

INVESTIGATION ON BEHAVIOUR OF COLD FORMED STEEL COLUMN WITH EDGE STIFFENER AND EDGE STIFFENED WEB OPENINGS

Submitted in partial fulfilment of the requirements for the award of
Master of Engineering in
Structural Engineering

By

LOGESH ANNADURAI (Register No: 42380002)



**DEPARTMENT OF CIVIL ENGINEERING
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY) Accredited with Grade "A++" by NAAC
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

April 2024



SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with "A++" grade by NAAC
Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai - 600 119
www.sathyabama.ac.in



DEPARTMENT OF CIVIL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **LOGESH ANNADURAI** (Register No: 4238002) who carried out the project entitled **"INVESTIGATION ON BEHAVIOR OF COLD FORMED STEEL COLUMN WITH EDGE STIFFENER AND EDGE STIFFENED WEB OPENINGS"** under our supervision from September 2023 to April 2024.

Internal Guide
(Dr. R. NIRMALA)

Head of the Department

Submitted for Viva voice Examination held on _____

Internal Examiner

External Examiner

DECLARATION

I, **LOGESH ANNADURAI** (Register No: 42380002) here by declare that the Project Report entitled “**INVESTIGATION ON BEHAVIOUR OF COLD FORMED STEEL COLUMN WITH EDGE STIFFENER AND EDGE STIFFENED WEB OPENINGS**” done by us under the guidance of **Dr. R. NIRMALA** is submitted in partial fulfilment of the requirements for the award of Master of Engineering degree in Structural Engineering.

DATE: 20.04.2024

PLACE: Chennai



SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

I convey my thanks to **Dr. Devyani Gangopadhyay, B.Arch., M.T.P., Ph.D.**, Dean, School of Building and Environment and **Dr. S. Packialakshmi, M.E., Ph.D.**, and **Dr. R. Padmapriya, M.E., Ph.D.**, Head of the Department, Dept. of Civil Engineering for providing us necessary support and details at the right time during the progressive reviews.

I would like to express our sincere and deep sense of gratitude to our Project Guide **Dr. R. Nirmala, M.E., Ph.D.**, for her valuable guidance, suggestions and constant encouragement paved way for the successful completion of our project work.

I wish to express our thanks to all Teaching and Non-teaching staff members of the Department of Civil Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

Cold-Formed Steel (CFS) sections have grown in popularity due to their multiple advantageous characteristics, and with ongoing study on the different constraints of such members, their utility in the construction sector has grown significantly. CFS sections were widely used in structural and non-structural applications because they provide numerous benefits such as lightweight structures, high strength-to-weight ratios, increased stiffness due to enhanced sectional profiles, ease of installation and construction, and so on. Apart from this, the optimization of these CFS elements will allow for the construction of structures at very reasonable prices while also increasing load capacity, resulting in a stable and economical structure. Problem of buckling is existed when the ultimate load or the strength of the column before achieved of the cross-section yield. The different types of buckling, sensitivities to imperfections and uncertainties, related to the material properties of CFS. Moreover, Edge or double stiffeners are introduced where the stiffness is insufficient. To investigate the suitable method of strengthening the CFS. The main objective of the study is to analyze the strengthening method for CFS G-section column with edge stiffened holes sections with ANSYS Software and under experimental conditions. The results shows that the column with edge stiffened holes improves the stiffness of the column. The test results showed that for the case of CFS channel sections having edge-stiffened web openings, the compression resistance was higher than the plain channel sections. The G section column with edge stiffened three holes has low stiffness that can be used as a support member.

TABLE OF CONTENTS

CHAPTER NO	TITLE	PAGE NO
	ABSTRACT	i
	LIST OF TABLES	iii
	LIST OF FIGURES	iv
1	INTRODUCTION	
	1.1 GENERAL	1
	1.2 ADVANTAGES OF COLD-FORMED STEEL MEMBERS	3
	1.3 TYPES OF COLD-FORMED STEEL SECTIONS	3
	1.4 LOCAL BUCKLING IN COLD-FORMED STEEL SECTIONS	3
	1.5 BEHAVIOR AFTER POST-CRITICAL ANALYSIS OF CFS	4
2	LITERATURE	
	2.1 GENERAL	5
	2.2 REVIEW OF THE LITERATURES	5
	2.3 INFERENCE FROM THE LITERATURES	10
	2.4 OBJECTIVE OF THE STUDY	12
	2.5 METHODOLOGY	12

3	ANALYSIS AND RESULTS	
3.1	GENERAL	13
3.2	OVERVIEW OF ANSYS	13
3.3	MODELING OF COLUMN USING CATIA	13
3.4	ANALYSIS OF COLUMN USING ANSYS.	17
3.5	COMPARISION OF RESULTS	27
4	EXPERIMENTAL ANALYSIS	
4.1	GENERAL	31
4.2	FABRICATION OF COLD FORMED STEEL G-SECTION COLUMN.	31
4.3	TESTING OF FABRICATED G-SECTION COLUMN	35
4.4	RESULT AND DISCUSSION	35
5	SUMMARY AND CONCLUSION	43
5.1	SUMMARY OF THE STUDY	43
5.2	CONCLUSION	43
5.3	FUTURE SCOPE	43
	REFERENCES	44

LIST OF TABLES

TABLE NO	TITLE	PAGE NO
3.1	DIMENSION OF THE G-SECTION COLUMNS	14
3.2	PROPERTIES OF MATERIAL	18

LIST OF FIGURES

FIGURE NO	TITLE	PAGE NO
2.1	METHODOLOGY FLOW CHART	12
3.1	STIFFENED G-SECTION COLUMN WITH SINGLE OPENING-TOP VIEW	14
3.2	STIFFENED G-SECTION COLUMN WITH SINGLE OPENING-SIDE VIEW	14
3.3	STIFFENED G-SECTION COLUMN WITH SINGLE OPENING-3D VIEW	15
3.4	STIFFENED G-SECTION COLUMN WITH THREE OPENINGS-SIDE VIEW	15
3.5	STIFFENED G-SECTION COLUMN WITH THREE OPENING-3D VIEW	16
3.6	STIFFENED G-SECTION COLUMN WITH FIVE OPENINGS-SIDE VIEW	16
3.7	STIFFENED G-SECTION COLUMN WITH FIVE OPENING-3D VIEW	16
3.8	STIFFENED WITH G-SECTION COLUMN SEVEN OPENINGS-SIDE VIEW	17
3.9	STIFFENED WITH G-SECTION COLUMN SEVEN OPENINGS-3D VIEW	17
3.10	TOTAL DEFORMATION OF STIFFENED EDGE SINGLE OPENING COLUMN	18
3.11	DIRECTIONAL DEFORMATION OF STIFFENED EDGE SINGLE OPENING COLUMN	19

3.12	EQUIVALENT ELASTIC STRAIN OF STIFFENED EDGE SINGLE OPENING COLUMN	19
3.13	NORMAL ELASTIC STRAIN OF STIFFENED EDGE SINGLE OPENING COLUMN	19
3.14	EQUIVALENT STRESS (PA) OF STIFFENED EDGE SINGLE OPENING COLUMN	20
3.15	NORMAL STRESS (PA) OF STIFFENED EDGE SINGLE OPENING COLUMN	20
3.16	TOTAL DEFORMATION OF STIFFENED EDGE THREE OPENING COLUMN	21
3.17	DIRECTIONAL DEFORMATION OF STIFFENED EDGE THREE OPENING COLUMN	21
3.18	EQUIVALENT ELASTIC STRAIN STIFFENED EDGE THREE OPENING COLUMN	21
3.19	NORMAL ELASTIC STRAIN STIFFENED EDGE THREE OPENING COLUMN	22
3.20	EQUIVALENT STRESS (PA) STIFFENED EDGE THREE OPENING COLUMN	22
3.21	NORMAL STRESS (PA) STIFFENED EDGE THREE OPENING COLUMN	22
3.22	TOTAL DEFORMATION EDGE STIFFENED WITH 5 OPENING COLUMN	23
3.23	DIRECTIONAL DEFORMATION EDGE STIFFENED WITH 5 OPENING COLUMN	23
3.24	EQUIVALENT ELASTIC STRAIN EDGE STIFFENED WITH 5 OPENING COLUMN	24

3.25	NORMAL ELASTIC STRAIN EDGE STIFFENED WITH 5 OPENING COLUMN	24
3.26	EQUIVALENT STRESS(PA) EDGE STIFFENED WITH 5 OPENING COLUMN	24
3.27	NORMAL STRESS(PA) EDGE STIFFENED WITH 5 OPENING COLUMN	25
3.28	TOTAL DEFORMATION EDGE STIFFENED WITH 7 OPENING COLUMN	25
3.29	DIRECTIONAL DEFORMATION EDGE STIFFENED WITH 7 OPENING COLUMN	26
3.30	EQUIVALENT ELASTIC STRAIN EDGE STIFFENED WITH 7 OPENING COLUMN	26
3.31	NORMAL ELASTIC STRAIN EDGE STIFFENED WITH 7 OPENING COLUMN	26
3.32	EQUIVALENT STRESS(PA) EDGE STIFFENED WITH 7 OPENING COLUMN	27
3.33	NORMAL STRESS (PA) EDGE STIFFENED WITH 7 OPENING COLUMN	27
3.34	NORMAL STRESS OF G – SECTION EDGE STIFFENED COLUMNS	28
3.35	EQUIVALENT STRESS OF G-SECTION EDGE STIFFENED COLUMNS	28
3.36	NORMAL ELASTIC STRAIN G-SECTION EDGE STIFFENED COLUMNS	29
3.37	EQUIVALENT ELASTIC STRAIN G-SECTION EDGE STIFFENED COLUMNS	29

3.38	DIRECTIONAL DEFORMATION G-SECTION EDGE STIFFENED COLUMNS	30
3.39	TOTAL DEFORMATION G-SECTION EDGE STIFFENED COLUMNS	30
4.1	COLD ROLLED SHEET	31
4.2	LASER CUTTING PROCESS	32
4.3	PRESSING SHEETS INTO G-SECTIONS	32
4.4	FABRICATED UNSTIFFENED G-SECTION COLUMN WITH THREE OPENINGS	33
4.5	FABRICATED STIFFENED G-SECTION COLUMN WITH THREE OPENINGS	33
4.6	FABRICATED UNSTIFFENED G-SECTION COLUMN WITH FIVE OPENINGS	34
4.7	FABRICATED STIFFENED G-SECTION COLUMN WITH FIVE OPENINGS	34
4.8	EXPERIMENTAL SETUP	35
4.9	UNSTIFFENED G-SECTION COLUMN WITH THREE OPENING	36
4.10	LOAD DEFLECTION CURVE OF THE UNSTIFFENED G-SECTION COLUMN WITH THREE OPENING	36
4.11	STIFFENED G-SECTION COLUMN WITH THREE OPENING	37
4.12	THE LOAD DEFLECTION CURVE OF THE STIFFENED G-SECTION COLUMN WITH THREE OPENING	37
4.13	UNSTIFFENED G-SECTION COLUMN WITH FIVE OPENING	38

4.14	THE LOAD DEFLECTION CURVE OF THE UNSTIFFENED G-SECTION COLUMN WITH FIVE OPENING	38
4.15	STIFFENED G-SECTION COLUMN WITH FIVE OPENING	39
4.16	THE LOAD DEFLECTION CURVE OF THE STIFFENED G-SECTION COLUMN WITH FIVE OPENING	39
4.17	COMPARISON OF EXPERIMENTAL AND ANALYTICAL VALUES OF G-SECTION COLUMN WITH WEB STIFFENED THREE OPENING	40
4.18	COMPARISON OF EXPERIMENTAL AND ANALYTICAL RESULT OF G-SECTION COLUMN WITH WEB STIFFENED FIVE OPENING	40
4.19	COMPARISON OF UNSTIFFENED AND STIFFENED WEB OPENING RESULT OF G-SECTION COLUMN WITH THREE OPENING	41
4.20	UNSTIFFENED AND STIFFENED WEB OPENING RESULT OF G-SECTION COLUMN WITH FIVE OPENING	41
4.21	EXPERIMENTAL RESULTS OF G-SECTION COLUMNS TESTED	42
4.22	THE COMPARISON BETWEEN RESULT OF G-SECTION COLUMNS WITH STIFFENED WEB OPENING	42

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Structural steel is a popular construction material, often used alongside concrete to create impressive and long-lasting buildings. Its versatility, sustainability and flexibility are some of the main reasons for its use, as well as being a very cost-effective material. With a high strength-to-weight ratio, steel can often provide a solution where other materials are unsuitable.

Steel has several environmental benefits, such as being 100% recyclable. In the UK, the estimated recovery rate of recycled steel from steel structures is 96%, and globally recycled steel accounts for 50% of new steel production. Prefabricated and highly accurate steel structures also allow for easy and waste-free assembly on site, reducing construction duration as well as the amount of materials sent to landfill.

Within the realm of cold-formed thin-walled steel (CFTWS) components, C- and Z-sections are prevalent in residential, commercial, and industrial construction. Unlike C-section columns, which are characterized by lipped channels, G-section columns exhibit an additional inward return lip. Consequently, G-sections fall into the category of channels with intricate edge stiffeners. In contrast to C-section columns, G-section columns boast a superior elastic buckling stress and ultimate load-bearing capacity. It's widely acknowledged that distortional buckling is disadvantageous due to its reduced post-buckling resilience and heightened sensitivity to imperfections, compared to local buckling. The presence of complex edge stiffeners enhances the rotational restraint of the flange, rendering the column more resistant to distortional buckling a primary motivation for utilizing complex edge stiffeners.

The utilization of cold-formed steel (CFS) channel sections is gaining popularity as load-bearing components in building structures. These channel sections often incorporate web openings to facilitate the installation of various services. Traditionally, web openings have been created through punching and are left unstiffened, which can limit the size and spacing of these openings.

Recently, a new generation of CFS channel sections featuring edge-stiffened web openings has emerged and found widespread use in New Zealand. However, there is a noticeable absence of experimental investigations in the existing literature regarding the compression behavior of such channel sections.

This study presents a comprehensive analysis, comprising a total of seven results, including three axial compression tests and seven finite element analysis outcomes. The focus is on assessing the compression resistance of CFS channel sections, specifically G-section columns, equipped with both edge-stiffened and unstiffened web openings

The term "cold-formed steel (CFS) section" refers to products created by shaping thin steel sheets through processes such as rolling or pressing. These CFS products are manufactured by manipulating thin steel sheets using methods like stamping, rolling, or pressing to transform them into usable products. In the construction industry, both structural and non-structural components are fashioned from these thin steel sheets. These components can include columns, studs, beams, floor decking, built-up sections, and various other parts of a structure. Cold-formed steel construction materials have distinct characteristics compared to other steel construction materials, such as hot-rolled steel. The manufacturing of CFS products takes place at room temperature through rolling and pressing techniques. The strength of elements is assessed using buckling properties. Construction practices for CFS are akin to timber framing, involving the assembly of stud frames using screws.

Applications of CFS members encompass a wide range, including buildings, bridges, car bodies, storage tanks, highway products, railway coaches, transmission towers, drainage facilities, and more. Thin-walled steel members typically have thicknesses ranging from 0.4 mm to 7 mm. Even steel plates and bars with a thickness of 25.4 mm can be transformed into cold-formed structural shapes. The steel sheets used in CFS construction should possess a minimum yield strength of 280 MPa, with a growing trend toward using higher-yield-strength steel sheets.

