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PARAMETRIC STUDY OF STEEL BEAM WITH WEB OPENING OF DIFFERENT SHAPE, SIZE AND POSITION USING FINITE ELEMENT METHOD

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Abstract - *In multi-story steel buildings from economical and aesthetic point of view height limitation is a more common problem. Some spaces are required to pass the large pipes and ducts for electricity and AC ducts and it leads to increase in floor height. The most suitable solution for this problem is to introduce the steel beam with web opening. This introduction of opening could lead to some effect in structural behavior of steel beam. It could lead to decrease in load carrying capacity of the beam depending on shape, size, position of openings and spacing between two openings. The web opening provided in steel beam generally are in shape of circular, rectangular, hexagonal, square and sinusoidal. The aim of present work is to predict the behavior of steel beam under such condition with the application of finite element analysis software(ANSYS). The different span length of steel beam is to be analyzed for a different shape, size and position of web opening and graphs of Load Vs Deflection is to be a plot, stress distribution and stress values in the beam is to be compared.*

Key Words: **Steel beam with web opening, Finite Element analysis, Load vs Deflection, Shear stress distribution, Von Mises Stress Distribution, Long span steel beam, simply supported beam.**

1. INTRODUCTION

Steel beam with web opening is a type of structural steel beam having opening in its web to allocate space for passage for large pipes and air conditioning ducts within the web of structural steel beam it is considered to be very effective in increasing floor height in high-rise building and industrial building where floor height is very critical requirement. The provision of beams with web openings has become an acceptable engineering practice and eliminates the probability of a service engineer cutting holes subsequently in inappropriate locations. Beams with web openings can be competitive in such cases, even though other alternatives to solid web beams such as stub girders, trusses etc. are available. This form of construction maintains a smaller construction depth with the placement of services within the girder depth, at the most appropriate locations.

When steel beam is under primary loading, the behaviour of steel beam with web opening is different from a regular steel beam in terms of stress pattern, shear concentration, the stiffness of beam, deflection and strength.

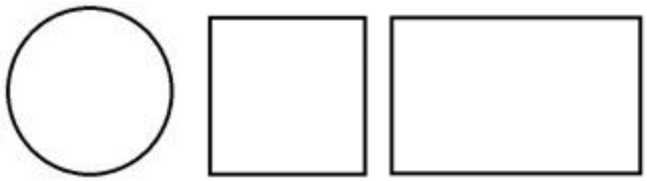


Fig -1: Common types of opening (a) Circular (b) Square (c) Rectangular

The strength of the beams with openings may be governed by the plastic deformations that occur due to both moment and shear at the openings. of the beam. The reduction in shear capacity at the opening can be significant. Therefore, the ultimate capacity under the action of moment and shear at the cross section where there is an opening will be less compared to that at the normal cross section without opening

2. Research Significance

There is very limited information on the comparison between the analytic results of a steel beam with different size and shape of web opening as well position and spacing between openings as per Indian codes. Further such comparative analysis is not found to be carried out for different span length.

In this paper three parameters are compered such as Deflection, Shear stress and Von mises stress for different type of web opening shape, size and position to give conclusive results.

3. Modelling and Analysis

3.1 Parameters for analysis

A detailed study of this parameters is analysed and comprehensive results are obtained. A summary of the parametrical analysis for ISMB 400 detailed in Table-1 and Table-2. Parameters like steel beam span length, web

opening geometry, the position of web opening according to beam span, size of web opening. In a beam with a rectangular opening, opening length will be taken as twice the size of its opening height. Total 70 models are analysed

Table -1: Parametric Study Variables Overview

Span length	Opening geometry	Position of opening	Size of opening
10m and 12m	Circle, Rectangle, Square	0.15l	0.3h
			0.5h
			0.75h
		0.5l	0.3h
			0.5h
			0.75h

Where l and h indicates span length of steel beam and height of web of steel beam respectively.

Other parameter spacing between two consecutive openings are listed in Table-.2. The spacing between openings is considered as centre to centre spacing.

