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STUDY ON FLEXURAL BEHAVIOR OF COLD FORMED C-SECTION PURLIN WITH DIFFERENT OPENING SHAPES

Kaluram T. Jadhav[1], Pramod V. Kharmale[2]

[1]PG Student, [2]Assistant Professor

[1,2] Department of Civil Engineering, G.H.Raisoni College of Engineering & Management, Chas, Ahmednagar, Maharashtra,(India)

ABSTRACT

As increased steel demand in many construction industries, due this phenomenon, the price of steel is also increased. The cost and weight of steel are major consideration during design stage of project. So that to reduce overall cost of the project, web-opening concept for purlin was introduced to reduce its self-weight. If the weight from the top of structure is reduced, it will result in fewer loads transferred to the column and therefore it reduce the size of other structural elements. In this project, we are present study on flexural behavior of cold formed C-section purlin with different opening shapes. Total 13 number of different web opening shapes (C-hexagon, Circular, square and without opening) was provided into the c purlin and it should be tested. In this project finite element analysis is planned for different opening models and there representation with respective various analysis parameters. To investigate that shapes of opening which gives the least reduction in bending moment and to understand the weight to flexural strength for different shapes and to investigate stress-strain variation of C-section purlin using finite element method. The results shows that the CFS C-section purlin of hexagon shape opening gives better strength results and less deflection with respect to the loading, than other shape of opening sections.

Keywords – Cold formed C-Section, Castellated purlin, F.E.A. by ANSYS-16 Software, Opening sizes, UTM testing, web Opening shapes.

I. INTRODUCTION

In the steel structures, purlin is an important factor. Purlin is used to sustain the loads from the roof deck and properly supported by rafters or walls. The use of cold formed steel members in building construction began in the 1850s. The cold formed steel members offers advantages such as lightness, high strength and stiffness, mass production, fast and easy installation, economical transportation and handling. In cold formed purlin, C and Z sections commonly used due to their structural advantages. In this project we are introduce web-opening concept for cold formed C-section purlin to reduce its weight. We are introducing castellated opening so that the purlin depth is increase by 50%, it gives more efficient structural performance against bending and improve the aesthetic value of structure.

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

II. LITERATURE REVIEW

Jin Ying Ling et.al [1], they had made a numerical study of buckling behavior of cold formed C-channel purlin with perforation. Five different shapes of opening investigated. It has seen that c-hexagon shape opening shows smallest reduction on buckling moment capacity compared to other. They says that web opening is to affects the buckling moment capacity of the c-channel purlin. As the opening size increases, the buckling moment capacity decreases.

Ali Awaludin et.al [2], they worked study on development of cold formed steel-timber composite for roof structure; compression member. This study is done for to improve buckling performance of cold formed steel members by attaching 15mm thick timber to the web portion of cold formed z, c& double c- section at constant spacing of 100-mm. compression test was done over five different effective length. They says that the compressive load carrying capacity increase for short member and decrease as the length of member was increases.

Jun Ye et.al [3], they had presented study on development of more efficient cold formed steel channel section in bending. Total ten different types of CFS channel cross section are studied. They says that the edge stiffeners are much more efficient in increasing the section capacity than intermediate web stiffeners for a CFS beam. The results shows that optimized folded section bending capacity is 57% more than optimized shapes with the same amount of material.

Congxiao Zhao et.al [4], they worked on rotational stiffness of cold formed steel roof purlin-sheeting connections. They represent both analytical method to predict the rotational stiffness for cold formed zed and sigma purlin sections and it validated by a series of F-tests on both zed and sigma section. It was found that sheet at flange-web junction line the rotational stiffness was higher than sheet is at the flange-lie junction line.

Adi Susila et.al [5], they had presented study on flexural strength performance and buckling mode prediction of cold formed steel C-section. The experimental work done in laboratory and numerical done by using finite element software ABAQUS. The results analyzed by using effective width method and direct strength method. At the intermediate web stiffeners, the effectiveness between EWM and DSM have shown no significant improvement of the bending capacity. They says intermediate web stiffener was only provide protection of the local buckling with in the web.

