

EXPERIMENTAL & ANALYTICAL STUDY ON COLD-FORMED STEEL WELDED BATTENED CONNECTIONS IN TWO SIGMA-SHAPED SECTIONS

Submitted in partial fulfillment of the requirements for the award of Master of Engineering degree in Structural Engineering

by

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**DEPARTMENT OF CIVIL ENGINEERING
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SATHYABAMA

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

Accredited with Grade "A++" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of Sai Jawahar Reddy Bogolu (Register No: 42380004), who carried out the project entitled "**Experimental & Analytical Study of Cold-Formed Steel Welded Battened Connections in Two Sigma-Shaped Sections**" under our supervision from September 2023 to April 2024.

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DATE: 20.04.2024

PLACE: Chennai



SIGNATURE OF THE CANDIDATES

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ABSTRACT

Cold-formed steel (CFS) built-up battened columns are employed to obtain a sufficient load-bearing capacity when individual profiles cannot withstand the specified stresses. This sufficient load-bearing capacity can be obtained when the individual profiles present a composite action. This paper presents the optimal layout for CFS built-up battened columns to achieve a high level of composite action between two $\mathcal{L}$ -shaped CFS profiles. A calibrated finite element modelling technique was used to evaluate the effect of the number of fasteners per batten panel and the distance between the batten panels on the axial capacity of CFS built-up battened columns. The optimal number of fastener rows and the distance between the batten panels were determined using 100 models, in which a high level of composite action was achieved between CFS profiles. Then the maximum axial load-bearing capacity of additional 600 finite element models using the optimal layout was compared with the analytical predictions in the European standard EN1993-1-1. The result suggested an optimal distance of each plate between 186mm batten panels. The result shown the Ultimate load of welded battened connection. The test done on the load cell & LVDT Set up. The Analytical & Experimental result was compared & shown the compression graph for CFS welded Battened columns. The 100mm welded Battened plate shown best performance compare to 50mm & 75mm welded connections.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Hot rolled steel sections and cold-formed steel sections are widely used as structural members in steel-framed structures. The cold-formed products are extensively used in modern construction like low-rise and high-rise steel buildings. When compared with thick hot-rolled shapes, the cold formed light members can be used for light loads and shorter spans. Also, unusual sectional configuration can be made economically by cold-forming operations. It has more advantages such as lightness, high strength and stiffness, ease in fabrication, mass production, fast and easy erection and installation, substantial elimination of delay due to weather, more accurate detailing, non-shrinking, non-creeping at ambient temperatures, absence of form work, uniform quality, economy in transporting and handling and non-combustibility (Yu 1999, Yu 2000).

The cold-formed sections are made from carbon or low alloy steel sheet, strip, plate, or flat bar in cold-rolling machines or by press brake or bending brake operations. Cold-rolling method is used for large volume production and press breaking method is used for low volume production. The thickness of such members usually ranges from 0.378 mm to about 6.35 mm. Generally, the cold-formed steel sections are used as a primary framing members in buildings up to four or five stories in height and also they are used as roof decks, floor decks, wall panels, and siding materials in 2 buildings. Steel panels and decks provide not only structural strength to carry loads, but also a surface on which flooring, roofing, or concrete fill can be applied. In tall multi-storey buildings, the cold-formed steel structural members can be used as secondary members such as wall studs, joists, decks, and panels. If it is possible to achieve a high load to weight ratio of cold formed steel section, it can be also used as a primary member in high rise building. Hence, research is necessary on higher loading capacity of cold-formed steel structural members. The load carrying capacity and structural behavior of the steel members can be improved by providing edge and intermediate stiffeners in the single and

built-up sections. Compared to single section, the built-up section has more load carrying capacity and higher torsional stiffness. A lot of research is carried out on a single section with edge and intermediate stiffeners. But very little research is carried out in the built-up section with edge and intermediate stiffeners. Therefore, the understanding of structural behavior of cold-formed steel built-up closed section is essential and needs greater attention.

1.2 TYPES OF COLD-FORMED STEEL SECTIONS

Cold-formed steel elements are having types of stiffened or unstiffened. The stiffened elements obtained by an element supported by webs along both longitudinal edges. While the unstiffened element is obtained when the element supported along any one longitudinal edge only and the other edge can have the displacement.

The intermittently stiffened element is made by thin element divided into two or more narrow sub-elements and this is prefabricated by the introducing intermediate stiffeners in the rolling process. If the stiffener is adequate then, in that case, the edge stiffened element will be treated as the local buckling coefficient value of 4.0. While if the edge found to be inadequate or partially adequate then, in that case, its effectiveness is disregarded and the element is regarded as unstiffened.

1.3 OBJECTIVE

A hard tough metal composed of iron alloyed with various small percentages of carbon & often variously with other metals, as nickel, chromium, manganese to produce hardness, resistance to rusting.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

The following major research work has been taken from international journals as reference to analyze the concepts for the project.

2.2 REVIEW OF THE LITERATURES

Feiliang Wang, et al., (2020) Conducted Study on “Experimental and numerical evaluations of the distribution and effect of roll-forming residual stress on CFS sigma beams”, In This paper they Carried out the high-efficiency and versatile production approach, roll forming process, which involves a continuous roll set system, can bend the flat sheet to targeted sectional configurations gradually. During the process, the sheet experiences a repeat bending-unbending at each roll set and residual stress, resistance of the inner web will be deteriorated by the compressive residual stress in the place. Based on the FE study of the sigma beams with varying sections, it reveals that the ultimate load-resistance capacity of sigma beam is slightly decreased when considering residual stress, and the model which considered residual stress can get a better agreement against the experimental results.

Man-Tai Chen, et al., (2020) Conducted Study on “Beam-column tests of cold-formed steel elliptical hollow sections” In This Paper they Studied the cold-formed steel elliptical hollow section (EHS) beam-columns is described in this paper. Forty-two beam-column members with two different specimen lengths were tested at different eccentricities the load-moment interaction relationship. The initial geometric imperfections were determined before the formal tests. However, all of these design methods are quite conservative, and among those design methods, the American Specification ANSI/AISC360 using equivalent diameter provides more accurate and reliable design predictions.

Moussa Lebloubaa, et al., (2020) Conducted Study on “Elastic buckling behaviour of Σ -shaped rack columns under uniaxial Compression”, In This paper deals the accurate estimation of the elastic buckling properties of Σ -shaped rack sections with patterned holes. The investigation of the elastic buckling behaviour of three different Σ -shaped rack sections (with and without patterned holes) under compression is presented. More than 4000 finite element simulations were performed on these rack sections using the finite element program, ANSYS 18.1. The influences of the holes, perforation pattern, number of buckling half-wavelengths, and boundary conditions on the section buckling behaviour were studied. the elastic buckling behaviour of the rack columns with three different Σ -shaped sections under uniaxial compression.

M.Anbarasu (2019) Conducted Study on “Simulation of flexural behaviour and design of cold-formed steel closed built-up beams composed of two sigma sections for local buckling” In This Paper study focused on the structural behaviour of cold-formed steel (CFS) closed Built-up beams composed of two sigma sections primarily fail due to local buckling under four-point bending about the major axis. It is aimed to establish accurate finite element models for CFS built-up I-beam subjected to a transverse load. The numerical model is validated by means of comparison with the experimental results published in the literature in terms of moment capacities, moment versus deflection curve and failure mode of specimens. Nonlinear shell FE models were first developed in the finite element package ABAQUS for CFS closed built-up beams predisposed to local buckling.

Rinchen, et al., (2019) Conducted Study on “Design of cold-formed steel single C-section portal frames” In this Paper Study They Observed C-section portal frames based on the Direct Strength Method and the Direct Design Method. For the Direct Strength Method, two approaches are presented, one that determines the design capacity of portal frames ignoring the effect of bimoment, as in current practice, and one that considers the effect of bimoment. The Direct Design Method determines the frame strength directly using geometric and material nonlinear analysis, also referred to as Advanced Analysis. The attractiveness of the DDM using Advanced Analysis lies in its capability to capture all nonlinearities in a single-step analysis by which the frame capacity is directly obtained without the lengthy

member capacity check as is required in conventional member-based design.

Ye Yao, et al., (2019) Conducted Study on “Cross-section behavior of cold-formed steel elliptical hollow sections – A numerical study” In this Paper Study They Observed a finite element model for the stub columns of cold-formed tubular sections is presented, in which residual stresses, strength enhancement, geometric imperfection resulting from cold forming are predicted by using a rigorous finite element simulation of the roll-forming process. The accuracy of the finite element model for stub columns was verified by comparing the numerical predictions with test results. It can be found that the equivalent diameter method together with the current CHS slenderness limits in existing design codes can be safely adopted for cold-formed steel EHS. In addition, a new yield slenderness limit for cold-formed steel EHS is proposed.

Yuner Huang, et al., (2018) Conducted Study on “Design of cold-formed stainless steel circular hollow section columns using direct strength method” In This study focused the DSM is developed for coldformed steel sections with plate rather than curved elements, and thus its applicability for cold-formed stainless steel CHS is worth investigating. This paper presents a numerical investigation of cold-formed stainless steel CHS columns. A non-linear finite element model was developed and verified against column tests. and ferritic stainless steel CHS columns has been performed to obtain column strengths The parametric study includes cold-formed duplex, lean duplex and ferritic stainless steel. The column strengths obtained from the parametric study, together with the available data of stainless steel circular hollow section columns, were compared with the design strengths calculated by the current direct strength method in North American Specification (AISI)

Jai-Hui Zhang, et al., (2018) Conducted Study on “Design of cold-formed stainless steel circular hollow section columns using direct strength method” In this study focused the single open sections were formed by brake press operation with high strength steel plate of thickness of 0.48 and 1.0 mm, then two identical sections were connected together face-to-face by self-tapping screws. After the measurements of material properties and the initial geometric imperfections were made, the built-up closed section specimens with inward or outward stiffeners at the

web were tested between fixed-end boundary conditions with various column lengths ranging from 300 to 3200 mm. The results show that the direct strength method is applicable for the design calculation of cold-formed steel built-up closed section compression members with web stiffeners.

Bassem L. Gendy, et al., (2017) Conducted Study on “Effect of geometric imperfections on the ultimate moment capacity of cold-formed sigma-shape sections” This Paper Observed That the numerical investigation concerning the effect of these imperfections on the behavior of the simply supported beams subjected to a uniform bending moment. The beam profile is cold formed sigma sections. Group of beams with different overall member slenderness ratios were studied. Several approaches have been imperfections. First, the elastic buckling modes were considered as the imperfect beam shape. In this approach, the elastic buckling analysis was done first to get the elastic buckling modes. the ultimate bending moments of beams with short and intermediate overall slenderness ratios are sensitive to the imperfect shape that comprise compression flange local buckling.

Aghoury and Hanna., (2017) Conducted Study on “Experimental and theoretical investigation of cold-formed single lipped sigma columns” This Paper Observed That the tested specimens are subjected to an axial compressive load. The developed model includes both geometric and material nonlinearities. Numerous models of slender sigma column sections with different variables such as flange width–thickness ratios, and overall slenderness ratios are chosen. The behavior of sigma columns along with different failure modes illustrated local, distortional, and global buckling is investigated. Finite element axial capacities are compared with the predicted capacities using AISI. Both AISI and DSM results are comparable with the finite element results. Eventually, A reliability analysis is carried out.

Feng Zhou, et al., Conducted Study on “Element interaction of cold-formed stainless steel cross-sections subjected to major axis bending” In This Paper an Attempt is made by A non-linear finite element model which includes geometric and material non-linearities was developed and verified against experimental results. The material properties of the flat portions of the specimen sections were carefully

incorporated. An accurate and efficient finite element model (FEM) was developed in this study. The initial local imperfection and non-linear material properties of the flat and corner portions of the cross-section have been carefully incorporated in the FEM.

Baofeng Zheng, et al., (2016) Conducted Study on the “Bending Capacity of Cold-formed Stainless Steel Hollow Sections” In This Paper an Attempt is made by Finite element models were developed, and were verified using the test data. Material nonlinearity and geometric imperfections were considered in the modeling. Parameter studies were conducted to expand test data with different material properties and section slenderness. Direct strength formulas were proposed for rectangular and circular hollow sections, respectively. The performance of CSM method is better than the design codes. The proposed formulas show better accuracy in predicting bending capacities of cold-formed stainless steel hollow sections.

Luis Laim, et al., (2015) Conducted Study on the “Flexural behaviour of beams made of cold-formed steel sigma-shaped sections at ambient and fire conditions” In This article Reported a series of flexural tests at ambient and fire conditions on simply supported cold-formed steel beams made of one or two sigma-shaped profiles. including no restraints, partial axial and beam supports rotational thermal restraints. That CFS beams with web stiffeners may have different structural responses under fire conditions depending on the section shape. In other words, whereas the sigma beams presented similar critical temperatures to the C beams independently of the boundary conditions, the 2- sigma beams behaved differently from the lipped-I beams.

Qiang Liu, et al., (2015) Conducted Study on the “Numerical simulation of sleeve connections for cold formed steel sigma sections” In This article Reported In modern roof construction, the sleeve connection for sigma purlins is often favoured due to advantages such as adequate structural efficiency, ease of installation and freedom from restrictions on the length of the connected purlins. This paper presents a finite element (FE) model developed for typical sleeve connections used in the sigma purlin system. The aim of the modelling is to numerically reveal the structural

behaviour of such a connection, and to provide supplementary information that is usually lacking in laboratory tests.

Na Yang, et al., (2014) Conducted Study on the “Hysteretic behaviors of cold-formed steel beam-columns with hollow rectangular section: Experimental and numerical simulations” In This article they Reported cyclic response of cold-formed steel columns with hollow rectangular sections. The present study examined the columns’ post-buckling strength and rigidity degradation, deformation and failure modes, ductility, and energy dissipation capacity. The cold-formed steel members exhibited stable hysteretic performance up to the point of local buckling with considerable degradation in strength and ductility. The study investigated the buckling strength, post-buckling stiffness, failure mechanism, ductility, and energy dissipation capacity

Quach, et al., (2014) Conducted Study on the “Strength and ductility of corner materials in cold-formed stainless steel sections” In This article they Conducted Due to a high cost of stainless steels, it is desirable to utilize this enhanced strength and avoid the early fracture in cold-formed stainless steel members. The paper is concerned with the prediction of the enhanced stress–strain behaviour and reduced ductility of materials in cold-formed stainless-steel sections. This paper has been concerned with the accurate prediction of the enhanced strength, reduced ductility and stress–strain behaviour of the corner material in cold-formed stainless-steel sections by presenting an advanced numerical approach for the simulation of corner coupon test.

Ehab Ellobody (2013) Conducted Study on the “A consistent nonlinear approach for analysing steel, cold-formed steel, stainless steel and composite columns at ambient and fire conditions” In This article they Studied for analysing steel, cold-formed steel, stainless steel and composite columns at ambient and fire conditions. The main parameters affecting the finite element approach, which has accounted for the nonlinear material properties of the column cross-sections at ambient and elevated temperatures, initial local and overall geometric imperfections and residual stresses. The paper has shown that the finite element approach presented provided better understanding for the behaviour of the columns at

ambient and fire conditions and assessed the accuracy of design rules specified in current codes of practice.

M.Book, et al., (2013) Conducted Study on the “Study of web crippling in ferritic stainless steel cold formed sections” In This article they that instability phenomena such as web crippling, where the web locally buckles due to concentrated transverse forces, must be considered. On the other hand, the emergent ferritic stainless steel has very low nickel content and therefore, they are cheaper and relatively price stable compared to austenitics and duplex.study of web crippling in ferritic stainless steel cold formed sections.

