KAUNAS UNIVERSITY OF TECHNOLOGY

MECHANICAL ENGINEERING AND DESIGN FACULTY

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Analysis of Welded Joints and Improvement of their Manufacturing Process

Master's Degree Final Project

Supervisor

Assoc.prof. Dr. Jolanta Baskutiene

KAUNAS,2017

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Master's Degree Final Project

Industrial Engineering and Management (code 621H77003)

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KAUNAS, 2017

KAUNAS UNIVERSITY OF TECHNOLOGY

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(Title and code of study programme)

"Analysis of Welded Joints and Improvement of their Manufacturing Process"

DECLARATION OF ACADEMIC INTEGRITY

24 May 2017
Kaunas

I confirm that the final project of mine, **Manikandan Devadoss**, on the subject "**Analysis of Welded Joints and Improvement of their Manufacturing Process**" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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Production engineering
Department

____
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Kazimieras Juzėnas
(Name, Surname)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme INDUSTRIAL ENGINEERING AND MANAGEMENT

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

Analysis of Welded Joints and Improvement of their Manufacturing Process

Approved by the Dean Order No.V25-11-8, 21 April 2017

2. Aim of the project

To analyse the full penetration welding process by improving the manufacturing process in structural beams.

3. Structure of the project

1. Literature review
2. Selection of material and the welding process
3. Type of bend formations and its manual correction methods
4. Improvement in material preparation
5. Improvement in welding process
6. Improvement in production process
7. Analysis of results
8. Conclusions

4. Requirements and conditions

The beam is improved for the bevel dimensions from 45° to 30°.The amount of force developed is calculated as 103.5N for the 30°bevel. This value of 103.5N is used as the force input value during analysis. The flange plates of the experimental beam are of dimension 340mm width, 2582mm length and 65 mm thickness. The web plate is of 470mm width, 2582mm length and 60mm thickness.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2017 June 10

Student Manikandan Devadoss ______________________
(*Name, Surname of the Student*) (*Signature, date*)

Supervisor Assoc.Prof.Dr. Jolanta Baskutiene ______________________
(*Position, Name, Surname*) (*Signature, date*)

Devadoss Manikandan. Suvirintų sujungimų analizė ir jų gamybos proceso tobulinimas. *Magistro* baigiamasis projektas / vadovas doc. dr. Jolanta Baskutiene; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.

Mokslo kryptis ir sritis: Technologijos mokslai, Gamybos inžinerija

Reikšminiai žodžiai: suvirinti sujungimai, modeliavimas, Solidworks, Ansys, įtempiai, deformacijos.

Kaunas, 2017. 51 p.

SANTRAUKA

Šiame projekte nagrinėjamas gamyboje suvirinimo metu atsirandančių įlinkių formavimasis. Palyginti įlinkių koregavimo procesai didelėse ir mažose įmonėse bei iškeltos problemos dėl suvirinimo metu atsirandančių nevaldomų įlinkių, kurie aptinkami montavimo metu. Eksperimentinis strypo modelis parengtas įvertinant gamybos įmonės rekomendacijas. Solidworks programa atliktas strypo modeliavimas ir atlikta analizė ANSYS programa. Siekiant rasti priimtiniausią suvirinimo sprendimą, palyginti įtempių analizės rezultatai esant skirtingiems suvirimo jungties griovelio matmenims ir, kaip tinkamiausias patobulinimo sprendimas, pasiūlytas pilno pravirinimo procesas. Siekiant patobulinti suvirinimo procesą, nagrinėti skirtingi eksperimentinio strypo suvirinimo sluoksniai. Gamybos proceso patobulinimui suvirinimo metu siūloma naudoti skirtingas strypo atramas. Skirtingo tipo atramų analizė atlikta esant toms pačioms apkrovoms. Siekiant parinkti labiausiai priimtinas surinkimo proceso operacijas, palyginti skirtingo tipo strypų įtempių ir deformacijų analizės rezultatai. Palyginta strypų gamybos trukmė mažose ir didelėse gamybos įmonėse. Nustatyta, kurioje vietoje veikia maksimalūs įtempiai ir pasiūlytos prevencinėms priemonės, kurias siūloma taikyti. Siekiant nustatyti, kurioje vietoje esant atitinkamai apkrovai strypas deformuojamas labiausiais, atlikta strypo deformacijų analizė. Pateiktos projekto tyrimų išvados.

Devadoss Manikandan. ANALYSIS OF WELDED JOINTS AND IMPROVEMENT OF THEIR MANUFACTURING PROCESS. *Master's* thesis Final project/ Supervisor
Assoc. prof. dr.Jolanta Baskutiene. The Faculty of Mechanical engineering and design, Kaunas University of Technology.

Research area and field: Technological sciences, Production Engineering

Key words: welded joints, simulation, Solidworks, Ansys, stress, deformation.

Kaunas, 2017. 51 p.

SUMMARY

This project analyses the formation of bends occurring during the welding in fabrication industries. The bend correction process of large and small scale industries is compared and the problems due to the un-controlled bends in the erection site are to be analysed. The experimental beam is taken into analysis from the fabrication company. The beam is modelled in Solid works and undergoes analysis using ANSYS. The stress analysis is compared between the different weld bevel groove dimensions and full penetration welding process is proposed as the best solution to pursue the improvement of the material preparation. Aiming to improve the welding process different weld layers of the experimental beam is analysed. It is proposed to use different type supports of the beam during the welding process. Different type of supports are analysed under the same loads. The resulting stress and deformation is compared for different type beams. The time needed to finish the entire process in build up the beams is compared between the large scale and small scale fabrication industries. The area of maximum stress is analysed and preventive means to be used prior to welding are proposed. Aiming to define the area of maximal deformation under particular loads the deformation analysis is carried out. The conclusions of the project analysis are given.

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Introduction

Nowadays in Fabrication industries, based on the client needs there is a process of built up the beams is happening when there is no need of standard beam. The standard beam is that beams of pre-fabricated dimensions which depend upon the ISO or ANSI standards. Due to the needs of the architectural design, clients go with the non-standard beams. This is done by the welding of flanges with web plates separately as per the required thickness and dimensions.

The working procedure varies from large scale industries to small scale fabrication industries. In large scale industries this welding is carried out by using the automatic welding or robotic welding where the welding speed and power supply is controlled. And also this work is made with the proper fixture specially made for this work. But in the case of small scale fabrication industries, the use of these machines is not feasible. They depend upon the skilled workers to perform the jobs, but the defects raises are not controlled in the process.

In the large scale industries, there are large advanced machineries to control and remove the bends. In the case of small scale, there is always problem with the formation of bends in the beam due to the welding process. They are using traditional method of heating to remove the bends raised in the welding area. This utilise much energy from manpower and utilities. The utilities are oxygen-acetylene gas supply to make the heating process. This may damage the welded area occasionally, and leaves the welded area tempered which has the high probability in the formation of cracks.

Even though much bend removal process is done, it doesn’t fulfil the control of bends for 100%. It leaves with some defects which causes lots of problems in the erection area. When the erection is happening in heights, if the beam is made with bends, it is difficult to connect with the parent beam already erected. The chances of errors are flanges don’t match, web plates mismatch, connection holes mismatch, erection plates mismatch. This made the entire part of the structure unstable and needs lot of time to correct and finish the erection. To avoid these problems in the initial stage of fabrication, this project deals with ideas of improvement in the welding and manufacturing process of how to control the bend formation.

This project also undergoes stress analysis of different ideas and compares the results of the ideas generated. The best idea is selected based on the need of the job under fabrication. This project takes an sample drawing from the fabrication company and analyse the stress formation for the un-controlled welding process and reveals the formation of bends and cracks in the fabrication stage which is later be controlled.

Aim

To analyse the full penetration welding process by improving the manufacturing process in structural beams.

Tasks Involved

The tasks involved in this project are

1. Selection of material and the welding process
2. Type of bend formations and its manual correction methods
3. Improvement in material preparation
4. Improvement in welding process
5. Improvement in production process
6. Analysis of results

By achieving these tasks, the bends formed due to the full penetration welding process is controlled which helps small and medium scale industries to increase their production and productivity.

1. Literature Review

1.1 Production process of large scale companies in removal of welding bends [1]

In the large scale companies, there are lot of machines to remove the bends raises in the beams due to welding. Where, this process requires large advanced machineries in eliminating bends such as sweep bends, camber bends, bow bends, flange bends and buckling of webs.

Special machineries are installed in the factory to remove these bends which involve heavy requirement of space and high skilled workers, which is obviously not possible in medium scale industries and small scale industries.

It also involves the excess amount of man power, electricity consumption after the common welding process. This manpower and utilities may install in the other production functions in the organization for increasing the production and productivity.

The cost of those machines depends upon the capacity of the machine and typical view of eliminating the different type of bends in a single machine itself.

Fig. 1 Hydraulic jack to remove the flange bends [1]

The figure 1 shows the usage of hydraulic jack machines to remove the war-pages raised in the beams. It involves hydraulic and machine installations in large facility location in the company. It shows the machine assembly of removing the flange bends in the beams. This involves the installation of large space area which is highly not possible in the medium sized companies. It also includes the skilled man power in operating the machine and electricity too. The above shown image works in the removal of flange bends in the beam by giving hydraulic pressure opposed to the area of bends. The machines are limited to remove the bends form the beam of particular dimensions. For bigger sections, it needs large advanced machines in use.

Fig. 2 Elimination of bow bends in the entire length [1]

The above figure 2 shows the removal of bow bends in the entire length of the beams. For example, a beam of 12 metre is to be undergone the bend removal process, the facility area of installing the beam is of 14 metre length and 2.5 metre width. It also involves the work of skilled labour and electricity to process the function. When this facility area is utilised for the production process in medium sized companies, it will help in improving the production and increase the productivity [1].

1.2 Reasons behind the formation of bends

1.2.1 Completion of entire welding in a single side

It is quite common in medium scale companies that in the built-up of beams, for processing the complete joint penetration welding (CJPW) the entire welding is done in the single side instead there is a double groove provision for welding process. It is done that the complete welding process in a single side of the beams made the amount of weld material deposited is high

Due to the amount of material deposited in the weld area is high; the heat generated in the area is also high. Due to the heat generated, the stress experienced in the area is quite high; this obviously causes the bending of flange plates associated with the weld area. After the metal gets solidified, it doesn’t retract to the original position when the welding process in the opposite side does.

The error is that the welding process is done completely in the side 1, so that the amount of weld material deposited is high. The stress induced in the weld area is high due to the heat generated by the amount of material deposited. Where, the heat generated is directly proportional to the stress produced [1]. The figure 3 shows the built-up beam section with the weld groove. It is modelled as per the real time drawing from the fabrication industry which is attached in the annexure 2. The annexure 2 shows the built-up beam section of dimensions 340mm×600mm for the length of 2582mm.

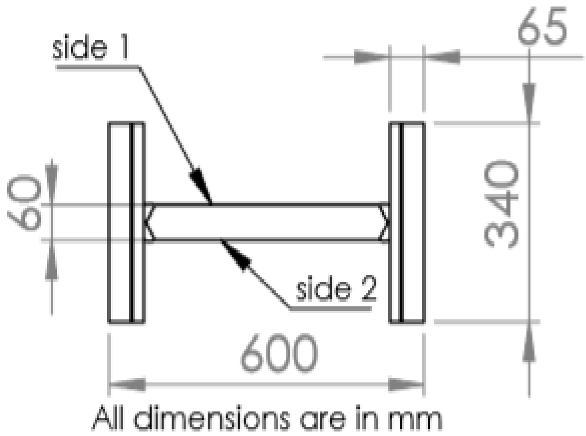


Fig. 3 A Built up beam of CJPW groove [Annexure. 2]

The error is that the welding process is done completely in the side 1, so that the amount of weld material deposited is high. The stress induced in the weld area is high due to the heat generated by the amount of material deposited. Where, the heat generated is directly proportional to the stress produced [1].

1.2.2 Improper welding speed

The welding speed plays a prominent role in the arrival of bends. Due to the improper welding speed, the weld material deposited in areas gets different. The area which has more weld material deposited results in the huge amount of stress developed in the particular area. The figure 4 represents the different weld profiles for different welding speed, since based upon the weld profile the heat dissipated is analysed.

Weld profile	Welding speed (cm/min)
	25
	50
	75
	100

Fig. 4 Weld profile for different welding speeds [2]

Where in large scale companies, the welding process is processed by the automatic welding machine or Robotic welding arms, where the travel speed is determined and the arms holding the welding rods travels in the uniform speed. So there is no probability of over deposition of weld material in a selected area. This automatically reduces the amount of stress produced due to heat. Hence the probability of bends raises is totally reduced [2].

1.2.3 Improper welding current and voltage

Due to the improper welding current and voltage, the defect occurs varies. The welding current and voltage varies from type of material gets welded, the size of the weld which is based upon the requirements of the job, and the volume of the weld to be done as total. The improper welding current and voltage leaves lot of defects which include the excess deposition of the weld material over the weld itself. Due to this the production of large amount of heat in the selected welds area. This heat produced contracts the parent material towards the weld beads, which causes bends in the area.

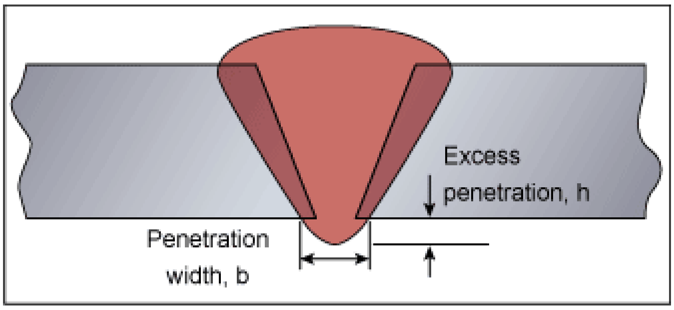


Fig. 5 Excess penetration of weld material [2]

The figure 5 represents the excess penetration of the weld material in the designed bevel groove. In large scale companies, where welding process is done automatically the welding current and voltage is set to the weld size and the welding speed. But in small scale companies, due to manual operations the welding speed and voltage cannot be controlled up to the mark. So due to this, the defect of excessive penetration of weld material happens. The figure 6 shows the excess deposition of the weld material in the width and height which causes more dissipation of heat when compared to normal.

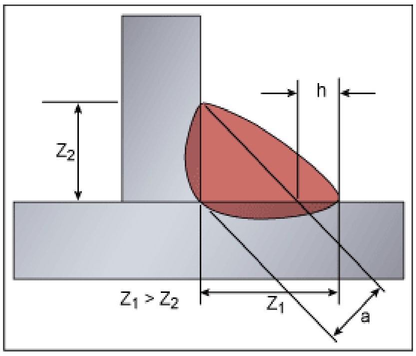


Fig. 6 Excess deposition of weld material [2]

Due to this excess penetration and excess deposition of weld material, the heat developed is high in this area. Hence the bend raises in the area is high too. In the figure Z1 is the amount of material deposited in the horizontal position; Z2 is the amount of material deposited in the vertical position.

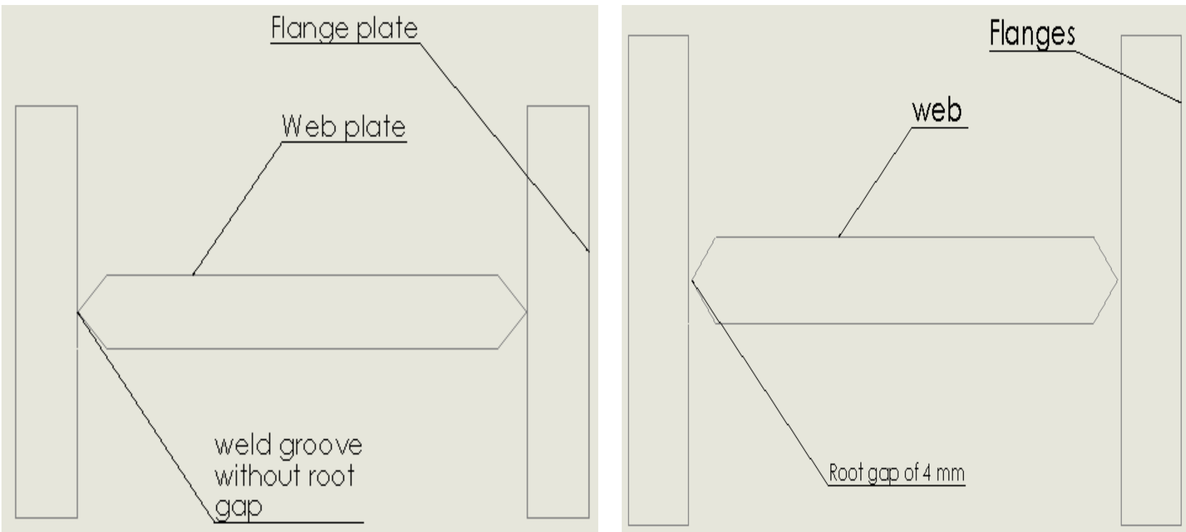
Z1>Z2

The material deposited in this area is higher than needed which causes unnecessary generation of heat which obviously increases the chance of bends formation [2].

1.3 Common production process errors in medium sized fabrication companies

In the production process, the built up of beams is done by the assemblage of flanges and a web plate. In medium sized companies, what the common error is done is that the web plate is fitted up with flange with no gap for welding process.

Due to this there is no achievement of full penetration weld in the welding process. Hence the beam requires gouging process to achieve the full penetration process. Due to this excess heat generated which automatically produce the stress in the gouged area. It also involves the heat developed due to re-welding process in the area to achieve the full penetration weld [2]. The figure 7 shows the built-up beam without root gap which causes the failure of full penetration weld. This need gouging process in extra to grind the area in the bottom side and made the welding process afterwards. Thus the full penetration welding process is achieved. This extra process applies more heat in the parent material in addition to the welding process.



(7a) (7b)

Fig.7 Built-up beam: a-without root gap, b-with root gap

2. Selection of material and welding process [3]

Weld-ability is determined by the properties of the mild steel. The selection of the mild steel depends upon the usage of the metal in most of the heavy structural fabrication industries. Mild steel has its own strength where it is highly suitable for the steel structural applications in high rise buildings and power plants.

Based on the carbon content and the manganese, the mild steel are classified into three categories named high, medium and low weld ability. If the mild steel has the carbon content of less than 0.15% and the manganese content less than 0.6%, it comes under the low weld-ability. When the material has the carbon content range of 0.15%-0.6% and manganese content of 0.9% it comes under the medium weld ability. If the carbon content beneath the 0.22% especially, the material has great weld-ability [3].

Welding heat input

Based on the welding heat there are so many grain structure changes in the entire mild steel. It totally depends upon the effect of heat experienced by the material. The welding area is in molten state at the time of welding process, the area near to the welding results in austenite grain structure where it is highly responsible for the formation of stress and bends in the welded area. The figure 8 shows the difference in the grain structure for the changes in position of heat generation in welding process.

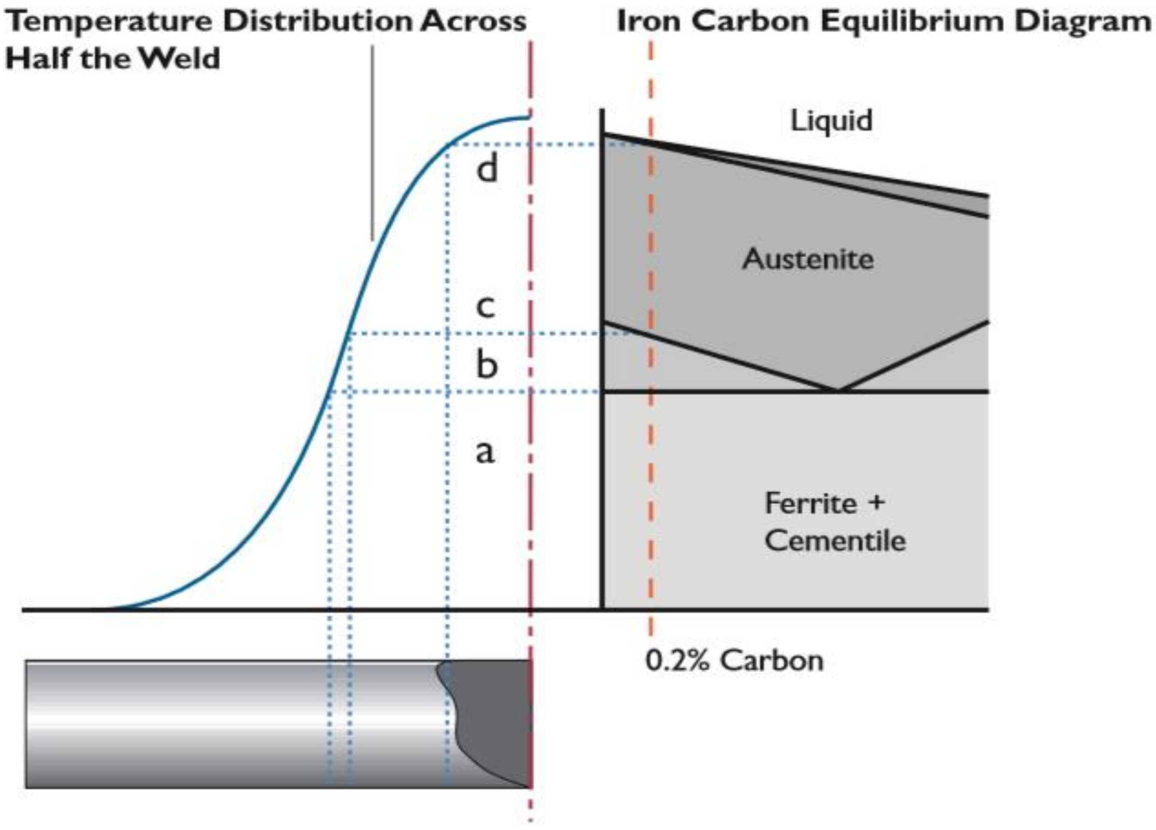


Fig.8 variation in temperature from the centre of the weld to the base material [3]

(Source: kobelco.co.org)

Types of welding process

2.1 Flux coated arc welding process (FCAW)[4]

Flux coated arc welding process (FCAW) is the method in which the welding is done by the effective supply of molten weld material between the anode wire. The anode wire is covered with the flux material to prevent the molten metal from oxidizing and it acts as a kind of protecting gas.

It is largely used in the fabrication industries since it is one of the traditional ways of doing welding. It dissipates more heat in welding when compared to other advanced welding process. Hence it is used in some of the heavy thickness plates where the plates are able to withstand the heat dissipated from the arc welding process.

It is used minimum in welding the low thickness plate ranges from 5mm-20mm where there are chances for bend formations due to the inability of withstand the heat dissipated due to the welding. The stress produced is also high, if unnoticed it results in the formation of cracks in the parent material and the entire structure may goes unstable [4].

Effects of welding current

The welding current and voltage is made suitable for the required weld fillet. Otherwise there will be lot of defects raise which includes the lack of penetration of weld material in the welded area.

Due to the improper welding current or sudden change in the welding current, there is high probability of formation of pinholes within the weld material. These pinholes are the start of formation of cracks. It involves much time to identify and rectify the defect. At the time of rectification, there is a need of re-weld the given defected area which causes the irregular bends which is very hard to remove [4].

The figure 10 shows the variations in the weld bead and the penetration of weld material based on the different welding current and voltage. It shows the heavy deposition of weld material for low travel speed.

Travel speed

The travel speed results in the proper welding based on the requirements of the job. If the job needs a 6 mm fillet, the welding speed should be low with proper welding current and voltage. It can be finished in the single run to achieve the 6mm fillet. If the travel speed is high, it results in the achievement of 4mm instead of 6mm and more work is needed to achieve the required weld fillet. The figure 9 shows the achievement of weld beads for different weld speed. This results in effective control of amount of weld material deposited in the weld area [4]. The deposition of molten weld metal is directly proportional to the amount of heat generated. This heat generation produces much stress which is responsible for the deformation of flange plates and web plates. The figure 9 shows the represents the different weld bead formation for different travel speed.