Table -2: Parametric Study Variables Overview(Spacing)

Span length	Opening geometry	Size of opening	Spacing between opening
10m and 12m	Circle, Rectangle, Square	0.5h	$L/_2$
			$L/_3$
			$L/_4$
			$L/_5$
			$L/_6$
			$L/_7$

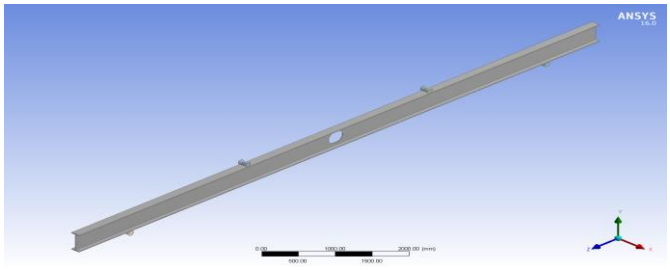
L indicates centre to centre distance between two extreme web openings

3.2 Model Preparation

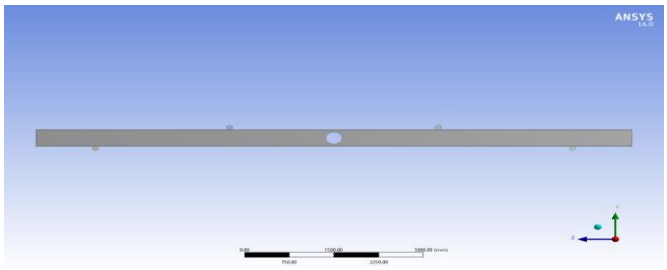
Modelling and analysis is done using ANSYS 2016.

Table -2: Steel section geometrical dimension

Beam	Flange width (mm)	Flange thickness (mm)	Web height (mm)	Web thickness (mm)
ISMB 400	140	16	368	8.9



(a)



(b)

Fig -2: (a) Isometric view of steel beam with web opening (b)Side view of steel beam with web opening.

3.3 Loading Data and Failure Criteria

Live load of total 400kn is applied by two point loads on top of beam in 8 steps to get accurate results. Von misses stress is used in ANSYS in order to find the failure criteria of beam at applied load as steel is used as material in analysis and yield stress of steel is 250 N/mm^2 so von misses stress greater than yield stress of material at given load is considered as failure of beam.

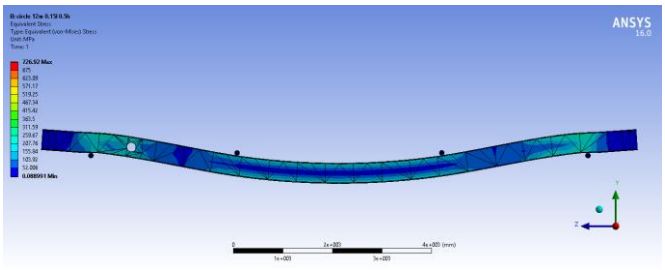
4. RESULTS AND DISCUSSION

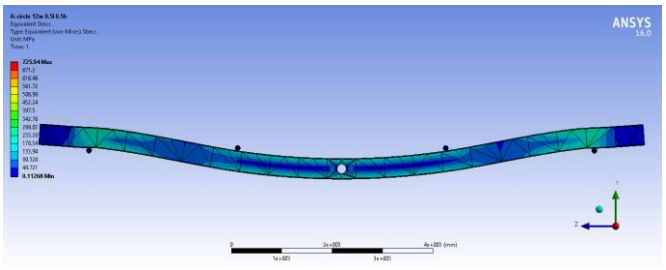
Total of 72 analytical models are analyzed and comparative study of these results are done using several sets of combination of several parameters. These sets are combining all comparative results and give a clear view on the structural behavior of steel beam with web opening.

4.1 Discussion Based on Position of Web Opening

Two position of opening is used of analysis (a) Web opening near the right support (0.15l) (b) Web opening at mid-span of beam (0.5l)

In beam with web opening near the support shows greater amount of Von-misses stress, shear stress and deflection values compared to opening at mid span of beam still beam with circular opening shows less amount of stress values than other opening at given load but web opening of rectangular shape has very high amount of stress and deflection near support which is not advisable.