Yuner Huang, et al., (2012) Conducted Study on the “Material properties of cold-formed lean duplex stainless steel sections” In This article they presents the behaviour of cold-formed lean duplex stainless steel for six different sections, among which two are square hollow sections and four are rectangular hollow sections. The test specimens were cold-rolled from flat strips of lean duplex stainless steel. The material properties of high strength cold-formed lean duplex stainless steel square and rectangular hollow sections were determined. American, Australian/New Zealand Standard and European specifications for stainless steel structures. It is shown that the design strengths predicted by the three specifications are generally conservative for the cold-formed lean duplex stainless steel stub columns.

Jian Yang, et al., (2012) Conducted Study on the “Sleeve connections of cold-formed steel sigma purlins” In This article they presents the Structural characteristics of sleeve connections of sigma purlins. Experimental data of moment resistance, rotational stiffness and typical failure modes reported. Design models for the M-theta relationship and moment resistance of sleeve connections proposed. Sleeve connections exhibit typical features of a semi-rigid joint. The moment–rotation response, moment resistance and typical failure modes were recorded and examined carefully for each test specimen. Based on the test results and observations, a three-stage moment–rotation model for sleeve connections was proposed.

2.3 NEED FOR THE STUDY

To present the optimal number of welded plat rows and the distances between the welded panel, representing a composite action between the individual CFS $\mathcal{L}$ -shaped profiles. The built-up battened columns were assembled using two CFS sigma ($\mathcal{L}$)-shaped profiles connected using welded panels. The welded panels are weld to the flanges of the CFS $\mathcal{L}$ -shaped profiles. The optimal number of the weld rows per welded panel to reach a composite action between two CFS profiles is unclear. Therefore, the effect of the number of welded plat rows was considered by examining 1 row welded per batten. These CFS $\mathcal{L}$ -shaped profiles can be positioned at various spacing's as a result, different geometries and load-bearing capacities depending on the design requirement, can be achieved.

2.4 SCOPE OF THE STUDY

1. This project mainly focuses on the investigation on strength and behaviour of an innovative cold-formed welded battened connections steel column.
2. The numerical analysis was performed using ANSYS software. The developed finite element model was verified with the experimental results.
3. A parametric study was carried out to understand the factors that influenced the strength and behaviour of the section, using verified finite element model.

CHAPTER 3

METHODOLOGY

3.1 METHODOLOGY

The Methodology flow chart for cold formed steel welded battened connection in two sigma column is shown in figure 3.1

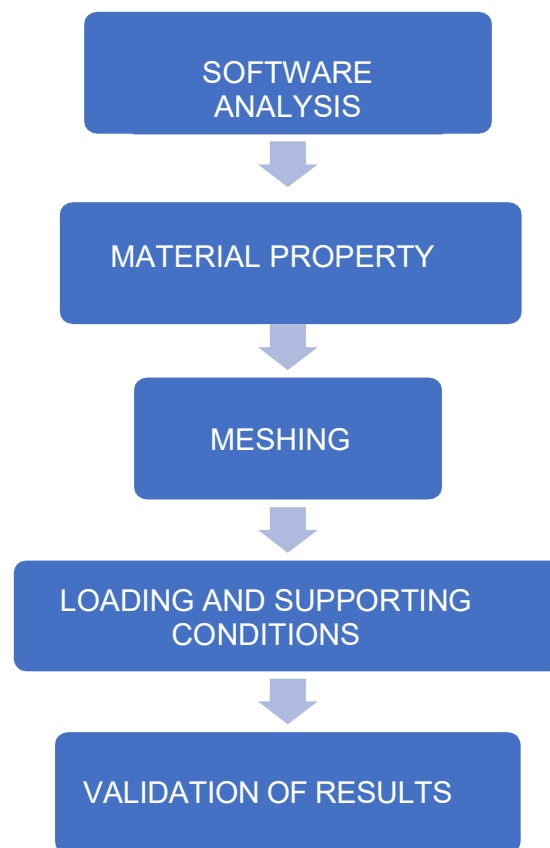


Figure : 3.1 Methodology

3.2 ANALYTICAL PROCEDURE

Ansys Mechanical finite element analysis software is used to simulate computer models of structures, electronics, or machine components for analyzing strength,

toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Finite element analysis is performed for all the specimen is using ANSYS 2021 Workbench and their behavior is studied.

3.2 COLD FORMED STEEL SHEET

Cold Rolled steel sheet properties are referred as per IS 513:2008. In this study we have used a cold rolled sheet of grade IS 513 CRS of 3mm thickness. The chemical composition of the CRS (Drawing) is tabulated and the mechanical properties of the CRS is tabulated as per IS 513:2008.

Table 3.1 Chemical Composition of CRS (IS 513:2008)

Chemical Constituent	%
Carbon	0.12
Manganese	0.5
Sulphur	0.035
Phosphorus	0.04

Table 3.2 Mechanical Properties of CRS (IS 513:2008)

Properties	Max Value	Units
Yield Stress	240	Mpa
Tensile Strength	370	Mpa
Elongation %	30	%

The CR Sheet was available from 0.4mm thickness to 3mm thickness. To attain maximum strength 3mm sheet was chosen. The sheet was in silver colour. Due to its manufacturing process when it reacts in atmosphere soon it gets rusted. Hence to avoid rusting, columns are painted.

SIGMA SHAPE

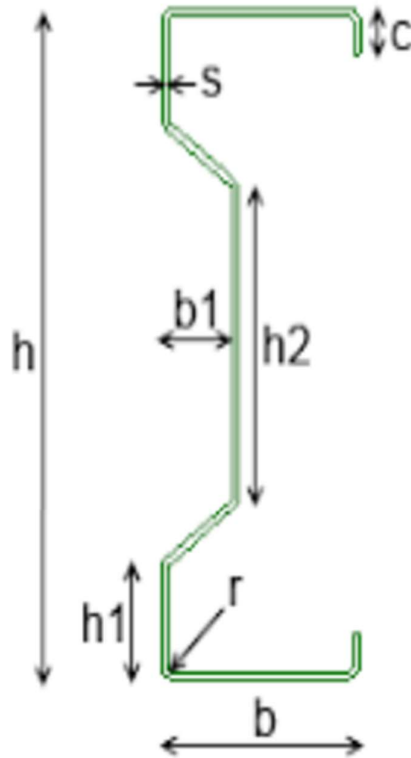


Figure:3.2 Shape of Sigma Section (Sample)

3.4 INTERNATIONAL STANDARDS STEEL PROPERTIES

S280GD+Z steel is a hot-dip galvanized structural steel that belongs to the European standard EN 10346. The “S” in its name refers to structural steel, while “280” represents its minimum yield strength in megapascals (MPa). The “GD” refers to galvanized steel, and the “+Z” specifies the surface condition, which means it has a zinc coating.

One of the key properties of S280GD+Z steel is its high strength. With minimum yield strength of 280 MPa, it offers excellent structural integrity and load-bearing capacity. This makes it suitable for applications that require strong and

durable components, such as construction beams, Column, roof trusses, and support structures.

Another important property of S280GD+Z steel is its excellent corrosion resistance. The zinc coating on the surface acts as a protective layer, preventing the steel from coming into direct contact with the environment. This protects it from rust and corrosion, even in harsh conditions or humid environments. As a result, this type of steel is commonly used in outdoor applications, including roofing, cladding, and fencing.

S280GD+Z steel also offers good formability, which refers to its ability to be shaped or bent without cracking or breaking. This allows manufacturers to easily mold it into various forms and sizes, making it suitable for a wide range of applications. From simple metal brackets to complex structural components, S280GD+Z steel can be formed into different shapes to meet specific requirements.

Furthermore, this type of steel is weldable, meaning it can be easily joined together using various welding techniques. This property is crucial in industries where components need to be assembled or connected, such as the construction and automotive sectors. Welding allows for strong and reliable joints, ensuring the overall integrity of the structure or product.

In summary, S280GD+Z steel is a hot-dip galvanized structural steel with excellent strength, corrosion resistance, formability, and weldability. Its high strength makes it suitable for load-bearing applications, while its corrosion resistance makes it ideal for outdoor use. The good formability and weldability of this steel provide versatility in various manufacturing processes.

As a result of these properties, S280GD+Z steel is commonly used in a wide range of industries. Some major applications include construction (roofing, pillars, beams), automotive manufacturing (chassis, body panels), electrical appliances (cabinets, enclosures), and general engineering (metal brackets, frames). Its combination of strength, corrosion resistance, and formability makes it a popular choice for many demanding applications.

In conclusion, understanding the key properties and applications of S280GD+Z steel is essential for industries that rely on steel for their products or structures. Its high strength, corrosion resistance, formability, and weldability make it a versatile and reliable material. Whether it's in construction, automotive, or general engineering, S280GD+Z steel offers a wide range of possibilities for manufacturers.

3.5 SPECIMEN SET UP FOR ANALYTICAL

As shown in below fig 3.5 a total of three pairs of Sigma column sections were taken. All sigma columns were in lengths of 150mm, Height of 1200mm & width of 43mm. The welded Battened Plate used for joint plate width of 50mm. We add 50mm Plate of 8pcs of each side to join the both sigma column. After that we are adding one more battened with the dimensions of (50mm+75mm+100mm) for another pair of sigma column. Comparing of three different battened plates the details of the models to be found in Ansys software.

In using of Ansys software the total three dimensions of 50mm, 75mm & 100mm are tested with constant load of 50KN. The 50KN Load is Tested on three pairs and the result is shown below.

3.6 MODELING OF COLUMN USING ANSYS

The below figure 3.3 shows the dimensions of welded battened connections in Ansys software. The 50mm welded battened shape of sigma column was shown in figure 3.4

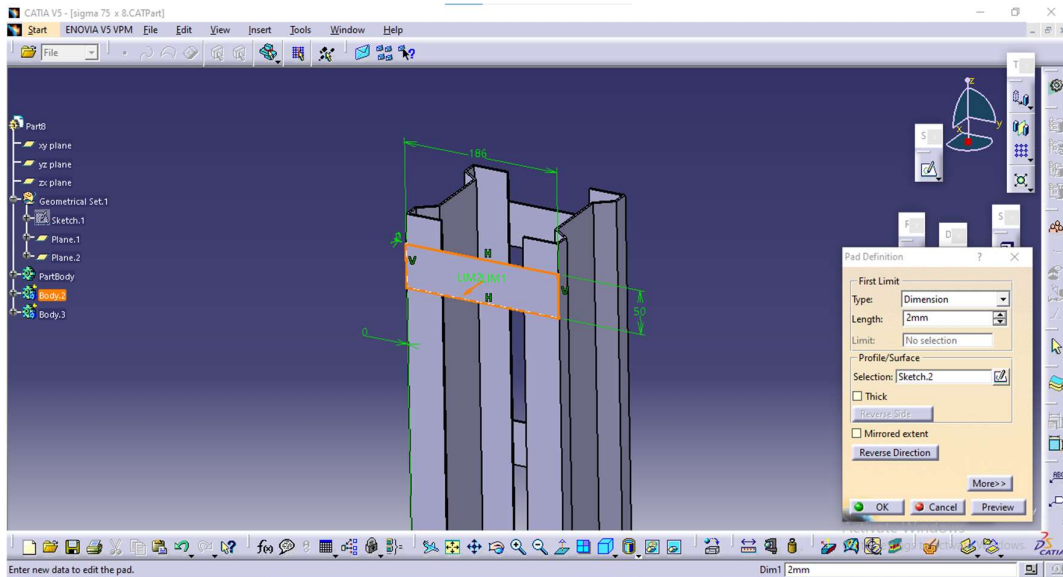
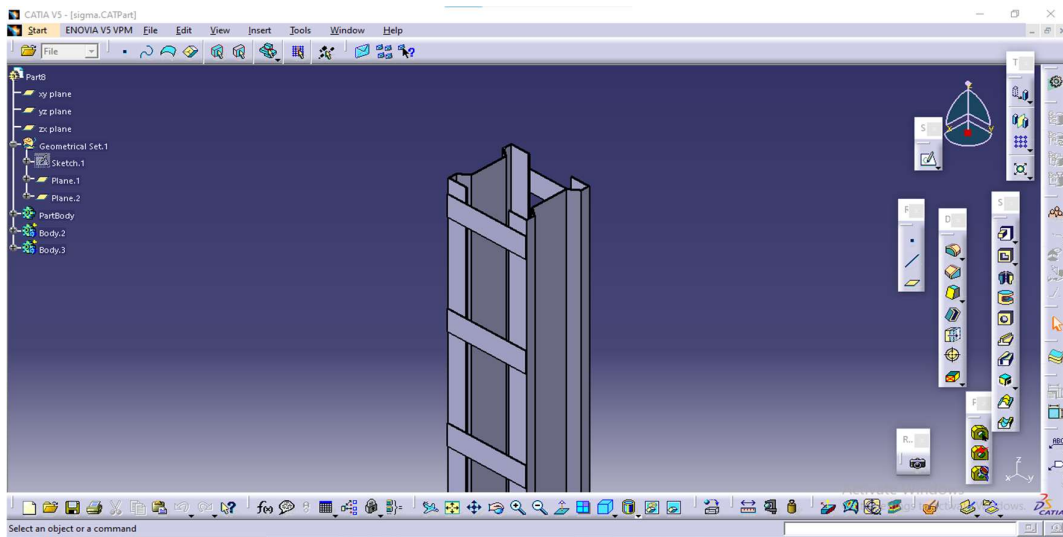


Figure:3.3 Dimensions of 50 MM Welded Battened Connections



*Figure:3.4 Shape of 50MM*8 Welded Battened Connections*

The below figure 3.5 shows the dimensions of welded battened connections in Ansys software. The 75mm welded battened connections of sigma column was shown in figure 3.6

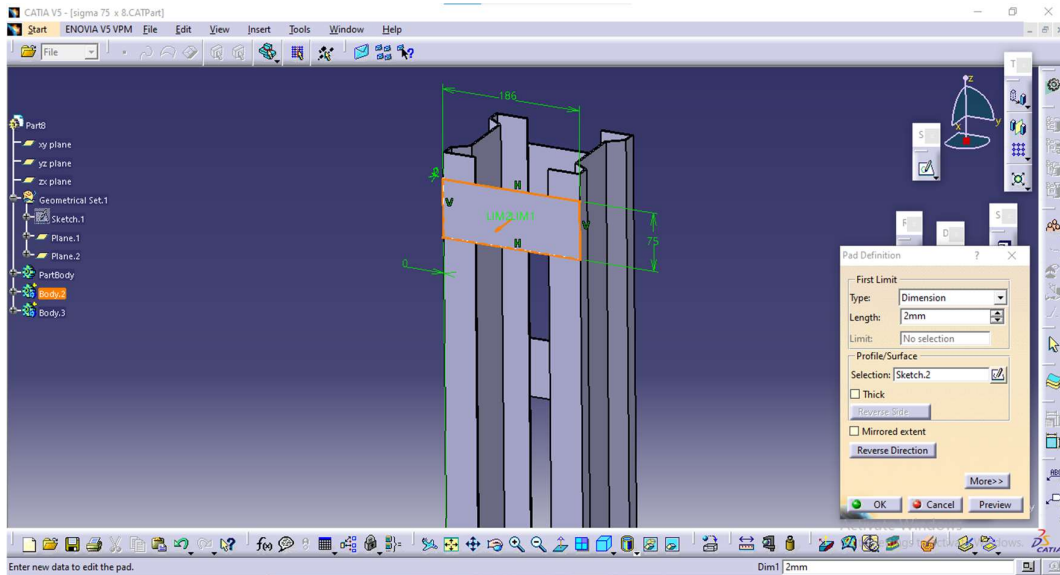
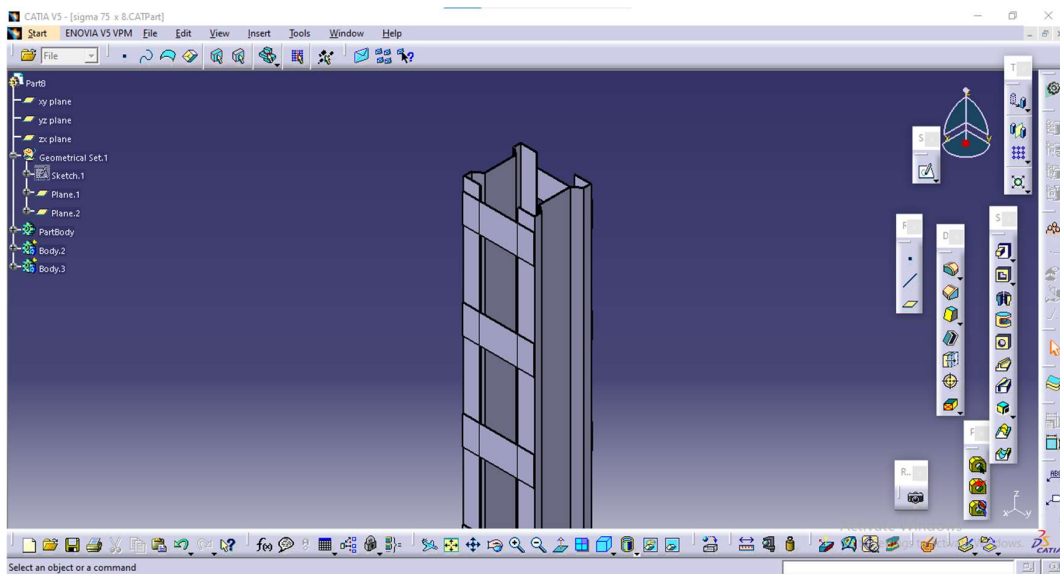