Xing Zhao Zhang [6], they had presented comparative study of hot formed, hot finished and cold formed rectangular hollow section. It was found that the tested hollow section chemical composition and geometrical parameter are similar and mechanical properties are significantly different. While the hot formed and hot finished sections treated as same in design, their residual stresses distribution and mechanical properties are actually different.

Mohamed Salah Al-din Soliman [7], they had made numerical study on web crippling and interaction between bending and web crippling. FEM is used to find out the interaction between bending and web crippling in C-sections. It was found that, the strength given by design codes are generally inadequate for channel with a practical web slenderness range. So that a modifications was proposed to improve the strength predicted by codes.

IJARSE
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ISSN (P) 2319 - 8346

III. MEANING OF COLD FORMED C-SECTION PURLIN WITH DIFFERENT OPENING SHAPES.

CFS is the product made by pressing or ro000lling steel into semi-finished or finished good at relatively low temperature. First codified standards is introduced in 1946. Cold formed material was easily workable it could deform into many shapes. If a small change in geometry created it was affect, strength characteristics of the section. The purlin is commonly used in cold formed steel section. There are three types of cold formed steel sections such as, z, c and hollow section purlin. C-section purlin with different opening shapes means the opening of different shapes such as hexagonal, square, circular are provided in center of web of the section at specific opening sizes, edge distance, spacing between two openings and number of openings.

IV. EXPERIMENTAL WORK

4.1. Material Properties

1. Material: CR steel as per IS: 513, galvanized as per: 277.
2. Thickness: 2mm.
3. Length: 1065mm.
4. Yield strength: 345Mpa.
5. Tensile strength: 410Mpa.
6. Purlin in galvanized coated steel in 120Gsm.

4.1. Cutting of Members

The different shapes of web opening to provide in C-section purlin is the main aim in the casting. First to define all the parameter such as opening shapes, opening sizes, edge distance, spacing between two opening and number of opening as per criteria given by euro code. Castellated purlin created from a standard wide flange beam by cutting it longitudinally in a zigzag or semicircular pattern, separating and offsetting the two halves. The cutting procedure was done by using lesser cutting machine, with no any structural disadvantages.

4.2. Welding of a Member:

Metal arc welding can be used for cold formed steel application with smaller diameter electrodes and low welding current. The welding process in which an electric arc forms between an electrode and the work piece metal, which heats the work piece metal, caused them to melt and join.

IJARSE
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Fig-1: Number of Specimens

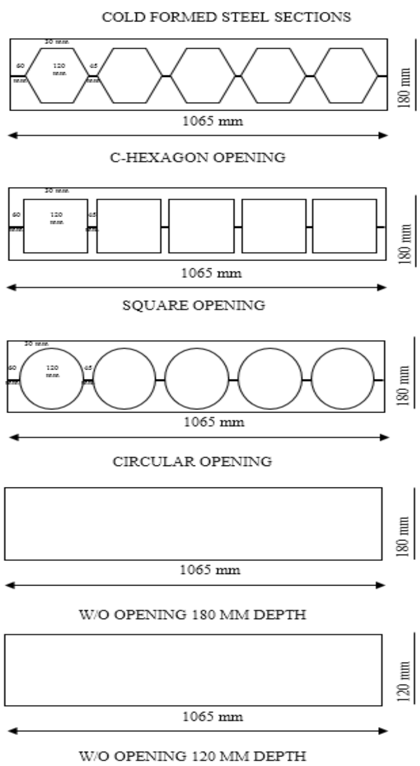

Fig-2: Parameters of CFS Sections

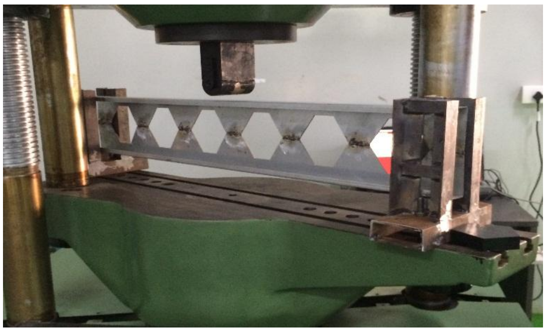

Fig-3: Testing Set-up

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

4.3. Three Point Bending Flexural Test

The three point bending flexural test had been done to get the values of modulus of elasticity, flexural stress, flexural strain and the flexural stress- strain response of the material. The bending flexural testing done over the universal testing machine of 100-ton capacity. The specimen was placed simply supported and load will be act at the center of top of the section.

