COMPARATIVE ANALYSIS OF TRUSS BRIDGE BY REPLACING SOLID SECTIONS WITH HOLLOW SECTIONS

A

PROJECT REPORT

Submitted in partial fulfilment of the requirements for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN-173234

HIMACHAL PRADESH, INDIA

May-2019

STUDENTS' DECLARATION

We hereby declare that the work presented in the project report entitled **"Comparative Analysis of Truss Bridge by Replacing Solid Sections with Hollow Sections"** submitted for partial fulfilment of the requirements for the degree of Bachelor's of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of our work carried out under the supervision of **Mr. Kaushal Kumar.** This work has not been submitted elsewhere for the reward of any other degree/diploma. We are fully responsible for the contents of my project report.

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Civil Engineering	Civil Engineering	Civil Engineering

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Comparative Analysis of Truss Bridge by Replacing Solid Sections with Hollow Sections"** in the fulfilment of the partial requirement for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering. **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Divyam Thakur (151633), Ajay Mahajan (151635), Akshay Kumar (151640)** under the supervision of **Mr. Kaushal Kumar** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date: May, 2019

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ACKNOWLEDGEMENT

This report highlights the progress of our work that we have achieved in "comparative analysis of truss bridge by replacing solid sections by hollow sections" till the month of May. The main aim of this project is to compare the bridge with solid sections and bridge with hollow sections with respect to different parameters and check which bridge will perform better in the same loading conditions.

We would like to take an opportunity to extend our heartily gratitude to our project guide **Mr. Kaushal Kumar, Assistant Professor** who has helped us in every situation and has always entertained our doubts no matter how much busy or exhausted he was. We want to thank **Dr. Ashok Kumar Gupta, Professor and H.O.D., Civil Engineering** who helped us in achieving the progress we could not have made without his help. A special thanks to **Mr. Rajesh Kumar Sahu (Lab assistant, Software Lab) and Mr. Pradeep Kumar (Lab assistant, Work Lab)** who provided us with knowledge and equipment that was necessary for the initiation of the project. We would like to thank all the faculty and staff for their constant support and guidance.

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ABSTRACT

Steel Truss Bridges are often used in construction of railway and road bridges. Truss is a rigid structure and transfers the load from a single point to the wider area that's why it is preferred over other types. Bridges comprising solid sections often results in expensive work and difficulty in transporting from one place to other. It has been found that hollow sections have greater radius of gyration that results in greater compressive strength.

During the design of truss bridge, we have to check the effective length and other parameters of the members which don't hinders the properties of the hollow sections that results in buckling. We will first analyse the bridge on ANSYS with solid sections and then replace it with hollow sections and compare the results. If in case hollow sections cannot perform effectively then we will do the partial replacement of the sections that are in compression. According to the study, hollow section will not create problem in tension part.

After the completion of software analysis, we proceed to the modelling part. We compare the solid and hollow sections practically by modelling bridges on a smaller scale.

Keywords: Solid sections; Hollow sections; Radius of gyration; Effective length; ANSYS

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CHAPTER 1

INTRODUCTION

Bridges are one of the important structures that are used to provide a passage or connection for locomotives, pedestrians and for other material carried across in pipes or conveyors where there is an obstruction without blocking passage way or the opening. Bridges are used to pass over any gap such as river, creeks, valleys, streams, canal etc. (natural obstructions) as well as passing over roads or railways (manmade obstructions).

Bridges are classified on different basis. One of the main criteria of classification is based on the type of superstructure i.e., Truss, Girder, Suspension, Arch and Cable stayed. As we are designing the minor span length bridge, therefore we can't use Suspension and cable stayed bridge as they are used in longer span. Moreover, our motive is to include the hollow section in our structure that is not possible in arch bridge as arch bridge is mainly constructed using stone or brick. So, we are selecting the truss bridge for our design and analysis purpose because its convenient to use hollow sections in truss bridges.

Now as we decided to use the truss bridge the material that we can use is steel, aluminium, wood. As steel is very elastic in nature and has higher yielding point so its a best material to be used in truss bridges.

We will compare the truss bridge with solid sections with the truss bridge with hollow sections according to their performance.

This objective will be achieved by two methods-
(i) By comparing the displacement, shear force and bending moment of the different members present in the truss bridges by applying the software ANSYS.
(ii) By making the model of both the bridges and comparing both of them on same parameters.

1.1 ANSYS Workbench[1] :

The ANSYS Workbench is a finite element analysis tool that is used in conjunction with CAD systems and DesignModeler. It is a software environment for performing structural, thermal, and electro analysis. The class focuses on geometry creation and optimization, attaching existing geometry, setting up the finite element model, solving, and reviewing results. The class will describe how to use the code as well as basic finite element simulation concepts and results interpretation.

1.1.1 Task that can be performed in ANSYS workbench software are:

- Importing models from a variety of CAD systems.
- Optimising design using DesignXplorer or DesignXplorer VT.
- Conditioning models for design simulations using the DesignModeler.
- Performing FEA simulations using Simulation.

1.1.2 DesignModeler

DesignModeler is simply a geometry editor for existing Computer Aided Design models. It is a parametric feature – based solid modular and is designed so that one can quickly begin drawing 2D sketches, model the 3D parts, or upload 3D CAD models for engineering analysis pre-processing.

1.1.3 Simulations

Workbench Simulation module can be used to define your model's environmental loading environment, solve the simulations and go over results in diverse format depending on the category of simulation.

1.2 Truss Bridges

1.2.1 History

Steel is said to have been known in China by 200BC and in India by 500BC, its widespread use materialised in the latter half of 19^{th} century after the discovery of Bessemer process in 1856. Steel was 1^{st} used extensively in the Eads Bridge at St. Louis, Missuri, built in 1874 as a steel arch bridge of three spans 153, 158, and 153m. Inspired by the success of this bridge, many fine steel truss bridges were built.

Consequent on the introduction of steel, the earlier truss forms yielded place to more efficient forms such as Pratt, Howe, Warren, Parker, Baltimore, Pennsoilvania truss types. In India, many major bridges were built with steel decks in the late 19^{th} century and early 20^{th} century to carry the railway tracks across the major rivers. Truss Bridges have been used economically in the span range of 100-200m mainly for Railway Bridges.

1.2.2 General

A truss bridge which help its economy from its two main structure advantages:

(a) The main forces in its member are axial forces.

(b) Greater overall depths allowable with its open web constructions lead to reduce self-weight when compared to solid web system.

The assembly of a truss bridge is significantly cut down because of the relative lightness of the constituent members.

1.2.3 Types of truss bridges:

The major type of truss bridges is shown in fig 1.1.

The most commonly used form is the Warren Truss. The Pratt Truss is considered to be advantageous because in this type the longer diagonals are in tension while the verticals that are shorter are in compression.

