

“STUDY ON BEHAVIOR OF COLD-FORMED STEEL BUILT UP COLUMN”

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

by

P ASWIN (39380003)



**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

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DEPARTMENT OF CIVIL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **P ASWIN (39380003)** who carried out the project entitled “**STUDY ON BEHAVIOR OF COLD-FORMED STEEL BUILT UP COLUMN**” under my supervision from November 2020 to April 2021

Internal Guide

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Assistant Professor

Submitted for Viva voce Examination held on _____

Internal Examiner

External Examiner

DECLARATION

I **P ASWIN** hereby declare that the Project Report entitled “**STUDY ON BEHAVIOR OF COLD-FORMED STEEL BUILT UP COLUMN**” done by me under the guidance of **Mr. C. MANOJ KUMAAR** at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** is submitted in partial fulfillment of the requirements for the award of Masters of Engineering degree in Structural Engineering.

DATE:

PLACE:CHENNAI

SIGNATURE OF THE CANDIDATE

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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.

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ABSTRACT

Cold-formed steel (CFS) is a type of steel manufactured by cold-working process which has been carried out at room temperature, by the process such as rolling, pressing, stamping, bending, etc. The types of CFS sections are cold-formed from steel sheet, plate, or flat bar, by press brake (machine press) or bending operations. Indian standard code of practice for use of cold-formed light gauge steel structural members in general building construction is IS 811 : 1987. In my project, behavior of built-up cold formed steel I section column with various web stiffeners under loading is discussed. Failure modes were observed and buckling of column is obtained. Buckling failure modes were observed.

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CHAPTER- 1

INTRODUCTION

1.1 GENERAL

Steels are of two types namely hot rolled steel and cold rolled steel. Hot rolled steel manufactured at high temperature and cold rolled steel manufactured at room temperature. Hot rolled steels are heavy weight steel where as cold rolled steels are light weight steel. In the project cold rolled is used for making of columns. Five different types of built up cold formed steel I section column with various web stiffeners are made.

1.2 COLD FORMED STEEL

Cold-formed steel is a type of steel made at room temperature by cold-working process such as rolling, pressing, stamping, bending, etc. Generally cold-rolled steel sheets and stock bars are used for manufacturing cold-formed steel products. CFS will be as thin gauge sheets commonly used in the construction industry for structural or non-structural elements such as columns, beams, built-up sections and other components. CFS also used in various types of equipment. Cold-formed steel products was formed at room temperature. The manufacturing process of CFS involves press-braking , cold roll forming to achieve the desired shape.

1.3 PROPERTIES OF COLD FORMED STEEL

- Less in weight.
- It has high strength and stiffness.
- Fabrication is easy.
- It is very useful for mass production.
- Erection and installation will be easy.
- Doesn't need any formwork.
- It is non-combustible.
- It can be recyclable.
- Non shrinking and creeping at normal temperature.

1.4 INTRODUCTION TO WELDING

Built-up column is made using welding operation. There are different types of welding operations available namely,

- Arc welding
- Gas Metal Arc welding
- Tungsten Inert Gas welding

Here arc welding is employed. In arc welding, fillet welding is employed.

1.5 PROJECT INTRODUCTION

Nowadays CFS has made innovations in steel structures. CFS can also be used for minor works and government has taken necessary steps to improve the usage of CFS in steel products. Here, CFS is used for making built up column. For making the column welding is used instead of bolted connection since bolted connection reduce the area of the column. While using bolted connection bearing capacity will be reduced to avoid welding is preferred so that the column will be more stronger. In case of steel beams the load carrying capacity can be increased by increasing the weight and size of the column. In our case, using of I section reduce the weight of the column, thereby reducing the cost. Welding is a tedious and welding of shorter column will be easy but welding of longer column is more tedious. Built up I section column is analyzed and experimentally tested for load vs buckling. The analytical and experimental results are compared and better section is identified. Totally 5 built up I section columns are created with the help of ANSYS software.

CHAPTER- 2

Literature Review

Tianhua Zhou et.al, General lots of research were made in hot rolled steel and conservative strength were estimated. In this paper computing method has been arrived for determining the flexural buckling bearing capacity of cold formed steel built-up back to back section columns. New flexural buckling model is prepared to establish the kinematic relationship. In this paper shear panels were employed at the location of screw which is considered as the discrete shear deformation restraint effect. The rigidity of the shear panel was determined using the cross-sectional shear stress. By using energy method the computing method has been derived. To verify the the computing method a finite element model is developed. Then based on developed finite element model parametric studies were performed to verify the derived computing method. By comparing the ultimate strength based on direct strength method and finite element model the comparison and the validation results shows the formula derived can predict the critical structural buckling load as well as corresponding buckling strength based on direct strength method, increasing screw spacing modified slenderness method will results conservative strength estimates for cold formed steel built up back to back section column.

Shao-Feng Nie et.al, In this paper thirty specimens of built-up closed box section consisting of two cold-formed steel channels sections of various cross sections with different lengths of 3000, 1500, 450 and 270 mm and thickness of 1.2 and 1.5 mm are created. The specimens are tested with concentric and eccentric axial compression. Analysis were made for different failure modes and curves were obtained for load versus displacement. The test results indicates long column which is subjected to concentric axial compression undergoes flexural buckling about the weak axis where as short column undergoes local buckling, when the column is subjected to eccentric axial compression strong and weak axes exhibit flexural torsional buckling and flexural buckling respectively. Finite element model were created. Parametric studies were performed to determine the accuracy of code equation. The finite element analysis results indicates the

concentric axial compressive strength of the column decrease with an increase in slenderness ratio of column or web height to thickness ratio, increasing the flange width which increase the stability and strength of the column, the eccentric axial compression strength of the column about the weak axis decreases faster than about the strong axis.

Jia-Hui Zhang et.al, this paper clearly explains about experimental investigation on cold-formed steel built up closed section column with web stiffeners. To create built-up closed section, first single open sections were formed by brake press operation with high strength steel plate of thickness 0.48 and 1 mm. Then two single open sections were connected together face to face by self tapping screws. After determining the material properties the initial geometric imperfections were made. The specimens were tested and failure modes observed. The specimens failed by local buckling and interaction between local and flexural buckling. Ultimate strength of the specimen were determined which is used to compare the column strength calculated using direct strength method. The results shows direct strength method is suitable for design calculation of cold-formed steel built up closed section column with web stiffener.

Francisco J. Meza et.al, in this paper there are 24 built-up columns in total, each with a different cross-sectional geometrie. The loads were applied with nominal eccentricities of $L/1000$ or $L/1500$, and the specimens were examined between pin-ended boundary conditions. Between specimens of the same geometry, the connector spacing was varied. The flat parts and corners of the sections were checked for tensile strength to assess their material properties, as well as precise measurements of the geometric imperfections. The isolated behaviour of the bolts and screws used in the specimens was also investigated. The interaction between the different components and the spacing between the connectors were found to influence the buckling patterns in the built-up specimens. The connector spacing had a slight impact on the ultimate capability of the columns in cases where global buckling of the components in between connector points was not critical.

Francisco J. Meza et.al, This paper describes a detailed experimental programme that looked at four different cross-sectional geometries of built-up cold-formed steel stub columns. Individual channels and flat plates with nominal thicknesses ranging from 1.2 mm to 2.4 mm were fabricated and assembled using bolts or self-drilling screws to create twenty built-up parts. In order to investigate the effect of connector spacing, specimens of the same geometry were varied. Tensile coupons were taken from the corners and flat portions of the constituent parts to assess their material properties, and a laser displacement sensor was used to take precise measurements of each specimen's geometric imperfections. During buckling, the tests showed a considerable amount of restraint and contact between the individual components of the columns, with connector spacing having a significant effect on the buckling modes observed. Within the considered range of connector spacings, however, the ultimate cross-sectional capability was found to be less dependent on connector spacing.

Krishanu Roy et.al, The flexural potential of back-to-backgapped built-up cold-formed steel (CFS) channel sections under four-point bending was investigated experimentally and numerically in this paper. The difference between the back-to-back channels was created by screwing intermediate link-channels to the back-to-back channels' webs. On the flexural potential of back-to-back gapped built-up CFS channel sections under four-pointbending, a total of 90 results were recorded, including 18 laboratory tests and 72 finite element (FE) analysis results. The built-up channels were made up of three different types of channels: clear channels, channels with one web stiffener, and channels with two web stiffeners. Two separate beam spans were tested: 1000 mm and 2000 mm. Prior to bending tests, all research specimens had their initial geometric imperfections measured. The findings of a nonlinear FE model were then compared to the laboratory test results and found to be in good agreement. The effects of web stiffeners and link-channel spacing on the flexural ability of such gapped built-up beams were investigated using the validated FE model in a parametric analysis. As compared to gapped built-up beams with plain channel section, the flexural performance of back-to-back gapped built-up parts with two web stiffeners was improved by 10% on average.