V. FINITE ELEMENT ANALYSIS

The finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problem for partial differential equation. It is also referred to as finite element analysis (FEA). It subdivided a large problem into smaller and simple parts that are called finite element. Finite element analysis for cold formed steel sections, there are different types of software is available such as, ABAQUS software, ANSYS software. ANSYS is a finite element analysis software used for structural analysis, including nonlinear, linear and dynamic studies. It provide a complete set of element behavior, material models and equation solves for a wide range of structural design problem.

5.1. Modelling and Meshing

The CFS C-section purlin with different opening shapes are modelled and analyzed in ANSYS Software by FEA. The parameters which are defined for experimental work as per euro code, the same parameter are used for finite element analysis in ANSYS software. The purlin section is modelled as 3D shell element and the meshing of model is quadrilateral meshing is used. The material properties given are modulus of elasticity, Poisson's ratio and yield strength.

TABLE -1: MATERIAL PROPERTIES OF COLD FORMED STEEL

Modulus of Elasticity (Es)	203395 Mpa
Poison's Ratio (ν)	0.3
Yield Strength (fy)	345Mpa

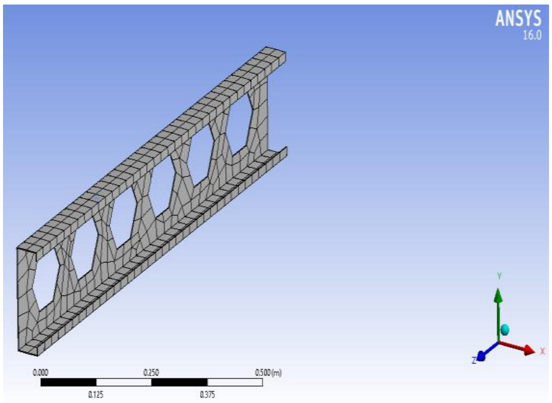

Fig-4: Meshing of CFS castellated C-section in ANSYS

5.2. Analysis

The finite element analysis is carried out in ANSYS software to determine the stress variation and deflection of CFS sections. The load is applied on the Centre of the top of flange of a section and the simply supported

IJARSE
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condition is used. After getting the finite element analysis in ANSYS software the different stress and deflection values are given which are shown below in results.

VI. RESULTS AND DISCUSSIONS

The results are discussed mainly in three parts such as; experimental results, analytical results and comparison of experimental and analytical results of cold formed steel C-section purlin of different opening sections.

6.1. Experimental Results

After getting experimental testing of all CFS specimens on universal testing machine, the results of this specimen are shown below. This results shows the behavior of CFS specimens and their load carrying capacity.

Table -2: Load carrying capacity of different opening shapes

Opening Shapes	Load Carried N
Square	6050
Hexagon	10425
Circular	7425
W/o opening (120mm)	8475
W/o opening (180mm)	12000

Table-3: Experimental maximum stresses and deflection of different opening shapes

Opening shapes	Experimental	
	Stress (N/MM^2)	Deflection (MM)
Square	20.625	1.8
Hexagon	28.958	2.7
Circular	16.806	1.9
W/o opening (120mm)	33.333	1.6
W/o opening (180mm)	29.305	2.1