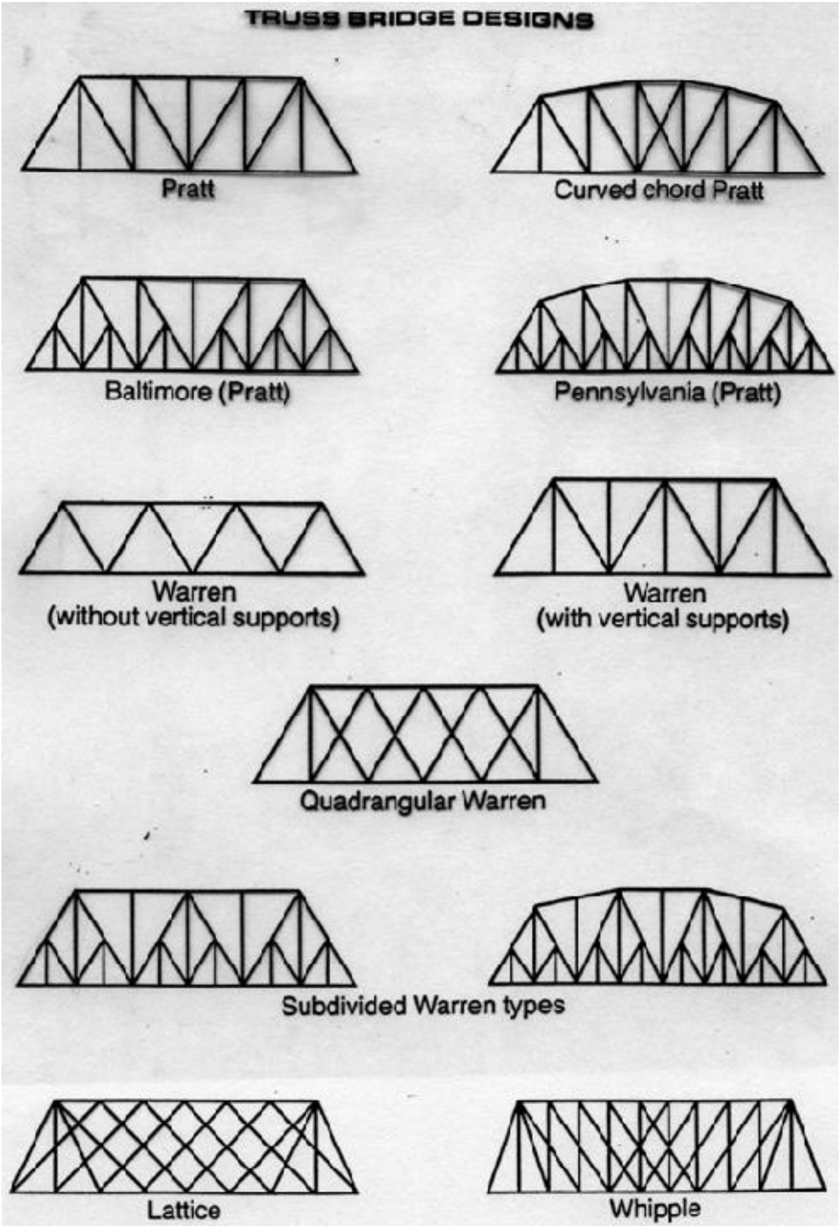


Figure 1.1 Typical Bridge Trusses[2] Source- Victor(2012)

Pratt Truss: This type of truss has diagonal members that slope down towards the centre, this type is completely differing of the Howe truss. The inner diagonals of the truss are having tension whereas compressive force acts upon vertical members. This truss was invented by Caleb Pratt and Thomas Pratt in 1844. This type is practical for spans up to 75 metres .

Baltimore Truss: This is a subclass of Pratt Truss. This type of truss is having an additional bracing in its lower sections. This bracing prevents buckling in the compression members and controls the deflection. This design is simple but very strong and is used for the bridges which takes high load like Railway Bridges.

Pennsylvania Truss: This is variation of the Pratt Truss. It adds to the design struts of half length or ties in bottom, top, or in both the parts of panels. Its name is kept after the Railroad of Pennsylvania. It was used majorly but fell out its favour in 1930.

Warren Truss: it was patented by James Warren in 1848. It consists of longitudinal members joined by Cross members that are angled. Its forms alternatively inverted equilateral triangles ensures that no strut, tie or beam is subjected to bending or torsion strain nature forces.

Whipple Truss: It got its name after the inventor Squire Whipple. It is usually considered Pratt Truss's subclass because of the fact that diagonal members work in tension. Its main characteristic is that its tension members are long, thin, and at a shallow angle and can cross two or more bays.

Lattice Truss: This type of truss in bridges use a large number of elements of light weight which ultimately eases the construction process.

Some of the panels towards the middle may be provided with counters if there is possibility of reversal of stress in the diagonals. The diagonals of the Pratt Truss slope downwards towards the centre, whereas the diagonal of the Warren Truss alternate between downward towards the centre and downward away from the centre.

The various components of a typical through truss highway are indicated in fig

These components are:

(a) Flooring

(b) Stringers

(c) Floor Beams

(d) Two main Trusses

(e) Lateral bracing provided at the top and bottom chord levels to cater the horizontal transverse loads
(f) Sway Frames

1.2.4 Components of Truss Bridge

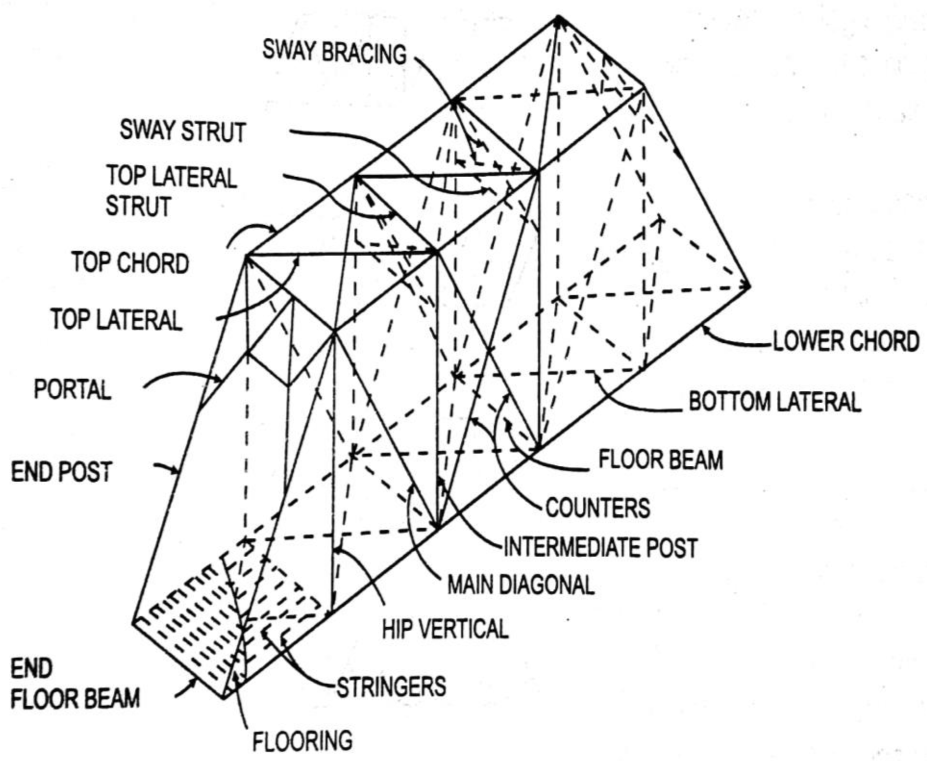


Figure 1.2 Components of a Truss Bridge[2] Source- Victor(2012)

1. Top chords:

These members are either inclined or horizontal that establish upper edge of a truss. These are the members that are highly stressed in compression and bending stresses. These members need a special attention while proportioning and detailing.

2. Bottom chords:

These are horizontal and inclined (only in case of scissor trusses) defining bottom edge of truss which is used to carry ceiling loads where applicable. These are the members that are extremely stressed in tension. The members may be joined by means of bolting, riveting or welding.

3. Web members.

These are members that could be vertical or diagonals comprising of tension or compression depending on the truss type. Vertical members in compression are known as "post" and those are in tension are known as "hangers"

4. End posts or rakers:

The members placed towards the end of the truss that carry the lateral forces from top chord level to the bridge bearings.

5. Cross bracing or Sway bracing:

These bracings are providing for dispense the sloping loads to the lateral system. This also provides the torsion rigidity to frame structure.

6. Portal bracings :

These are situated at the finish posts. These bracings serve the corner supports to the top lateral bracing system.