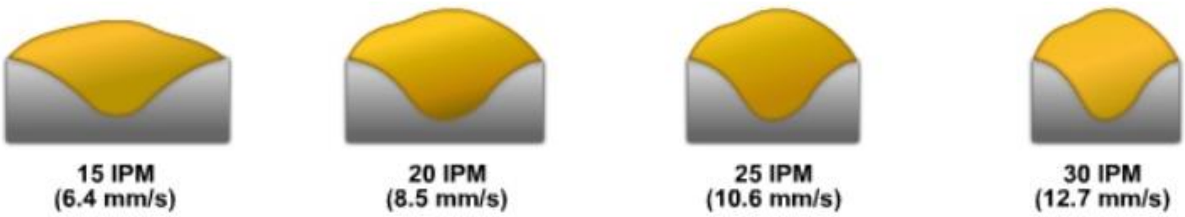
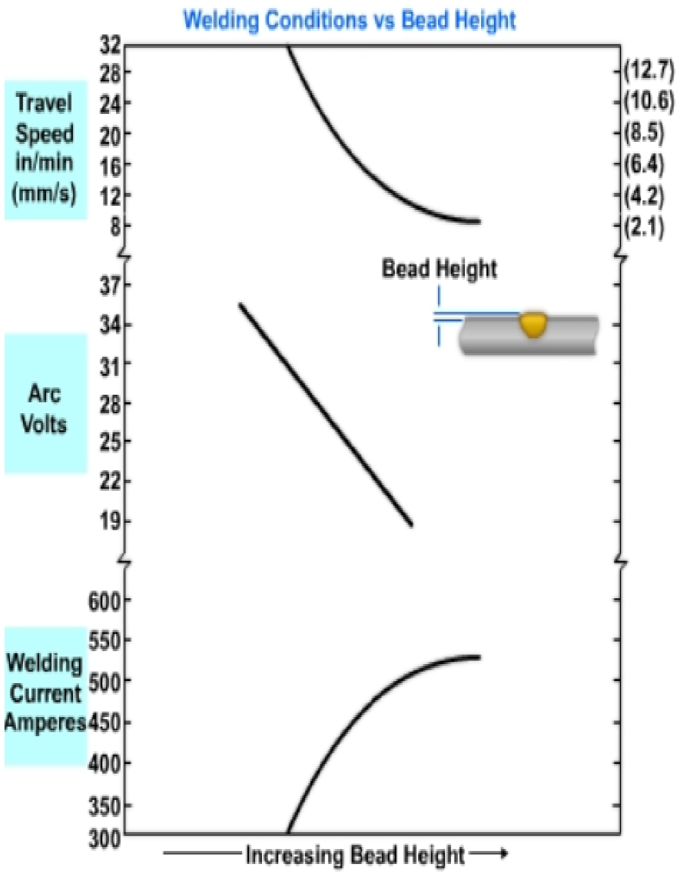
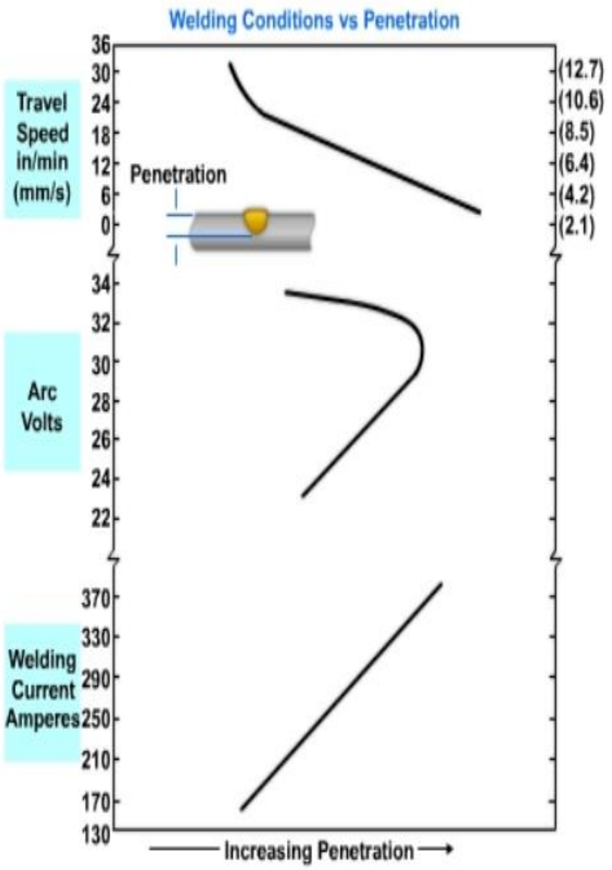


Fig.9 Difference in weld beads for different travel speeds (source: weldguru.com)

The figure 10a shows the bead height variation for different welding speed, welding current and welding voltage. It clearly shows the large deposition of weld metal and the bead height when there is minimum welding speed which gives more heat in that particular area. The figure 10b shows the penetration variation for different welding current, welding voltage and the welding speed. The penetration of the molten metal increases in the minimal travel speed of the welding. These penetration is highly affected the heat produced.



(10a)



(10b)

Fig.10 Variations in weld bead [4]: a- bead height, b- penetration

2.2 Calculation of heat input to the parent metal (FCAW)

$$Q = \frac{(k \times v \times I \times 60)}{S \times 1000} \text{ KJ/mm}$$

1. For 225 amperes current ,25 volts, travel speed of 80 mm/min

   Heat input to the parent material is,

   Q = 225×25×60 / (80×1000)

   Q = 4.2 KJ/mm

2. For 375 amperes current ,26 volts, travel speed of 130 mm/min

   Heat input to the parent material is,

   Q = 375×26×60 / (130×1000)

   Q = 4.5 KJ/mm

3. For 450 amperes current ,30 volts, travel speed of 107 mm/min

   Heat input to the parent material is,

   Q = 450×30×60 / (107×1000)

   Q = 7.5 KJ/mm

The above calculations clearly indicates the increase of heat applied to the parent material is resulted by the increase in the voltage ,current and the decrease of travel speeds of flux coated arc welding (FCAW) process.

2.3 Gas metal arc welding process (GMAW) [5]

Gas metal arc welding process is also known as MIG welding, where the welding is done by the means of wire. The wire is the filler material needed for the welding purposes. This wire is allowed to pass through the gun, where the required speed is maintained and controlled. Through this speed welders can be able to perform the uniform welding throughout the welding process.

Even though it is costlier than the conventional welding process, it is used in fabrication industries nowadays to increase their production. It is faster than arc welding process. In the arc welding process where the welder needs to change the welding rod for every finish of the filler material. But this is not in the case of MIG welding process, continuous supply of the filler material is possible here. This rapidly reduces the time required to complete the welding process.

It is also used in the industries for the small generation of heat when compared to the arc welding process, where this entire project is subjected to the analysis of bends caused by the heat generated from the welding process [5]. The table 1 shows the average value of welding voltage, welding current and travel speed for the better outcome of weld.

For single pass, welding flow of GMAW process is determined from the table 1,

Table.1 welding parameters of GMAW process (source: tpub.com)

S.no	Welding voltage (volts)	Welding current (amps)	Travel speed (inches/min)
1.	15-17	30-50	15-20
2.	17-19	80-100	35-40
3.	18-20	110-130	25-30
4.	19-21	140-160	20-25
5.	20-23	180-200	18-22

2.4 Calculation of heat input to the parent metal (GMAW)

$$Q = \frac{(k \times v \times I \times 60)}{S \times 1000} \text{ KJ/mm}$$

1. For 50 amperes current , 17 volts, travel speed of 20 inches/min

   Heat input to the parent material is,

   Q = 0.8×50×17×60 / (508×1000)

   Q = 0.08 KJ/mm

2. For 130 amperes current ,20 volts, travel speed of 30 inches/min

   Heat input to the parent material is,

   Q = 0.8×130×20×60 / (762×1000)

   Q = 0.16 KJ/mm

3. For 200 amperes current ,23 volts, travel speed of 30 inches/min

Heat input to the parent material is,

Q = 0.8×200×23×60 / (762×1000)

Q = 0.28 KJ/mm.

The comparisons show that the amount of heat produced is high in the Flux coated arc welding process than the Gas metal welding. So it is nice to use the GMAW process in welding the built-up beams of heavy thickness as to control the deformation in its initial stage of fabrication.

3. Type of bend formations and its manual correction methods [6]

3.1 Sweep bends

Sweep bends are the bends occurred in the built-up beams due to the improper welding process. This is happened by the welding process done maximum in the single side. This results in the application of more heat in the parent material which resulted in the sweeping bends in the beams. This is done by the maximum heat generated by the welding process [6].

The sweep bends is that the flange of the beams is deviated from the centre line or midline of the beams. This is done by the force experienced by the heat generated due to welding process. Due to this force, the flange of the beams deviates from the centre line results in sweeping [6]. The figure 11 and 12 shows the geometric view of the sweep bend formations in the beam. It is happened by the improper input of welding heat produced from the welding process. Due to that the beam deviates from the centre axis for its overall length. This is more common in the lengthy structural beams.

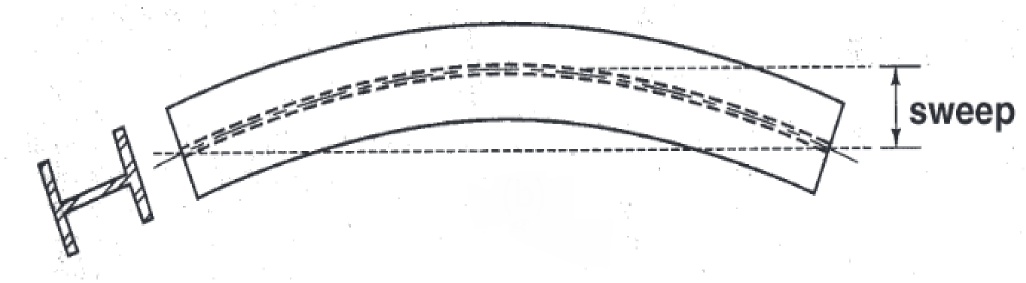


Fig.11 Geometric view of sweeping in beams (source: aisc.org)

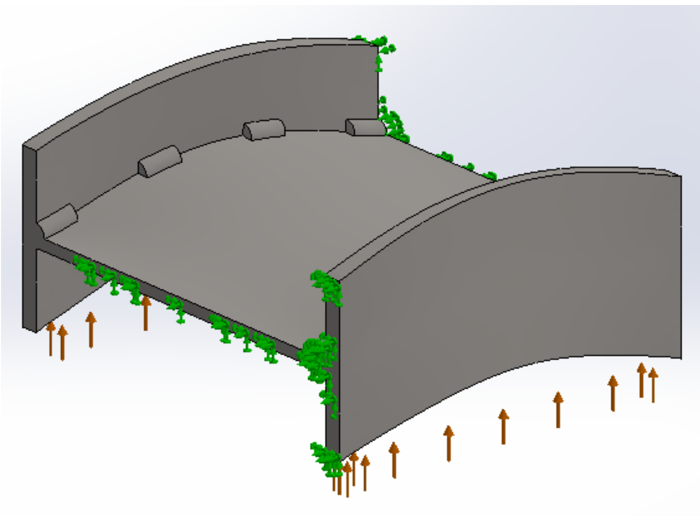


Fig.12 Sweep bends in beams by loads experienced by welding process [6].

3.2 Camber bends

Camber bends is that the bend occurred due to the continuous welding in the one side of the web. This initiate the continuous distributive loading along the flange results in the bow bend or camber bend .This is identified by reference line where the centre line of web deviates from the reference line .This is experienced by the heat generated by welding which gives the much force that tend beam to bend [6]. The figure13 and figure 14 shows the formation of camber bends in the beam where the beam

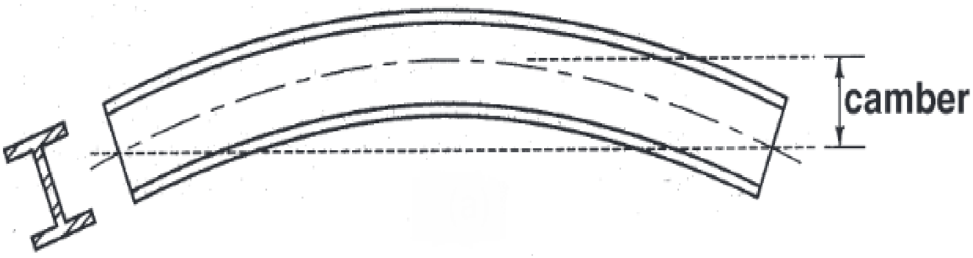


Fig.13 Camber bends of a section (aisc.org)

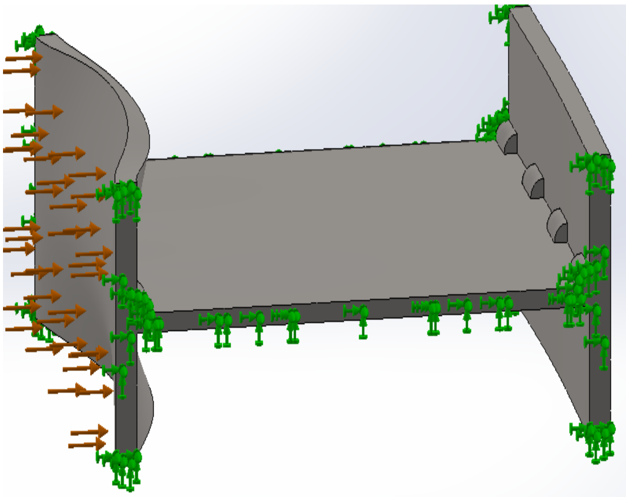


Fig.14 Camber bends in the beam by continuous load on flanges [6]

3.3 Buckling of webs

Buckling of webs is caused by the bending of web by forces experienced on the web centre line. These forces are generated by heat developed when all the flange and web connections are welded continuously. By this, force is developed which is flow and acting towards the centred reference line of web.

3.4 Shortening of sectional length and width

This is the defect where the length and the section dimensions get decreased from original lengths and sections. This results in the huge error due to erection of the beams after getting fabricated. The figure 15 shows the buckling of web plates due to the excess heat generation in the welding process.

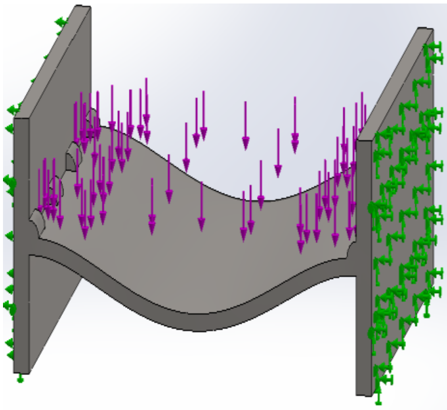


Fig.15 buckling of web plates [6]

3.5 Dimensional shrinkage

This is the defect where the length and the section dimensions get decreased from original lengths and sections. This results in the huge error due to erection of the beams after getting fabricated. This is done by generating large amount of heat by continuous welding process [6].For example, in the length of 5000mm, the shortened length results in 4995 mm which gives shortage of **5 mm**. In the section depth of 544 mm, the shortened section is 541 mm which gives shortage of **3 mm**.

3.6 Twists

Twists are the defect caused by the improper welding process where one end section is deviated to the other end of the section. The end to end section is deviated from the centre line which results in the improper assembly of fabricated components. In the erection, the section of the bended beam doesn't match with the female section for assemblage, where the bolting will be big problem. In medium scale industries it requires large skilled manpower which goes useless at the end, when involved in the production process it will yield productivity [6]. The figure 16 shows the twisted area in the beam due to improper welding process.

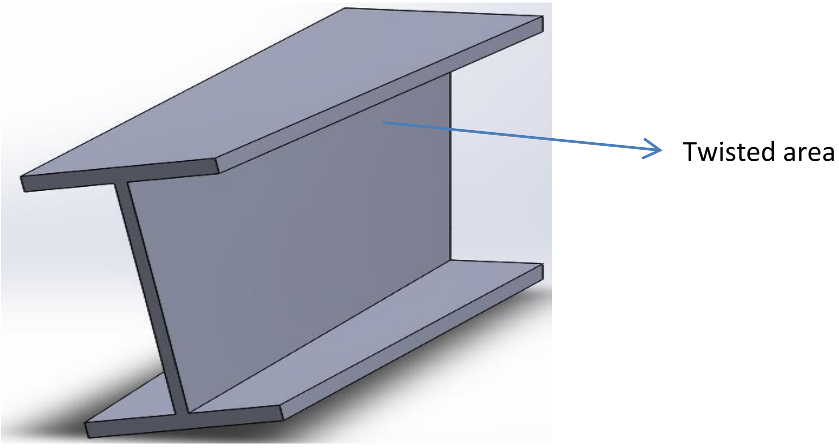


Fig.16 Twists in sections of a beam [6]

3.7 Manual correction of bends

The above said bends are removed by different types of heating process. Each defect should deal with different heating process for their removal. The area to be heated to remove the bends also differs. To remove the bends the beam should undergo different heating methods such as [7]

1. Pre-heating
2. Inter pass heating
3. Annealing
4. Normalizing
5. Quenching and tempering
6. Stress relieving methods

3.8 Pre-heating

Pre- heating is the process where the entire part of the parent material gets heated to certain temperature before the welding process. Then the welding process starts along with the previous heat applied. When the product gets cooled, there is less contraction occurs and less stress produced. The contraction and stress produced is less when compared to the material welded without pre heating process[7].

3.9 Inter pass heating

Inter pass heating is the process of heating the weld material between the passes. This automatically reduces the amount of heat generated and stress produced as a result of welding process. For every pass of the weld, the external heat to be supplied to reduce the heat generated from the particular area and stress produced from the particular area. It helps in the stress reduction of thick plates and thick pipes.

3.10 Annealing and Normalizing

This is the process in which the material gets heated to deform the welded bend plate to its original position. This is done after welding process where the metal is already in the bend position. The metal gets heated in the opposite direction of the weld, particularly in the weld bead area. This allows the metal gets heated to certain temperature, and regains its original position when it is getting cooled.

This is suitable for only plates of low thickness. For heavy thickness plates this process is highly negligible [7]. To overcome this process, the material can be prepared in the fit up stage itself. The flange and web plates are tack-welded with the slight deviation from the original dimension. When the welding is done the plates are arrived to the original dimension as per the drawing. The figure 17 shows the material preparation in the initial stage of welding process. This is suitable for medium thickness plates where for heavy thickness plates there is chance for plates not to deform.

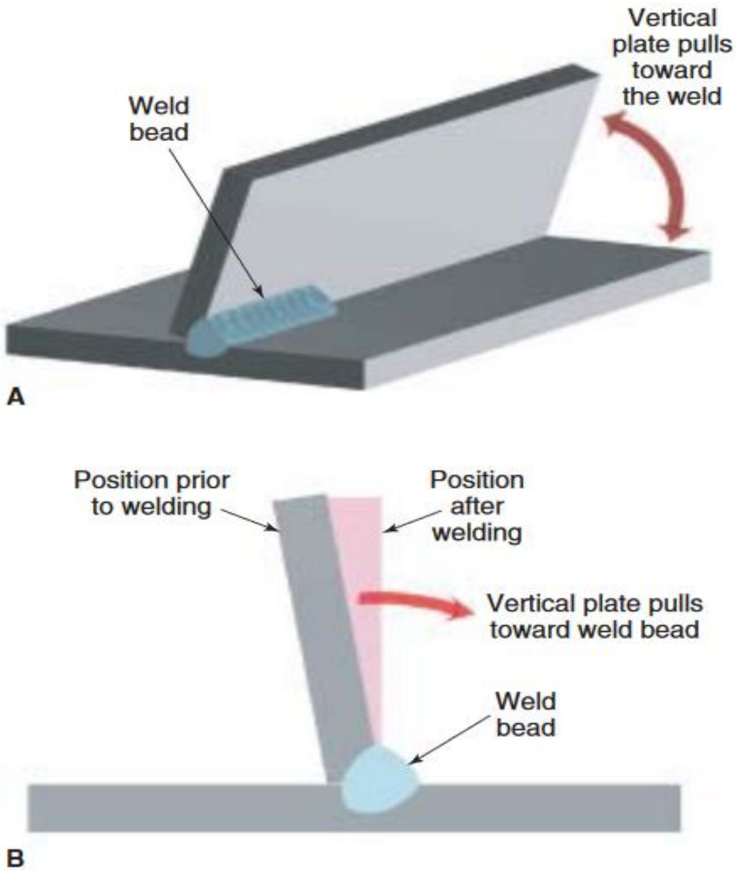


Fig.17 Pre heated area for the weld [7]: A-weld area, B-direction of bend

3.11 Quenching and tempering

This is the process in which the material gets heated to the particular temperature. After attaining the calculated temperature, the material is allowed to cool suddenly by immersing it in the liquid or water. This makes the material hardened where it gives less response to the heat generated during the welding process. Thus the stress produced in the hardened material remains low and hence this not causes the deformation in beams [7].

3.12 Stress relieving

It is that the material is heated to 1200 F and allowed to air cool. It is allowed to keep at the temperature for few hours. It is similar to annealing process but the usage of temperature is low here.

These all above said process involves the enormous usage of energy to heat the material. For heating, the gas mixture of Oxygen-acetylene is to be used. The combination of Oxygen- LPG is used in some special cases.

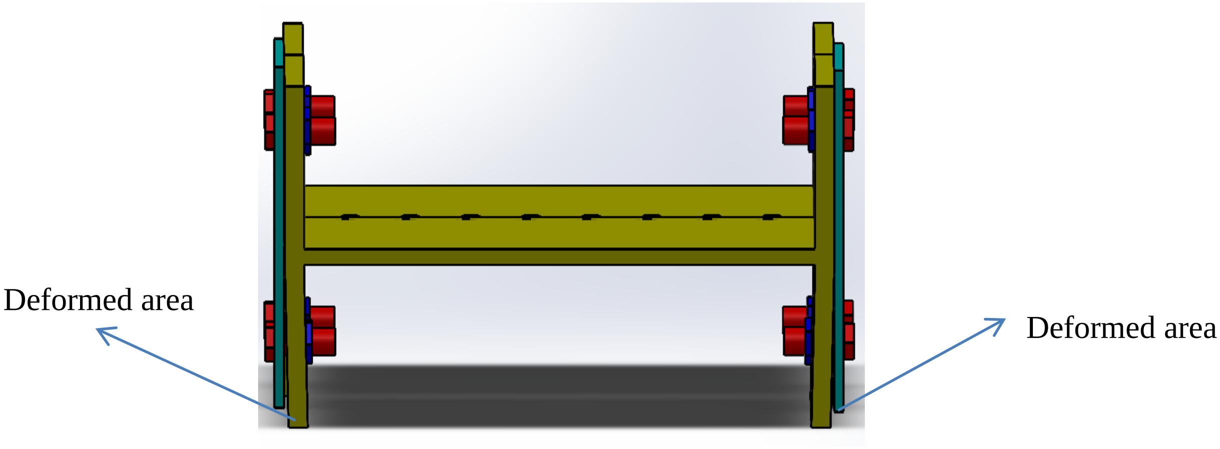
Considering the enormous usage of these gases may be feasible in large scale companies, but in small and medium sized companies this is consider as the costly feature to remove the bends. In this case, it is very much better to get weld the beams without any bends, which may be possible by optimising the welding process and production process in the early stage itself [7]

Major problems in the erection

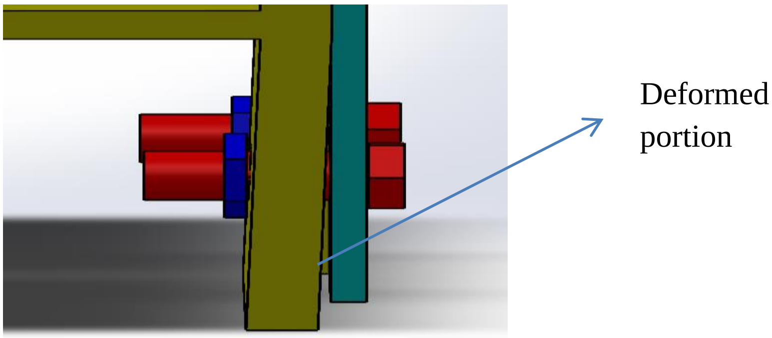
3.13Flange mismatch [8]

In the erection process, due to bend raised by the welding, the two flanges get bend towards the position of welding. Hence the section varies in dimension. For example if the section varies for 5 mm each side, the entire section differs from 10 mm of its original length. Due to this there is a huge mismatch from the parent beam. So the bolting of the two beams for its connection is made much more difficult or even impossible.

Even after the crucial erection, there is a high probability of breakage of bolts. This made the entire erection is going unstable [8]. It also involves the improvement in the production process and the welding process. The below figure18A shows the flange mismatch of the beam with the parent beam, where the chance of the breakage of bolts is increased with the time goes [8]. The figure 18B shows the instability in the bolted connection of the erected part.



(A)



(B)

Fig.18 Flange mismatches [8]: A-entire part, B-mismatched part

This mismatch leaves the deformed gap between the flange surface and the connection plate that makes the beam differs from the parent beam. This action makes the entire structure goes unstable.

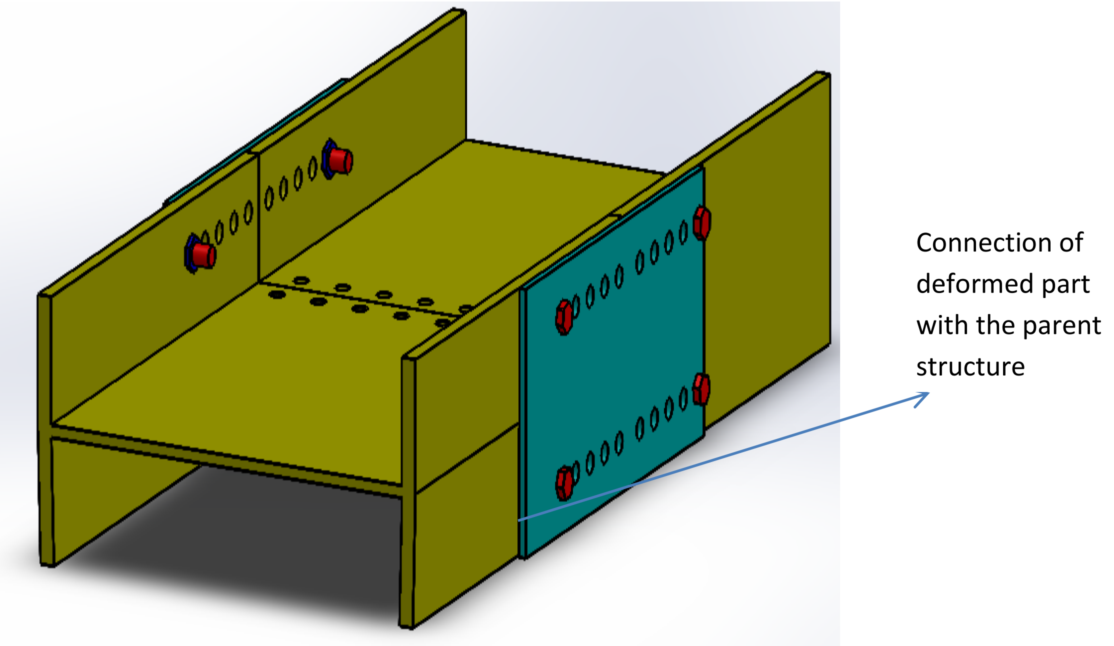


Fig.19 Entire connection of bended beam with the parent beam [8]

As the above figure 19 indicates that there is a difficult in the bolting of connection plate when the deformed flange surface and the good parent metal flange surface get connected. The amount of deformation depends upon the type of welding process, welding speed and the input welding current and voltage. Even though a minimum deformation makes the connection of entire steel structure goes unstable.