After getting testing following graph and chart results are given

IJARSE
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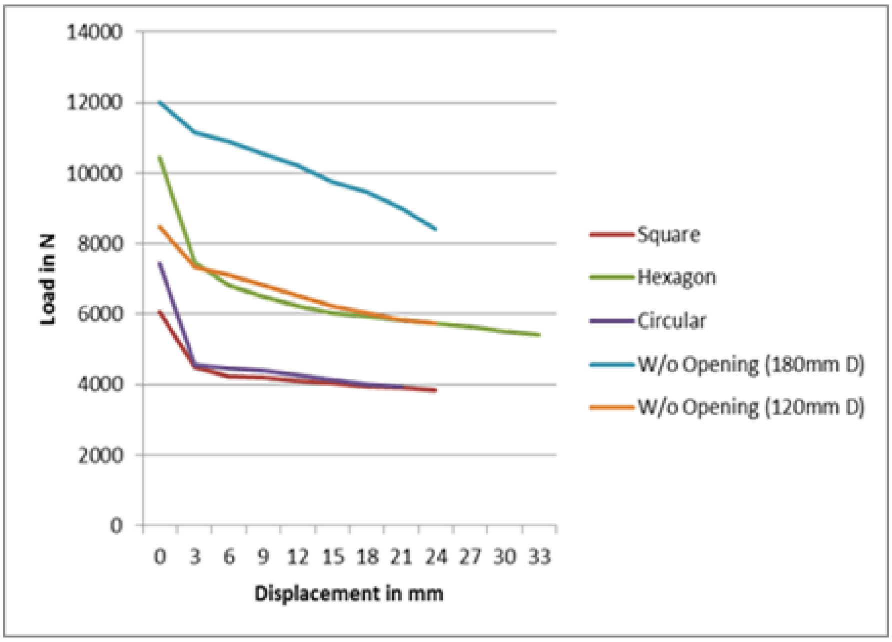