Amir Jameei Osgouei et al., Web openings are often required in cold-formed steel members to enable building utilities such as mechanical plumbing, electrical wiring, and air conditioning systems to move through the roof, reducing the total height of the building and, as a result, the lateral forces exerted on the structure. Members with openings have different stress distributions than members without holes, resulting in different buckling properties, shapes, and modes, resulting in lower buckling ability and ultimate power. Edge and intermediate stiffeners are fabricated into the web to compensate for some of the lost power, complicating the properties and buckling mode. This research develops and summarises a series of analytical solutions for local buckling of cold-formed steel webs with rectangular openings stiffened by intermediate and edge stiffeners subjected to compression, bending, and their combination. The suggested solutions are applicable to a variety of rectangular web openings. Energy-based approaches are used to perform analyses, and the results are compared to numerical data collected from commercial finite element software (Abaqus). The numerical results show that one of the eight proposed formulas can effectively predict the critical buckling stress with minor modifications.

Mohamed Dabaon et al., The nonlinear behaviour and architecture of built-up cold-formed steel segment batten columns are discussed in this paper. The pin-ended built-up columns were made up of two cold-formed steel channels that were mounted back-to-back and connected with batten plates. To simulate the structural performance of the axially loaded columns, nonlinear 3-D finite element models were created. The models took into account the nonlinear material properties of the flat and corner portions of the channels, as well as initial geometric imperfections, real geometries, and boundary conditions. The finite element models were compared to experiments on the same type of construction that the authors had recently performed and published on. The finite element analyses predicted column weights, failure modes, deformed shapes at failure, load lateral displacement, and load-axial strain relationships, which matched the test results well. Furthermore, the validated finite element models were used to conduct a parametric analysis examining various parameters influencing the behaviour of the columns, including slenderness, column lengths, cross-section geometries, steel weights, channel spacing, and batten plate spacing. In addition,

the parametric study's projected column strengths were compared to design strengths determined using the North American Specification, Australian/New Zealand Standard, and European Code for cold-formed steel columns.

Krishanu Roy et.al, Column members in cold-formed steel systems, such as cold-formed steel trusses, space frames, and portal frames, are increasingly using face-to-face built-up cold-formed steel channel sections. Intermediate fasteners prevent the members from buckling independently in this configuration. There is no study for such face-to-face built-up cold-formed steel columns in the literature. The problem is discussed in this article. The results of 36 experimental experiments on face-to-face built-up cold-formed steel channel-sections covering a wide spectrum of slenderness from stub to slender columns are presented in this paper. After that, a nonlinear finite element model is represented, which agrees well with the experimental results. Material non-linearity, initial imperfections, and modelling of intermediate fasteners are all included in the finite element model. The design strengths measured in conjunction with the American Iron and Steel Institute (AISI), as well as the experimental results, are compared. A parametric analysis with 90 models is conducted using the verified finite element model. The influence of fastener spacing on axial strength was studied. According to the results of experiments and finite element analyses, architecture in accordance with the AISI& AS/NZS and Eurocode (EN 1993-1-3) is typically conservative by about 15%; however, AISI& AS/NZS and Eurocode (EN 1993-1-3) can be un-conservative by 8% on average for face-to-face built-up columns that failed due to local buckling.

M. Adil Dar et.al, The performance of built-up cold-formed steel (CFS) columns under monotonically increasing axial compression loading is the subject of this research. Using four CFS angle sections linked by single lacing systems, five test specimens of built-up columns were fabricated. In the test specimens, the width-to-thickness ratios and slenderness ratios of chord and lacing components, as well as the height of columns, were varied. The key parameters tested in the experimental investigation were column strengths, axial load vs. displacement response, mode of failure, and deformed configurations. The test results were used to validate the established numerical models. For built-up laced CFS

columns, the test results were used to create column strength curves. Finally, the findings of this research were compared to the design strength predictions for CFS sections given by North American and European Standards.

M.Anbarasu et.al, Where a single individual section is inadequate, cold-formed steel built-up parts are widely used as compression components to support larger loads and over longer spans. The cold-formed steel built-up web stiffened lipped channel parts under axial compression are studied in this paper. Two identical lipped channels are mounted back to back with batten plates and connected by a self-driving screw to shape the built-up parts. ABAQUS software is used to construct the finite element model, which is then checked against published data. Based on the AISI-S100:2007 Geometric limitations, three types of web stiffened lipped channel cross sections were chosen for the analysis. The validated model for different slenderness ratios is added to the parametric analysis. The finite element analysis predicted column strength is compared to the direct strength approach predicted column strength (DSM). DSM will be given a recommendation based on this research.

Krishanu Roy et.al, Cold-formed steel structures such as trusses, wall frames, and portal frames use back-to-back built-up cold-formed steel un-lipped channel sections. Intermediate fasteners in such built-up columns prevent individual channel sections from buckling. For back-to-back built-up cold formed steel un-lipped channel parts, no experimental experiments or finite element analyses have been published in the literature, and no one has looked into the effect of screw spacing on axial strength of such columns. In this article, the problem is discussed. 95 finite element studies spanning stub to slender columns are presented. The authors' experimental tests for back-to-back built-up cold-formed steel lipped channel sections are used to validate the finite element model. The validated finite element model is then used in a parametric analysis to look into the effect of screw spacing on the axial strength of back-to-back cold-formed steel un-lipped channel parts. When the results are compared to the axial strength of built-up lipped channel sections, it is discovered that the un-lipped built-up sections have a 31 percent lower axial strength on average than the built-up lipped channel sections. The American Iron and Steel Institute (AISI) and the Australian

and New Zealand Standards were both found to be over-conservative by about 15% for built-up columns that failed due to overall buckling, but un-conservative by around 8% for built-up columns that failed due to local buckling.

M. Anbarasu et.al, The aim of this paper is to look into the structural response of cold-formed steel built-up columns made up of lipped sigma sections with pinned ends and predict their ultimate resistance. The finite element code ABAQUS is used to build a numerical model for this purpose. Geometric and material nonlinearity are used in the finite element models. In the finite element modelling, the effects of initial local and overall geometric imperfections were taken into account. The results of the nonlinear finite element analysis were cross-checked against existing experimental results in the literature. The effect of member slenderness, height-to-width ratio, and trapezoidal stiffener depth on the ultimate resistance of cold-formed steel closed built-up columns was investigated using the proven finite element model in a parametric analysis. The suitability of the existing direct strength system in the North American Specification for cold-formed steel columns is evaluated based on the parametric results presented here. Based on these findings, a design term is proposed for predicting the design strength of a cold-formed steel built-up column made up of lipped sigma parts, which is then tested through reliability testing.

M. Anbarasu et.al, The structural behaviour of closed cold-formed steel (CFS) was the subject of this investigation. Under four-point bending around the main axis, built-up beams made up of twosigma parts fail mainly due to local buckling. Its aim is to develop precise finite element models for CFS built-up I-beams that are subjected to a transverse load. The numerical model was created using the ABAQUS 6.13 Finite Element (FE) programme. The numerical models were discretized using the S4R element, with the end condition set to simply supported, and a non-linear analysis that took into account material, geometric, and touch non-linearities, as well as geometric imperfections. The numerical parametric analysis was carried out using the validated FE model for different cross-section geometries and thicknesses of the built-up closed beam, and the obtained flexural resistances were compared with those expected using current DSM and DSM proposed for built-up beams. As the compression flange width to

thickness ratio is increased, the moment power decreases. In general, as the aspect ratio decreases, the section's moment of resistance increases. The improvement in web stiffener depth has no noticeable impact on the flexural strength of built-up closed beams. Based on the comparison of results, suitable modifications for DSM are proposed herein, especially for closed built-up beams made of two sigma sections that are commonly failed by local buckling, and the performance of the current DSM, DSM proposed for built-up beams, and the DSM proposed by this study are also assessed through reliability analysis.

