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Study on the Shear Characteristics of Perforated Lean Duplex Stainless Steel Rectangular Hollow Beams

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Abstract: The paper deals with the shear behavior of the Lean duplex stainless steel perforated hollow beams. Lean duplex stainless steel offers significant advantages such as better economy, improved strength, high temperature properties, acceptable, weldability and fracture toughness properties. Hollow beams have wide range of applications in the construction industry, such as in buildings, bridges, oil refineries etc. The ultimate strength and elastic stiffness of a structural member can vary with perforation position, size, shape, and orientation. In this study the shear behaviour of perforated hollow beam is studied based on different shapes of perforation. . Different shapes of perforation mainly include circle, square and diamond. ANSYS Workbench is used to analyze the shear behavior of perforated lean duplex stainless steel rectangular hollow beams.
Keywords: Weldability, Fracture, toughness, Duplex, perforation

I. INTRODUCTION

Stainless steels belong to the ferrous alloy group which contain an approximate content of chromium of 11%. This is generally a composition which improves the properties of heat resistance and prevents the rusting of iron. Hence, they are generally known as rust less steel. The classification of stainless steel is normally based on their composition which include elements like nickel, carbon, molybdenum, copper etc. Its designation is done with the three-digit number by AISI. The chromium content present in the stainless-steel acts as a passive film which protects it from corrosion. In presence of oxygen, it also provides the material with self-healing capacity. Due to different qualities like less maintenance, resistance to corrosion, familiar luster etc. stainless steels are used. It is used in situation where both resistance to corrosion and strength are essential. For a long time, steel constructions have been akin to the structural uses of carbon steel, essentially due to its numerous advantages such as low cost, easy availability, long experience, established design rules, different strength grades etc. However, a major disadvantage of carbon steel in the construction industry is its relatively low corrosion resistance. On the other hand, stainless steel has significant appealing structural behavior such as good corrosion resistance, higher strength to weight ratio, low maintenance cost, high ductility, impact resistance, greater durability, fire resistance, recyclability etc. in addition to its aesthetically pleasing good finish. Hence, in the recent past, an increase in the use of stainless steel in the construction industry can be observed, more specifically in exposed architectural applications and where total life economics, durability, improved resistance to aggressive environment etc. are prime deciding criteria. Examples of the application of stainless steel in construction are shown in Figures 1.1 to 1.5.

Fig. 1.1 General view of Stonecutters Bridge (www.worldstainless.org)

Fig. 1.2 Cala Galdana Bridge (www.worldstainless.org)

Fig. 1.3 Helix Pedestrian bridge (www.e- architect.co.uk)

Fig. 1.4 Walt Disney Concert Hall (http://interactive.wttw.com)

Fig. 1.5 Cloud gate (www.aviewoncities.com)

II. OBJECTIVE OF PRESENT STUDY

Mainly the project aims at the detailed study on the shear behaviour of lean duplex stainless steel perforated rectangular hollow beams.

The objectives of the project are:

1) To study the shear behaviour of lean duplex stainless steel perforated rectangular hollow beams.
2) Develop Finite Element model of LDSS rectangular hollow beam and validate against the existing results.
3) Different shapes of Perforation.

III.METHODOLOGY

1) Literature review.
2) Validation of journal.
3) Analysis of shear behaviour of lean duplex stainless steel perforated rectangular hollow beams considering different shape of perforation.
4) Analysis of shear behaviour of lean duplex stainless steel perforated rectangular hollow beams considering different size of perforation.
5) Analysis of shear behaviour of lean duplex stainless steel perforated rectangular hollow beams considering number of perforations. Analysis of shear behaviour of lean duplex stainless steel perforated rectangular hollow beams considering location of perforations.
6) Analysis of shear behaviour of lean duplex stainless steel perforated rectangular hollow beams considering different length of beam.
7) Analysis of shear behaviour of lean duplex stainless steel perforated rectangular hollow beams considering different thickness of beam.
8) Interpretation of results and discussion.