Chart-1: Load vs. Displacement

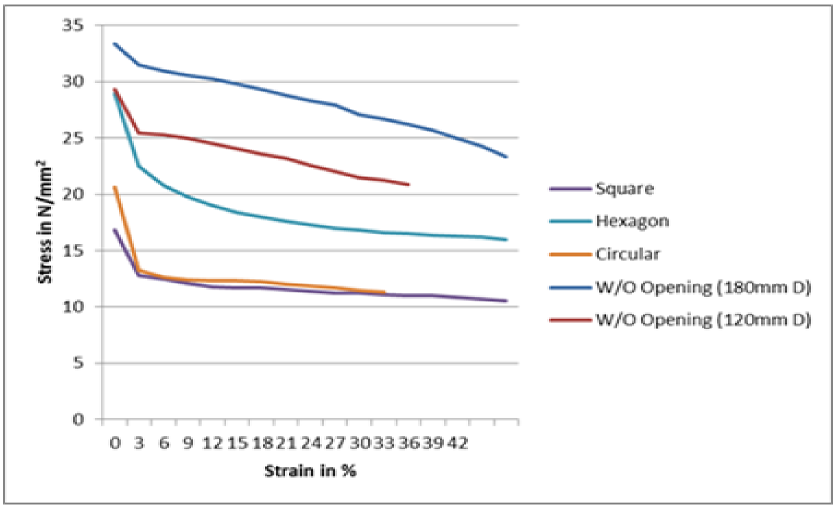

Chart-2: Stress vs. Strain

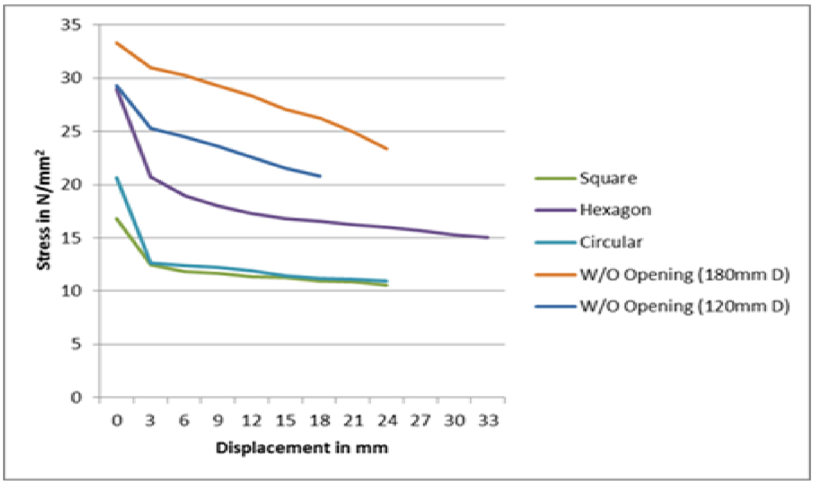

Chart-3: Stress vs. Displacement

IJARSE
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ISSN (P) 2319 - 8346

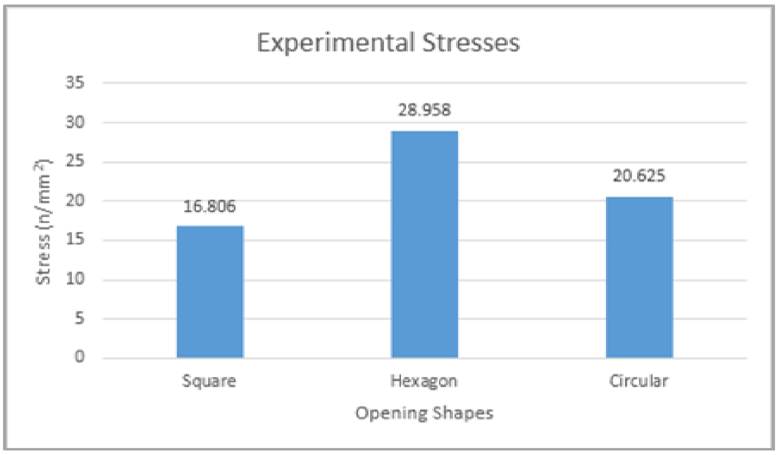

Chart-4: Experimental stresses of different opening shapes

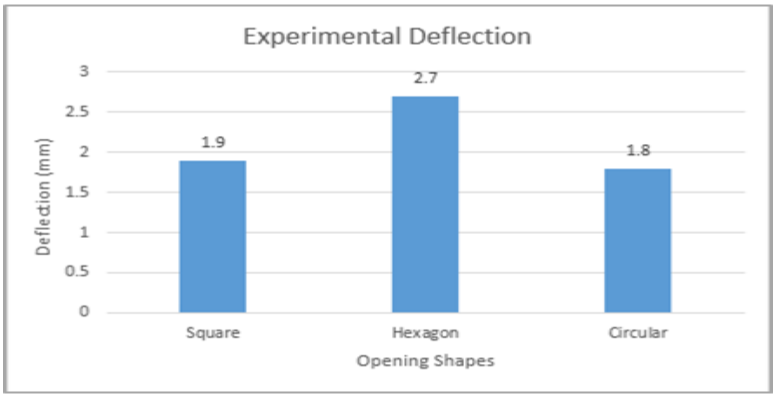

Chart-5: Experimental Deflection of different opening shapes

From experimental results it is observed that the hexagon opening cold formed C-section purlin behaves satisfactorily in respect of load carrying capacity (10.425KN). It gives more load carrying capacity comparing the other opening shapes. Hexagon section also taking more load capacity than its parent 120mm depth of without opening sections and gives maximum stress values than other opening shapes. Which means that hexagon shape gives maximum strength against loading and less deflection as comparing with loading than other shapes.

6.2. Analytical Results

The Finite element analysis is done by ANSYS 16 Software. The analytical results of maximum stresses and deflection with respect to the ultimate loading on cold formed steel C-section purlin of different opening shapes are shown below. This results shows the behavior of CFS specimens and the deflection of the specimens under ultimate loading conditions.

Table -4: Analytical maximum stresses and deflection of different opening shapes

Opening shapes	**Analytical**	
	Stress (N/MM^2)	**Deflection** (MM)
Square	15.836	1.85
Hexagon	13.653	2.04
Circular	12.105	1.52
W/o opening (120mm)	16.395	2.70
W/o opening (180mm)	11.573	1.64

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After getting FEA the following results are given for different opening shapes:

