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Comparison of Deflection and Moments Between Plate with Square and Circular Perforations

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Abstract - *The importance of perforated plates as structural members is evident in many engineering applications, especially in aeronautical, naval, marine, offshore structures and in civil and mechanical engineering structures. Mainly the perforations most widely in used are either square perforations or circular perforations. Deflection and moment play an important role in designing these structures. So, the objective of this paper is the comparative study of effect on deflection and moment for plates with square perforations and plates with circular perforations. The aspect ratio of 0.2 is used for the study of the square plate with different combination of square and circular perforations during the analysis and the changes in the plate deflection and bending moment are determined. From analysis it can be concluded that the deflection and bending moments are more in plate with square holes than the plate with circular holes. From the variation curves it can also be concluded that these parameters are more when a hole or group of holes are located on the diagonals of the plate.*

***Key Words* -** Square perforation, Circular perforations, Finite element method, Deflection, Bending moment.

1. INTRODUCTION

The plates with perforations are widely used in structural members. Design Engineers come across design problems in many engineering structural applications, especially in aeronautical, naval, marine, offshore structures and in civil and mechanical engineering structures design problems arises due to perforations in a plate. Different types and shapes of holes i.e. perforations are used for different applications. The most common types that are widely in use are square and circular perforations. Perforated plates with square and circular holes which are manufactured easily offer the wide area of applications such as metal ceiling tiles, air conditioning grilles, civil, mechanical, naval and aeronautical engineering structures and hence their analysis and design poses the problems before the design engineer. In practical design issues occur often necessary to identify the deflections and moments which are due to forces acting at right angle to the plate surface. Keeping in mind the objective to compare the deflection and moments of plate having square perforations with plate having circular perforations, a simply suppurated square plate of size 2.0 m x 2.0 m with the ratio of plate thickness to plate lateral dimension equal to 0.005 having number of square and circular perforations with aspect ratios of 0.2 are analysed by using the Finite Element Method (1). Hinton's eight noded isoparametric plate element (2) is used for analysis purpose. Perforated plate with simply supported boundary condition and uniformly distributed transverse load is analysed for various combination of square holes and circular holes. Maximum deflections and maximum bending moments are presented in the form of tables and graphs are plotted for variation of deflections and moments along Y-axis and the results of these parameters are compared. Analysis is done through simulation for eight noded isoparametric plate element in cartesian co-ordinates. The conclusion is drawn that the deflection and moments for plate with square perforations are more than for plate with circular perforations. The data thus obtained are also useful to the design engineer in designing the perforated plate with similar type of location and shape of perforation.

2. NUMERICAL EXAMPLES

Usual finite element formulation has been used to analyse the perforated plate having square and circular perforations by using eight noded isoparametric plate element in cartesian co-ordinate through simulation (1). Joint displacement code number approach is used for assembly of element stiffness matrices into structure stiffness matrix. This is found to be quite convenient as zero code numbers are assigned to the restrained displacements. Thus, equations are formed corresponding to the unrestrained displacements only. The input consists of material properties, geometrical data for plate and hole, loading, etc. The co-ordinates of the nodes and code numbers are generated by simple technique so as to reduce the data. The structure stiffness matrix is assembled in half band form. The output of the program consists of the nodal displacements and stress resultants at Gauss points.

3. PLATE DISCRIPTION

A homogeneous isotropic plate with all edges simply supported is considered for analysis. Only cartesian co-ordinates for geometric modelling of the plate with holes have been used. The position and number of holes are selected such that only quarter of the plate needs to be analysed. The symmetry conditions are (i) rotation of normal about X-axis, θx=0, along X-axis and (ii) rotation of normal about Y-axis, θy=0 along Y-axis. At simple support the boundary condition is w=0 and free edge condition at the boundary of the hole.

The constant numerical data adopted for analysis of perforated plate is -
a= Plate size=2.0m
t= Plate thickness = 0.01 m,
E=2.1 x 10^5N/mm^2
q= Uniformly distributed load (u.d.l.) =10 Kpa
μ = Poisson's ratio = 0.3

4. ANALYSIS OF PLATE WITH SQUARE AND CIRCULAR PERFORATIONS

For comparison purpose a simply supported square plate with square perforations and circular perforations of aspect ratio b/a=0.2 and d/a=0.2 respectively, (b= size of square hole and d= dia. of circular hole), are analysed. Total eight number of problems have been solved for each set of perforated plate with different combination of hole for each square and circular perforated plate. The results of these analysis are presented in the tables and graphs.