The mechanical properties of steel material change due to the cold-working process involved in shaping it. The yield strength and ultimate strength of steel sections created from steel plates/sheets are increased. To protect cold-formed steel sections from

corrosion, they are coated with zinc or galvanizing, with the thickness of the coating typically being 0.04 mm for internal environments. Thicker coatings are applied in the presence of prolonged moisture to enhance protection.

Compared to hot-rolled sections, cold-formed steel (CFS) sections have greater moment of inertia and section modulus in both the x and y directions, leading to higher load-carrying and moment-resisting capacities.

1.2 ADVANTAGES OF COLD-FORMED STEEL MEMBERS

1. Lightweight members.
2. High strength and stiffness in sections.
3. Easy erection and installation procedures.
4. Compatibility with conventional connection methods like riveting, bolting, or welding.
5. Elimination of the need for formwork in the construction process.
6. Attainment of desired shapes and lengths through prefabrication.
7. Reduced transportation costs due to lightweight sections.
8. Ease of recycling.
9. Termite-proof and rot-proof sections.
10. Enhanced moment-carrying capacity compared to hot-rolled sections, thanks to thinner wall sections.

1.3 TYPES OF COLD-FORMED STEEL SECTIONS

Cold-formed steel elements come in two main types: stiffened and unstiffened. Stiffened elements have support along both longitudinal edges, while unstiffened elements have support along only one longitudinal edge, with the other edge being free to move. Intermittently stiffened elements are formed by dividing a thin element into two or more narrow sub-elements and introducing intermediate stiffeners during the rolling process. The effectiveness of edge stiffened elements depends on the presence of adequate stiffeners, with a local buckling coefficient value of 4.0. If the stiffeners are found to be inadequate or partially adequate, their effectiveness is disregarded, and the element is treated as unstiffened.

1.4 LOCAL BUCKLING IN COLD-FORMED STEEL SECTIONS:

Local buckling is a crucial aspect of cold-formed steel elements. Thin steel elements buckle before yielding, with thinner plates experiencing lower buckling loads. Plates with one free edge and one supported edge buckle at considerably lower loads, reducing the value of 'K' to 0.425. To prevent local buckling, free edges are equipped with lips to constrain their movement.

1.5 BEHAVIOR AFTER POST-CRITICAL ANALYSIS OF CFS:

When subjected to uniform bending through moment application at the end of a cold-formed steel section, the top layer of the thinner plate experiences flexural compression and buckles. This buckling results in ripples on the top layer of the section along its length. The stiffer edges near the supports resist the applied moment to a large extent, while the region near the center is less effective. Local buckling is avoided by providing lips to the free edges, ensuring they remain straight.

After critical loading, non-flat plates deform out of the plane, leading to a non-uniform state of stress across the cold-formed steel sections. The effect of local buckling is assessed using the concept of effective width, with regions near supports considered fully effective and the low-stressed center region regarded as the least effective. The effective width for compression in a cold-formed section depends on the width/thickness ratio, support conditions, and applied stress.

CHAPTER 2

LITERATURE STUDY

2.1 GENERAL

The formation of research problem for the study has been taken from the references of international journals listed below.

2.2 REVIEW OF THE LITERATURES

Ziqi He, et.al. (2023) research paper focusing on experimental results of built-up sections of cold-formed steel with V-stiffeners and -stiffeners under axial and eccentric compression loading. It includes details on the experimental setup, such as initial geometric imperfections and tensile coupon tests, and discusses the findings regarding buckling behavior, failure modes, and load response curves. The study also analyzes the influence of member parameters on axial strengths and suggests avenues for future research and computational model development.

Yi Xiang, et.al. (2020) In this study, we examined pin-ended G-section columns, both perforated and non-perforated. We conducted tests on 20 non-perforated and 16 perforated columns under axial compression, revealing diverse failure modes and behaviors. A numerical model in ABAQUS aided our investigation into the impact of opening dimensions and positions. Key findings include the significant influence of perforations on ultimate strength and deformation shape, particularly in longer columns. Smaller-diameter circular opening spaced between $3d_c$ to $6d_c$ are recommended for practical engineering applications. Compliance with AISI S201 is advised for slotted opening spacing.

Shaofeng Niea, et.al. (2020) Our research delves into built-up double-box columns, constructed from four cold-formed steel channels, investigating their compressive behavior via experiments and numerical analysis. Under concentric axial compression, we observed different failure modes based on column length. Screw spacing minimally affected the flexural buckling strength of long columns, and increased slenderness ratios shifted failure modes. Design codes yielded conservative estimates, especially for eccentric axial

compression. These findings call for improved design methods, particularly for eccentric axial strength prediction.

Dobri, et.al., (2020) We conducted a comprehensive finite element analysis of cold-formed stainless steel plain channel columns under pure compression, considering factors like minor and major axis buckling and flexural-torsional buckling. The study recommends revising design parameters in EN1993-1-4, suggesting different approaches for different steel grades and cross-section classes. Adjustments to Equation (5.7) are proposed, aiming for lower safety factors in stainless steel column design.

Boshan Chena, et.al., (2019) We present a comprehensive investigation into the compression resistance of Cold-Formed Steel (CFS) channel sections with edge-stiffened web openings, combining experimental testing and numerical analysis. CFS channel sections with edge-stiffened web openings exhibited higher compression resistance, while unstiffened openings reduced resistance. A validated finite element model explored opening spacing and column slenderness. The study highlights discrepancies between test results, FEA, and design methods, calling for refinement in design methodologies for accurate structural performance predictions.

Sadovskýa and Kriváček. (2018) This study explores using preliminary eigenvalue analysis data to efficiently select influential eigenmode imperfections for calculating ultimate buckling strength in thin-walled structures through the GMNIA method. The focus is on cold-formed lipped channel columns under axial compression with varying boundary conditions and load eccentricity. Instead of traditional amplitude measures, an energy measure normalizes eigenmode imperfections, aiding in their assessment. The study reveals that a significant increase in buckling loads reduces the likelihood of higher eigenmodes becoming influential. Normalizing eigenmodes by energy measure helps identify influential eigenmodes and assess their impact on structural behavior, particularly under different boundary conditions.

Jia-Hui Zhang and Ben Young (2018) This paper reports findings from a test program on cold-formed steel built-up closed section columns, comparing two types with inward and outward web stiffeners of different thicknesses. Axial compression tests examine material properties, initial geometric imperfections, ultimate strengths, and failure

modes. The study finds that design strengths calculated with PDSM-t, assuming the thickness at the contact area is the nominal plate thickness, provide accurate and dependable predictions for cold-formed steel built-up closed sections with web stiffeners. Rational considerations are key to achieving these accurate design predictions, highlighting the suitability of the direct strength method.

Krishanu Roy, et.al. (2018) This paper presents a detailed experimental investigation into the axial strength of back-to-back gapped built-up Cold-Formed Steel (CFS) channel-sections. It includes 40 tests, discussing failure modes, load-axial shortening, load-axial strain, and deformed shapes at failure. The impact of the gap between sections and link-channel spacing on axial strength is examined. Comparisons between test results and numerical models show good agreement. The study recommends using $\lambda_{c,GAP}$ as the parameter for calculating the axial strength of back-to-back gapped built-up CFS columns, providing more accurate and reliable design predictions than non-dimensional slenderness (λ_c).

Daniel Cardoso, et.al. (2017) This paper discusses differences in methods for calculating distortional buckling critical stress as the flange width to web width (b_f/b_w) ratio decreases below 0.4. It introduces Model 2 as a method with superior agreement among compared approaches when b_f/b_w is 0.4 or higher. Model 1, Schafer's approach, and Lau and Hancock's approach also provide accuracy. Model 1 is highlighted for its simplicity in calculating distortional buckling critical stress, making it practical for various cross-sectional geometries and loading conditions, including monosymmetric and antisymmetric sections. It offers versatility in analyzing columns with double curvature distortional modes.

Wei-bin Yuana, et.al., (2017) This paper investigates the distortional buckling behavior of Pre-Cambered Cold-Formed Steel (PCFS) channel-section beams with circular opening in the web. Numerical and analytical methods are employed to assess the influence of web openings on distortional buckling behavior and critical stress under pure bending. Findings reveal that larger circular opening decrease the critical moment for distortional buckling but increase the half-wavelength associated with it. Circular opening reduce the rotational restraint of the web on the compressed flange-lip system, affecting

critical moments. This research enhances our understanding of how web openings impact PCFS channel-section beams under pure bending.

Fangfang Liao, et.al. (2017) This study explores multi-limbs built-up cold-formed steel stub columns, focusing on failure modes, integral behavior, comparative performance, and plate geometry's influence. It found that these columns exhibit local and distortional buckling, showcasing their integral behavior. Moreover, connecting two specimens showed interesting test results. Finite Element Analysis validated the findings. Plate width-thickness ratio significantly affects bearing capacity, while screw spacing does not impact axial compression bearing capacity.

Vijayanand and Anbarasu (2017) This study combines numerical and theoretical analyses to assess the strength of built-up columns with spacers. It validated a finite element model using experimental tests and conducted a parameter study. Theoretical analyses, including DSM1, DSM2, and EWM, were performed and compared to numerical results. The Equivalent Width Method (EWM) showed better predictions for column strength in this configuration.

Alexandre Landesmann, et.al. (2016) This study evaluates the distortional buckling behavior of cold-formed steel lipped channel columns with web and flange V-shaped intermediate stiffeners. It assesses claims made in a previous study and compares them to numerical analyses of various column geometries. The proposed DSM distortional strength curve was found suitable for some columns but not plain lipped channel columns, especially for slender ones.

Guanbo Bian, et.al. (2016) This research investigates the torsional response of thin-walled cold-formed steel members, emphasizing their twist rotations and inelastic reserve strength. Finite element models illustrate plastification during torsion. The study introduces an idealized warping-fixed boundary condition to account for longitudinal warping stresses. Torsional slenderness is proposed for predicting ultimate torsional strength, aligning with the DSM approach.

Zhanjie Li, et.al (2016) This study optimizes cold-formed steel lipped channel sections to meet performance criteria while minimizing weight. It uses two optimization levels, a Particle Swarm Optimization algorithm, and a genetic algorithm to find families of

sections. The method prioritizes manufacturability and can be extended to other shapes, limit states, and geometries.

Alenezi, et.al (2015) The paper investigates shear connectors in a connecting system between cold-formed steel channels and a ferrocement jacket. It identifies failure modes, optimal connector types, and their capacities. Finite Element Method simulations confirm the experimental results, suggesting the suitability of these connectors for composite action.

Landesmann and Camotim (2015) This study assesses the DSM distortional strength curve's performance under various uniform temperature distributions for cold-formed steel columns. It discovers that ultimate loads are influenced by temperature but proposes modifications to improve prediction accuracy, especially for stocky columns.

Shanshan Cheng, et.al (2015) The paper examines the buckling behavior of cold-formed steel channel section columns under cross-sectional non-uniform temperature distributions. It highlights the significance of accurate temperature modeling in determining critical buckling loads and column slenderness.

Gunalan, and Mahendran (2015) This study experimentally investigates web crippling capacities of cold-formed steel unlippped channels with stocky webs under end two-flange (ETF) and interior two-flange (ITF) load cases. It finds that existing design equations are unconservative, prompting the proposal of new equations to accurately predict web crippling capacities.

Juarez Moara Santos Franco, et.al (2014) The paper addresses the optimization of cold-formed steel shapes, presenting a Shape Grammar approach. It discusses optimization challenges, the role of AI and engineering experience, and limitations. Future research areas, including incorporating additional variables and encoding functional constraints, are suggested.

Hélder Craveiro et.al. (2014) explores the structural behavior of CFS columns under fire conditions. Key findings include the significant influence of end-support conditions, initial load levels, and surrounding structure stiffness on the fire performance of CFS columns. The paper suggests a need for a refined design methodology that considers

various parameters to accurately predict their behavior under fire conditions, emphasizing the importance of cross-section shape and the interaction between different failure modes.

Moharrami a, et.al. (2014) focuses on optimizing the cross-sectional geometries of CFS columns under compression. It expands the design space to consider different cross-sectional geometries and employs a hybrid optimization strategy. The study enhances compressive capacities significantly and highlights the importance of considering boundary conditions and practical manufacturability when optimizing CFS columns.

Shanmuganathan Gunalan et.al (2013) investigates the behavior of CFS columns under flexural and flexural-torsional buckling. It compares experimental results with existing design standards and proposes improved design rules for scenarios involving fixed ends and warping fixity. The research enhances the reliability and safety of CFS structural designs.

Kulatunga et.al (2013) examines the load capacity of lipped channel CFS sections under compression loading, including the impact of perforations. It validates buckling behavior through experiments and finite element simulations, finding that existing design standards may be conservative. The study underscores the utility of Finite Element Analysis in predicting load-carrying capacity.

Alireza Bagheri Sabbagh a, et.al (2013) focuses on the behavior of connections in steel structures under cyclic loading. It emphasizes the influence of connection slip, the effects of imperfections, and the need to consider cyclic loading to predict strength degradation accurately. The research provides insights into designing connections based on dominant behavior and improving slip-bearing modeling.

Ashkan Shahbazian, et.al (2012) investigates the applicability of the Direct Strength Method (DSM) to thin-walled steel columns with both uniform and non-uniform temperature distributions within their cross-sections. It offers modified DSM equations and buckling curves for non-uniform temperature distributions, ensuring consistent results across different buckling modes.

Eliane S. dos Santos a, et.al (2012) presents experimental findings on fixed-ended lipped channel CFS columns, particularly addressing the triple mode interaction involving local, distortional, and global buckling modes. It reveals that local buckling has minimal

influence on post-buckling behavior, with distortional and global deformations being predominant. The research aims to develop a DSM-based design approach for such columns.

Pedro B. Dinis, et.al (2012) discusses ongoing research on fixed-ended lipped channel columns affected by local-distortional-global (LDG) interaction. It highlights the significant reduction in ultimate strength due to LDG mode interaction and suggests using DSM strength curves for accurate predictions. Further experimental and numerical research is recommended to validate these findings.

2.3 INFERENCE FROM THE LITERATURES

Advantages in Construction: Cold-formed steel (CFS) offers numerous advantages in construction, including its light weight, high strength, and stiffness. It simplifies the erection and installation process, making use of conventional connection methods such as riveting, bolting, or welding. The absence of the need for formwork and the ability to prefabricate shapes and lengths result in cost-effective and efficient construction.

Versatile Applications: Cold-formed steel finds extensive applications in various industries, including buildings, bridges, car bodies, storage tanks, highway products, railway coaches, transmission towers, drainage facilities, and more. It can be used to create a wide range of structural components, offering versatility in design and functionality.

Material Properties: The mechanical properties of steel sheets change during the cold-forming process, with increased yield strength and ultimate strength. This makes CFS an attractive choice for applications requiring high strength-to-weight ratios.

Local Buckling Considerations: Local buckling is a critical aspect of cold-formed steel sections. Thin steel elements are susceptible to buckling before yielding, and factors like free edges and support conditions play a significant role in the load-bearing capacity and behavior of CFS elements.

Corrosion Protection: To protect cold-formed steel sections from corrosion, zinc coating or galvanizing is commonly applied. The thickness of the coating varies depending on the environmental conditions, with thicker coatings used in more corrosive settings.

