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COMPARISON OF MAXIMUM DEFLECTION AND MAXIMUM BENDING MOMENT FOR PLATE WITH CENTRALLY LOCATED SQUARE AND CIRCULAR CUTOUT/HOLE OF VARYING SIZE

PRAMOD V. DESHMUKH

Principal, Dr. Panjab Rao Deshmukh Polytechnic, Amravati

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Abstract: - The plates with cutout/hole is widely used in structural member. To compare the effect of size and shape of cutout/hole on the maximum deflection and maximum bending moment of a simply supported square plate is the main focus of this study. Finite Element Analysis is used to analyse a simply supported square plate with square & circular cutout/hole of varying sizes. The results of the analysis are compared with the help of graphs and tables. Contours for stress concentration factors for a simple plate with square and circular cutout/hole are also presented for a sample case.

Keywords: Maximum deflection, Maximum bending moments, Finite Element Analysis.



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Corresponding Author: MR. PRAMOD V. DESHMUKH

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INTRODUCTION

The different types of shape of cutout/hole are in use for different engineering applications. A simply supported square plate with centrally located square and circular cutout/hole of varying sizes are considered for analysis. Comparison of maximum deflection and maximum bending moment for centrally located square and circular cutout/hole of varying sizes have been the main focus of this paper. In recent studies (1) the author used the eight noded isoparametric plate element with 3 d.o.f. per node for the analysis of perforated plate. Analysis is done through the same simulation for eight noded isoparametric plate element in Cartesian coordinate. The results are compared through the graphs and tables. Contours for stress concentration are presented for a sample case of plate with square hole and circular hole. The effect of increasing aspect ratio and percentage of opening on the maximum deflection and maximum bending moment are also studied. The tables and graphs will be useful to the design engineer to solve the complicated plate bending problems.

MATERIAL AND METHODS:

Finite element analysis is carried out for maximum deflection and maximum bending moment for a square plate with simply supported boundary condition and uniformly distributed transverse load weakened by square and circular cutout/hole at the centre of the plate. A simply supported square plate of size 2000mm x 2000mm with the ratio of plate thickness to plate lateral dimension equal to 0.005 is analysed. The aspect ratio b/a and d/a respectively for plate with centrally located square and circular cutout/hole considered are 0.05, 0.1, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40. Material properties are Young's modulus, $E=2.1 \times 10^5$ N/mm², Poisson's ratio, $\mu = 0.3$ and uniformly distributed load, $q_z=10$ KPa is considered for analysis. Usual finite element method for formulation with an eight noded Hinton's isoparametric plate element with Cartesian coordinate used for modelling the plate and the analysis is carried out through simulation.

RESULTS AND DISCUSSIONS:

In 1973 Hinton (5) developed an isoparametric plate element in Cartesian co-ordinates based on Mindlin plate theory. It is convenient to use Hinton's element for analysis of plates with cutout/ hole, i.e. perforated plate. This eight noded isoparametric plate element, based on thick plate theory, in which normal remains straight but does not remain normal to the middle plane, enhanced the applicability of finite element method for modelling perforated plates with

various boundary conditions. With this background, the square plate with simply supported boundary condition and uniformly distributed transverse load with centrally located square and circular cutout/hole of varying sizes is considered for analysis. The objective of the work is to compare the maximum deflection and maximum bending moment for a simply supported square plate with central square and circular cutout/hole of varying sizes. The effect of opening is studied by increasing the area of square and circular cutout/hole. Contours of stress concentration factor, K are also drawn for a sample case of square and circular hole at centre of the plate.

The results obtained by analysis of a simply supported square plate of different aspect ratios b/a and d/a respectively for plate with centrally located square and circular hole are presented in the form of graph and table of maximum deflection and maximum bending moment. Fig 1 shows the typical simply supported square plate (Quarter plate) with centrally located square and circular cut out with mesh. Fig. 2 shows the variation of maximum deflection with percentage opening λ for a plate with square and circular hole at centre. Fig.3 shows the variation of maximum moment M_x with percentage opening λ for a plate with square and circular hole at centre. Results of maximum deflection and maximum bending moments for different aspect ratio and percentage of opening are also tabulated in table 1. Contours of stress concentration factor for a S.S. Sq plate with square hole at centre of size 400mm x 400mm are presented in Fig. 4 and Fig. 5 shows the Contours of stress concentration factor for S.S. sq. plate with circular hole at centre of 400mm dia.