Yan Lu et.al, The aim of this paper is to look into the structural response and predict the ultimate strength of cold-formed built-up I-section columns that have been subjected to local, distortional, global, and, in particular, local-distortional (LD) interactive and local-distortional-global (LDG) interactive buckling modes. Under uniaxial compression load, a total of 18 single C-section columns and 18 built-up I-section columns were evaluated for this purpose. The test varied the cross-sectional size, thickness, and length of the measured members to cover a wide spectrum of local, distortional, and overall slenderness. LD interaction was observed in the test for a built-up column with a short duration, as well as LDG interaction for a built-up column with an intermediate length. Since the test revealed that LD and LDG interactions cause significant ultimate strength erosion in cold-formed built-up I-section columns, this paper proposes a novel direct strength dependent approach to measure such an erosion effect. The comparison results showed that the proposed approach would accurately estimate the ultimate intensity of a cold-formed built-up I-section column subjected to both pure and interactive buckling.

CHAPTER- 3

MATERIAL PROPERTY

The material property of cold-rolled steel sheets are generally obtained by testing cold-rolled steel sheet. It undergoes tensile testing so that the properties can be obtained. IS 513:2008 is Indian standard used for cold-formed section.

Table: 1 MATERIAL PROPERTY

Property	Value	Unit
Density	7860	kg/m ³
Poisson's ratio	0.3	-
Yield stress	240	MPa
Tensile strength	370	MPa
Young's modulus	200000	MPa
Elongation percent	30%	-

CHAPTER- 4

SPECIMEN SETUP

Five different types of cold-formed steel columns are modeled namely BI (Built up I section column), BIT (Built up I section column with double Tee section), BIIT (Built up I section column with double Tee inverted section), BIA (Built up I section column with double angle section) and BIC (Built up I section column with double channel section) using ANSYS workbench software. Among them, three sections are fabricated namely BI (Built up I section column), BIT (Built up I section column with double Tee section) and BIA (Built up I section column with double angle section) using cold-formed steel sheets of grade CR2. The sections are fillet welded using arc welding as shown in figure.

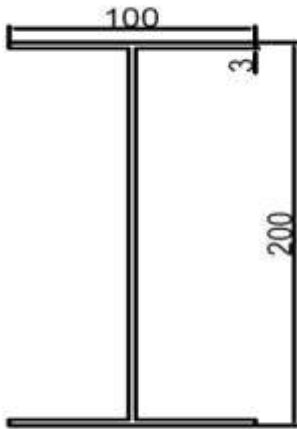


FIG 4.1

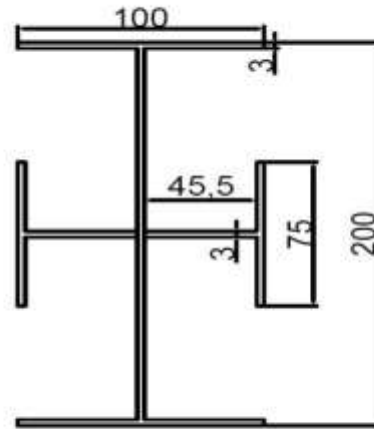


FIG 4.2

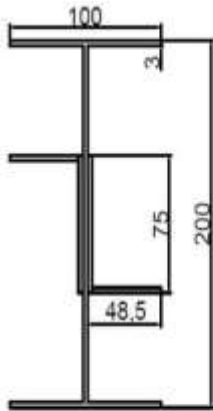


FIG4.3

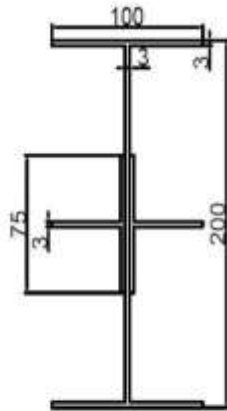


FIG 4.4

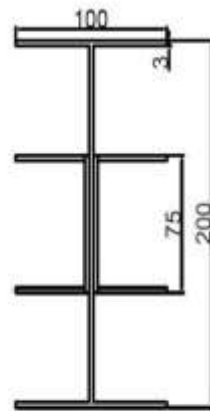


FIG4.5

CHAPTER- 5

STRUCTURAL ANALYSIS USING ANSYS

5.1 ANSYS WORKBENCH

Structural analysis is performed using ANSYS software. ANSYS software is used for determining the total deformation and buckling modes in built-up column. In ANSYS, geometry was created with sketching command following that constraints are given. Dimensions of the model were made with equal length command. Fixed support conditions were given after completing the geometry. Loads were applied with force command. Required results were inserted with analysis command and total deformation were obtained for the given load. Buckling was obtained with the help of eigenvalue buckling, in that deformation about different axes were obtained.