3.14 Buckling of webs

In the erection process, due to the buckling of webs there is mismatching between the webs of different beams. Due to this, bolting of the web plates is made highly impossible or if it is made it will be unstable. The connection plate erection in this area will leave a huge problem.

It is to be eliminated in the production stage itself. Due to the bend, there is mismatching in the web plates for 10mm as an example. Due to this it is not possible to connect both plates in the web using the given connection plates is highly impossible. It leaves huge space between the web surface and the connection plate surface. Thus the bolt has no support and leaves much stress in the gap space, which leads to breakage of the bolts. As long the days go, the chance of breakage is increased which leads to collapse of the entire structure [8].

The below figure20 shows that the buckling of web plates and also the connection holes present in the web plates gets mismatched. This results in avoidance of bolting of web plates.

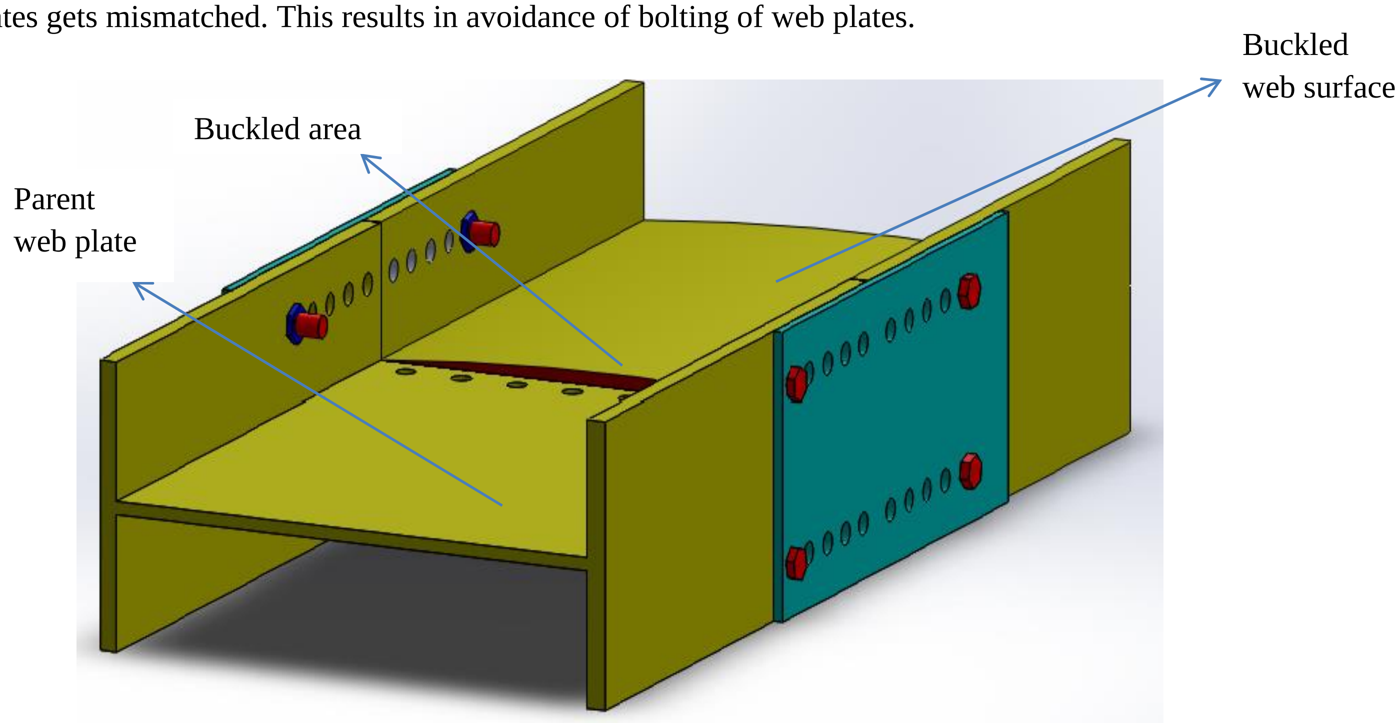


Fig.20 Buckled web plates shown in the beam erection [8]

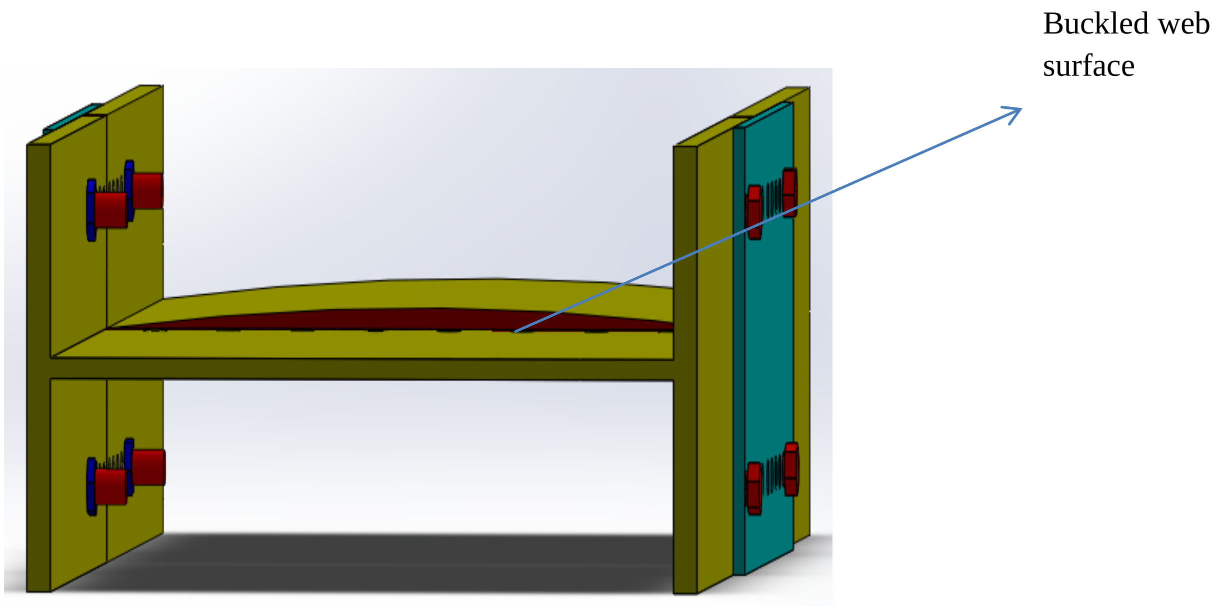


Fig.21 Mismatching of web plates [8]

The above figure21 shows the 3D model of a fabricated beam with the web plate deviation from the original dimension. This deviation also leads to the breakage of web plates too. There are also several other problems that made the entire erection structure goes unstable such as shortened length, twists formation in the bends, camber bend formations. To avoid these erection errors effectively, it is necessary to fabricate the beam with high quality by following the coming improvements in this project.

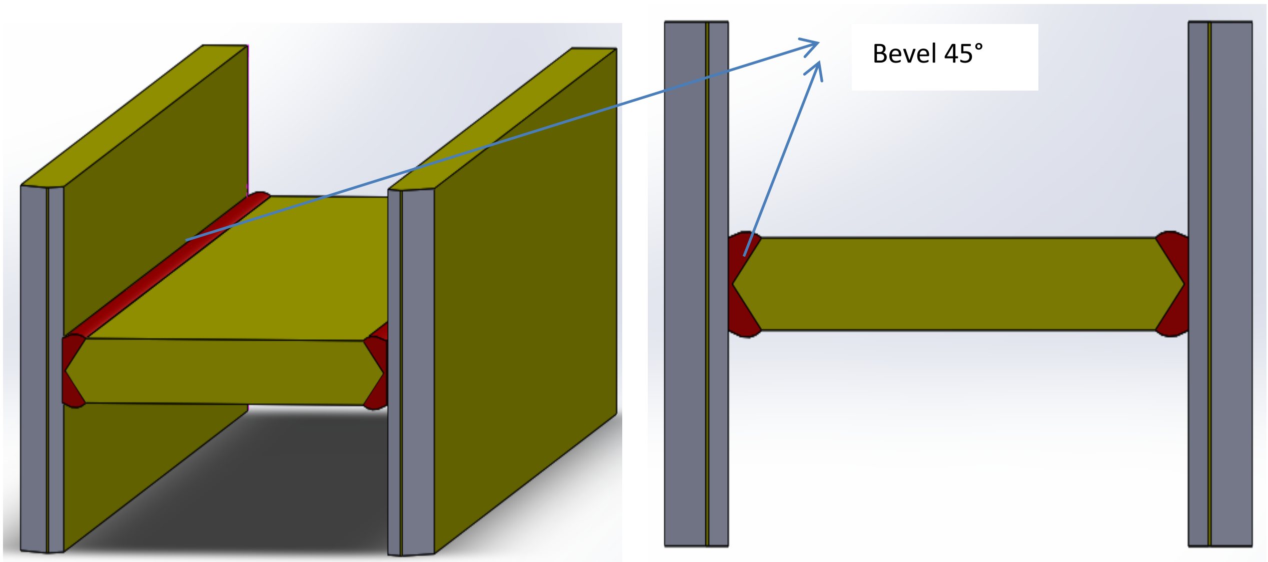
4. Improvement in the material preparation

4.1 Calculations of material deposited in the weld groove of 45° [9]

Due to unskilled man power, it is quite common in medium scale industries to make the weld groove of welding for 45°. This degree leaves the major area for welding. Hence the weld material deposited in the area is also high. The heat produced in the large weld area due to the high weld material deposited is also high. Since the stress produced is directly proportional to the amount of heat developed, the 45° bevel area leaves with more amount of stress [9].

The figure shows the bevel of 45° taken in the given beam. The beam is taken to analysis as per the dimensions of drawings from a large scale industry named EVERSENDAI engineering India limited. The given drawing is modelled in a 3D software solid works, and taken into analysis. This is an example of a real time work which is happening in that industry.

The beam is analysed in ANSYS for the force produced during welding process. The force developed is depends upon the amount of weld material deposited during the welding process. It varies for different types of weld area and the volume of weld material deposited in the designed weld area.



(A) (B)

Fig.22 Beam with bevel 45° [Annexure.2]: A- entire beam, B- bevel position

The figure 22 shows a flange and web plate connections with a bevel of 45° as a weld groove. The weld grove is completely filled with the weld material where heat and its respective stress are produced in that area which leaves bends in the flange plate. The detailed 2D drawing of the bevels and its angle are as shown below. The 2D drawing of the model and dimensional change is shown in the annexure 2.

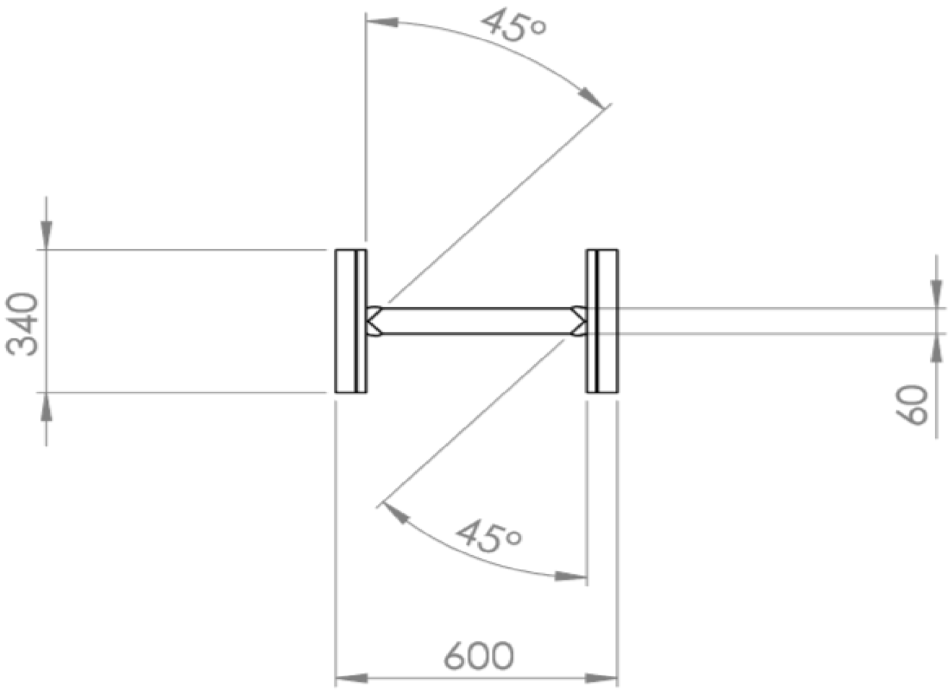


Fig.23 A 2D drawing of the experimental beam with bevel [Annexure.2]

The figure 23 shows the dimensions of the built up beam with the bevel groove of 45°.

The volume of the weld is calculated using the following calculations,

Width of the weld cap, $W = (\tan b \times t)$

Where, b = groove angle of 45 degrees

t = thickness of the parent material in which weld should be done in cm

g = Root gap in cm

Width of the weld cap, W= (tan 45 x 3)

W = 3 cm

Area of the weld cap, $A = W \times h$

Where, h= height of the weld cap

Area of the weld cap, A = 3 x 0.2 = 0.6 cm^2

Area of the Bevel B = (W x 3) / 2 = (3 x 3) / 2 = 4.5 cm^2

Total Area of the weld = A+B = 4.5+0.6 = 5.1 cm^2

Volume of the weld, $V = A \times L$

Where, L = Length of the weld area

V = 5.1 x 258.2

V = 1316.82 cm^3

Heat input to the parent material is calculated using the formula,

$$Q = \frac{(k \times v \times I \times 60)}{S \times 1000}$$

The welding current of 50 amperes, voltage of 17 volts and welding speed of 40 inches/min is taken into analysis, then the heat produced is

Q = 0.8×50×17×60 / (1016×1000)

Q = 0.0402 KJ/mm

Thus the thermal force expelled under the given conditions for the length of 2582 mm is of 103.5 N.

4.2 Calculations of material deposited in the weld groove of 30° [9]

In the previous section it is shown that the area exerted by the weld groove, the weight of the weld material deposited, the volume of the weld material and the load acts due to that. This load act is applied in the analysis using ANSYS, where the stress developed during the welding process is calculated [9].

When going for this project, to minimize the amount of stress developed, it is necessary to reduce the amount of material deposited and minimize the heat produced due to that. Hence the project is to minimize the size of the bevel. The bevel degree is reduced from 45°to30°. The full penetration weld (CJPW) or complete joint penetration weld is achieved by having the root gap of 4 mm. This process is used to eliminate the gouging process to achieve the full penetrations. When the size of the weld decreases the volume of the weld material deposited is also decreased since they are directly proportional. When having the non-destructive testing check for the full penetration, due to the root gap, the result is easily achieved [9].

The below figure 24 represents the change in the bevel dimensions from 45° to 30°. The same experimental beam is taken into consideration for analysis. The width of the entire section is maintained same by reducing the width of the web plate and by providing the root gap. It is also explained that the root gap is made to achieve the full penetration in welds by eliminating the gouging process as excess. The 2D model of the beam with the bevel groove of 30° and the dimensional change of the bevel in the beam is shown in the annexure 3.

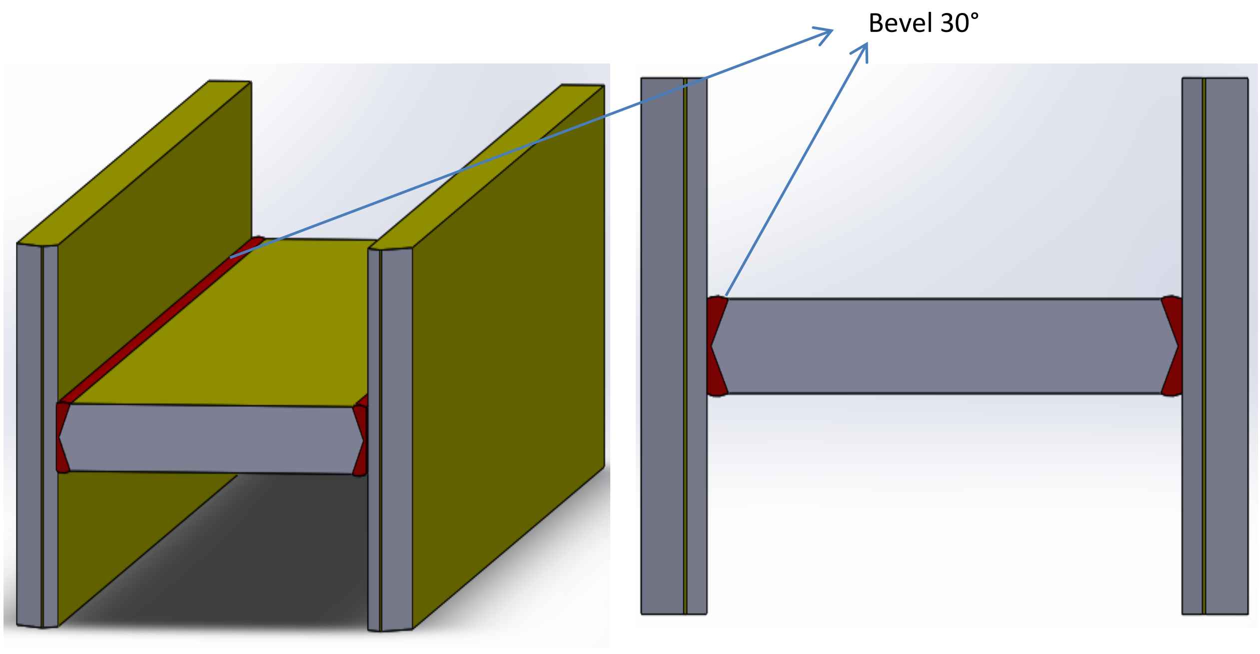


Fig.24 Beam with bevel 30° [Annexure.3]: A-entire beam, B- bevel position

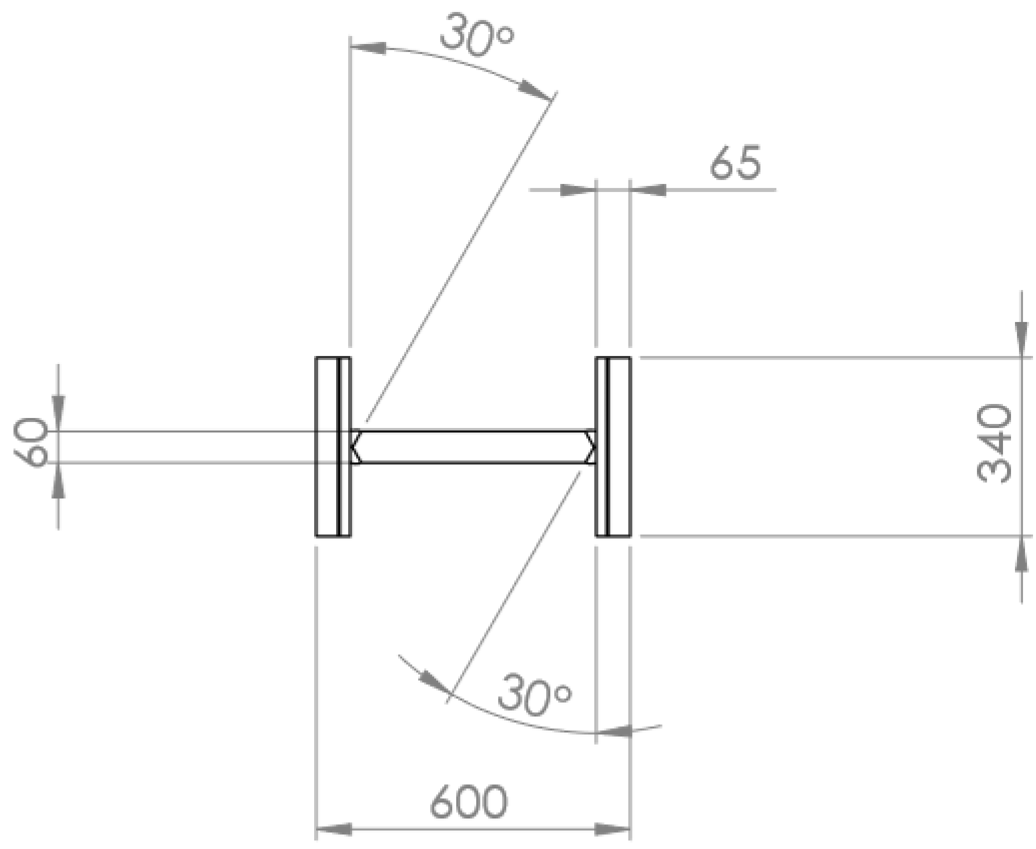


Fig.25 A 2D drawing of the experimental beam with bevel of 30° [Annexure.3]

The figure 25 shows the built up beam with the bevel groove of 30° where the width of the weld is decreased and the amount of material deposited is also minimised. The decrease in the weld with is shown in the annexure 3.

The volume of the weld is calculated using the following calculations,

Width of the weld cap, $W = (\tan b \times t)$

Where, b = groove angle of 30°

t = thickness of the parent material in which weld should be done in cm

g = Root gap in cm

Width of the weld cap, **W= (tan 30° x 3)**

W = 1.732 cm

Area of the weld cap, $A = W \times h$

Where, h= height of the weld cap

Area of the weld cap, A = 1.732 x 0.2 = 0.3464 cm^2

Area of the bevel B = (W x 3) / 2 = (1.732 x 3) / 2 = 2.59 cm^2

Total Area of the weld = A+B = 0.3464+2.59 = 2.9364 cm^2

Volume of the weld, $V = A \times L$

Where, L = Length of the weld area

V = 2.9364 x 258.2

V = 758.18 cm^3

4.3 Stress analysis of beam with bevel 45°

The beam is bevelled for 45° as groove for its welding and it is taken into analysis. The beam is taken into ANSYS for analysis where the corresponding load of 103.5 N is given as the force. Hence due to there is no supports, the beam flanges bends together due to the stress produced in the welding process [9]. As a result the maximum stress achieved is of 0.0020192 MPa or 2019.2 N/m^2. The beam is analysed for the triangular mesh type with the force of 103.5 N is applied at the welding area between the flange plates and the web plate. The force is given as a line contact between the plates rather giving it as the surface contact in the weld area. The figure 26 shows the meshed image of the fabricated beam with the bevel of 45°, where the beam is meshed to the below said boundary conditions.