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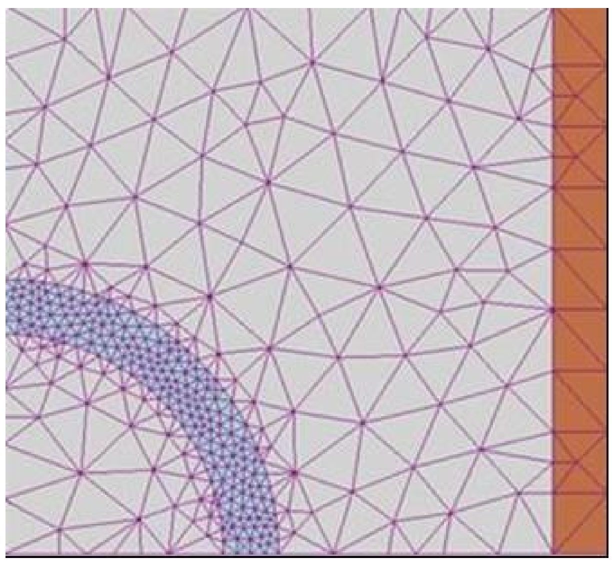
IV. FINITE ELEMENT METHOD AND SOFTWARE

In finite element analysis, first the selected structure is to be divided into several very small regions called finite elements. The analysis done by idealizing the geometry, material, and boundary conditions. It is assumed that the field variable can fluctuate across a single element (i.e., constant stress, linear stress, etc.). The next step is to put together a matrix that accounts for the node-to-node contact between the elements. The matrix is then solved to obtain the overall response to the applied loads. The easiest way to understand FEM is to look at how it's used in practice, which is known as finite element analysis (FEA). Engineers use FEA as a computer technique to undertake engineering analysis. It includes the use of mesh generation techniques to break down a complex problem into smaller pieces, as well as the usage of FEM-coded software. FEM allows for the construction, refinement, and optimization of whole designs before they are built. With the advent of increasingly powerful computers, FEA applications are becoming more commonly available. The analysis is carried out by constructing a mesh of points in the shape of the object, each of which carries information on the material and the object.

Figure 3.1 depicts a FEM mesh built by an analyst prior to using FEM software to solve a magnetic problem. The colors show that the analyst has assigned material attributes to each zone, in this case an orange conducting wire coil, a light blue ferromagnetic component (perhaps iron), and grey air. Although the design appears straightforward, calculating the magnetic field for this arrangement without FEM software and using only equations would be quite difficult.



V. INTRODUCTION TO ANSYS

The most critical and preliminary step in ensuring that a structure is used efficiently for the purpose for which it was designed is to model it. Only if a structure can resist the loads it is projected to transport during its service life can it be regarded worthy. A good model is required for the successful execution of an analytical investigation, just as a material model is required for the successful conduct of an experiment. After completing a proper design, analytical A variety of designing and drawing applications can be used to create models. For engineers, ANSYS is a general-purpose program that allows them to simulate interactions between all disciplines of physics, structural, vibration, fluid dynamics, heat transfer, and electromagnetics. The ANSYS workbench architecture has been reengineered with the introduction of ANSYS 12. Engineers deal with stimulus in a new way thanks to a unique project schematic view. Projects are graphically depicted as interconnected systems in a flowchart-like layout. Users can quickly grasp technical intent, data relationships, and the current state of the analytic project. Working with the new project system is simple: simply drag and drop the desired analysis system into the project schematic from the toolbox on the left. Complete analysis systems have all the necessary components and will guide you through the analysis process as you work your way from top to bottom through the system. The whole thing takes a long time. Changes to any part of the analysis can be made, and the ANSYS workbench platform will automatically handle the execution of the required applications to update the project, drastically lowering the cost of executing design iterations. The ANSYS workbench platform is designed to be stable. It's as simple as dragging in a follow-on analysis system and dumping it into the source analysis to create complicated, coupled analysis combining multiple physics. Automatically, the necessary data transfer links are established.