Comparative Advantages: When compared to hot-rolled sections, cold-formed steel sections generally exhibit higher moment of inertia and section modulus in both the x and y directions. This translates to increased load-carrying and moment-resisting capacities, making them a preferred choice in certain applications.

Recyclability: Cold-formed steel is not only efficient during its service life but also environmentally friendly due to its recyclability. The ease of recycling makes it a sustainable material choice in construction and other industries.

Design Challenges and Solutions: The design and analysis of cold-formed steel structures involve specific challenges, such as addressing local buckling and effective width considerations. Researchers and engineers continue to develop innovative solutions and design guidelines to enhance the safety and efficiency of CFS structures.

Evolving Standards: The field of cold-formed steel is dynamic, with evolving design codes and standards to accommodate new developments and materials. Staying updated with the latest standards is essential for practitioners in the industry.

Research and Innovation: Ongoing research in the field of cold-formed steel focuses on enhancing its performance, optimizing designs, and expanding its applications. Innovations in materials and manufacturing techniques continue to drive improvements in the industry.

2.4 OBJECTIVE OF THE STUDY

The objective of the present study focuses on

To design the different CFS G-section column with edge stiffened opening sections with Catia Software.

To analyze the structural behavior of CFS G-section column with edge stiffened openings using ANSYS software.

1. To investigate the behavior of CFS G-section column experimentally.
2. To compare the experimental values of CFS G-section column with analytical results.

2.5 METHODOLOGY

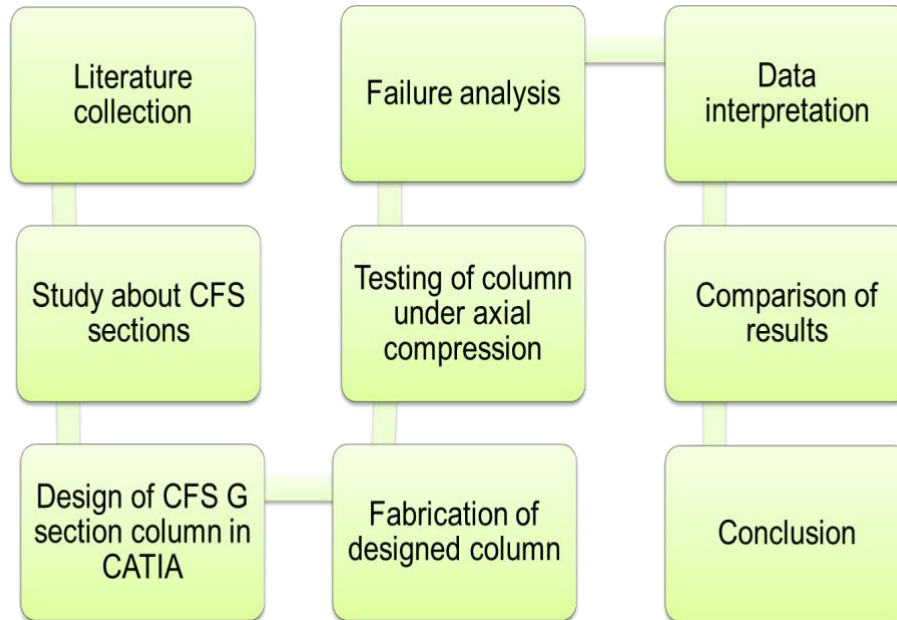


Figure 2.1: Methodology flow chart

The methodology of the study is shown in Figure 2.1 describes a system of methods used in this study.

CHAPTER 3

ANALYSIS USING ANSYS WORKBENCH

3.1 GENERAL

In this chapter the G-section columns with edge stiffened web openings are designed using CATIA and analyzed using ANSYS software and the results are compared.

3.2 OVERVIEW OF ANSYS

ANSYS Workbench is a widely recognized and versatile software platform used in engineering and scientific simulations. It offers a comprehensive suite of tools and features that facilitate the analysis and optimization of complex systems, helping engineers and researchers solve intricate problems across various industries. With a strong focus on accuracy, reliability, and user-friendliness, ANSYS Workbench has become an essential tool for product design, structural analysis, fluid dynamics, electromagnetics, and more.

As a simulation environment, ANSYS Workbench streamlines the entire simulation process, from model creation to results analysis, enabling users to make informed decisions and enhance the performance and reliability of their designs. It combines a range of ANSYS software applications, making it a powerful and integrated platform for performing multi physics simulations.

The primary advantage of ANSYS Workbench is its ability to address real-world engineering challenges through virtual testing, reducing the need for costly physical prototypes and experimental testing. This not only saves time and resources but also allows for the exploration of a broader design space and the optimization of product performance.

3.3 MODELING OF COLUMN USING CATIA

CATIA, developed by Dassault Systems, is a robust multi-platform software suite used for computer-aided design (CAD). It enables the creation, simulation, analysis, and optimization of complex 3D designs. Its features include parametric and surface modelling, assembly design, and drafting, making it a powerful tool for comprehensive product development and visualization.

The G section column with edge stiffened single opening model is modelled in CATIA and imported to ANSYS, Design modeler. Figure 3.1 to 3.3 shows the geometric of the stiffened single opening column modelled using CATIA software.

MODEL	H(mm)	F(mm)	L(mm)	A(mm)	D(mm)	a(mm)	T(mm)	No of holes
G200-75-1500UH3	200	75	40	16	90	-	2	3
G200-75-1500UH5	200	75	40	16	90	-	2	5
G200-75-1500EH3	200	75	40	16	90	16	2	3
G200-75-1500EH5	200	75	40	16	90	16	2	5

Table .3.1: Dimension of the G-section Columns

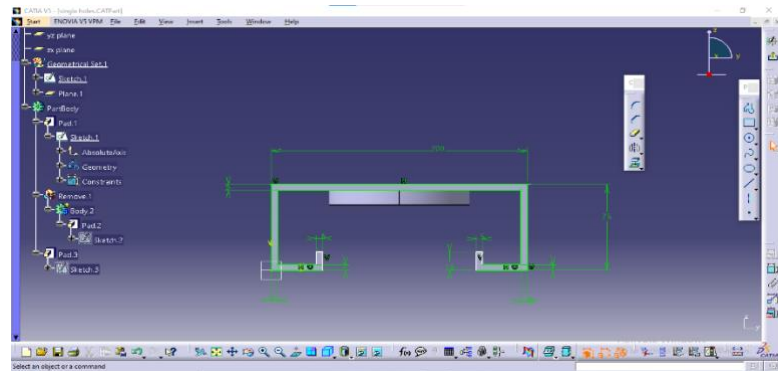


Figure.3.1: Stiffened G-section column with single opening-Top view

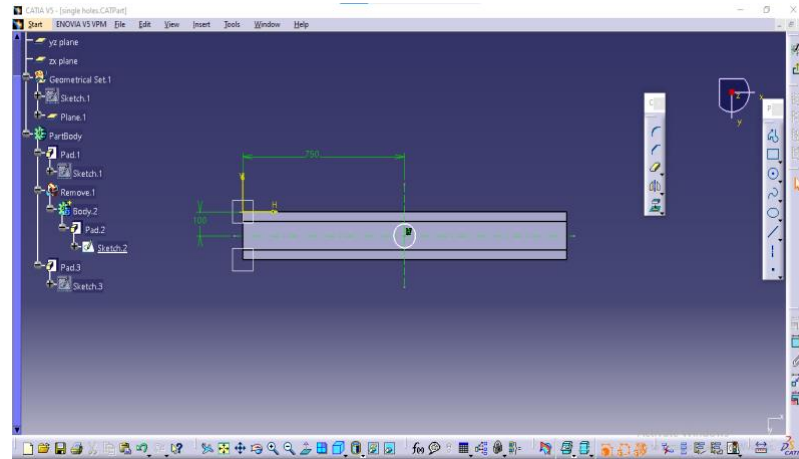


Figure.3.2: Stiffened G-section column with single opening-side view

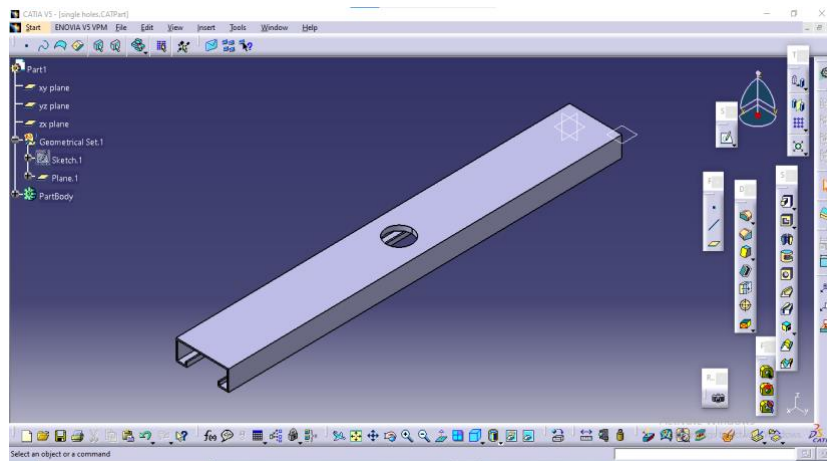


Figure.3.3: Stiffened G-section column with single opening-3D view

Geometry of specimen the G section column with edge stiffened three opening model is modelled in CATIA and imported to ANSYS, Design modeler. The Figure 3.4 to 3.5 shows the geometry of the stiffened three opening column modelled using CATIA software.

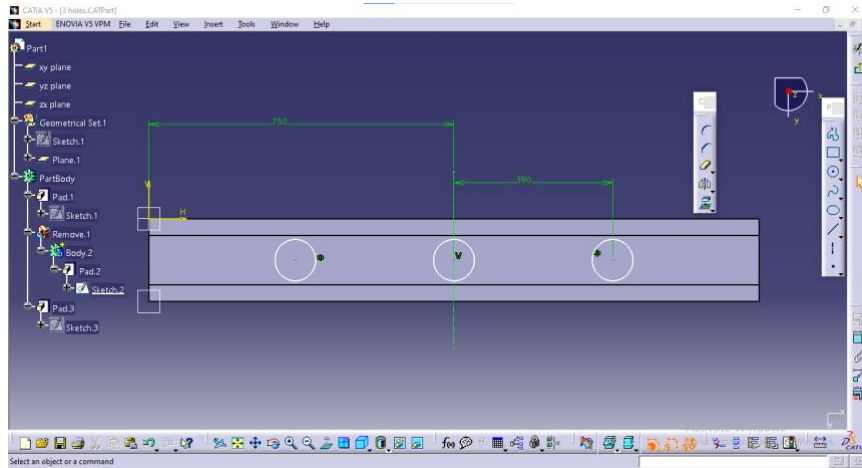


Figure.3.4: Stiffened G-section column with three openings-side view

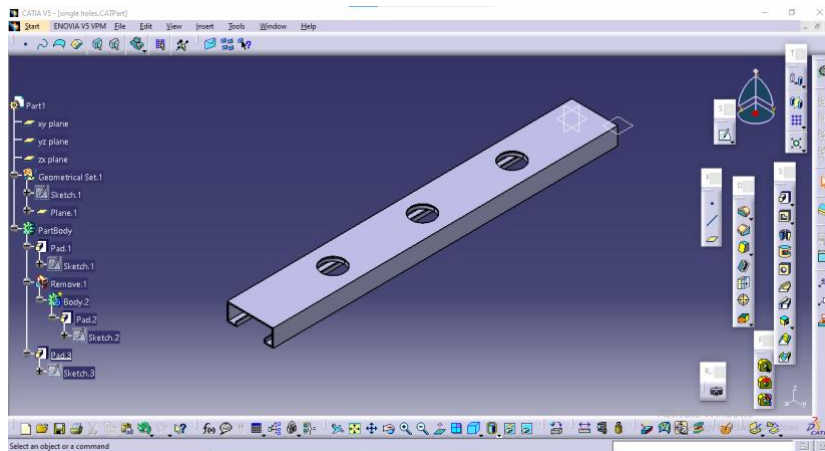


Figure.3.5: Stiffened G-section column with three opening-3D view

Geometry of specimen the G section column with edge stiffened five opening model is modelled in CATIA and imported to ANSYS, Design modeler. The Figure 3.6 and 3.7 shows the geometry of the stiffened five opening column modelled using CATIA software.

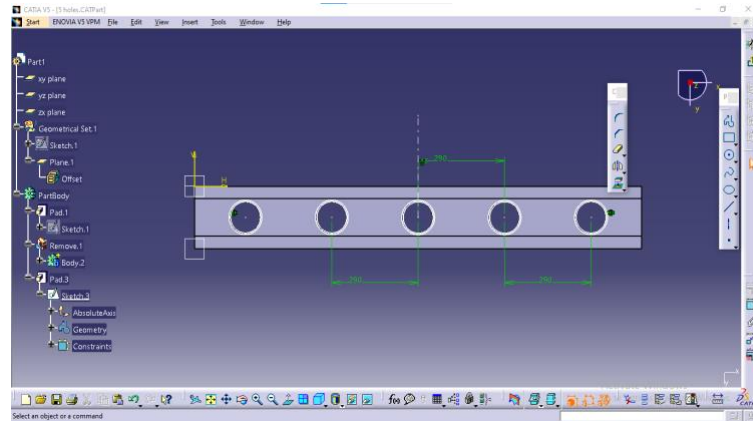


Figure.3.6: Stiffened G-section column with five openings-side view

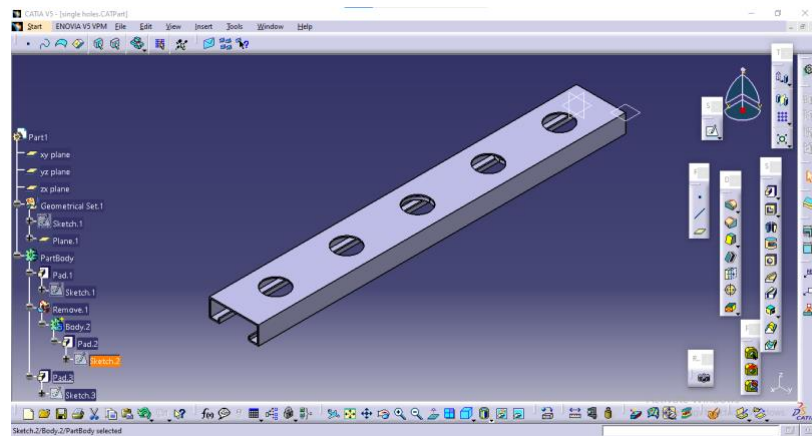


Figure.3.7: Stiffened G-section column with five opening-3D view

Geometry of specimen the G section column with edge stiffened seven opening model is modelled in CATIA and imported to ANSYS, Design modeler. The Figure 3.8 to 3.9 shows the geometry of the stiffened seven opening column modelled using CATIA software.