i) Comparison of Maximum Deflection:

From the Fig. 2 and Table 1 it is observed that the maximum deflections for the plate with central circular hole is less than the maximum deflections for the plate with central square hole with same percentage openings. In both the cases, as the area of opening increases the maximum deflection increases. It is maximum at 6.25% opening and aspect ratio 0.25 for the plate with square cutout/hole and at 1.767% opening and aspect ratio 0.15 for the plate with circular opening at the centre of plate. Further increase in the area of opening and aspect ratio the maximum deflection, in both the cases of opening, decreases. This is because after this amount of percentage opening the reduction in load over the plate becomes predominant than the reduction in the stiffness of the plate.

ii) Comparison of Maximum Bending Moment:

From the Fig. 3 and Table 1 it is observed that the maximum bending moments in the case of plate with central circular cutout/hole is less than the maximum bending moments for the plate with central square cutout/hole up-to 4% opening in the plate. Between 4% and 9% opening in the plate, the maximum bending moment in the former case is more than the later.

For the plate with central circular cutout/hole, the maximum bending moment is maximum at 4.908% opening and aspect ratio of 0.25. For the plate with central square cut out/hole, the maximum bending moment is maximum at 6.25% opening and aspect ratio of 0.25.

iii) Comparison of Stress Concentration Factors:

From the Fig. 4 and Fig. 5 it is observed that the concentration of stresses are more in case of square cutout/hole than the circular cutout/hole. Hence, the deflection and bending moment quantities are more in case of square cutout/hole than the circular cutout/hole. It is also observed that the stress concentration is more at re-entrant corner than at mid-point on the square holes in the plate. As the size of holes increase, the stress concentration at there entrant corner of square holes also increases. Stress concentration is also observed at corner of the plate with central square and circular hole. This is because of the lifting of edge of the plate.

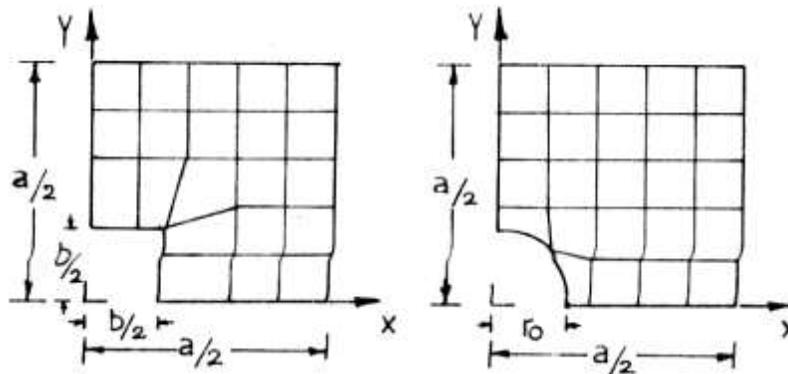


Fig. 1 : Finite Element Model of S.S. Sq. Plate with cutout/hole (Quarter Plate)

All Edges Simply Supported

Plate size $a = 2000\text{mm}$

Thickness $t = 10\text{mm}$

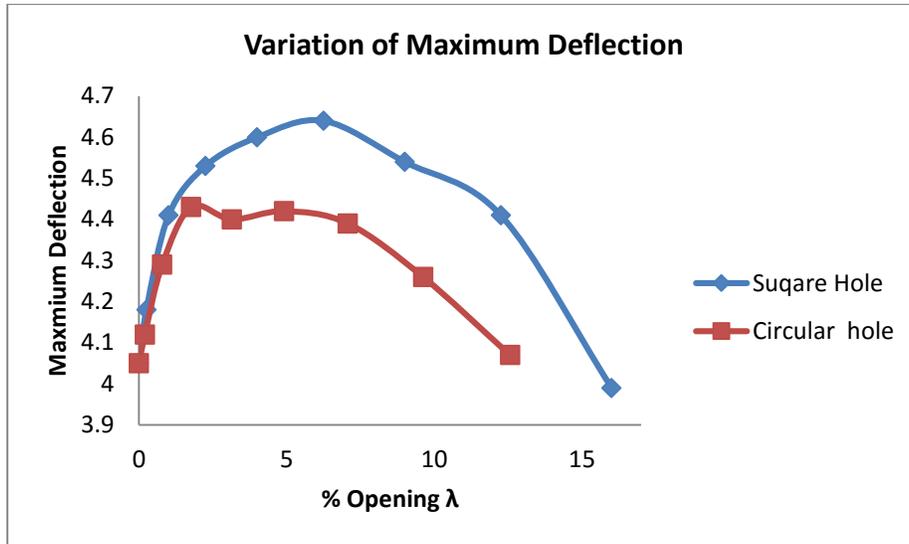


Fig. 2 : Variation of maximum deflection with % opening λ for plate with cutout/hole at centre.