Parametric variations are supported by the ANSYS workbench program, which include CAD (Computer Aided Designing) geometry dimensions, material properties, boundary conditions, and derived results. Parameters created in applications can be controlled directly from the project window, allowing a series of design points to be defined and executed in a single operation to complete a study. Engineering data, Geometry, Model/Mesh, setup, solution stages, and output data can be acquired through the solution information option in the specification presented in the ANSYS workbench. Different systems, such as analytic systems, component systems, and design exploration, are included in the workbench project schematic. Electric, Explicit Dynamics, Fluid Flow, Harmonic Response, Hydrodynamic Diffraction, Linear Buckling, Magneto Statics, Modal, Random Vibration, Response Spectrum, Shape Optimization, Static Structural, Steady State Thermal, Thermal-Electric, Transient structural, Transient Thermal, and others are included in the analysis system. Bidirectional, parametric interfaces with all major CAD systems, integrated, analysis-focused geometry modelling, repair, and simplification via ANSYS Design modeler, highly automated, physics-aware meshing, and automatic contact detection are just a few of Workbench's key features.

A. Square Perforation

The model is a LDSS rectangular hollow beams with a single square shaped perforation of side 200 mm at 300 mm from one end of the support. Figure 5.1 shows the model of LDSS rectangular hollow beam with a single square shaped perforation. The material properties and other details were given as per the validated model which was discussed in chapter 4. The perforation was provided at a distance of 300 mm from the support of web of the beam.

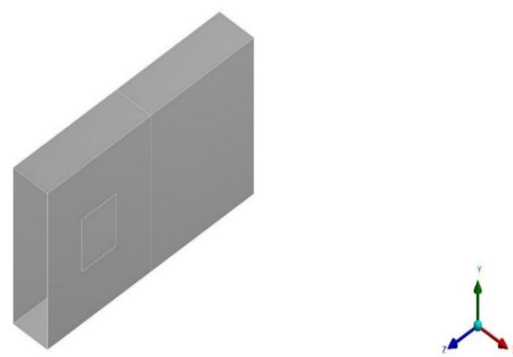


Fig. 5.1 Model of LDSS rectangular hollow beam with a single square shaped perforation

B. Circular Perforation

The model is a LDSS rectangular hollow beams with a single circular shaped perforation of diameter 200 mm at 300 mm from one end of the support. Figure 5.2 shows the model of LDSS rectangular hollow beam with a single circle shaped perforation. The material properties and other details were given as per the validated model which was discussed in chapter 4. The perforation was provided at a distance of 300 mm from the support of web of the beam.

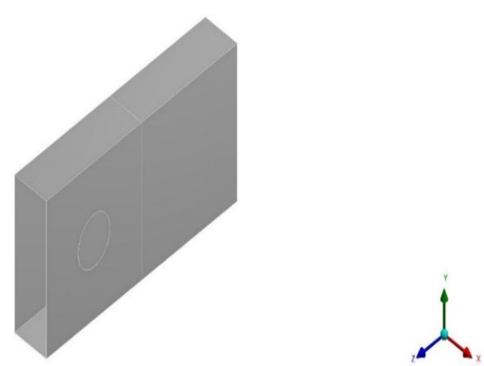


Fig. 5.2 Model of LDSS rectangular hollow beam with a single circle shaped perforation

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C. Diamond Perforation

The model is a LDSS rectangular hollow beams with a single diamond shaped perforation of diagonal 200 mm at 300 mm from one end of the support. Figure 5.3 shows model of LDSS rectangular hollow beam with a single diamond shaped perforation. The material properties and other details were given as per the validated model which was discussed in chapter 4. The perforation was provided at 300 mm from the support of web of the beam.