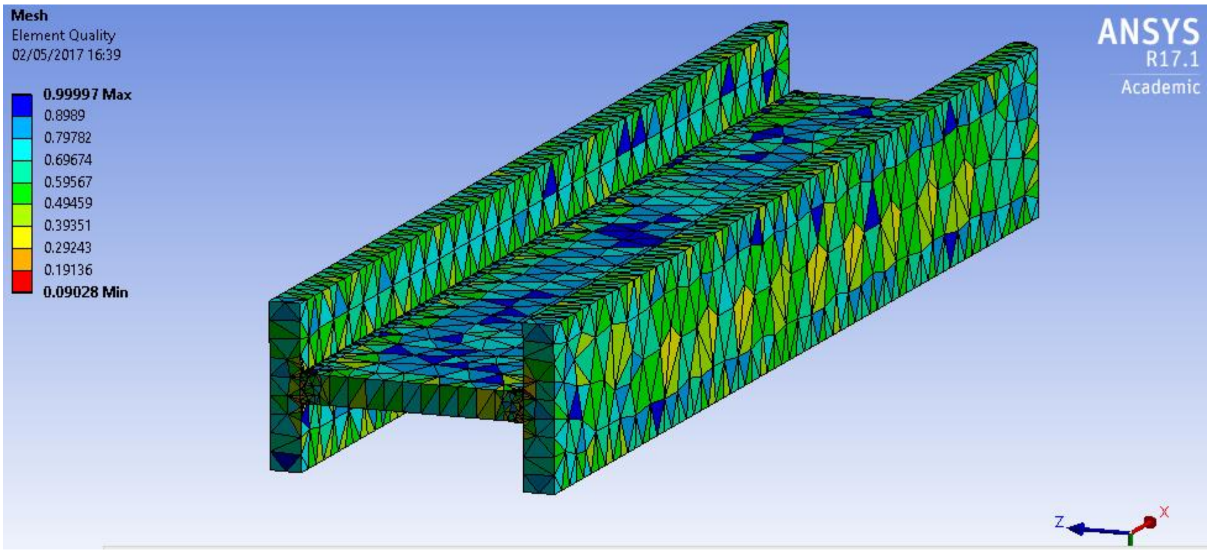


Fig.26 Meshed beam structure with bevel of 45°

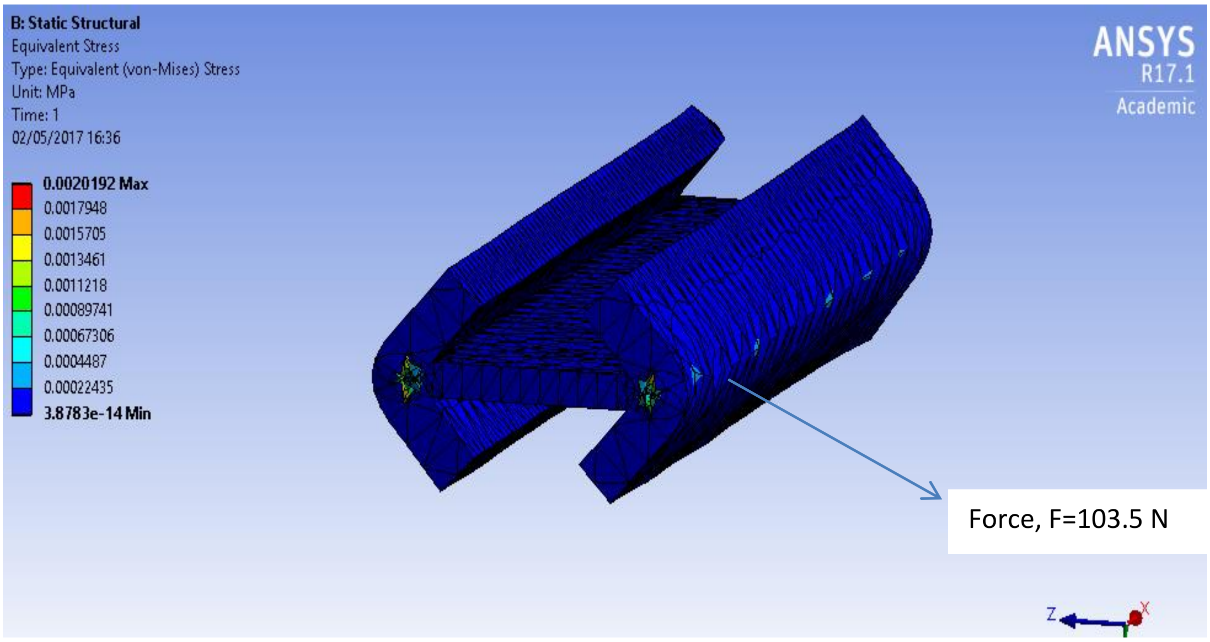


Fig.27 Stress image of beam with bevel 45° [Annexure.4]

The figure 27 shows the stress image of the beam where the heat produced due to the number of passes in the bevel produces the stress in the flange plates and web plates. The analysis is shown in the annexure 4.

Boundary conditions

Type: Fine quality triangular mesh

Thermal Force: 103.5 N in the weld surface

Fixed supports: Web plate surface

Results analysis

As a result the stress developed when the web plate for the beam is bevelled for 45° is of 2019.2 N/m^2. The stress varies for the different type of flange plates of different thickness. In this analysis the web plate is acting as the fixed support where the flange plate deforms due to the force in the welding area. This makes the flange plate bends; the chance of formation of cracks in the parent material is increased. The plates of heavy thickness are not regained to its original position when it even undergoes heating process for correction. The flange plates of low thickness are regained to its original dimension when heating. This requires lot of time and energy to rectify the errors. Hence it is controlled in the initial stage of material preparation by reducing the bevel size. This automatically reduces the area required for welding process. This leads to less amount of material deposited. The strength of the weld is not decreased since it contains the weld gap of 4 mm in the initial stage of material preparation. The figure shows the type of bend occurs due to the welding force acts in the given area [9].

4.4 Stress analysis of beam with bevel 30° [9]

The beam is bevelled for 30° as groove for its welding to reduce the amount of material deposited. The beam is taken into ANSYS for analysis where the corresponding load of 103.5 N is given as the force. Hence due to there is no supports, the beam flanges bends together due to the stress produced in the welding process. As a result the maximum stress achieved is of 0.0011627 MPa or 1162.7 N/m^2. The figure 28 shows the meshed image of the beam with the bevel of 30° and the conditions are shown in the annexure 5.

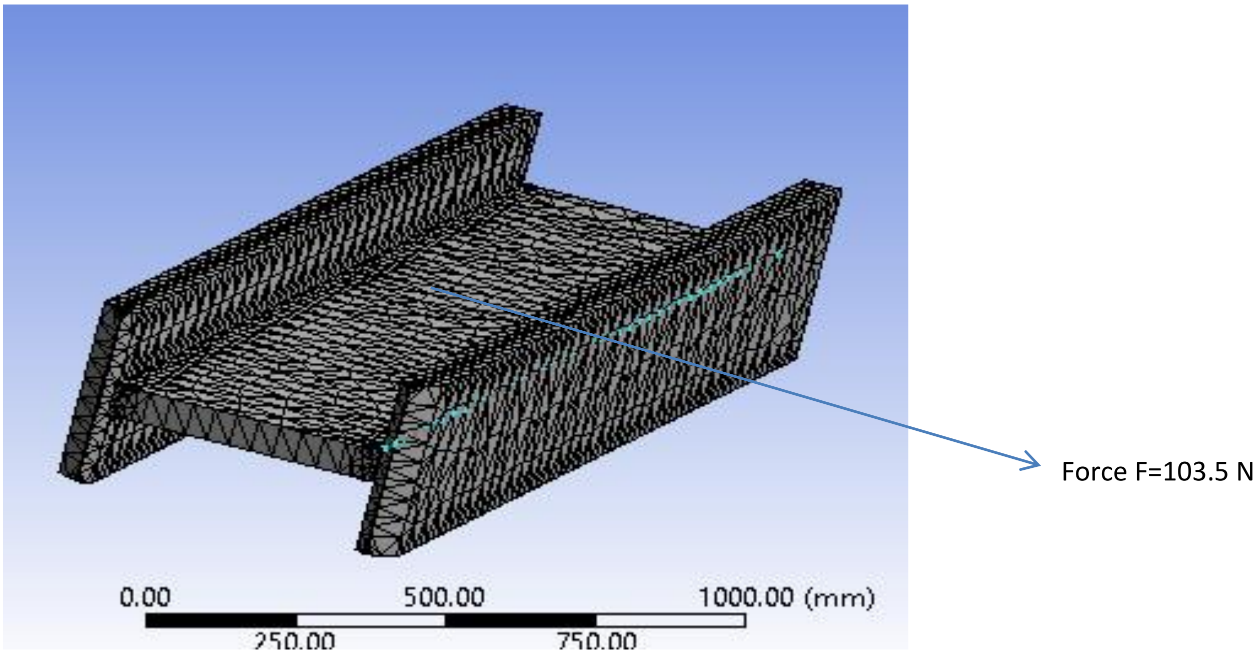


Fig.28 Meshed image of the beam with bevel 30° [Annexure.5]

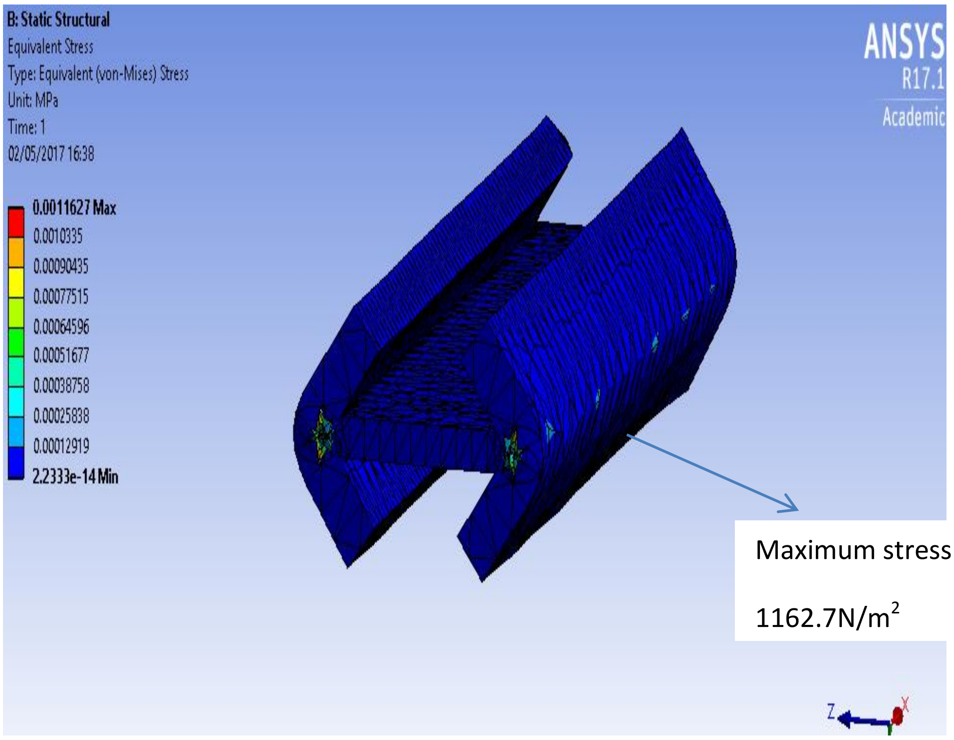


Fig.29 Stress image of beam with bevel 30° [Annexure.5]

Boundary conditions

Type: Fine quality triangular mesh

Thermal Force: 103.5 N in the weld surface

Fixed supports: Web plate surface

The figure 29 shows the stress image of the beam with the bevel of 30°. The flanges are bending together in the direction of welding process. These bends are not easily to retrieve to its original position since the thickness of the plates is very high which is of 65 mm. For low thickness plates these bends are easily get corrected using the above discussed heating types [9].

From the above figure, it is to be noted that the flange plates bend towards the area of welding process where the forces are acting due to the welding is in the opposite direction. To remove the bend what is to be done that, heat is given as the input to remove the bends. This is that the heating process is to be done in the area in the opposite direction of the developed bend [9].It requires high skilled manpower and much time to remove the bends. Sometimes in the heavy thickness plates these removal process is highly impossible. The stress values are getting compared for the web plates of bevel size 45° and 30°. The result is that the thing which developed low stress in the welding process made small deformations in the beams. The stress value changes due to the change in the parametric dimension of different weld bevel grooves. The much stress produced as the result of design of much weld area.

4.5 Parametric comparison

The various parameters calculated for different bevel of 45° and 30° are shown in the table 2.

Table.2 Parametric comparison of various bevel dimensions results [9]

S.no	Parameters	Bevel 45°	Bevel 30°
1.	Width of the weld cap	3.0 cm	1.732 cm
2.	Area of the weld cap	0.6 cm^2	0.3464 cm^2
3.	Area of the Bevel	4.5 cm^2	2.59 cm^2
4.	Total area of the weld	5.1 cm^2	2.9364 cm^2
5.	Volume of the weld	1316.82 cm^3	758.18 cm^3

The above table 2 defines the changes in the parameters for different type of bevel grooves in the material preparation. Due to the change in the bevel dimensions, there is decrease in the width of the weld from 3cm to 1.732cm. The area of the weld cap decreased from 0.6cm^2 to 0.3464cm^2 which includes the consideration of weld gap of 4mm between the web plate and the flange plate set up in the material preparation stage itself. The total area is the area of the weld cap and the bevel area which is decreased from 5.1cm^2 to 2.9364 cm^2. Obviously the volume of weld material deposited in the bevel area is decreased due to minimised total area of the weld. Considering the density of mild steel, the force of the weld is calculated [9].

4.6 Stress results comparisons

The stress produced in welding the beam of different bevels is analysed from the annexure 4 and the annexure for the bevel 45° and bevel 30° respectively. The stress value ranges from minimum to maximum is noted and compared. The maximum stress produced in the beam of bevel 45° is 2019.2 N/m^2. The maximum stress produced in the beam of bevel 30° is of 1162.70 N/m^2. There is a huge decrease in the stress produced by the percentage of 42.4%. The percentage differs for different type of flange plates of different thickness. It also depends upon the type of welding process and the welding method. The welding method is that which is of fillet weld, full penetration weld or partial penetration weld.

The stress values are compared between 45° and 30°; they are tabulated as follows,

Table.3 Stress results comparison of different bevels [9]

Stress	Bevel 45° (N/m^2)	Bevel 30° (N/m^2)
S1	0	0
S2	224.35	129.19
S3	448.70	258.38
S4	673.06	387.58
S5	897.41	516.77
S6	1121.80	645.96
S7	1346.10	775.15
S8	1570.50	904.35
S9	1794.80	1033.50
S10	2019.20	1162.70

The above table 3 shows the stress comparisons of the beam with different bevels. By comparing the above stress values it is clearly indicates that there is decrease in the stress formation when the amount of material deposited. In the bevel 30° the weld material deposited is much lesser when compared to the higher bevel. By optimizing the bevel groove we can reduce the stress produced in our initial stage of material preparation. There is average decrease of 42% from welding the beam with bevel 45° to weld the beam with bevel 30°.

It can be conclude that the beam with minimum bevel responds to the weld material deposition for low. Due to this the weld process requires minimum number of passes to finish the process. The heat produced due to the excess passes is eliminated for the same welding current, welding voltage and welding speed. Thus the generation of heat is reduced in the improved bevel position. This depends upon the different welding types and processes. This project is taken into analysis of beam with the flange plate thickness of 65mm, web plate 60mm and full penetration welding process as the required welding process using MIG welding [9].

5. Improvement in the welding process [10]

The improvement in the welding process is done by divide the entire welding process in three steps. At first the welding process is done by having the primary pass. The primary pass is that welding the root area gap by filling with the single run rather completely welding the entire portion. Hence the weld material deposited is much less when compared to the complete welding in a single time. The weld volume is divided into three divisions as, primary pass, second pass and final pass [10].

5.1 Primary pass

In the primary pass, welding is done in the root gap. It covers the root gap for the entire length. Then the beam is turned to the down side and welds the root gap in the area. The weld volume produced in the welding area is low hence the amount of heat dissipated by the welding process is also low. Hence the stress produced in that area is low. When the beam is welded in the downside the stress produced in the top side is get equalised each other or cancelled each other. For this experimental beam the flange plate is of heavy thickness, it does not respond to the low weld heat produced from the single pass. The figure 30 shows the built up beam with the primary pass of welding in the beam modelled.

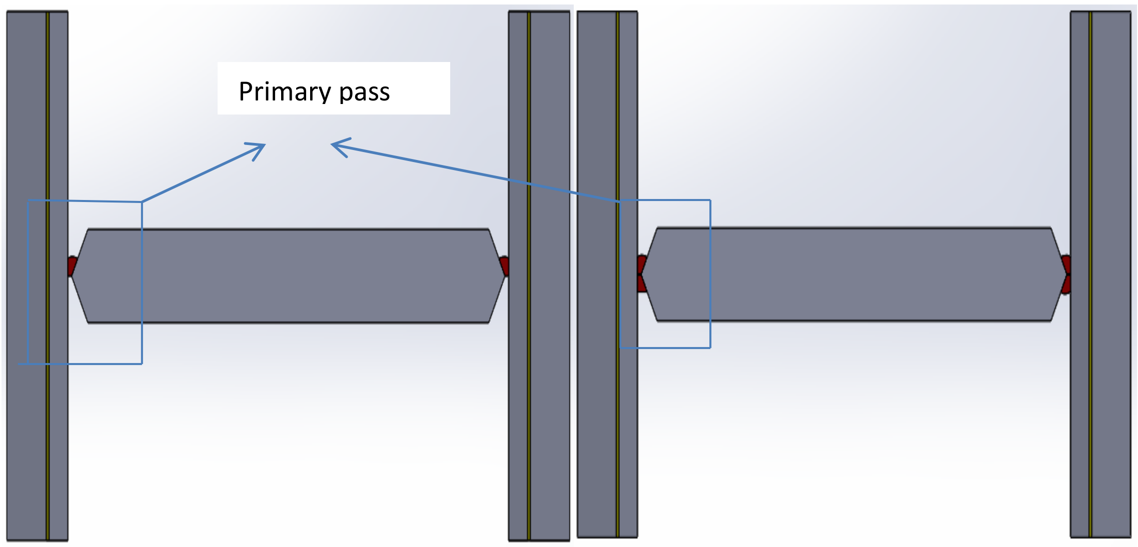


Fig30. Primary pass in the experimental beam [10]

5.2 Second pass

The second pass is done welding above the primary pass. At that time the primary pass made lost its stress and heat produced and acts as the supports for the second pass welding. So when the welding is done, the initial weld acts as the supports and does not allow the flange plates to bend. The load acts by the second pass welding process is 20N. The force acts also divided into three parts [10]. The figure 31 shows the beam with the primary pass and secondary pass of the welding where the primary pass acts as the support for the secondary pass made when it is air cooled.

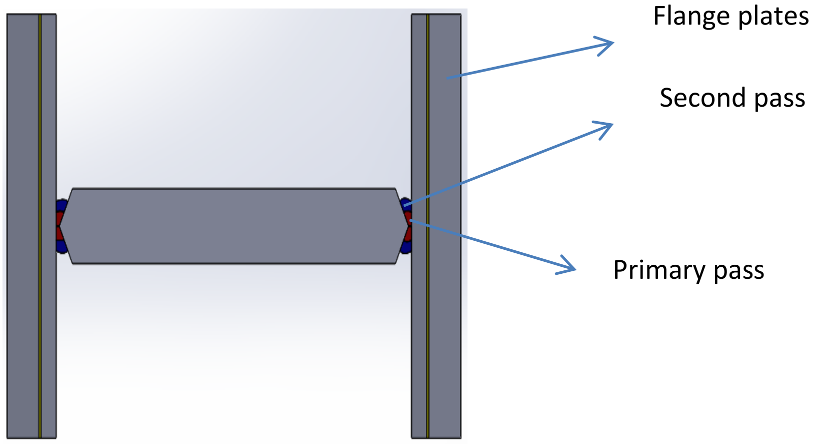


Fig.31 Secondary pass welding [10]

5.3 Final pass

The final pass is done by welding the portion above the second pass, where the previous done passes acts as the supports. The final pass is done on either side, where the stress produced from the final pass welding gets cancelled each other. In the large scale industries the welding is done by the robots or it would be automated, hence the distortions caused by the welding process are controlled heavily. Apart from them it uses the large machineries to remove the bends if raised. The three layers of welding automatically divide the stress produced among the layers. So when the primary pass is done only 1/3rd of the stress acts in the area which does not affect the flange plates to deform. Even though it requires much time to turn the job front and back to pursue the welding process it helps to avoid the costs required for purchasing large machines. But in the case of small scale industries, these facilities are not possible. The figure 32 shows the beam with the primary pass, secondary pass and the final pass of the welding process.

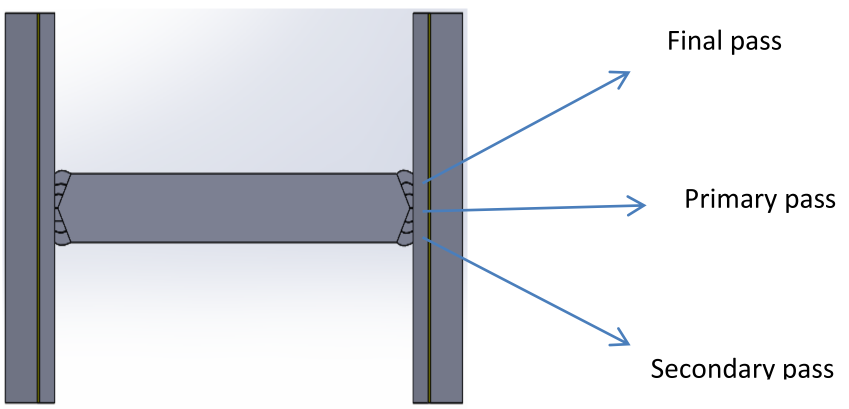


Fig.32 Final pass welding [10]

6. Improvement in the Production process

As the way of improving the production process in welding the beams the bends occurred is controlled. There are 4 different ways to be followed in this project under production process. They are majorly involved in the control of the flange bends more than the stress produced in the welding process since the same bevel of 30° is maintained in full penetration welding process using metal inert gas welding (MIG) process [11].

6.1 Type A. Provide temporary stiffeners

As the improvement in the production process, the first step to eliminate the bends the temporary stiffeners are to be provided. The temporary stiffeners are to be fabricated based on the inner sectional dimensions of the beam taken for welding. The stiffeners should be in the thickness which tackles the bending motion of the flange plates. It depends on the thickness of the flange plates. For example, flange plate of thickness more than 36 mm, it is necessary to give the stiffeners of thickness more than 10 mm. If the stiffeners below the said thickness are used to control the bends, the stress induced by the flange plates is experienced by the stiffener plates which are placed temporary.

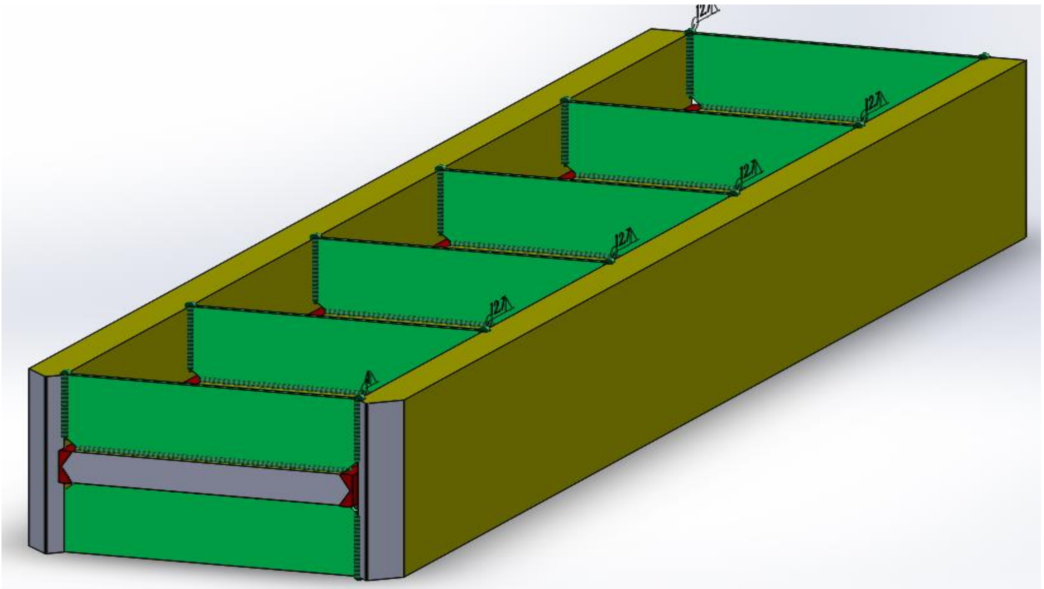
Due to this it allows the flange plate to bend, by accepting the stress induced by them. Hence it leaves no use of placing the temporary stiffeners. And also the stiffeners are placed at the regular intervals to eliminate the bend formation equally. The below figure reveals the process of placing the temporary stiffeners in the sectional portion. It should be placed at regular intervals to control the bends uniformly. The diagram represents that the stiffeners which are temporary are places at the regular intervals of 500 mm.

The stiffeners should equally divide the entire length of the beam. The stiffeners are welded or tack welded along the connections based on the fabrication needs. Even it is quite difficult to remove the weld beads after the process completion, it will leave the effective control in bends where the final result what we want is achieved efficiently [11].

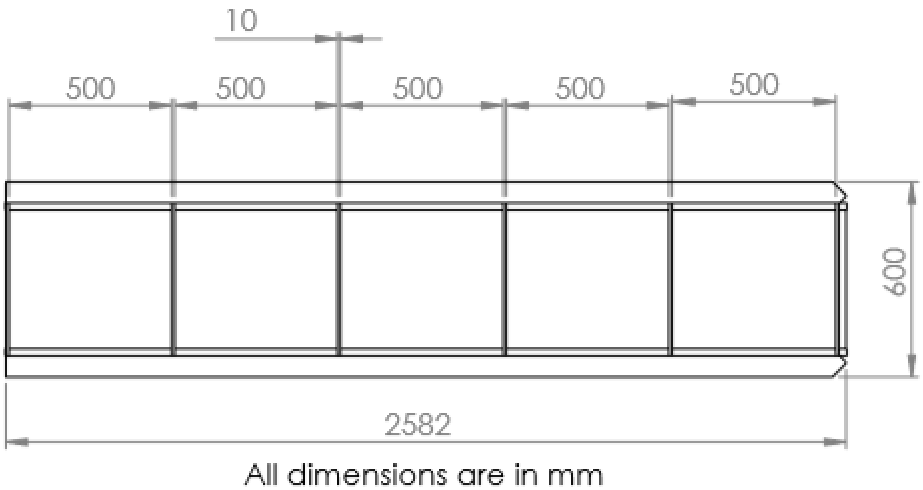
After decreases the bend in the initial stage of material preparation by taking the bevel of 30°, the next step is to provide the temporary stiffeners in between the sectional width. The area of contact between the support plates, flange plates and the web plate is made as the fixed support. The input of 103.5 N is given as the force in the weld area of flange and web plates. The force is acting as the line contact in the weld area where the entire force acts in the direction normal to the flange plates.

