FINITE ELEMENT ANALYSIS OF TRAPEZOIDAL CORRUGATED WEB BEAM TO DETERMINE STRENGTH

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Abstract

In the era of optimization, it is important to optimize the design for weight, cost, strength, stiffness etc. In this regards an attempt is done to increase the stress carrying capacity of I section beam used in structural application. In this research first standard I section beam is selected then by considering same volume criteria corrugated web beam is designed. A corrugated web beam is investigated for its suitability in structural application. In this proposed work, initially the shape of the corrugated beam is defined and the geometric parameters like thickness of web, angle of corrugation are fixed. From literature we found that 30^0 corrugation angle sustain more loads than other corrugation angles. A numerical analysis for the strength is carried out for a regular I section and trapezoidal corrugated I section to ensure the strength. To determine the stability in modal analysis is proposed followed by experimental validation. The proposed work aims at investigating a trapezoidal corrugated I section beam replacing the regular I section to achieve increase in stress carrying capacity.

Index Terms: Trapezoidal Corrugated Beam, Optimization etc.

I. INTRODUCTION

The topic deals in two areas, Strength and modal analysis of both beams. The paper is about design and experimentation of I section and trapezoidal corrugated beam and to study the effect of corrugation on strength of beam. I section beams are widely used in automobile chassis and in construction industry such as bridges, slender structure etc are available in variety of standard sizes. An I beam also known as universal beam, H beam, W beam, Rolled steel joist. The vertical element of the I section is known as web, while the horizontal elements of the I are known as flanges.

Today's mechanical and civil industry are becoming larger and higher, the need of horizontal structure members which are suitable for long spans require high strength but these steel structural member have many flaws, such as less resistance to lateral to bucking, maximum deflection under vertical loading, not able to carry fatigue loading, static and dynamic vibrations. To eliminate these difficulties number of types of corrugated web profiles is designed. Due to Trapezoidal corrugation in web profile these beams have benefits like stability against asymmetrical loads because the shear buckling strength in and Out of plane loading is more than that of I-section beam. Especially for the frames of steel buildings the use of corrugated web beams (mostly sinusoidal corrugation) has been increased very much during the last couple of years. With thin web of 3 or 4 mm thickness, corrugated web beams afford a considerable weight reduction as compared with hot rolled profiles or welded I-sections. Lateral torsional Buckling failure of the web is also prevented because of corrugation. In load carrying application, the web usually takes most of the compressive stress and transmits shear in the beam while the flanges support the major external loads. The web withstands shear forces, while the flanges oppose most of the bending moment taken by the beam. I-shaped section is a very efficient form for both bending and shear loads in the plane of the web. On the other side, the cross-section has a less capacity in the transverse direction, and is also inefficient in carrying torsion, thus, by using more part of the material for the flanges and making web thinner, materials saving could be achieved without reducing the load-carrying capability of the beam[2]. As the compressive stress in the web has increased the critical point before the happening of yielding, during this process web loses its stability and deforms transversely. In order to avoid this failure and make beam more stable the corrugated web beam, an alternative to the plane plane I section web is used, which produces higher stability and strength without additional stiffening and use of more thickness in the web region.

From the literature review, it is found that the stress carrying capacity of corrugated web beam is high as compared with normal plane web also other shapes for webs are also studied like sinusoidal web, triangular web [3]. Some work was also done on corrugation angle of the beam. Strength of beam is tested for number of corrugation angles. 30^0 corrugation angles provide maximum strength than that of other corrugation angles [1]. The study deals with modal and stress analysis of trapezoidal corrugated web beam and I section beam which will be efficient for various application in mechanical and civil industry.

II. ANALYTICAL DESIGN

From bureau of Indian standard I section beam is selected which is ISMB 100 and calculated its various parameters like mass, volume, area these are as follows.

A. Standard dimensions for I section ISMB 100[6]

Depth of beam(D)	Flange width(B)	Flange thickness(t)	Web thickness(T)
100	50	7	4.7

Table 1: Standard dimensions for I section

Length (L) of beam is considered to be 1000 mm. Area, mass, volume are calculated by following equations

- Area = [Dt +2TB]
- Volume= [Dt +2TB]*L
- Mass = [Dt +2TB]*L*Density

Area (mm2)	Volume (mm3)	Mass(Kg/m)
1140	1140000	8.9

Table 2: Area, mass, volume calculated

B. Properties of structural steel

- Density - 0.0078 kg/mm3.
- poisons ratio - 0.26.
- Young's modulus - 200 GPA.
- Modulus of rigidity - 75 GPA.
- Yield strength - 250 MPA.
- Ultimate tensile strength - 400-450 MPA.