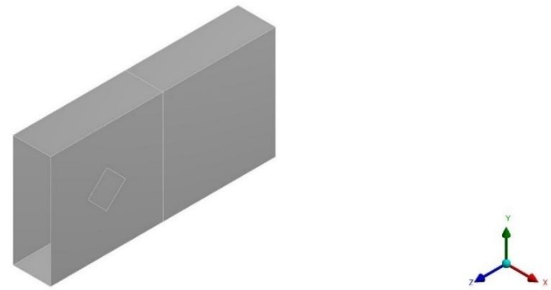
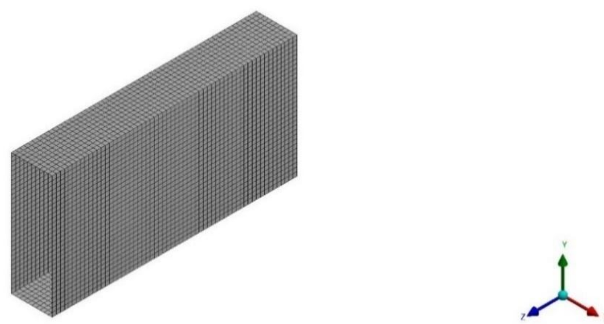


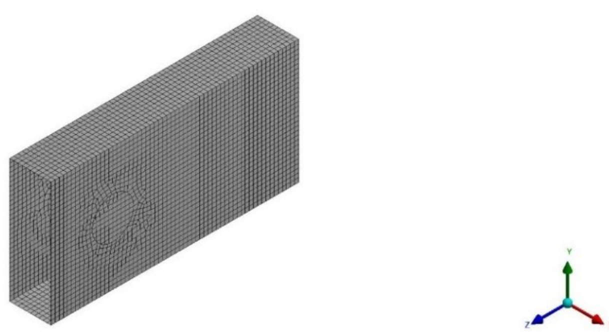
Fig. 5.3 Model of LDSS rectangular hollow beam with a single diamond shaped perforation

VI. MESHING AND ANALYSIS

Beam was analyzed as static structural analysis system. SHELL 181 element type was used. This element has four nodes with six degrees of freedom at each node. Meshing size used was of 20 mm. Figure 5.4 shows the meshed models of beams with square, circle, and diamond perforation respectively. Displacement controlled loading was applied in the Y direction. A displacement of 15 mm was provided at the middle reference point of the model. The boundary conditions were applied to the models having square, circle, and diamond perforations respectively similar to that of the validated model as discussed in chapter 4. Figure 5.5 shows the boundary condition and load applied on beams with square, circle, and diamond perforation respectively.



(a)



(b)

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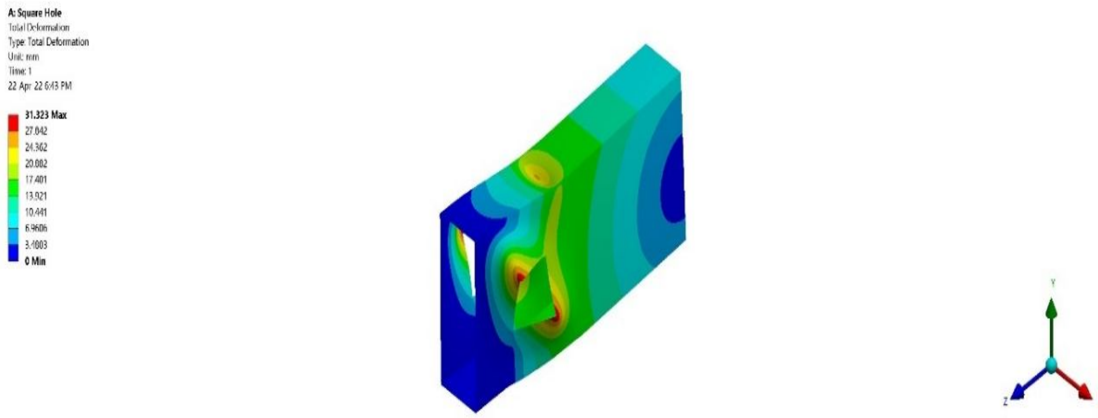
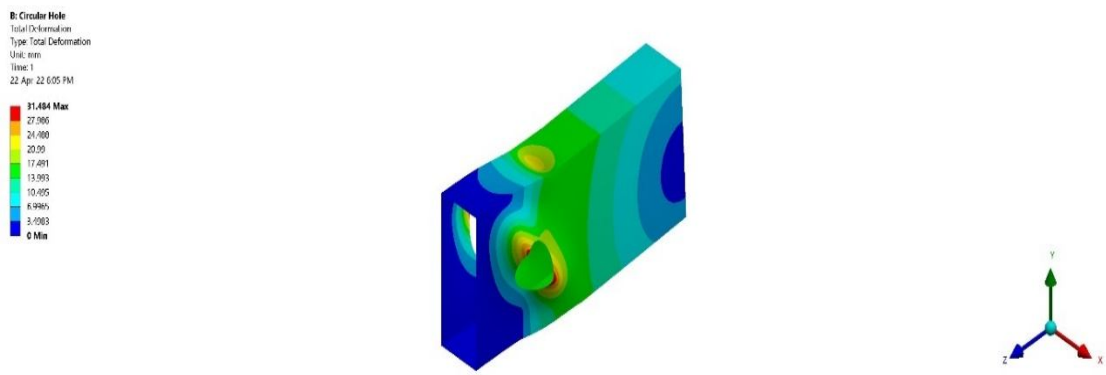
VII. RESULTS AND DISCUSSIONS