5.2 MODELLING OF SPECIMEN



FIG 5.1 3D MODEL OF BUILT UP I SECTION



FIG 5.2 3D MODEL OF BUILT UP I SECTION WITH DOUBLE TEE SECTION

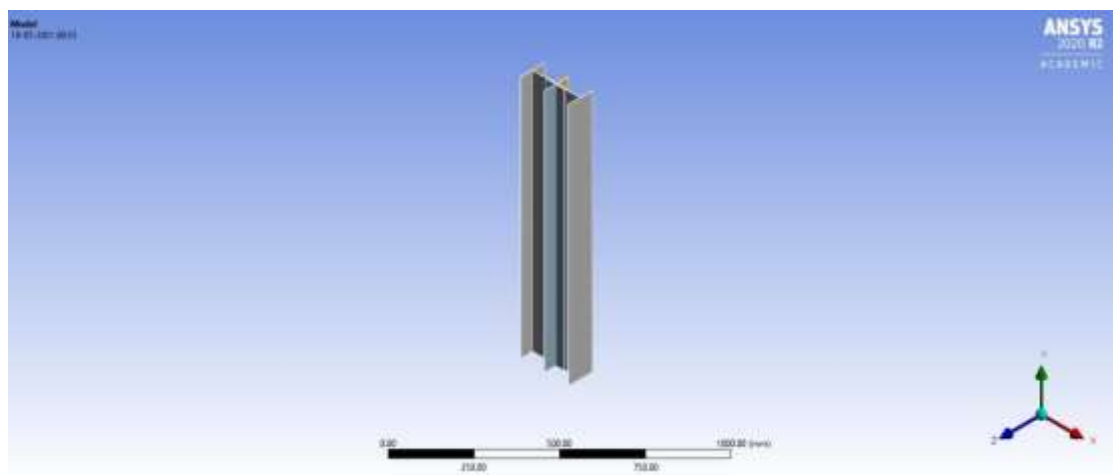


FIG5.3 3D MODEL OF BUILT UP I SECTION WITH INVERTED DOUBLE TEE SECTION

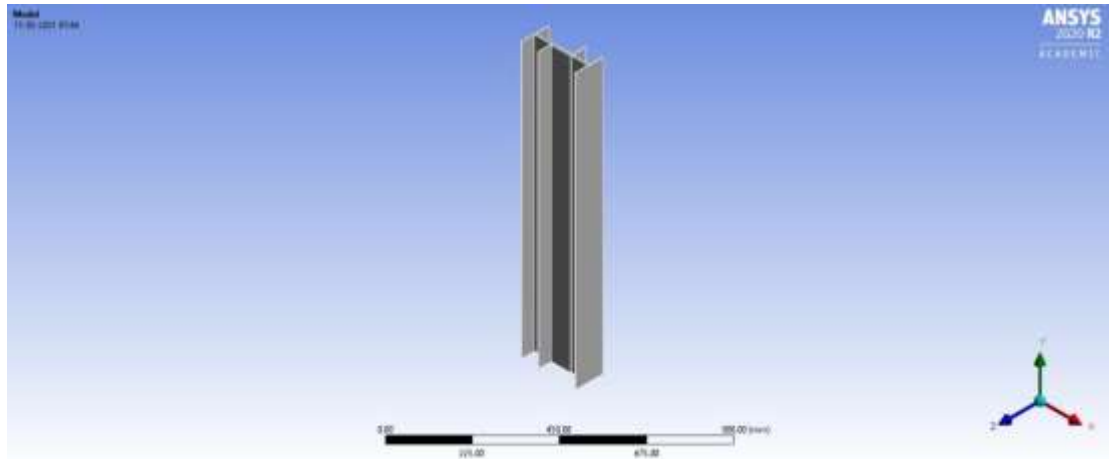


FIG5.4 3D MODEL OF BUILT UP I SECTION WITH DOUBLE ANGLE SECTION

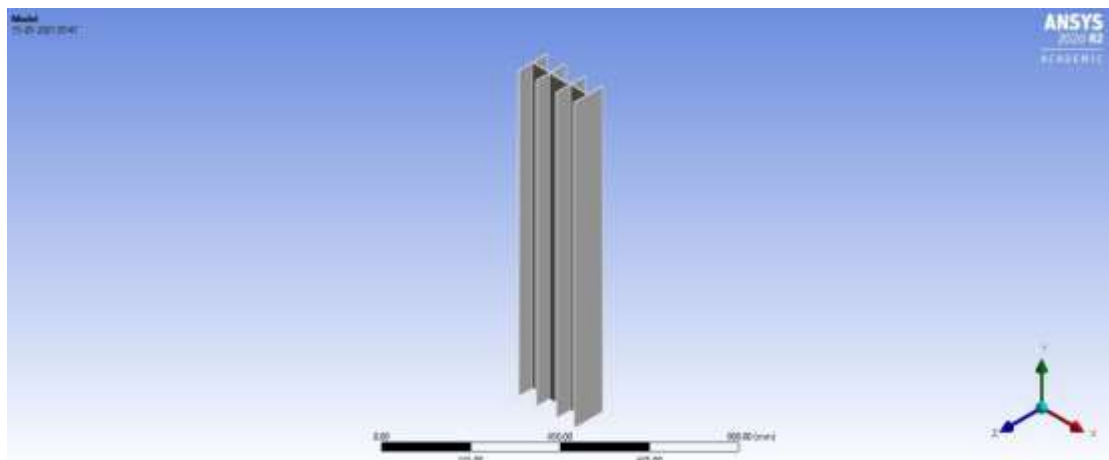


FIG5.5 3D MODEL OF BUILT UP I SECTION WITH DOUBLE CHANNEL SECTION

5.3 MESHING OF SPECIMEN



FIG5.6 MESHING OF BUILT UP I SECTION