7. Lateral bracing:

This bracing is located between the top and bottom chords of a pair of trusses.

1.2.4 Design

Practically all triangulated trusses are designed on the assumption that the members are subjected to axial forces only. This assumption is valid when no transverse loads are applied away from the nodal points and when no moments are transmitted at the joints. These direct stresses are called primary stresses, whereas the Bending stresses are called by secondary stresses.

Secondary stresses are caused by:

(a) Eccentricity in connections;
(b) Torsional Moments due to floor beams;
(c) Transverse Loads;
(d) Rigidity of joints and Truss distortion

The main decisions needed in the design of the main trusses of the truss bridge are:

(a) Truss type;
(b) Truss Depth;
(c) Length of Deck Panel;

The type of truss can normally be decided from convenience of detailing and on grounds of aesthetics.

1.3ADVANTAGES OF HOLLOW STEEL SECTIONS

(1) HSS has higher strength to weight ratio which means there is less use of steel and will be less cost optimisation due to reduction in weight.
(2) This section is very useful in compression and support characteristics of structural elements.
(3) Due to its torsional strength, HSS suited good for the bracing members in structure.
(4) The torsional constant of HSS is 200 times greater than that of an open section.
(5) The internal void present in hollow section can be used in different way. For e.g, void filled with concrete help in gaining the strength in compression.
(6) Hollow sections are helpful in fire protection as water circulation could be done through internal void of section which helps in keeping the temperature of the steel low.
(7) During transmitting same torque, hollow sections undergo a smaller amount of shear stress than that of solid one.

1.4 ADVANTAGES OF ANGLE SECTIONS:

(1) Affordable

It’s a strong, light weighted section compared to the other steel section or other composite material section which is relatively affordable in terms of strength and durability as compared to others. It can be used in the low cost project and can be effective in smaller projects without exceeding their budget.

(2) Versatile

It's a versatile in nature, as it can be used for small (light weight) as well as for heavy high structural elements. I can act as a rafter in roof truss and as a bracing or frame in heavier structural members.

(3) Easy to work with

Angle section is easy to handle which makes it simple to work in structural elements. It's simple to do bolting and riveting in angle sections. For high strength joint, one may use welding but needed a little bit experience.

(4) Strong

As there is 90 degree bend in angle section, this makes it extremely strong along its length which ultimately helps in resisting the bending.

(5) Little maintenance

Angle sections structural elements require a little maintenance as it is sealed or coated by corrosion resistance material as soon as work is completed. Due to this there is very little maintenance involved in the structure.

(6) Size and Easy to find

Angle sections are easily available in market with different sizes having both equal and unequal legs as per the requirement of the structure.

1.5 Problem Statement

Most of steel structures mainly truss bridges are builded up with conventional sections of steels which are designed and constructed by conventional methods. This leads to heavy or uneconomical structures. Hollow steel sections are the best replacement to the conventional ones with their useful and comparatively better properties. It is obvious that due to the profile of the hollow section, dead weight is likely to be reduced for many structural members which ultimately derives overall economy.

To determine the effectiveness of tubular sections a Pratt Truss bridge is considered. Analysis and design is carried out using angular steel connections and hollow tubular steel sections.

1.6 Significance of Study

Truss bridges are one of the strongest of all the bridge type because these consists of triangles and triangles are the strongest shape because any added force is evenly spread through all the sides. The strength and overall convenience of truss bridges make them most widely used. Usage of solid steel sections leads to heavy bridges and are uneconomical. Enhancing the bridge design by replacing solid sections with hollow sections can reduce the weight of overall structure while keeping the performance similar.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The section presents an overview of existing studies on the design, analysis and behaviour of steel truss bridge. It includes procedures, guidelines and trends regarding steel truss bridges from various researchers along with experiment and other studies completed recently and are available in public domain.

2.2 Previous Studies

Bakht and Jaeger (1987)[3] :

In the paper "Behaviour and evaluation of pin-connected steel truss bridges" it is concluded that tension chords were not taking equal load because of not participating equally by truss members. This type of bridges is out of trend because reserve strength may be less than that calculated analytically and tension chords do not participate fully in sustaining loads because of possible lack of fit.

Lee (1995)[4] :

In the paper "FATIGUE FAILURE OF WELDED VERTICAL MEMBERS OF A STEEL TRUSS BRIDGE" it is concluded that while analysing the welds it was found the penetration of the welds was not adequate. S-N curves also recommended that structure would not have unsuccessful if welds were penetrated to full depth.

Chiewanichakorn et al (2006)[5] :

In the paper "Dynamic and fatigue response of a truss bridge with fibre reinforced polymer deck" it is concluded that for structural health monitoring analytical approach was performed which uses the strain history data and continuum damage fatigue model. Between FRP deck and floor beams interface elements were introduced because composite achievement was not developed between steel floor and deck.

Minhui Tong et al (2011)[6] :

In the paper "Structural Stability Analysis for Truss Bridge" it is concluded that the whole shakiness appear earlier than local shakiness LRB can reduce the truss bridge's steadiness, but truss bridge has good stability all the same; truss bridge's structure safety is primarily controlled by stiffness index.

Zhongshan and Liu (2011)[7] :

In the paper "Crack Research for Welded Joint of Steel Truss Bridge" it is concluded that the fatigue cracks due to the long term dynamic loading. Factor of intensity is the major term that is pointed out. Modelling method is based on the idea of breakup the whole structure into the parts. By Boolean operation value of stress intensity factor (SIF) which carried that directly relates to the fatigue life estimation.

A. Bouchair et al (2012)[8] :

In the paper "Connection in Steel – Concrete Composite Truss" it is concluded that Shear Connectors are useful to overcome relative slip. Shear connectors - distribution of shear forces and concrete - resistance to connectors. As a whole this composition helps in reducing the deflection up to 50%.

Shivraj and Upase (2015)[9] :

In this paper analysis is carried out by using the software SAP-2000. This journal concluded that the designed plate girder bridge is very stable in Bending moment, Shear Force and deflection which makes this bridge as one of the most economical in terms of construction as well as cost. This dissertation work gives basic principles for portioning of plate girder to help designer.

Bačinskas et al (2016)[10] :

In the paper "Structural Analysis of GFRP Truss Bridge Model" it is concluded that GFRP applied to deck of bridge. As a whole this results in high structural stiffness by governing the deflection that is subjected to static loading.

P. Madhu et al (2017)[11] :

In this paper, analysis and design of Steel truss bridge is carried out using the StaadPro software. This journal concluded that the use of IS codes and IRC6 is not sufficient for the calculation of design loads in case of oil/water pipelines support systems. To get the most accurate design criteria, one has to depend upon the Petrochemical Industry standards.

Kalyanshetti and Mirajkar[12] :

In this paper "Comparison between Conventional Steel Structures and Tubular Steel Structures". An industrial shed is considered. Its design and analysis was carried out using conventional steel sections and tubular steel sections. In tubular sections circular, rectangular and square shapes are considered. Cost comparison was made for all the sections. Software used was STAAD-PRO. Different load combinations were applied and it is concluded that using tubular sections can save about 50-60% cost. From rectangular, circular and square shapes due to the difficulties of connection in circular tube sections it is recommended to adopt square and rectangular section.

2.3 Summary of literature review:

It was concluded that there is very less research done on our topic. Generally hollow truss members are used in the roof trusses and a decent research is done on this topic (as mentioned in the above paper). We came to a conclusion that in the bridges hollow sections can be used because these sections perform better in compression because the radius of gyration is more in hollow sections and we can reduce the cost of the bridge. However we cannot use this concept in bridges with long span because buckling effect in the hollow section exceeds the strength of the members, but it should not pose any problem in the small or medium span lengths. Moreover the hollow sections provide a protection against corrosion. Hollow sections also provide protection to supply pipes and wires. The overall dead load on bridge will also reduce considerably. Therefore not only we reduce the cost and increase the strength of the bridge but also get other benefits of hollow sections over solid sections.