Figure 5.6 shows the total deformation observed in beams with square, circle, and diamond shape perforations. In the case of square and circular shaped perforated beam, the deformation was more around the perforation and around the loaded area. But in the case of diamond shaped perforated beam the deformation was more at the loading area and propagated towards the perforation. All the specimens showed buckling in the web. Beams with circular and square shaped perforation showed more lateral deformation compared to diamond shaped perforated beam.



(a)



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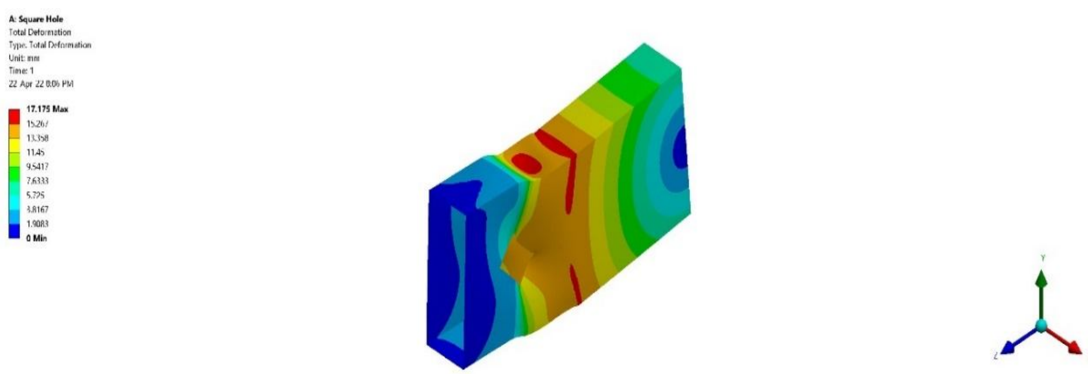

(c)

Fig. 5.6 Total deformation in beams with (a) square, (b) circle and (c) diamond perforation respectively

Table 5.1 Results of FE model

Cross Sectional Dimension(mm)	Length of Beam (mm)	Size of Perfortion(mm)	Shape of Perforation	Ultimate Load (kN)
200 x 600 x 10	1200	200	Square	3697.9
			Circular	4329.3
			Diamond	4641
		250	Square	3024.5
			Circular	3787.8
			Diamond	4206.9
		300	Square	2349.9
			Circular	3243.5
			Diamond	3708.1

VIII. CONCLUSIONS

Analysis on shear behaviour of LDSS rectangular hollow perforated beam based on different shapes of perforation having same size was carried out. In case of beams with same size of perforation the maximum ultimate load was seen in beams with diamond perforation and then in circular perforation and the least ultimate load in square perforation. As the size of the perforation increases the ultimate load value decreases. The percentage increase in the ultimate load for square to circle and circle to diamond shaped perforated beams with same size of perforation of 200 mm was 17.1% and 7.2%. The percentage increase in the ultimate load for square to circle and circle to diamond shaped perforated beams with same size of perforation of 250 mm was 25.2% and 11.1%. The percentage increase in the ultimate load for square to circle and circle to diamond shaped perforated beams with same size of perforation of 300 mm was 38%.

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