

Experimental Investigation on Flexural Behavior of Corrugated Web Beams

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering in
Civil Engineering

by

Rithish S (39200034)
Thirunavukarasu A (39200040)



DEPARTMENT OF CIVIL ENGINEERING

SCHOOL OF BUILDING AND ENVIRONMENT

SATHYABAMA

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

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Gandhi Salai, Chennai – 600 119
www.sathyabama.ac.in



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **Rithish.S (39200034)** and **Thirunavukarasu.A (39200040)**, who carried out the project entitled **"Experimental Investigation on Flexural Behavior of Corrugated Web Beams"** under my supervision from December 2022 to April 2023.

Internal Guide
(Dr. C. MANOJ KUMAAR)

Head of the Department

Submitted for Viva voce Examination held on 19.04.2023

Internal Examiner

External Examiner

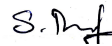
DECLARATION

We, hereby Rithish S (39200034) and Thirunavukarasu A (39200040), declare that the Project Report entitled “Experimental investigation on flexural behavior of corrugated web beams” done by us under the guidance of Dr. C. Manoj Kumar., M.E., Ph.D., at Sathyabama Institute of Science and Technology is submitted in partial fulfilment of the requirements of the award of Bachelor of Civil Engineering.

DATE: 13.04.2023

PLACE: Chennai

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SIGNATURE OF THE CANDIDATES

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ABSTRACT

Cold formed steel (CFS) is one of the most commonly used materials in light weight steel structures in the past decade. The structural elements of light weight buildings such as columns, beams, joists, purlins, and built-up sections are being designed with cold formed steel sections. The research work deals with the comparison of flexural behaviour among beams with flat web, rectangular corrugated web, trapezoidal corrugated web and by conducting the experimental investigation and numerical simulation using ABAQUS software. The type of cold formed steel used in the study is stainless steel due to its good formability, ductility, corrosion resistance and has a high thermal conductivity. The performance of the corrugated web beam is done under bending test using four point loads with simply supported ends. To prevent the failures of steel beams like lateral torsional buckling, yielding, Shear failure, local buckling, and vibration, the corrugated web beams are found to be helpful when reviewed from the past literatures. By using different shapes of corrugation, the strength of the beam can be increased, and the structural performance can also be enhanced. The test specimens are of three types - flat web with stiffener, trapezoidal corrugated web beam, rectangular corrugated web beam, and beam are modelled and analytically tested in ABAQUS software. The span of the specimens used are 1200 mm with the geometrical properties are taken from EURO code 1993-1-5. The failure mode, load deflection curves, bending strength capacity and shear capacity are compared with each specimen both experimentally and analytically.

KEY WORDS: Corrugated web beams, Flexural behaviour, cold formed steel beams, ABAQUS, light weight structure, stainless-steel, built-up section.

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LIST OF ABBREVIATIONS

CWB	Corrugated Web Beam
RCWB	Rectangular Corrugated Web Beam
TCWB	Trapezoidal Corrugated Web Beam
ISB	I Section Beam
kN	Kilo Newton
mm	Millimeter
FEA	Finite Element Analysis
Kg	Kilogram
CR2 sheet	Cold Rolled Sheet
Tig welding	Tungsten Inert Gas
FEM	Finite Element Method

CHAPTER 1

INTRODUCTION

1.1 GENERAL

I-section beams, which are commonly used in structural steel works, have a shape that consists of two parallel flanges and a web. In medium and narrow flange types of beams, the web part contributes about 30-40% of the entire weight. In construction, the web primarily bears the compressive stress and transmits shear within the beam, while the flanges support the main external loads. Corrugated web beams are a cost-effective alternative to conventional steel beams due to their unique design, which uses a thinner web that results in lower material costs. Studies show that corrugated web beams can save up to 30% in comparison to conventional fabricated sections and over 30% compared to standard hot rolled universal beams. These beams have been in development since the 1990s, particularly in Germany and Austria, and have been used in various applications, including supporting roofs, floors, and columns. Light gauge corrugated web beams are made of thin gauge sine curve corrugated web that is welded to wide plate flanges. Due to the corrugated design, the web does not participate in the longitudinal transfer of bending stresses. Instead, in static terms, the corrugated web beam behaves similarly to a lattice girder, in which bending moments and applied forces are transferred only via the flanges. The transverse forces are transferred through the diagonals and verticals of the lattice girder, which in this case is the corrugated web. Corrugated web beams offer a cost-effective solution to conventional steel beams with their unique design, resulting in lower material costs. They have been extensively studied and used in various applications due to their superior strength and stiffness. With the ability to transfer forces and moments through the flanges and corrugated web, these beams provide an efficient solution for construction projects.

1.2 COLD FORMED STEEL

Cold-formed steel refers to the process of bending and shaping steel into different shapes and sizes while it is cold, rather than hot. This process creates a strong and durable material that is commonly used in the construction industry.

Cold-formed steel is also known as light gauge steel or sheet steel and is available in a variety of shapes and thicknesses. One of the main advantages of cold-formed steel is its strength-to-weight ratio. Compared to other materials, such as wood or concrete, cold-formed steel is much stronger for its weight. This makes it an ideal material for use in buildings, where a high strength-to-weight ratio is required. Another advantage of cold-formed steel is its versatility. It can be easily shaped into different sizes and shapes, allowing for customization to fit specific building designs. Cold-formed steel is also highly durable, resistant to fire, and can withstand harsh weather conditions. Cold-formed steel is widely used in construction applications such as framing, roofing, and wall systems. It is also used in the manufacturing of products such as appliances, furniture, and vehicles. Its lightweight and strength make it an excellent choice for these applications. In recent years, the use of cold-formed steel has grown due to its sustainability and environmental benefits. Steel is highly recyclable, and the cold-forming process requires less energy than the hot-forming process. This makes it a more sustainable and eco-friendly option for construction projects. Cold-formed steel is a highly versatile and durable material that offers many advantages over other construction materials. Its strength-to-weight ratio, customization options, and sustainability make it a popular choice for a wide range of applications in the construction and manufacturing industries.

1.3 CORRUGATED WEB BEAMS

Corrugated web beams are a type of steel beam used in construction. They have a unique design, with a web that is corrugated rather than flat. This design provides several advantages over traditional steel beams. One key advantage of corrugated web beams is their increased strength and stiffness. The corrugated web design allows for a greater surface area, which enhances the beam's resistance to bending and torsion. Additionally, the corrugations act as reinforcing ribs, providing additional support to the beam. Another advantage of corrugated web beams is their reduced weight. The corrugated design allows for a thinner web, which reduces the amount of steel needed to manufacture the beam. This not only reduces material costs but also makes the beams easier to handle and install on-site. Corrugated web beams also offer improved fire resistance compared to traditional steel beams. The corrugated web design provides greater surface area, which allows for more efficient

heat dissipation. This slows down the heating of the beam, giving it a longer time before it loses its load-bearing capacity. corrugated web beams offer several advantages over traditional steel beams, including increased strength and stiffness, reduced weight, and improved fire resistance. These benefits make corrugated web beams an attractive option for construction projects where structural integrity and safety are top priorities.

1.4 IS 513 CR2 STEEL SHEET

IS 512 CR2 steel sheet is a type of low carbon, cold rolled steel that is commonly used in the manufacturing industry. This steel sheet has good formability and weldability, making it ideal for a variety of applications such as automotive parts, electrical components, and household appliances. The CR2 designation refers to the level of work-hardening that the steel undergoes during the cold rolling process, which results in a higher yield strength and improved surface quality. The low carbon content of this steel sheet also contributes to its high ductility and toughness, allowing it to withstand deformation and impact. IS 512 CR2 steel sheet is available in a range of thicknesses and widths, allowing for customization to fit specific manufacturing needs. Its high quality and reliability make it a popular choice for various applications in the manufacturing industry. IS 512 CR2 steel sheet is a low carbon, cold-rolled steel that is widely used in the manufacturing industry due to its good formability, weldability, and high strength. Its availability in different thicknesses and widths makes it customizable to fit specific manufacturing needs, while its reliability and durability make it a popular choice for a variety of applications.

1.5 LITERATURE REVIEW

Nimbalkar Amol N et.al, (2012) conducted a study on “strength of the trapezoidal corrugated web beam” When it comes to optimization, it's critical to improving the design for strength, cost, and weight rigidity, etc. This is an attempt that is made to enhance I's ability to withstand stress employed in structural applications is section beam. First standard I section beam in this study then chosen while taking into account the same volume a beam with criteria corrugated web is created. A investigating the strength of a corrugated web beam suitable for structural use. That is planned piece of art, firstly the The definition of a corrugated beam and its geometric factors such as web thickness and angle of Rubbing surfaces are

permanent.

Iyappan G, (2012) This paper presents an experimental and numerical study on the flexural behavior of cold-formed steel built-up sections. Two specimens were tested, one with a lip and one without, using channel sections with dimensions of 200x80x2 mm. The experimental results showed that the beam with a lip had a higher flexural capacity. Finite element analysis using ABAQUS software verified the experimental results. This study provides important insights into the design and construction of cold-formed steel members for building applications.

Divahar & Joanna, (2013) This paper describes an experimental study on the load-carrying capacity of cold-formed steel sections with trapezoid web corrugations. Six cold-formed steel beams with plain webs and corrugated webs were tested under two-point loading for pure flexural behavior. The load-carrying capacity of the cold-formed steel beam with a plain web was compared to the load-carrying capacity of beams with trapezoidal corrugated webs having 300 and 450 corrugations. Results showed that the cold-formed steel beam with a trapezoidally corrugated web having 300 corrugations had a higher load-carrying capacity compared to the beams with plain webs and 450 corrugated webs. The use of corrugated webs with trapezoidal corrugations can significantly increase the shear capacity of the web of large steel plate girders. This study provides useful insights for the design and construction of cold-formed steel beams with trapezoidal corrugated webs in various fields of application.

Tahiliani et al., (2013) This research aimed to evaluate the performance of corrugated web steel built-up beams through experimental testing in terms of applied load and resulting displacement. Three different types of corrugated web profiles with the same material properties were tested under point load conditions. The performance of each beam was recorded and compared. The experimental results provided valuable information on the role of various parameters in the performance of corrugated web steel built-up beams. Corrugated steel plates have been extensively used in steel structures, particularly as corrugated webs of girders. This study provides insights into the design and construction of corrugated web steel built-up beams for various applications in the steel construction industry.

Krishnan & Daset et.al., (2013) Beams with corrugated webs (CWB) are increasingly used in buildings and bridges. They consist of wide flanges and a thin corrugated web. CWBs are more economical and offer increased buckling resistance without welded stiffeners, resulting in cost savings of up to 30%. The use of CWB in bridge construction can reduce the need for intermediate diaphragms and allow for hybrid bridges with different cross-sections.

Kanon & Adnan Suhel, (2014) This paper presents an analytical study of the flexural behavior of steel beams with flat web and corrugated web. The study includes five simply supported beam specimens with a total length of 3m, with variable corrugated shapes in the mid-span of the section (flat, trapezoidal, rectangular, sinusoidal, and zigzag), which were tested under two-point load. Finite element analysis was carried out using ANSYS 14.5 to verify the behavior of the corrugated web. Solid 185 and shell 181 elements were used to represent steel elements and stiffeners. The study also investigated the change in fold dimensions for rectangular and trapezoidal corrugated webs. The results showed an increase in beam stiffness and capacity when using rectangular corrugated shapes or reducing corrugated dimensions. The findings of this study can be useful in designing steel beams with enhanced flexural strength and stiffness.

Dubina et al., (2015) The new structural solution for steel beams with corrugated webs is presented in this research. The system has built-up cold-formed steel members for the flanges and a web composed of trapezoidal cold-formed steel sheet. Self-drilling screws or spot welding can be used to join the flanges to the web. The report outlines experimental studies conducted at the Politehnica University of Timisoara's CEMSIG Research Centre to assess and validate the technical solution. In comparison to hot-rolled or welded steel beams, the study seeks to offer a weight reduction alternative. The solution's technical limits for applications will be estimated by numerical studies that will be reported in a forthcoming publication.

Leblouba et al., (2015) Unlike straight web I-girders, the construction industry's demand for corrugated web steelgirders is increasing due to their high shear strength without needing transverse stiffeners. Although the corrugation fabrication cost could be high, savings on material, transportation, and erection costs can compensate for the expenditures needed to build flat-plated girders with

stiffeners. This study investigates the shear behavior of straight and corrugated webs with different geometries and corrugation profiles (triangular and trapezoidal) through laboratory testing. Following a detailed parametric study, the results of the experimental program were used to formulate a reliability-based design optimization (RBDO) problem to achieve target reliability. When applied to two case studies related to girders of a building and a bridge, the RBDO demonstrated that it is possible to design girders with corrugated webs to achieve economic designs in terms of material volume in the range of 20% to 40% with thinner webs and without the need for transverse stiffeners.

Fernandez-Lacabe et al., (2015) Using corrugated web girders can increase lateral-torsional buckling resistance, but the value of the critical moment varies based on cross-section geometry. The paper presents a finite element numerical analysis of girders with different corrugated web shapes and demonstrates that the increase in torsion resistance is mainly due to a higher torsional constant. The paper compares elastic critical moment values obtained through finite element analysis with theoretical expressions using equivalent section properties and presents closed form expressions to directly compute approximate equivalent section properties of any girder with corrugated web. The results show that the equivalent section properties approach provides values very close to those obtained using finite element buckling analysis.