2.4 Objectives of the Study

(1) Comparative analysis of the truss bridge having different sections (solid and hollow) for different loading in ANSYS Workbench.

(2) Structural modifications (if required) in the critical parts (joints mainly to avoid failure).

(3) Modelling of bridge and validating ANSYS result.

CHAPTER-3

METHODOLOGY

3.1 General:

A bridge is used to carry railway, road or other service over the obstacles that come in way like valley, river, or carrying one road or railway line on each other, these obstacles may have no intermediate support or very limited supports at locations that are convenient.

Bridges can range in size from short spans we can say a bridge over a small river to the extreme span length like suspension bridges which crosses very wide estuaries. Appearance in bridges is usually not much crucial for small bridges but designers consider appearance as a basic element. The use of steel in bridge construction can help to make bridges that are aesthetically pleasing.

Structural steel has a main advantage over other materials of construction because of its strength and ductility. Also it is having high strength to cost ratio in tension but when it comes to compression strength to cost ration is low if we compare it to concrete.

3.2 Bridge Classification:

There can be several ways of classification of bridges which depends up on the classification objective. Few classifications are discussed below:

3.2.1 Classification on the basis of Material:

i. Concrete Bridges: Most common material used in Bridge construction is concrete. In this case bridges are constructed using reinforced concrete or prestressed concrete.

ii. Wooden Bridges: These bridges have relatively short spans and mainly used to carry pedestrian traffic. As its name suggests structure is made up of wood.

iii. Steel Bridges: Steels as a primary material in different parts of bridge is used like in decks, trusses, arches and suspension cables.

3.2.2 Classification by Function:

i. Pedestrian Bridges: Simply carry pedestrian traffic over the obstacle.
ii. Combined Bridges: When a bridges carries both vehicles and trains we call them combined bridges. There may be two decks one over the other or rails fitted besides carriage way.
iii. Railway Bridges: These Bridges Carry trains that are why called Railway Bridges.
iv. Highway Bridges: These Bridges are called highway bridges because it carries vehicle traffic like cars, trucks, trailers, tanks etc.

3.2.3 Classification by Structural System:

i. Box-Girder Bridges: This type of Bridges has main girder that consists multiple or single box beams fabricated from steel plates.
ii. Beam or I-Girder Bridges: In this type of bridge the main girder consists of either rolled plate girders or I-shapes.
iii. T-beam Bridges: Reinforced Concrete Beams are placed side by side that supports the live loads.
iv. Truss Bridges:. The members of truss bridges are arranged in a continuous pattern which is base on the structural rigidity of triangles.
v. Orthotropic deck Bridges: In this Bridge the deck consists rib stiffeners and steel deck plate.
vi. Cable-Stayed Bridges: In these bridges the main girders of the bridge are supported by high strength steel cables from towers the number of towers can be one or more than one based upon the span length. For long span bridges these types of bridges are suited.
vii. Arch Bridges: In arch bridges the super structure is curved vertically and it resist load in axial compression. Compression loads gets transferred by curved arch in the abutments.
viii. Suspension Bridges: Main girders in these bridges are supported by vertical hangers which are then supported by suspension cable. The main suspension cable extend over anchorage to tower anchorage. The design of these Bridges is mostly suitable for long bridges and large spans.

3.2.4 Classification by Support Condition:

i. Continuously Supported Bridges: Trusses or the girders are supported continuously which rests in a structurally intermediate system. This type of Bridges tends to be more economical since fewer expansion joints will have less maintenance and service problem. Support settlements in these systems is generally neglected

ii. Simply Supported: Trussed or main girders are simply supported by hinge that is movable at one end and hinge that if fixed at the other end. They can be analysed by using the equilibrium conditions.

iii. Rigid Frame Bridges: The main girders of the bridge are connected to the substructure rigidly.

3.2.5 Classification depending upon the span length:

i. Long span Bridges: These bridges have very long span of the length more than 200 meters.

ii. Medium span Bridges: If span length of a bridge is between 50 and 200 meters then we call it medium span bridges.

iii. Short span bridges: Bridges having span length smaller than 50 meters then the bridge is called short span bridges.

3.2.6 Classification based up on the life of the bridge:

(i) Permanent Bridges:- If a bridge is used throughout its lifetime then we call it permanent bridge. Lifetime of a bridge depends upon various factors like their design and sometimes life of a permanent bridge can be as long as 200 years.

(ii) Temporary bridge:- When a bridge is used of a short span of time and then demolished or may be used in other areas when its need is felt for example in case of military bridges.

3.2.7 Classification based on the position of carriageway:

These bridges may be of the ‘semi-through type’, ‘through type’ or ‘deck type’. With respect to truss bridges these types are described below:

i. Through Type: In this bridge the carriageway rest at the bottom level of the members that carry the main load. The railway or roadway is kept at the bottom flanges level. The level of bottom chord level is equal to level of railway or roadway.

ii. Deck type: On the upper side of the main load carrying members the carriage rests. In deck type plate Girder Bridge, the railway or road way is placed on the top chord level.

iii. Semi through type: the location of the deck is in between the bottom and top of main load carrying members. The top chord or top flange bracing under compression is not done and load carrying system part above the floor level.

3.3 Causes of Bridge Failures:

The bridge failures occurs in various forms in materials and are very likely to be different for concrete, timber, and steel, bridges. Common reasons for failure to occur in a steel bridge are, buckling, yielding, fracture and fatigue, corrosion and shearing. Due to sway, impact, shaking in seismic events, soil erosion during floods or the settlement in case of expansive soils can cause failure in both concrete and steel bridges. The most common bridge failure cause includes: design deficiencies and defects, overstress of structural elements due to section loss, failures during construction, long term fracture and fatigue, accidental impacts by trains, ships, damage due to fire, earthquakes, lack of inspection. Any of the mentioned causes may contribute to bridge failure.

3.4 Load Distribution on Steel Truss Bridge.

In case of truss bridges gravity load induced by vehicles moving on bridge is transferred to supporting piers. Depending upon various conditions like span length of bridge and other site conditions the truss bridge may be either deck type or through type. Usually the framing that supports the carriage way is designed to transfer the loads to the nodal points of the truss.

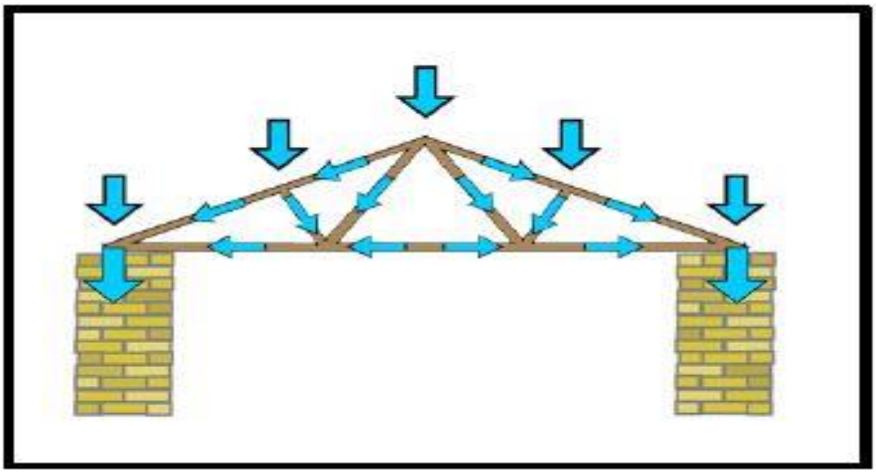


Figure 3.1 Distribution of load over a truss bridge[13] Source- Jasim(2016)

3.5 Loads on Bridges:

There are various loads that act up on the bridges and are considered for computing purpose. The information on loads discussed below is taken from IRC:6-2017.