5. RESULT AND DISCUSSION

The present work deals with the comparison of deflection and bending moments for plate having square perforations with plate having circular perforations subjected to transverse uniformly distributed load. Hinton's (2) developed an isoparametric plate element in certesion co-ordinates based on Mindlin plate theory in which Love-Krichoff's hypothesis is violated. It is convenient to use Hinton's element for analysis of perforated plate since this plate element based on thick plate theory enhanced the applicability of finite element method for analysis of perforated plates. The various combination of square holes and circular holes with aspect ratio of b/a=0.2 and d/a=0.2 respectively with respect to solid plate on the maximum deflection and moments along Y-axis for different combination of square and circular holes is also studied.

The results of the analysis are tabulated in Table 1 for the maximum deflection and maximum bending moment for solid square plate and plate with square hole and circular hole at centre of plate and various combination of square holes and circular holes, with aspect ratio of b/a=0.2 and d/a=0.2 respectively. The results are also presented in the form of graphs showing the variation of deflection and bending moment along Y-axis. It is felt that these graphs and table will be useful to the design engineers.

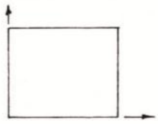
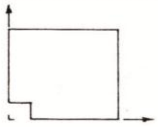
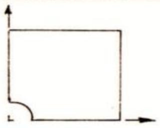
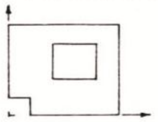
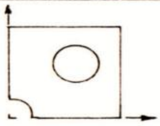
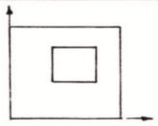
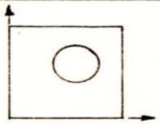
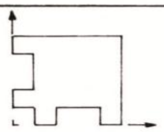
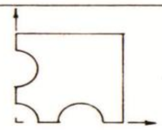
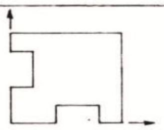
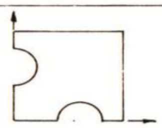
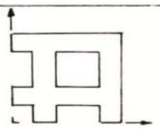
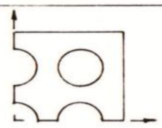
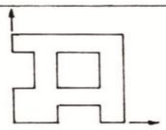
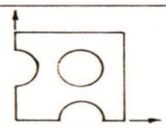
Sr. no.	Quarter plate with hole	w_{max}	max. Mx	Quarter plate with hole	w_{max}	max. Mx
1		4.05	4.75		4.05	4.75
2		4.60	6.38		4.40	5.76
3		5.15	6.79		4.68	5.16
4		4.52	6.19		4.29	4.75
5		4.60	5.37		4.36	5.09
6		4.24	5.34		4.14	4.93
7		5.02	5.29		4.53	4.52
8		4.62	6.91		4.19	4.07
	Multiplier	$\frac{q_z a^4}{D} \cdot 10^{-3}$	$q_z a^2 \cdot 10^{-2}$	Multiplier	$\frac{q_z a^4}{D} \cdot 10^{-3}$	$q_z a^2 \cdot 10^{-2}$

Table 1 : Maximum Deflection and Maximum Moment Mx for S.S. Square perforated plate with different combination of square and circular perforations (Aspect ratio =0.2)