The stiffener plates arrest the flange and web plates from deformation. The flange plates are not deformed even after the removal of support plates. The beam is taken into analysis with the input force of 103.5 N and fixed support where the support plates made the connection. The thermal force is given in the weld surface.

6.1.1 3D view of the beam with stiffeners



(A)



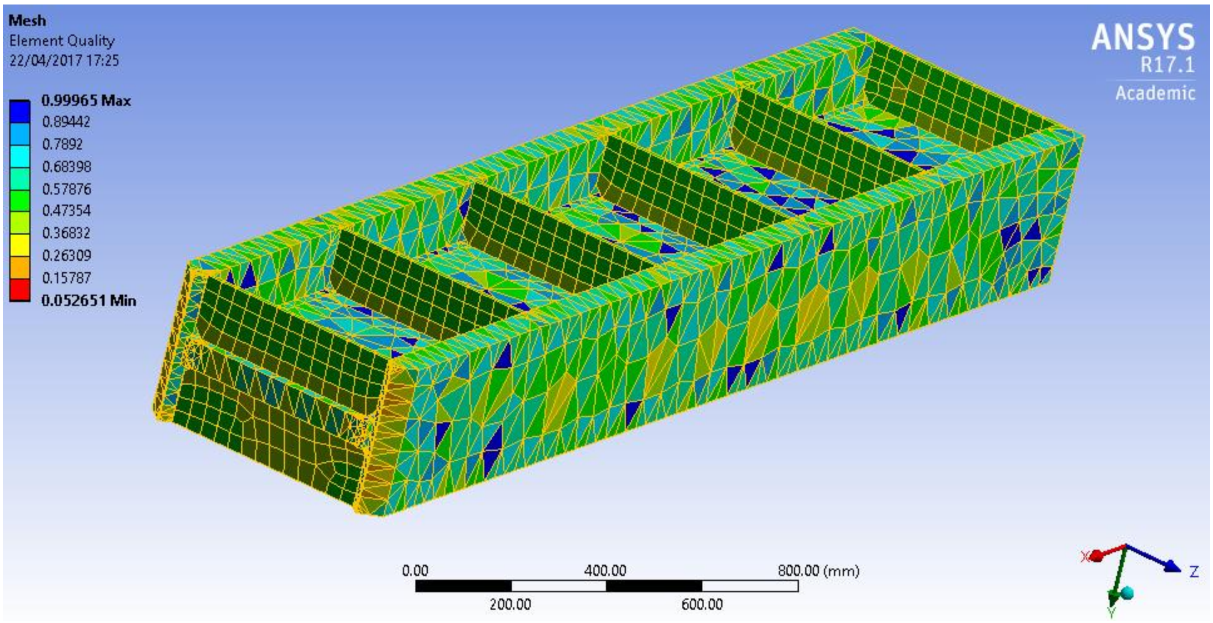
(B)

Fig.33 Beam with temporary stiffeners [Annexure.6]: A-3D view, B-2D view.

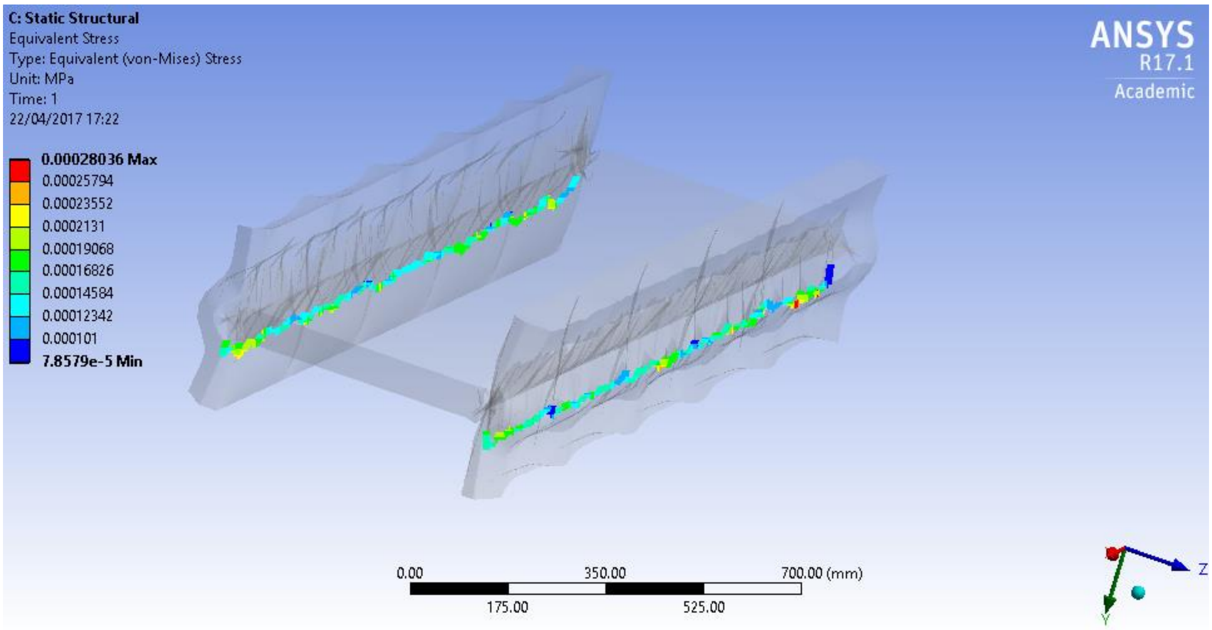
The figure 32 show the 3D modelled beam with the temporary stiffeners welded to the flange plates and web plates. The figure 33 shows the 2D view of the beam with temporary stiffeners where the interval in which the support plates should be placed is understood clearly. The modelled beam is taken into analysis for the force of 103.5 N of bevel 30° in ANSYS, where the stress experienced is calculated and compared. From the above figure it is clearly noted that the support plates arrest the flange and web plates. The support plates are tack-welded for easy removal after the completion of process. The beam is taken into analysis using ANSYS to determine the amount of stress produced after placing the support plates in the beam, which is done in the stage of fabricating the beam.

6.1.2 Stress analysis of the beam

The beam is modelled for the AISI 304 in solid works and taken into analysis using ANSYS. The figure 34 shows the meshed beam and the beam with produced stress under defined boundary conditions.



(A)



(B)

Fig.34 ANSYS results [Annexure.6]: A-meshed image, B-stress results

Boundary conditions:

Force: 103.5 N as line contact in the weld area

Fixed support: Contacts between the flange, web and support plates

Mesh type: Fine type triangular mesh

The maximum stress produced is of 280.36 N/m^2, which reduces the chance of formation of bends in the beams. Since the flange and web plates are arrested using support plates, there is not much deformation produced. The stress produced with support plates (temporary stiffeners) and the beam without support plates are compared and analysed. The comparisons between the stress values of beam with bevel 30° and the beam contains temporary stiffeners along with bevel 30° are tabulated as follows,

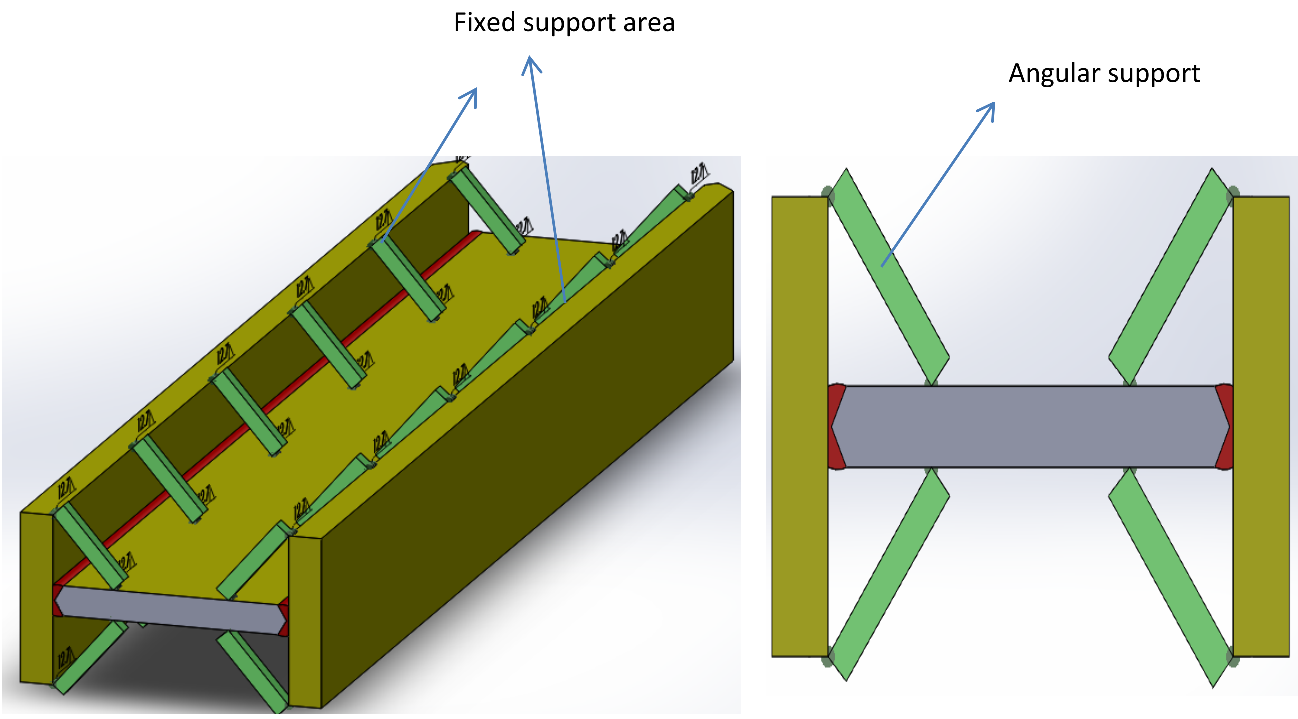
Table.4 Stress comparisons of beam with temporary stiffeners [11]

Stress	Beam with bevel 30° (without support plates) N/m^2	Beam with bevel 30° (with temporary stiffeners) N/m^2
S1	0	0
S2	129.19	101.0
S3	258.38	123.42
S4	387.58	145.84
S5	516.77	168.26
S6	645.96	190.68
S7	775.15	213.10
S8	904.35	235.52
S9	1033.50	257.94
S10	1162.70	280.36

As from the table 4, it clearly indicates that the maximum stress produced in the beam of bevel 30° is of 1162.70 N/m^2. But the beam with temporary stiffeners produces the maximum stress of 280.36 N/m^2. It shows that the support plate doesn't allow the stress to produce more since it arrested the flange and web plates entirely. The more stress is formed when the flange plate responds to the heat produced during welding process is more. There are different type of support plates where it depends upon the thickness of the plates undergoes welding process. For this experimental beam, it undergoes a different support plate analysis to find the best one [11]. There is a huge decrease in stress percentage by 75% which goes more effective when used in the fabrication industries.

6.2 Type B. Provide angular supports

The method of controlling the bends caused by the welding process is to give the angular supports between each flange plates to the web surface. The stress produced in the welding process is taken by the supports given; as a result the deformation may happen in the given temporary supports. This causes the supports to bend instead the flanges to bend. The Force of 103.5 N is given in the same welding position and the fixed support is given in the point of contact between the flange plates to support plate and web plates to support plate.



(A) (B)

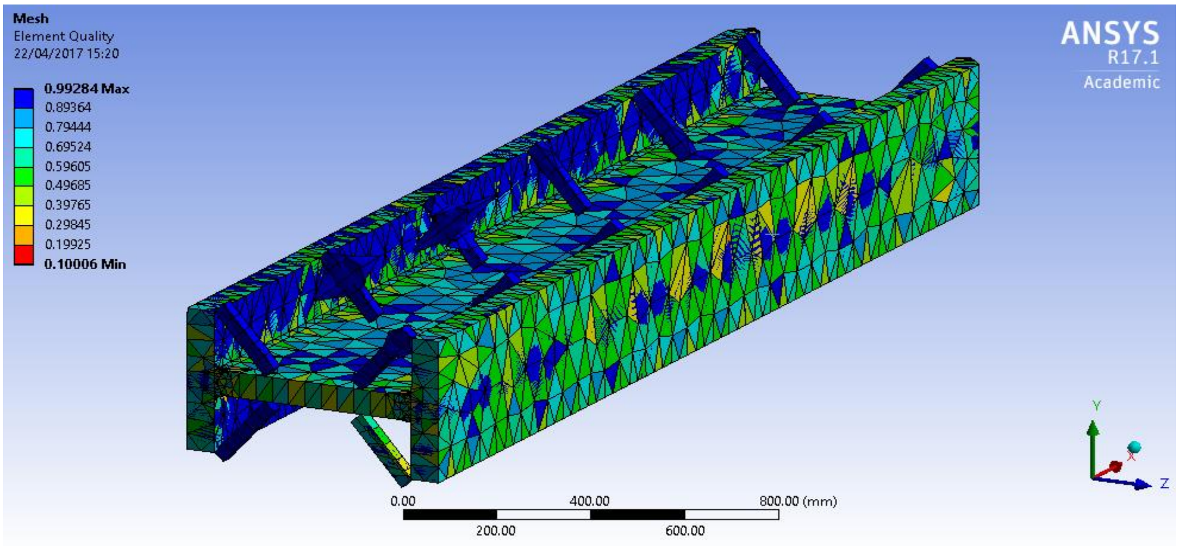
Fig.35 Beam with angular supports [Annexure.7]: A-entire beam, B-angle supports

The figure 35A show the beam with angular support plates which is welded to the flange edges and to the web surface as the fixed support. The figure 35B shows the side view of the beam with the angular support plates. The angular support plates of thickness which should be able to control the bends caused by the heavy thickness plates. For heavy thickness plates, the support should be made of heavy thickness plates. The support plates are welded in the point of contact between the flange plates and web plates. The weld fillet is made high as the welding volume increases. Then the support plates are removed using the cutting process or grinding process, which can be used in further welding process [12].

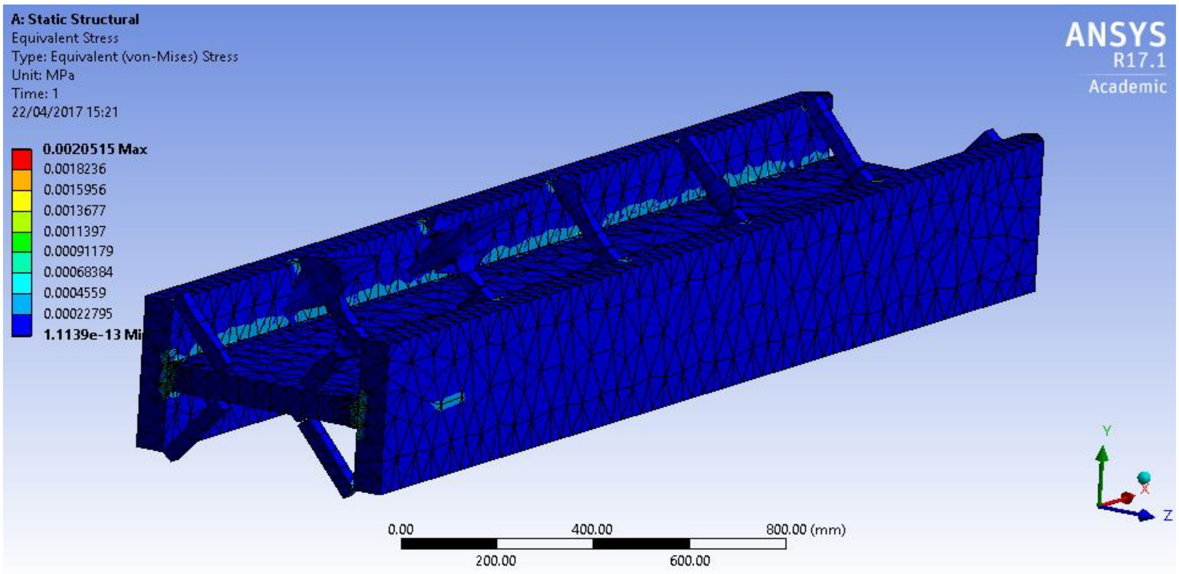
The angular supports are placed at the regular intervals to eliminate the bends uniformly. It is shown in the annexure how to place the supports at regular intervals and it should divide the entire length of the beam taken for welding process

6.2.1 Stress analysis [12]

The beams with the angular supports are taken into analysis in ANSYS, where the object is meshed to the fine quality as a complete object. The point of contact between the flange plates and the web plates are made as a fixed supports, and the force of 103.5N exerted by the welding process in the bevel 30^0 is given in the welding area, then the beam is subjected to analysis.



(A)



(B)

Fig.36 ANSYS stress results [Annexure.7]: A-meshed image, B-stress image

The figure 36A and 36B shows the meshed and stress image of the beam with angular support plates which is made under defined conditions considering the entire supports along with the beam as single part.

6.2.2 Deformation analysis

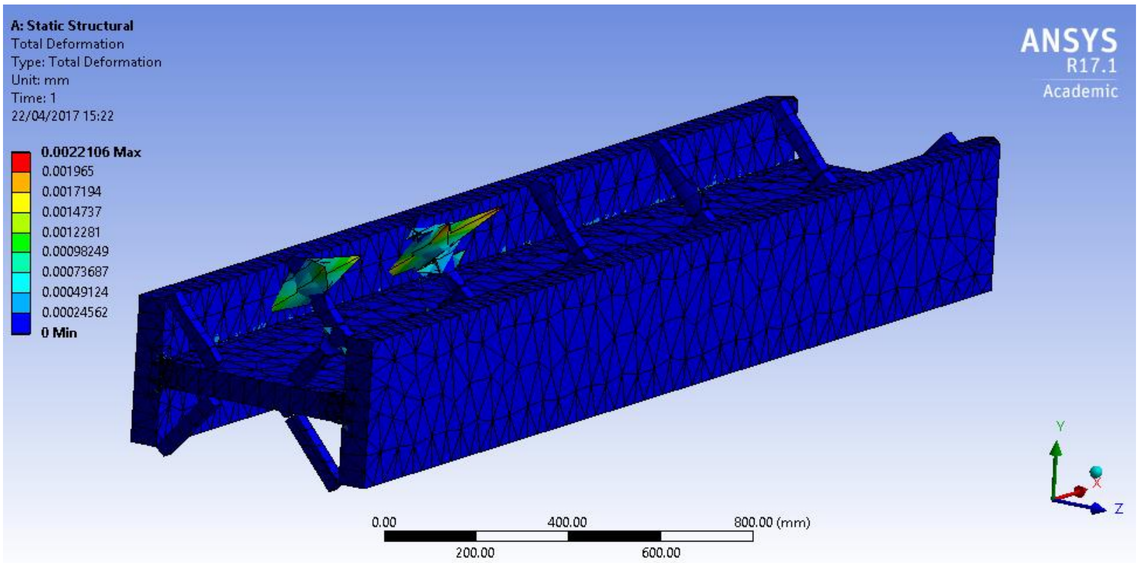


Fig.37 Deformation results [Annexure.7]: A-deformed image, B- strain image

The above figure 37 shows the deformation of support plates due to the produced stress which indicates the breakage of support plates when stress exceeds. It totally depends upon the flange plates of different thickness. For medium thickness flange plates the probability of breakage is low. The maximum deformation achieved is 0.0022mm which is too small and highly negligible. As a result we can find there is no deformation in the flange plates due to the full penetration welding process (FCAW), where the entire deformation is taken by the angular support plates it includes the high probability of breakage of the support plates. Thus the beam is controlled from the bends raised by the welding process using the angular support plates [12]. From the figure it is noted that these types of support plates are suitable for the low thickness flange plates to control the bends. This is not fair idea to be used for heavy thickness plates. Because for that much welding process, the stress produced is more and the flange plates exerts much force to the support plates connected to that. Due to this support plates break and allow the flange plates to bend towards the direction of welding.

In low thickness plates, these support plates of thickness more than the flange plate thickness is easily withstand the force exerted by the flanges. So there is very less chance of deformation and no probability of breakage. The control of bends using the plates is made more efficient. Hence these types of supports are well suited for the low thickness plates. It is because there is only a point contact between the flange and web plates to the support plates which is not able to withstand high force exerted by the welding process.

6.3 Type C. Provide flange to flange supports

This is the type of bend controlling process in which there is welding of large support plates between the two flanges. There is no more contact with the web surface, where the force exerted by the two flange plates is cancelled each other. One flange plate acts as the support when the other flange plate undergoes welding process. Even though there is a requirement of huge volume of material for usage it will control the bends more effectively. The length of the support plates varies as the sectional width of the beam varies [13].

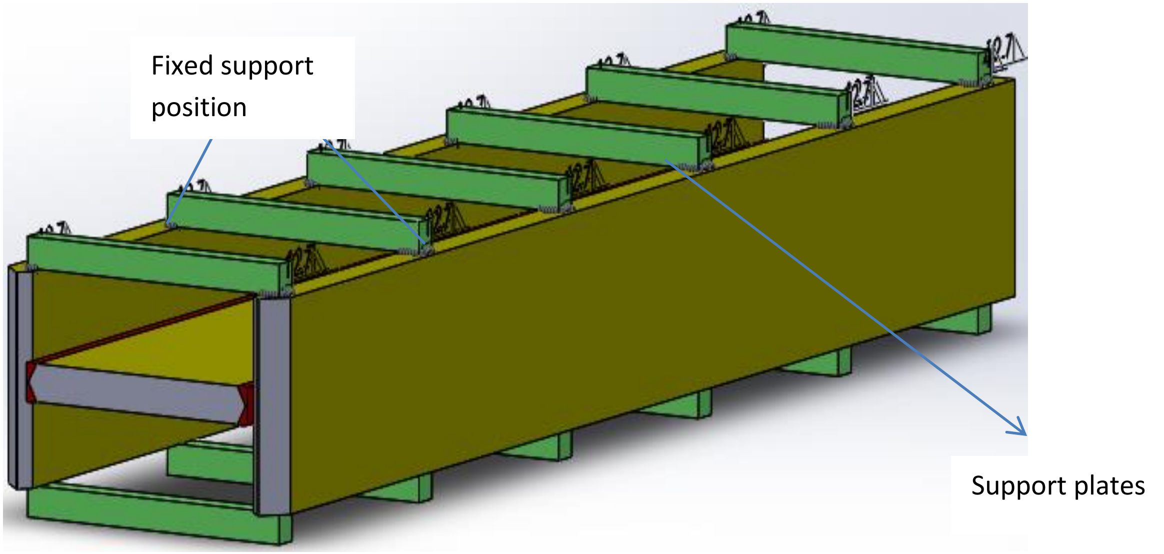


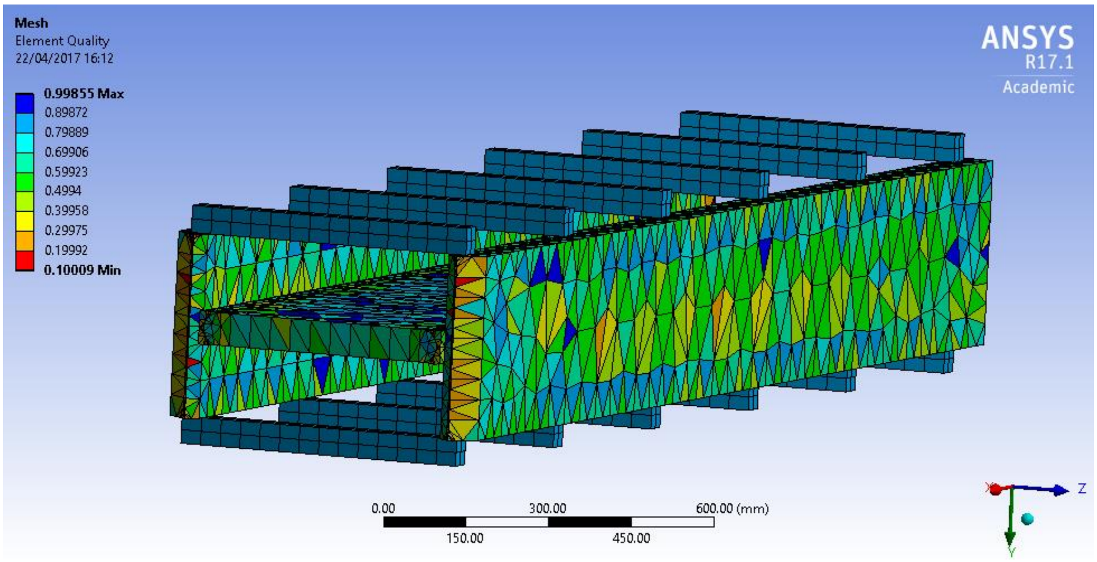
Fig.38 3D view of flange to flange support plates in the beam [Annexure.8]

The figure 38 shows the 3D modelled beam with flange to flange support plates welded with the flange surface as the fixed support. The support plates are equally divided for the entire length and to be welded in the flanges at regular intervals. The weld size is depending upon the thickness of the plates. For low thickness plates, it will react to the weld heat more severe so the support plates are welded with maximum fillet size [13]. The modelled beam is shown in the annexure 8.