1. Dead Load
2. Live Load
3. Impact Load
4. Wind Load
5. Longitudinal Load
6. Seismic Load

3.5.1 Dead Load:

The mass of the equipment load that has constant magnitude and attached to the structure permanently represents the dead load. It consists of the main truss weight the floor beams or girder weight and stringer of the floor system. The dead load that acts on the member should be assumed before the design of the member. A member of structure should be designed in such a sequence that to as great an extent as practicable the weight if each member designed is a portion of the dead load carried by the next member to be designed. In case of a road bridge, first slab is designed, then the stringer that transfers the load from slab to the floor beams, floor beams transfers the load from stringers to main girders or trusses. Therefore it is necessary to make the preliminary estimate of the structure weight.

Table 3.1 Dead load of various materials[ref]

Material	Dead Load(Kg/m^3)
Steel	7849
Timber	801
Aluminium	2803
Pavement	2402
Concrete	2402
Macadam or Rolled Gravel	2242
Stone Masonry	1121

3.5.2 Live Load:

It is the weight applied by movement of pedestrians and vehicles. Bridges are designed to support all vehicle loads that might pass over them during the life span of the structure.

There are mainly four type of loadings Whose usage depends on the purpose, location, and properties of the bridge. There are following type of loadings as listed:

1. IRC Class 70R Loading
2. IRC Class AA Loading
3. IRC Class A Loading
4. IRC Class B Loading

Let us further discuss the types of loadings one by one:

1. **IRC Class 70R Loading**

   In these cases of design and construction of permanent bridges and culverts this type of loading is used. This is the heaviest type of loading but it is advisable to check the bridge with IRC class A loading too in certain conditions, because it may generate higher stresses in class A loading.

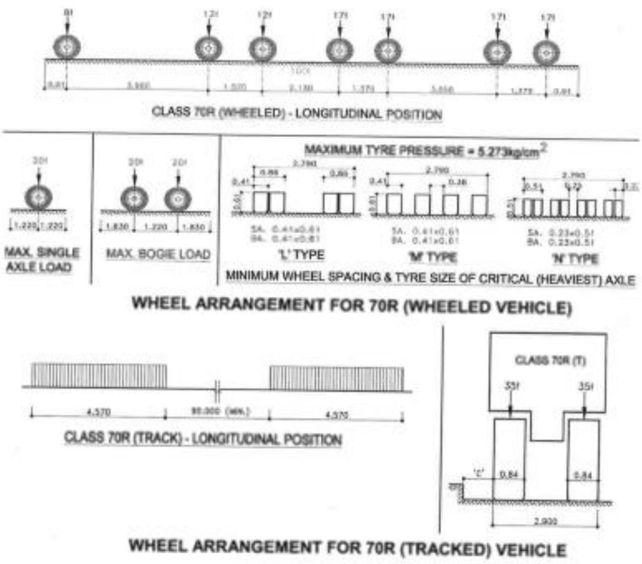


Figure 3.2 Class 70R loading Imprint Details[14], IRC-6 (2014)

2. **IRC Class AA Loading**

   In this loading is adopted in certain municipal limits such as certain existing or contemplated areas, other specified highways or other areas. Bridge designed in this loading should also be checked for the IRC class A loading for the same reason as above.

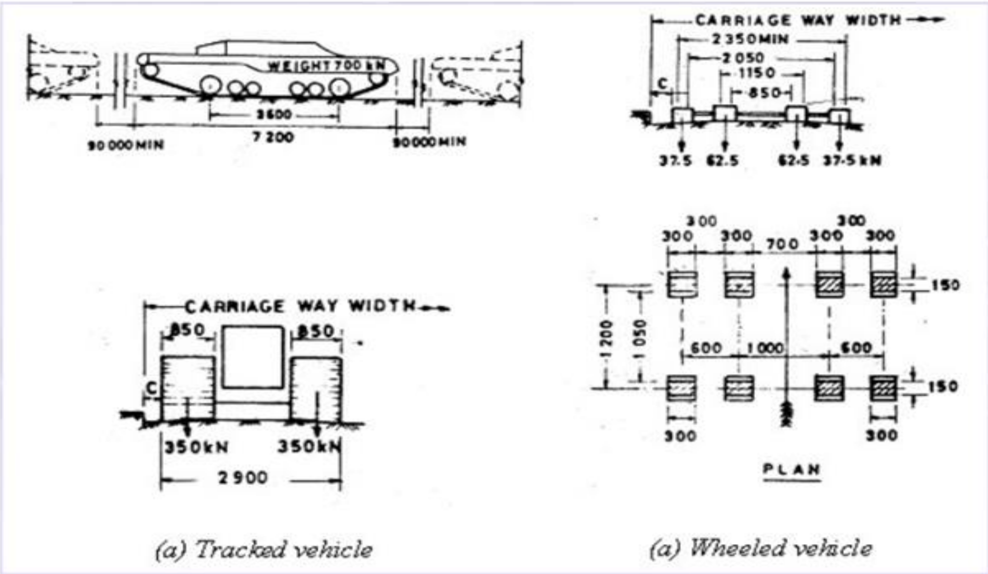


Figure 3.3 Class AA loading Imprint Details[14] IRC-6 (2014)

3. **IRC Class A Loading**

This type of loading consists of a wheel load train composed of a driving vehicle and two trailers of specified axle spacing. This loading is used for designing as well as confirming the bridges designed in upper class loadings.

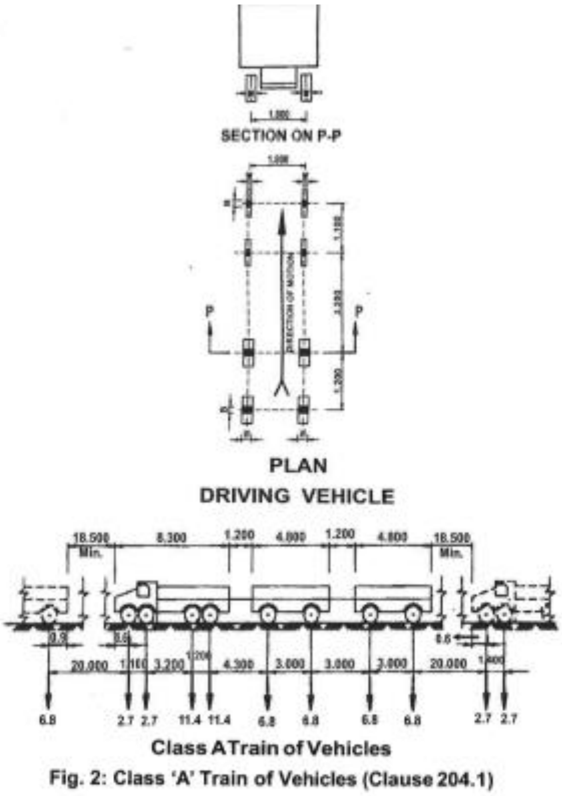


Figure 3.4 Class A loading Imprint Details[14] IRC-6 (2014)

4. **IRC Class B Loading**

Class B loading is adopted for temporary structures and for bridges in specified areas.