Figure:3.5 Dimensions of 75 MM Welded Battened Connections



*Figure:3.6 Shape of 75MM*8 Welded Battened Connections*

The below figure 3.7 shows the dimensions of welded battened connections in Ansys software. The 100mm welded battened connections of sigma column was shown in figure 3.8

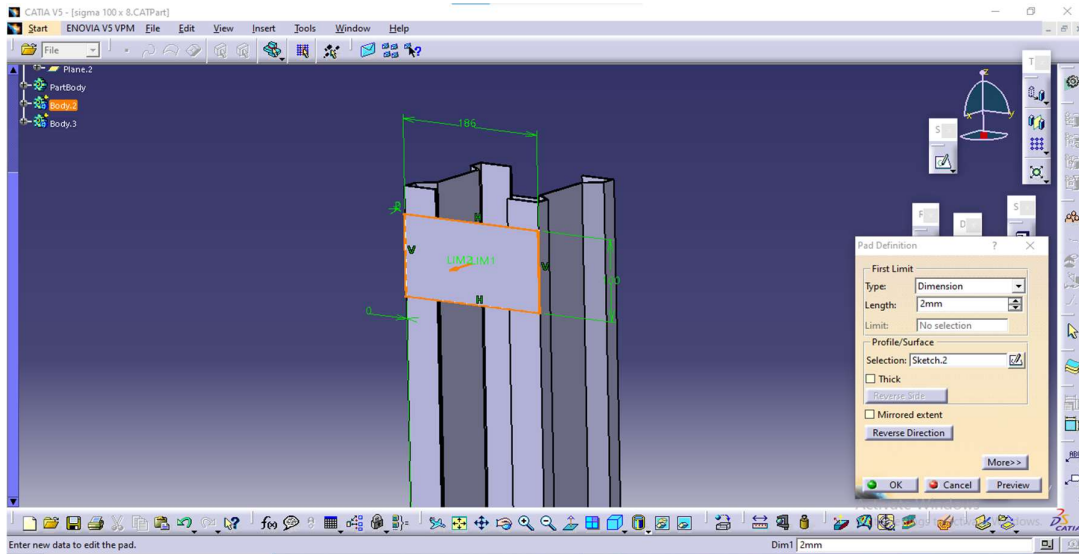
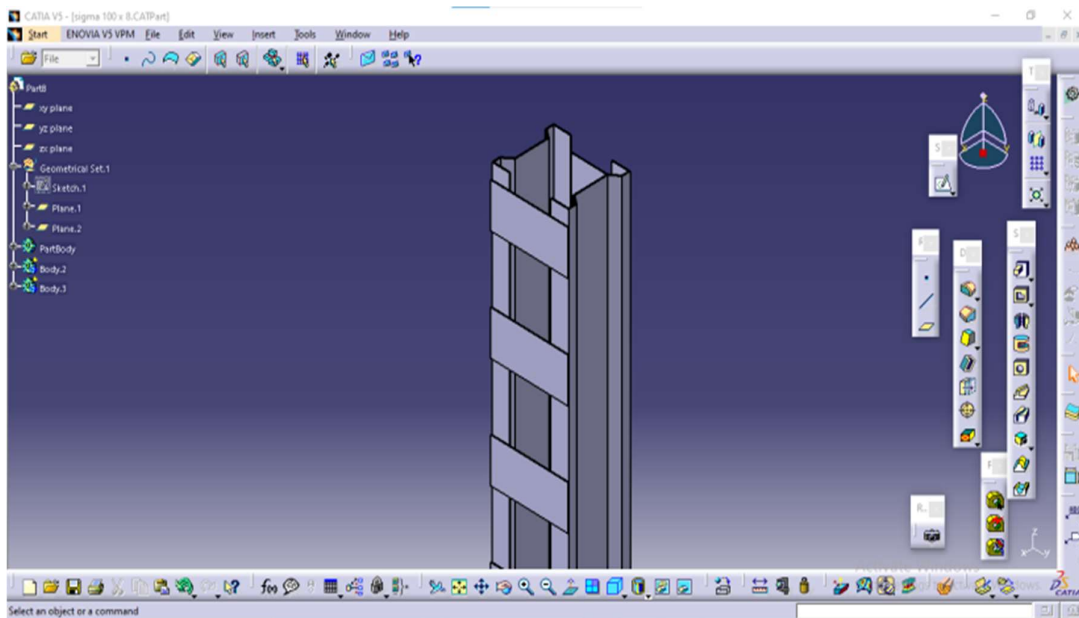


Figure: 3.7 Dimensions of 100MM Welded Battened Connections



*Figure :3.8 Shape of 100MM*8 Welded Battened Connections*

3.7 ANSYS RESULT OF CFS WITH 50mm X 8pcs

The below figure 3.9 shows the total deformation of welded battened connection after applying the load. The directional deformation of Sigma Welded battened connection after applying load was shown in figure 3.10

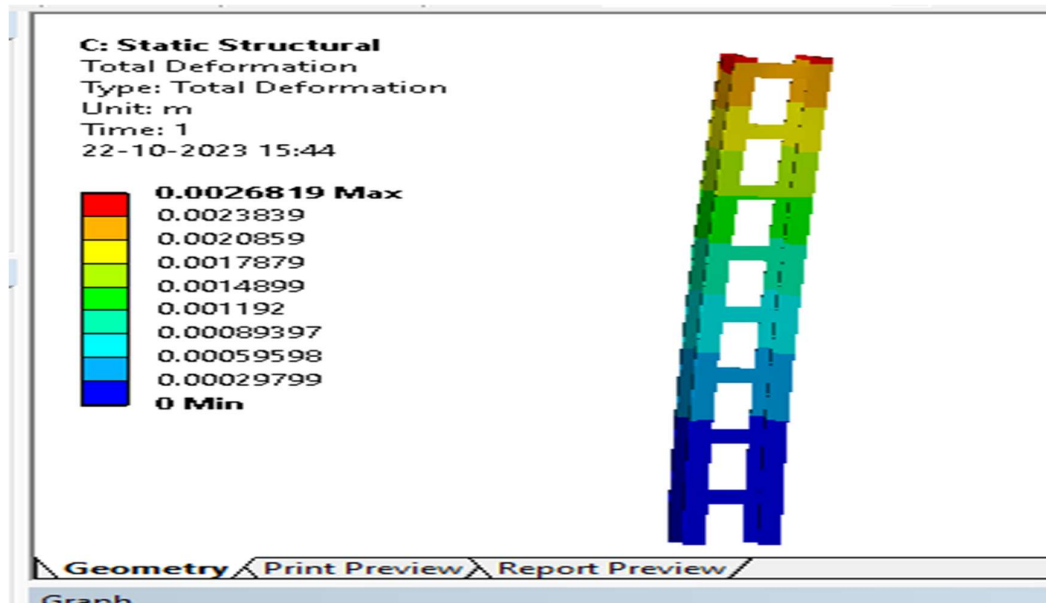


Figure:3.9 Total Deformation(m)

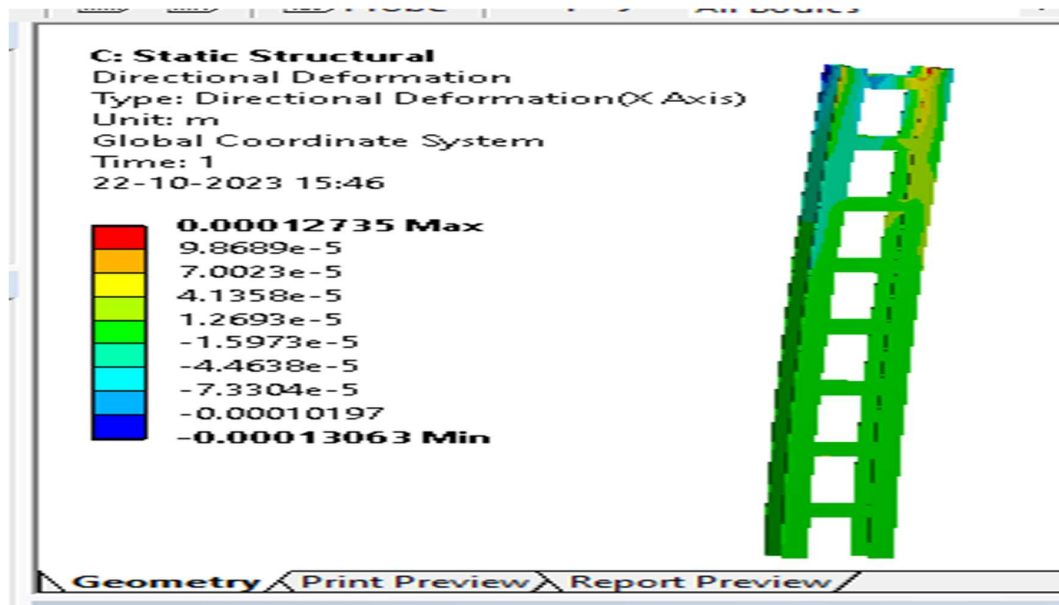


Figure :3.10 Directional Deformation(m)

The below figure 3.11 shows the equivalent Elastic of welded battened connection after applying the load. The normal elastic strain of Sigma Welded battened connection after applying load was shown in figure 3.12

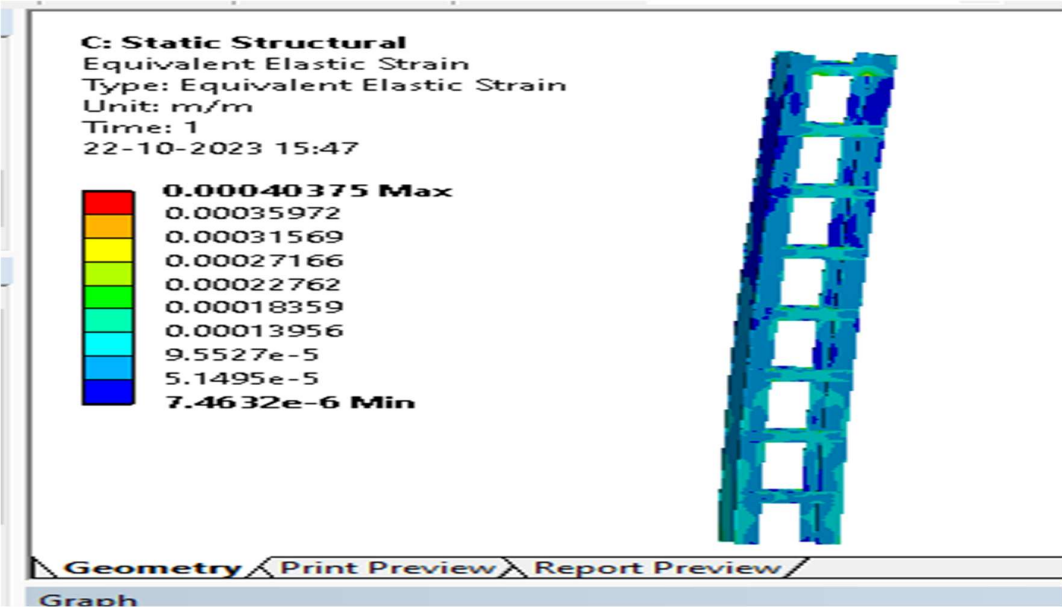


Figure:3.11 Equivalent Elastic

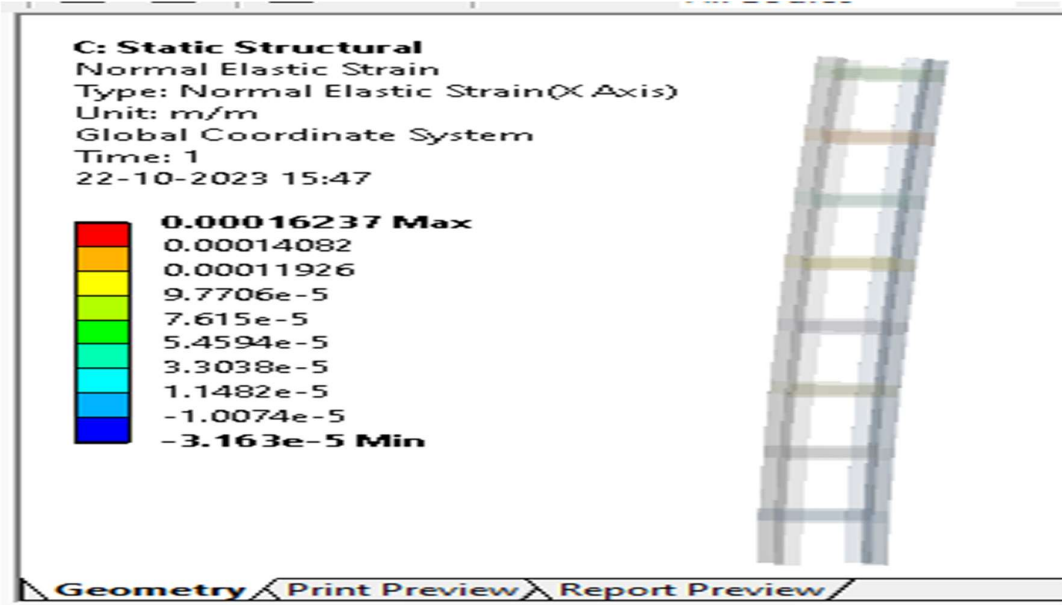


Figure : 3.12 Normal Elastic Strain

The below figure 3.13 shows the equivalent stress of welded battened connection after applying the load. The normal stress of Sigma Welded battened connection after applying load was shown in figure 3.14