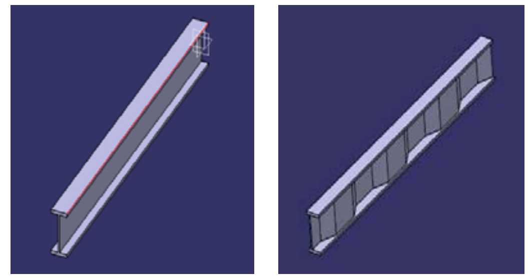


Figure 1: Cad Model of I section & Trapezoidal section

According to these dimensions of I section beam Trapezoidal corrugated web beam is designed by considering equal volume and length of the beam. In trapezoidal corrugated web beam flange dimensions are also same only thickness of web is varied. So only volume of web section is varied and thickness is calculated.

- Volume of I section =Volume of Trapezoidal section
- Front area*actual length of web(I)=Front area*actual length of web(trap)
- t(I)*Height(I)*L(I)=t(trap)*Height(I)*L (trap)

Height is same for both the beam hence eliminating

- t(I)*L(I)=t(trap)*L(trap)
- 4.7*1000=t(trap)*1140
- **t(trap)=4.13mm.**

After finding thickness of web internal dimensions of trapezoidal beam are designed by considering 30 degree corrugation. 30 degree corrugation is considered because it gives best result compared to other corrugation angles.

- d=50mm
- b=100mm
- h=d*tan∝=30mm
- c=2(b+d)=2(100+50)=300mm
- s=2(b+d)/cos 30 =346.41 mm
- a=60 mm

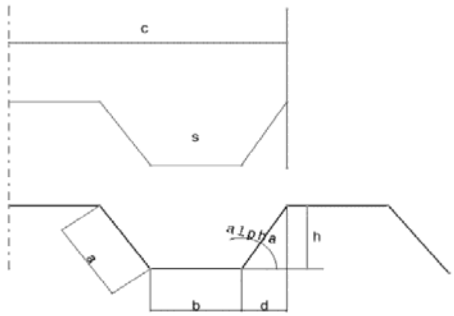


Figure 2: Trapezoidal Beam Internal Design parameters

C. Designed Trapezoidal section Dimensions

Depth of beam(D)	Flange width(B)	Flange thickness(t)	Web thickness(T)
100	50	7	4.14

Table 3: Designed Trapezoidal section Dimensions

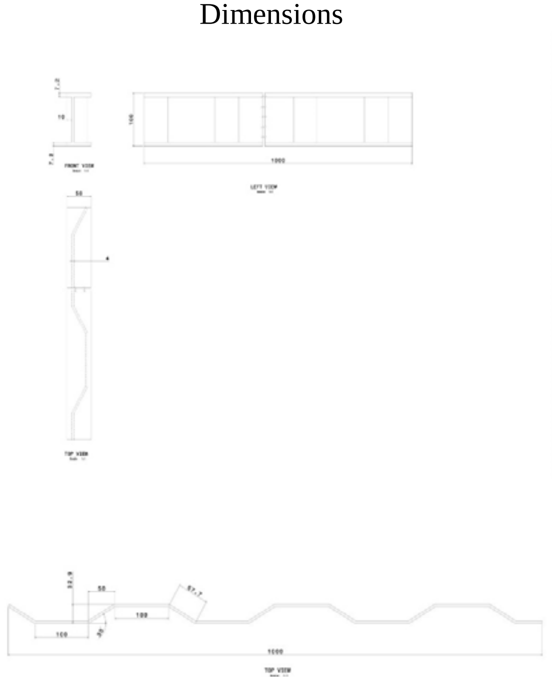


Figure 3: Designed beam Dimensions

NUMERICAL ANALYSIS:

A. Strength Analysis [3]:

The strength of components is a important requirement in gaining knowledge about product's performance, lifecycle and possible modes of failure. Mechanical loading, thermal stress, bolt tension, pressure conditions and rotational acceleration are number of individuals that will show strength requirements for materials and designs. Here we are going to determine which beam is strong for same loading condition.

1. Preference

A static structural analysis gives the deflection, stresses, strains, and forces in structures or elements caused due to loads that do not produce significant inertia and damping effects.