Khalid.Y.A, et.al (2016) conducted study on the performance of mild steel corrugated web structural beams under three-point bending. Finite element technique was used to analyse semicircular web corrugation both experimentally and computationally in both the horizontal and vertical directions of the beam's span. A non-linear analysis was carried out after the test specimen was simulated using the widely available finite element programme LUSAS. The base sizes were chosen to have a corrugation radius of 22.5 mm, a thickness of 4 mm, a consistent corrugation amplitude to cycle length ratio, and a flange thickness of 6 mm. When compared to planar and horizontally corrugated web beams, a vertically corrugated web beam could carry a moment that was 13.3 to 32.8% higher. Additionally, the vertical-corrugated web could be used to reduce weight.

Ahmed Elamary,et.al (2016) presented the research Study of flexural strength is essential for steel beam design. The goal of the current research is to define the flexural strength of traditional steel I beams and steel beams with corrugated web. Four simply supported beams with variable web configurations (flat or corrugated) and flange compactness were the subject of the experimental program . The loss in steel beam flexural strength caused by corrugated web has been identified through experimental study. To investigate the impact of CW on the flexural behaviour of a composite concrete-steel beam, the experimental programme was expanded. Two more corrugated-webbed composite concrete-steel beams have been created and put to the test under flexural loads. The comparison of the calculated values of the bending moment came to an acceptable level of degree accuracy with the values obtained experimentally.

Hassan H. Abbas,et.al (2017) conducted a study on the behaviour of corrugated web I-girders under in-plane loads in both torsional motion and linear elastic in-plane motion is theoretically described and demonstrated. Two steel flanges are often welded to a corrugated steel web to create a conventional corrugated web steel I-girder. The equilibrium of an infinitesimal length of a corrugated web I-girder is investigated, and the cross-sectional stresses and stress resultants owing to primary bending moment and shear are inferred under a set of simple assumptions. According to the analysis, when subjected to in-plane loads, a corrugated web I-girder will deflect in-plane and twist out-of-plane at the same time. In the study, the out-of-plane torsional behaviour is evaluated as a flange transverse bending problem while the in-plane bending behaviour is examined using traditional beam theory.

Dan Dubina,et.al (2017), conducted the research on the steel corrugated web beams are a relatively recent structural innovation that have only been around for 20 years. Compared to hot-rolled or welded beams, these beams offer a significant weight reduction thanks to the thin corrugated web. The flanges in the solutions currently available on the market are made of flat plates that are welded to the sinusoidal web sheet, require a certain type of welding method. The beam in this paper's innovative method is made up of flanges made of built-up cold-formed steel components and a web of trapezoidal cold-formed steel sheet (e.g. back-to-back

lipped channel sections or angles with turn lips). Self-drilling screws or spot welding can be used to join the flanges to the web.

Ezzeldin et.al, (2017) conducted a study without support from the corrugated web, which supplies the girder's shear capacity, the flanges of the girder are responsible for the girder's flexural strength. Steel yielding and web buckling cause the web to fail. Additional potential failure criteria for corrugated web girders include lateral torsion and local flange buckling. Here, the author's earlier research on corrugated web girders was gathered and presented in its entirety. The shear behaviour of the corrugated webs, which is explored with a focus on the failure mechanisms affecting the web design, serves as the starting point. In order to analyse the buckling modes of the corrugated web, confirm the accuracy of the suggested equation, and investigate the post-buckling strength of corrugated web girders, numerical calculations are carried out.

Mohammad Rezah,et.al (2018) conducted a study on the ultimate shear loading capacity (USLC) of sinusoidal corrugated web beams was examined in the current work using numerical and experimental methods. The consequences of various factors are then addressed following a thorough parametric analysis for 160 samples using the nonlinear finite element method. The chosen dimensions for numerical examples include the range of steel girders that are typically used in construction. The results of the parametric analysis are used to fit the numerical parameters of the proposed relation, which represent the web boundary conditions and inelastic effects on shear buckling capacity. With an average difference of 10%, the connection was able to satisfactorily forecast the UPLC of the numerical examples.

Huang,et.al.Z.Y (2018) conducted a research in this study used experimental, numerical, and analytical analyses to examine the flexural performance of CSW-equipped, simply supported composite box girders. Two 1:5 scale models of actual bridges, one with steel tubes filled with concrete and the other with hollow steel tubes, were built and tested. The two specimens had good ductility, according to the data, and failed in a ductile way. The yield load is increased and the deflection is decreased by the concrete filled steel tubes. The two specimens' cross sections essentially meet the "plane section assumption." For the

two specimens, finite element models were also created and validated based on the outcomes of the experiments. The validated finite element models were then used in a parametric investigation, which demonstrates that the steel ratios and the structure strongly influences the flexural behaviour.

Raiza Ashrawi,et.al (2019) conducted a study deals with a semicircular corrugated web beam. The load carrying capacity of the beam is studied under different cases by performing a nonlinear static analysis using commercial finite element software ANSYS 15.0 finite element software. There are many parameters that influence the bending and buckling behaviour of the corrugated web profile steel section such as web thickness(t_w), depth of web (d) and corrugation radius (r_o). This study is to investigate the static behaviour of semicircular corrugated web beams by varying the corrugation radius.

Krishnan.L,et.al (2019) presented a paper work dealt with the investigation on the behavior of cold form steel built up I - section with triangular web corrugation at varying depth. The effect of web corrugation and h_w/t_w ratio on the flexural strength of cold formed steel (CFS) lipped I section was presented in this paper. The length of the specimen was kept constant for 2000 mm and h_w/t_w ratio was varied from 166 to 250 keeping all other parameters as constant. In total three specimen were experimentally tested under two point loading with triangular web corrugation by considering simply support condition. The experimental results are verified with finite element analysis using ANSYS software. The results obtained from test experiments and ANSYS software were compared with the predicted Indian Specifications the experimental result shows that the flexural capacity of the triangular web was larger than flat web. Also the effect of h_w/t_w ratio on the flexural strength capacity was studied and discussed. Due to the provision of triangular web corrugation, there was no failure in shear zone or in web portion.

Sruthi v v,et.al, (2020) conducted a study on the usage of corrugated web beams (CWB) in structural applications including buildings and bridges is widespread. It typically consists of thin corrugated web and large, thick plate flanges. It is common to utilise webs with a sinusoidal, trapezoidal, rectangular, or triangular shape. To explore the strength behaviour of trapezoidal curved corrugated beams with varied radius of curvature, web thickness, and flange thickness, corrugated web

beams were compared to normal plate webs. Comparing the buckling strength of plate girders with and without trapezoidally curved corrugations was the goal. Increased buckling resistance without the need to weld stiffeners to the web is a benefit of corrugated web beams. As a result, the beam weight is reduced without sacrificing strength, with a reduction in 30% of cost is possible.

Zhang, A.L., et.al (2020) conducted a study in this paper to put forward a new type of earthquake-resilient prefabricated sinusoidal corrugated web beam-column joint (PSCWJ). Then, its constitution, its mechanics mechanism and its seismic design requirements are introduced. During the process of theoretical derivation, the influences of many design parameters are considered, such as the section parameters of the sinusoidal corrugated web beam and cantilever beam, the thickness of the flange cover plate, the material properties of the flange cover plate, the diameter of bolts, the middle bolt interval and the weaken rate of the cover plate. The PSCWJ designed through this theory has good bearing behaviour and ductility, which can make sure the main members, such as the beam and the column, remain in an elastic range and meet the requirements of earthquake resilience.

Limaye A. A. et.al, (2020) The corrugated steel plate is a widely used structural element in many fields of application because of its numerous favorable properties. To increase the shear capacity of web of large steel plate girders, the web with different patterns such as tapered web, haunches, corrugations of different shapes are used. Present paper deals with the determination of buckling strength of a plate girder considering rectangular corrugated web plate. The finite element analysis of a plate girder is carried out using ANSYS. The results obtained from analysis are then compared with the plate girder with plane web of uniform depth. Various parameters like buckling strength and weight are compared. It is concluded that the corrugated web plate has high buckling strength and sufficient reduction in weight with light gauge elements, than plate girder with plane web.

Prathebha P, et.al, (2020) Plate girders are widely used in bridges as well as industrial buildings. As we know, plate girders have maximum moment carrying capacity than any other hot rolled sections used. To carry these moments economically, normally webs with larger depth to thickness ratio are used resulting in slender sections which are susceptible to web buckling. Hence to

avoid web buckling and to gain maximum strength, corrugations are provided in the web region. The corrugated steel plate can be used in many fields of applications because of its favorable properties. This new achievement has helped engineers to design more optimal structures. In this paper, a review of the research carried out on corrugated web steel girders both experimentally and analytically is presented.

Raiza Ashrawi M.A.,et.al (2021) corrugated web beam is a built-up beam with thin walled corrugated web. The profiling of the web avoids the failure of the beam due to loss of stability before the plastic limit loading of the web is reached. The use of corrugated webs is a potential method to achieve adequate out of plane stiffness and bending resistance without using stiffeners. There are different types of corrugated web profiles such as triangular, trapezoidal, semi-circular etc. The study deals with a semi-circular corrugated web beam. The load carrying capacity of the beam is studied under different cases by performing a non-linear static analysis using commercial finite element software ANSYS 15.0 finite element software. There are many parameters that influence the bending and buckling behaviour of the corrugated web profile steel section such as web thickness(t_w), depth of web (d) and corrugation radius (r_o). This study is to investigate the static behaviour of semi-circular corrugated web beams by varying the corrugation radius.

Abdul-Ameer,et.al (2021) Flexural strength estimate is significant in the design of steel beams. In this paper carried out analytical study to realize flexural behavior of steel beam with flat web and corrugated web. Five specimens simply supported beams with (3m) total length including variable corrugated shapes in mid span of the section (flat, trapezoidal, rectangular, sinusoidal and zigzag) were tested under two points load. To verify behavior of corrugated web, finite element analysis with (ANSYS 14.5) were done. Solid 185 and shell 181 elements were used to representation steel elements and stiffeners. Also, the change in fold dimensions for rectangular and trapezoidal corrugated web were studied. The results showed an increase in beam stiffness and capacity when using rectangular corrugated shape or reduce corrugated dimensions.

Pengcheng Jiao,et.al (2021) study aims at theoretically investigating the effect of geometry on the buckling capacity of wood composite I-beams with sinusoidal corrugated web. Parametric study is conducted to indicate the effects of web geometry on the critical buckling load. A significant increasing of buckling load (minimum 17.7%) is obtained between flat and sinusoidal web I-beams. Sensitivity study is carried out to evaluate the influences of web thickness, beam length and beam height on the loading capacity of sinusoidal I-beams. Optimal design is conducted to investigate the impact of the ratios of wavelength-to-beam length and wave amplitude-to-flange width on the critical buckling load and volume of wood corrugated I-beams. The findings in this study can be further used as guidance for the design of composite I-beams with sinusoidal corrugated web.

Haider K. Ammash,et.al (2022) conducted study aims to comprise an experimental work by testing ten specimens to improve the girders shear resistance. One reference specimen with a flat web in addition to nine models that are categorised to three groups in which each group differs in the corrugation shape. Rectangular, trapezoidal and triangular corrugation shapes of different heights (20, 40, and 60 mm) were utilised. All specimens used in the study have equal weight, which is approximately 30 kilograms per specimen. The experimental work included measuring the ultimate load capacities and load-deflection curves. Results showed that different failure modes were observed for those beams. It was also found that the beam with trapezoidal corrugation web has an increase in its strength by nearly 28% compared with the reference beam.

Yousry B.I. Shaheen,et.al (2022) conducted a study a finite element analysis (FEA) model was developed using the ANSYS 16 software, to determine the elastic critical moments of continuous composite steel beams with various corrugated web profiles, such as trapezoidal, zigzag, and rectangular profiles, which were evaluated against numerical data of the sinusoidal one from the literature. Ultimately, the failure load of a composite steel beam with various web profiles was predicted by studying 46 models, based on FEA modeling, and a procedure for predicting the elastic critical moment of composite beams with various web steel profiles was proposed. When compared to sinusoidal web profiles, the trapezoidal, zigzag, and rectangular web profiles required an average increase in load capacity and stiffness

of 7%, 17.5%, and 28%, respectively, according to the finite element analysis. Also, the rectangular web steel profile has a greater stiffness and load capacity. In contrast, the sinusoidal web has lower values for these characteristics.

Kumar.U,Reddy,et.al (2022) The use of steel structures has been increasing in the world as they are more efficient and effective with high stiffness and strength. In order to achieve more strength and stiffness steel beams with corrugated web are widely used due to their light weight and high load carrying capacity. In the present research, corrugated sheets of different thicknesses, different corrugated angle and different shape of corrugated sheets are used to make a corrugated web beam. The connections between flanges and web can be either by self-drilling screws or by welding. The flexural behavior of those beams are studied in Ansys and reported here in this paper. The load carrying capacity of each beam is determined and the optimum corrugated angle and shape are found. Deformations and stress distribution are displayed. Failure modes are also determined.