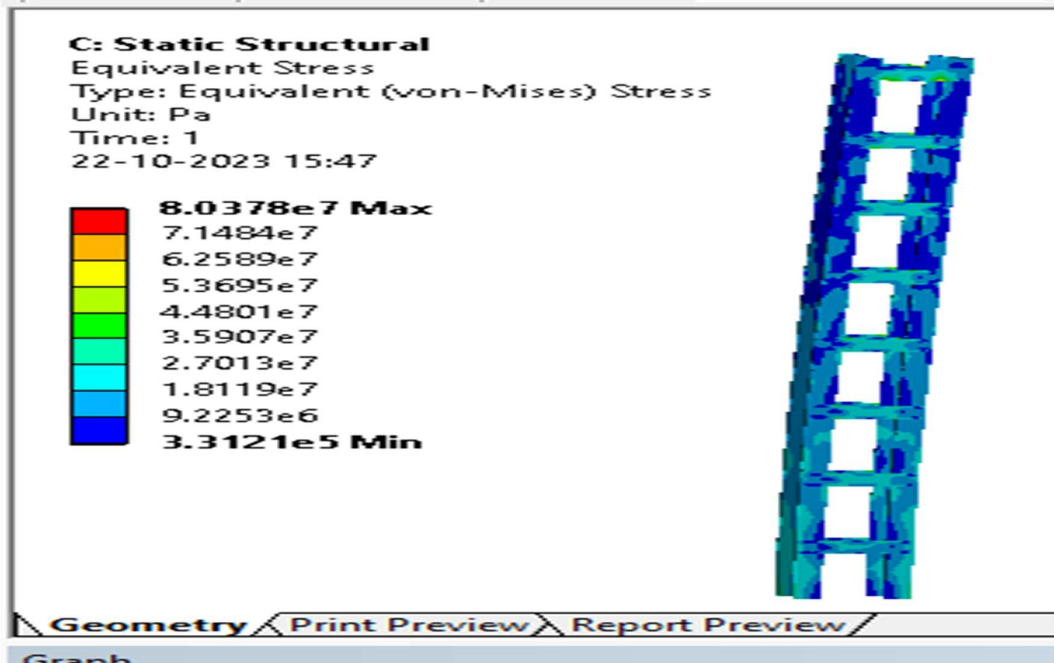


Figure:3.13 Equivalent Stress (pa)

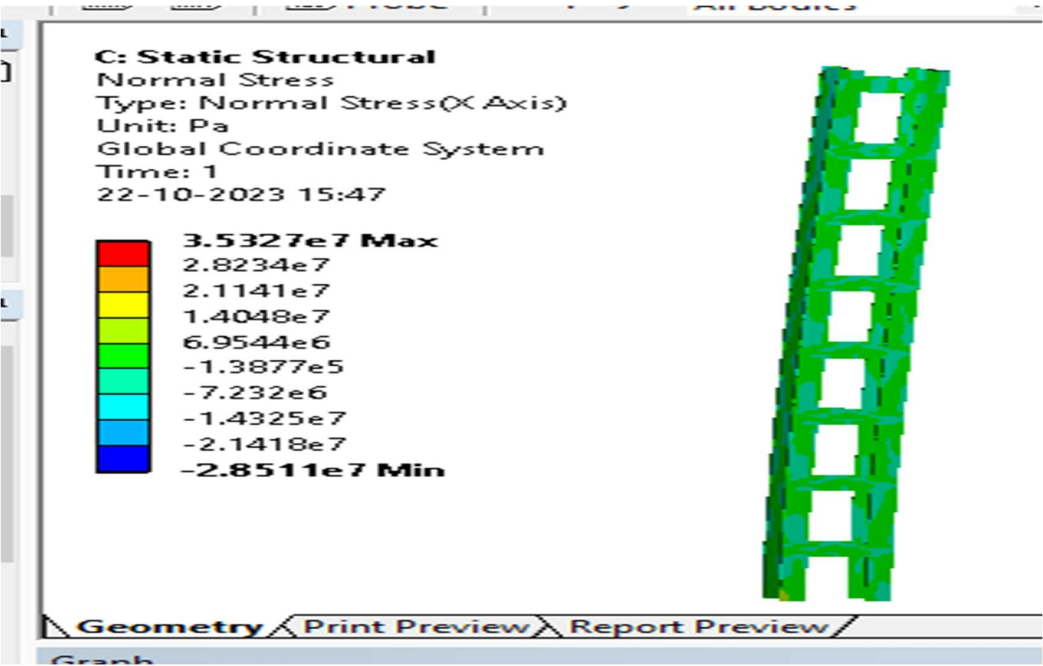


Figure:3.14 Normal Stress(pa)

3.8 RESULT OF CFS WITH 75mm X 8pcs

The below figure 3.15 shows the total deformation of welded battened connection after applying the load. The directional deformation of Sigma Welded battened connection after applying load was shown in figure 3.16

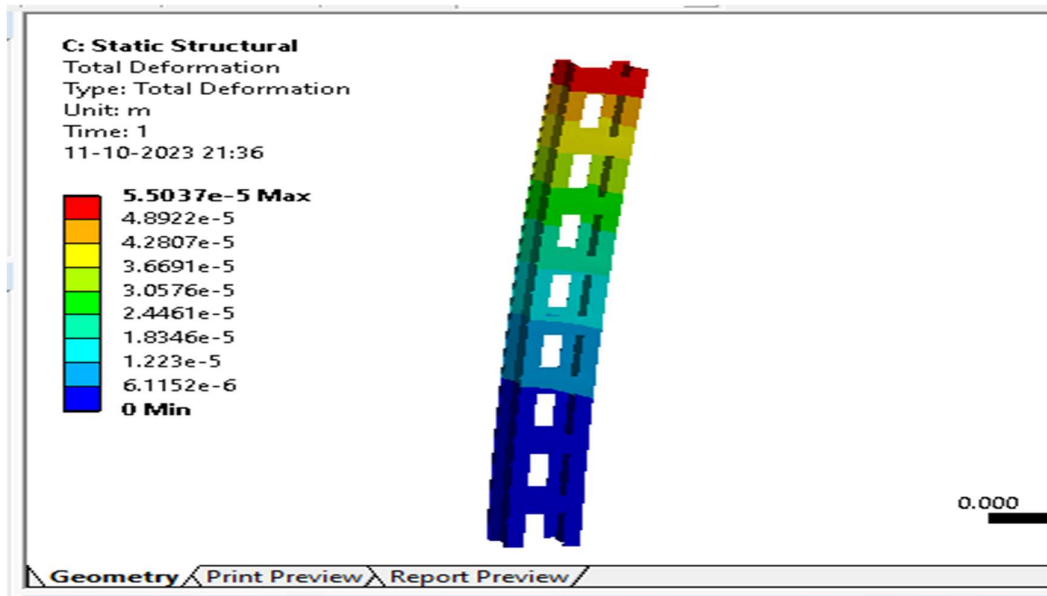


Figure : 3.15 Total Deformation(m)

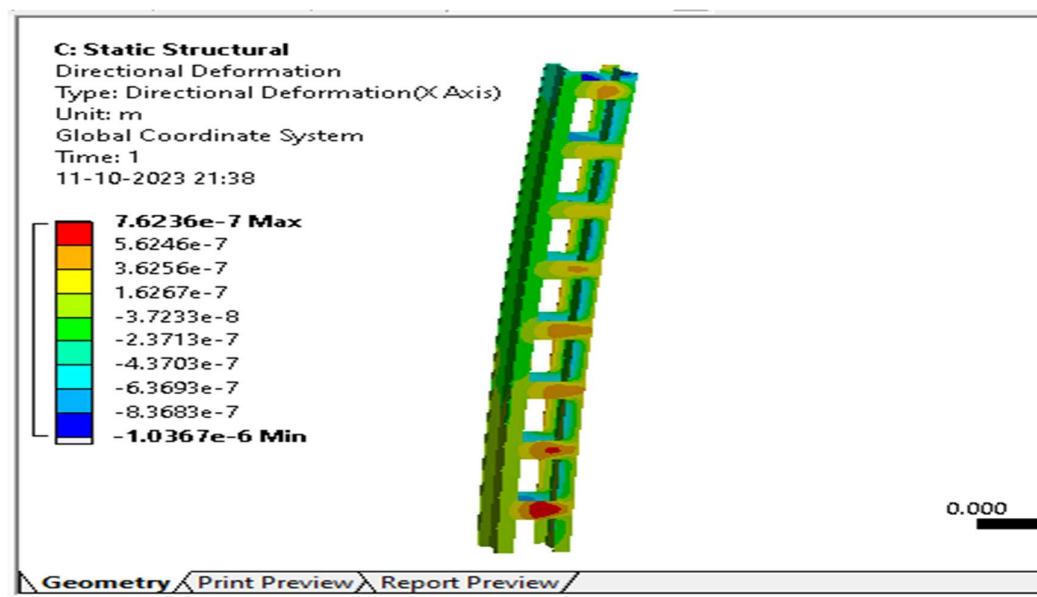


Figure: 3.16 Directional Deformation(m)

The below figure 3.17 shows the equivalent Elastic strain of welded battened connection after applying the load. The normal elastic strain of Sigma Welded battened connection after applying load was shown in figure 3.18

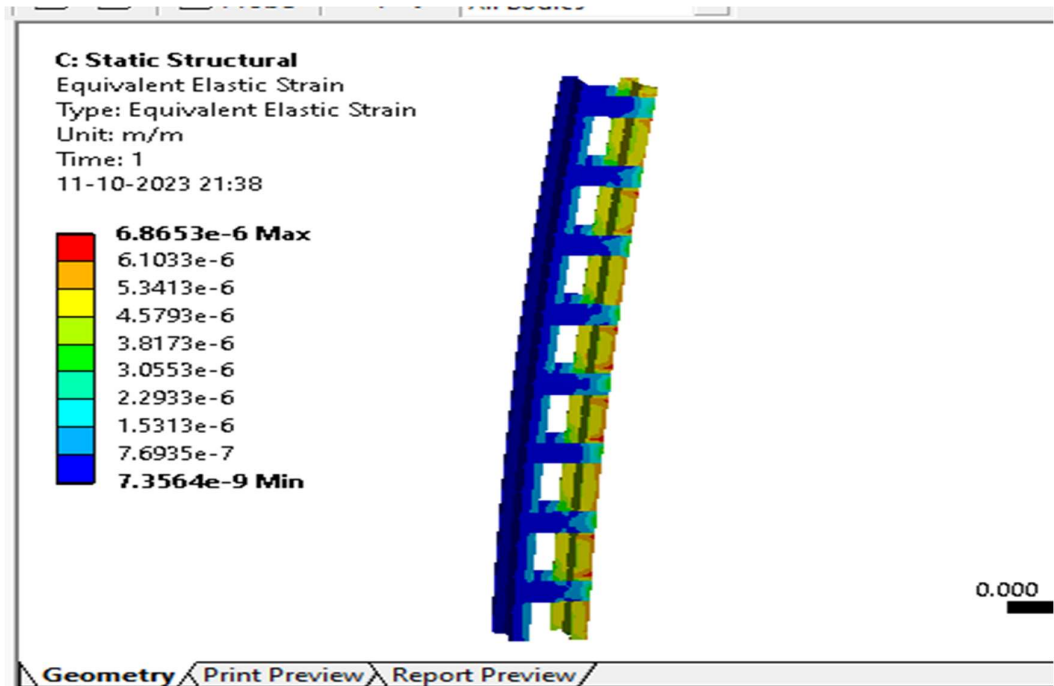


Figure:3.17 Equivalent Elastic Strain

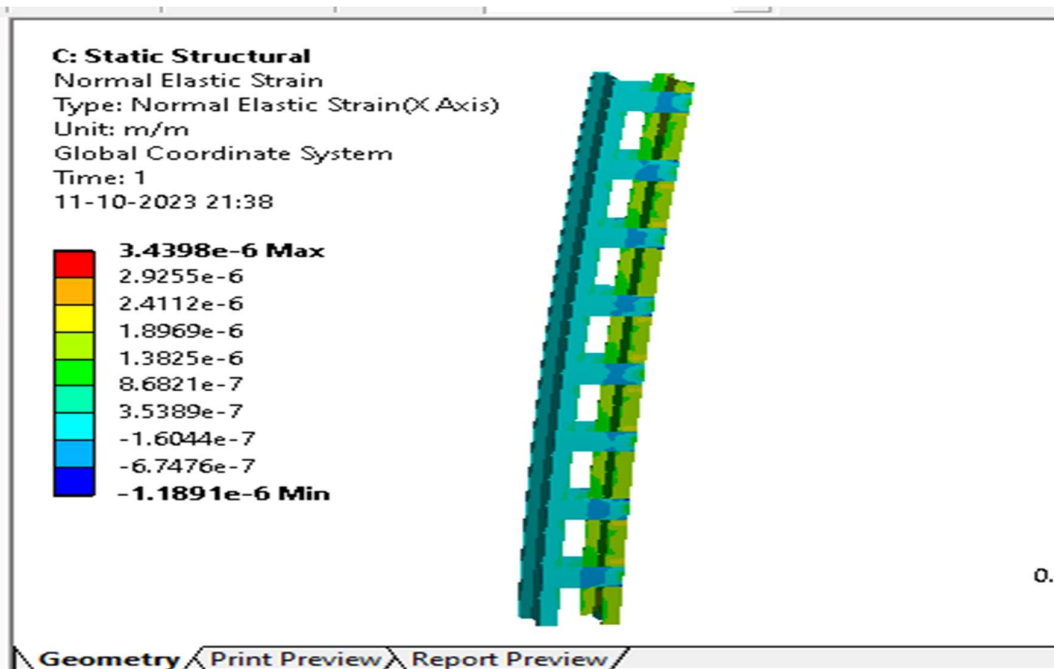


Figure:3.18 Normal Elastic Strain

The below figure 3.19 shows the equivalent stress of welded battened connection after applying the load. The normal stress of Sigma Welded battened connection after applying load was shown in figure 3.20

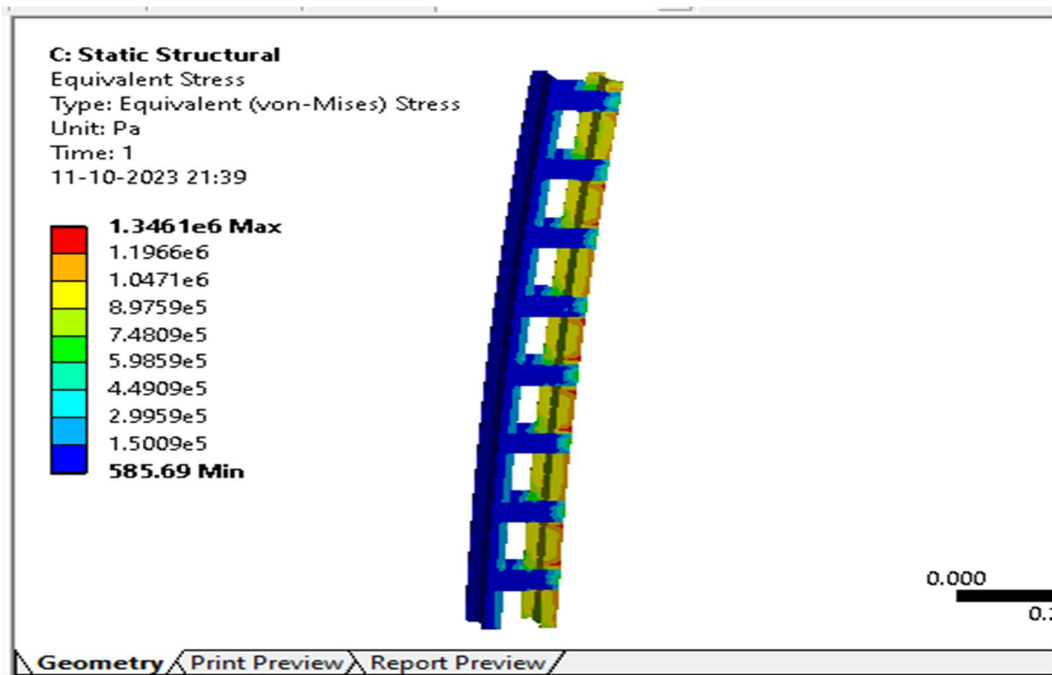


Figure:3.19 Equivalent Stress (Pa)