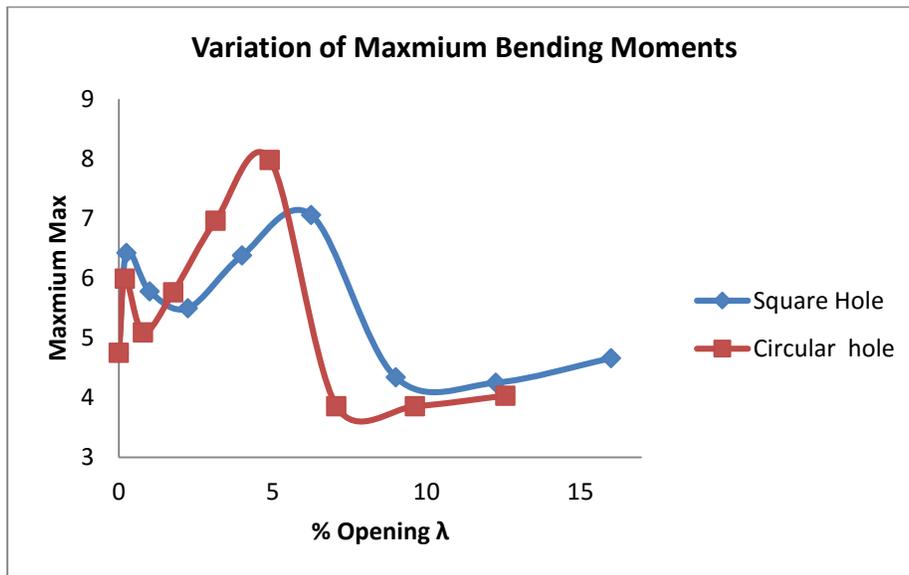


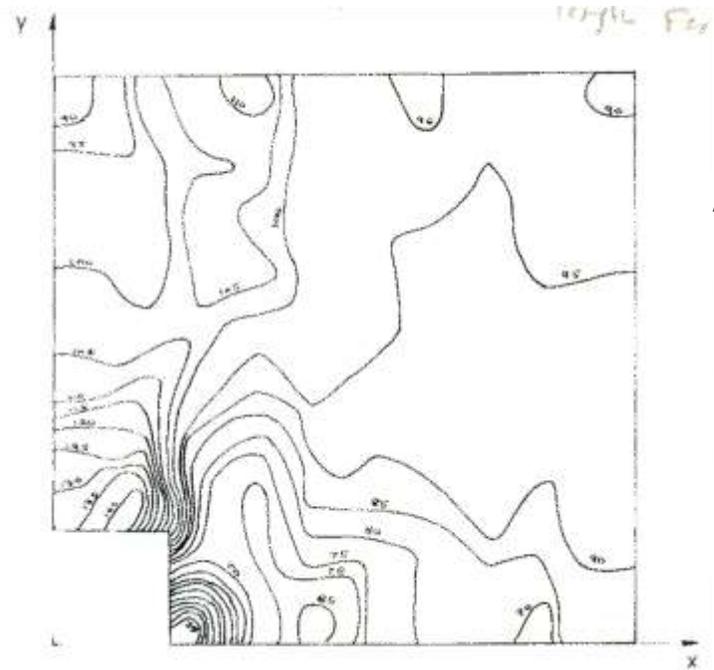
Fig. 3 : Variation of maximum moment M_x with % opening λ for plate with cutout/hole at centre.

Table 1 : Maximum deflections and Moments for a simply supported square plate with central cutout/hole subjected to uniformly distributed load and variation of cutout/hole size.