2. Pre-processor

a. Element type- Solid 185 is used for 3-D modelling of solid structures. It is defined by eight nodes having three degrees of freedom at each node.

b. Material Properties

Material properties are entered for structural steel (A36).

c. Modelling

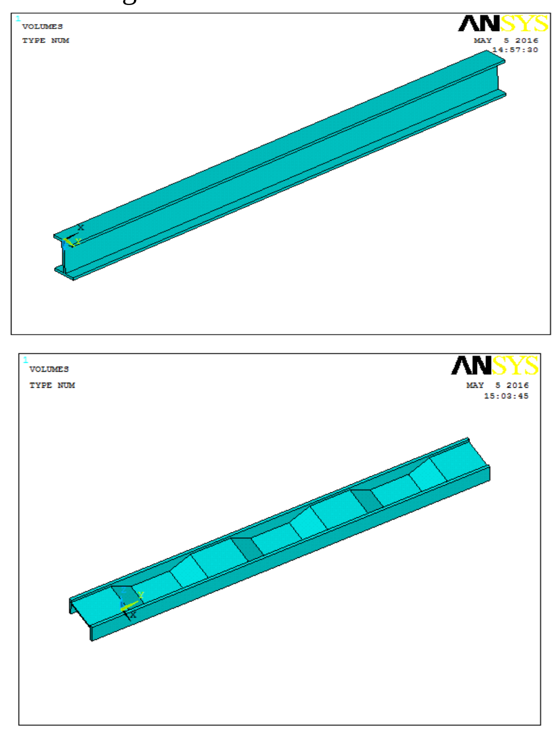
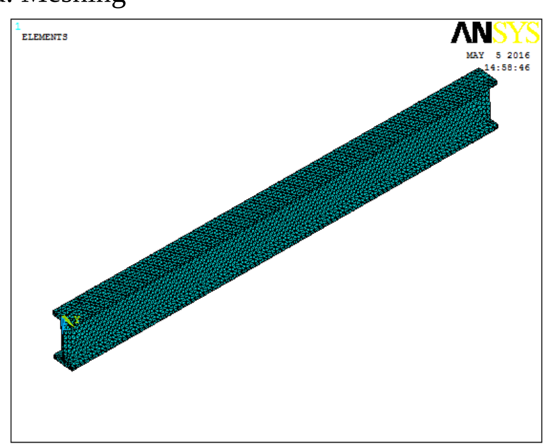


Figure 4: Imported models in ansys

d. Meshing



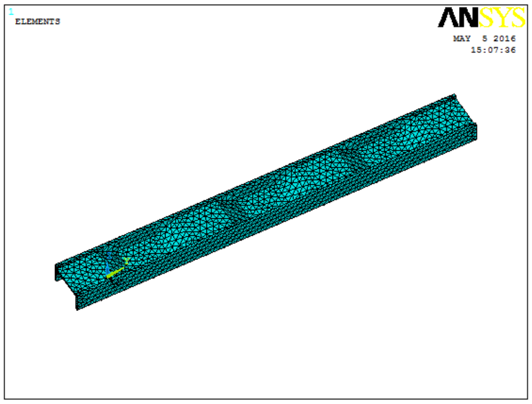


Figure 5: Meshing Models of I section and Trap Section

e. Loads

We can apply most loads either on the solid model (on key-points, lines, and areas) or on the finite element model (on nodes and elements).

Here to avoid singularity load is applied on entire line. for it box option is used. Loads are applied on 1/3 distance from both the ends with simply supported boundary condition.

3. Solution

Solve current LS

4. General Post-Processor

Here result is plotted for both the beams to determine its von misses stress distribution and deflection of beam. According to result the stress developed in I section beam is more than trapezoidal corrugated web beam for same load.