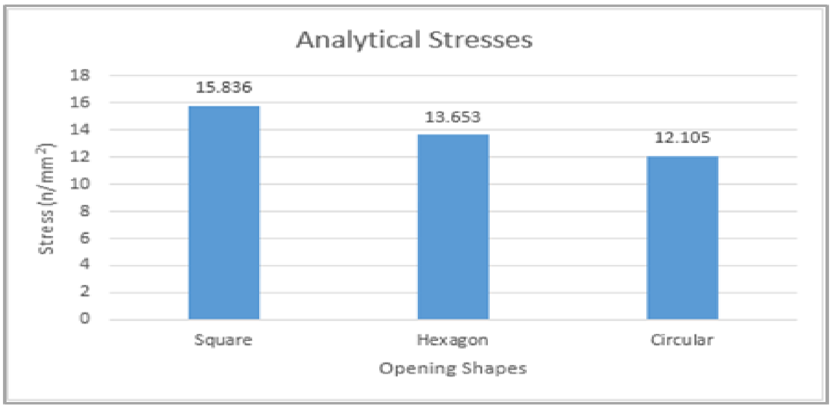

Chart-6: Analytical stresses of different opening shapes

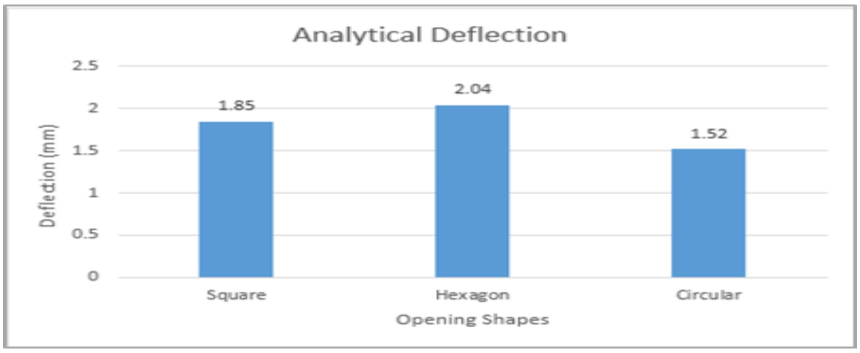

Chart-7: Analytical Deflection of different opening shapes

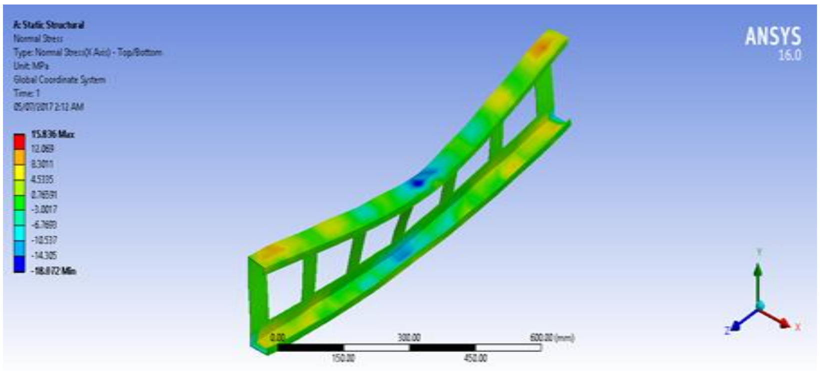

Fig-5: Variation in stresses of Square opening shape by ANSYS

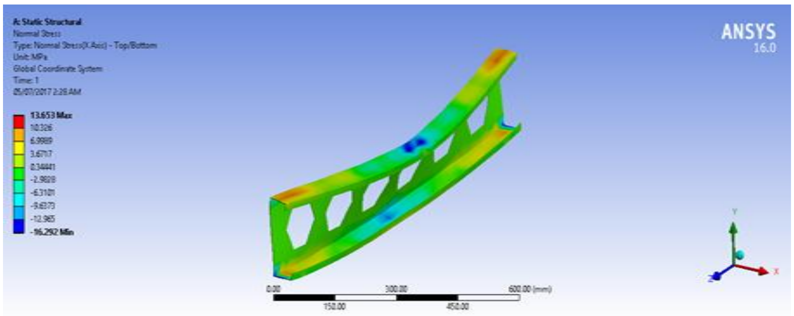

Fig-6: Variation in stresses of Hexagon opening shape by ANSYS

IJARSE
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ISSN (P) 2319 - 8346

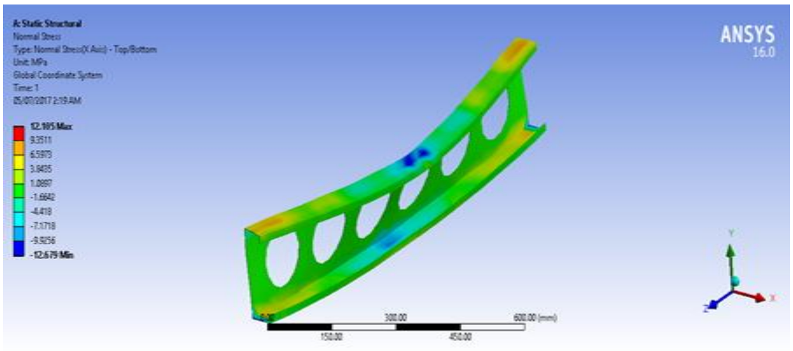

Fig-7: Variation in stresses of Circular opening shape by ANSYS

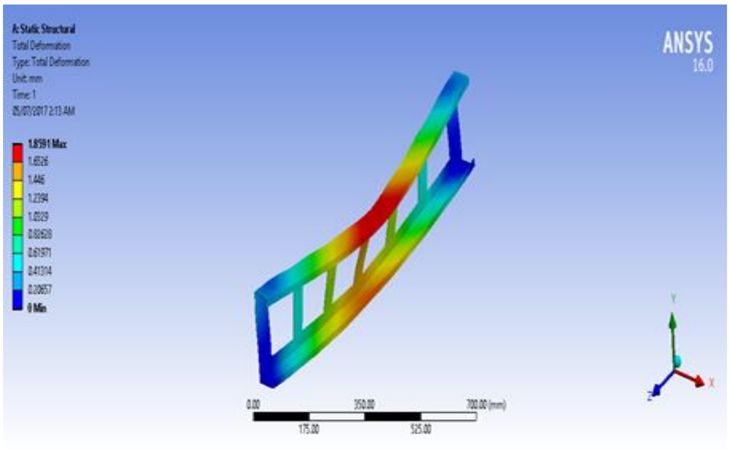

Fig-8: Deflection of Square opening shape by ANSYS

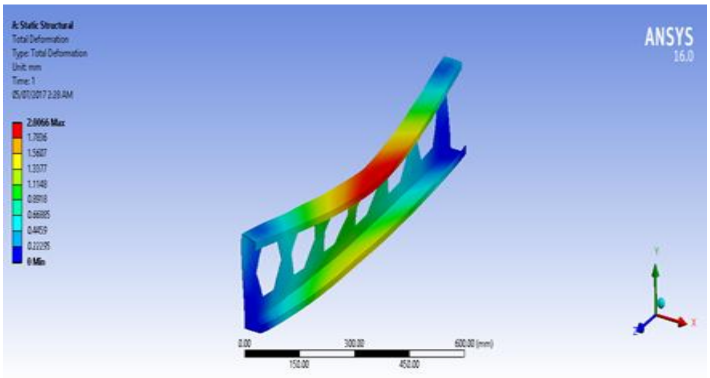

Fig-9: Deflection of Hexagon opening shape by ANSYS

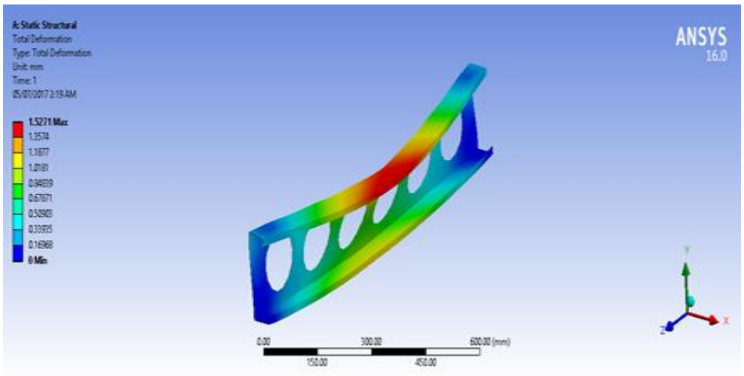

Fig-10: Deflection of Circular opening shape by ANSYS

IJARSE
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From the results of above analysis it is observed that the hexagon opening shapes gives more satisfactory results. It gives less deflection compare with other opening shapes with respect to the loading conditions. Finite element analysis is good agreement with the experimental results.

6.3. Comparison of Experimental and Analytical Results

The validation of experimental results it can be compare with the FEA results is necessary. The results obtained from experiment is compared with the results from the finite element analysis in ANSYS. This comparison of results of CFS C-section purlin with square, hexagonal and circular shaped openings are given in Table-5 below.