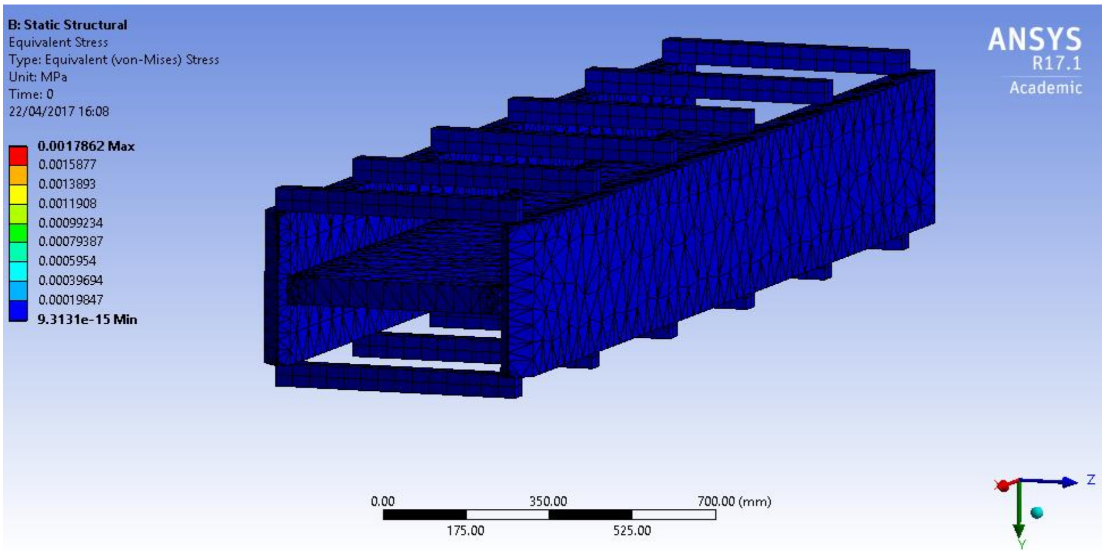
In the contrast, for heavy thickness plates the support plates are welded with normal fillet that suits the flange plates. It also depends upon the main type of welding is going to proceed in the process. In the analysis using ANSYS, the load is given in the main welding area where welding action does. The fixed support is given in the contact region between flanges and support plates. Among the other processes, this type of controlling is more welcome in the fabrication industries, even though it requires large volume of materials. The support plates are made up of heavy thickness plates to withstand the stress produced by the flange plates. These plates are not suitable for low thickness plates since it results in the formation of wave bends which is very hard to rectify by heating especially in small scale industries. The support plates are welded with flange surface also by considering the ease removal of it. Even though the material usage is high it will control the bends in heavy thickness plates more efficiently [13].

6.4 Stress analysis

The beams with the flange to flange supports are taken into analysis in ANSYS, where the object is meshed to the fine quality as a complete object. The point of contact between the flange plates and the support plates are made as a fixed supports, and the force of 103.5N exerted by the welding process in the bevel 30^0 is given in the welding area. The maximum stress achieved is 0.0017862 MPa [13].



(A)



(B)

Fig.39 ANSYS stress results [Annexure.8]: A-meshed image, B-stress image

The figure 39A show the meshed of the beam with flange to flange supports under defined conditions where the support plates along with the beam is considered as the single object. The figure 39B shows the stress image of the beam under the thermal force acts in the weld surface for bevel 30°.

6.5 Type D. Provide vertical supports

The method is of giving the vertical supports in the flange surface. Due to this the entire flange surface acts as the fixed support. Hence there is much control in the bend formation by the flanges. This is of same type of support plates given in the angular supports where it is placed in flange surface at the regular intervals. The intervals are equally divided for the entire length of the beam [13]. The beams with the vertical supports placed in the flange surface are taken into analysis in ANSYS, where the object is meshed to the fine quality as a complete object. The point of contact between the flange plates and the flange surface are made as a fixed supports, and the force of 103.5N exerted by the welding process in the bevel 30^0 is given in the welding area. The maximum stress achieved is 0.0017862 MPa. The beam with the vertical support plates are shown in the annexure 9.

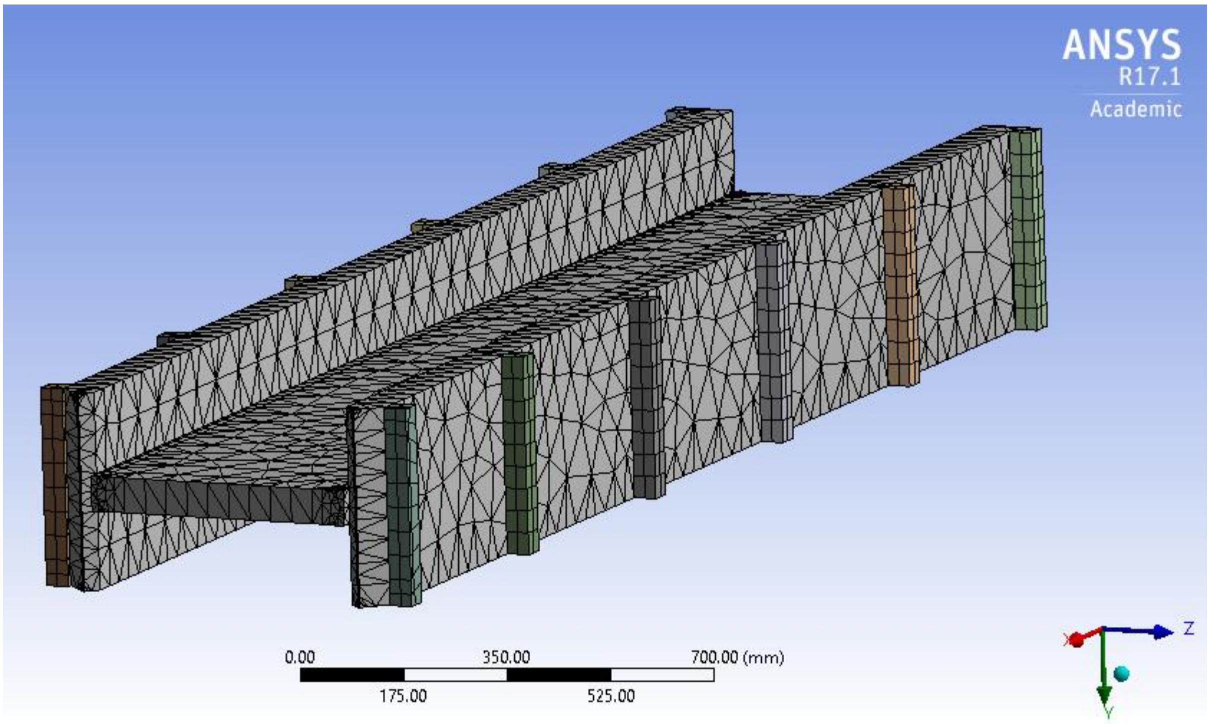


Fig.40 Beam with vertical support plates [Annexure.9]

The figure 40 shows the meshed image of the beam with the vertical support plates. The 3D modelled beam is taken into analysis in ANSYS. The force of 103.5 N is given as the input value in the welding line area in the web plates. The support plates acts as the fixed one. So when the welding process is done the stress exerted by the flange plates don't have any options for showing it. When the beam gets air cooled, the support plates get removed and used for any other beam requires similar process. These vertical plates are placed at regular intervals to control the bend formation uniformly. For heavy thickness plates, this leads to break the connected weld joint between the flange plates and support plates. Due to this the entire flange surface acts as the fixed support. The meshed analysis is shown in the annexure 9.

6.6 Stress analysis

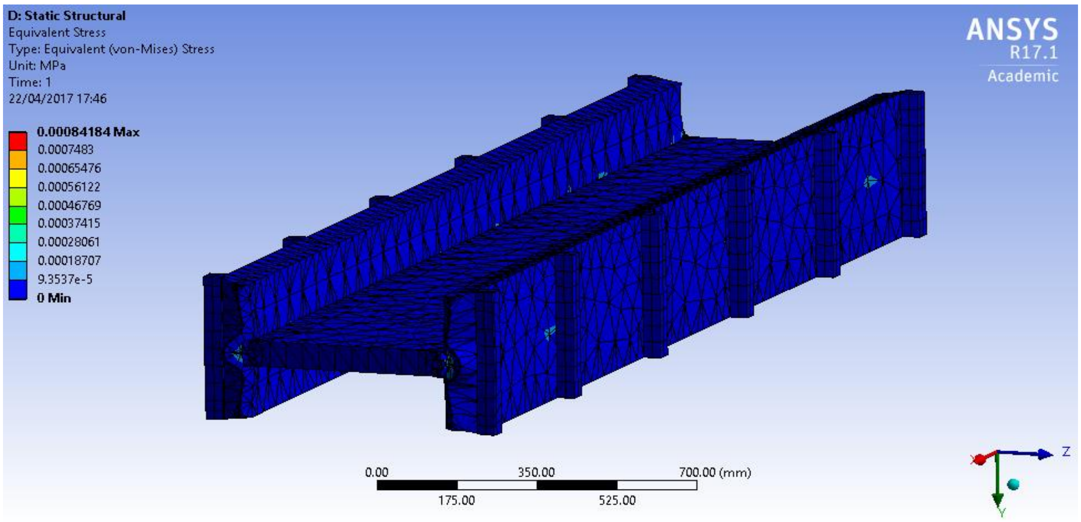


Fig.41 Stress analysis of beam with vertical supports [Annexure.9]

The figure 41 shows the stress result of the beam with vertical support plates and the analysis taken is shown in the annexure 9. The maximum stress experienced by the beam is of 841.84 N/m^2. Hence the sectional width of the beam is maintained and there is no chance for having buckling of web plates. The stress produced is low when compared to the beam without support plates and high when compared with the beam with temporary stiffener plates. The stress is compared for the beam of bevel 30° without support plates and with vertical support plates [12]. The table5 shows the stress comparison of beam with and without vertical support plates.

Table.5 Stress comparisons of beam with vertical support plates [12]

Stress	Beam with bevel 30° (no supports) N/m^2	Beam with bevel 30° (vertical support plates) N/m^2
S1	0	0
S2	129.19	0
S3	258.38	187.07
S4	387.58	280.61
S5	516.77	374.15
S6	645.96	467.69
S7	775.15	561.22
S8	904.35	654.76
S9	1033.50	748.30
S10	1162.70	841.84

6.7 Stress results comparison

The stress results analysed for the ANSYS are tabulated and compared and shown in the table 6.

Table.6 Stress comparison table for different supports [13]

Stress	Type A (MPa)	Type B (MPa)	Type C (MPa)	Type D (MPa)
Stress, S1	7.8579 e^{-5}	1.1139 e^{-13}	9.3131 e^{-15}	0
Stress, S2	0.00010100	0.00022795	0.00019847	9.3537 e^{-5}
Stress, S3	0.00012342	0.00045590	0.00039694	0.00018707
Stress, S4	0.00014584	0.00068384	0.00059540	0.00028061
Stress, S5	0.00016826	0.00091179	0.00079387	0.00037415
Stress, S6	0.00019068	0.00113970	0.00099234	0.00046769
Stress, S7	0.00021310	0.00136770	0.0011908	0.00056122
Stress, S8	0.00023552	0.00159560	0.0013893	0.00065476
Stress, S9	0.00025794	0.00182360	0.0015877	0.00074830
Stress, S10	0.00028036	0.00205150	0.0017862	0.00084184

Note

Type A- Beam with temporary stiffeners

Type B- Beam with angular support plates

Type C- Beam with flange to flange support plates

Type D- Beam with vertical supports

Stress, S1- Minimum stress produced in MPa

Stress, S10- Maximum stress produced in MPa

6.8 Graph comparisons

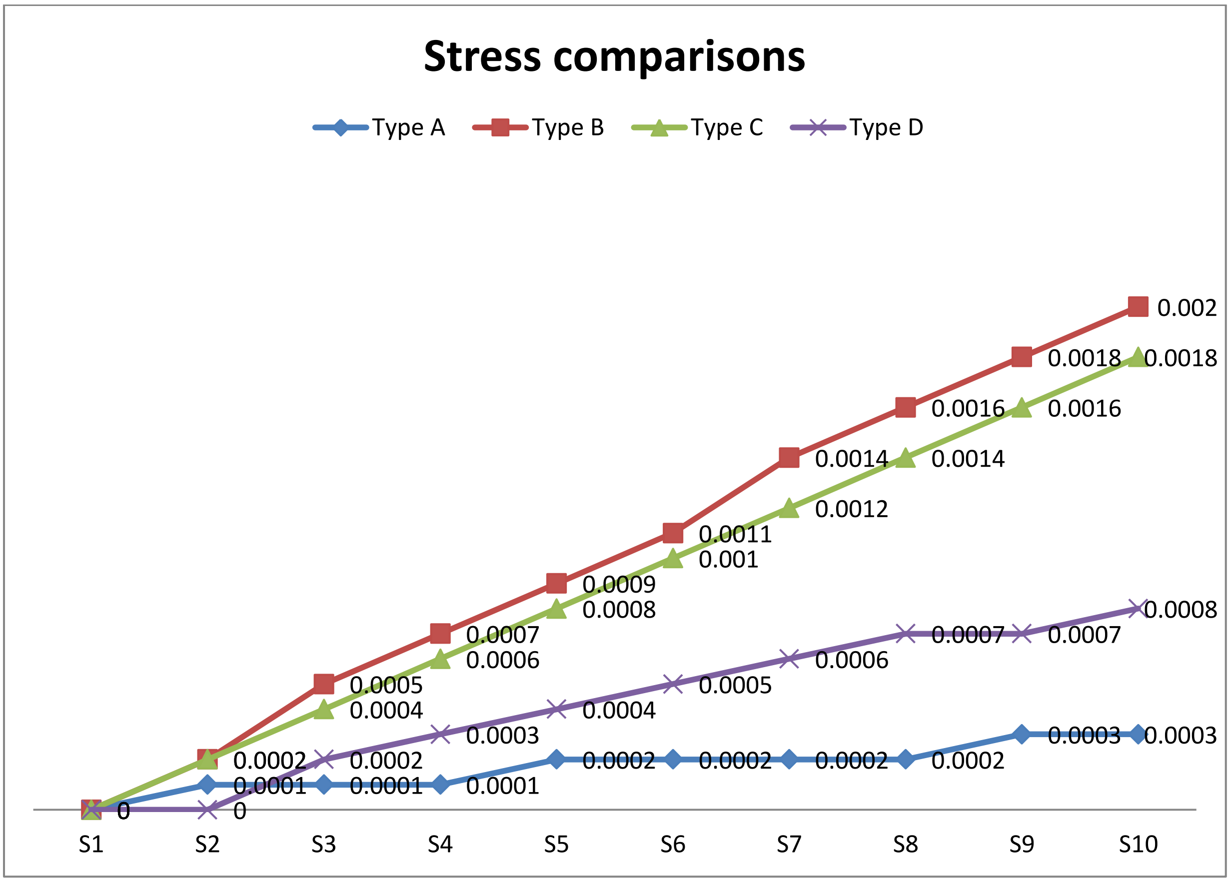


Fig.42 Graph shows the stress comparisons report [14]

The above figure 42 clearly indicates that the stress produced in the beam with temporary stiffeners is low when compared with the beam with other type of supports such as angular support plates, flange to flange support plates and vertical support plates. Ten types of stress values are taken into consideration which ranges from minimum to maximum. The maximum stress value produced in the beam with temporary stiffeners is about 280.36 N/m^2. The maximum stress value produced in the beam with other type of support plates such as angular supports, flange to flange supports, and vertical supports are noted as 2051.50 N/m^2, 1786.2 N/m^2, and 841.84 N/m^2 respectively. In this project for this experimental beam of required thickness of flange plates and web plates, the beam of bevel 30° with temporary stiffeners as support plates is made for better fabrication. This process will finish the beam with high quality and made no problem in the erection. This process easily avoids the mismatching errors during erection time. This avoids unnecessary correction works in the site. The support plates differ for different types of beam with different flange thickness and web thickness [14].

7. Analysis of results [14]

In the above analysis, it is to be noted that the stress produced in the type A of 280.36 N/m^2 is low when compared to other types. This is due to that there is weld arrest in the web plates and flange plates heavily when compared to others. Hence there is less distortion in the flange plates due to the welding process. In the case of angular supports, even though there is a weld arrest in the web and flange plates, due to less coverage of weld area, it leads to breakage in the support plates [14].

This automatically allows the flange plates to bend towards the welding processed area. This results in less efficient when compared with the previous process of having temporary stiffeners. The next process is about giving support plates between the flange plates. Since there is no connection between the web plates the web is not acting as the fixed support. So there is high possibility of producing much stress even though there is connection between the flanges. The stress produced is of 1786.2 N/m^2 where this stress is getting released when the support plates get removed. After this act the flange plates gets the distortion where the welding of support plates results in useless [14].

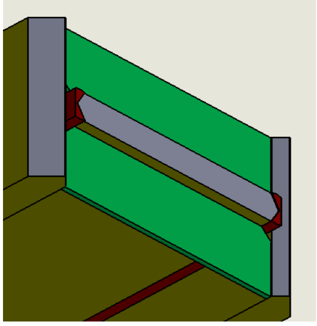
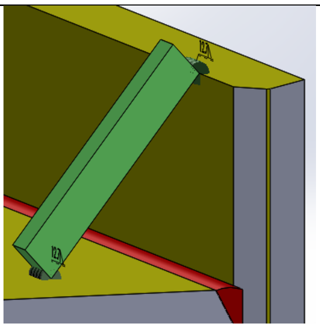
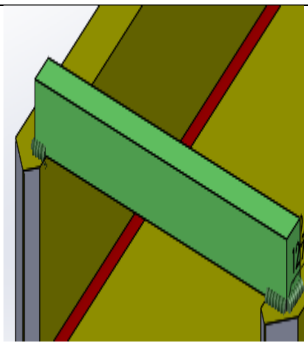
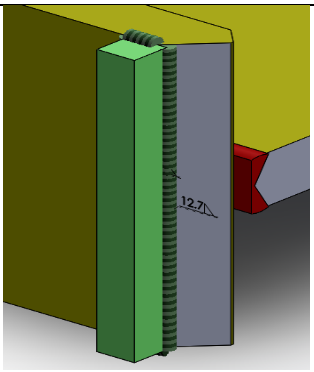
In the final method the supports are given in the flange surface, where the entire flanges acts as the supports so there is minimum probability of heavy stress produced. The support plates gets removed and used as the angular supports. The surface of the support plates are welded with the surface of the flange plates but in angular support plate case the edges are welded with web and flange plates.

The first step in reducing the bends and stress produced is of optimizing the bevel region from 45° to 30°. The next step is to take the built up beam to weld process by providing the temporary stiffeners before that. The next stage in the welding process is to make the welding properly as per the standards with high skilled welders [14].

This process is that in major small scale industries, there is no control in the welding current and voltage for the required weld. They are not taken into account the type of weld, weld size and the parent material thickness. It is to be done like the beam should be welded layer by layer. The first pass is to be made in the root region, and then the beam is to be turned downside and made the root pass. Then the second pass over the root pass is to be done, and it is followed by the second pass in the down side. This process is continuously done as per the fillet or cap size needed. The main problem occurs when the entire welding is completely done in the single side and after going for further process. This process is taken the material usage in consideration since it involves some decent costs which is much low when compared to buy advanced machines used in this process. These works are discussed in the forthcoming topics.

Material and manpower Analysis

Table.7 Material requirement analysis for temporary supports [15]

Type	Support	Dimensions (cm)	Thickness (cm)	Volume (cm^3)	Weight (kg)	Material required
A		**14cm×47cm**	**1 cm**	**658**	**5.165**	**12 No's**
B		**18.44×3.26**	**3cm**	**180.33**	**1.415**	**24 No's**
C		**53.5×4.5**	**5cm**	**1203.75**	**9.5**	**12 No's**
D		**34×4**	**4**	**544**	**4.27**	**12 No's**

The above table 7 shows the amount of material usage in giving the supports for controlling the bends. These supports are given for various beams of same size or minimum size. In this analysis, it shows that the type C gains more material usage when compared to other supports. It also shows that type B consumes less amount of material when compared to others. The stress produced in the type A is low but the amount of material used is somewhat high. These supports automatically eliminate the use of big machineries and bend removal machines as in the case of large scale industries. It involves the minimal supervision and use of skilled welders. This information is tabulated as follows [15],

Table.8 Manpower requirements [16]

Type	Manpower	Time needed to give support plates	Time needed for welding process
A	2 MIG welders	20 min	4 hours
B	2 MIG welders	15 min	4 hours
C	2 MIG welders	20 min	4 hours
D	2 MIG welders	10 min	4 hours

The above table 8 shows the manpower requirements to finish the entire welding process. This clearly indicates the costs required is very much low when compared to implement the advanced high technology machines in welding and bend removal process. This project is highly suitable for the small and medium scale industries where the buying behaviour of heavy machineries is not feasible [16].

As a result, how the taken experimental beam is being welded in well manner is by having the weld groove bevel for 30° and have the support of type A which is well suited for the beam and follow the three step process in welding as discussed earlier. The requirement of supports differs from beam to beam. The time require for the entire welding process is more or less equal in both small and large scale industries when done manually. But the error correction time differs with large and small scale industries if occurs. In large scale industries, it is corrected with the use of large machines and proper work location. But if it is in the small scale industries, it is done manually by extreme heat application using oxygen-acetylene mixture. This takes lot of time and enormous utilisation of manpower in process [16].

8. **Conclusions**

1. The mild steel is selected as the working material since most of the fabrication industries use mild steel for its fabrication of heavy structural beams since of its discussed quality. This selection is based upon the client needs where the experimental beam taken into analysis is of mild steel. The welding process is compared for the heat produced for different travel speeds and voltage, finally MIG welding process is taken for pursuing the fabrication process.
2. During welding process, the different types of bend are formed as discussed in the project. It is normally corrected using different heating process as per the type of bends formed. In the manual correction process, the application of heat is done by the external heating process where may result in the entire length shrinkage of 5mm from overall length of 2582mm.
3. In the material preparation stage for built-up beams, the bevel of 45° is normally taken for welding to achieve the full penetration process. Because of more area and large amount of weld metal deposited, heat produced is more which causes the flange plates to bend. But by giving the root gap of 4mm and improving the bevel dimension from 45° to 30° we can reduce the weld material required in minimized area and achieving the full penetration is made efficiently.
4. By pursuing the welding process layer by layer, we can reduce the enormous heat produced when the entire welding is done at the first time itself. This layers depend upon the weld fillet size varies from 2 to 5 passes normally.
5. By providing different type of support plates to the beam before the welding process, the stress produced in the beam is controlled, which doesn't affect the flange plates even after the removal of support plates. In this project the best support plate is chosen as temporary stiffeners for the minimum stress production of 280.36 N/m^2 when compared the same beam to other type of support plates.
6. This project works on reducing the stress produced from the initial stage of material preparation to the welding process, production process included in the fabrication of structural beams in fabrication industries. It is done by optimizing the bevel dimension from 45° to 30° and by controlling the stress produced to 1162.7 N/m^2. This is followed by the improvements in welding, production process.
7. This project shows the ways of determining the control parameters in welding process and the elimination of weld bends raised in the process. This paves a decent way in improving the productivity in the small scale and medium scale industries without the need of heavy machineries for the removal process. It will be useful in future for the ship building industries, heavy steel structural fabrication industries to minimize the usage of heavy machineries and minimize the usage of enormous time in the defects elimination process since they are monitored and controlled in the early stage of their process.