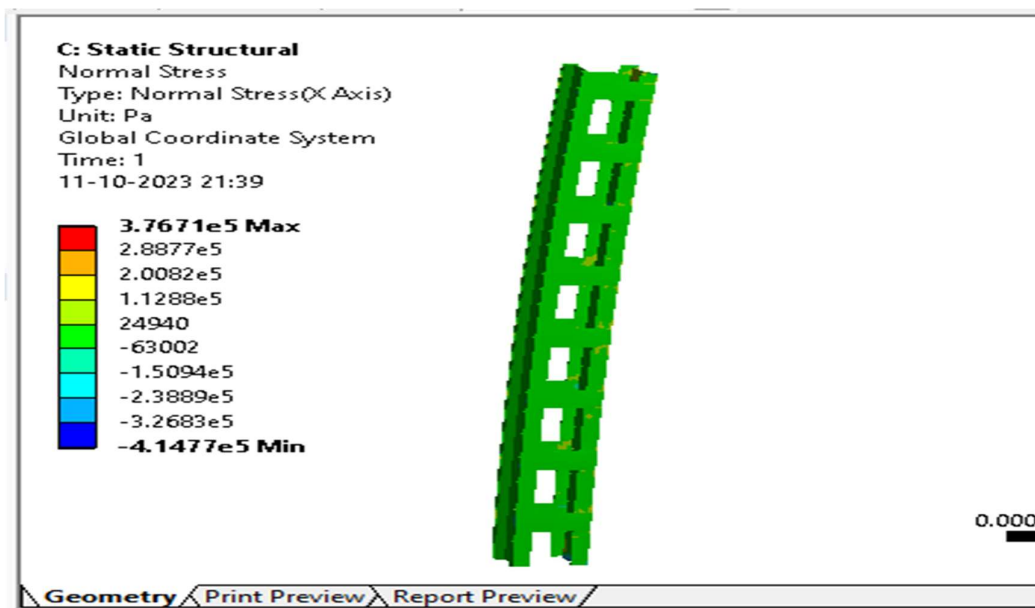


Figure:3.20 Normal Stress (Pa)

3.7 RESULT OF CFS WITH 100mm X 8pcs

The below figure 3.21 shows the total deformation of welded battened connection after applying the load. The directional deformation of Sigma Welded battened connection after applying load was shown in figure 3.22

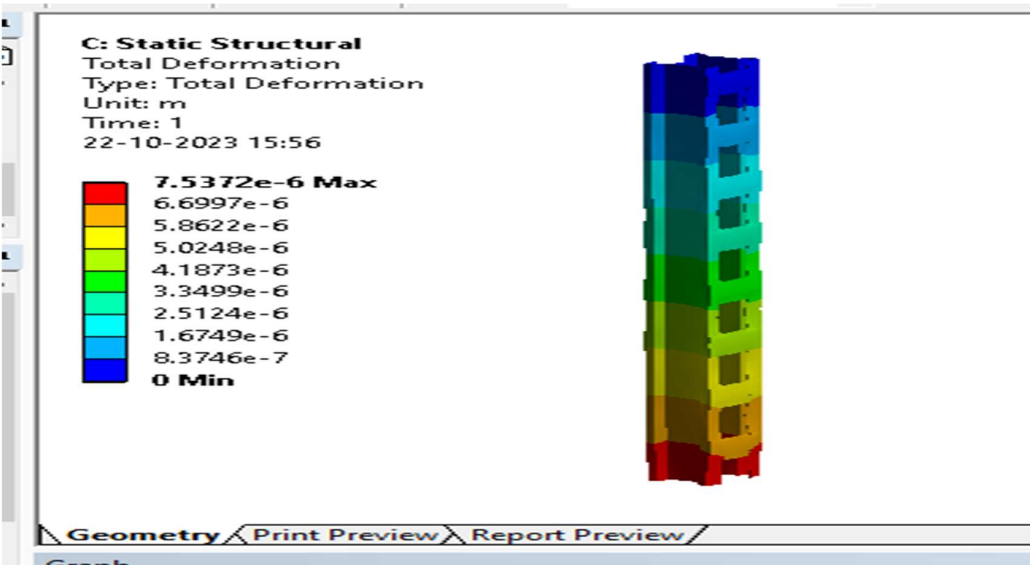


Figure:3.21 Total Deformation(m)

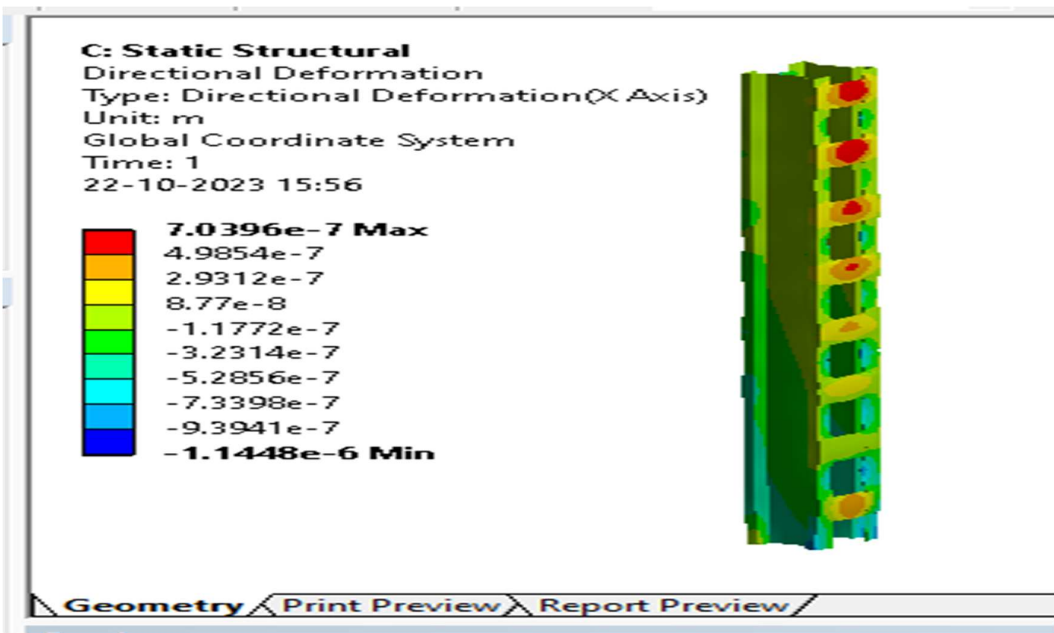


Figure:3.22 Directional Deformation(m)

The below figure 3.23 shows the equivalent Elastic strain of welded battened connection after applying the load. The normal elastic strain of Sigma Welded battened connection after applying load was shown in figure 3.24

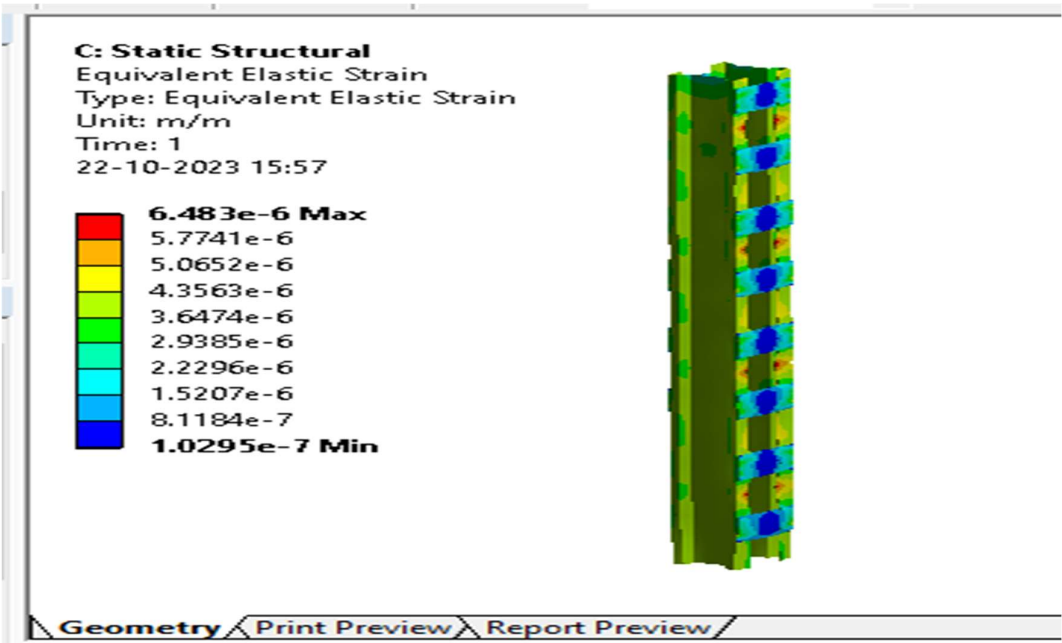


Figure: 3.23 Equivalent Elastic Strain

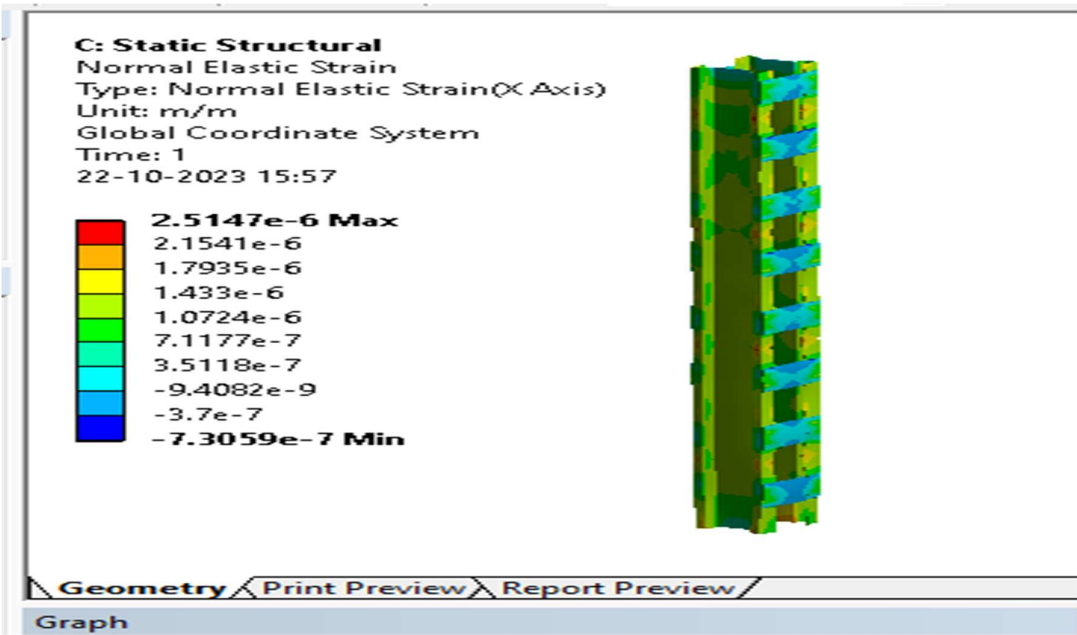


Figure: 3.24 Normal Elastic Strain

The below figure 3.25 shows the equivalent stress of welded battened connection after applying the load. The normal stress of Sigma Welded battened connection after applying load was shown in figure 3.26

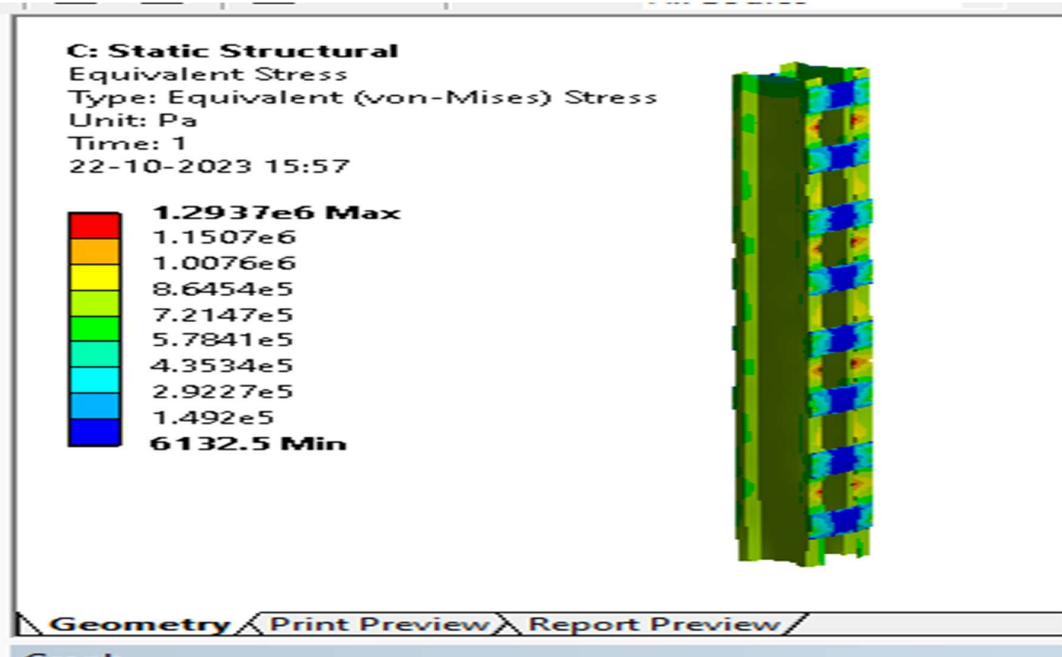


Figure: 3.25 Equivalent Stress (Pa)

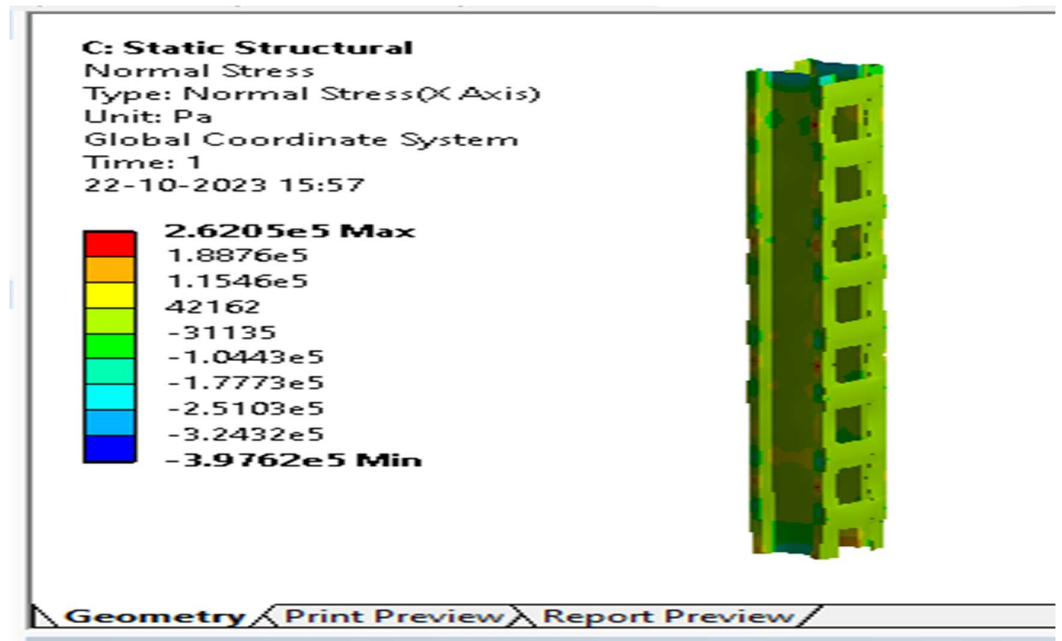


Figure:3.26 Normal Stress (Pa)

3.10 COMPRESION RESULT

The below figure 3.27 shows the maximum & minimum values of directional deformation of welded battened connection after applying the axial load. The values of total deformation in Sigma Welded battened connection after applying the axial load was shown in figure 3.28