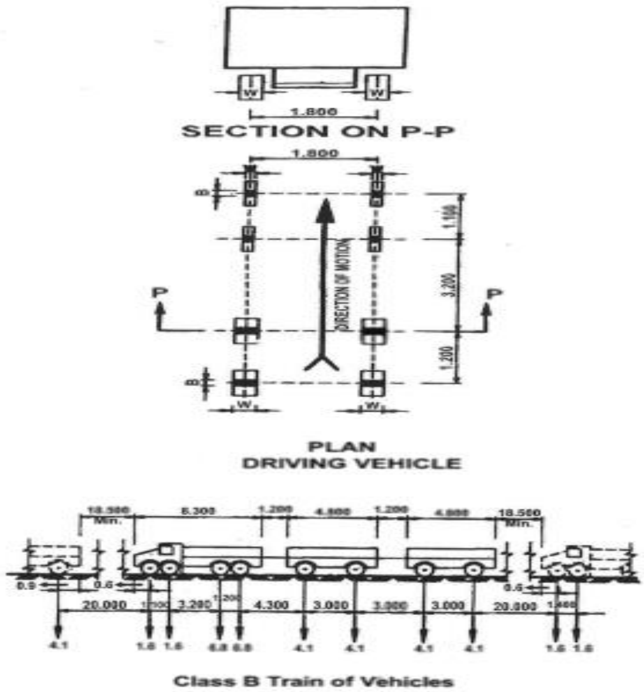


Figure 3.5 Class B loading Imprint Details[14] IRC-6 (2014)

Because IRC class 70R loading is superior to other loads in the stresses generated and other factors, we decided to take this loading into consideration, also we are aiming to design a bridge for regular uses so it is advisable to use this loading.

3.5.3 Impact Loading

The load produced by moving vehicle is greater than if it is considered in static position. The impact action provision shall be made by an increment in the live load by an allowance of impact expressed as percentage of live load.

i. **For loadings of Class A and Class B Loads:**

The fraction of impact shall be determined from the below mentioned equations. These equations are applicable for span from 3meters to 45metres.

a. For Reinforced Concrete Bridges $= \frac{4.5}{6+L}$

b. For Steel bridges $= \frac{9}{13.5+L}$

Where L is Length of span in meters.

ii. For loadings of class AA and 70R

a. For spans having length less than 9meters:

For tracked vehicles : 25% for the span length up to 5m and linearly reduce to 10% for span length up to 9m

For wheeled vehicles : 25%

b. For span length of 9metres or more:

For tracked vehicles : 10%

For wheeled vehicles : 25% for spans up to 23m and according to the curve for spans exceeding 23m.

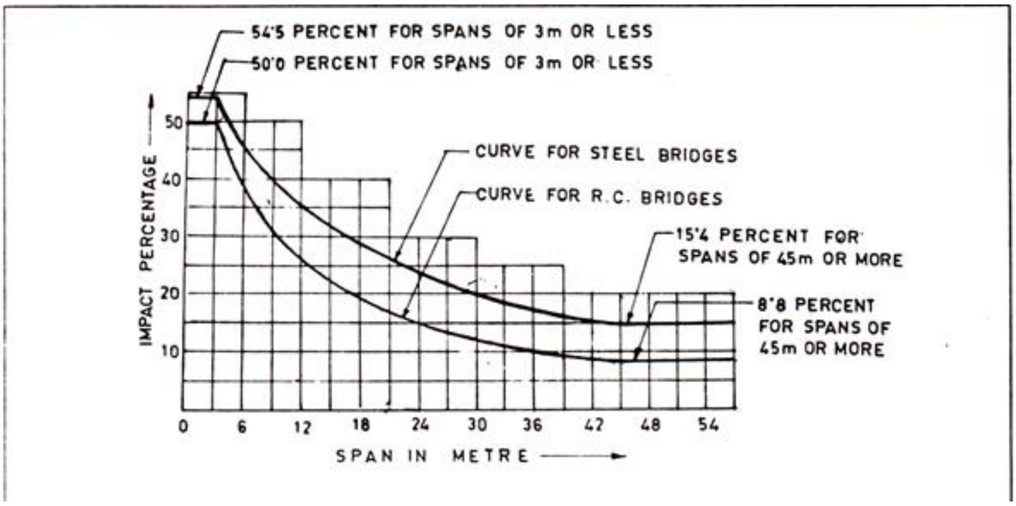


Figure 3.6 Impact percentage Curve[14] IRC-6 (2014)

3.5.4 Wind Load:

Wind load acting up on the bridges depends upon the geographical location, topography, height of bridge above the water level, cross section and horizontal dimensions

Table 3.2: Hourly Mean Wind Speed and Wind Pressure [14]

(For a basic wind speed of 33 m/s)

H(m)	Bridge situated in			
	Plain Terrain		Terrain with obstructions	
	V_z (m/s)	P_z (N/m^2)	V_z (m/s)	P_z (N/m^2)
Up to 10m	27.80	463.70	17.80	190.50
15	29.20	512.50	19.60	230.50
20	30.30	550.60	21.00	265.30
30	31.40	590.20	22.80	312.20
50	33.10	659.20	24.90	373.40
60	33.60	676.30	25.60	392.90
70	34.00	693.60	26.20	412.80
80	34.40	711.20	26.90	433.30
90	34.90	729.00	27.50	454.20
100	35.30	747.00	28.20	475.60

Where

H = the average height in metres of exposed surface above the mean retarding surface(ground or bed or water level)

V_z = hourly mean speed of wind in m/s at height H

P_z = horizontal wind pressure in N/m^2 at height H

Figure 3.7 Wind map of India [15] IRC-6 (2014)

3.5.5 Longitudinal Forces

There are various provisions made for longitudinal forces arising from any one of below mentioned causes:

a. Forces that are caused by driving vehicle acceleration.
b. Forces resulting from the braking effect of braking wheels..
c. The resistance of friction offered to the movement to the bearings that occurs due to temperature change or any other cause.

3.5.6 Thermal

Fluctuations in temperature of air, astral rays etc. causes the variation in bridge temperature which can be referred to as effective temperature of bridge. This temperature cause load effects due to expansion or contraction and friction at sliding or roller bearings referred as frictional bearing restraint.

3.6 Connections in Truss Bridges:

Truss members can be connected by welding, bolting, or riveting. Because of the involved the labour that is highly skilled is required. Nowadays days riveting is not common, excepting some railway bridges in India. In case of rail bridges due to fatigue considerations riveting may be used. But recent developments have made welding and high strength frinction grip bolting more common. Short span Trusses are usually made in workshops and transported to site as single unit. Long span trusses are made in segments by wilding in shop and assembled by means of bolting or welding at site.