- Stress Analysis applying same load on both beams

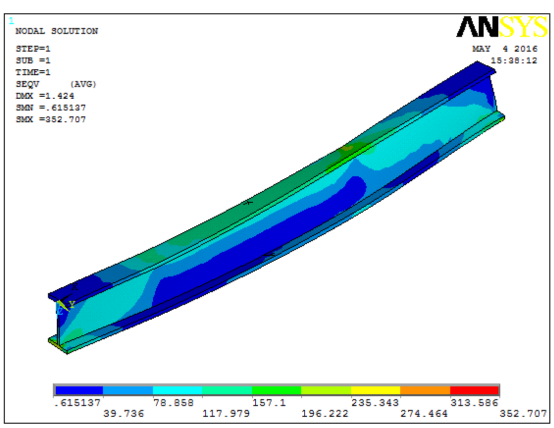


Figure 6: I section Beam Under 15 KN Loading

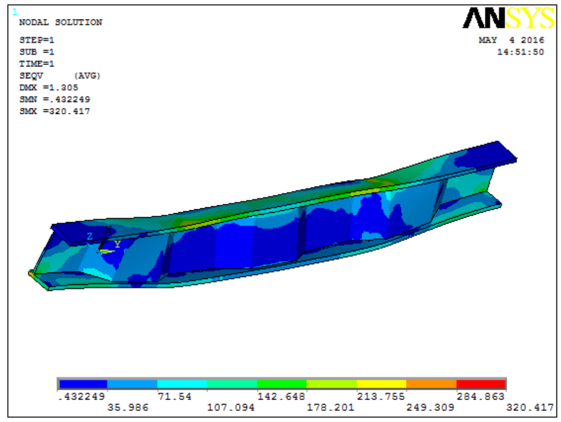


Figure 7: Trap Section Beam Under 15 KN Loading

- Stress analysis of both beam by considering failure

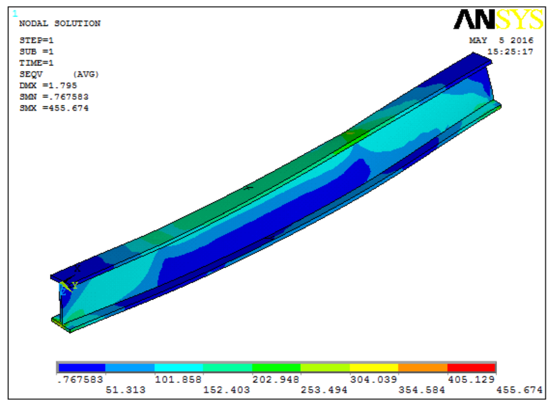


Figure 8: I section Beam Under 20 KN Loading

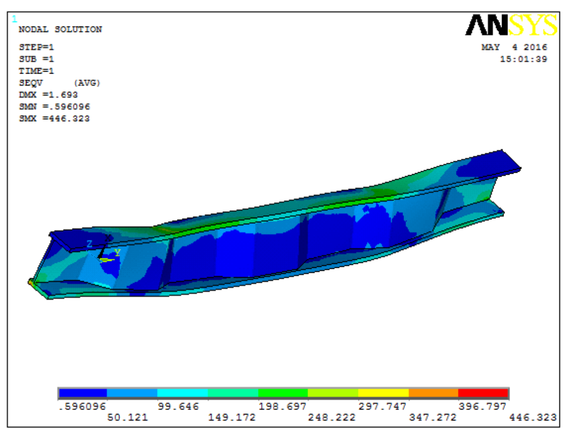


Figure 9: Trap Section Beam Under 22 KN Loading

B. Modal Analysis

Modal analysis is carried out to determine frequency and mode shapes of a given free-free beam using finite element analysis based software ansys. for free-free condition first six generated natural frequencies are not taken.

because of limitation of FEA software it cannot generate accurate result up to first six frequencies.