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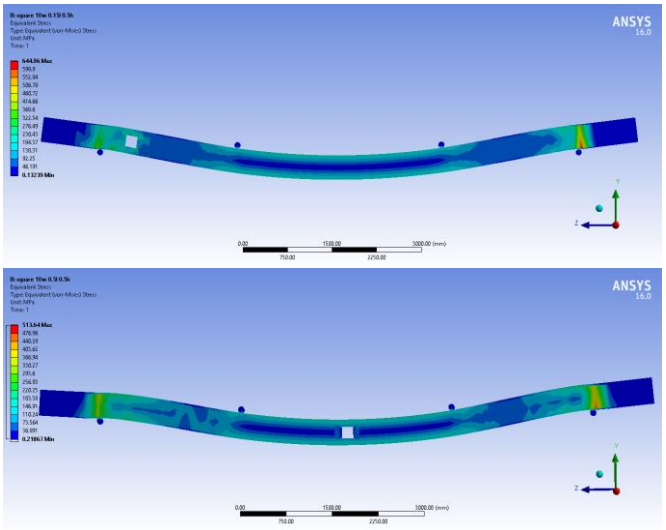

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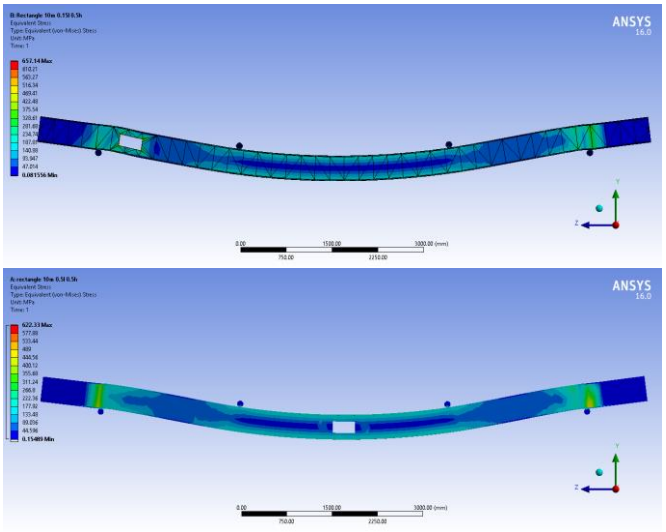
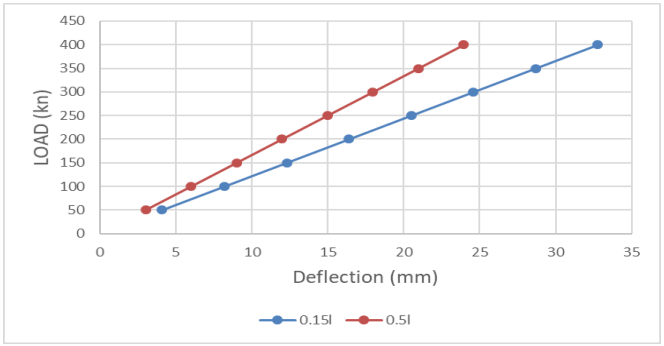


(c)

Fig -3: Von Mises Stress Distribution in Different Opening Position (a) Circle (b) Square (c) Rectangle

When the opening is at mid-span (0.5l) circle and rectangle has high-stress value and deflection value compares to square opening. In case of large web opening (0.75h) the only square has good structural behavior but in 0.5h 0.3h opening size, all opening geometry behaves well.



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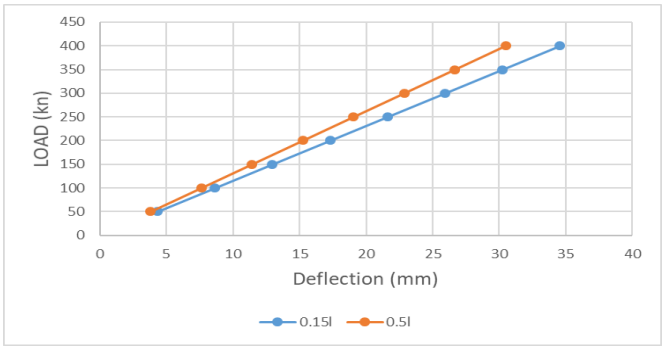