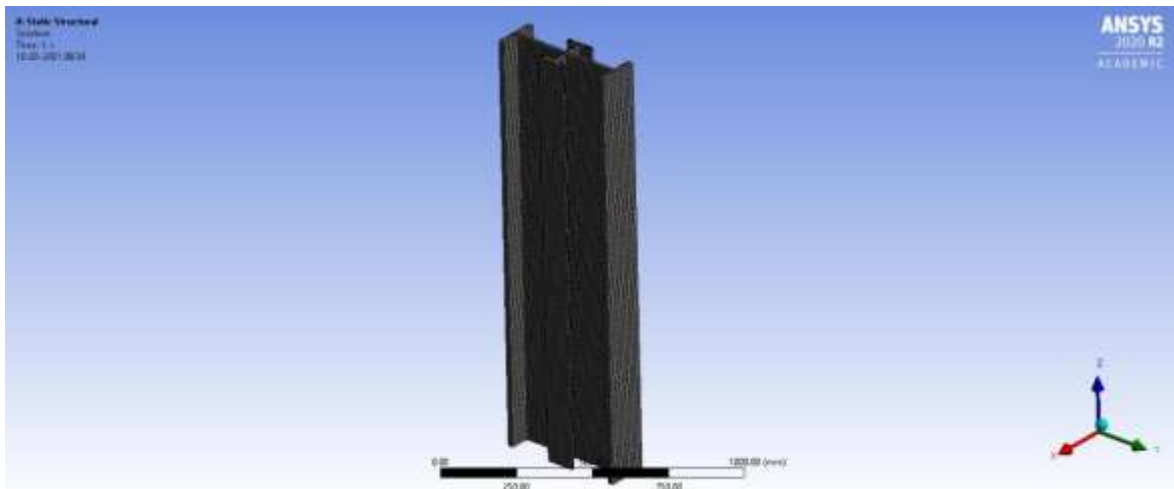


FIG 5.7 MESHING OF BUILT UP I SECTION WITH DOUBLE TEE SECTION

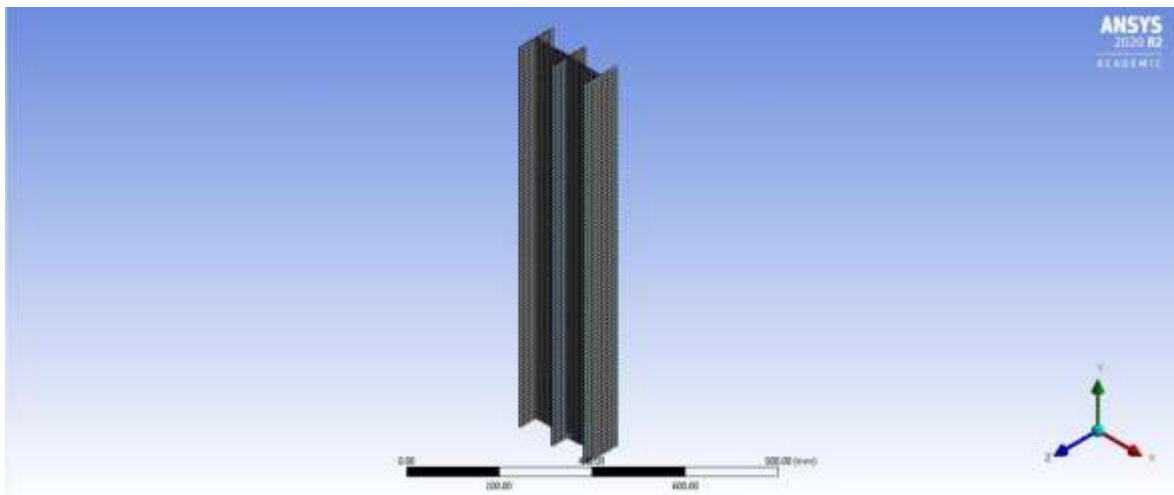


FIG5.8 MESHING OF BUILT UP I SECTION WITH INVERTED DOUBLE TEE SECTION

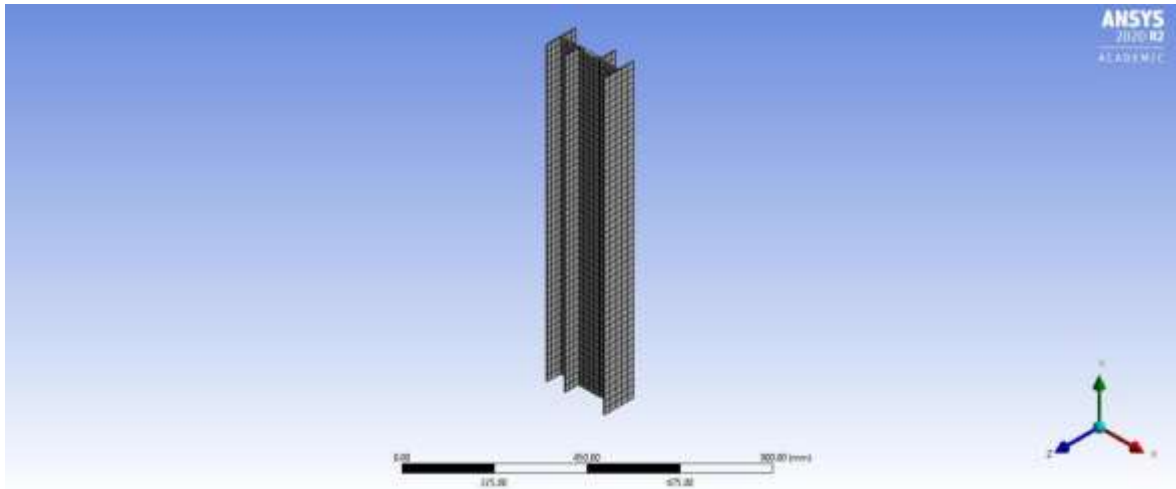


FIG5.9 MESHING OF BUILT UP I SECTION WITH DOUBLE ANGLE SECTION

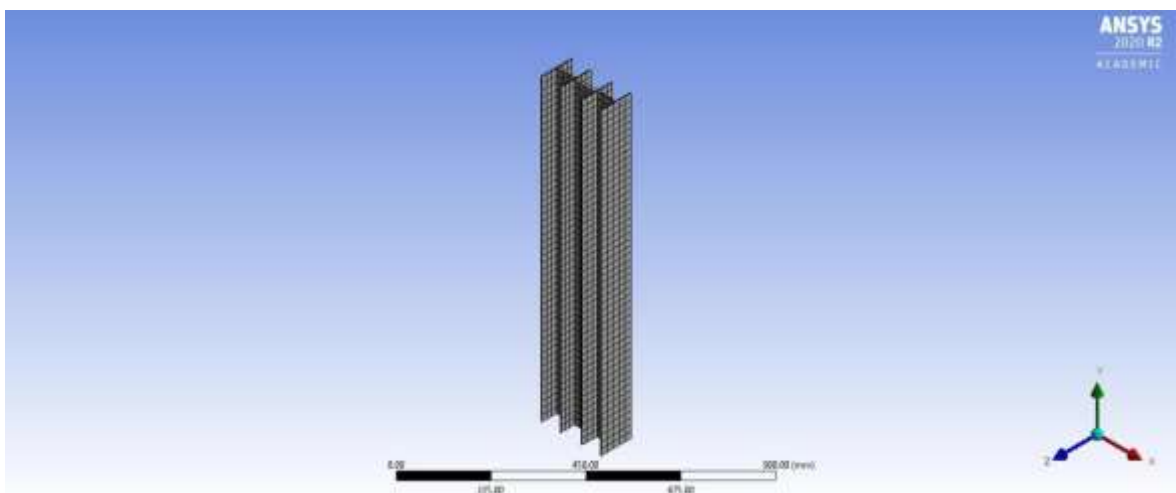
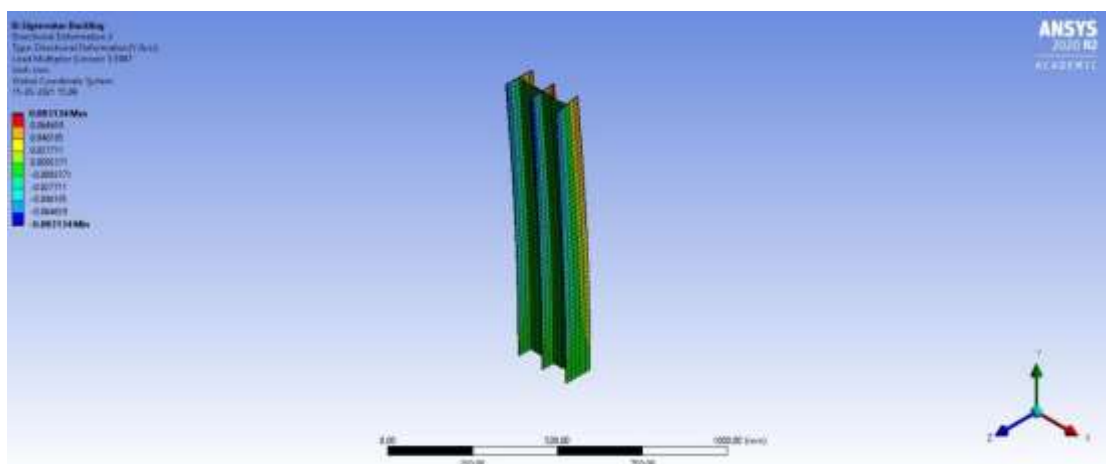
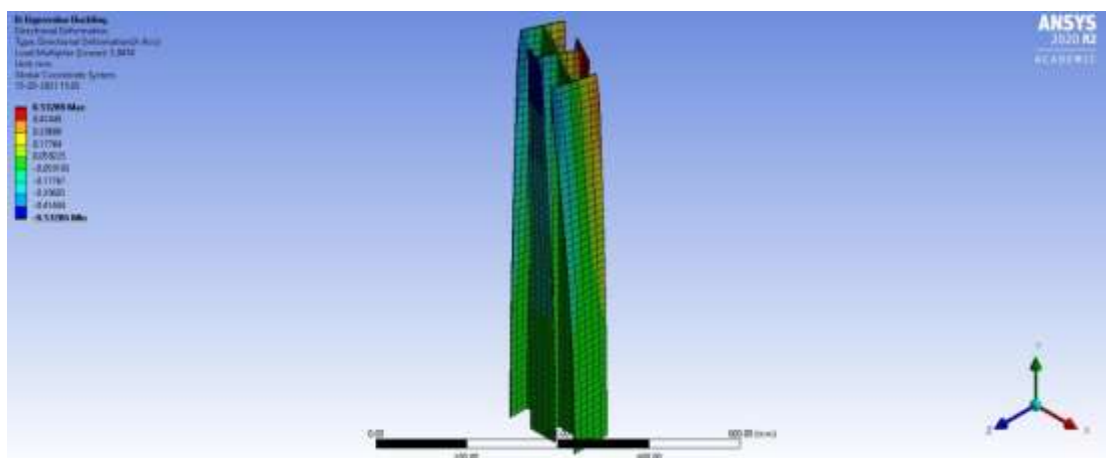
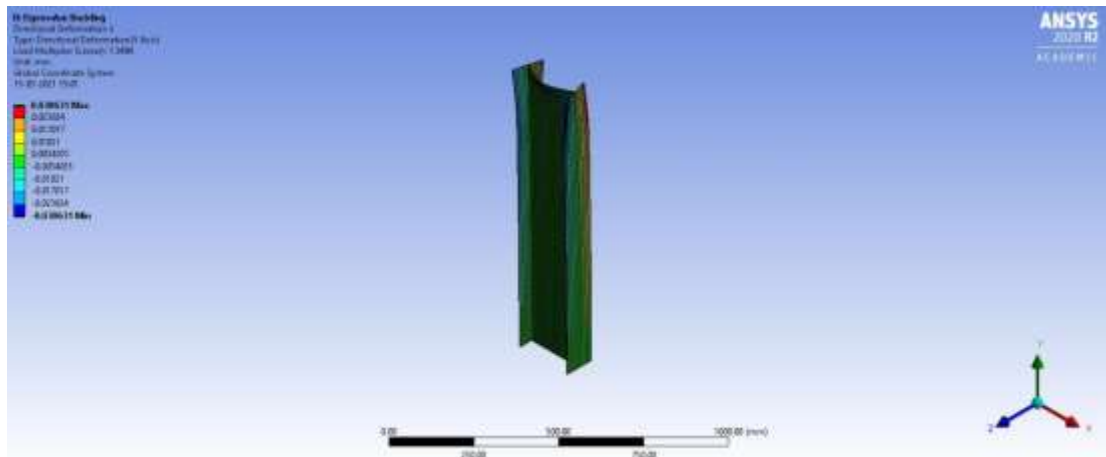
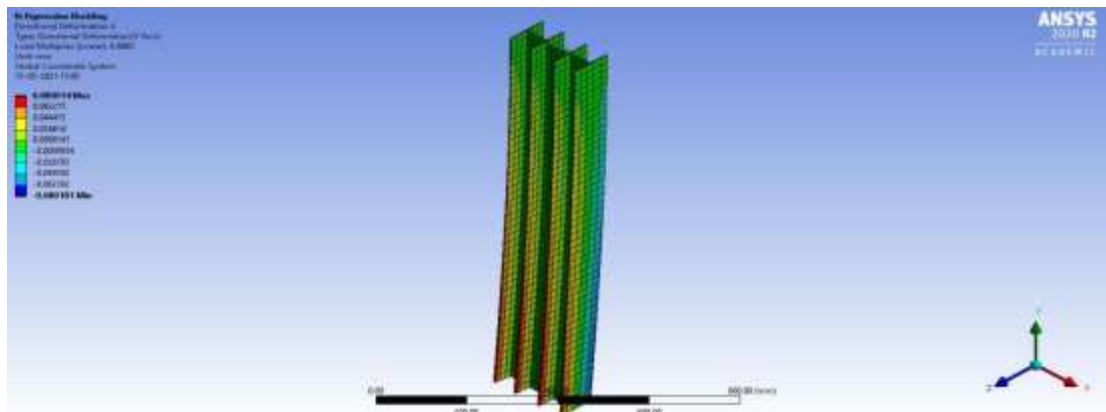
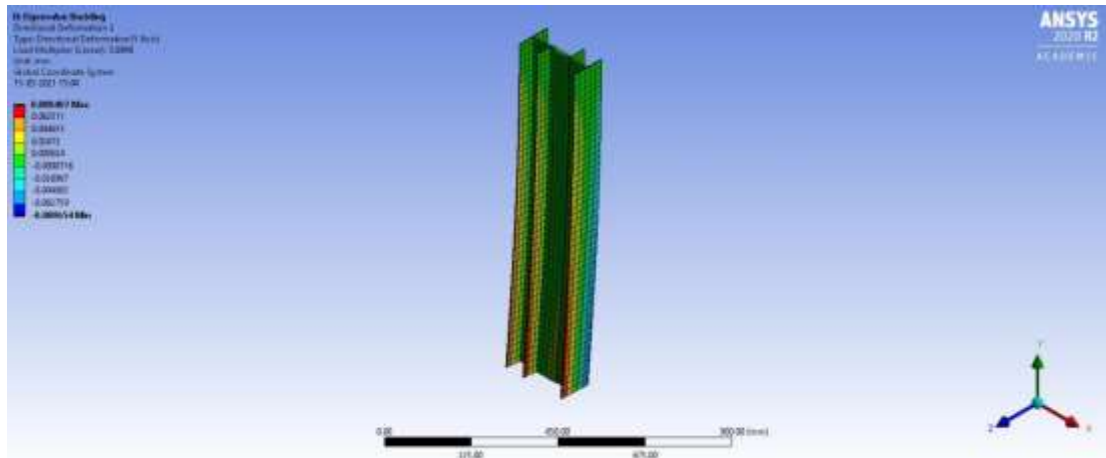