Sokołowski.D,et.al.(2022) The main aim of this work is a computational nonlinear analysis of a high strength steel corrugated-web plate girder with a very detailed and realistic mesh including vertical ribs, all the fillet welds and supporting areas. The analysis is carried out to verify mechanical structural response under transient fire temperature conditions accounting for an efficiency and accuracy of three various transient coupled thermo-elastic models. All the resulting stress distributions, deformation modes and their time variations, critical loads and eigenfrequencies as well as failure times are compared in all these models. Nonlinearities include material, geometrical and contact phenomena up to the temperature fluctuations together with temperature-dependent constitutive relations for high strength steel. They result partially from steady state and transient experimental tests or from the additional designing rules included in Eurocodes. A fire scenario includes an application of the normative fire gas temperature curve on the bottom flange of the entire girder for a period of 180 minutes. It is computed using sequentially coupled thermo-elastic Finite Element Method analyses. These account for heat conductivity, radiation and convection. The FEM model consists of a combination of 3D hexahedral and tetrahedral solid

finite elements and uses temperature-dependent material and physical parameters, whose values are taken after the experiments presented in Eurocodes. Numerical results presented here demonstrate a fundamental role of the lower flange in carrying fire loads according to this scenario and show a contribution of the ribs and of the welds to the strength of the entire structure

Pallavi Pasnur,et.al, (2022) Corrugated beam is a developed beam with thin wall corrugated web. The profile of the web maintains the stability of beam. Mostly there are diverse types of corrugated web shape which we will discuss in this paper. This paper contains study on expert's research paper on behaviour of steel beam with plain web, trapezoidal corrugated web, triangular corrugated web. The aim of this review paper was study of engineering properties such as stress, strain, lateral torsion, flexure of plain web, trapezoidal corrugated, triangular corrugated web. The load sustaining capability and manners of failure of beams were studied from previous research. And also comparison between the series of web is carried out to determine which is suitable and sustainable for construction.

1.6 SUMMARY

The general topic of the papers cited is the behaviour, design, and construction of steel beams with corrugated web profiles. The papers discuss the flexural and shear behaviour of cold-formed steel built-up sections with corrugated webs, as well as the load-carrying capacity and performance of steel beams with different types of corrugated web profiles. Additionally, some papers present analytical and experimental studies of the behaviour of steel beams with flat web and corrugated web profiles, and explore the use of corrugated web girders in building and bridge construction. Shape increases the stiffness and strength of the web, allowing the beam to support greater loads without increasing its weight or size. Corrugated web beams are commonly used in large construction projects, such as commercial buildings and bridges, where their strength and efficiency can provide significant benefits.

1.7 AIM

To study and determine the behavior of corrugated web beams and experimentally and analytically.

1.8 STUDY OF WORK

Due to their lightweight and superior load carrying capacity, corrugated web steel beams have gained popularity in the last few decades. The aims of this report are to study experimental response of three types of corrugated web from pre buckling stage until ultimate failure. examine the closed behaviour of steel beam with corrugated web beam. carry out experimental investigation and analytical results in corrugated web beam with different types of web sections. compare the performance of flat web with trapezoidal, rectangular web beams.

1.9 OBJECTIVES

The following objectives of this projects are:

- To determine the stress distribution of the beam.
- To examine the flexural capacity of the beam.
- To study the load-deflection behaviour.

1.10 SCOPE OF WORK

Static behaviour of cold-formed steel beams with corrugated web beams has been carried out to find its structural performance of simply supported beam under pure bending. The static performance of the corrugated web such as trapezoidal, rectangular, and flat web conducted including failure mode, load–deflection curves and strength capacity are compared and discussed in detail based on the experimental results. Finally, numerical analysis using abaqus results are analysed and the experimental results were validated with the results obtained from the finite element analysis.

1.11 NOVELTY

The following novelty of this projects are:

- Cold formed steel sheet material is used in the project
- Corrugation process is done at the web of the beam
- Comparison of beams

CHAPTER 2

METHODOLOGY

2.1 FLOWCHART

The given below figure shows the process of the project

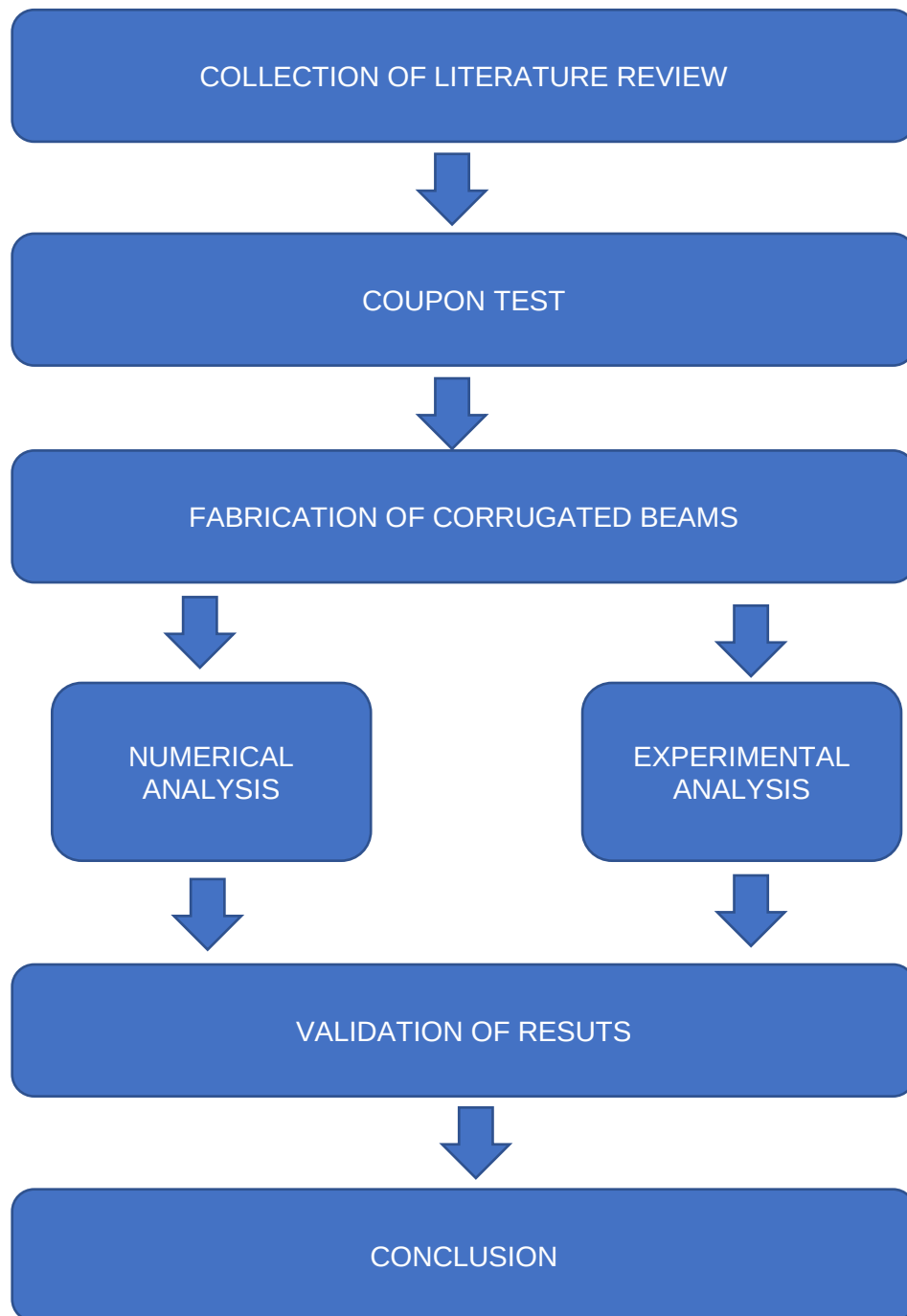


Fig 2.1: flowchart

2.1.1 Collection of literature review

There have been numerous studies conducted by researchers to analyze and understand the various failure modes of Corrugated web beams. One of the factors that can affect the behavior of these beams is the presence of corrugation, which can change the stress concentration of the beam. In recent years, cold-formed steel has become a popular trend in the construction industry, and as a result, researchers have become interested in studying the buckling behavior of cold-formed steel sections with corrugations. They have conducted studies on the effects of varying corrugation size, shape, and depth-to-height ratio. These studies have found that the presence of corrugations can have a significant impact on the behavior of the beams, and can even lead to failure in some cases. Researchers have also found that the size and shape of the corrugations can affect the behavior of the beam differently, and that the depth-to-height ratio of the corrugation can also play a role in determining the overall strength and stability of the beam. These studies have provided valuable insights into the behavior of corrugated web beams, and have helped to improve our understanding of the factors that can affect their performance. This information can be used by engineers and designers to create more efficient and reliable structures using Corrugated web beams, and can also inform future research in this area.

2.2.2 Coupon test

The coupon test is a common method used to evaluate the strength and other mechanical properties of steel. In this test, a small piece of steel, known as a coupon, is cut from a larger piece of steel and subjected to various stress tests. To conduct a coupon test for steel, the steel sample is first machined into a specific shape and size, typically a rectangular bar with a standardized cross-section. The dimensions of the coupon are carefully measured and recorded to ensure consistency and accuracy. The coupon is then subjected to a series of tests, including tensile tests, which measure the strength and deformation characteristics of the steel under tension. Other tests, such as compression and bending tests, may also be performed to evaluate other mechanical properties of the steel. The results of the coupon test are used to determine the strength and other mechanical properties of the steel, which are important for designing and engineering structures.

made from steel. The data gathered from the test can also be used to create material specifications for steel, ensuring that the steel used in construction meets specific performance standards. Overall, the coupon test is a valuable tool for evaluating the strength and mechanical properties of steel, helping to ensure the safety and reliability of steel structures in a variety of applications.

2.2.3 Experimental analysis

All the specimens I section, trapezoidal corrugated web beam, rectangular corrugated web beam are fabricated and tested in order to get the accurate results. The cold formed CR2 sheet is purchased and fabricated into built up beams. The fabricated beams are tested in a loading frame to analyze the flexural behavior of the beam and results are validated.

2.2.4 Numerical analysis

Finite Element Analysis (FEA) is a computer-based simulation technique used in civil engineering to analyze and predict the behavior of structures and materials under various conditions. It involves breaking down a complex system into smaller, more manageable parts, called finite elements, and using mathematical models to simulate how these elements interact with one another. FEA can be used to evaluate the strength, stiffness, and stability of structures such as bridges, buildings, and dams. It can also be used to study the effects of loads, temperature changes, and other environmental factors on these structures.

2.2.5 Validation of results

Project shows the results of experimental and analytical through graph and finally compares the all the beam in a single graph and data shows which beam carries the maximum load compared to all other beams.

2.3 DIMENSIONS

The study aims to investigate the stress-strain behavior of a beam with a corrugated web under various working conditions. this study is conducted experiments to determine how the height and span of the beam, as well as the width of the load platform, affect the stresses in the corrugated web. By analyzing the stress-strain behavior of the beam, This experiment can be useful in designing and optimizing these types of beams for use in various applications. This study

contributes to the ongoing research in the field of structural engineering and provides valuable insights into the behavior of corrugated web beams. Three beams were tested. webs of the beam differs in shape to analyse the flexural behaviour of the beams. The flat corrugated beam with stiffner is compared with trapezoidal corrugated beam and rectangular corrugated web beam. Dimensions of all the beam are similar 1200x200mm respectively.

2.3.1 Standard I section beam

A total of 3 beams is made of cold rolled steel beams CR2 is fabricated and tested. I section with stiffener, trapezoidal corrugated web beam and rectangular corrugated web beam. All beams are of same dimensions 1200X200mm respectively. Flanges, channels and web are having a same dimension.

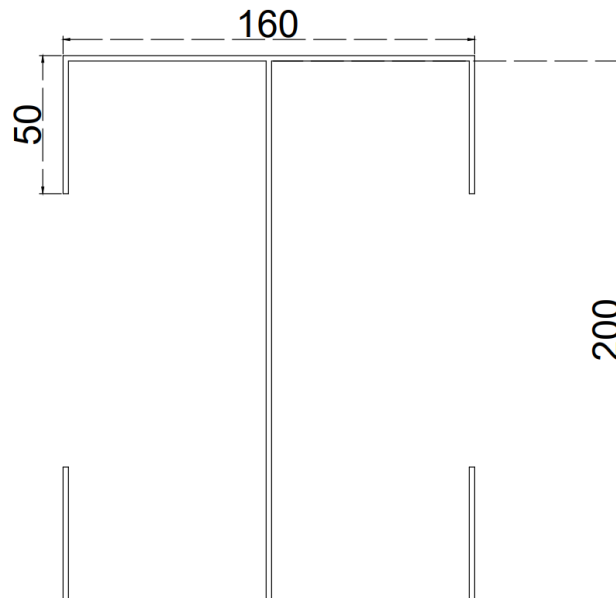


Fig 2.2: dimension of standard I section beam

Table 2.1: dimensions of flange, web and channel of i section beam

Profile	Width (mm)	Thickness (mm)	Length (mm)	Height (mm)
Flange	160	2	1200	-
channel	160	2	-	50
Web	-	2	1200	200

2.3.2 I section beam with stiffener

Total length of the beam is 1200mm and depth is 200mm. stiffener is placed with the spacing of 170mm.