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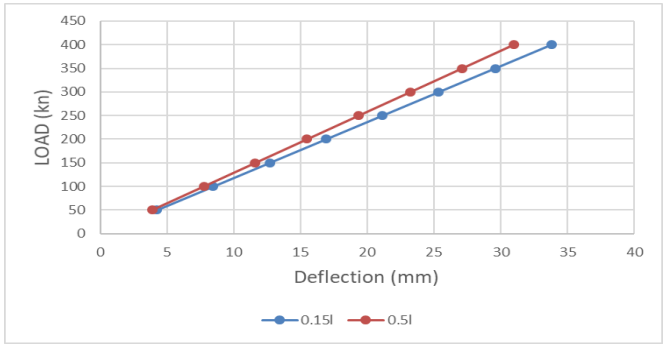


(c)

Chart -1: Load Vs Deflection Curve for Position of Opening (a) Square Opening(b) Circular Opening(c) Rectangle opening

4.2. Discussion Based on Spacing between Web Opening

As shown in table 2 different spacing as L/2, L/3, L/4, L/5, L/6, and L/7 are described. In larger span length circular and square opening gives good structural behavior. Circle and Rectangle opening has more stress value compare to Square opening.

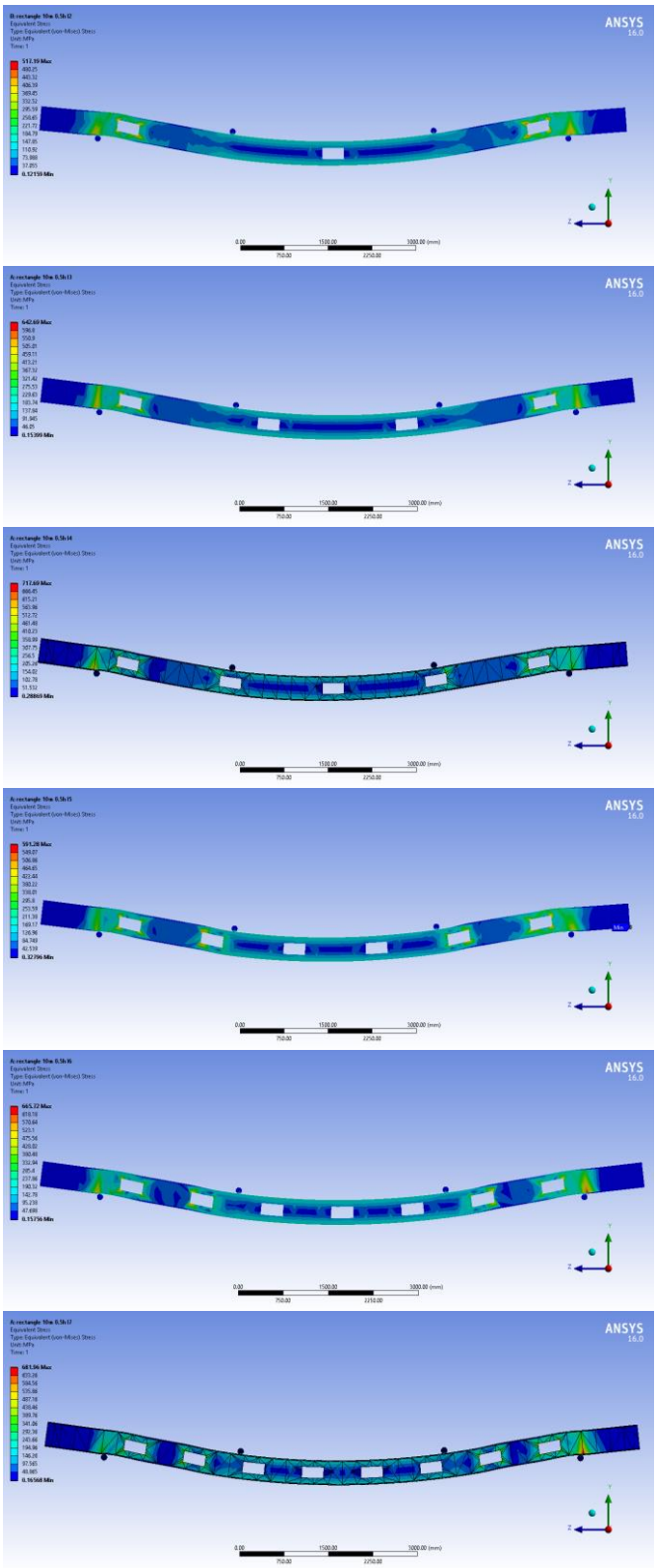
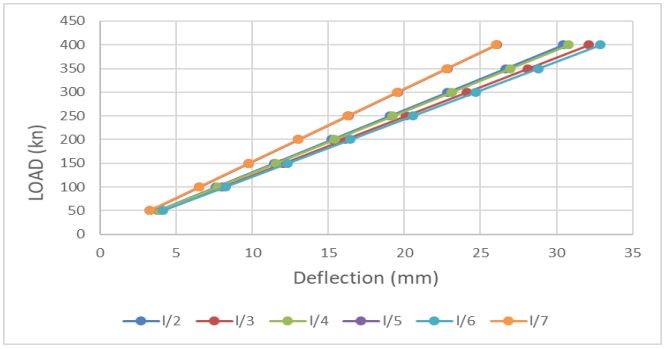