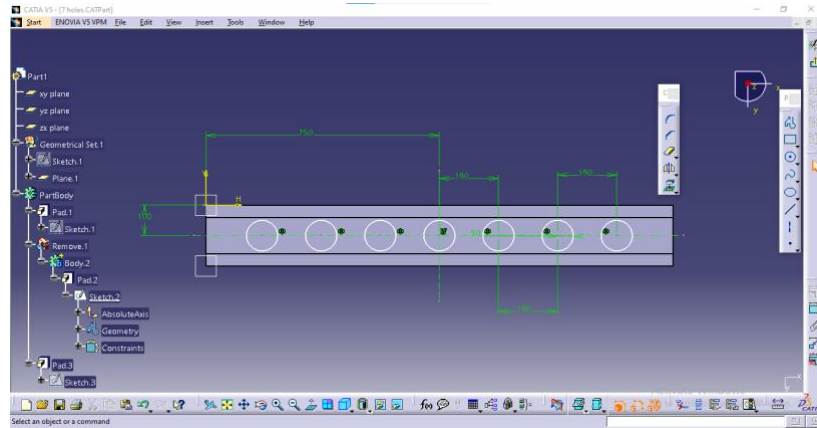


Figure.3.8: Stiffened with G-section column seven openings-side view

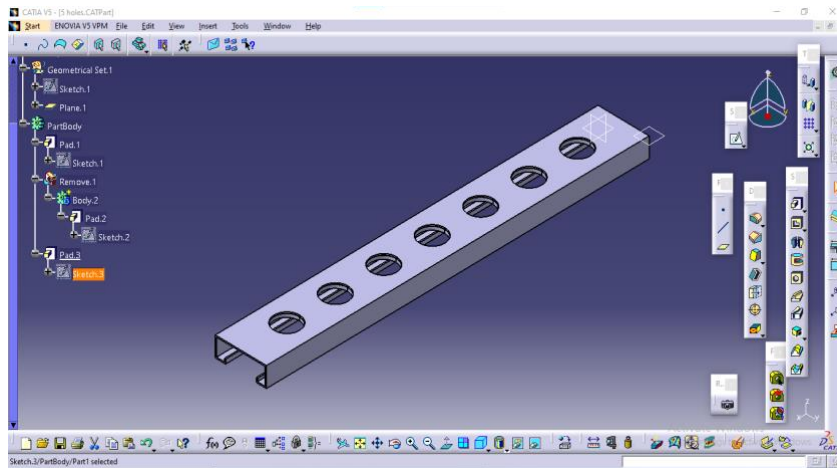


Figure.3.9: Stiffened with G-section column seven openings-3D view

3.4 ANALYSIS OF CFS COLUMN USING ANSYS SOFTWARE

For the analysis of column using ANSYS, the input parameters assigned are the mechanical properties of column section such as density, poisson's ratio, bulk modulus, young's modulus, shear modulus, tensile strength, compressive strength under the engineering data as per code IS 513:2008 are assigned. The table 3.1 shows the material property window for Grade IS 513.

Table .3.1: Properties of material

PROPERTY	VALUE	UNIT
Density	7850	Kg m ⁻³
Young's modulus	2E+05	MPa
Poisson's ratio	0.3	-
Bulk modulus	1.6667E+10	Pa
Shear modulus	7.6923E+10	Pa
Yield strength	240	MPa
Tangent modulus	1450	MPa
Tensile yield strength	240	MPa
Compressive yield strength	240	MPa
Tensile ultimate strength	370	MPa
Compressive ultimate strength	0	MPa

The end of the column is assigned as a fixed support condition at bottom and the axial compressive force of 1000N is applied from the top end. The Total deformation of the column is calculated by a substantial increase of loading of 20 N.

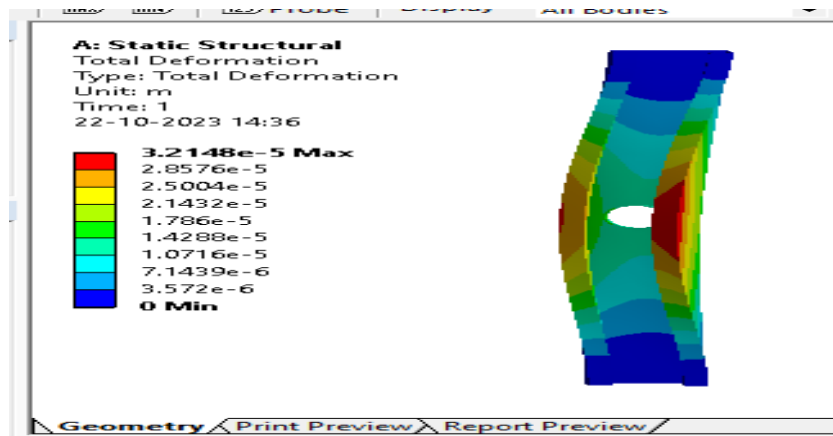


Figure. 3.10: Total Deformation of stiffened edge single opening column

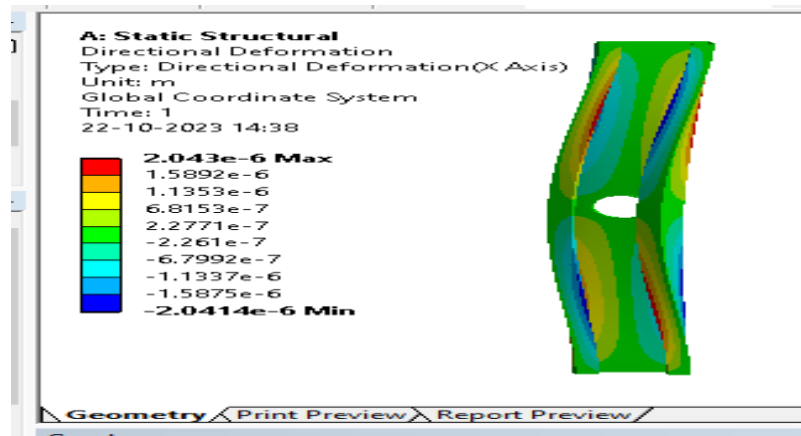


Figure.3.11: Directional Deformation of stiffened edge single opening column

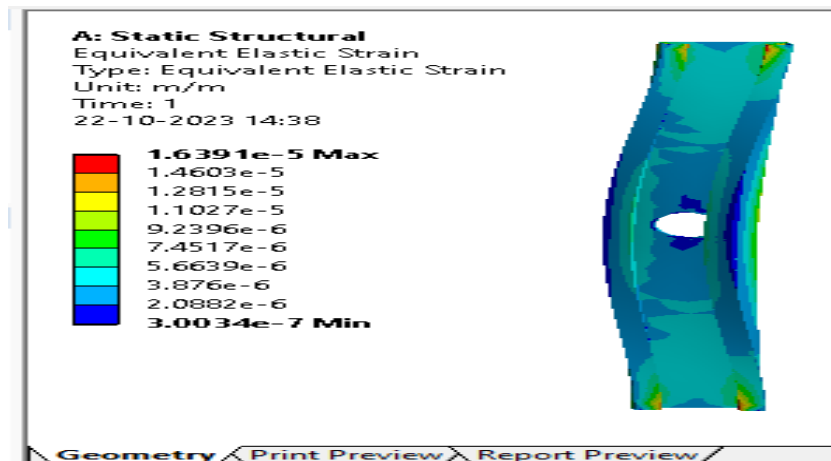


Figure.3.12: Equivalent Elastic Strain of stiffened edge single opening column

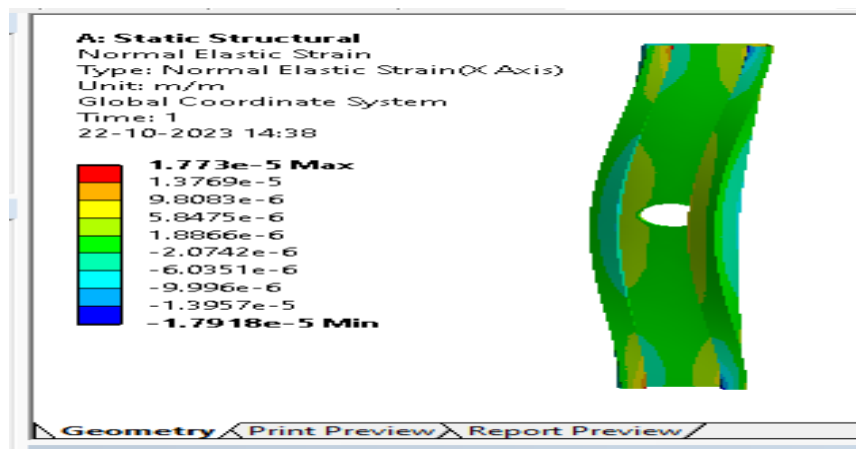


Figure.3.13: Normal Elastic Strain of stiffened edge single opening column

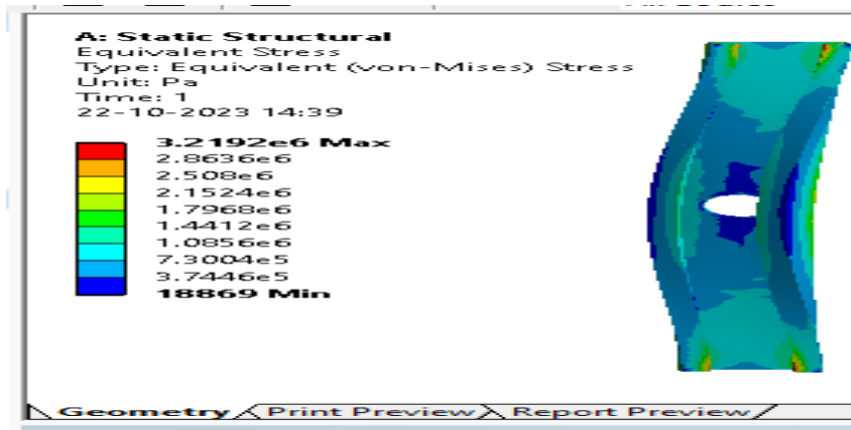


Figure.3.14: Equivalent Stress (Pa) of stiffened edge single opening column

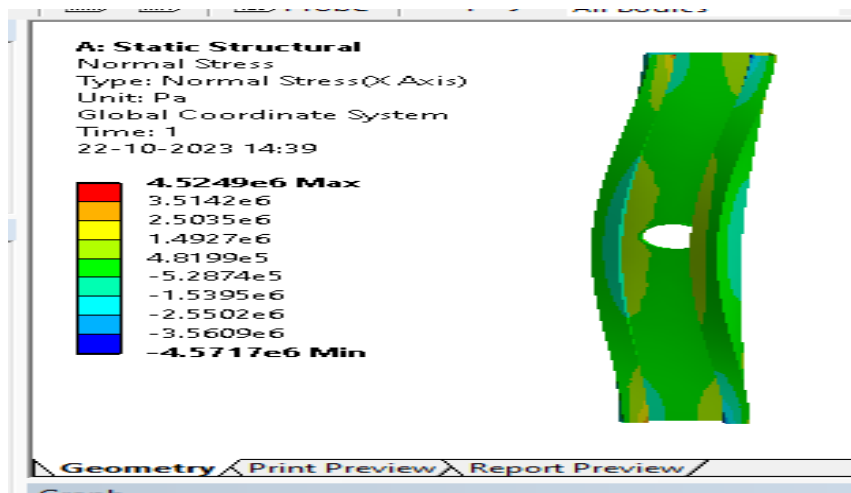


Figure.3.15: Normal Stress (Pa) of stiffened edge single opening column

The Total deformation, directional deformation, equivalent elastic strain, normal strain, equivalent stress and normal stress of G section edge stiffened column with single opening are shown in Figure from 3.10 to 3.15.

In this G-column edge stiffened web with single opening most of the stresses are concentrated in the mid of the section and gradually decreasing toward the ends, the maximum deformation of 3.21mm occurs at the mid of the column.