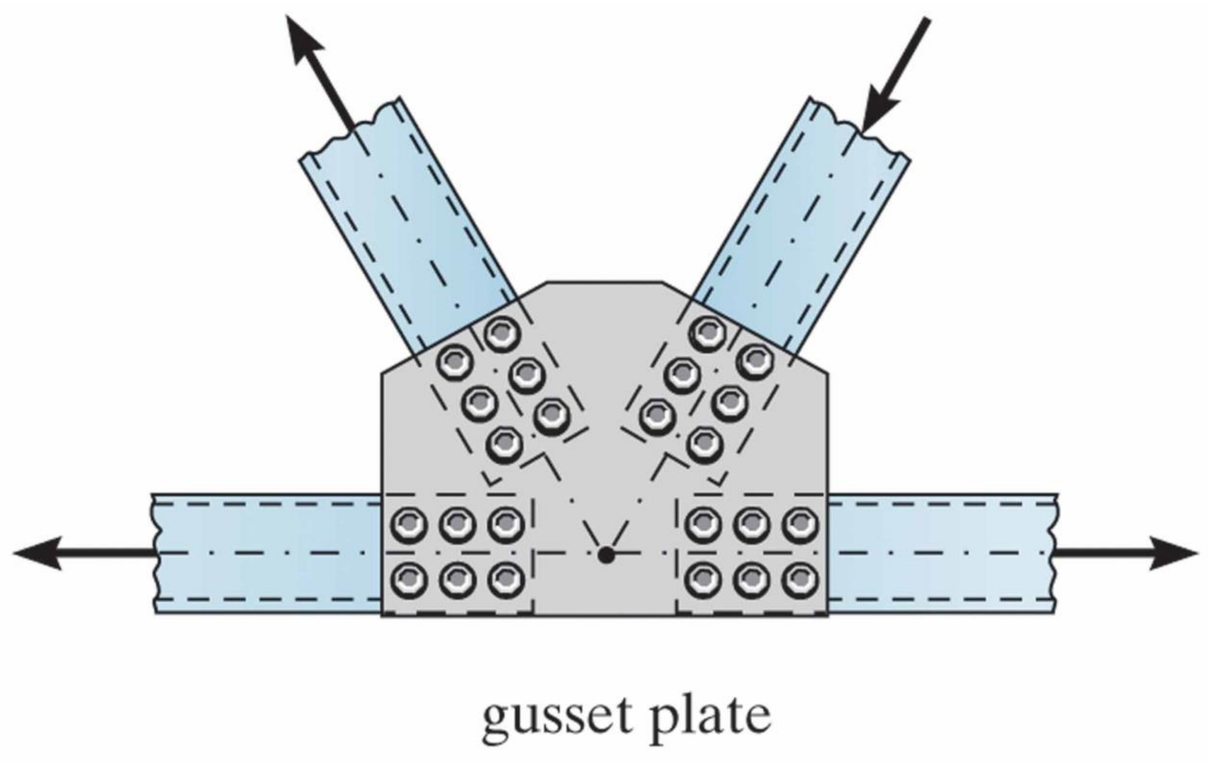


Figure 3.8 Typical Truss Bridge joint[16], Ponnuswamy(2014)

3.7 Analysis of Truss:

Truss members are generally assumed to be joined to transfer only axial forces and not shears and moments from one member to its adjacent and also the loads are assumed to be acting only at the nodes of the truss. Trusses can be provided in a single span and supported simply over the two supports at the end in case they are usually statically indeterminate also this truss can be analysed manually by method of sections or method of joints.

Further, some members of truss particularly chord members, can be continuous over some nodes. Such joints enforce not only compatibility of translation but also enforce the compatibility of rotation of the members that meets at the joints and as a result members of the trusses experience bending moment.

3.8 Steel Design:

Steel used in bridge construction is usually structural steel Confirming to IS:2062(steel for general purpose) or IS:8500(structural steel micro alloyed) or IS11587(structural weather resistant steel). Steel covered by the above specifications contain: iron, a small percentage of carbon and manganese, and very small quantities of alloying elements to improve specific properties of the final product, such as copper, nickel, chromium, molybdenum and zirconium. The strength of the steel increases with increase in the carbon content to an extent but its ductility and weld ability decreases.

3.8.1 Stresses in Steel:

i. *Basic permissible stresses:* The basic permissible stresses under dead load, live load with impact and centrifugal forces should be limited to those given in table below for structural steel. These values may be exceeded to specified extent for certain combinations of loads given in the code, subjected to the limitation that the increased stress should not exceed 0.9 of the yield stress. The permissible stress in axial and flexural compression should take into account the effects of buckling.

Table 3.3 Basic Permissible Stressses in Steel

S.No.	Description	Permissible Stress
1.	Axial Tension on net area	$0.60f_y$
2.	Axial Compression on effective width	$0.60f_y$
3.	Flexure;	
	In plates, flats and tubes	$0.66f_y$
	In girders and rolled sections	$0.62f_y$
4.	Shear	
	Maximum stress	$0.43f_y$
	Average stress	
	For $f_y \leq 250$MPa	$0.38f_y$
	For $f_y > 250$MPa	$0.35f_y$
5.	Bending stress on flat surface	$0.80f_y$

ii. Combined Stresses: Members subjected to both axial and bending stresses should be so proportional that the quantity

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1 \qquad \ldots 3.1$$

Where

f_a = calculated axial stress

F_a = appropriate allowable axial stress

f_b = calculated bending stress

F_b = appropriate allowable bending stress

Under combined bending, bearing and shear stresses, the equivalent stress f_e is computed as,

$$f_e = \sqrt{f_b^2 + f_p^2 + f_b \times f_p + 3f_s^2} \qquad \ldots 3.2$$

Where

f_b = bending stress

f_p = bearing stress

f_s = shearing stress

The equivalent stress under any combinations of loads should not exceed 92 percent of the yield stress.

3.8.2 General Details

i. Effective Span = The effective span of main girders will be distance between centres of bearings, and for cross girders the distance between the centres of main girders.

ii. Effective Depth = The effective depth of plate or truss girder is taken as the distance between the centres of gravity of the upper and lower flanges or chords.

iii. Minimum depth = The minimum depth is not to be less than the following;

For trusses; 0.1 effective span

For R.S. joists and plate girders; 0.04 effective span

For composite steel and concrete bridge

Overall depth; 0.04 effective span

Steel beam or girder; 0.033 effective span

iv. Spacing of main girders = The centre to centre spacing of main girders should not be less than l/20 of the span.

v. Minimum Sections = The minimum thickness of plate used in bridge construction is 8mm for main members and 6mm for floor plates and parapets. If one of the sides is not accessible for painting, the minimum thickness should be increased by 2mm. the minimum size of angle to be used is ISA 7550. End angles connecting cross girders to main girders should not be less than the three – quarters of the thickness of web of cross girders.

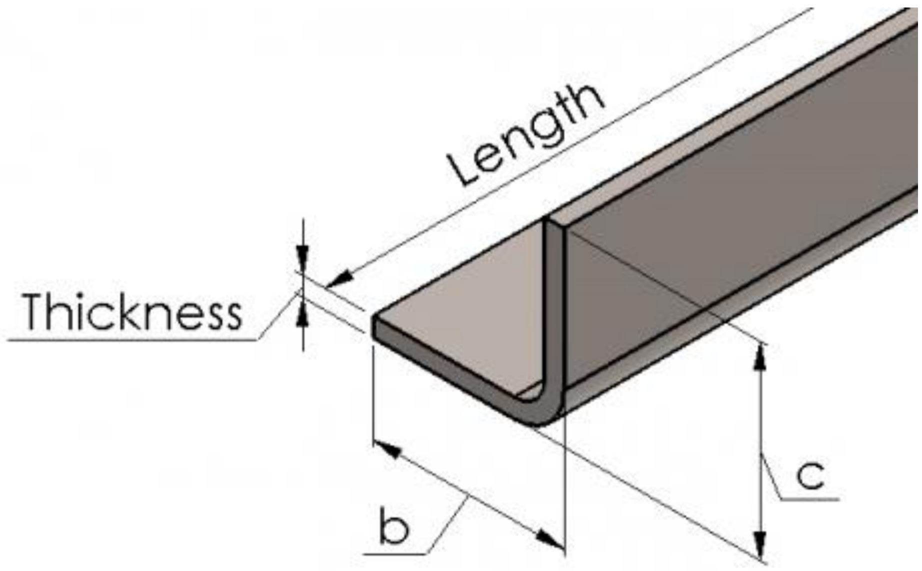


Figure 3.9 Angle section view

vi. Deflections = For rolled steel beams, plate girders and lattice girders, the total deflection due to dead load, live load and impact load should be limited to 1/600 of span and that due to live load and impact load should be limited to 1/800 of span. For cantilever arms, the above deflections at the tip should be limited to 1/300 and 1/400 of a span respectively. In the calculations for deflections, gross moment of inertia and gross area will be used.

vii. Effective length of struts = For the purpose of calculating the value of L/r ratio, thein this the length is taken as following;

a) Restrained at both end both side and position is held= 0.7L

b) Restrained at one end both side and position is held = 0.85L

c) There is no Restrained and position direction is both side held = 1L

d) Effective restrain at one end and position also in one end but restrain not in position= 1.5L

e) Effective held in position and restrained in direction at one end, but not held in position or restrained I direction at the other end = 2.0L