➢ Mode shapes of I section beam

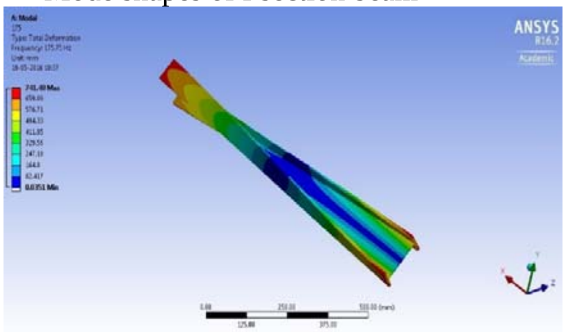


Figure 10: First Mode of I Section Beam

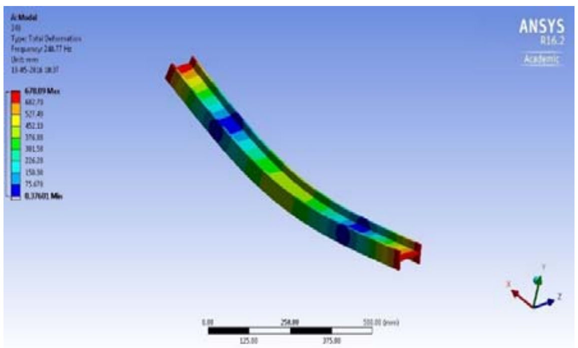


Figure 11: Second Mode of I Section Beam

➢ Mode shapes of trapezoidal corrugated web beam

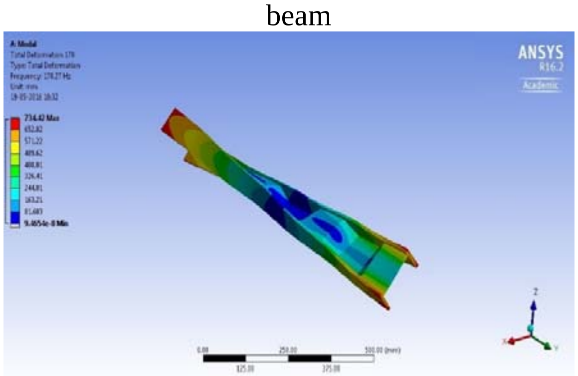


Figure 12: First Mode of trapezoidal corrugated web Beam

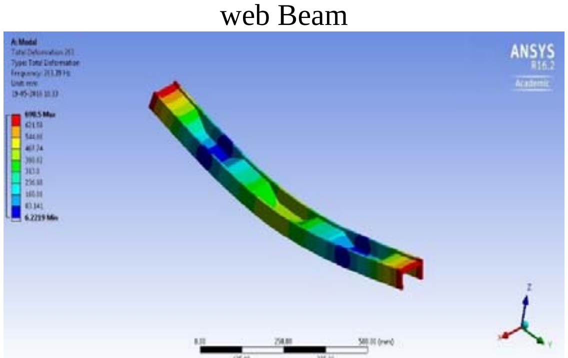


Figure 13: Second Mode of trapezoidal corrugated web Beam

IV. EXPERIMENTAL ANALYSIS

The aim of this experimental procedure is to determine natural frequencies of I section beam and trapezoidal corrugated beam in order to verify the result obtained by numerical process.

Experimental setup-

1. Impact Hammer-Dynapulse impulse hammer (DYTRAN), Model no-5800B4, Sensitivity-10mV/Lbf.
2. Accelerometer- Tri-axial accelorometer, Material-Titanium ASTM Grade 2, Piezoelectric sensor, Temp Range--54^0 to 100^0
3. Multi-channel vibration Analyzer.
4. Test Specimens(Both beam).
5. Computer with loaded software for modal analysis.
6. energy source.

Figure 14: Experimental Setup and Procedure.

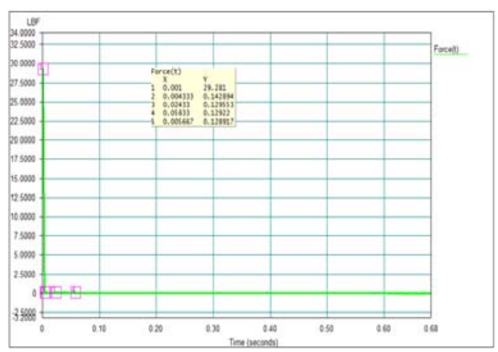


Figure 15: Load Graph for I Section Beam.

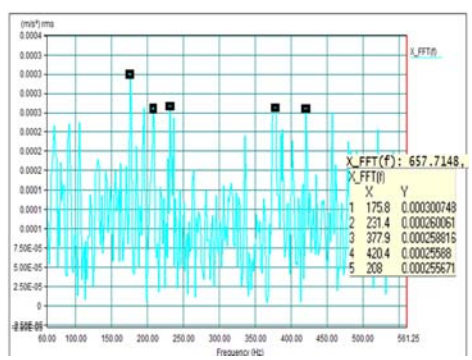


Figure 16: X Directional Waveform for I Section Beam

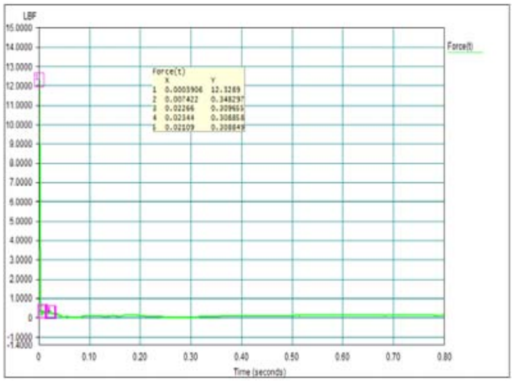


Figure 17: Load Graph for Trapezoidal Corrugated Web Beam

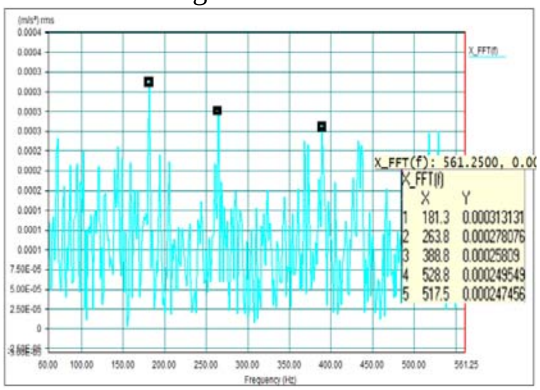


Figure 18: X Directional Waveform for Trapezoidal Corrugated Web Beam.