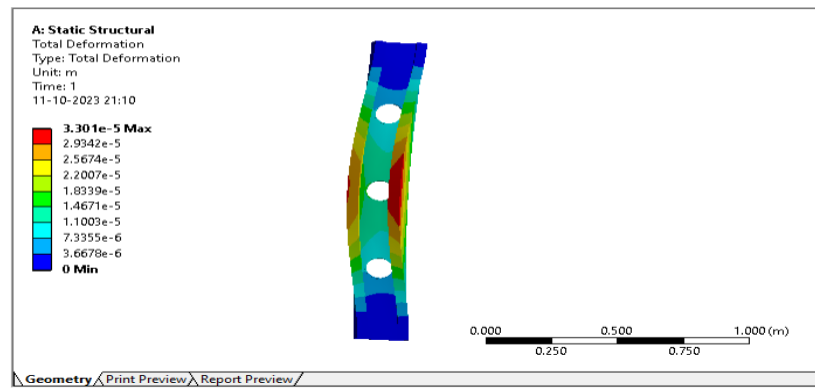


Figure.3.16: Total Deformation of stiffened edge three opening column

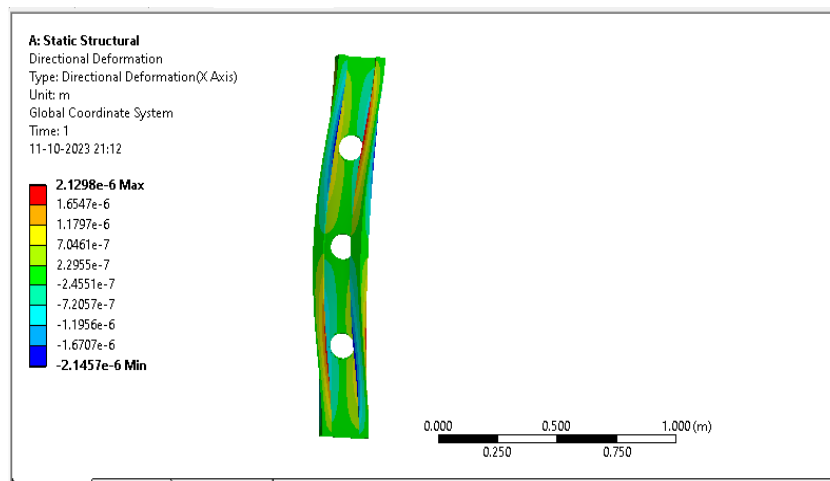


Figure.3.17: Directional Deformation of stiffened edge three opening column

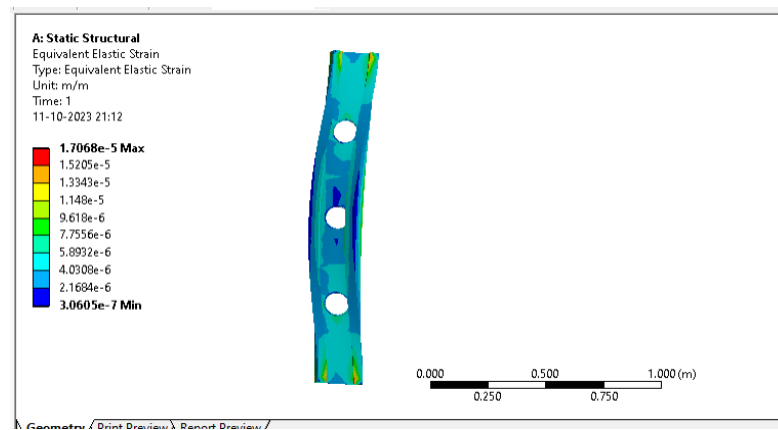


Figure.3.18: Equivalent Elastic Strain stiffened edge three opening column

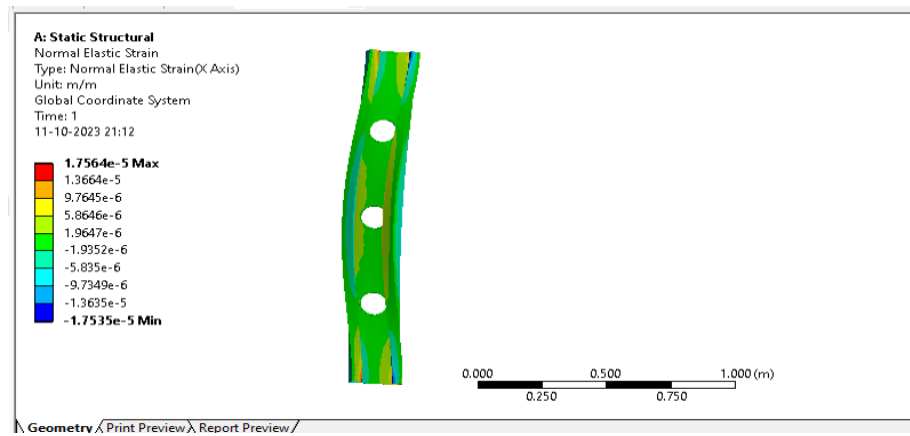


Figure.3.19: Normal elastic Strain stiffened edge three opening column

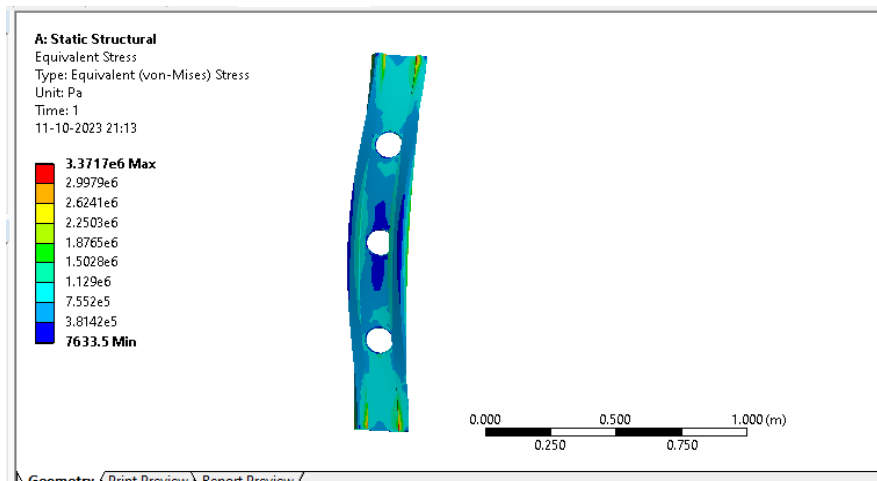


Figure.3.20: Equivalent Stress (Pa) stiffened edge three opening column

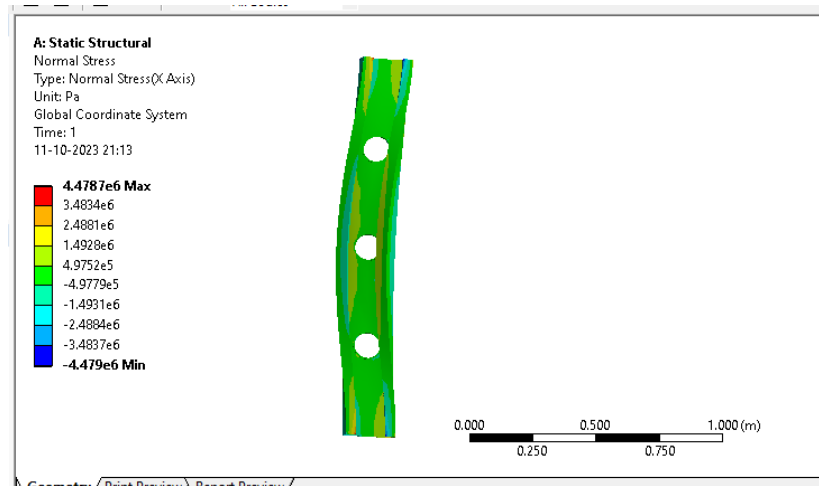


Figure.3.21: Normal Stress (Pa) stiffened edge three opening column

The Total deformation, directional deformation, equivalent elastic strain, normal strain, equivalent stress and normal stress of G section edge stiffened column with three opening are shown in Figure from 3.16 to 3.22.

In this G-column edge stiffened web with three opening most of the stresses are concentrated in the mid of the section and gradually decreasing toward the ends, the maximum deformation of 3.3mm occurs on the mid of the column

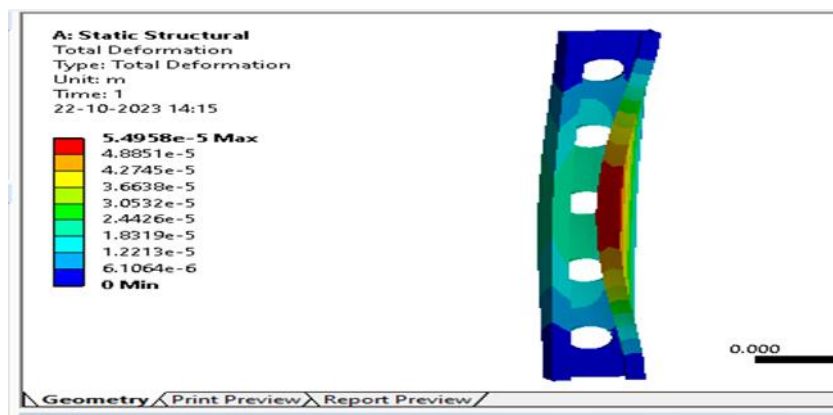


Figure.3.22: Total Deformation Edge Stiffened with 5 Opening column

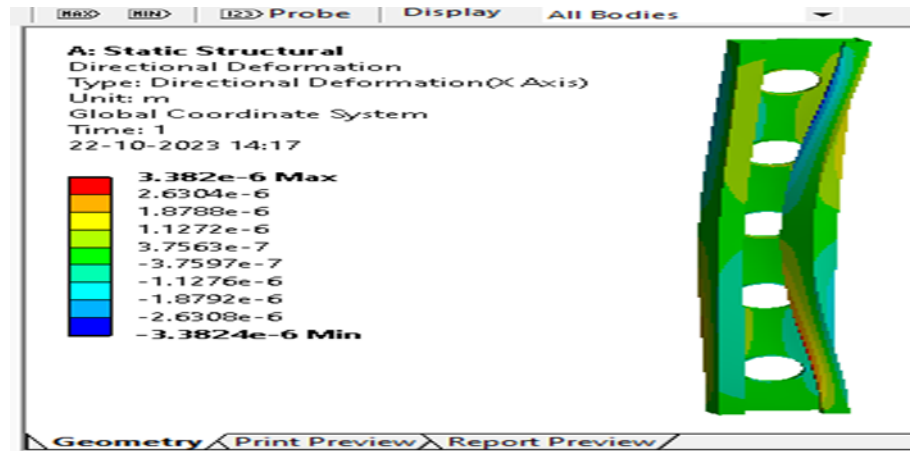


Figure.3.23: Directional Deformation Edge Stiffened with 5 Opening column

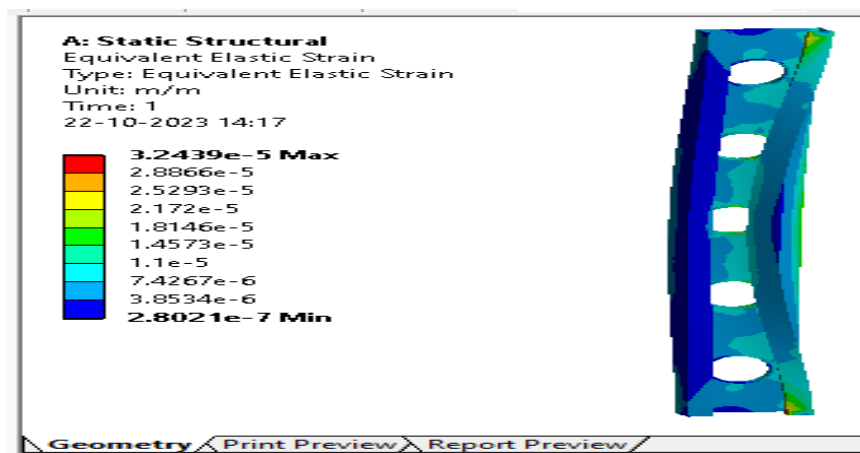


Figure.3.24: Equivalent Elastic Strain Edge Stiffened with 5 Opening column

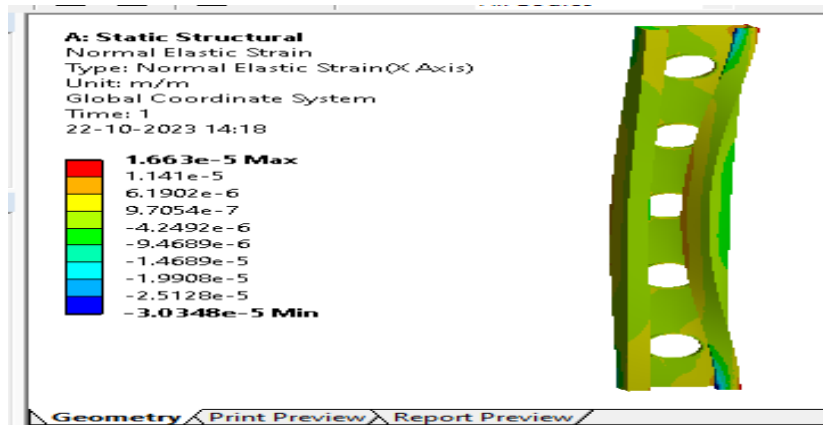


Figure.3.25: Normal Elastic Strain Edge Stiffened with 5 Opening column

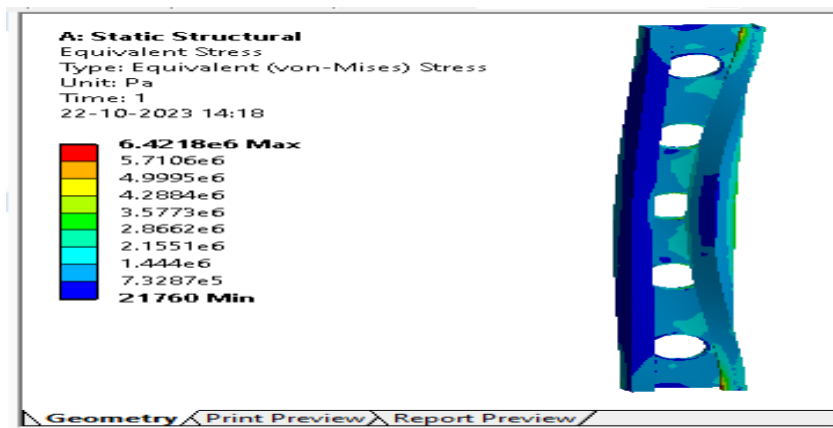


Figure.3.26: Equivalent Stress(Pa) Edge Stiffened with 5 Opening column

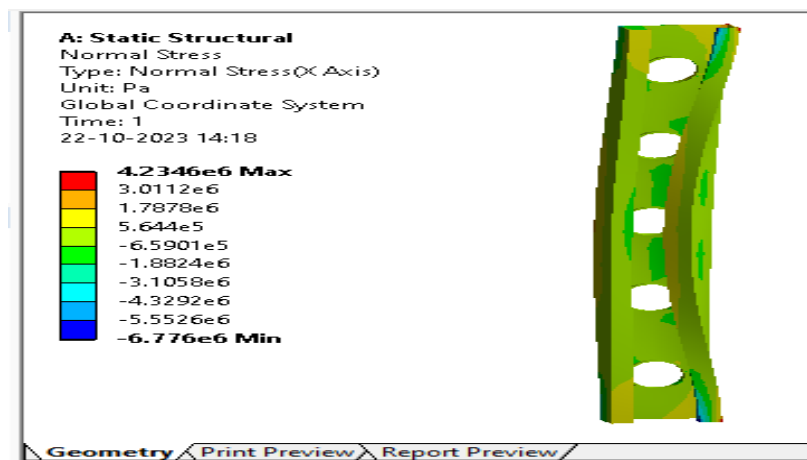


Figure.3.27: Normal Stress(Pa) Edge Stiffened with 5 Opening column

The Total deformation, directional deformation, equivalent elastic strain, normal strain, equivalent stress and normal stress of G section edge stiffened column with five opening are shown in Figure from 3.22 to 3.27.

In this G-column edge stiffened web with five opening most of the stresses are concentrated in the mid of the section and gradually decreasing toward the ends, the maximum deformation of 4.5mm occurs on the mid of the column.