Fig -4: Von Mises Stress Distribution Associated with Different Spacing between Web Openings (L/2, L/3, L/4, L/5, L/6, and L/7)



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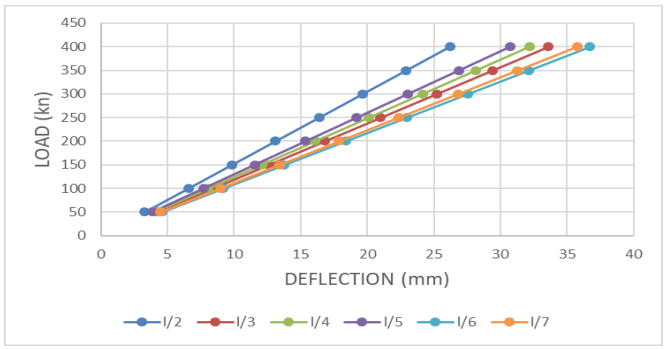

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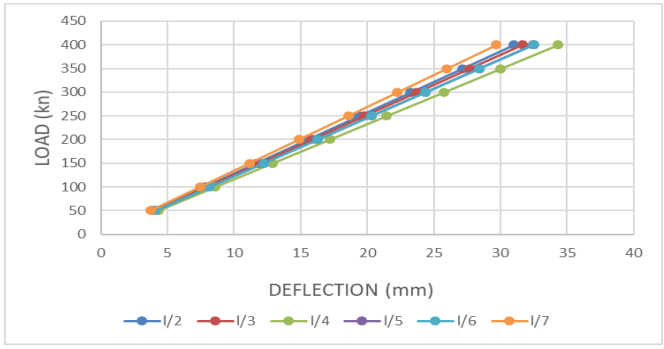


(c)

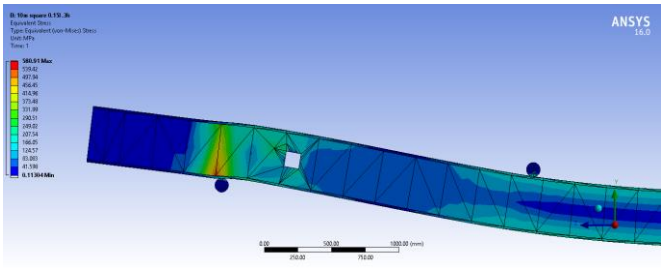
Chart -2: Load Vs Deflection Curve for Spacing between Openings for (a) Square Opening (b) Rectangle Opening (c) Circle opening.

Here in this graphs difference between different spacing can be seen clearly. From which we can say that close spacing has high deflection value so when possible it should be avoided.

4.3. Discussion Based on Size of Opening

As size increase, stress and deflection in beam also increase but in rectangle big size of opening it has very high stress and deflection so it is not advisable for structural practice.