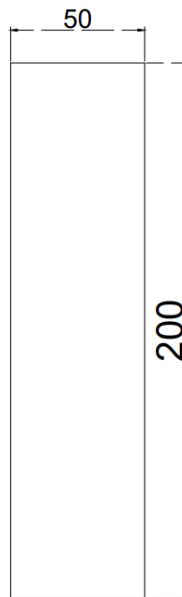


Fig 2.3: Dimension of stiffener

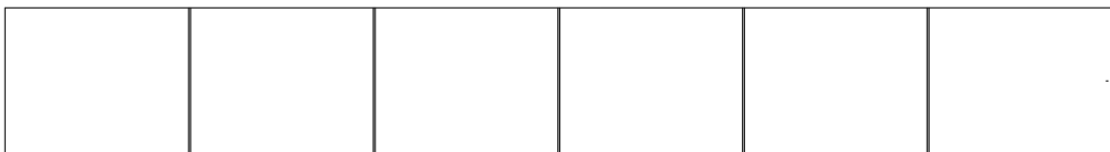


Fig 2.4: cross section of i beam

2.3.3 Trapezoidal corrugated web beam

Total length of the beam is 1200mm and depth of the beam is 200mm. there are totally four corrugation in a beam and the dimension of one corrugation is 300mm.

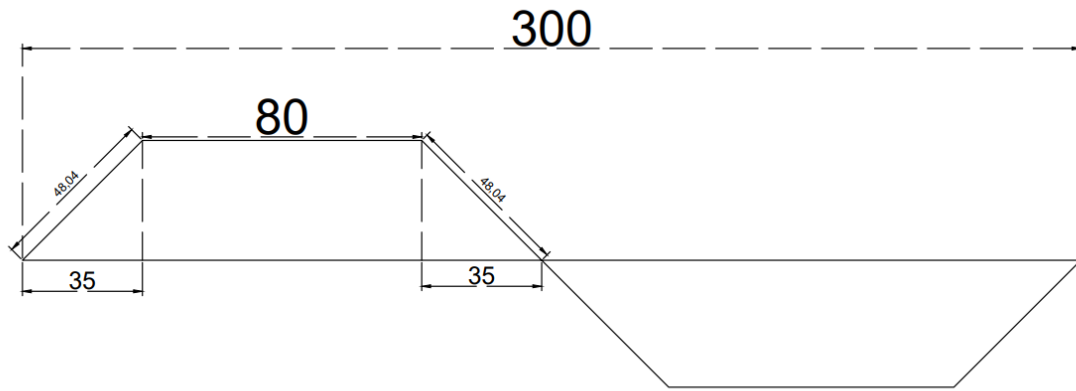


Fig 2.5: dimension of single corrugation of trapezoidal beam

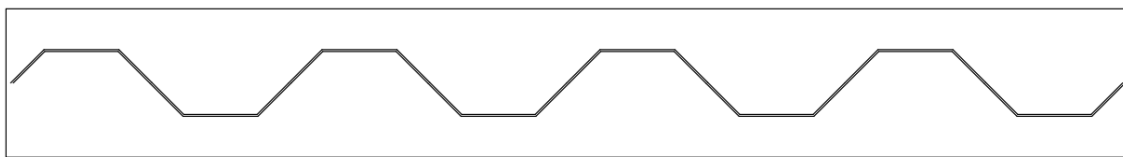


Fig 2.6: cross section of trapezoidal beam

2.3.4 Rectangular corrugated web beam

Total length of the beam is 1200mm and depth of the beam is 200mm. there are totally four corrugation in a beam and the dimension of single corrugation is 300mm.

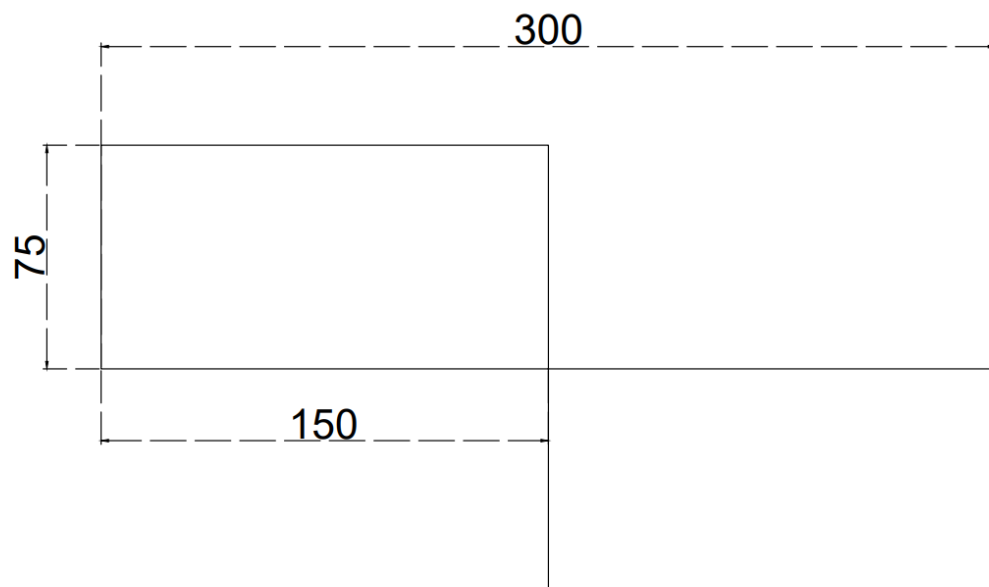


Fig 2.7: dimension of single corrugation of rectangular beam

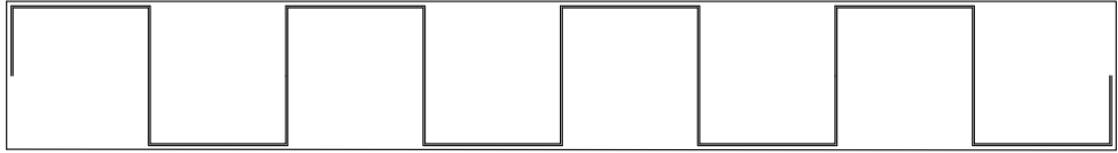
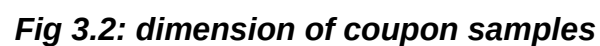


Fig 2.8: cross section of rectangular beam

EXPERIMENTAL ANALYSIS

A coupon test for CR2 steel sheet involves taking a small sample or coupon of the steel sheet and subjecting it to various mechanical and chemical tests to evaluate its properties and performance. The tests typically include tensile testing to measure the steel's strength and elongation, as well as hardness testing to assess its resistance to indentation and wear.



3.1.1 Material properties

Material properties refer to the characteristics of a material that determine its behavior and suitability for various applications. These properties can be physical, mechanical, thermal, electrical, magnetic, or optical. For instance, the strength of a material refers to its ability to resist deformation or failure under applied loads, while its ductility describes its ability to deform without fracturing. Other common material properties include hardness, toughness, elasticity, corrosion resistance, thermal conductivity, electrical conductivity, and magnetic properties. The material properties of a given material are influenced by its chemical composition, microstructure, and processing history. These properties can be modified through material processing techniques such as heat treatment, alloying, and surface treatment. The selection of materials with appropriate properties is essential to the design and performance of engineering structures and products. Material engineers often employ computer simulations, experiments, and analytical models to predict and optimize the properties of materials for specific applications. Overall, understanding the material properties of different materials is crucial in engineering and manufacturing industries.

3.1.2 Mechanical properties

The tensile strength of CR2 sheet can range from 370 to 540 MPa, depending on the specific grade and thickness the yield strength of CR2 sheet can range from 210 to 370 MPa, depending on the specific grade and thickness the elongation of CR2 sheet is typically around 30%, meaning that the material can stretch up to 30% of its original length before it breaks. CR2 sheet has a hardness of around 50-60 HRB (Rockwell B Hardness), which is relatively soft compared to some other steels. CR2 sheet is highly ductile, meaning that it can be easily formed into different shapes and sizes without breaking. CR2 sheet is a versatile material with good strength, ductility, and formability, making it suitable for a wide range of industrial applications, such as automotive parts, appliances, and construction materials.

Table 3.1 Mechanical properties of cr2 steel sheet

Properties	Max values	units
Elongation	38	%
Ultimate stress fu	350	MPa
Yield stress fy	240	MPa

3.1.3 Chemical composition

CR2 steel is a type of cold-rolled steel that is typically used for applications where a high level of surface quality is required. The chemical composition of CR2 steel can vary depending on the specific grade and manufacturer, but a typical composition might include Other elements that may be present in trace amounts include chromium (Cr), nickel (Ni), and copper (Cu), but these are not typically present in significant amounts in CR2 steel the exact chemical composition of CR2 steel can have an impact on its mechanical properties, such as strength, ductility, and toughness. Therefore, it is important to consider the specific grade and composition when selecting CR2 steel for a particular application.

Table 3.2 Chemical compositions of CR2 steel sheet

Chemical Constituents	%
Sulphur	0.035
phosphorous	0.04
Carbon	0.7
Manganese	0.4
Silicon	0.05

3.1.4 Coupon test results

To determine the tensile strength of the CR2 steel sheet two samples are tested for the coupon test . the grade of the steel sheet is IS 513:2008.

Sample 1:

Table 3.3: input and output data of sample 1 coupon test

INPUT DATA		OUTPUT DATA	
SPECIMEN SHAPE	FLAT	LOAD AT YIELD	6.154 kN
SPECIMEN TYPE	MILD STEEL	ELONGATION AT YIELD	2.686 mm
SPECIMEN WIDTH	15 mm	YEILD STRESS	205.15 N/mm2
SPECIMEN THICKNESS	2mm	LOAD AT PEAK	10.384 kN
INTIAL GL FOR % ELONGATION	100mm	ELONGATION AT PEAK	32.942 mm
PRELOAD VALUE	0 kN	TENSILE STRENGTH	346.117 N/mm2
MAX LOAD	50 kN	LOAD AT BREAK	8.658 kN
MAX ELONGATION	1000 mm	ELONGATION AT BREAK	42.533 mm
SPECIMEN CROSS SECTION AREA	30 mm2	BREAKING STRENGTH	288.583 N/mm2
		% REDUCTION AREA	35.2 %
		% ELONGATION AREA	32.94 %

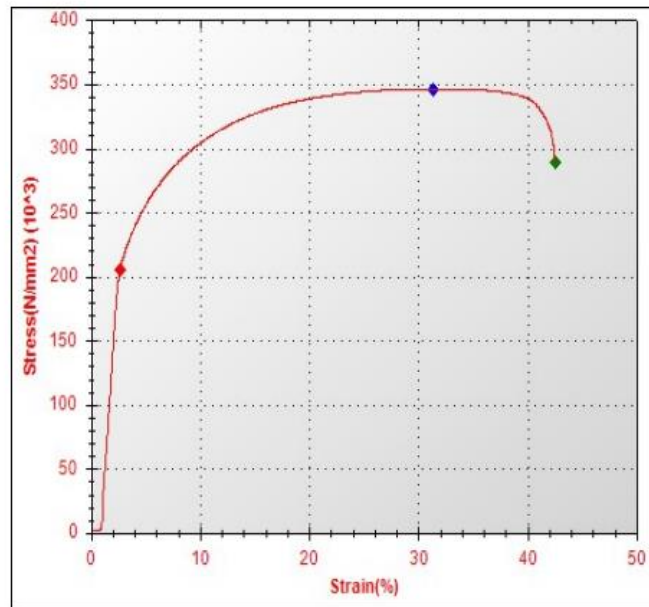


Fig 3.3: stress strain graph of sample 1 coupon test

Sample 2:

Table 3.4: input and output data of sample 2 coupon test

INPUT DATA		OUTPUT DATA	
SPECIMEN SHAPE	FLAT	LOAD AT YIELD	8.406 kN
SPECIMEN TYPE	MILD STEEL	ELONGATION AT YIELD	6.932 mm
SPECIMEN WIDTH	15 mm	YEILD STRESS	140.092 N/mm2
SPECIMEN THICKNESS	2mm	LOAD AT PEAK	10.435 kN
INTIAL GL FOR % ELONGATION	100mm	ELONGATION AT PEAK	34.025 mm
PRELOAD VALUE	0 kN	TENSILE STRENGTH	173.917 mm/2
MAX LOAD	50 kN	LOAD AT BREAK	8.805 kN
MAX ELONGATION	1000 mm	ELONGATION AT BREAK	45.118 mm
SPECIMEN CROSS SECTION AREA	60 mm2	BREAKING STRENGTH	146.750 N/mm2
		% REDUCTION AREA	34.57 %
		% ELONGATION AREA	34.03 %

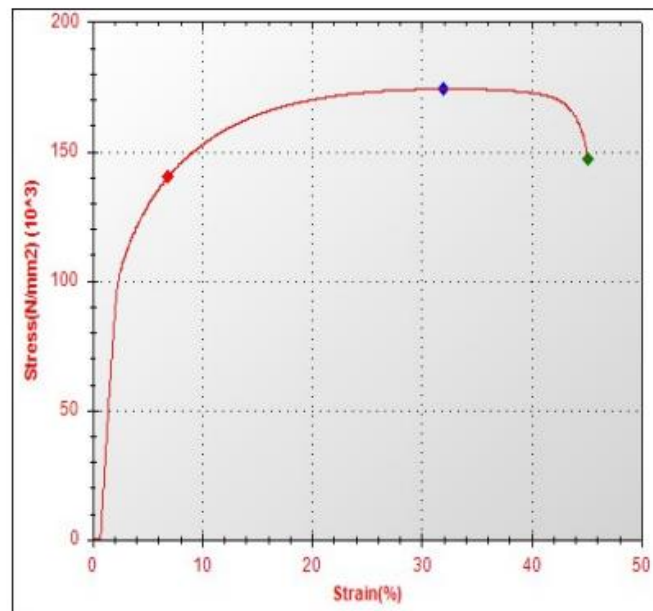


fig 3.4: stress strain graph of sample 2 coupon test

3.2 PURCHASING OF COLD FORMED STEEL

Cold formed steel CR2 sheet is purchased with the dimension of 1200X2400mm and thickness of the sheet is 2mm. weight of the sheet is 50kg. Grade of the sheet is IS 513 2008.