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Annexures

GRID LOCATION		QTY.	LEVEL
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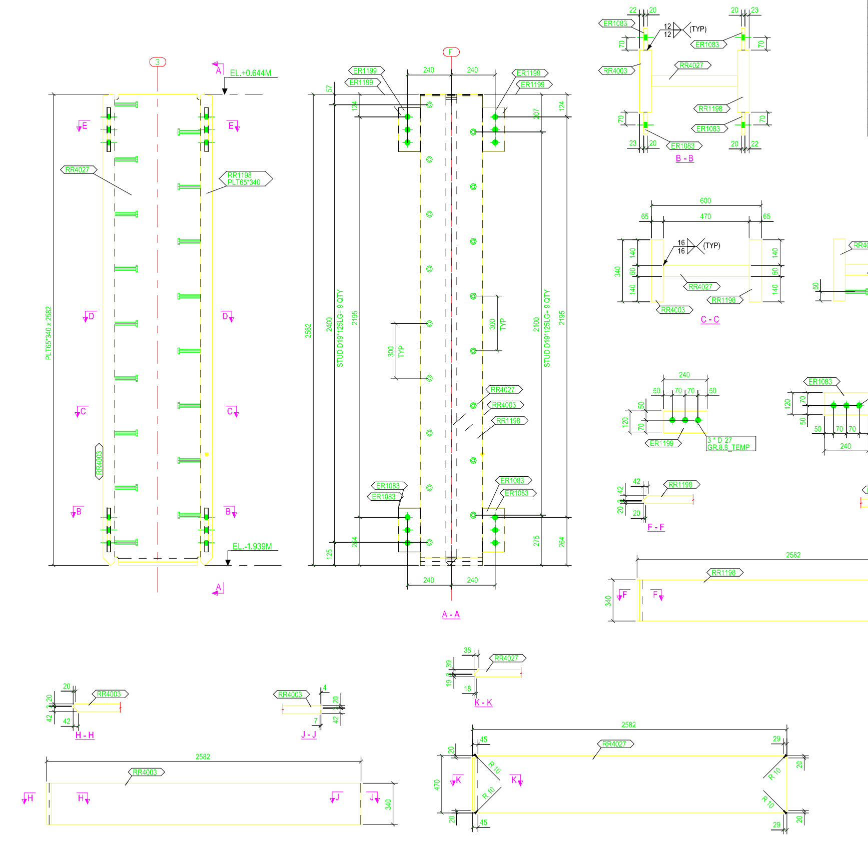
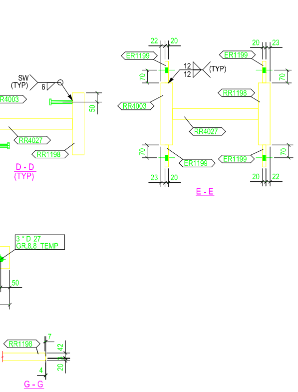


GENERAL NOTES: ALL HOLES ARE Ø22 mm UNLESS NOTED
ALL WELDS ARE 6 mm F.W UNLESS NOTED
ONLY FIGURED DIMENSIONS TO BE FOLLOWED

MATERIAL LIST FOR ONE ASSEMBLY MK'D G1-CL1175 1 No. Required

Mark	Size	Grade	Qty. (Nos)	Length (mm)	Area (m2)	Weight / One (Kg)	Total Weight (Kgs)	Remark
ER1083	PLT20*120	E250	4	240	0.07	4.52	18.09	
ER1199	PLT20*120	E250	4	240	0.07	4.52	18.09	
RR1198	PLT65*340	E450	1	2582	2.12	447.94	447.94	
RR4003	PLT65*340	E450	1	2582	2.12	447.94	447.94	
RR4027	PLT60*470	E450	1	2582	2.77	571.58	571.58	
TOTAL AREA. FOR 1 ASSEMBLY					7.58		1503.63	
	BOLT M 24*90	GR.8.8_TEMP	12			0.41	4.94	
	NUT M 24	GR8-HEX	12			0.13	1.54	
	WASHER 24		12			0.03	0.38	
	STUD D19 *125		17			0.322	5.47	
TOTAL WT. FOR BOLT							12.34	
TOTAL WT. FOR 1 ASSEMBLY							1515.97	
TOTAL WT. FOR1 ASSEMBLIES							1515.97	



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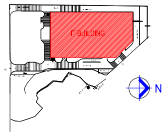

NO PAINT FOR ENTIRE ASSEMBLY

1 Nos. 2ND_TIER_COLUMN REQ'D AS DRAWN MARK NO. "G1-CL1175"

REV	DATE	DESCRIPTION	DRWN	CHEK	APPR
0	05.01.2017	ISSUED FOR FABRICATION	SMD	VPK	SHAH

CLIENT:
RUPA INFOTECH & INFRASTRUCTURE Pvt. Ltd.
Mumbai.

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STRUCTURAL PEER REVIEW CONSULTANT :
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Mumbai - 400 028,
India Tel: 91 22 2437 6001 and 91 22 2437 6003

STRUCTURAL CONSULTANT :
EVERSENDAI
EVERSENDAI CONSTRUCTION PRIVATE LTD.
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Email : eversendai.india@eversendai.com

STEEL WORK CONTRACTOR :
EVERSENDAI
EVERSENDAI CONSTRUCTION PRIVATE LTD.
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Tel: +91 44 4070 1200-49 Fax: +91 44 4070 1230
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PROJECT NAME
RUPA RENAISSANCE IT BUILDING

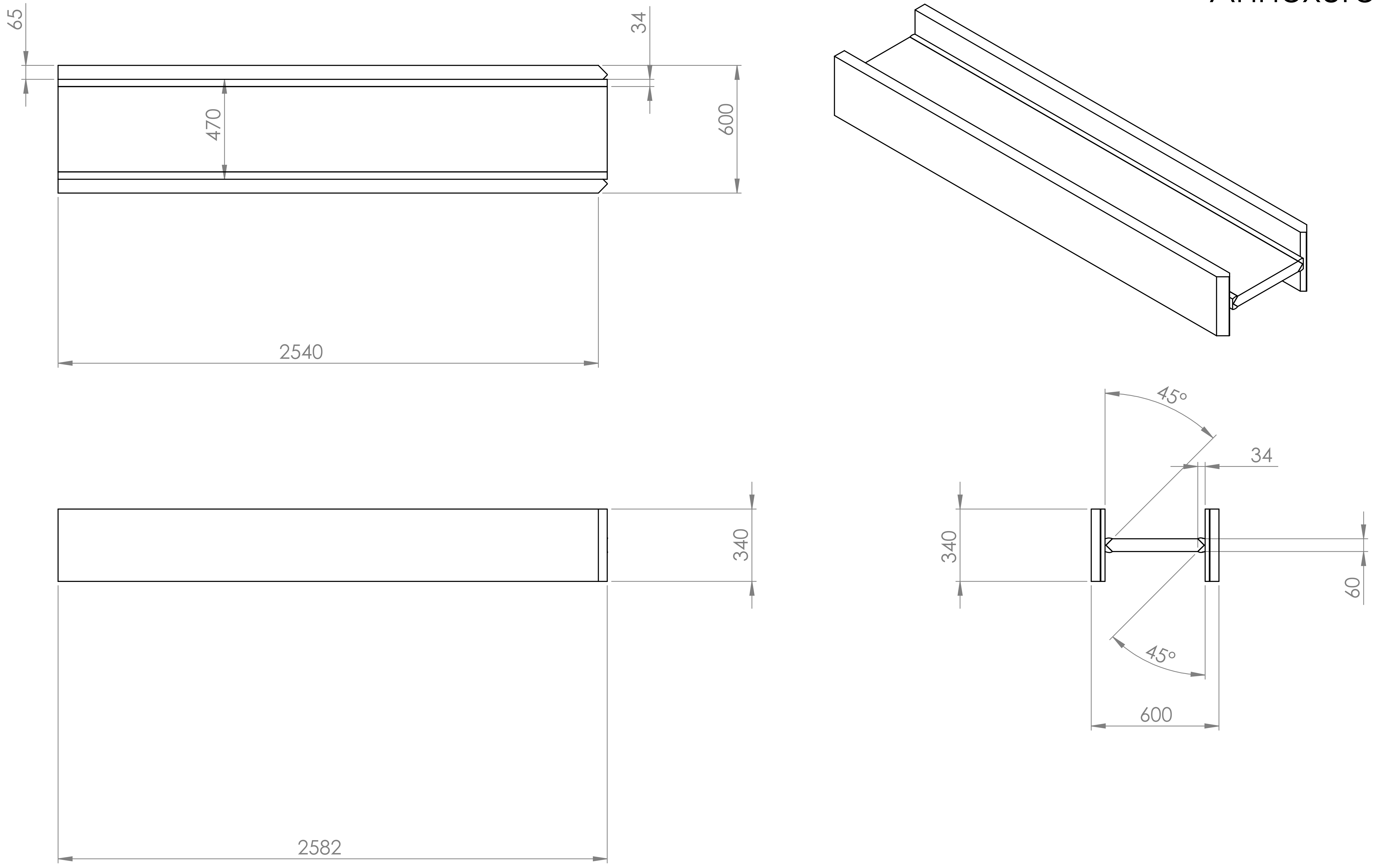
TITLE
DETAIL OF 2ND_TIER_COLUMN
MARKED AS G1-CL1175

Scale	Date	Drawn	Checked	Approved	Rev
1:10 1:15	05.01.2017	SMD	VPK	SHAH	0

Project Code	Drawing No.	Sheet.No.	Sheet
63015180	ECPL-RUPA-FD-G1-CL1175	1 OF 1	A1

RELEASED FOR
☐ PRELIMINARY ☐ TENDER ☐ INFORMATION ☐ APPROVAL ☑ CONSTRUCTION

Annexure 2



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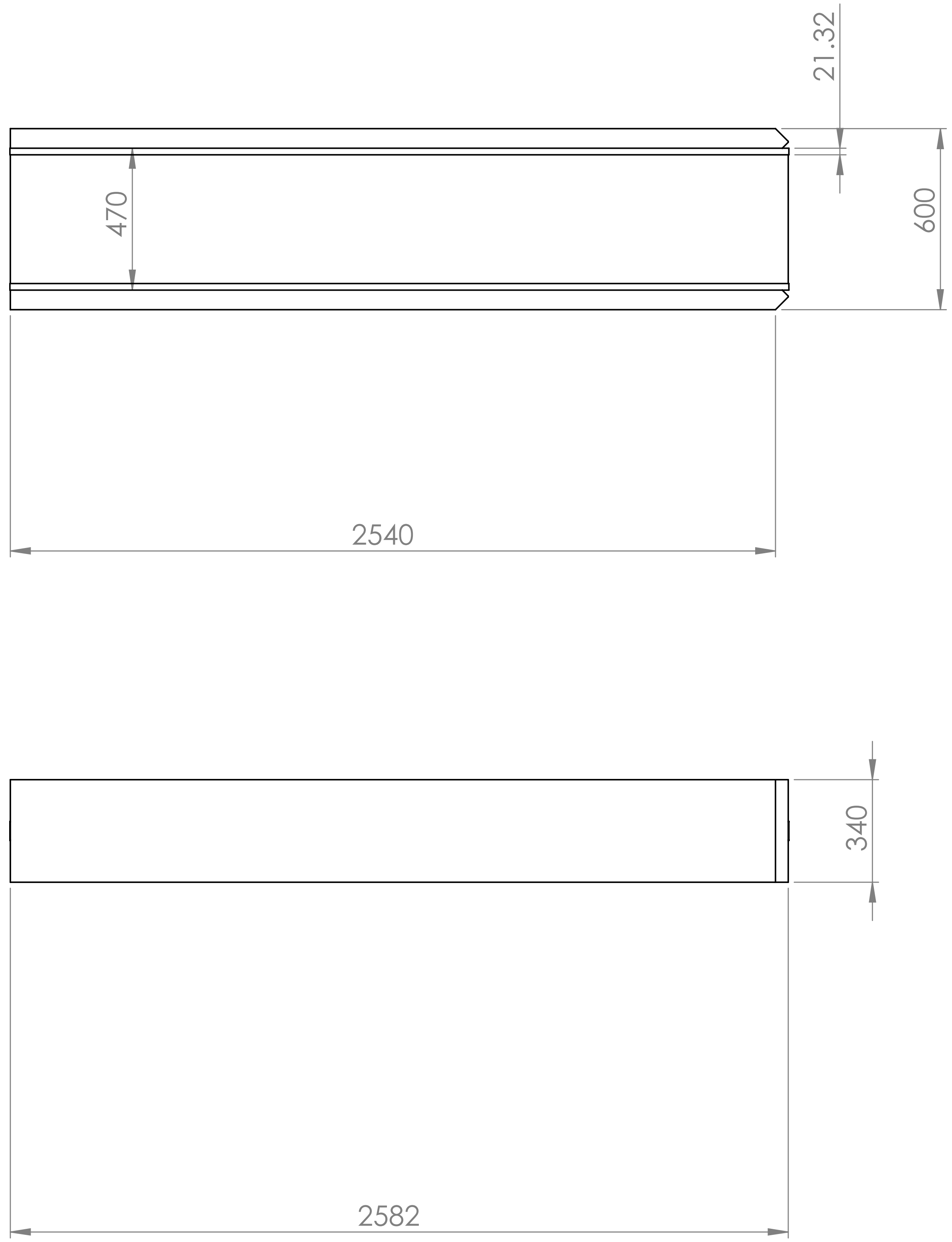
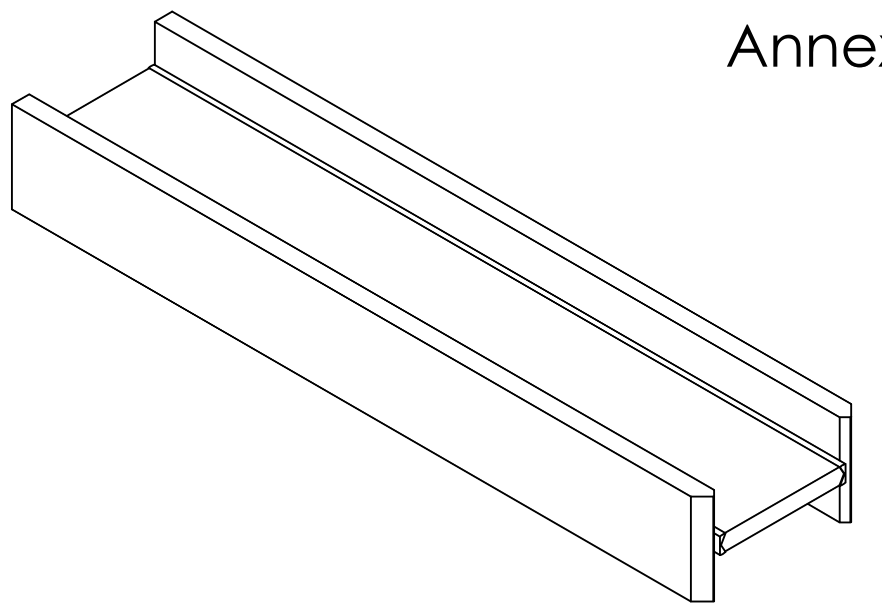
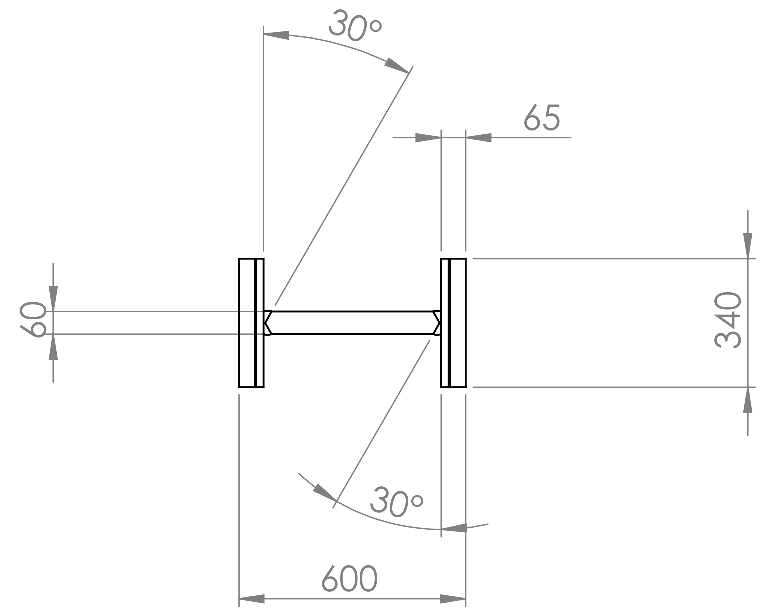
			Annexure 2		
	NAME	SIGNATURE	DATE	TITLE:	
DRAWN				Beam with weld groove 45 degrees	
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: Mild steel	DWG NO. 3	3. Bevel 45	A3
			WEIGHT:	SCALE:1:20	SHEET 1 OF 1

Annexure 3

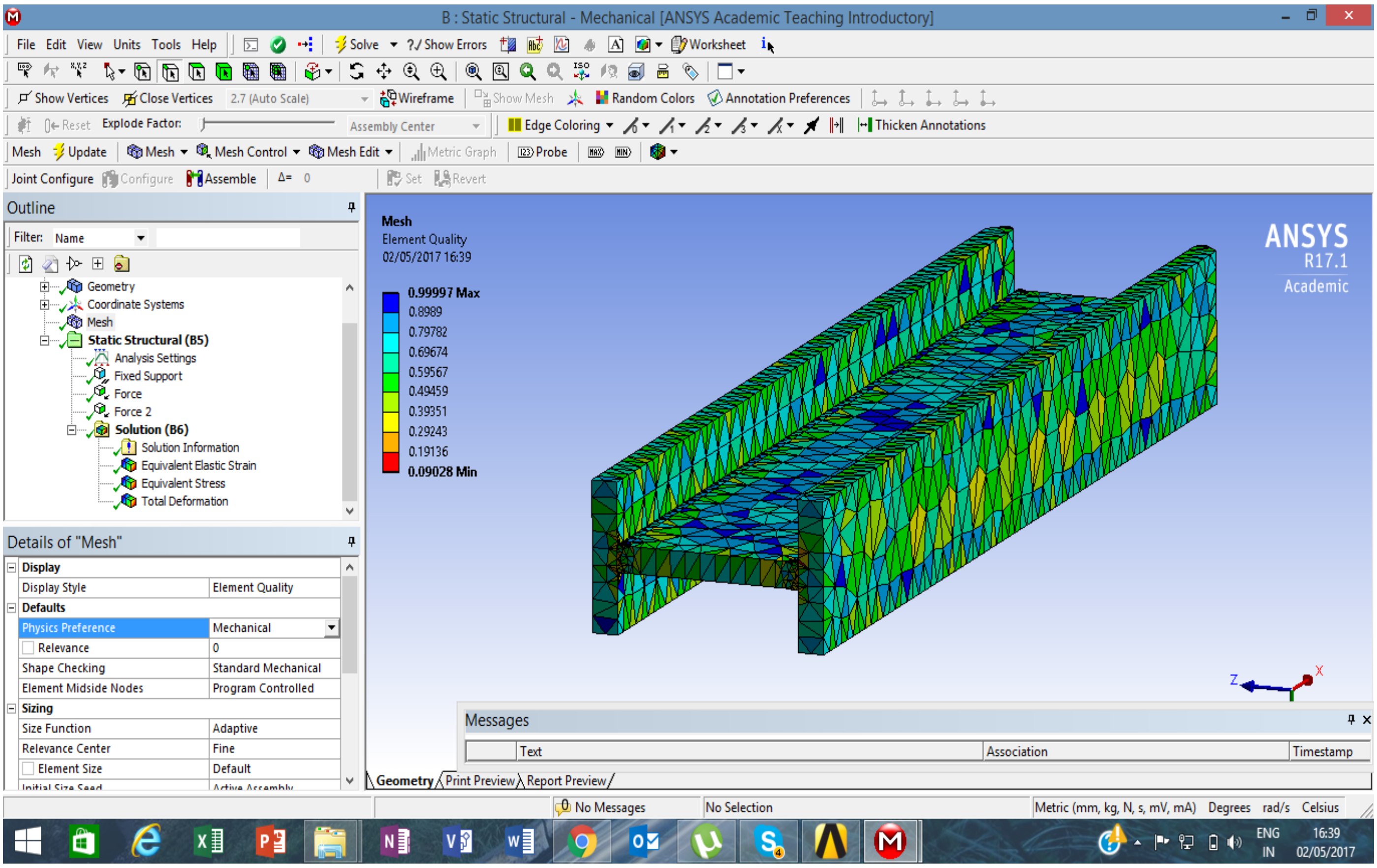


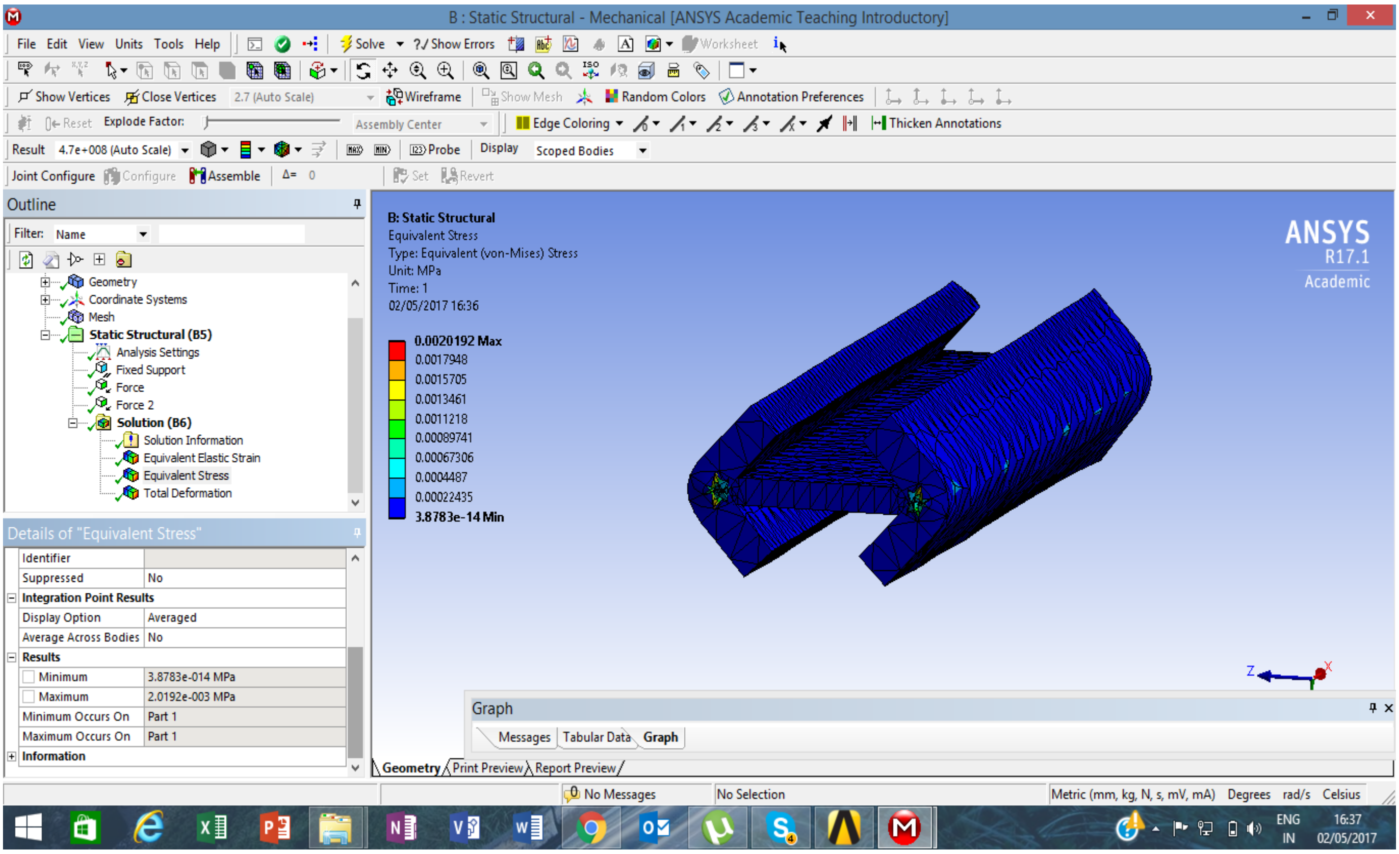




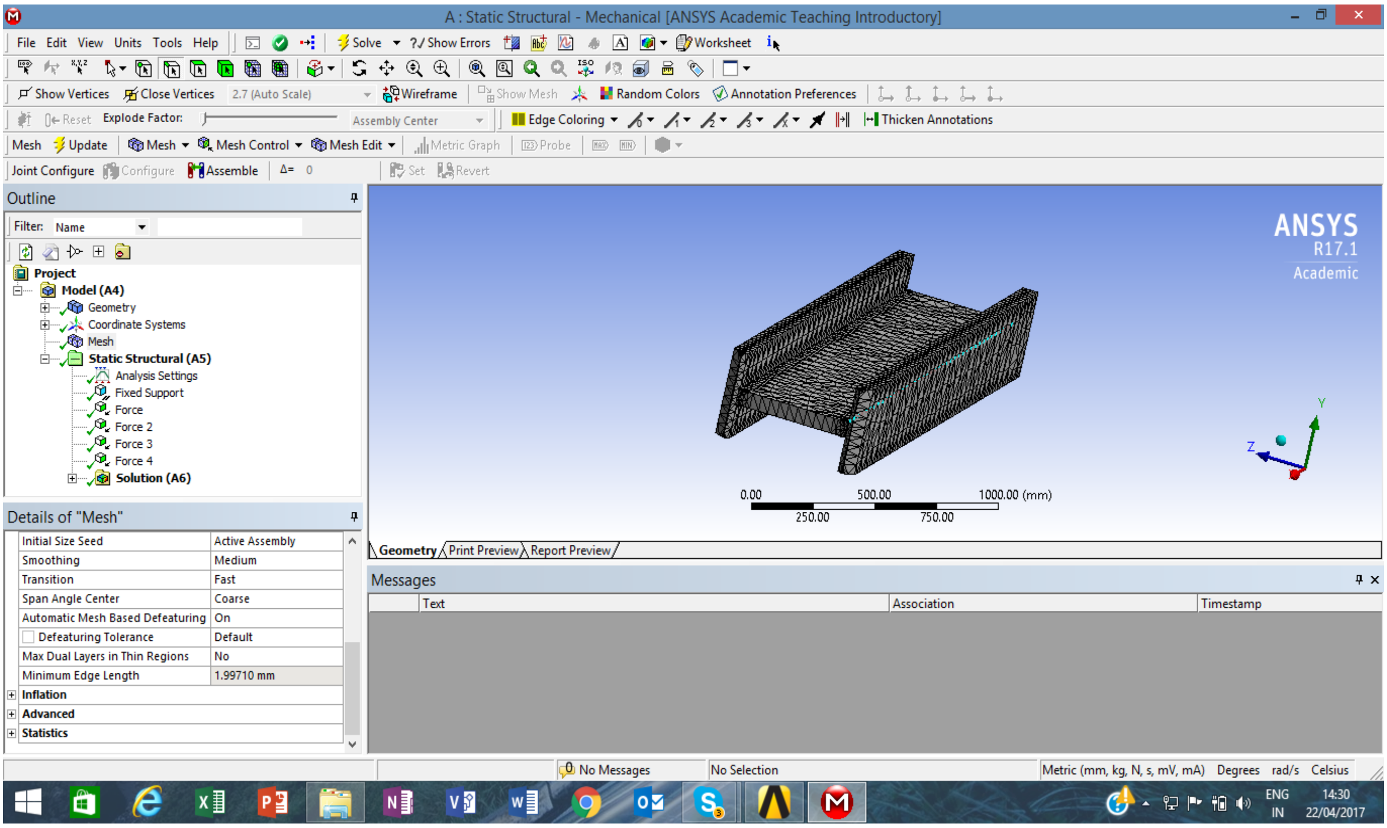
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
					Annexure 3	
	NAME	SIGNATURE	DATE		TITLE:	
DRAWN					Beam with weld groove 30 degree	
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL: Mild steel	DWG NO. 2 — 2. Bevel 30	A3
				WEIGHT:	SCALE:1:20	SHEET 1 OF 1