FIG5.10 MESHING OF BUILT UP I SECTION WITH DOUBLE CHANNEL SECTION

5.4 ANALYTICAL RESULT



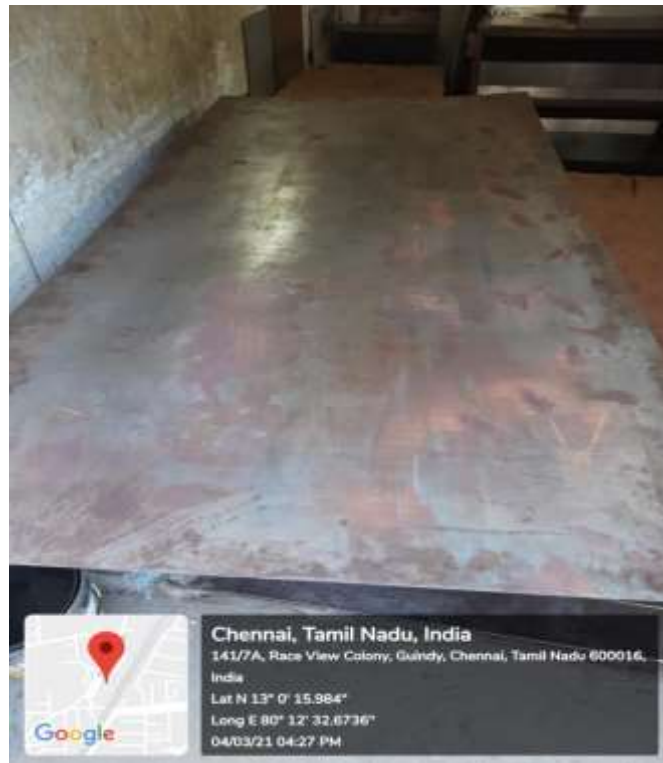


CHAPTER- 6

EXPERIMENTAL TESTING

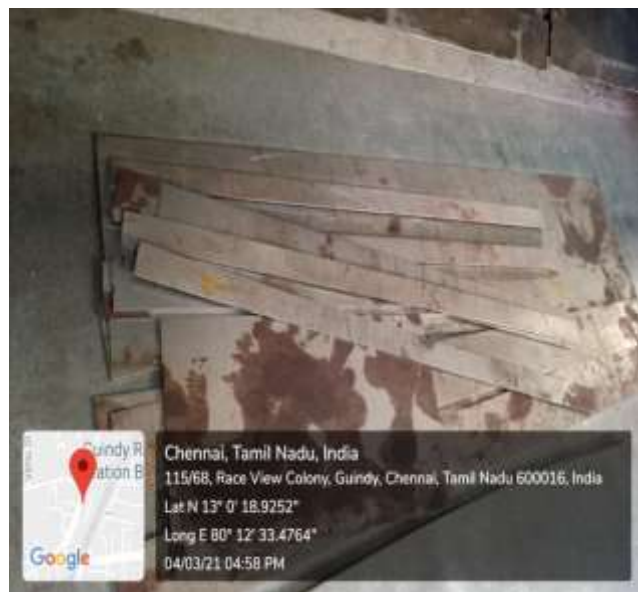
6.1 COLD ROLLED STEEL SHEETS

Cold rolled steel sheets of grade CR2 was used for making the built-up cold formed steel I section column. The size of the cold rolled steel sheets available in market is 1250mmx2500mm.



6.2 MAKING OF EXPERIMENTAL SPECIMEN

6.2.1 CUTTING OF COLD ROLLED SHEETS



6.2.2 WELDING

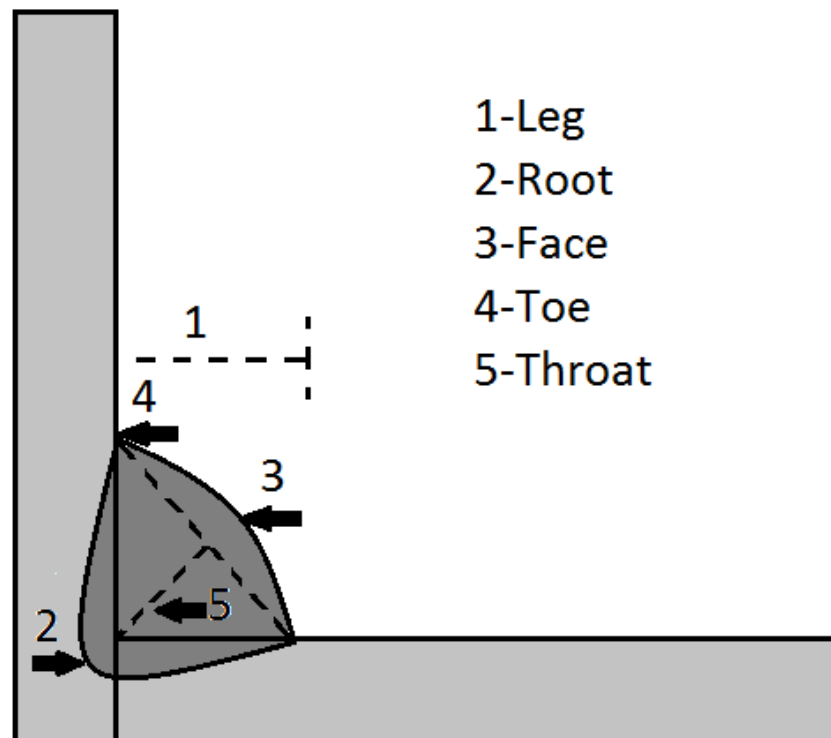
Welding is used for fabricating steel products with high temperature which is used to melt the metal parts and molten state it joints together and allowed to cool for hardening. In welding process, different types of welding are available namely, arc welding, gas welding, tungsten welding, metal gas welding etc.,

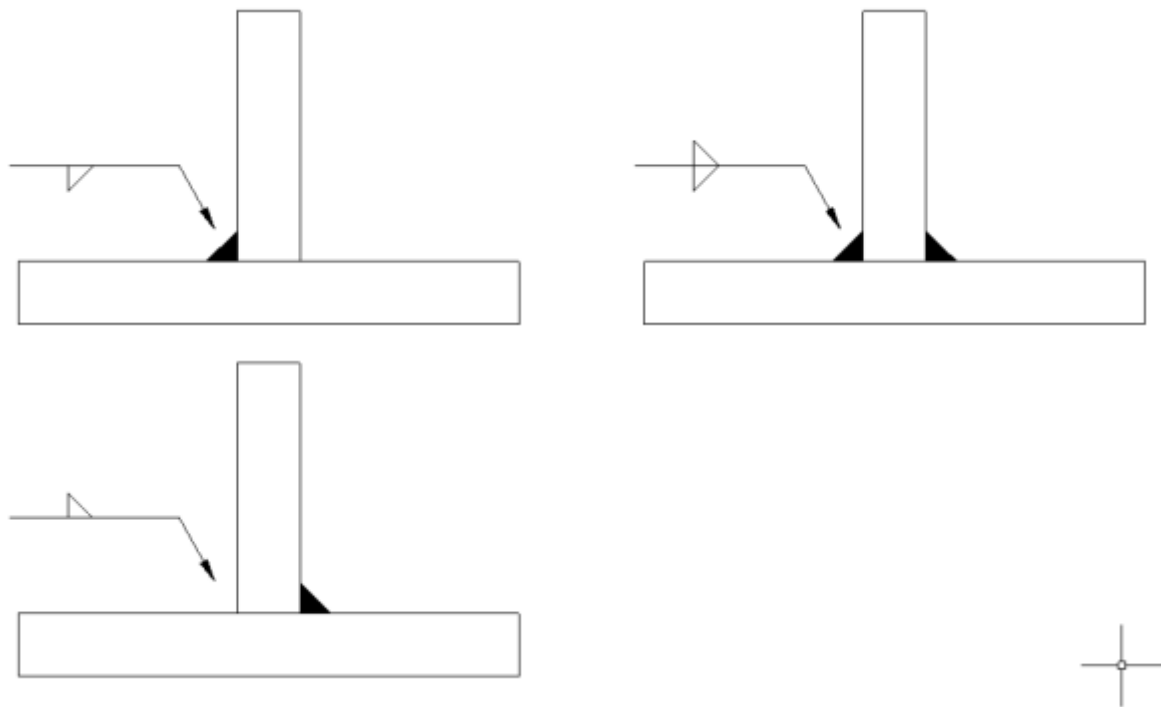
6.2.3 ARC WELDING

Arc welding is a type of welding which use the welding power to create an electric arc between an electrode (a metal stick) and the metal to melt at the point of contact. It may be manual, semi-automatic or fully automated. In arc welding, fillet weld is employed for making the specimen.