Fig 3.5: CR2 steel sheet of 2mm thickness

3.3 FOLDING AND WELDING

The sheets were cut into pieces for folding. A common I-section beam was used for all the beams. For trapezoidal corrugated web beams, the web of the beam was cut into a trapezoidal shape with a span of 1200mm, a height of 200mm, and an angle of 45 degrees. For rectangular corrugated web beams, the web of the beam was cut into a rectangular shape with a span of 1200mm and a height of 200mm. Finally, a flat web of 1200mm and a height of 200mm was used, and a stiffener of 200x50mm was provided with a spacing of 200mm each. After folding the specimens are welded using tig welding. Tungsten Inert Gas (TIG) welding, also known as Gas Tungsten Arc Welding (GTAW), is a welding process that uses a non-consumable tungsten electrode to produce an electric arc that melts and fuses the base metal. TIG welding is commonly used in aerospace, automotive, and other industries that require high-quality and precise welds. TIG welding requires a high level of skill and control, as the welder must simultaneously feed the filler metal into the weld pool while maintaining a consistent arc length and manipulating the torch to achieve the desired weld shape. TIG welding can be used to weld a wide range of materials, including stainless steel, aluminum, and copper alloys, among others. One of the advantages of TIG welding is its ability to produce clean, precise welds with minimal spatter and distortion. Additionally, TIG welding can be used to weld thin materials without causing burn-through or warping. However, TIG welding is generally slower and more expensive than other welding processes, and it may not be suitable for high-volume production applications.



Fig 3.6: Welding of cr2 steel sheet



Fig 3.7: specimens of all three beams

3.4 EXPERIMENTAL SETUP

A four-point loading test is a mechanical testing method used to evaluate the bending strength and stiffness of a structural beam or plate. During the test, a load is applied to the beam at four points, with two points near each end and two points at a distance from the ends. The test is designed to simulate real-world loading conditions, such as a person standing on a floor or a vehicle driving over a bridge. The test starts with a beam placed horizontally and supported at the two outer points, which act as fixed supports. A load is then applied at the two inner points, which create two separate spans in the beam. The magnitude and distribution of the load depend on the testing standards or specifications and the expected use of the beam. As the load is increased gradually, the beam experiences bending stresses that cause it to deflect downward in the unsupported central section. The deflection of the beam is measured using a displacement sensor or dial gauge, which records the amount of vertical displacement at various points along the beam. The load and deflection data are then used to calculate the beam's bending stress, bending moment, and curvature, as well as its stiffness, yield strength, and ultimate strength. The bending stress and bending moment values are calculated using beam theory equations, while the curvature is determined by measuring the slope of the deflection curve. The test is continued until the beam reaches its ultimate strength or failure point, which is typically characterized by a sudden increase in deflection or a crack in the beam. The load and deflection data obtained during the test are used to create a load-deflection curve, which provides a visual representation of the beam's behavior under load. The results of the four-point loading test can be used to evaluate the performance of a beam under various loading conditions and to optimize its design for specific applications. Additionally, the test can be used to compare the mechanical properties of different materials or beam shapes and sizes. Overall, the four-point loading test is a valuable tool in structural engineering for assessing the mechanical properties of structural beams and ensuring their safety and reliability in real-world applications.



Fig 3.8 Loading frame setup for testing

3.5 EXPERIMENTAL RESULTS

Gradually the load is applied to the specimens and the dial gauge is placed below the specimens. As the load applied on the specimens dial gauge reading is noted and with the help of the reading load vs deflection graph is plotted. There are totally three beams, I section, trapezoidal, rectangular.

3.5.1 I section with stiffener

The beam had a weight of 15.47kg and failed under a load of 25kN. Local buckling occurred in the flange while the web remained strong enough and did not shear. As a result, the span of the beam was reduced by 2mm. Additionally, the depth of the flange was reduced by 5mm at the roller support. These changes may have significant implications for the beam's structural integrity and will need to be carefully considered when evaluating its performance and potential for repair or replacement.



Fig 3.9: I Section beam after applying the load

3.5.2 Trapezoidal corrugated web beam

The result of the failure trapezoidal beam. The weight of the beam was 13.84kg and it failed under a load of 24.33KN. The failure occurred at the web of the beam, which is the central part connecting the top and bottom flanges. Buckling is a form of failure where the beam loses stability and collapses due to excessive compressive stress. In this case, the beam buckled at the web. Additionally, the deflection of the beam was 23mm, which is the amount of bending or curvature the beam experienced under load. The flange, which is the top and bottom part of the beam, was also deflected in the center region of the beam. Deflection of the flange indicates a deformation of the beam that occurred due to excessive stress. Overall, the given information indicates that the trapezoidal beam was not able to withstand the applied load and failed due to buckling and excessive deformation.

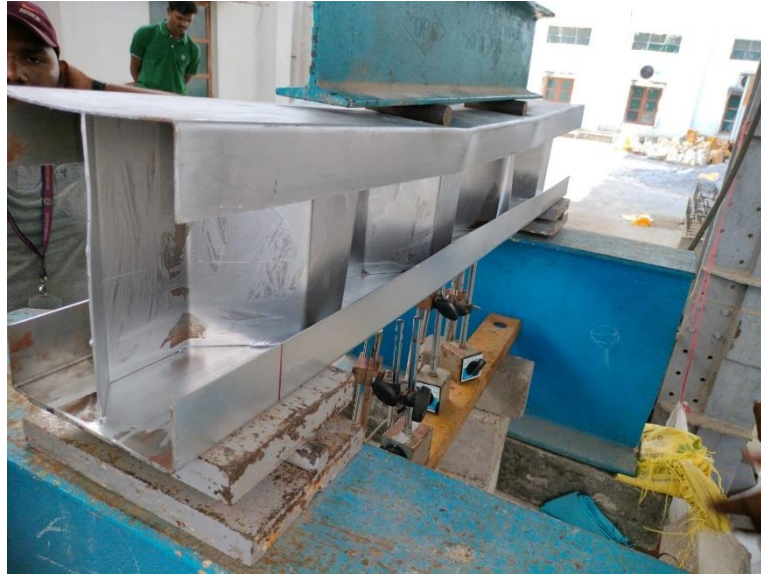


Fig 3.10: Trapezoidal beam after applying the load

3.5.3 Rectangular corrugated web beam

The rectangular beam had a weight of 16.69 kg and was subjected to a force of 12.38 kN, resulting in its failure. Specifically, local buckling occurred at the flange of the beam, indicating that this section was not able to withstand the applied load. However, the web of the beam was strong enough to avoid buckling. The beam's deflection was measured to be 30 mm, indicating that it had significant deformation under the applied load. The failure of the beam due to local buckling at the flange suggests that the design of the beam may not have taken into account the specific loads and stresses that it would be subjected to. It may be necessary to reassess the design parameters and consider modifications to ensure that the beam can withstand the expected loads and prevent failure due to buckling or other types of structural deformation. In general, understanding the failure of a beam is critical for improving future designs and ensuring that structures are safe and reliable. By examining the specific factors that led to this failure, engineers and designers can learn important lessons about the materials, design, and construction techniques used, and make informed decisions about how to improve future designs.



Fig 3.11: rectangular beam after applying the load

CHAPTER 4

ANALYTICAL ANALYSIS

4.1 FINITE ELEMENT ANALYSIS

The geometry of the specimens was modelled in ABAQUS Design Modeler with the help of a 3D scanner. The 3D scanner was used to capture the exact dimensions of the specimens, ensuring that all measurements were accurate and precise. The figures show the geometry of the flat beam with stiffener, trapezoidal corrugated web, rectangular corrugated web respectively, including their length and width as well as other features such as curvature or protrusions from their surface. All of these features were accurately modelled Design Modeler to allow for a precise simulation of each specimen's behaviour under different loading conditions.

4.2 GEOMETRY

Geometry of the specimens I section beam, trapezoidal beam and rectangular beam is designed in abaqus software and further analysed the flexural capacity of each beam.