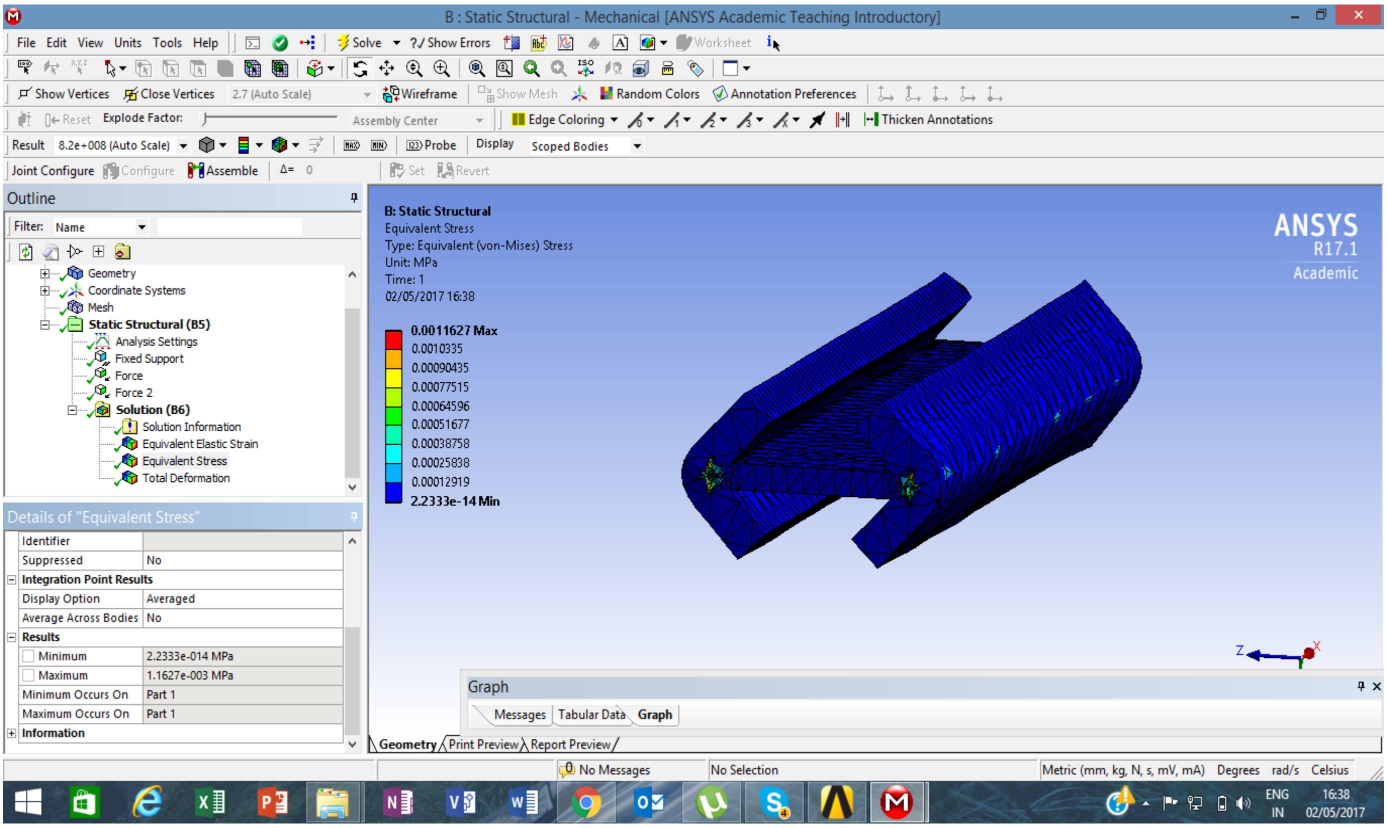
Annexure.4 Stress results for bevel of 45°



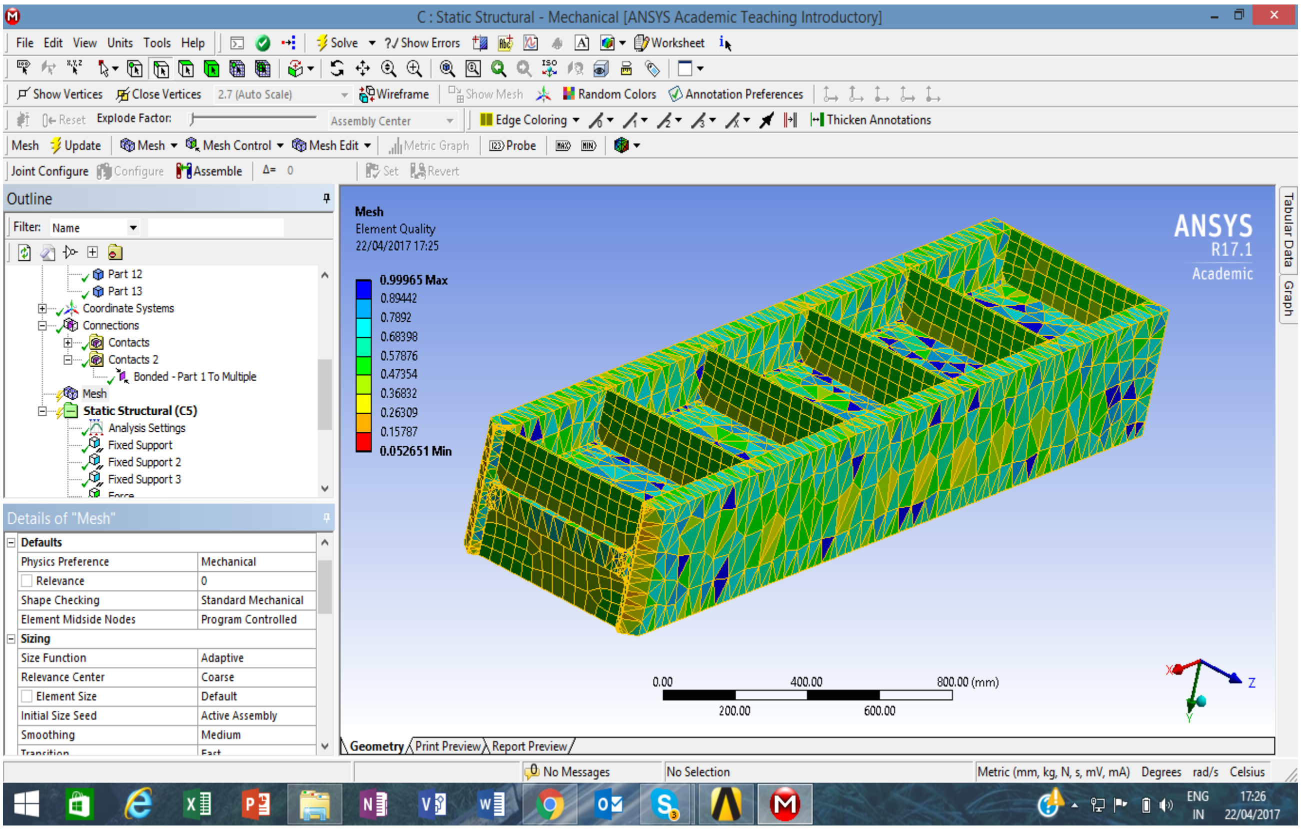


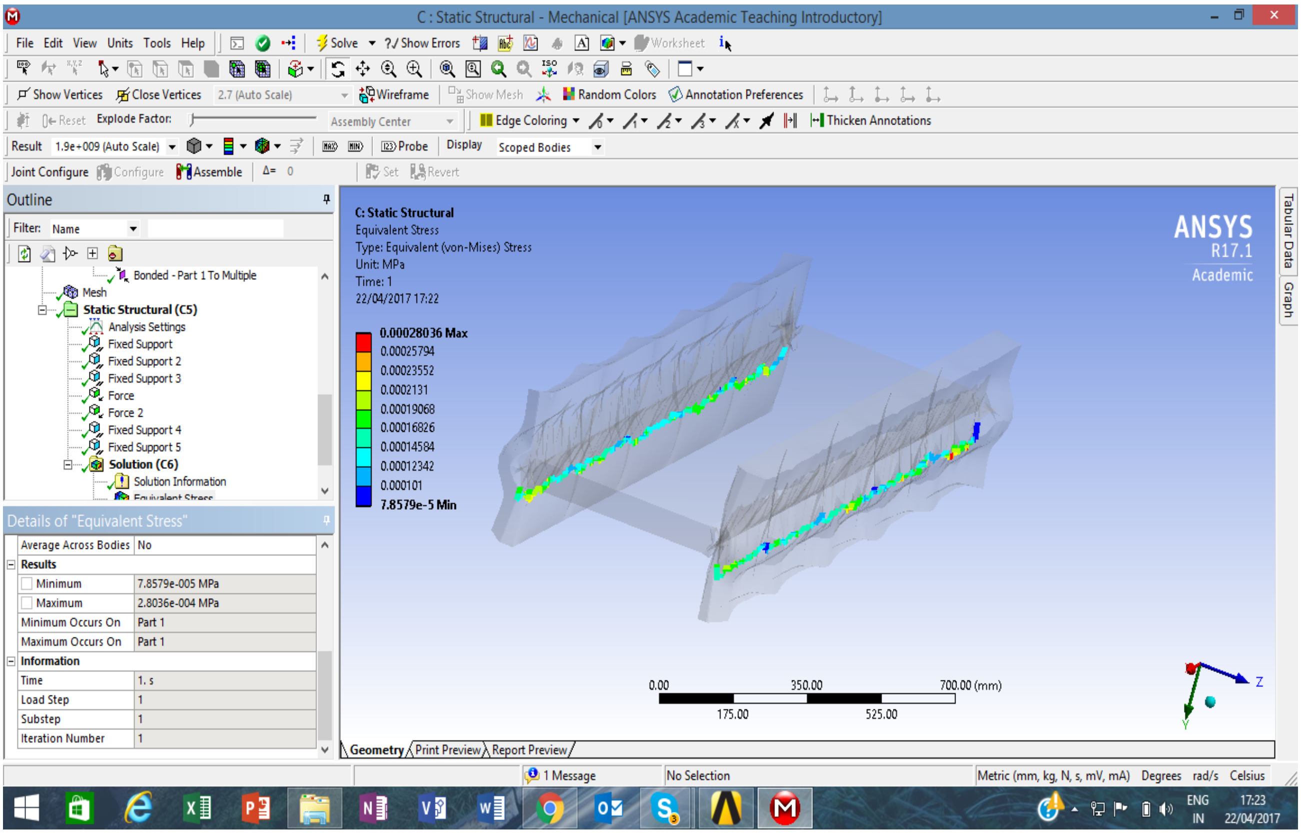
Annexure.5 Stress results for bevel 30°



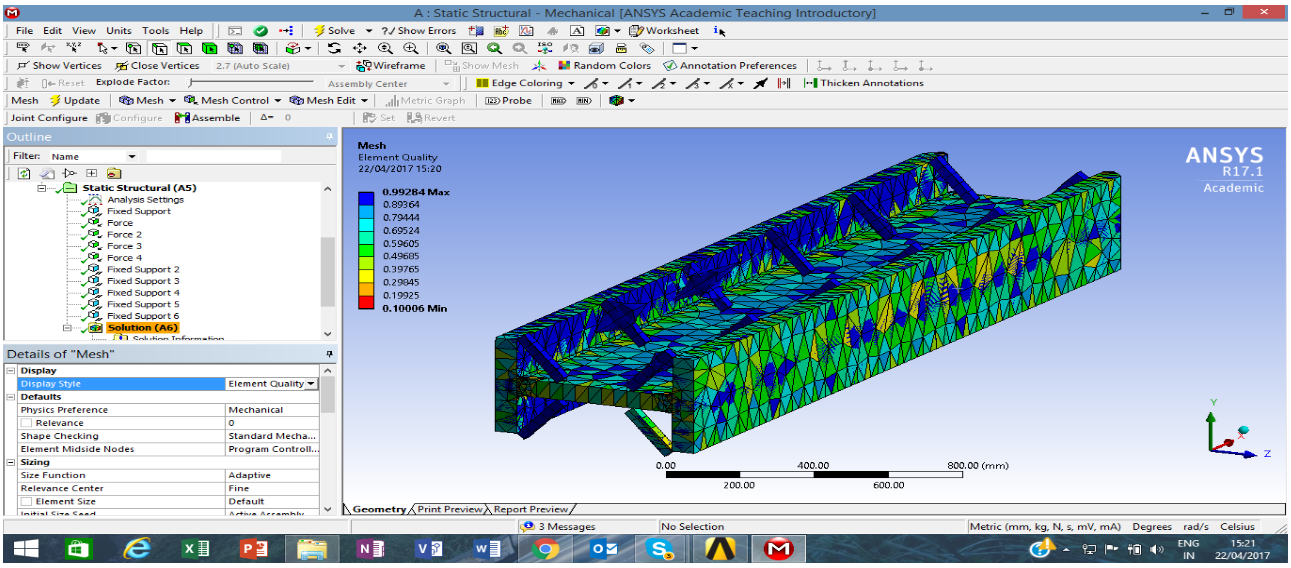


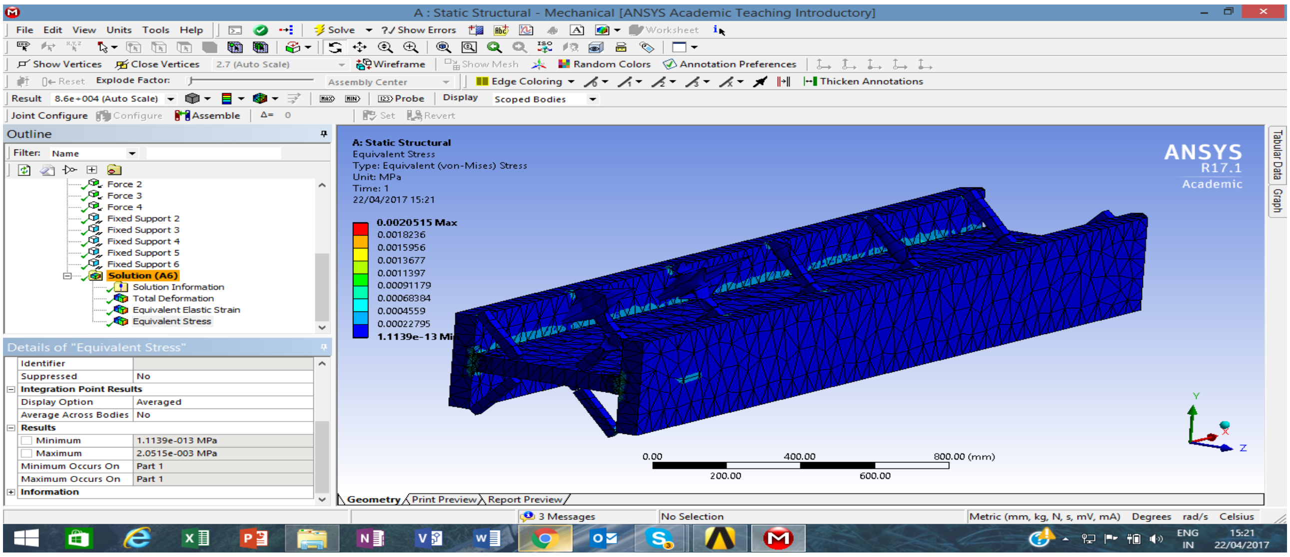
Annexure.6 Stress results for Beam with stiffener plates (Type A)

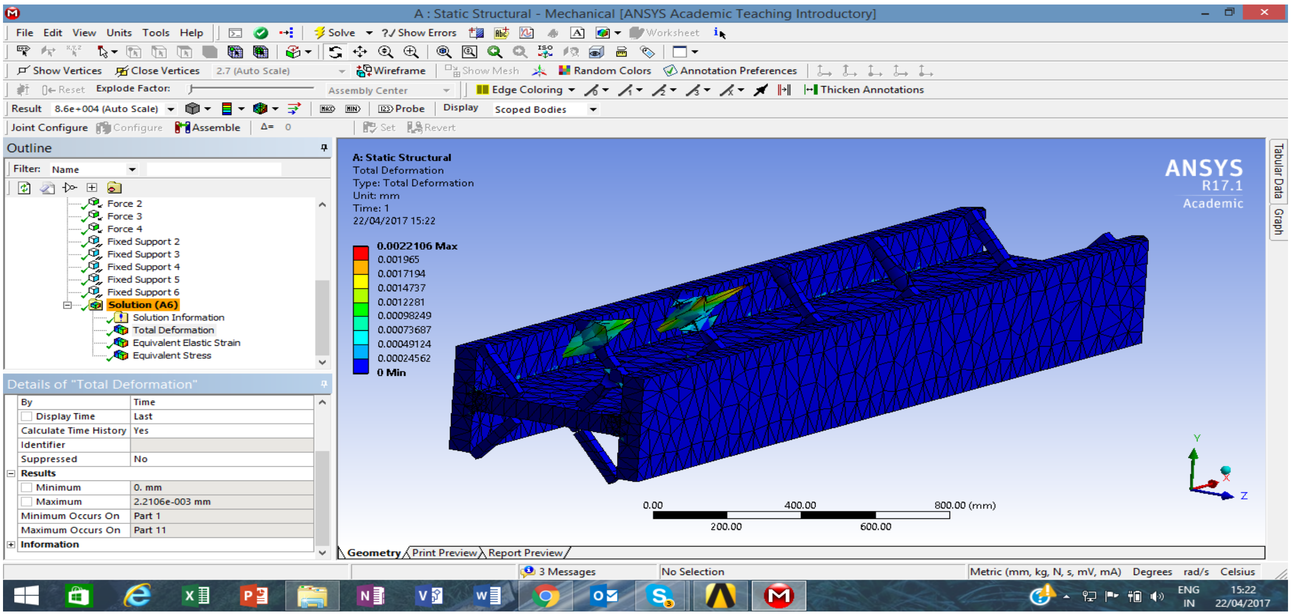




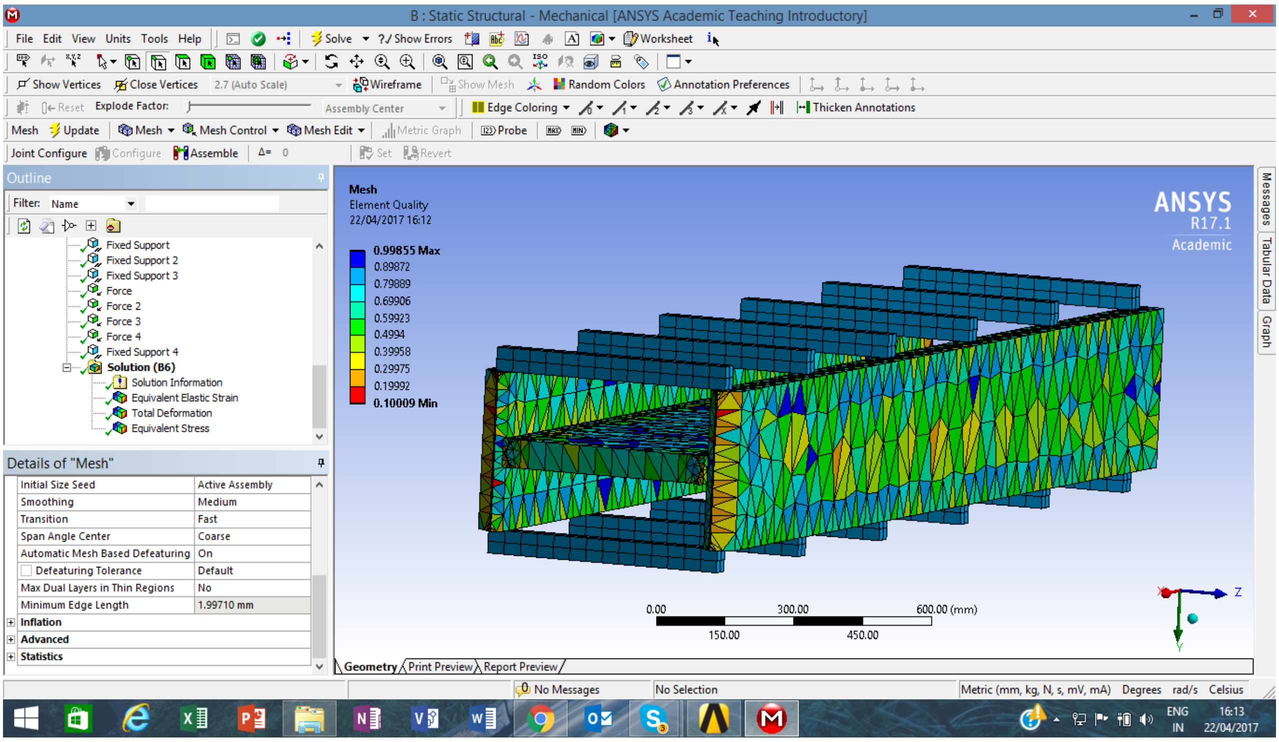
Annexure.7 Stress results for Beam with angular support plates (Type B)

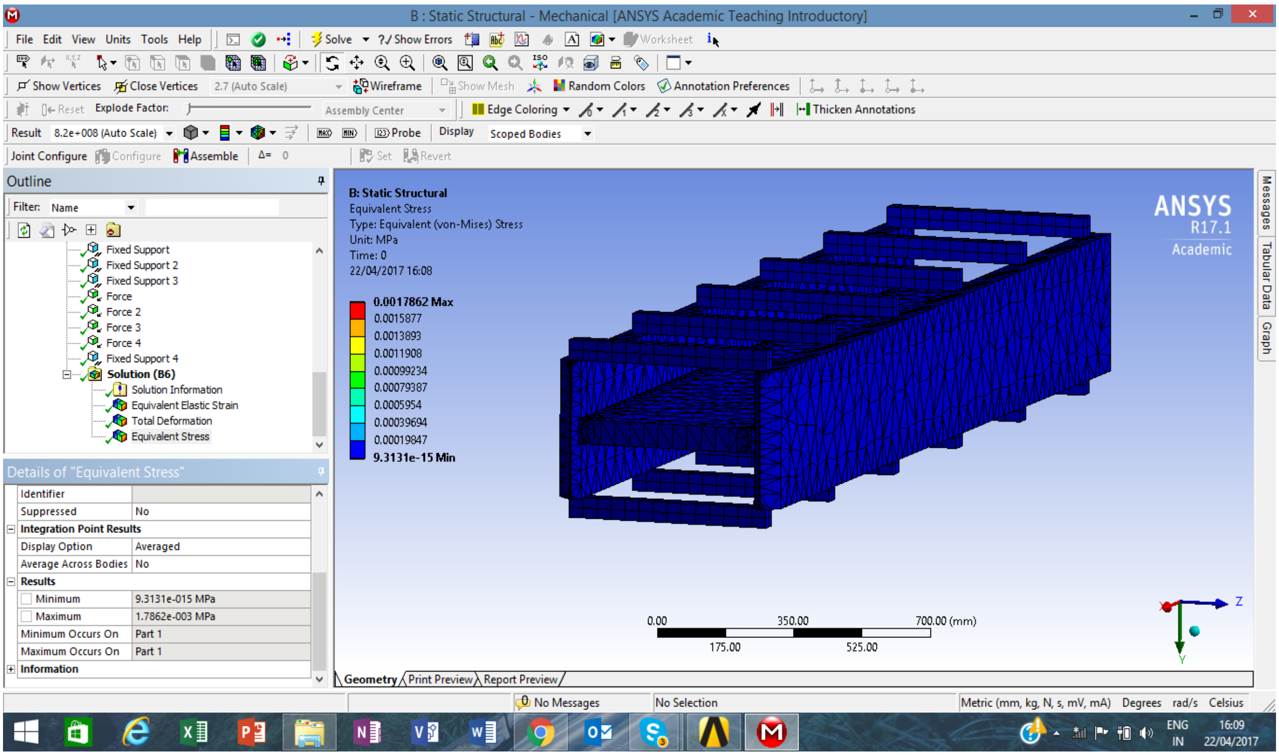






Annexure.8 Stress results for Beam with flange to flange supports (Type C)





Annexure.9 Stress results for Beam with vertical support plates (Type D)