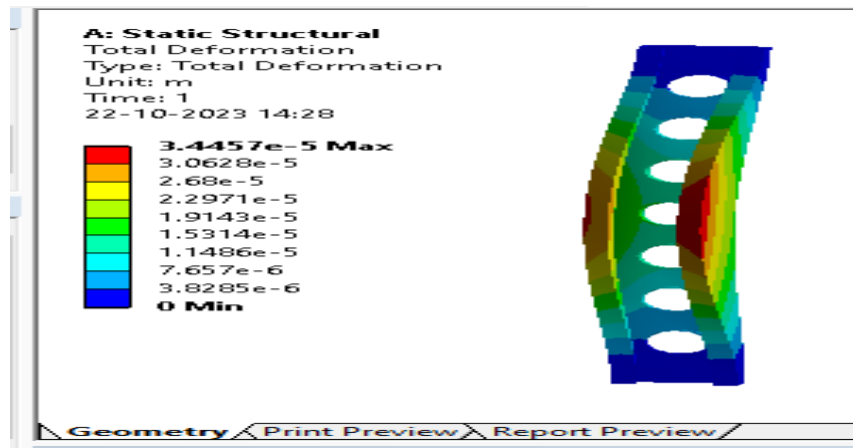


Figure.3.28: Total Deformation Edge Stiffened with 7 Opening column

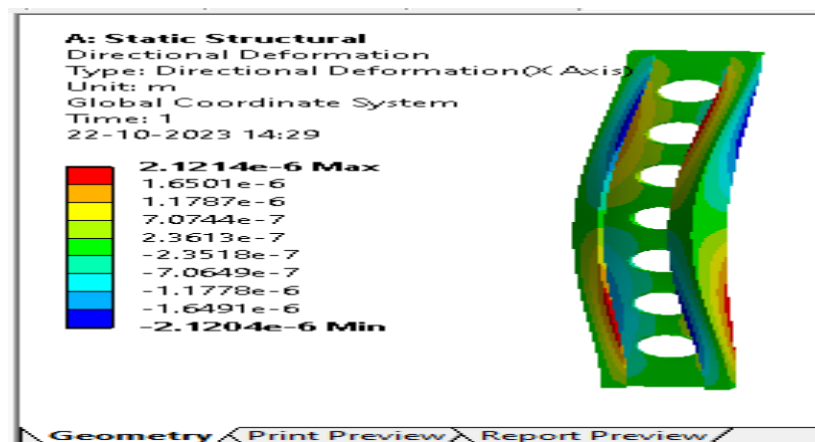


Figure.3.29: Directional Deformation Edge Stiffened with 7 Opening column

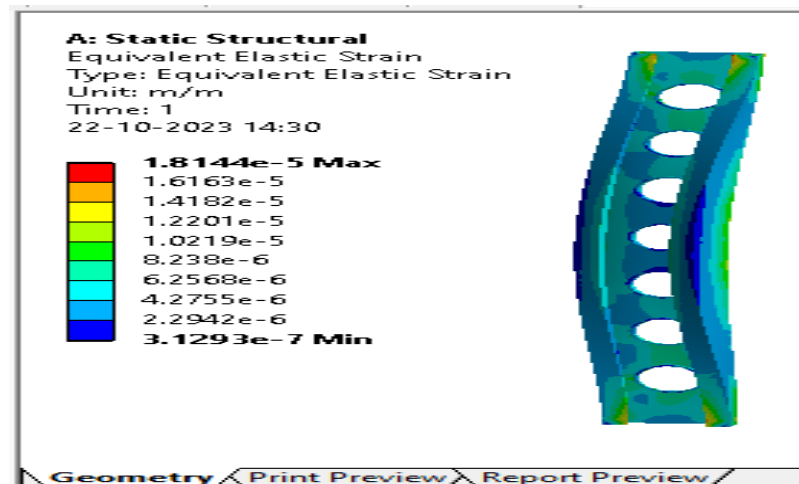


Figure.3.30: Equivalent Elastic Strain Edge Stiffened with 7 Opening column

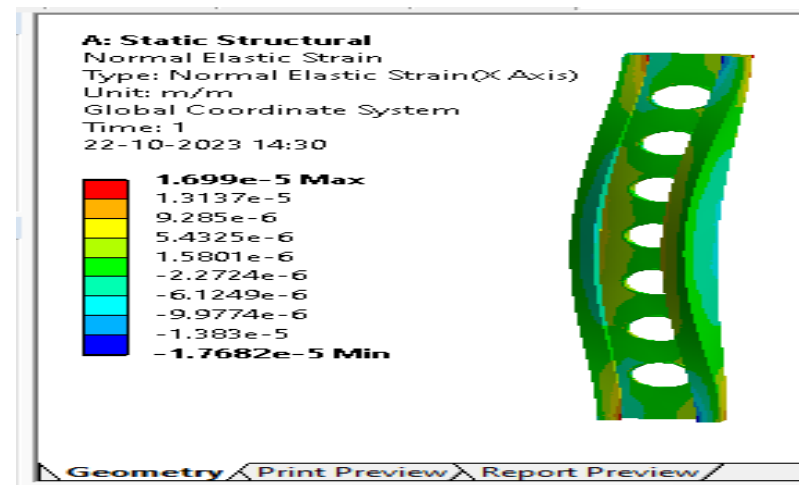


Figure.3.31: Normal Elastic Strain Edge Stiffened with 7 Opening column

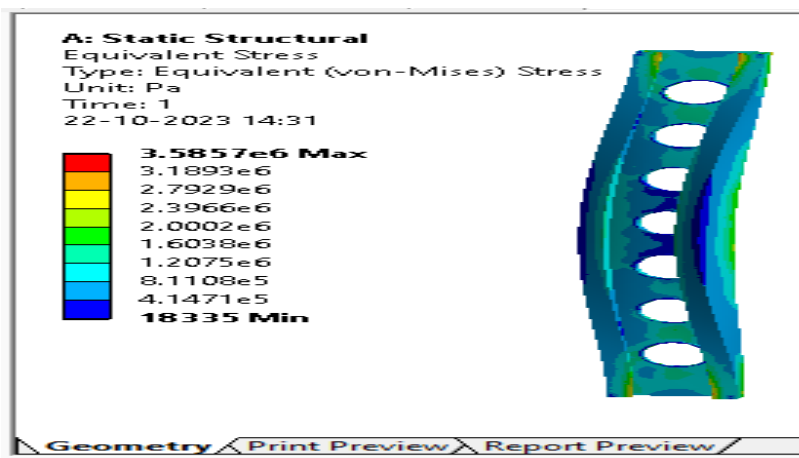


Figure.3.32: Equivalent Stress (Pa) Edge Stiffened with 7 Opening column

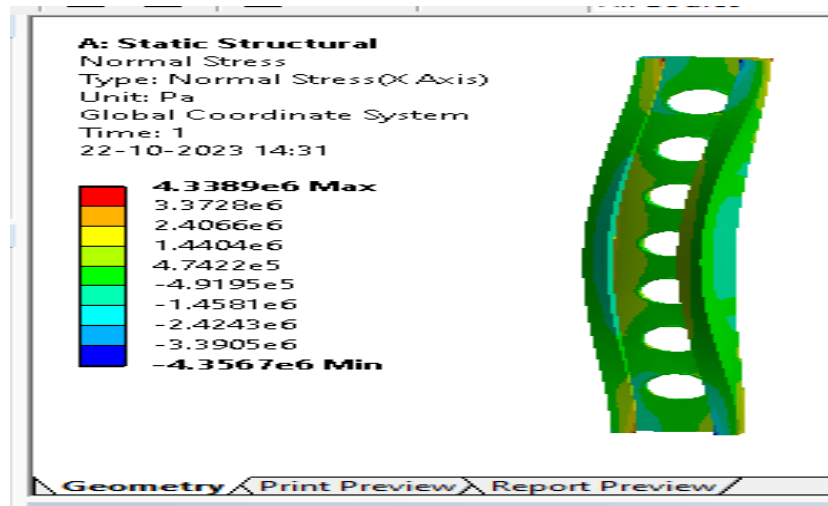


Figure.3.33: Normal Stress (Pa) Edge Stiffened with 7 Opening column

The Total deformation, directional deformation, equivalent elastic strain, normal strain, equivalent stress and normal stress of G section edge stiffened column with seven opening are shown in Figure from 3.28 to 3.33.

In this G-column edge stiffened web with seven opening most of stresses are concentrated in the mid of the section and gradually decreasing toward the ends, the maximum deformation of 3.24mm occurs on the middle of the column.

3.5 COMPARISON OF ANALYTICAL RESULTS OF CFS G-SECTION COLUMN

The structural performance of G section-edge stiffened column is studied, results between edge stiffened single opening column, edge stiffened three opening columns, edge stiffened five opening column and edge stiffened seven opening columns under axial compression is compared. The Figure 3.36 to 3.41 shows the graphical representation of the results obtained in ANSYS.

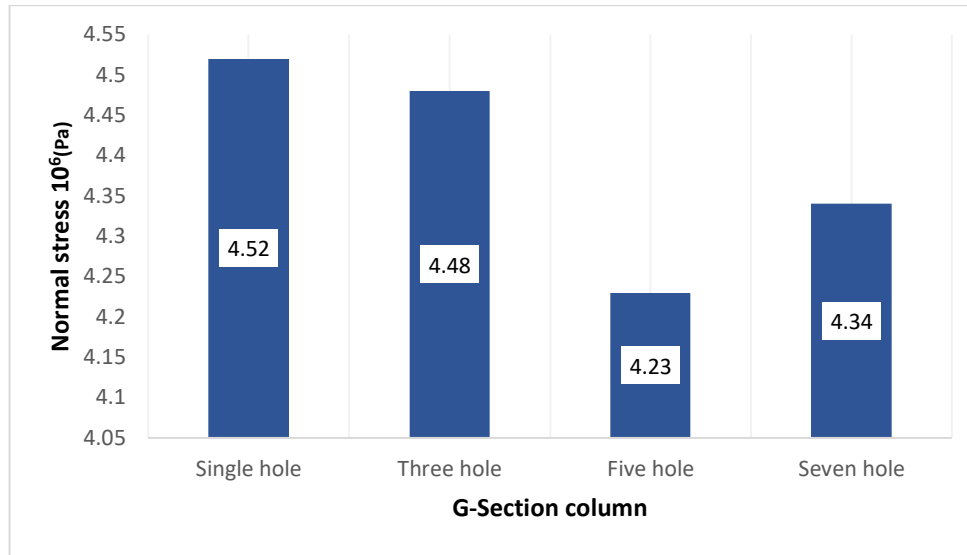


Figure.3.34 Normal Stress of G – section edge stiffened columns

From Figure 3.34, the variation of normal stress for G-section edge stiffened column with single opening is observed to be higher than G-section column stiffened with three, five and seven openings.

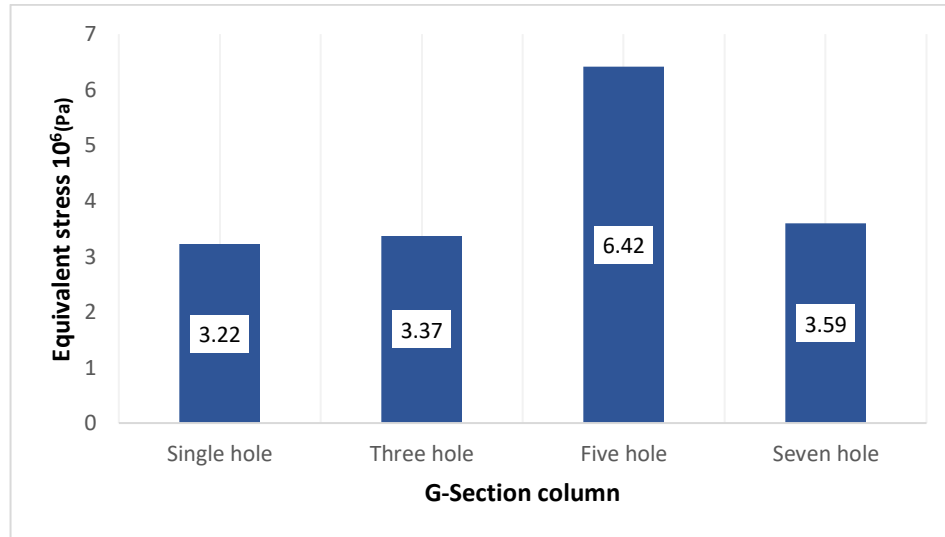


Figure.3.35 Equivalent Stress of G-section edge stiffened columns

From Figure 3.35, the variation of equivalent stress for G-section edge stiffened column with five opening is observed to be higher than G-section column stiffened with one, three and seven openings.

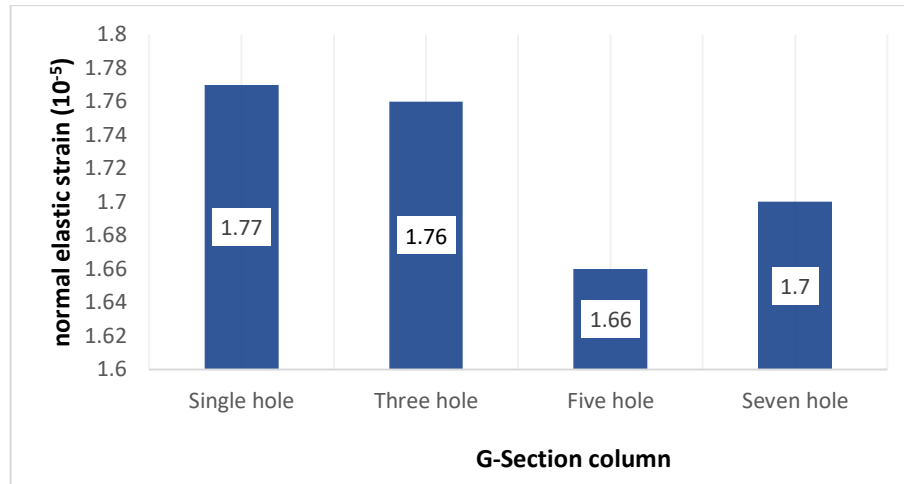


Figure.3.36 Normal Elastic Strain G-section edge stiffened columns

From Figure 3.36, the variation of normal elastic strain for G-section edge stiffened column with single opening is observed to be higher than G-section column stiffened with three, five and seven openings.

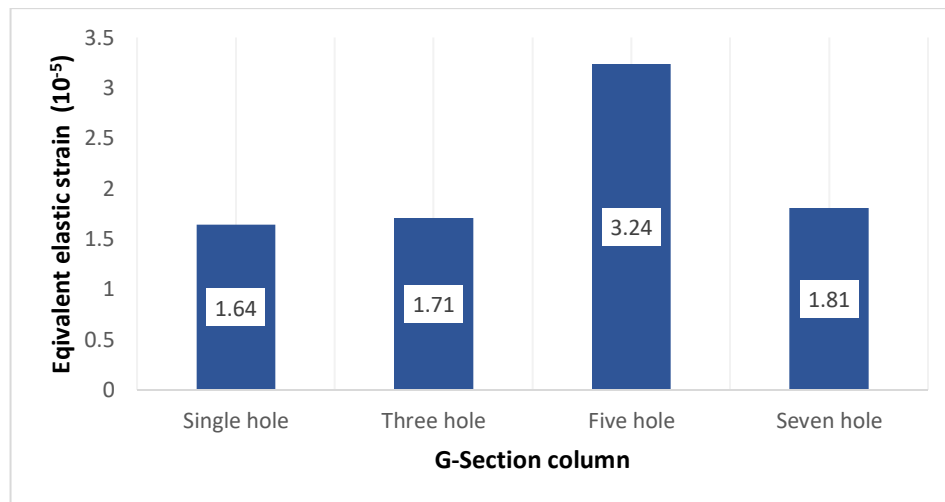


Figure.3.37 Equivalent Elastic Strain G-section edge stiffened columns

From Figure 3.37, the variation of equivalent elastic strain for G-section edge stiffened column with five opening is observed to be higher than G-section column stiffened with one, three, and seven openings.

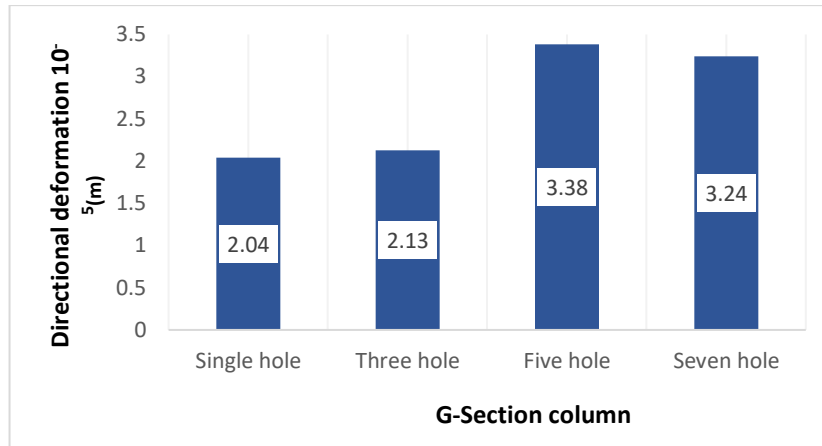


Figure.3.38 Directional Deformation G-section edge stiffened columns

From Figure 3.38, the variation of directional deformation for G-section edge stiffened column with single opening is observed to be minimal than G-section column stiffened with three, five and seven openings.

