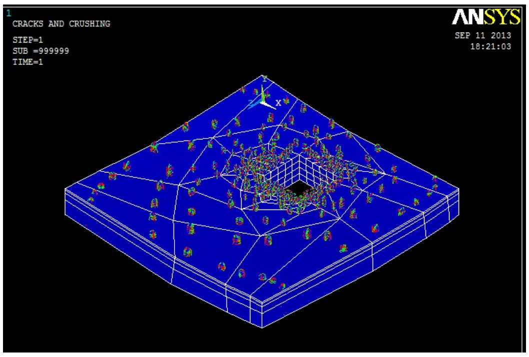

Fig. 16 Crack pattern of slab having circular opening at eccentric position

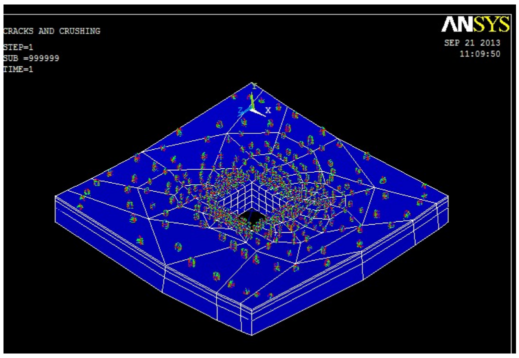

Fig. 17 Crack pattern of slab having circular opening at centre

4. Conclusions

From the different slab models results, the following major conclusions are listed below;

- Ultimate load carrying capacity of slab having opening is less as compared to solid slab.
- Slab having circular opening shows better result to carry load than slabs having square and rectangular openings.
- Slab with rectangular opening carries less load and deflection as compared to square opening.
- Crack pattern of ANSYS modeled slabs shows good agreement with experimental results.
- The deflection of slab with eccentric opening is less than the slab having opening at center.
- The results from ANSYS modeled slabs i.e. the finite element analysis is in good agreement with the experiment results under identical loading and boundary conditions.

  The literature review and analysis procedure utilized in this thesis has provided useful insight for future application of a finite element method for analysis. FEM model helps in comparing the results with experimental results data. Modelling the RC slab model in FEM based ANSYS software gives good results which can be included in future research. Further the numerical analysis can be done on slab with large openings, slabs with patch loadings and slabs by applying different composite materials.

Disclosures

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