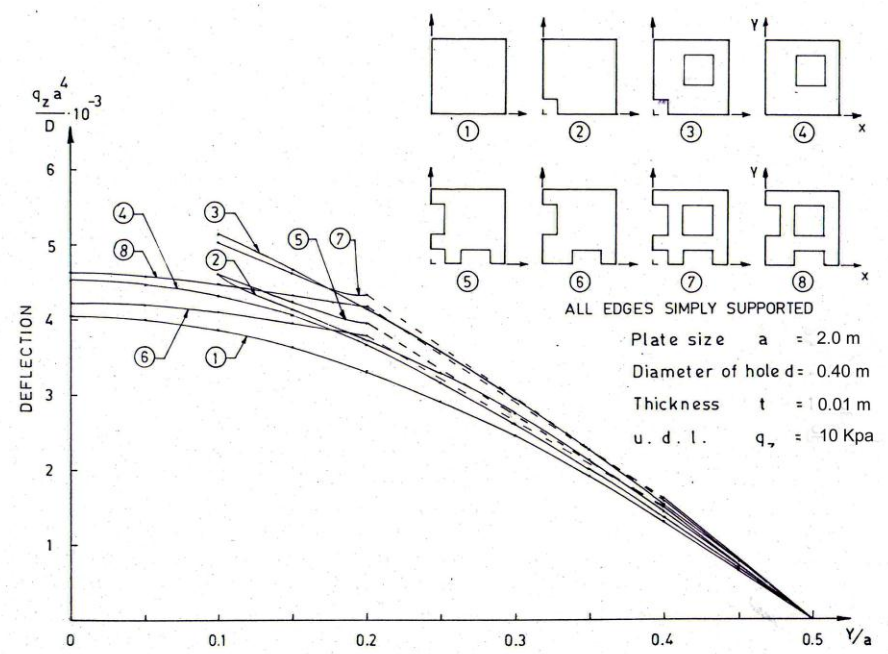


FIG. 1 VARIATION OF DEFLECTION ALONG Y-AXIS

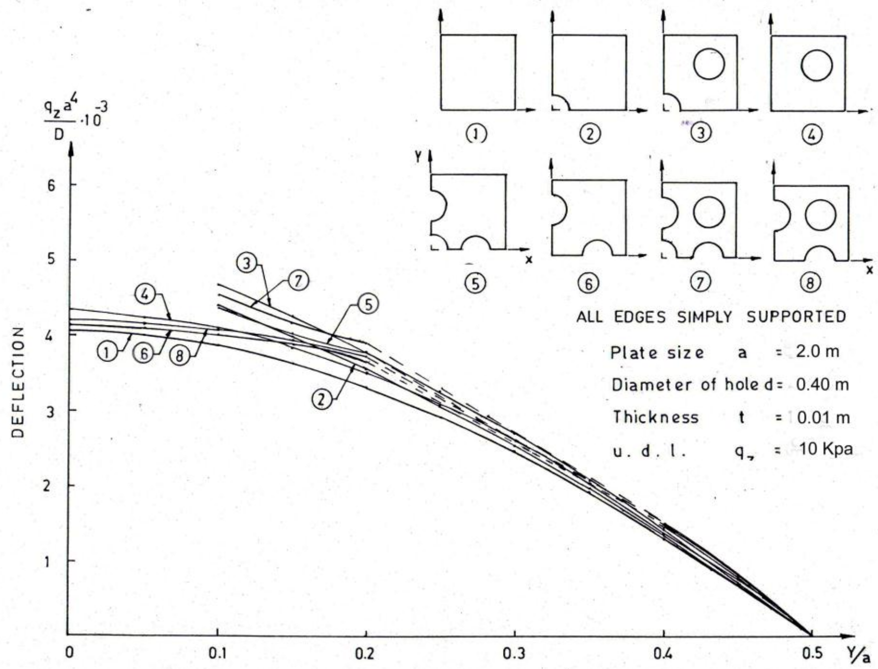


FIG 2 VARIATION OF DEFLECTION ALONG Y-AXIS

Graphs showing Variation of Deflection along Y-axis for S.S. Sq. perforated plate with different combination of square and circular perforations (Aspect ratio 0.2)