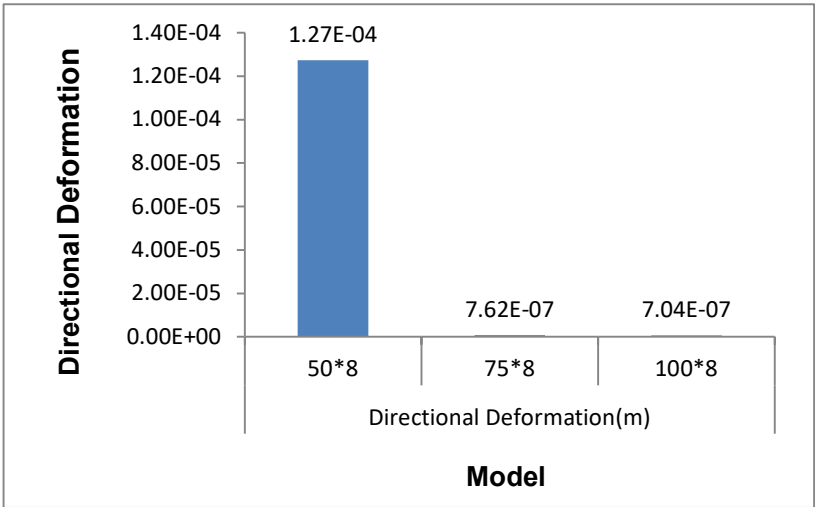


Figure:3.27 Directional Deformation(m)

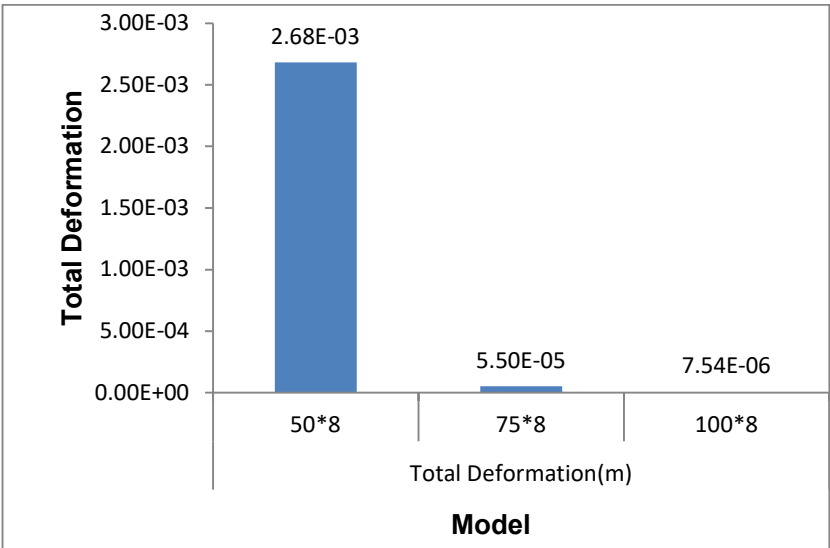


Figure:3.28 Total Deformation(m)

The below figure 3.29 shows the maximum & minimum values of equivalent elastic strain of welded battened connection after applying the axial load. The values of normal elastic strain in Sigma Welded battened connection after applying the axial load was shown in figure 3.30

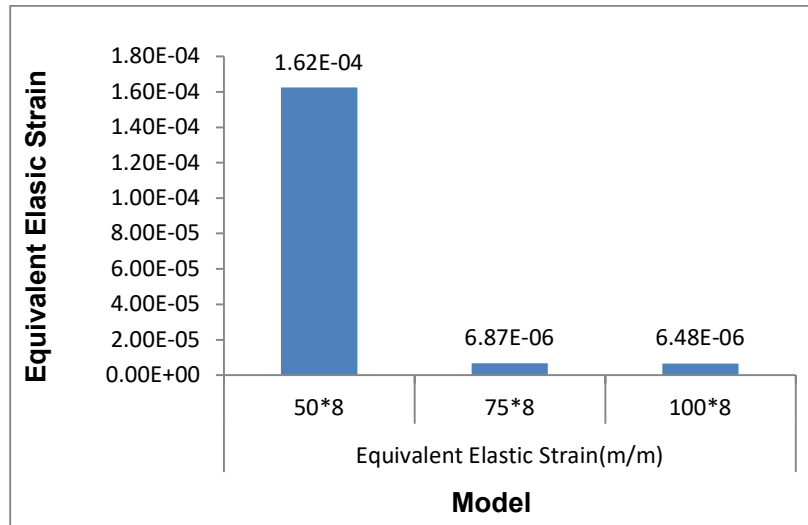


Figure:3.29 Equivalent Elastic Strain

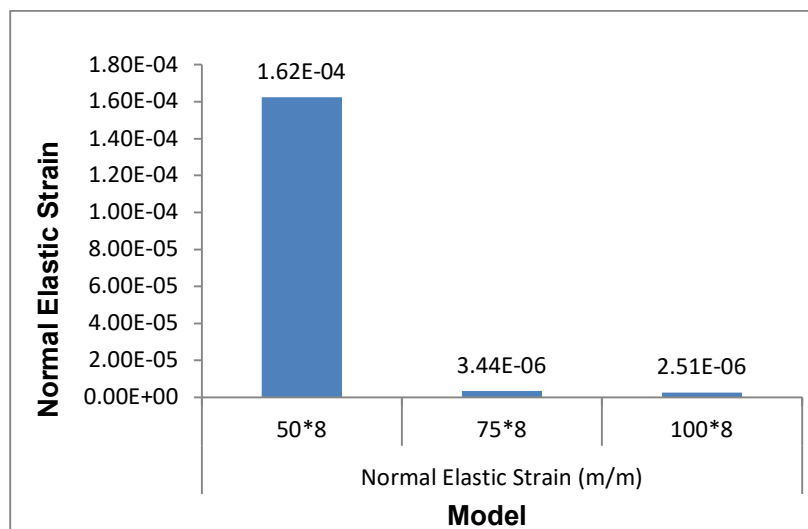


Figure:3.30 Normal Elastic Strain

The below figure 3.31 shows the maximum & minimum values of equivalent stress of welded battened connection after applying the axial load. The values of normal stress in Sigma Welded battened connection after applying the axial load was shown in figure 3.32

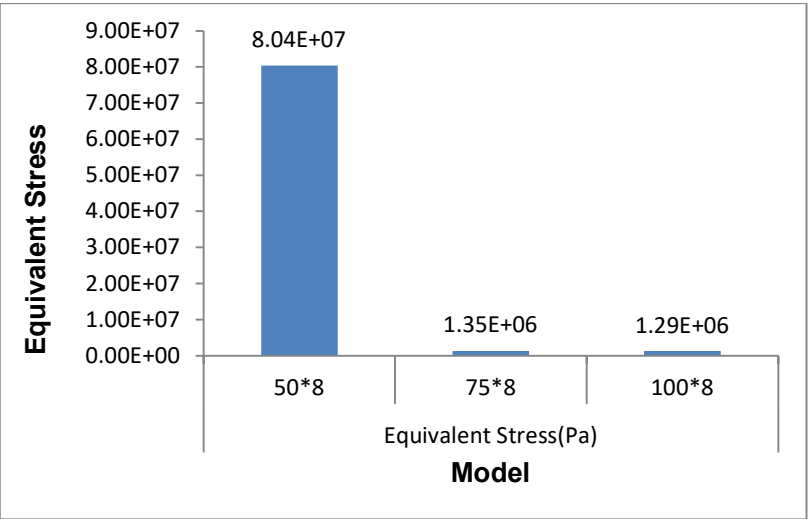


Figure:3.31 Equivalent Stress (Pa)

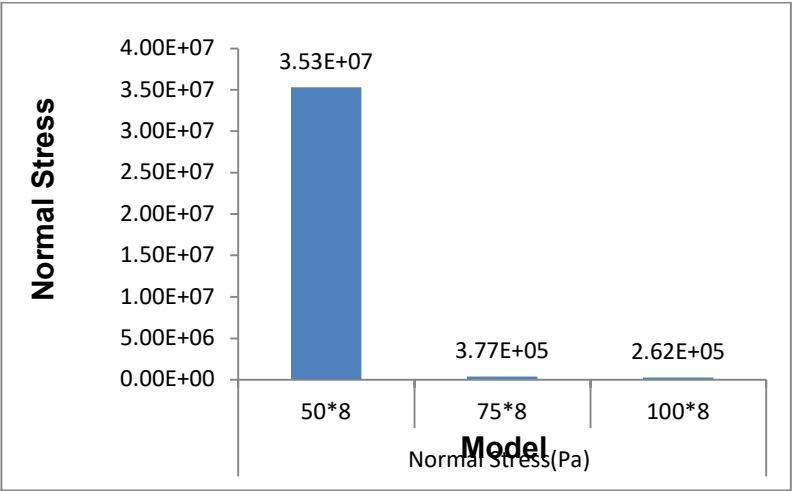


Figure:3.32 Normal Stress (Pa)

From the above figures 3.27,3.28,3.29,3.30,3.31 & 3.32 analytical data the 100mm welded connections performed well compare to 50mm & 75mm Welded connection plats.

CHAPTER 4

EXPERIMENTAL INVESTIGATION

4.1 INTRODUCTION

Steel is Environmental Nature, this is used as recyclable, Steel is Mould to which shape we Want. The Cold rolled Steel is a Construction Material, Compare to Concert Steel Construction work is easy. Steel Load Bearing Capacity we be Changed by Used Gauge.

To Analyze the behavior of two sigma column with battened connection using Ansys software. To test the designed column on loading frame under axial compression. Comparison of result both analysis & Experiment.

4.2 METHODOLOGY

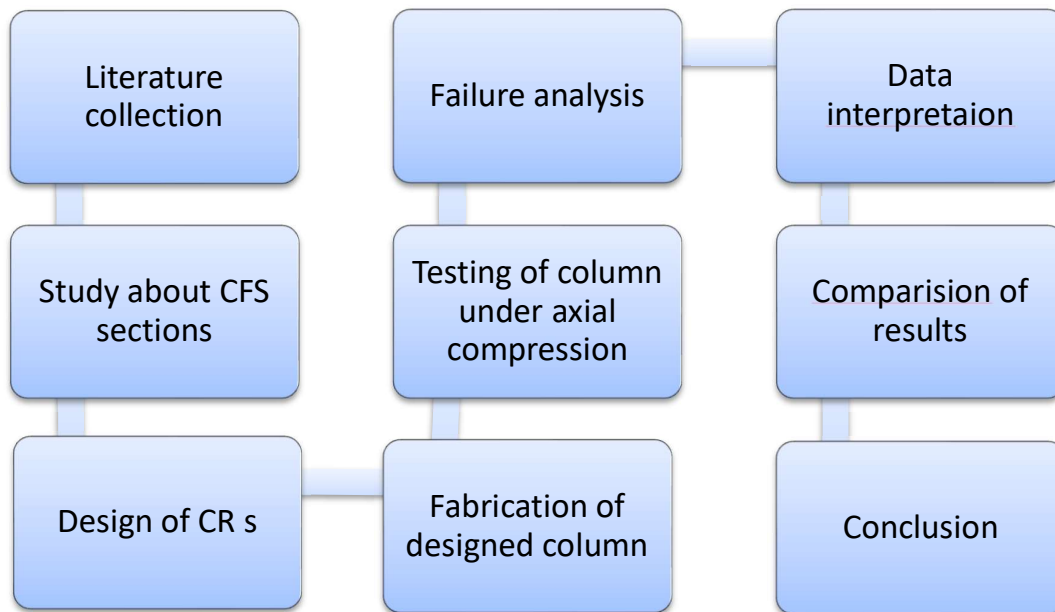


Figure: 4.1 Methodology

4.3 DESIGN OF SIGMA COLUMN

The below figure 4.2 shows the dimensions of welded battened connections for experimental data. The 50mm welded battened dimensions size & shape of sigma column for experimental was shown in figure 4.3

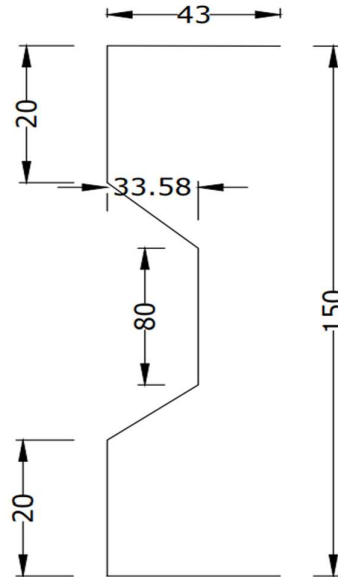
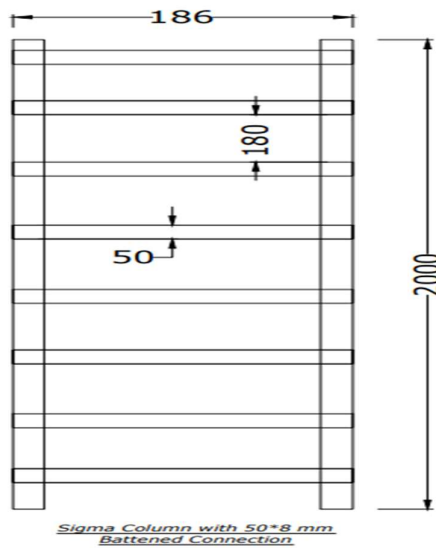
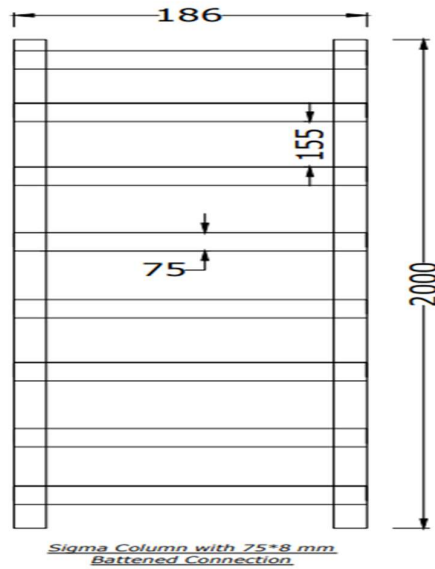


Figure: 4.2 Sigma Shape with Dimensions

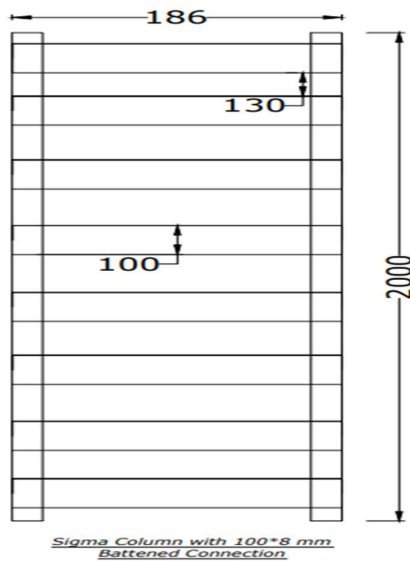


*Figure: 4.3 Sigma Column With 50*8mm Battened Connections*

The below figure 4.4 shows the dimensions of 75mm plat of welded battened connections for experimental data. The 100mm welded battened plates with dimensions & shape of sigma column for experimental was shown in figure 4.5



*Figure:4.4 Sigma Column With 75*8mm Battened Connections*



*Figure:4.5 Sigma Column With 100*8mm Battened Connections*

4.4 ANALYTICAL COMPARISON

The below figure 4.6 shown the analytical comparison of displacement when load applied on the sigma column.in this analytical data the 100mm welded connection is safe compare to 50mm & 75mm welded connection plates. 50mm plate reaches the 6.9mm displacement & 100mm plate reaches the 1mm displacement when load applied. For this below figure studied the 100 mm plate displacement is less than 50mm plat so the 100mm plate of sigma column is safe in analytical compression.