6.2.4 FILLET WELDING

Fillet welding is a type of arc welding in which two pieces of metals joined together at the perpendicular angle. It is also referred as joint welding. Two types of fillet weld namely transverse weld and parallel weld.

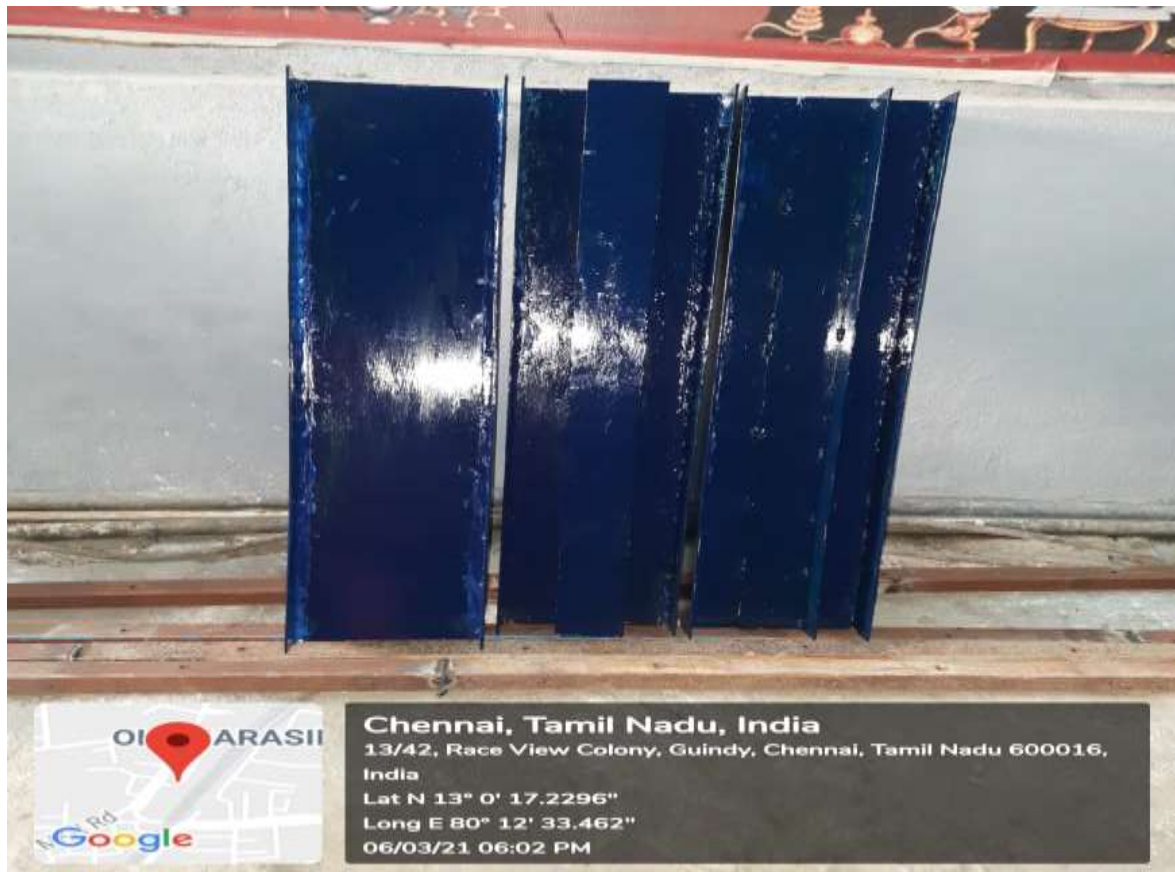




6.2.5 SPECIMEN WELDING







6.3 EXPERIMENTAL SETUP

Built up column is placed on loading frame for experimental testing. Load is applied with hydraulic jack and measured with proving ring. Load is applied as 5kN, 10kN, 15kN, 20kN, 25kN, 30kN etc., Deformation is measured with the help of dial gauges. Axial deformation and Lateral buckling in Y and Z directions are measured using dial gauge as shown figure .