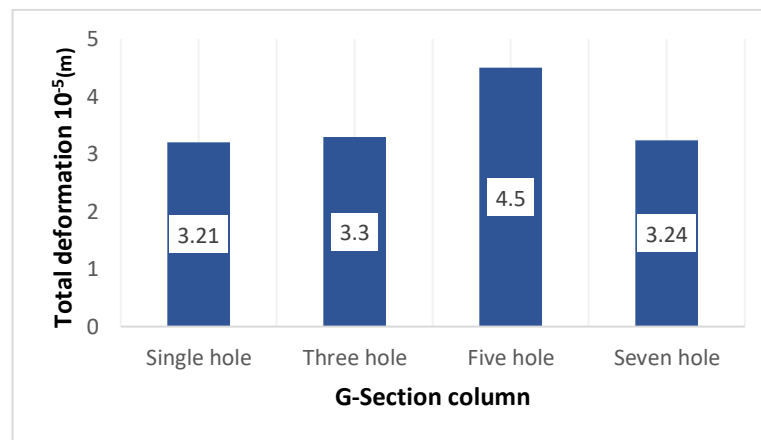


Figure.3.39 Total Deformation G-section edge stiffened columns

From Figure 3.39, the variation of total deformation for G-section edge stiffened column with single opening is observed to be minimal than G-section column stiffened with three, five and seven openings.

CHAPTER 4

EXPERIMENTAL INVESTIGATION

4.1 GENERAL

The unstiffened and stiffened G-section column with opening designed are analysed using experimental investigation and test results are discussed in this chapter.

4.2 FABRICATION OF COLD FORMED STEEL G-SECTION COLUMN.



Figure.4.1: Cold rolled sheet

Size of the sheets available in market is 1524mm x 2438mm. Material required for single model was 465mm x 1500mm (CR Sheet). The sheet is cut into specific sizes using hydraulic cutting machines.



Figure.4.2: laser cutting process

Web openings for three opening stiffened and unstiffened model, Web opening for five opening stiffened and unstiffened model are cut using laser cutting machines.



Figure.4.3: Pressing sheets into G-sections

Then the sheets are pressed into G-sections columns according to given dimensions in hydraulic pressing machine.



Figure.4.4: Fabricated unstiffened G-section column with three openings

Geometry of specimen the G section column with unstiffened three opening model is fabricated. The Figure 4.4 shows the geometry of the unstiffened three opening G-section column.



Figure.4.5: Fabricated stiffened G-section column with three openings

Geometry of specimen the G section column with edge stiffened three opening model is fabricated. The Figure 4.5 shows the geometry of the edge stiffened three opening G-section column.



Figure.4.6: Fabricated unstiffened G-section column with five openings

Geometry of specimen the G section column with unstiffened five opening model is fabricated. The Figure 4.6 shows the geometry of the unstiffened five opening G-section column.

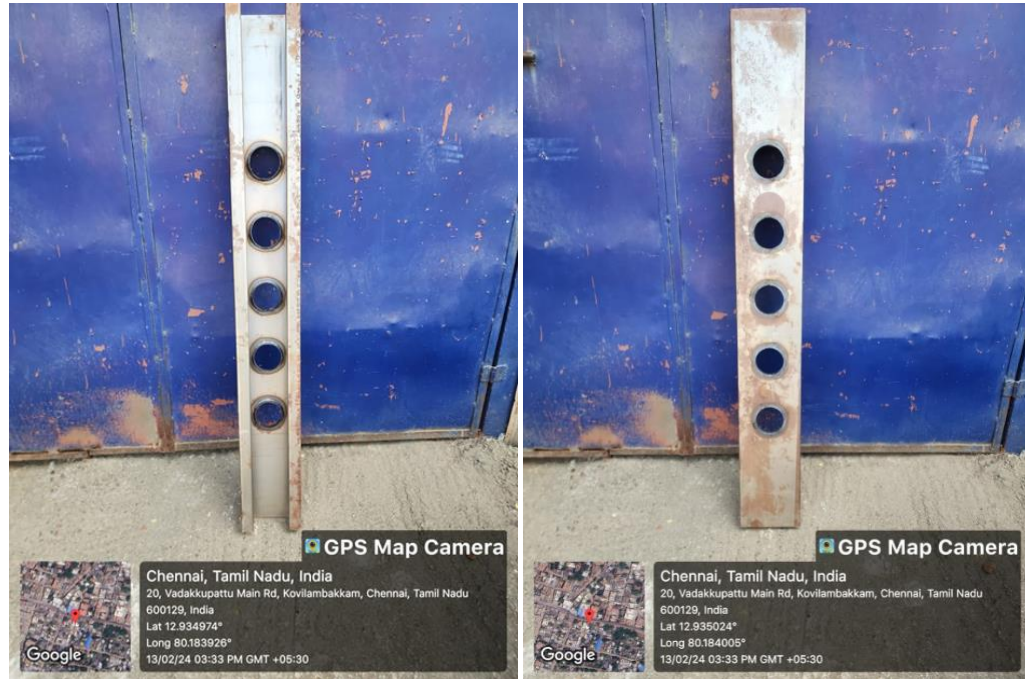


Figure.4.7: Fabricated stiffened G-section column with five openings

Geometry of specimen the G section column with edge stiffened five opening model is fabricated. The Figure 4.7 shows the geometry of the edge stiffened five opening G-section column.

4.3 TESTING OF FABRICATED G-SECTION COLUMN

The testing is carried out in a loading frame of 100ton capacity. The fabricated G-section column with edge stiffened web openings and unstiffened web openings are tested under axial compression loading. The applied load and deflections are measured using Load cell and LVDT setup. The load is applied in a non-linear pattern until failure.



Figure .4.8: Experimental setup

4.3 RESULT AND DISCUSSION:

In Figure 4.9, Unstiffened G-section column with three opening is tested in a loading frame under axial compression. Figure 4.10, depicts the load deflection curve of the Unstiffened G-section column with three opening. It has reached the ultimate load of 12.69 tons with deflection of 2.1mm.



Figure. 4.9: Unstiffened G-section column with three opening

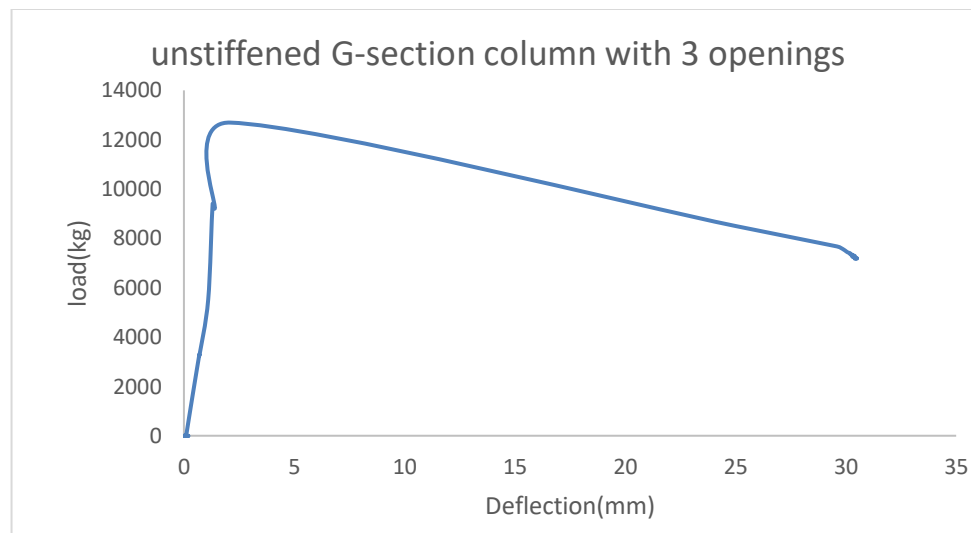


Figure.4.10: Load deflection curve of the Unstiffened G-section column with three opening

In a Figure 4.11 stiffened G-section column with three opening is tested in a loading frame under axial compression. The Figure 4.12 depicts the load deflection curve of

the stiffened G-section column with three opening. It has reached the ultimate load of 15.10 tons with deflection of 2.1mm.



Figure. 4.11: Stiffened G-section column with three opening

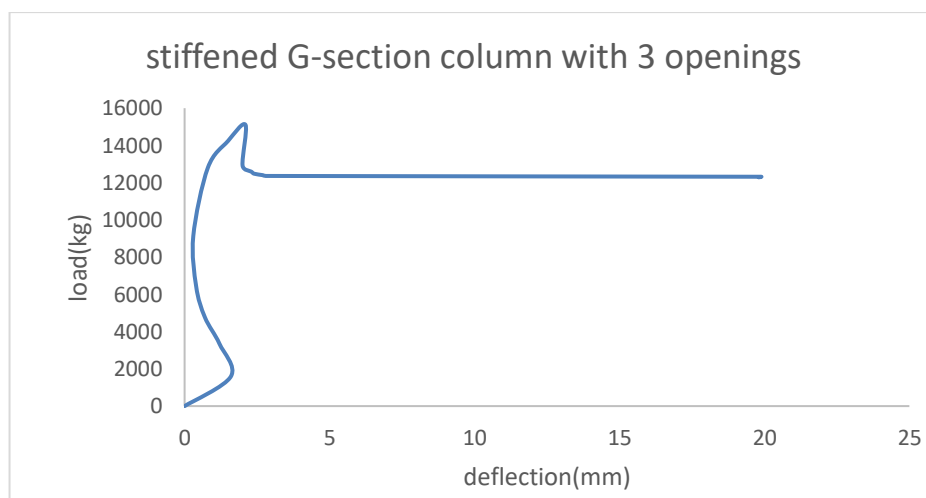


Figure.4.12: The load deflection curve of the stiffened G-section column with three opening

In Figure 4.13, unstiffened G-section column with five opening is tested in a loading frame under axial compression. Figure 4.14, depicts the load deflection curve of the unstiffened G-section column with five opening. It has reached the ultimate load of 12.64 tons with deflection of 6.1mm.



Figure.4.13: Unstiffened G-section column with five opening

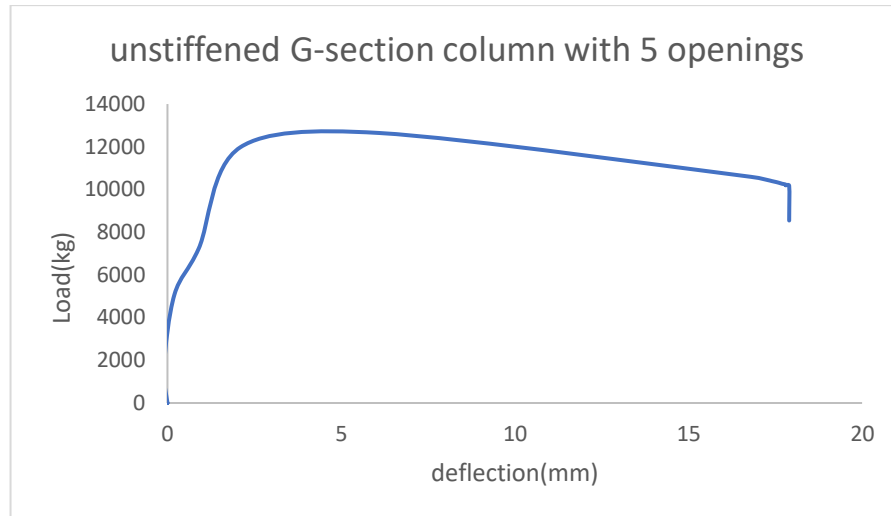


Figure.4.14: The load deflection curve of the unstiffened G-section column with five opening

In a Figure 4.15 stiffened G-section column with five opening is tested in a loading frame under axial compression. The Figure 4.16 depicts the load deflection curve of the stiffened G-section column with five opening. It has reached the ultimate load of 14.64 tons with deflection of 3.6 mm.



Figure.4.15 Stiffened G-section column with five opening

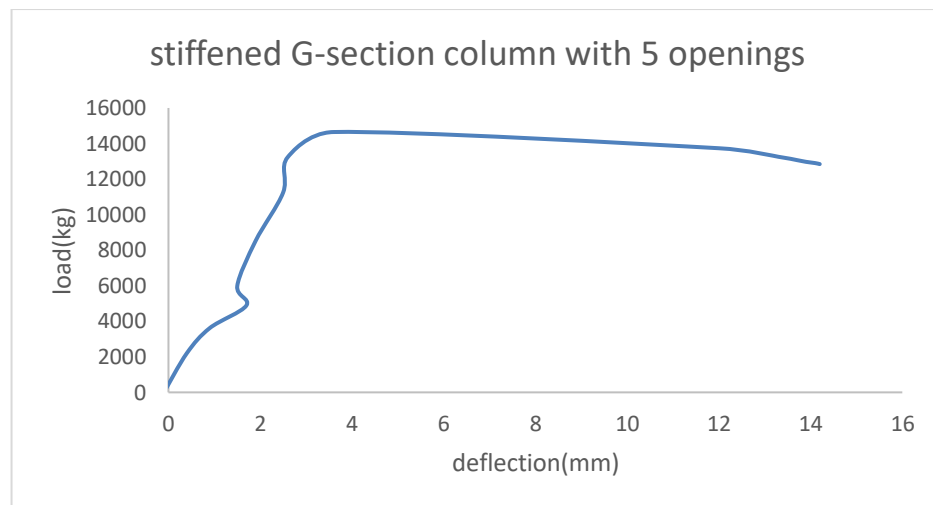


Figure.4.16: The load deflection curve of the stiffened G-section column with five opening

The Figure 4.17 depicts the comparison between experimental and analytical result of G-section column with web stiffened three opening. In this the result of experimental and analytical follows the similar path with almost same ultimate strength and deflection.

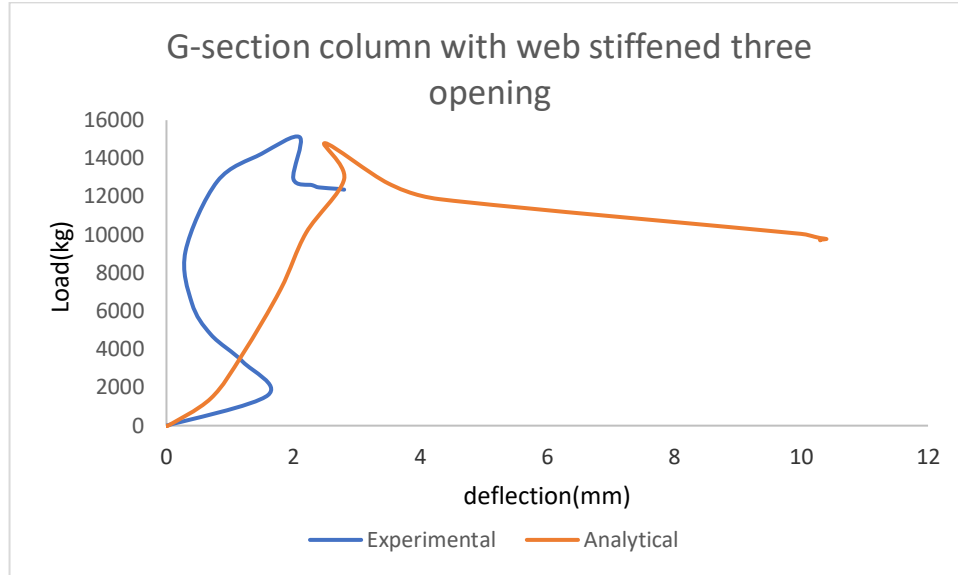


Figure.4.17: Comparison of Experimental and Analytical values of G-section column with web stiffened three opening

The Figure 4.18 depicts the comparison between experimental and analytical result of G-section column with web stiffened five opening. The result of experimental and analytical follows the similar path with almost same ultimate strength and deflection.