At mid-span of the beam for smaller opening 0.3h and 0.5h not much difference in behavior of stress and load-deflection but for big opening size 0.75h has high stress and deflection for near the support only circle with 0.75h has good structural behavior all other opening has high-stress values.



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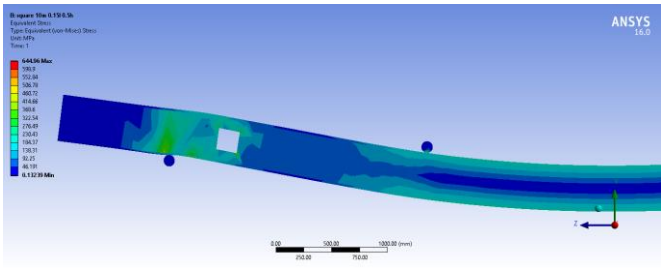

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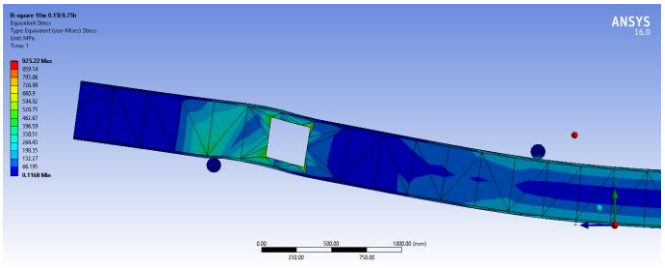

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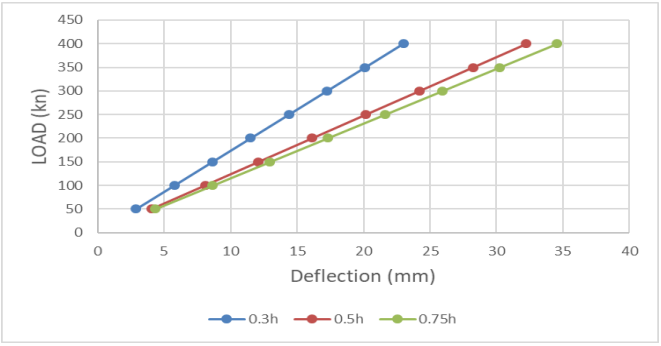
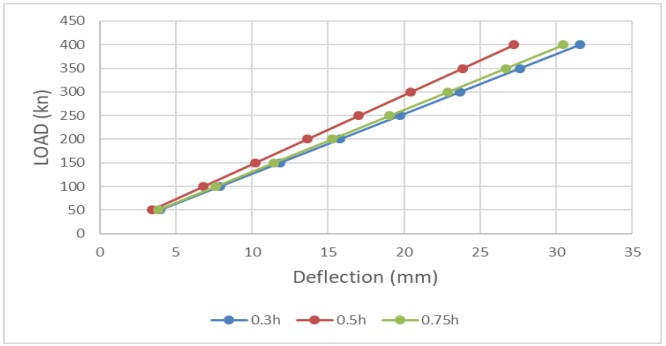
Fig -5: Von Mises Stress Distribution Associated with Different Sizes of Opening (a)0.3h (b) 0.5h (c) 0.75h



(a)



(b)

Chart -3: Load vs Deflection Curve for Size of Openings for (a) 0.15l (b) 0.5l

From the Load vs deflection curve for the size of opening, it is clearly seen that opening size of 0.75h has more deflection near support than at mid-span of the beam

5. CONCLUSIONS

For the analysis 10m & 12m span of steel beam (ISMB400) is considered and analyzed for Von-Misses stress, Shear stress and Deflection for different shape size and position of web opening using ANSYS software.
From the results it is observed that,

When opening is near the support (0.15l) it has high stress and deflection compare to opening at mid span. square has lower stress value than circular and rectangular opening at mid span of Beam.

Rectangular opening has high stress and deflection value in case of large opening area compare to circular and square opening when it is located near the support on steel beam
For large opening area (0.75h) every opening geometry has high stress and high deflection value circle opening has more stress value compare to Square opening for spacing criteria.

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