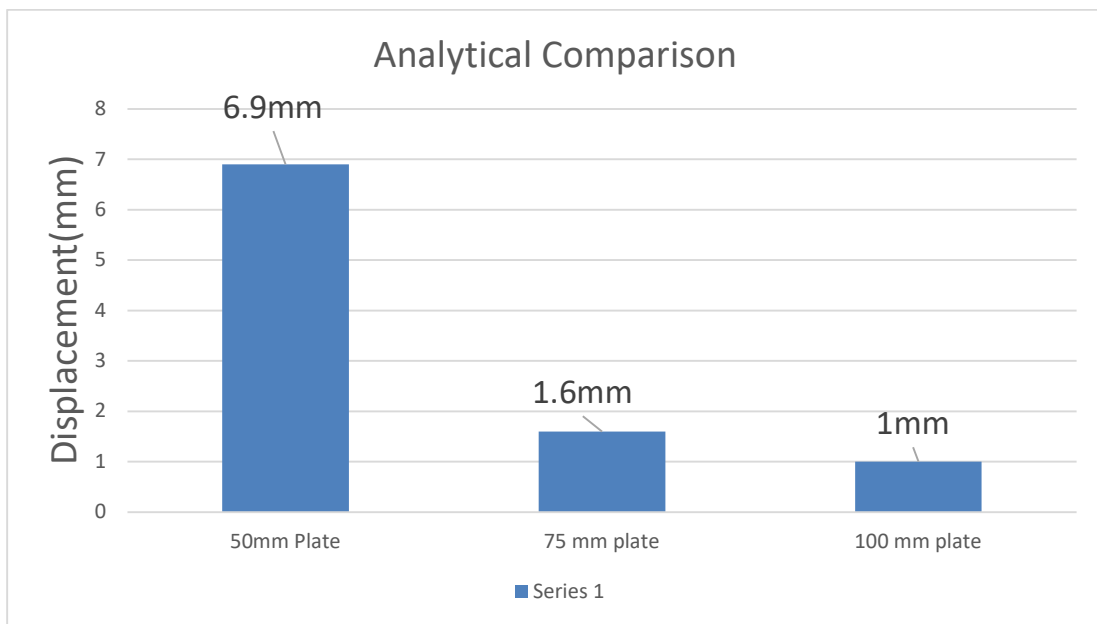


Figure:4.6 Analytical Comparison

4.5 PURCHASING OF CR SHEET

Available Cold rolled steel sheet in market with the dimensions of 1524mm X 2438mm. With the thickness of 2mm. The cost of CR Sheet is per 1kg 70rs. The weight of CR sheet is around 60kg. We have to do laser & Welded cutting into given model. In this experimental the CR sheet is Fabricated to sigma column & the sheet is shown in below figure 4.7

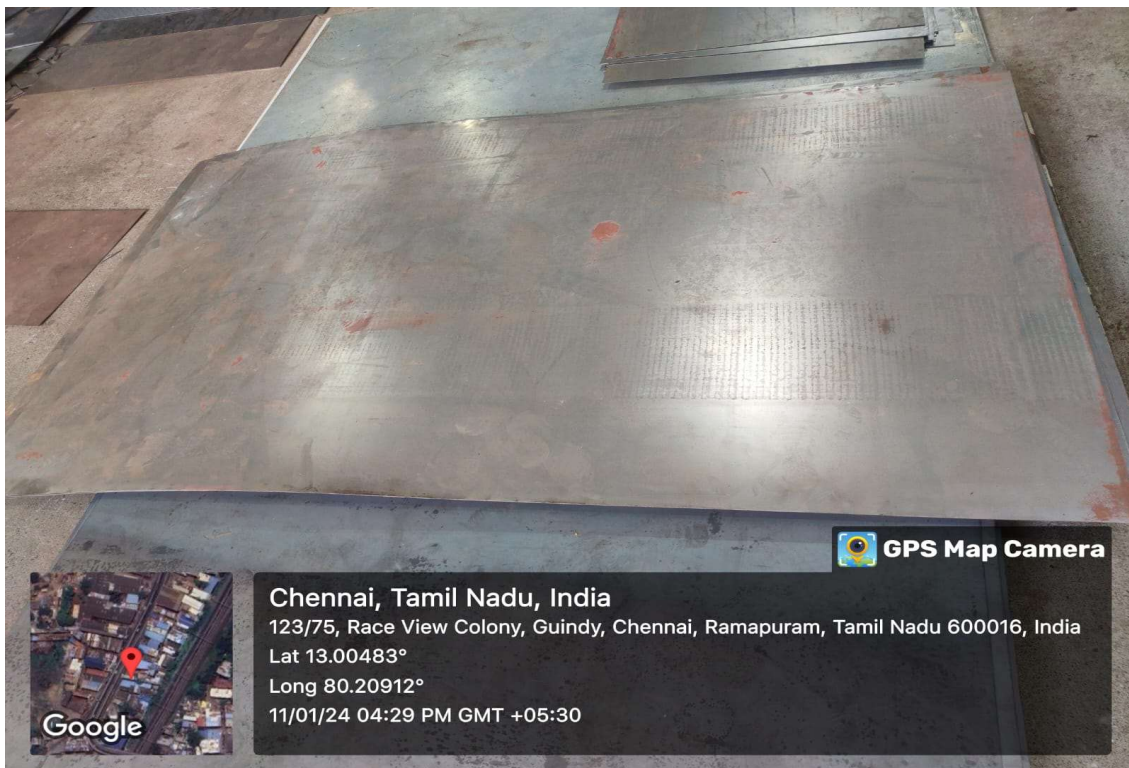


Figure: 4.7 Cold Role Sheet

4.6 MACHINE CUTTING & WELDING

The experimental dimensions for sigma column is length 2000mm & breath is 150mm, The distance between two sigma column is 186mm. The angle of Sigma column is 53.13° . Test done on three types of welded battened connections with 50mm,75mm & 100mm plats. Each side 8 no. of plats is welded to attach the two sigma columns. The CR sheet was cut into required size & it is shown in below figure 4.8

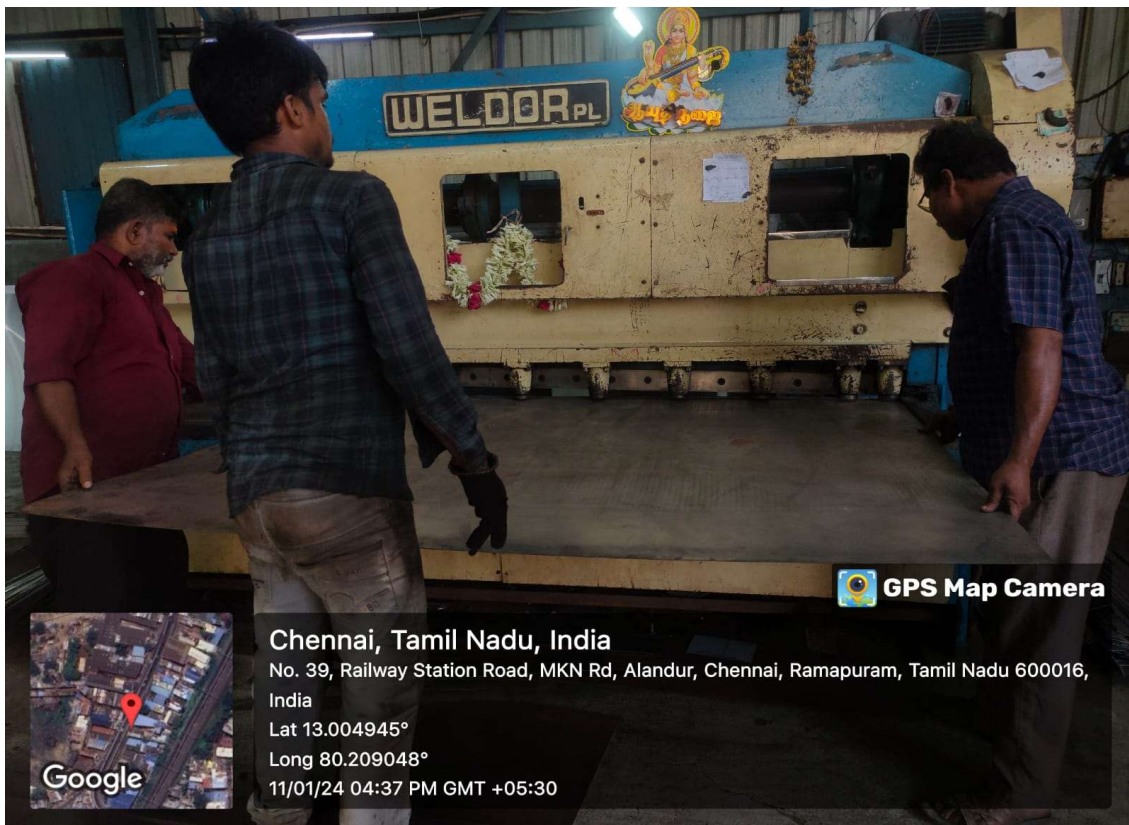


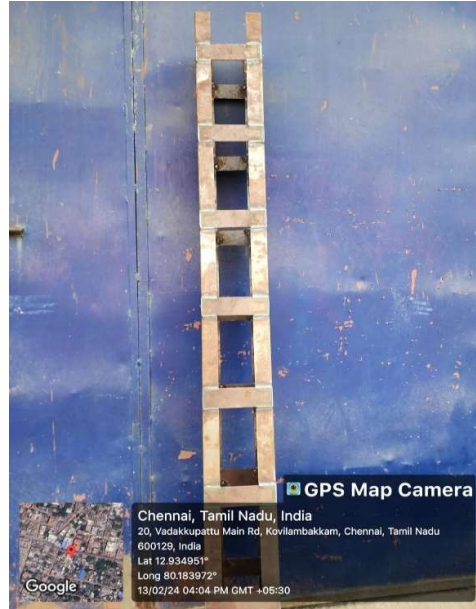
Figure:4.8 Machine Cutting

Welding is a Fabrication Process to Joint the Steel Materials, Using high heat to Melt the parts joint together & allowing them to cool. In this welding battened plates is welded to sigma section to joint the columns. 8 no. of plats is welded on each side with the distance between plate to plate is 210mm.in this process Mid welding is done to joint the plats as shown in below figure 4.9

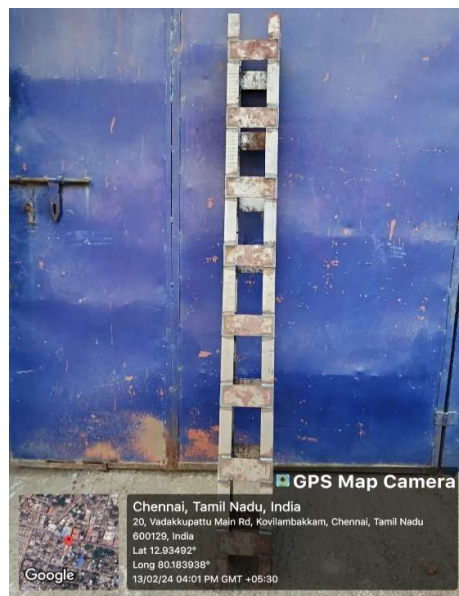


Figure:4.9 Welding of Battened Plates

The below figure 4.10 shows 50mm welded battened plates connection to the sigma section for the experimental investigation. The shape of the welded battened plates for 75mm sigma section is shown in the below figure 4.11



*Figure: 4.10 Shape of Sigma Column with 50 * 8mm
Plates*



*Figure: 4.11 Shape of Sigma Column with 75 * 8mm
Plates*

The below figure 4.12 shows 100mm welded battened plates connection to the sigma section for the experimental investigation. The shape & size of the three models of welded battened plates for experimental investigation is shown in the below figure 4.13



*Figure: 4.12 Shape of Sigma Column with 100 * 8mm Plates*

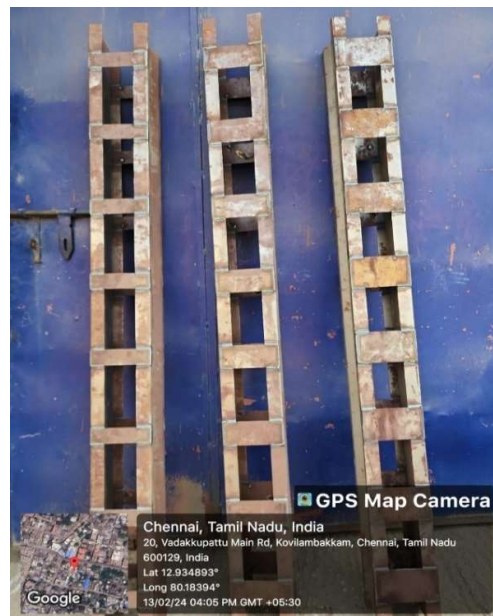


Figure:4.13 Shape of Sigma Column

4.7 EXPERIMENTAL SET UP

The experimental test is conducted on loading frame machine Capacity of 100 ton. Testing is done on Loading bearing capacity of sigma welded battened column. The Applied load & Deflection are measured using Load cell & LVDT Set up is Shown in the figure 4.14 & 4.15.



4.14: Setup for Experimental Test



Figure:4.15 Setup for Experimental Result

4.8 EXPERIMENTAL TEST RESULT

The below figure 4.16 shows the 50 mm Welded Battened sigma Column tested in Loading frame under axial compression load. The Ultimate Load for 50mm plat reaches the 183.7KN With displacement of 6.9mm. The validation of load & displacement was shown in figure 4.17



Figure: 4.16 50mm Welded Battened Plate Under Axial Load

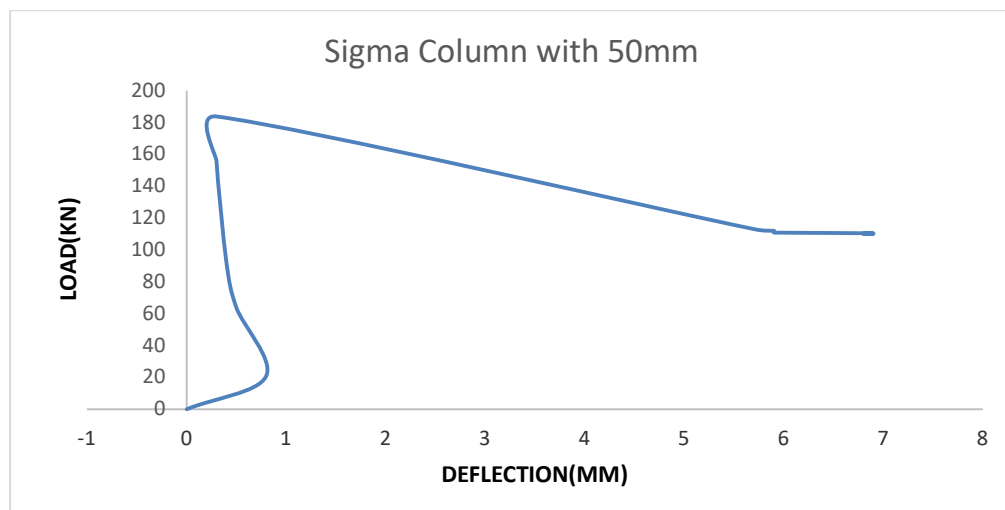


Figure:4.17 Load VS Displacement Curve for 50mm

The below figure 4.18 shows the 75mm Welded Battened sigma Column tested in Loading frame under axial compression load. The Ultimate Load for 75mm plat reaches the 187.96KN With displacement of 0.7mm. The validation of load & displacement was shown in figure 4.19