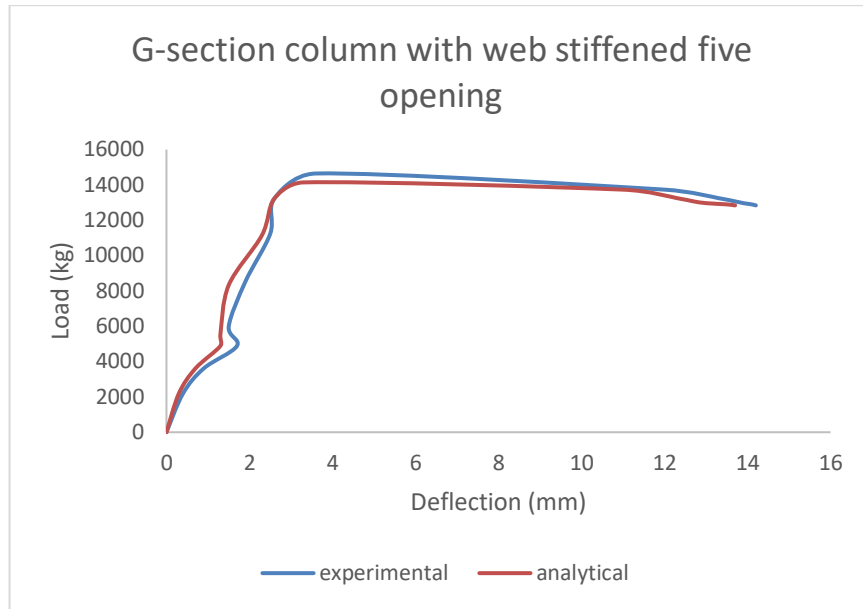


Figure.4.18: Comparison of Experimental and Analytical result of G-section column with web stiffened five opening

The Figure 4.19 depicts the comparison between unstiffened and stiffened web opening result of G-section column with three opening. On comparison the G-section column with stiffened opening has higher ultimate strength and lower deflection compared to unstiffened web opening G-section columns.

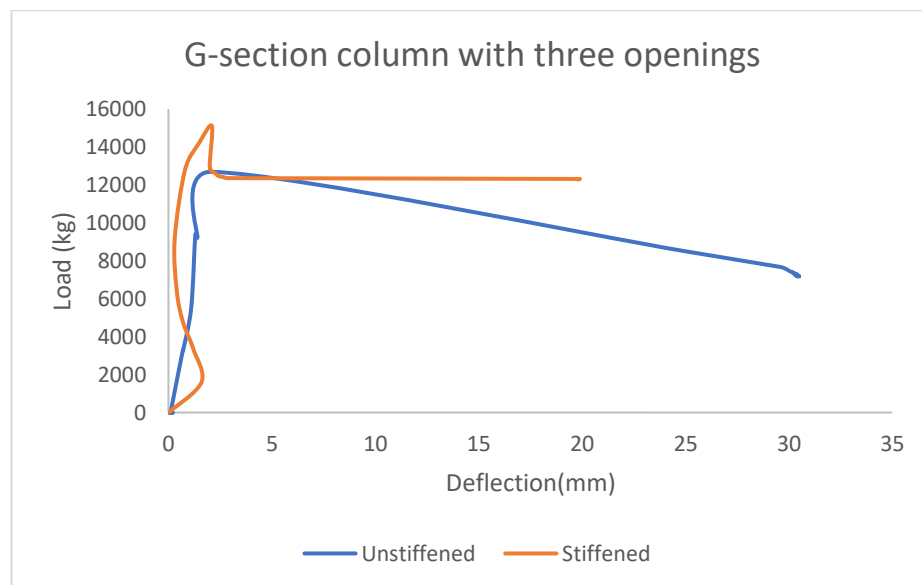


Figure.4.19: Comparison of unstiffened and stiffened web opening result of G-section column with three opening

The Figure 4.20 depicts the comparison between unstiffened and stiffened web opening result of G-section column with five opening. On comparison the G-section column with stiffened opening has higher ultimate strength and lower deflection compared to unstiffened web opening G-section columns.

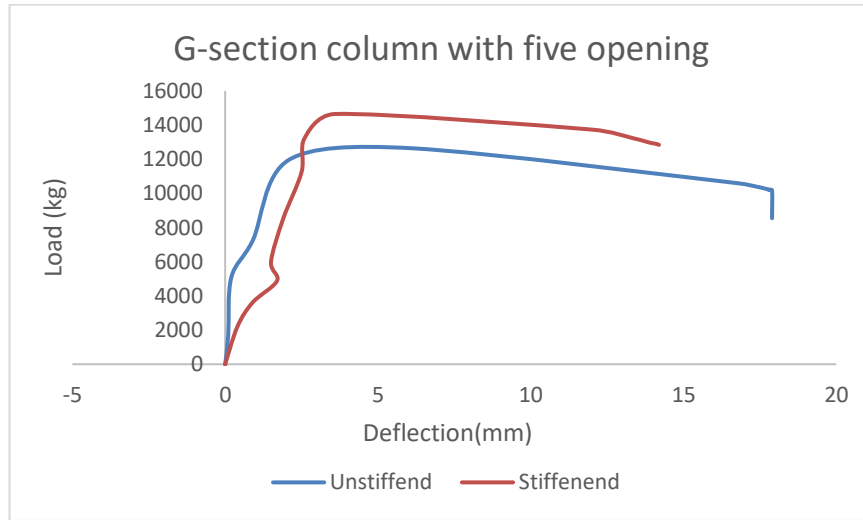


Figure.4.20: Comparison of unstiffened and stiffened web opening result of G-section column with five opening

The Figure 4.21 depicts the comparison of load-deflection behavior of G-section columns both stiffened and unstiffened with three and five web openings. The G-section column with web stiffened three opening has higher ultimate strength and lower deflection compared other G-section columns.

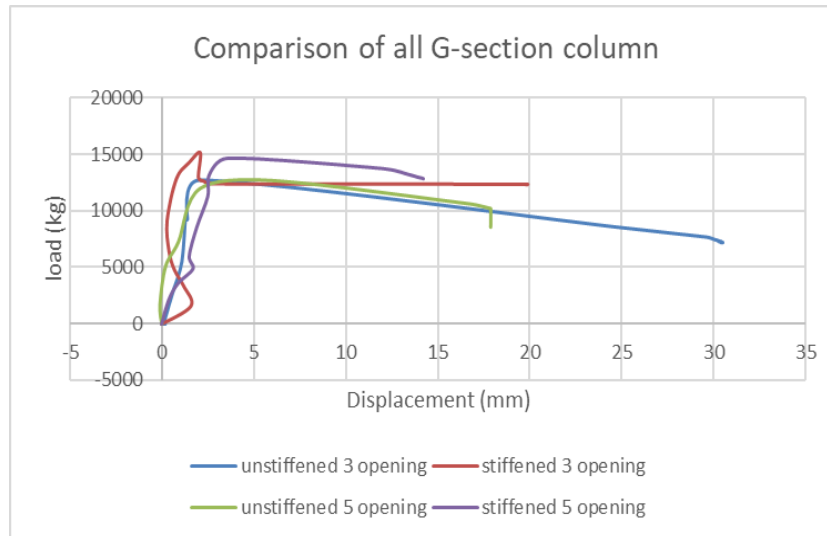


Figure.4.21: Experimental results of G-section columns tested

The Figure 4.22 depicts the comparison of load-deflection behavior of G-section columns with stiffened web opening. The G-section column with web stiffened three opening (experimental) has higher ultimate strength and lower deflection compared other G-section columns. The G-section column with five edge stiffened web opening as low deflection compared to three opening G-section column.

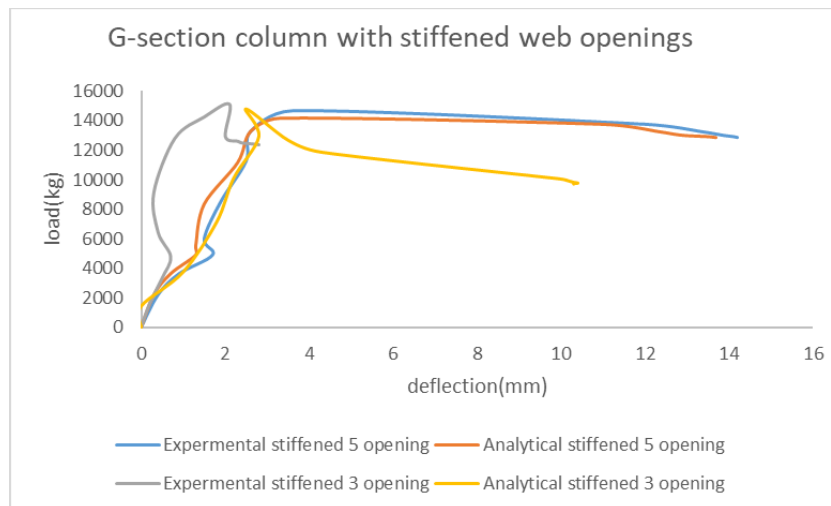


Figure.4.22: Comparison between result of G-section columns with stiffened web opening.

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 SUMMARY OF THE WORK

The popularity of Cold-Formed Steel (CFS) sections in construction is growing due to their advantageous characteristics. It highlights the benefits of CFS sections, such as lightweight structures and high strength-to-weight ratios, and addresses the problem of buckling in columns. The study focuses on strengthening CFS G-section columns with edge-stiffened holes, both through ANSYS software analysis and experimental testing. The results indicate that edge-stiffened holes improve column stiffness and compression resistance, particularly in CFS channel sections. However, G-section columns with edge-stiffened three holes exhibit higher stiffness and may be suitable as support members in a structure. Overall, the study suggests promising methods for enhancing the performance of CFS elements in construction.

5.2 CONCLUSION

The conclusions of the study are as follows:

- The nature of the G section column is better than the conventional channel with lipped in buckling properties.
- The column with edge stiffened opening improves the stiffness of the column.
- The test results showed that for the case of CFS channel sections having edge-stiffened web openings, the compression resistance was higher than the plain channel sections.
- The G section column with edge stiffened single opening has high compression resistance can be used as a support member in buildings
- The G section column with edge stiffened three opening has high stiffness can be used has a support member in buildings.

5.3 FUTURE SCOPES

- The G-section column can be tested under eccentric compression.

- The G-section column can be tested for seismic performance with seismic prequalification tests.

REFERENCES

1. Alenezi, Tahir M.M., Alhajri T., Badr M.R.K, Mirza J (2015), "Behavior of shear connectors in composite column of cold-formed steel with lipped C-channel assembled with ferro-cement jacket", *Construction and Building Materials*, Vol 84, pp:39–45
2. Alexandre Landesmann, Dinar Camotim, Rafaela Garcia (2016), "On the strength and DSM design of cold-formed steel web/flange-stiffened lipped channel columns buckling and failing in distortional modes", *Thin-Walled Structures*, Vol 105, pp:248–265
3. Boshan Chena, Krishanu Roya, Asraf Uzzamanb, Gary M. Rafterya, David Nashb, G. Charles Cliftona, Pouya Pouladia, James B.P. Lim (2019), "Effects of edge-stiffened web openings on the behaviour of cold-formed steel channel sections under compression", *Thin-Walled Structures*, Vol 144, pp:1-17
4. Daniel C.T. Cardoso, Guilherme C. de Salles, Eduardo de M. Batista, Paulo B. Gonçalves (2017), "Explicit equations for distortional buckling of cold-formed steel lipped channel columns", *Thin-Walled Structures*, Vol 119, pp: 925–933
5. Dobri, Jovana Ivanovi, Barbara Rossi (2020), "Behaviour of stainless steel plain channel section columns", *Thin-Walled Structures* Vol 148, pp:1-18
6. Fangfang Liao, Hanheng Wu, Ruizhi Wang, Tianhua Zhou (2017), "Compression test and analysis of multi-limbs built-up cold-formed steel stub columns", *Journal of Constructional Steel Research*, Vol 128, pp:1-20
7. Guanbo Bian, Kara D. Peterman, Shahabeddin Torabian, Benjamin W. Schafer (2016), "Torsion of cold-formed steel lipped channels dominated by warping Response", *Thin-Walled Structures*, Vol 98, pp:565–577
8. Gunalan S, Mahendran M (2015), "Web crippling tests of cold-formed steel channels under two flange load cases", *Constructional Steel Research*, Vol 110, pp: 1–15
9. Jia-Hui Zhang, Ben Young, (2018) "Experimental investigation of cold-formed steel built-up closed section columns with web stiffeners", *Journal of Constructional Steel Research*, Vol 147, pp:380–392

10. Juarez Moara Santos Franco, Jose Pinto Duarte, Eduardo de Miranda Batista a, Alexandre Landesmann (2014), "Shape Grammar of steel cold-formed sections based on manufacturing rules", *Thin-Walled Structures*, Vol 79, pp:218–232
11. Krishanu Roy, Tina Chui Huon Ting, Hieng Ho Lau, James B.P (2018), "Lim- Nonlinear behaviour of back-to-back gapped built-up cold-formed steel channel sections under compression", *Journal of Constructional Steel Research*, Vol 147, pp:257–276
12. Landesmann A, D. Camotim (2015), "DSM to predict distortional failures in cold-formed steel columns exposed to fire: Effect of the constitutive law temperature-dependence", *Computers and Structures*, Vol 147, pp:47–67
13. Sadovskýa Z, Kriváček J (2018), "Influence of boundary conditions and load eccentricity on strength of coldformed lipped channel columns", *Thin-Walled Structures*, Vol 131, pp:556–565
14. Sani M. S. H. M., Muftah F., Osman A. R (2019), *Materials Today: "A Review and Development of Cold-formed Steel Channel Columns with Oriented Strand Board", Sections Proceedings*, Vol 17, pp:1078–1085
15. Shanshan Cheng, Long-yuan Li, Boksun Kim (2015), "Buckling analysis of partially protected cold-formed steel channel-section columns at elevated temperatures", *Fire Safety Journal*, Vol 72, pp:7–15
16. Shaofeng Niea, Tianhua Zhoua, Matthew R. Eathertonb, Jiang Lib, Yang Zhang (2020), "Compressive behavior of built-up double-box columns consisting of four cold-formed steel channels", *Engineering Structures*, Vol 222. pp:1-17
17. Vijayanand S and Anbarasu M (2017), "Effect of Spacers on Ultimate Strength and Behavior of Cold-Formed Steel Built-up Columns", *Procedia Engineering*, Vol 173, pp:1423 – 1430
18. Wei-bin Yuana, Nan-ting Yua, Long-yuan Lib (2017), "Distortional buckling of perforated cold-formed steel channel-section beams with circular opening in web International", *Journal of Mechanical Sciences*, Vol 126, pp:255–260
19. Yi Xiang, Xuhong Zhou, Yu Shi, Lei Xu, Yunpeng Xu (2020), "Experimental investigation and finite element analysis of cold-formed steel channel columns with complex edge stiffeners", *Thin-Walled Structures*, Vol 152. pp:1-19

20. Zhanjie Li, Jiazhen Leng, James K. Guest, Benjamin W. Schafer (2016), "Two-level optimization for a new family of cold-formed steel lipped channel sections against local and distortional buckling", *Thin-Walled Structures*, Vol 108, pp:64–74