(a=2000mm, t=10mm, q_z=10KPa, E=2.1x10⁵N/mm², μ = 0.3, λ = Varying)

Square hole at centre				Circular hole at centre			
b/a	λ %	W _{max}	Max. Mx	d/a	λ %	W _{max}	Max. Mx
0	0.0	4.05	4.754	0	0.0	4.05	4.754
0.05	0.25	4.18	6.425	0.05	0.196	4.12	5.995
0.10	1.00	4.41	5.780	0.10	0.785	4.29	5.090
0.15	2.25	4.53	5.500	0.15	1.767	4.43	5.764
0.20	4.00	4.60	6.380	0.20	3.141	4.40	6.962
0.25	6.25	4.64	7.060	0.25	4.908	4.42	7.982
0.30	9.00	4.54	4.340	0.30	7.068	4.39	3.854
0.35	12.25	4.41	4.250	0.35	9.621	4.26	3.854
0.40	16.00	3.99	4.660	0.40	12.566	4.07	4.030
Multiplier		$\frac{q_z a^4}{D}$ x 10 ⁻³	q _z · a ² x 10 ⁻²	Multiplier		$\frac{q_z a^4}{D}$ x 10 ⁻³	q _z · a ² x 10 ⁻²

Where, a= Length of a square plate, b= Length of square hole, d= diameter of circular hole



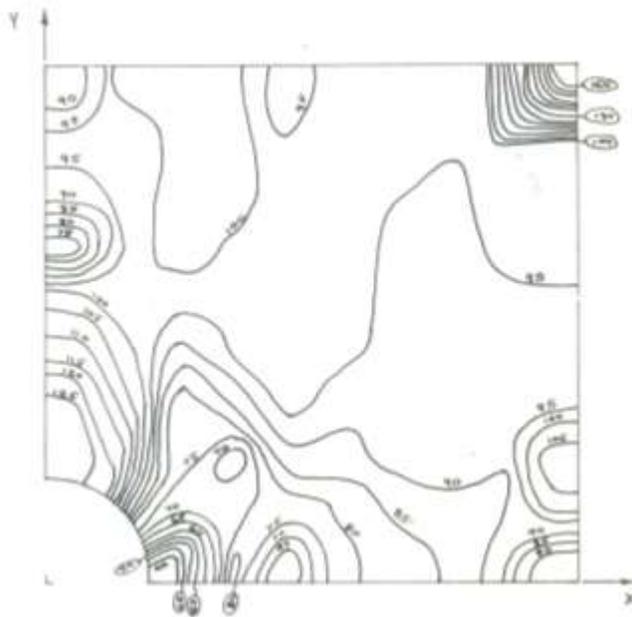
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Hole Size = 400 x 400 mm²

$K = M_{xh} / M_{xs}$

M_{xh} = Moment per unit length
for plate with hole

Fig. 4 : Contours of Stress Concentration Factor 'K' for Square cutout/hole at centre of plate.



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Dia. of hole = 400 x 400 mm²

$K = M_{xh} / M_{xs}$

M_{xh} = Moment per unit length
for plate with hole

Fig. 5 : Contours of Stress Concentration Factor 'K' for Circular cutout/hole at centre of plate.

CONCLUSION:

In this paper the results of maximum deflection and maximum bending moment for a transversely loaded simply supported square plate with centrally located square and circular cutout/hole of varying sizes are compared. Stress concentration factor is also observed by plotting contours of stress concentration factor. Finite Element with eight noded isoparametric plate element [Hinton's element (5)] is used to analyse the plate with cutout/hole. The results are presented in the form of graph and table and the values of maximum deflection and maximum bending moment for a S.S. Square plate with centrally located square and circular cutout/hole are compared. Contours of stress concentration factor are presented for sample case of plate with square and circular cutout/hole at centre. From this study it can be concluded that the maximum deflection and maximum bending moments in case of plate with square cutout/hole at centre is more than the circular cutout/hole at centre. The effect of size of cutout/hole (Percentage of opening and aspect ratio) also affects these quantities. As the percentage of opening / aspect ratio increases maximum deflection and maximum bending moment increase upto certain value and then decreases because load decreases as size of opening increase and becomes predominant than the decrease in stiffness of the plate due to cutout/hole. The stress concentration factors observed from the contours shows that the stress concentration is more for plate with square cutout than the circular cutout. It is also more at re-entrant corner and corner of the plate.

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