Figure :4.18 75mm Welded Battened Plate Under Axial Load

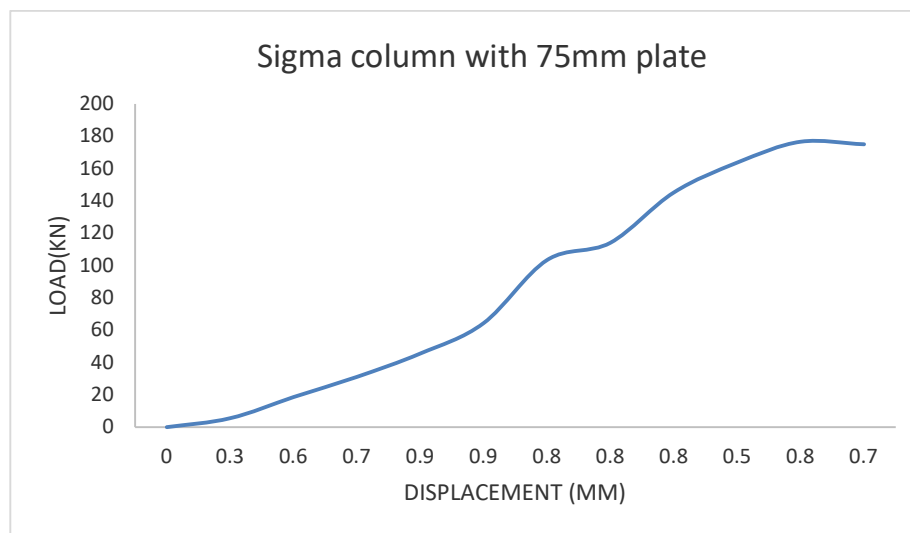


Figure :4.19 Load VS Displacement Curve for 75mm

The below figure 4.19 shows the 100mm Welded Battened sigma Column tested in Loading frame under axial compression load. The Ultimate Load for 100mm plat reaches the 227.99KN With displacement of 1.1mm. The validation of load & displacement was shown in figure 4.20

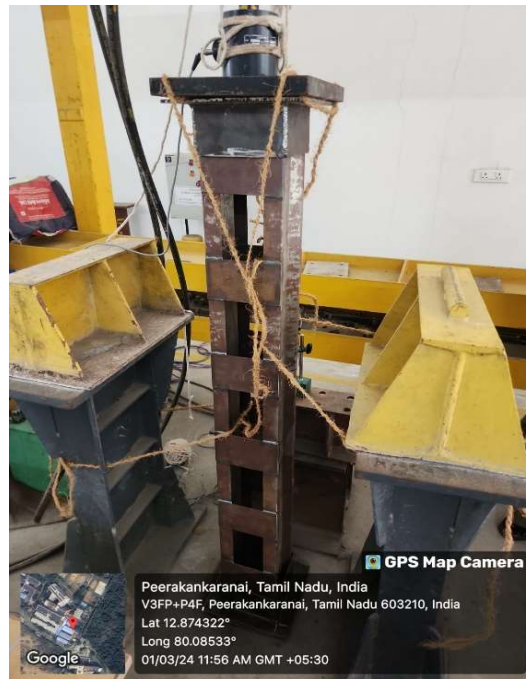


Figure 4.20 100mm Welded Battened Plate Under Axial Load

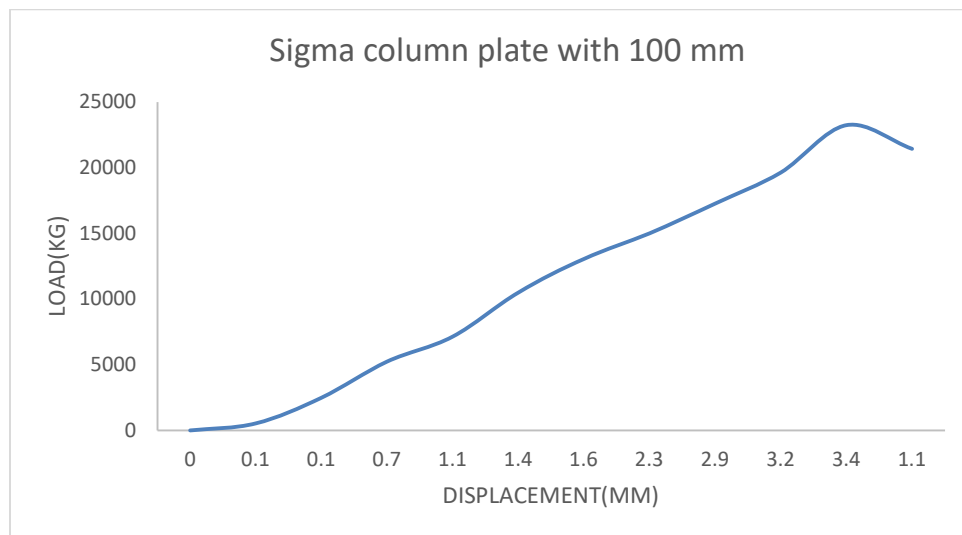


Figure 4.21 Load VS Displacement Curve for 100mm

CHAPTER 5

RESULT & DISSUCSION

5.1 COMPRESSION GRAPH

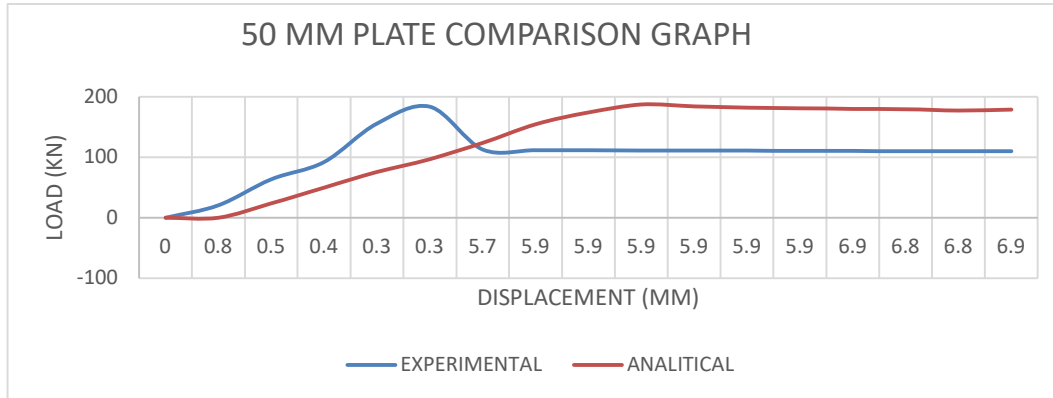


Figure:5.1 Compression Curve for 50mm Battened Connections

The above figure 5.1 shows the comparison of experimental & analytical. In this analytical Value is reaches the load of 187.24KN with displacement of 5.9mm.

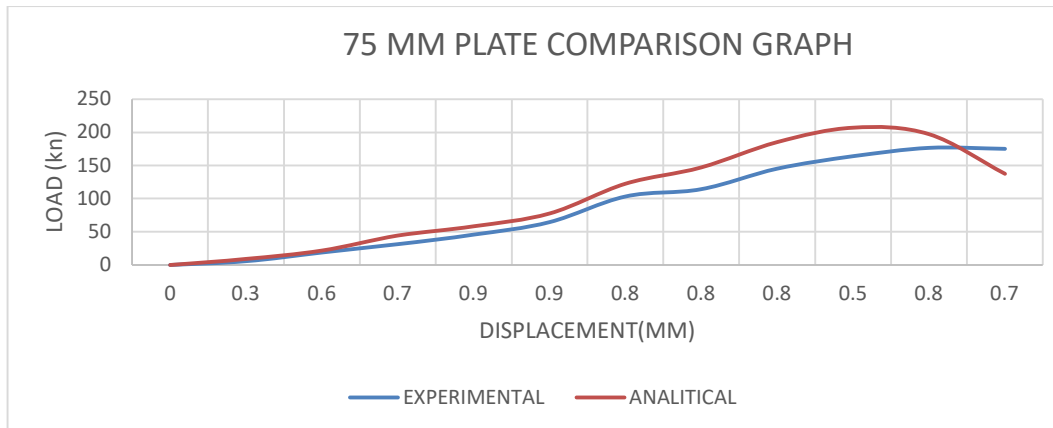


Figure: 5.2 Compression Curve for 75mm Battened Connections

The above figure 5.2 shows the comparison of experimental & analytical of 75 mm welded battened sigma column. Analytical Value reaches the ultimate load of 197.38KN with displacement of 0.7mm.

The below figure 5.3 shown the comparison of experimental & analytical of 100 mm welded battened sigma column. Experimental Value reaches the ultimate Value of 227.99KN with displacement of 3.4mm

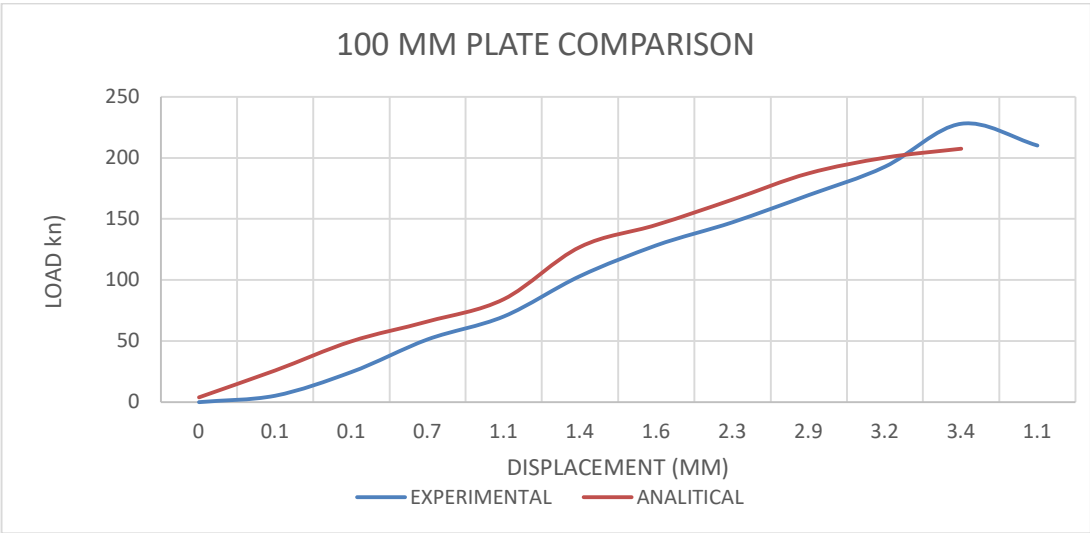


Figure :5.3 Comparison Curve for 100mm Battened Connections

The below figure 5.4 shows the experimental Compression between 50mm, 75mm & 100mm sigma welded battened Column. Compare to Three 100mm Plate reached the ultimate load of 227.99KN with displacement of 1.1mm.

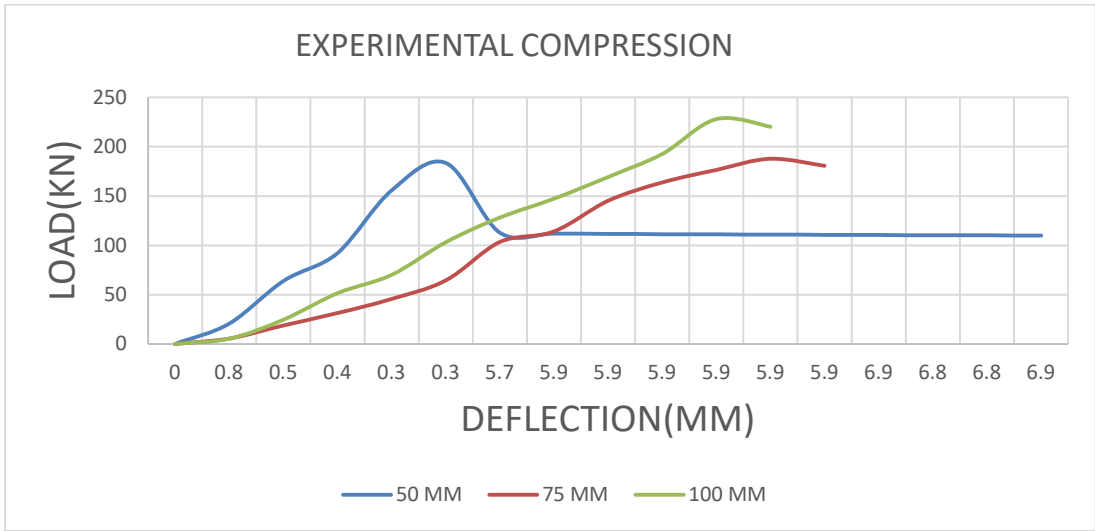


Figure :5.4 Experimental Compression for Three Models

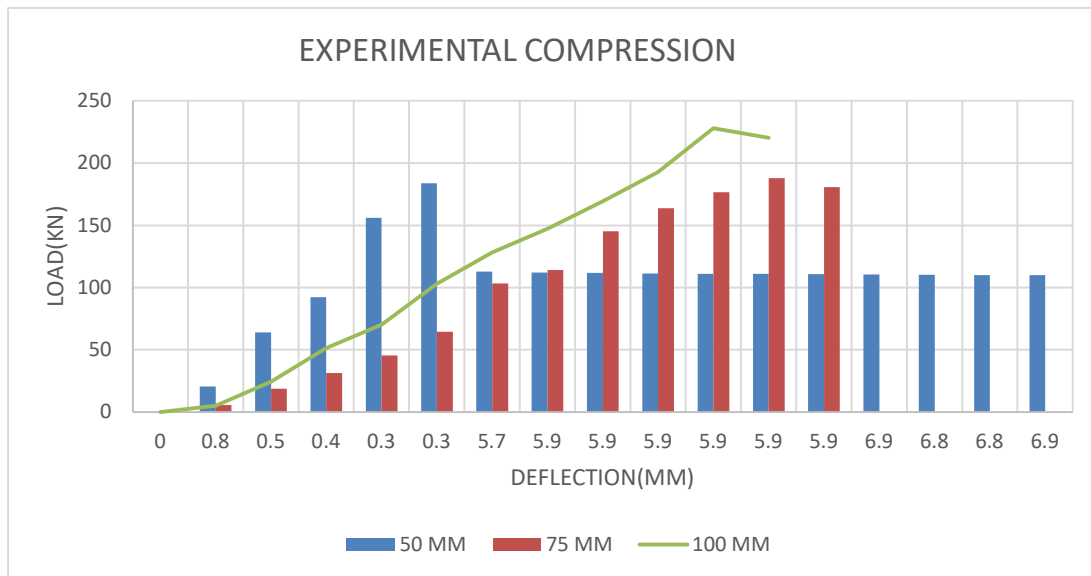


Figure:5.5 Experimental Compression for Three Models

The above figure 5.5 shows the bar chart of experimental compression & analytical compression. But in this bar chart shows the difference of each KN of load applied on the samples. For this above compression studied the 100mm plate is safe than remaining 50mm & 75mm sigma Welded plats.

CHAPTER 6

CONCLUSION

6.1 SUMMARY OF THE WORK

In this work we use sigma column welded battened connection of 50mm,75mm & 100mm. 2m of height with each side 8 plats joint total 16 plats of each column. For analytical data done in Ansys software. Compared the analytical & experimental data for the best result.in this study cold rolled steel is used. After compression data 100mm welded plat given the best result.

6.2 CONCLUSION

The Welded battened connection of Sigma Column is Studied by Analytical & Experimental. In this Study Consider 50mm,75mm & 100 mm Welded plates to joint the two sigma columns. Experimental test of these three columns the 100mm plate is reached the ultimate load with 227.99kn.50mm plate is reached the low ultimate load with 183.7kn. Experimental Values Compare to Analytical values the 50mm & 75mm Welded Plates given high ultimate Load Carrying Capacity. In Analytical 100mm Welded plate is given Low Ultimate loading capacity compare to Experimental Values.For 50mm Welded Battened connection the Analytical load is 187.23kn, Experimental Load is 183.69kn. For 75mm Welded Battened connection the Analytical load is 207.09kn, Experimental Load is 187.96kn. For 100mm Welded Battened connection the Analytical load is 227.99kn, Experimental Load is 187.96kn. The values are Nearly Equal to the Analytical & Experimental so we use this Process for Further.

6.3 FUTURE SCOPE OF THE STUDY

Although studied was conducted on CFS built-up battened columns, many details are still missing to present a fully reliable design methodology. The compression behaviour of CFS built up battened columns can be explored more when the batten panels are positioned in the minor axis of the columns. Therefore, more experimental, numerical & analytical are suggested for future studies to address more remained details of CFS welded battened columns.

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2. Bassem L.Gendy & M.T.Hanna, "Effect of geometric imperfections on the ultimate moment capacity of cold-formed sigma-shape sections", Volume 13,Pg No.163-170,2017.
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