FIG 6.1 BI



FIG 6.2 BIA



FIG 6.3 BIT

6.4 EXPERIMENTAL RESULTS

BI RESULTS



FIG 6.4



FIG 6.5

BIA RESULTS



FIG 6.6



FIG 6.7

BIT RESULTS



FIG 6.8



FIG 6.9

CHAPTER- 7

RESULTS AND DISCUSSION

7.1 RESULTS

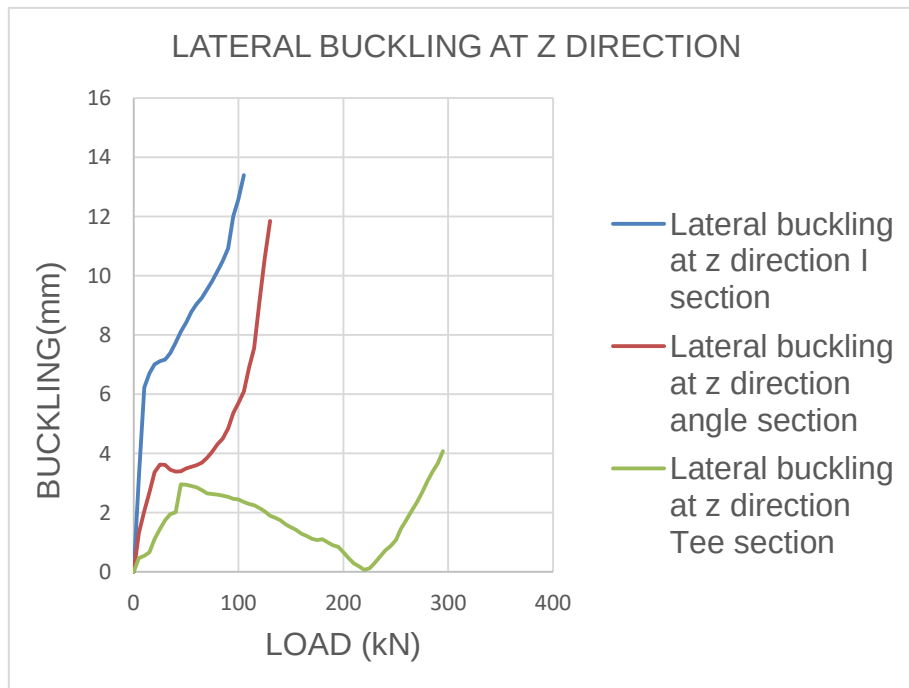
7.1.1 ANALYTICAL RESULT

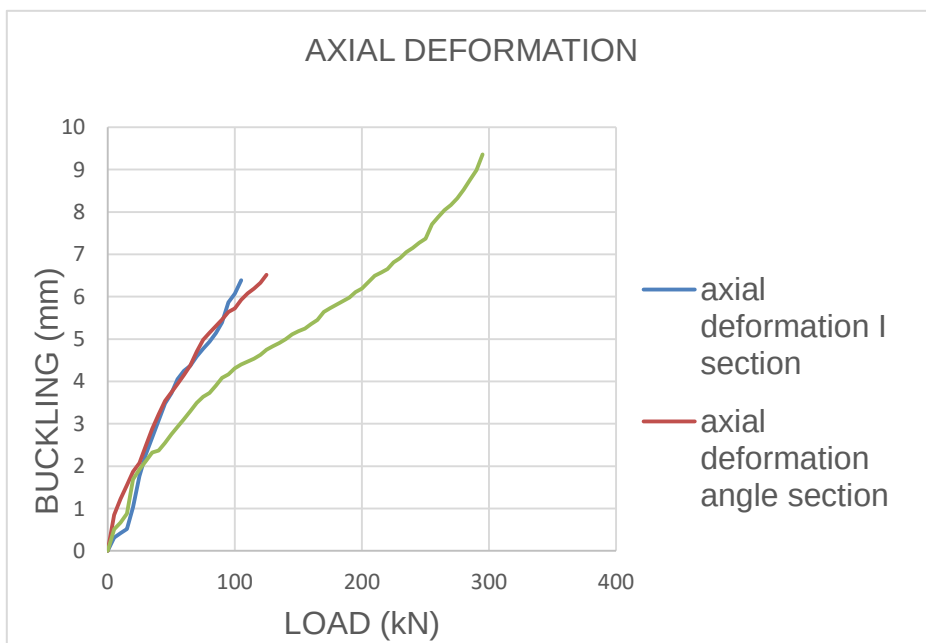
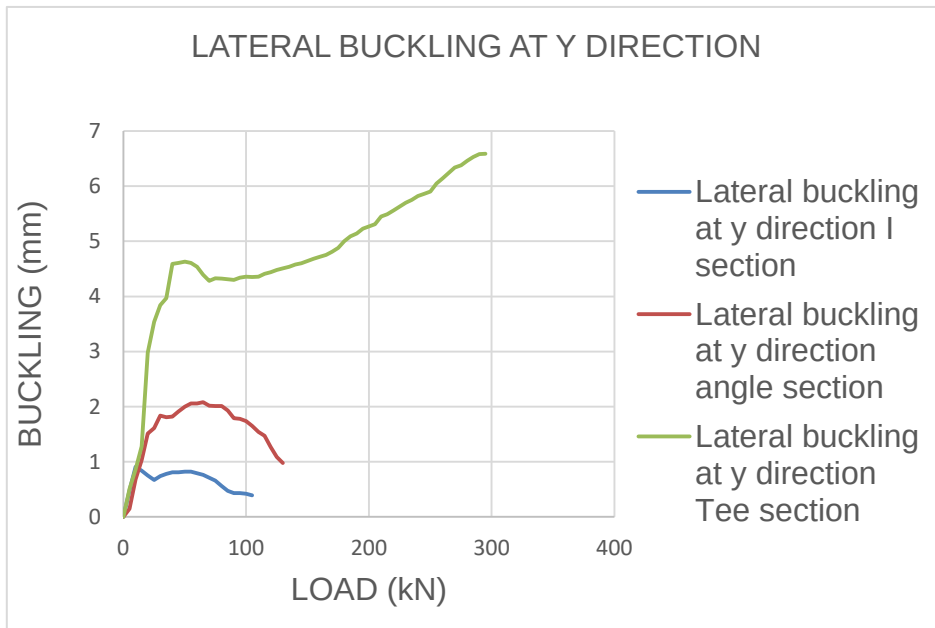
Total deformation is maximum in BI where as in BIT and BIA total deformation will be minimum as their webs are stiffened with double tee section and double angle section respectively.

BIT has the capacity to carry more loads when compared to other specimens. By ANSYS analysis, total deformation is obtained with static structural analysis and buckling is obtained with eigenvalue buckling.

7.1.2 EXPERIMENTAL RESULT

Based on analytical results, specimens are selected for experimental testing. Load is applied with the increment of 5kN. With the help of deformation values, load vs deflection curve is plotted. Load will be in X direction and deflection will be in Y direction.





7.2 DISCUSSION

- Various cold-rolled steel columns are tested and its behaviour is studied. The five cold-rolled steel columns are analyzed with the help of ANSYS software and three cold-rolled steel columns are selected for testing experimentally i.e BI, BIT and BIA. In BI, buckling will be maximum at the web of the BI. When the load is applied web starts buckle, this is because web is not stiffened so that web starts buckling.

- Where as in BIA, buckling will be maximum along the axis of the column. As the load applied, column starts buckling in this section buckling will be along the axis since the web is stiffened with the angle section on both sides.
- In BIT, buckling will be maximum along the flange of the BIT. Load is applied on the column, buckling happens along the flange, the presence of Tee section on both sides make the web stiffened and axial deformation also controlled.
- When we compare lateral buckling at z direction, it will be maximum at BI. As the load applied buckling starts since the web is not stiffen so that buckling will be maximum at the web. It will be least at BIT as the web is stiffened with Tee section on both sides.
- Likewise when we compare lateral buckling at y direction, it will be maximum at BIT. This is because of the presence of Tee section makes the column more stiffened at the web so that flange gets buckled easily. It will be least at BI as the load applied column starts buckling along the axis.
- In axial deformation, it will be maximum at BI. Load is applied and the column begins to buckle in axial direction as there is stiffening element the column fails easily. It will be least at BIT as the web is stiffened with Tee section on both sides and axial deformation also controlled with the presence of Tee section.
- Out of three specimens, load carrying capacity will be maximum at BIT. When specimens are compared with BI, load carrying capacity is increased by 23.8% by angle section and 180% by Tee section.
- On the basis of comparison, we came to know about load carrying capacity is increased where as buckling is decreased in angle section and Tee section. This is because of stiffening element provided in other two specimens.
- Based on the experimental results, we came to know that BIT has the high load carrying capacity and buckling is controlled when compared to BI and BIA respectively.

CHAPTER- 8

CONCLUSION

Three built up columns are fabricated and tested. Based on the experimental study we came to know the BIT has the high load carrying capacity when compared to other columns. This is because of stiffening of web with Tee section on both sides and the axes behaves like a major axis. Twisting of column gets avoided due to the presence of double Tee section at the web portion. Out of three specimens tested maximum lateral buckling at both the directions will be at BI, axial deformation will be at BIT.

REFERENCE

- [1] Tianhua Zhou, Yanchun Li , Hanheng Wu, Yan Lu, Lujie Ren (2020) Analysis to determine flexural buckling of cold-formed steel built-up back-to-back section columns.
- [2] Shao-Feng Nie , Tian-Hua Zhou , Yang Zhang , Bo Liu (2020) Compressive behavior of built-up closed box section columns consisting of two cold-formed steel channels.
- [3] Jia-Hui Zhang, Ben Young (2018) Experimental investigation of cold-formed steel built-up closed section columns with web stiffeners.
- [4] Francisco J. Meza, Jurgen Becque, Iman Hajirasouliha (2019) Experimental study of cold-formed steel built-up columns.
- [5] Francisco J. Meza , Jurgen Becque , Iman Hajirasouliha (2020) Experimental study of the cross-sectional capacity of cold-formed steel built-up columns.
- [6] Krishanu Roy, Hieng Ho Lau, Tina Chui Huon Ting, Boshan Chen, James B.P. Lim (2020) Flexural capacity of gapped built-up cold-formed steel channel sections including web stiffeners.
- [7] Amir Jameei Osgouei, Yousef Hosseinzadeh, Hamid Ahmadi (2019) Local buckling analysis of cold-formed steel webs with stiffened rectangular openings.
- [8] Mohamed Dabaon, Ehab Ellobody, Khaled Ramzy (2015) Nonlinear behaviour of built-up cold-formed steel section battened columns.
- [9] Krishanu Roy, Chia Mohammadjani, James B.P. Lim (2019) Experimental and numerical investigation into the behaviour of face-to-face built-up cold-formed steel channel sections under compression.
- [10] M. Adil Dar, Dipti Ranjan Sahoo, Sunil Pulikkal, Arvind K. Jain (2018) Behaviour of laced built-up cold-formed steel columns on experimental investigation and numerical validation.
- [11] M. Anbarasu,K. Kanagarasu, S. Sukumar (2014) Investigation on the behaviour and strength of cold-formed steel web stiffened built-up battened columns.
- [12] Krishanu Roy, Tina Chui Huon Ting, Hieng Ho Lau, James B.P. Lim (2018) Nonlinear behavior of axially loaded back-to-back built-up cold-formed steel

un-lipped channel sections.

- [13] M.Anbarasu (2019) Numerical investigation on behaviour and design of cold-formed steel built-up column composed of lipped sigma channels.
- [14] M.Anbarasu (2019) Simulation of flexural behaviour and design of cold-formed steel closed built-up beams composed of two sigma sections for local buckling.
- [15] Yan Lu, Tianhua Zhou, Wenchao Li, Hanheng Wu (2017) Experimental investigation and a novel direct strength method for cold-formed built-up I-section columns.