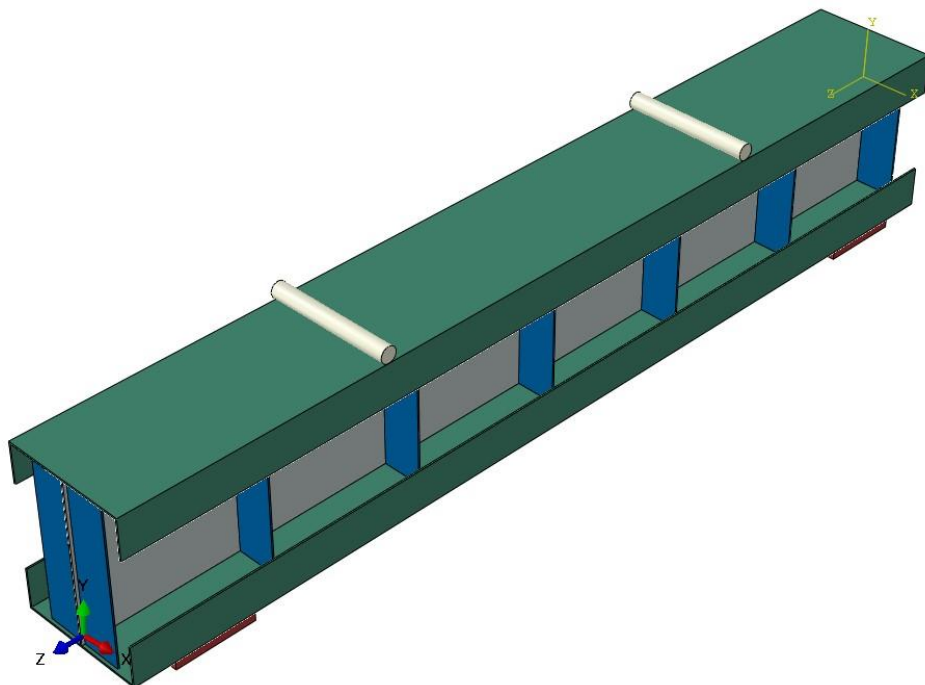


Fig 4.1: I Section beam designed in abaqus

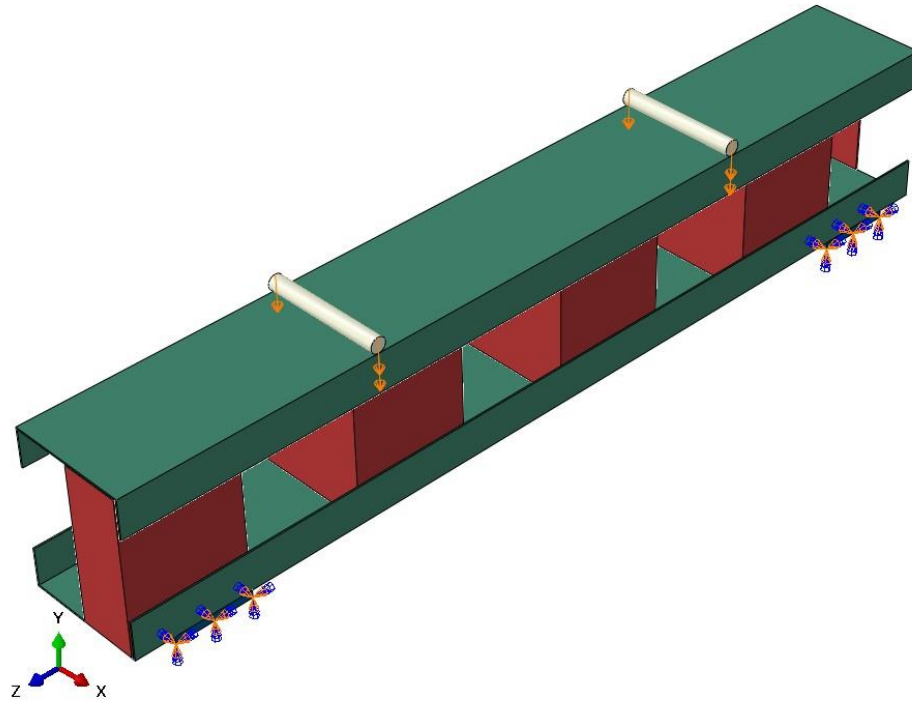


Fig 4.2: Rectangular corrugated web beam designed in abaqus

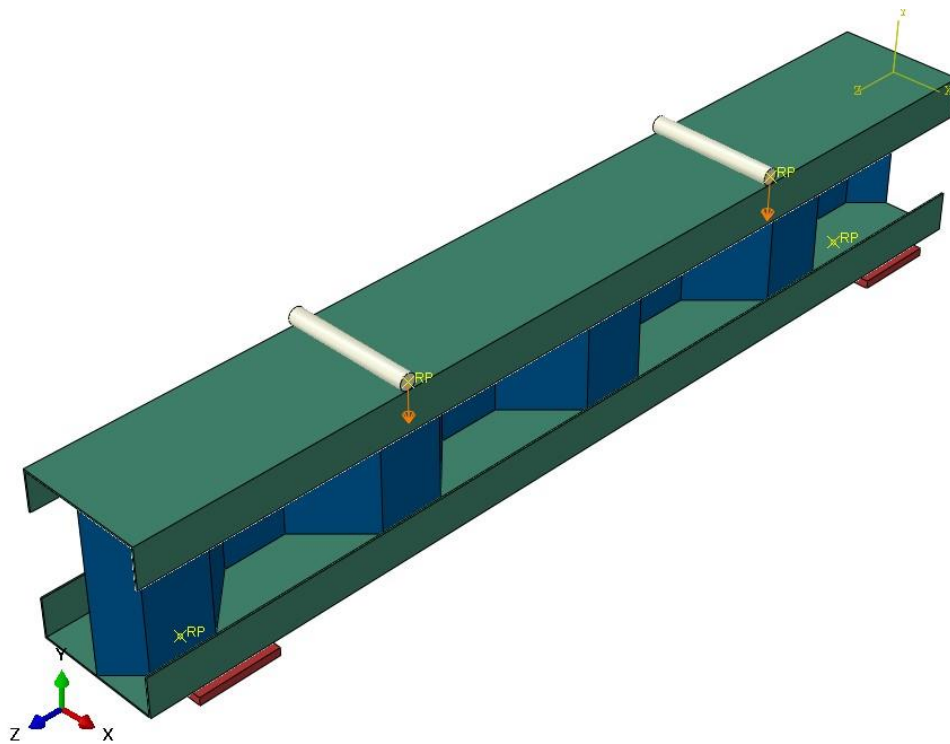
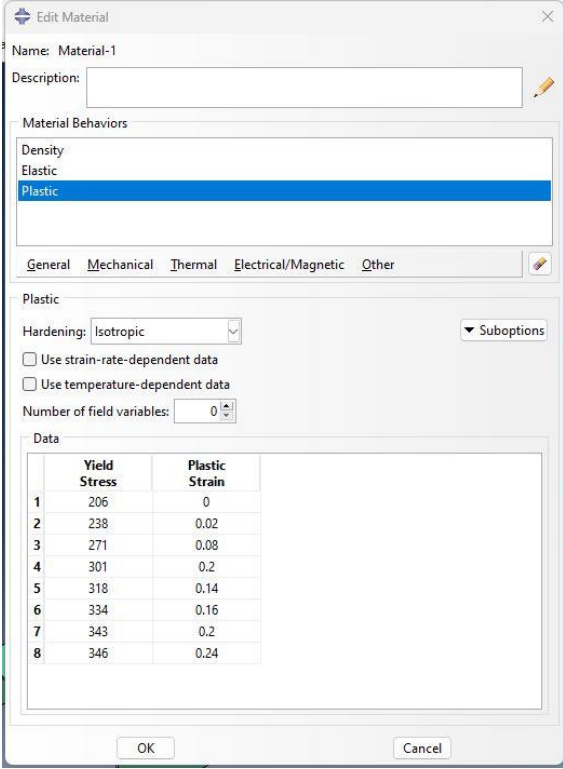


Fig 4.3: trapezoidal corrugated web beam designed in abaqus

4.3 Material properties

In engineering data, the mechanical properties for cold rolled sheet as per code IS 513:2008. Below table shows the data of material properties of GRADE IS 513 CR2 sheet.



The 'Edit Material' dialog box shows the 'Plastic' behavior selected. The 'Hardening' is set to 'Isotropic'. The 'Number of field variables' is 0. The 'Data' table is as follows:

	Yield Stress	Plastic Strain
1	206	0
2	238	0.02
3	271	0.08
4	301	0.2
5	318	0.14
6	334	0.16
7	343	0.2
8	346	0.24

Fig 4.4: Material properties data in abaqus

4.4 MESHING

Meshing is the process of dividing a model into small elements, and Abaqus provides manual meshing, automatic meshing, mapped meshing, and adaptive meshing methods. Manual meshing allows users to specify node and element locations, while automatic meshing generates a mesh based on user-defined criteria. Mapped meshing uses a pre-defined mesh pattern, and adaptive meshing adjusts the mesh based on solution error. These options provide users with flexibility and control over the meshing process, allowing them to choose the most appropriate method for their specific needs.

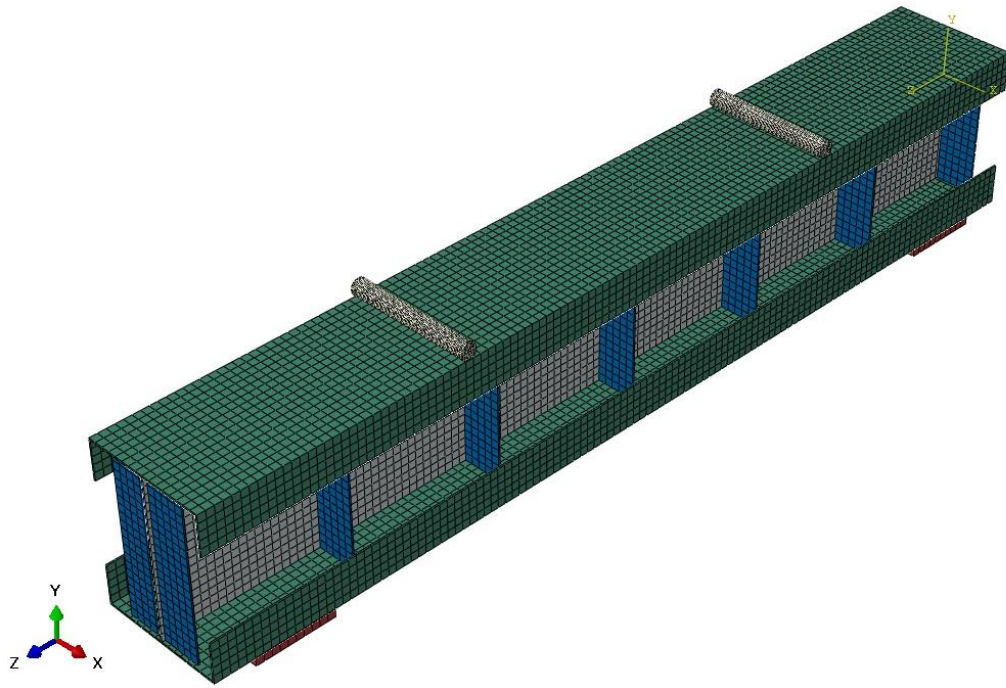


Fig 4.5: I Section beam meshed in abaqus

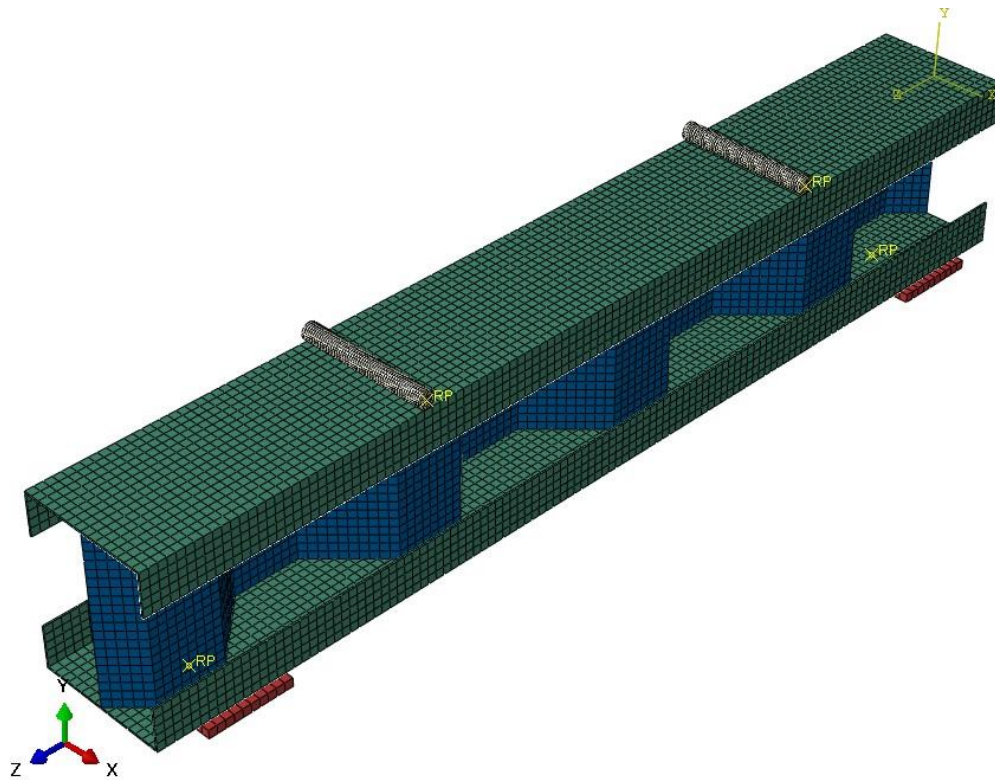


Fig 4.6: Trapezoidal beam meshed in abaqus

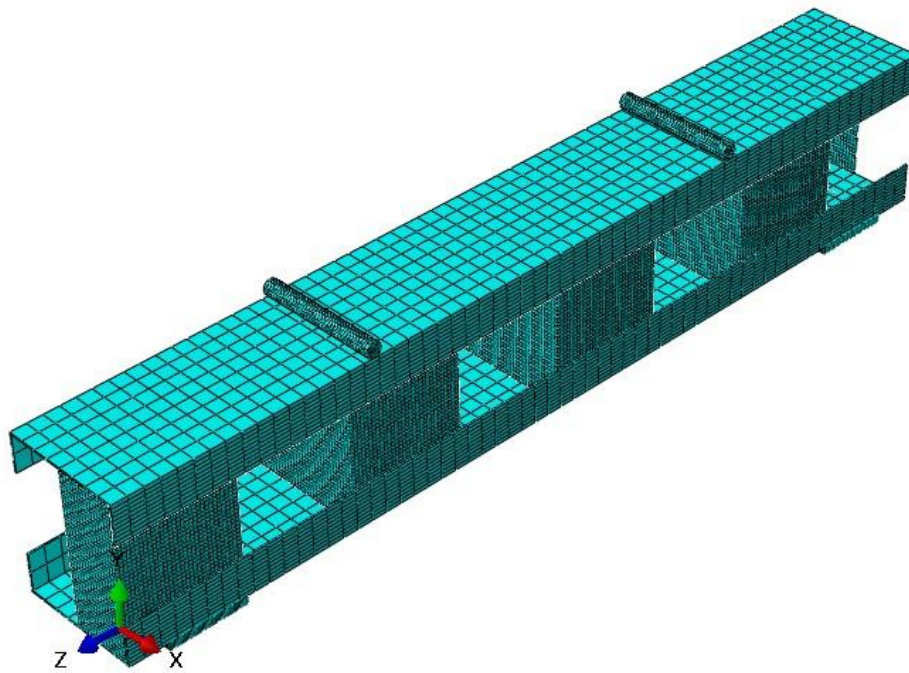


Fig 4.7: Rectangular beam meshed in abaqus

4.5 INTERACTIONS

Interactions can occur between parts that are in contact or separated by a small gap. There are two main types of interactions that can be modeled in Abaqus: surface-to-surface and node-to-surface interactions. Surface-to-surface interactions are used when the contact between the parts is significant, and the surfaces deform as they come into contact. This type of interaction can model friction, adhesion, and separation between the parts. Node-to-surface interactions are used when the contact between the parts is negligible, and the parts do not deform as they come into contact. This type of interaction is used to model constraints and tie constraints between parts. To model interactions in Abaqus, the contact surfaces must be defined, and the interaction properties, such as friction coefficient and separation behavior, must be specified. Proper modeling of interactions is essential for obtaining accurate and realistic simulation results.