V. RESULTS

Numerical analysis is performed for the both the beams. Stresses and deflections are calculated and compared below.

Type of Beam	Load (KN)	Max Von misses Stress(MPA)	Deflection (mm)
I section beam	15	196.22	1.425
Trapezoidal section beam	15	178.201	1.205

Table 4: Stress & Deflection Comparison of Both Beams (15KN)

Type of Beam	Load (KN)	Max Von misses Stress(MPA)	Deflection (mm)
I section beam	20	250	1.795
Trapezoidal section beam	22	250	1.692

Table 5: Comparison of Load & Deflection at which Beam Fail

Similarly modal analysis also performed on both the beams and natural frequencies are determined and tabulated below for same with the help of FEA software ansys.

Beam NO	I Section(Hz)	Trapezoidal corrugated Web Beam(Hz)	Increase in Frequency(Hz)
1	175.75	178.27	2.52
2	248.77	263.39	15

Table 6: Comparison of Natural Frequencies of both beam (FEA)

Beam NO	I Section(Hz)	Trapezoidal corrugated Web Beam(Hz)	Increase in Frequency(Hz)
1	175.80	181.3	5.5
2	231.40	263.80	32.4

Table 7: Comparison of Natural Frequencies of both beams Experimental (FFT)

➢ Result Discussion-

In this paper we studied the various properties of beam like its load carrying capacity, modes of failure, natural frequencies. first I section and trapezoidal section beam are tested for same loading condition of 15 KN. Loads are applied at one third distance from both the ends with simply supported condition. here we can see that stress developed in I section beam is 196.22 MPA is more than Trapezoidal section beam which is 178.201 MPA as shown in table 4. as we see deflection is also more in case of I section beam, these two beams are again tested for failure modes. by increasing load with trial and error method we found that both beams fails at 20 KN and 22 KN respectively mentioned in table 5.

Both beams are again tested to determine natural frequencies. we found two natural frequencies by FEA and by experimental procedure also. these frequencies are tabulated in table 6. As we see from result the first natural frequency of both beams are 175.75 Hz and 178.27 Hz respectively, there is increase in frequency in case of trapezoidal corrugated web beam, also there is increase in second natural frequency.

These natural frequencies found out by FEA analysis are validated by experimental procedure and shown in table 7. Experimental values of frequencies are 175.80 Hz and 181.30 Hz are near about similar to FEA results. The small amount error present in the measurement is may be because of environmental condition like speed of air noise etc. Wrong method of using impact hammer also affect the load applied, so this could be the reason of error.

VI. MANUFACTURING OF BEAM

I section beams are generally manufactured by welding the metal plated together but for manufacturing of I section beams there are other methods also available but we manufactured I section beam by welding. For manufacturing simple I section beam plates are cut down in required size and shapes. Flanges and web connected together by electric arc welding process. For trapezoidal corrugated web beam bending of web is required. There are also two methods available for bending. by generating die and block the required shape is formed by hammer but in our case thickness of web is 4 mm and we can’t hammer it manually so bending is done on bending machine, and required shape is generated then web is welded to flanges by electric arc welding process.

Figure 19: Manufactured Beams

VII. CONCLUSION

As we can see from the result tables the load carrying capacity of trapezoidal section is more than I section beam.I I section fails at 20 KN and Trapezoidal section fails at 22 KN. from this result we can say that load carrying capacity of trapezoidal section beam is 10 % more than that of I section beam. Deflection observed is also 16 % less in case of Trapezoidal section beam. Natural frequency of trapezoidal corrugated beam is increased by around 5 % also the stability of beam is also increased. So we can use this beam in excess load carrying application. The trapezoidal beam also has some disadvantages like manufacturing of its shape is very complicated. Because of requirement of bending machine to generate web profiles cost of manufacturing is also more. With mass production we can eliminate cost problem.

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