Table -5: Comparison of experimental and analytical stresses

Opening Shapes	Load (N)	Experimental Maximum Stresses (N/MM2)	Analytical Maximum Stresses (N/MM2)
Square	6050	16.806	15.836
Hexagon	10425	28.958	13.653
Circular	7425	20.625	12.105

Table -6: Comparison of experimental and analytical deflection

Opening Shapes	Load (N)	Experimental Deflection (MM)	Analytical Deflection (MM)
Square	6050	1.9	1.85
Hexagon	10425	2.7	2.04
Circular	7425	1.8	1.52

After getting Experimental testing and FEA the following chart results are given for different opening shapes:

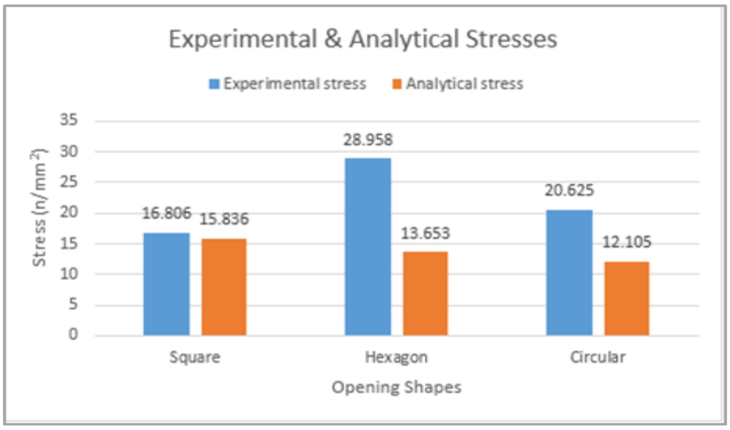

Chart-8: Comparison of experimental and analytical stresses

IJARSE
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ISSN (P) 2319 - 8346

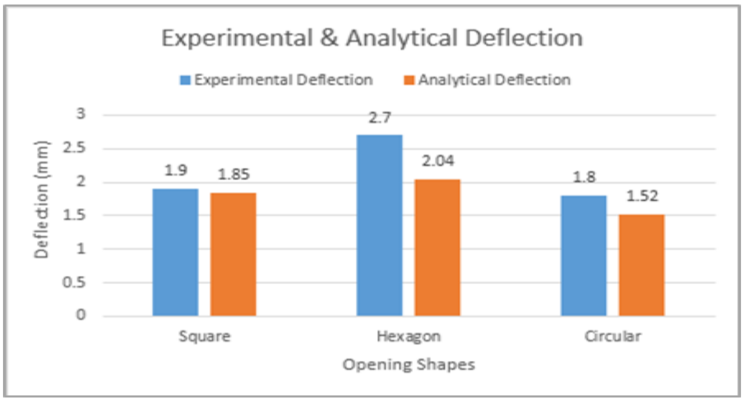

Chart-9: Comparison of experimental and analytical deflection

From the comparison of results it is observed that the experimental results is good agreement with finite element analysis results of ANSYS software. From both results it is concluded that the CFS C-section purlin with hexagon opening shape is more reliable in respect of strength requirement. That means it gives more satisfying strength results than the other square and circular opening shapes.

VII. CONCLUSION

After carrying out the testing on cold formed C-section purlin with different opening in castellated manners following conclusion can be drawn;

1. After converting the cold formed C- section purlin into the cold formed C- section castellated purlin with hexagonal opening, the load carrying capacity of section increases.
2. The load carrying capacity of section varies with various shapes of openings.
3. Castellated purlin with hexagonal opening carrying 42% more load than square and 29% more load than circular opening and it also takes 19% more load than the parent 120mm depth of without opening sections.
4. Hexagon opening C-section purlin of depth 180mm take a load near about, 180mm depth of without opening sections.
5. Experimental and ANSYS software results prove that hexagon shape opening gives maximum stress and less deflection values with respect to loading, it means that the CFS C-section purlin with hexagon opening shapes gives more strength and more satisfactory results than other opening shapes.
6. Results of ANSYS software (FEA) are in good agreement with the results of experimentation.

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