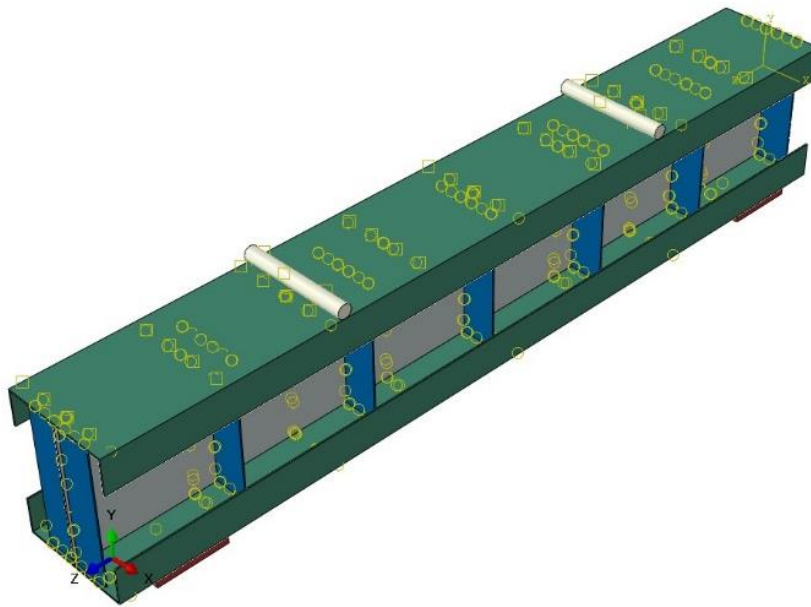


Fig 4.8: Interaction in I section beam

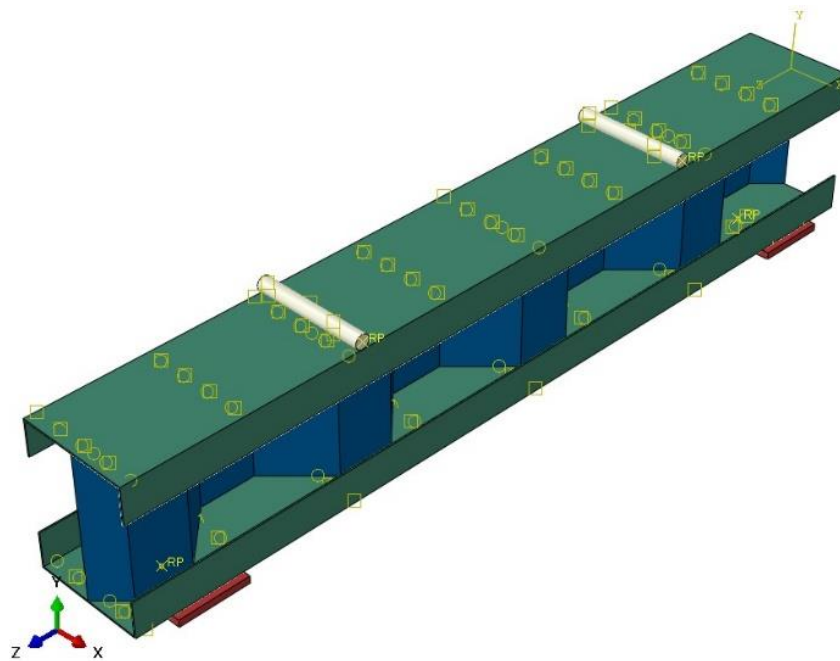


Fig 4.9: Interaction in trapezoidal beam

4.6 LOADING AND SUPPORT CONDITIONS

Loading and support conditions are assigned as per to perform the Four-point flexure testing with 2 support pins and two loading pins. One side of the support pin is roller support and the other side of the support pin is hinged support. Length of the loading pins is 100mm and the diameter of the loading pins is 50mm respectively.

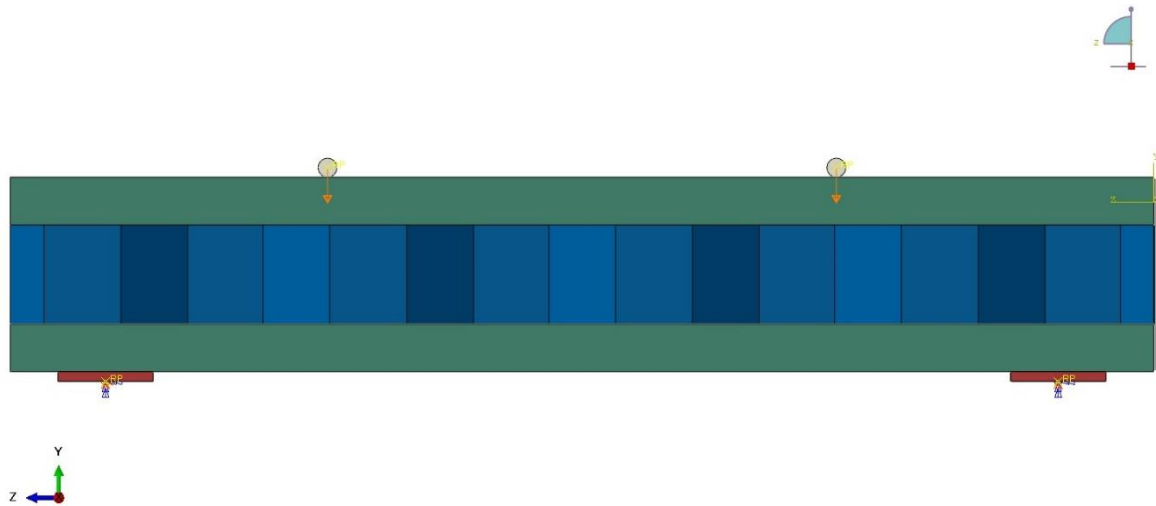


Fig 4.10: Loading conditions

4.7 ANALYTICAL RESULTS

The analytical results are of two types they are deflection of beams and stress distribution of beams the results and values are given below

4.7.1 Deflection of beams

The total deflection of beams is calculated by gradually increasing the load upto 2kN for all beams. The below figures shows the deflection of beams.

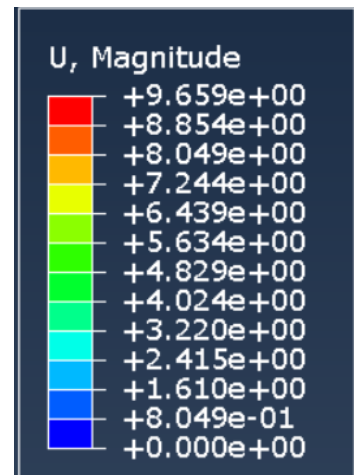
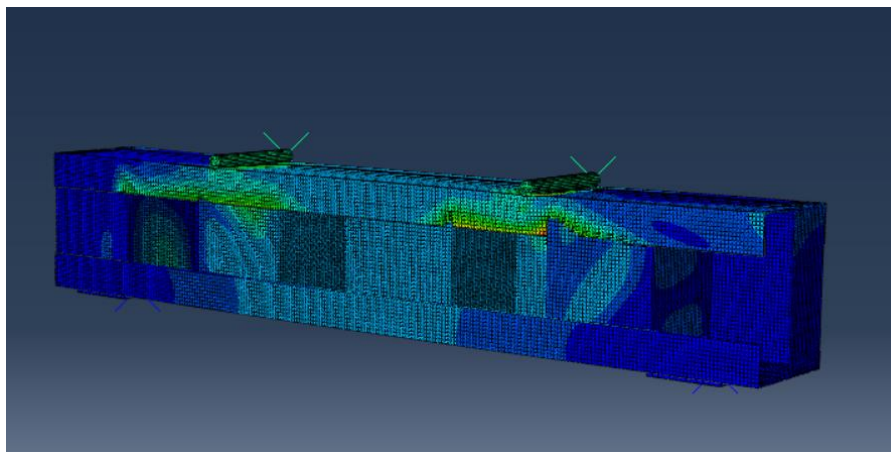


fig 4.11: deflection of rectangular beam and values

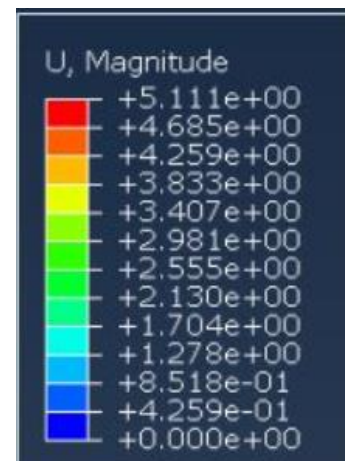
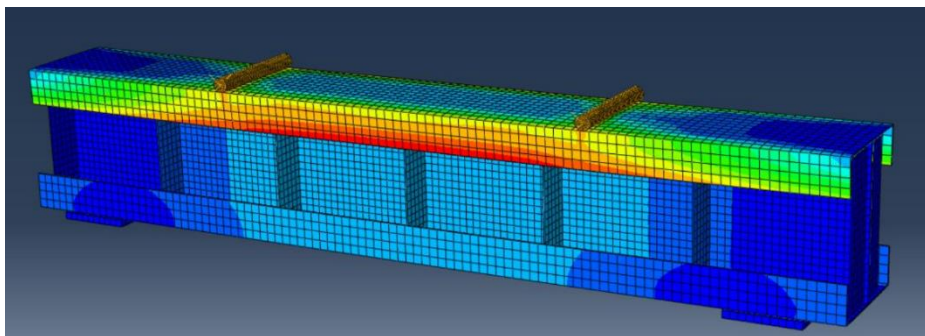


Fig 4.12: deflection of I section beams and values

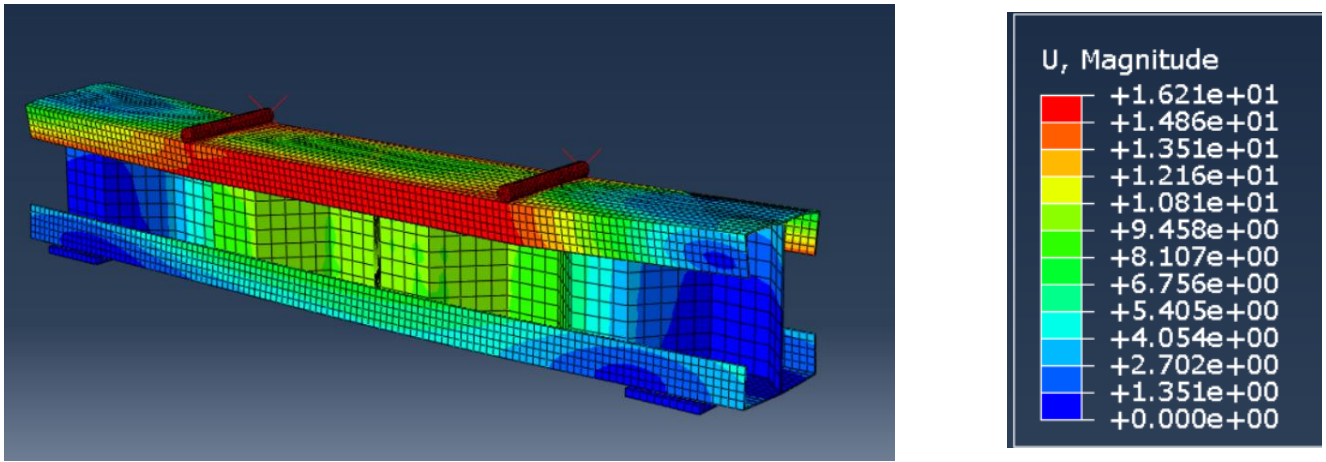


Fig 4.13: deflection of trapezoidal beam and values

4.7.2 Stress distribution of beams

The Equivalent stress (von mises) of the beam is calculated for the load at the yield point. Below figures show the stress distribution in abaqus software.

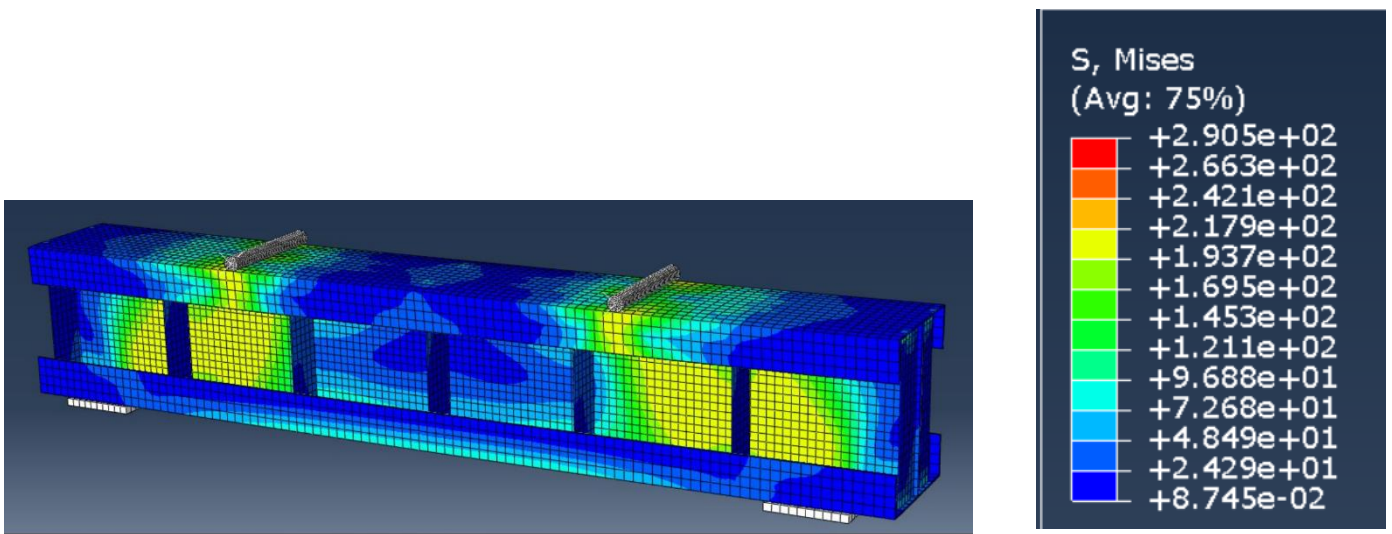


Fig 4.14: stress distribution of I section beam and values

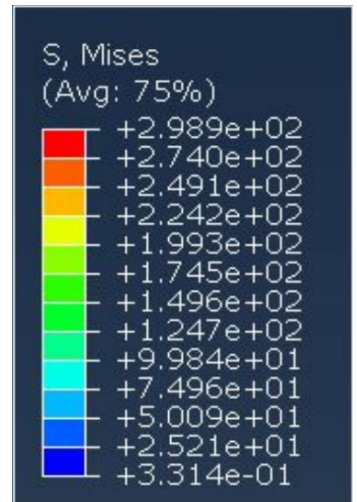
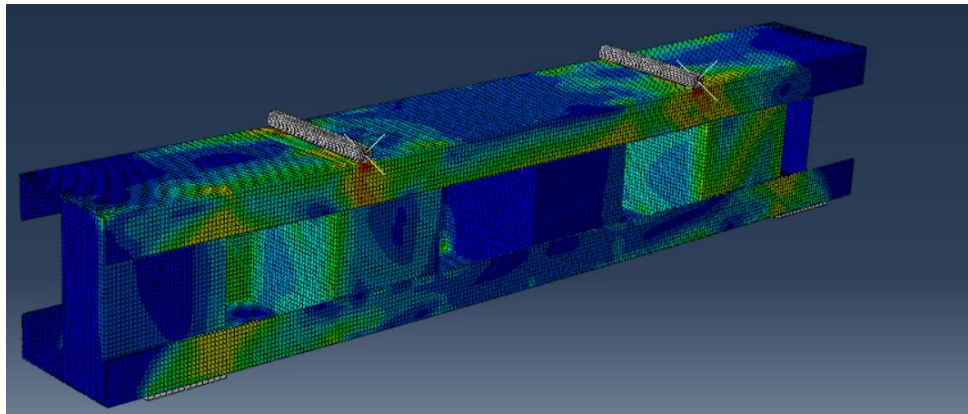