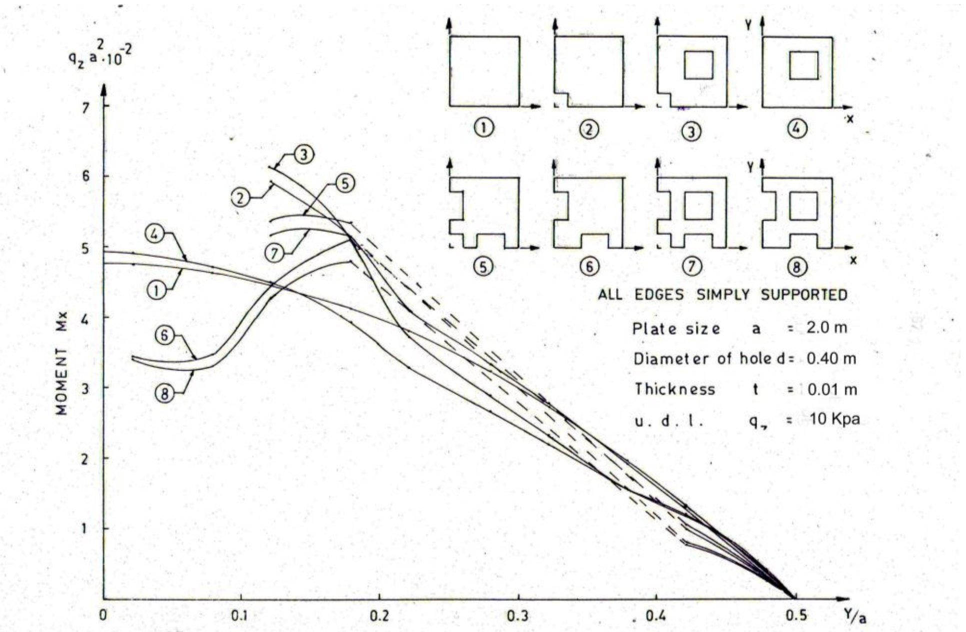


FIG. 3 VARIATION OF MOMENT Mx ALONG Y-AXIS AT GAUSS POINTS

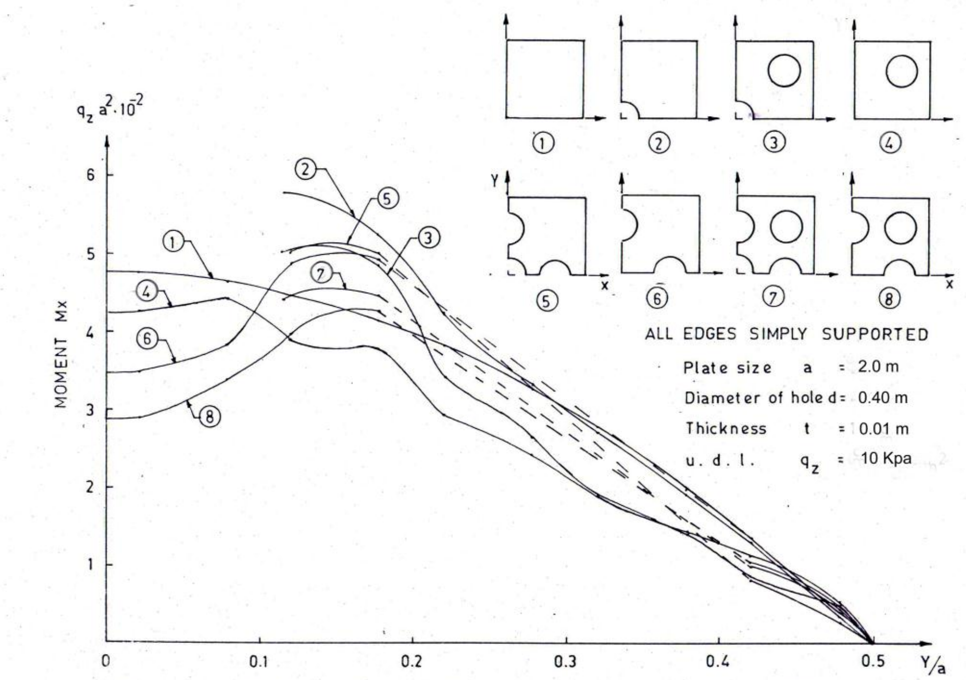


FIG. 4 VARIATION OF MOMENT Mx ALONG Y-AXIS AT GAUSS POINTS

Graphs showing Variation of Moment Mx along Y-axis at Gauss points for S.S. Sq. perforated plate with different combination of square and circular perforations (Aspect ratio 0.2)

COLUSTION- From the careful study of tables and graphs it is seen that the maximum deflection and maximum moments for plate with square perforations are more than the plate with circular perforations. This is because, the concentration of stresses are more in case of plate with square holes than the plate with circular holes. From the variation curves of deflection and bending moments, it can also be concluded that these quantities are more when a hole or group of holes are located along the diagonals of the plate.

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