Fig 4.15: stress distribution of trapezoidal beam and values

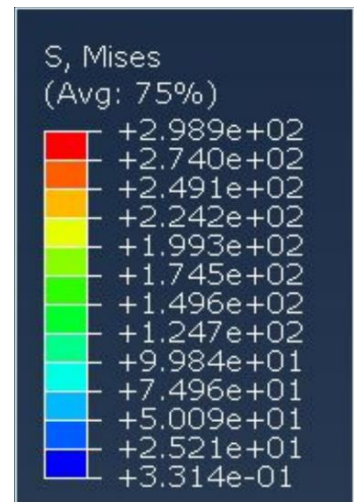
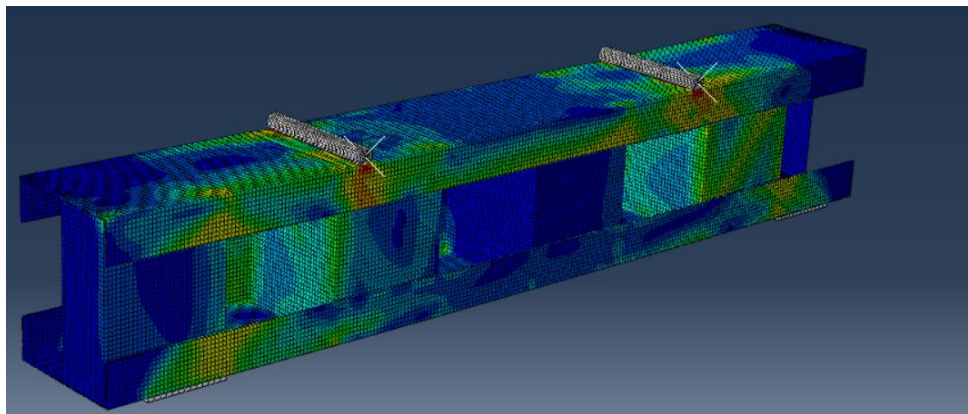


Fig 4.16: stress distribution of rectangular beam and values

CHAPTER 5

RESULTS AND DISCUSSION

5.1 ABAQUS RESULTS

The yield point is obtained at 30.4kN, 25kN, 12.5kN for trapezoidal corrugated beam, rectangular corrugated beam, I section beam respectively. The load vs deflection graph for all three specimens are obtained from abaqus software. Trapezoidal corrugated beam carries the highest load. Fig 5.1 shows the load vs deflection graph for all three specimens

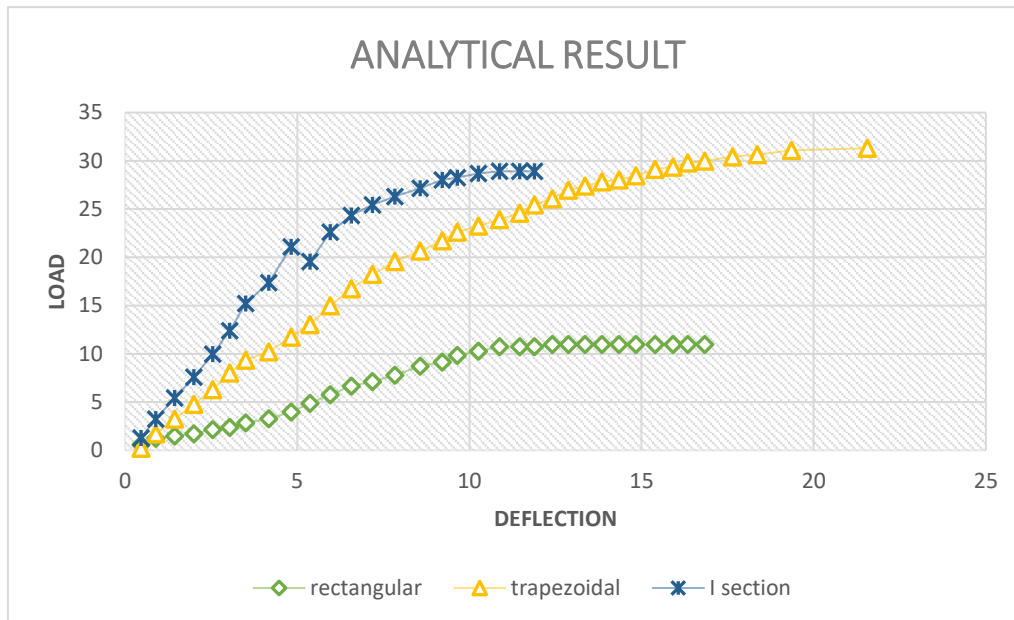


Fig 5.1: load vs deflection analytical graph

5.2 EXPERIMENTAL RESULTS

The yield point is obtained at 30.4kN, 25kN, 12.5kN for trapezoidal corrugated beam, rectangular corrugated beam, I section beam respectively. The load vs deflection graph for all three specimens are obtained from experimental investigation. Trapezoidal corrugated beam carries the highest load. Fig 5.2 shows the load vs deflection graph for all three specimens



Fig 5.2: load vs deflection experimental graph

5.3 COMPARISON OF BEAMS

The load vs deflection curve for both analytical and experimental is compared is shown in the fig 5.3. Graph shows the deformation of beams.

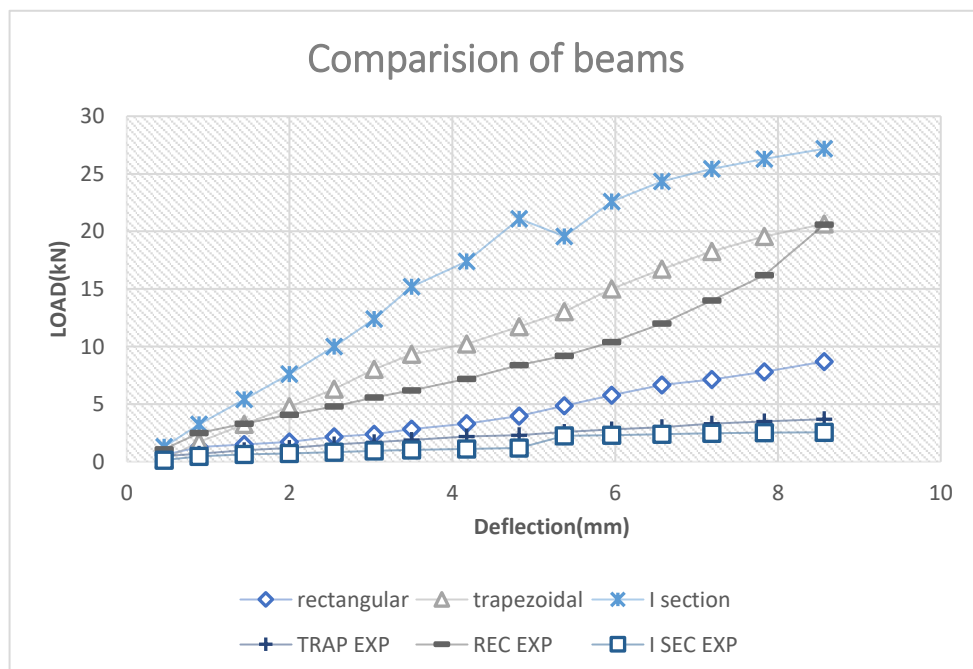


Fig 5.3: load vs deflection for both experimental and analytical

5.4.1 DISCUSSION

The failure modes and properties of different types of beams under varying loading conditions. The trapezoidal beam failed due to web buckling, while the rectangular beam failed due to flange buckling, and the flat beam failed due to flange buckling as well. The weight of the trapezoidal beam was 13.84kg, and it failed under a load of 30.4kN, with a deflection of 15mm. The rectangular beam weighed 16.69kg, and it failed under a load of 12.38kN, with a deflection of 20mm. In contrast, the flat beam weighed 15.47kg and failed under a load of 25kN, with changes made to reduce the span and depth of the flange. The web of the rectangular beam was strong enough and did not buckle under the applied load. Corrugated web beams can reduce the use of the web stiffeners due to the corrugated shape of the web. Therefore, even more than 20% of the material weight could be saved in the design optimisation process using CWBs. Understanding the failure behaviour of beams is essential for designing structures that can withstand the expected loads and prevent catastrophic failures, highlighting the importance of considering the beam's properties and loading conditions. Use of vertical core corrugation may change the failure mode depending on flange corrugation height and web width. Decreasing web width by 50% of original corrugated width makes a reduction in both ultimate load and deflection of tested specimen, also it will change the failure mode from shear to flexural failure which ensure that stresses were redistributed to be more concentrated on flanges. Overall, trapezoidal corrugated beam has highest load of 30.4kN and rectangular corrugated beam carries a least load of 12.38 kN. In addition to their superior strength and efficiency, corrugated web beams are also cost-effective and sustainable, as their unique shape allows them to be produced with less material than traditional beams This can result in lower costs and reduced environmental impact compared to other structural solutions.

CHAPTER 6

CONCLUSION

It is proved that the web local destruction is not the criterion of total destruction of corrugated beams. The tests showed that under the action of concentrated forces the exhaustion of the load capacity of corrugated beams occurs either because of the loss of local stability of the corrugation, or due to the achievement of metal yield limit in the flanges. When metal yield strength in the web of beams is achieved, flanges tension is only 60-90% of this value. The load bearing capacity of corrugated beams is significantly influenced by eccentricity between the axes of flanges and webs. Up to the destruction of corrugated beams, there is a linear correlation between deflection and load. Lateral torsional buckling can happen in a beam that is not restrained, meaning its compression flange can move sideways and rotate. When an external load is applied to such a beam, it can cause both lateral displacement and twisting, leading to lateral torsional buckling. This happens because the load creates compression and tension forces in the beam's flanges, causing the compression flange to move laterally while the tension flange tries to keep the beam straight. Even though the beam tries to return to its original shape, the restoring forces are not strong enough to resist the lateral deflection, and along with the tensile forces, they determine the beam's buckling resistance.

Local buckling

Local buckling is a type of structural failure that occurs when a section of a member, such as a beam or column, is unable to withstand the compressive forces placed upon it, causing it to buckle or deform. This failure typically occurs at the flanges of beams and can be prevented through proper design and material selection to ensure that the member can withstand the compressive forces without buckling.

Flexural torsional buckling

Flexural torsional buckling is a type of structural failure that occurs when a beam or column is subjected to both bending and torsional forces. This type of failure can result in significant deformation or collapse of the member, particularly if

it is not designed to withstand the combined loading. Flexural torsional buckling is caused by a combination of compression and twisting forces that act on the member, leading to instability and failure. It can be prevented through proper design and material selection, which may involve increasing the stiffness of the member or using stronger materials. Engineers must consider the specific loading conditions and other factors when designing structures to prevent flexural torsional buckling.

Deformation

Deformation in beams is the change in shape or size of a beam under load. This bending or deflection is influenced by factors such as the magnitude and direction of the load, material properties of the beam, and its cross-sectional shape. Engineers measure deformation by recording the displacement or strain caused by the applied load. Proper design and selection of materials can help to minimize deformation and ensure the safe and reliable performance of the structure.

Compression force

Compression in the steel members is the structural members that are only subjected to the compression force. In the compression members, loads that act on the member are generally along the length wise direction and through cross section's centroid

Tensile force

Tensile strength is the resistance of steel to breaking under tensile tension. It's used to specify the point when steel goes from elastic (temporary) to plastic (permanent) deformation. Usually, it's measured in units of force per cross-sectional area.

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