Here centre to centre length of strut is taken as L

viii. Effective Sectional Area = The effective sectional area of a member or flange in tension is the gross sectional area with deduction for rivet and bolt holes. The area to be deducted is the sum of the sectional areas of the maximum number of holes in any cross section at right angles to the direction of stress in the member. The diameter of the hole for this calculations is taken as the actual diameter of hole for shop rivets and turned and fitted bolt and 3mm over the diameter of the bolt or rivet for countersunk bolts or rivets.

ix. Plates in compression = The unsupported width of a plate measured between adjacent lines of rivets, bolts or welds connecting the plate to other parts of the sections shall preferably not exceed 45t, where 't' is the thickness of single plate or aggregate thickness of two or more plates provided these plates are adequately tacked together. The unsupported projection of any plate measured from its edge to the line of rivets, bolts or weld connecting the plate to the other parts should not exceed 16t.

x. Pitch of rivets and bolts = The minimum distance between centres of rivets or bolts will be 2.5 times the diameter of the rivet or bolt. The maximum distance between the centres of any two adjacent rivets or bolts connecting together elements in contact of compression or tension members shall not exceed the smaller of 32t or 300mm, where t is the thickness of member of the thinner outside element. The maximum pitch in the direction of stress shall not exceed 16t or 200mm in tension members and 12t or 200mm in compression members. The pitch of rivets or bolts in a line adjacent to and parallel to an edge of an outside plate should not exceed 100mm plus 4t or 200mm whichever is smaller.

xi. Edge distance = The minimum edge distance from the centre of any rivet or bolt to the edge should be 1.5 times the diameter.

xii. Curtailment of flange plates = Each plates should be extended beyond its theoretical cut-off point the extension should be adequate to accommodate rivets, bolts or welds to develop the loads in late for the computed moment at the theoretical cut-off point.

xiii. Web thickness = The minimum thickness of web plate is 10mm. The ratio of clear depth between the flange angles to the web thickness should not exceed 200mm for mild steel nd 180mm for high tensile steel for vertically stiffened webs.

xiv. Web Stiffeners = Stiffeners should be provided at the points of support and concentrated loads, on both sides of the web plate. The outstanding legs of each pair stiffeners should be proportioned such that the bearing stress does not exceed the permissible bearing stress.

3.8.3 Load Deflection Limit

It is a very important issue in serviceability of steel bridges, limit of load deflection attracts our attention because ensuring safety is number one priority in structure design. It should be ensured that the deflection is within the acceptable range.

To study the deflection limit criteria, we gone through a research conducted by Dr. Chung C. Fu of University of Maryland and in that report he studied the deflection behaviour on bridge using multiple load types and came to a conclusion that for general vehicular bridges with pedestrian traffic universally accepted criteria for load deflection limit is L/1000. Where L is the span length of the Bridge.

3.9 Software Analysis of Bridge:

Task1: Creating Geometry in DesignModeller

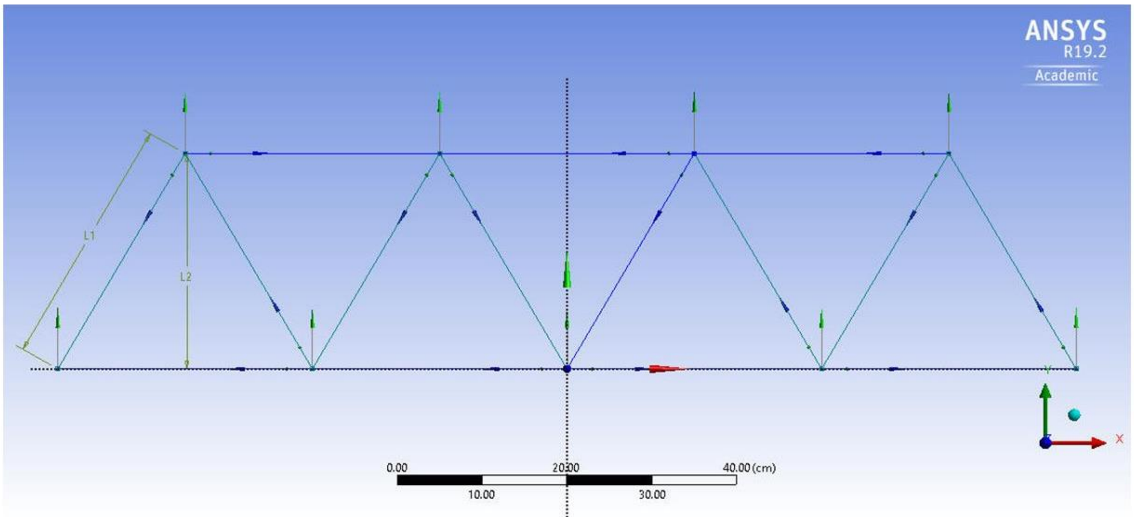


Figure 3.10 Line Body geometry of bridge.

Here

L_1 is Length of all members = 30cm

L_2 is Height of Truss Triangles = 26cm

Task 2 Defining Cross Sections: -

Two cross sections are then defined one is for solid section the other is for hollow sections.

(i) Section I Details: -

It is solid section and we have chosen angular section for the purpose.

This angular section if having unequal leg length so

W_1=3.81cm

W_2=2.54cm

Where W_1 and W_2 are the lengths of the leg

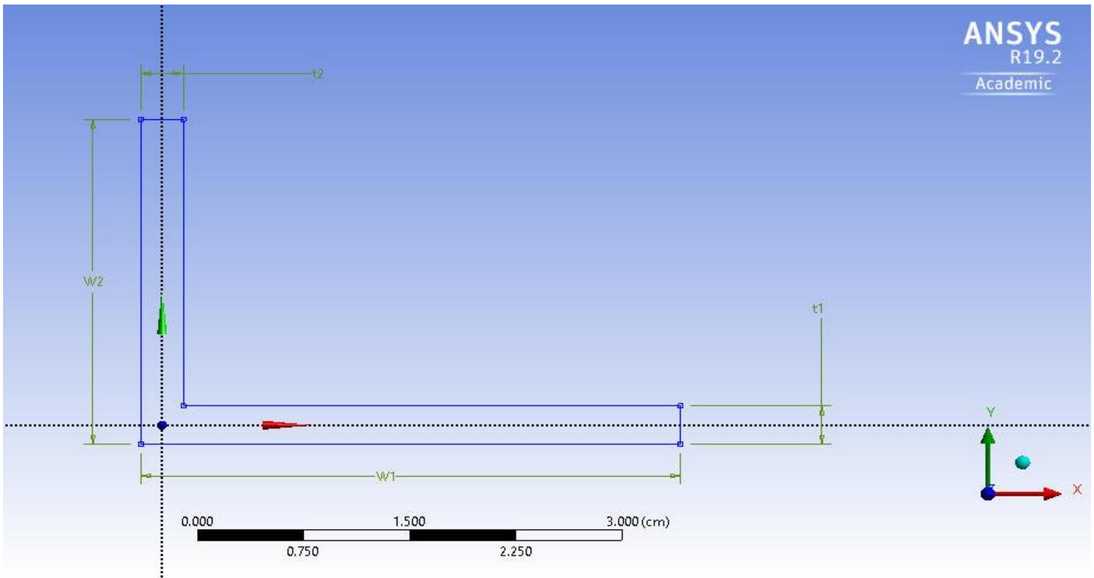
Both legs are having equal thickness so

T_1=T_2= .4cm

Where T_1 and T_2 are the thicknesses of legs

Figure 3.11 Cross Section view of solid(angle) section.

(ii) Section II Details: -



It is Hollow section and we have chosen rectangular section for the purpose.

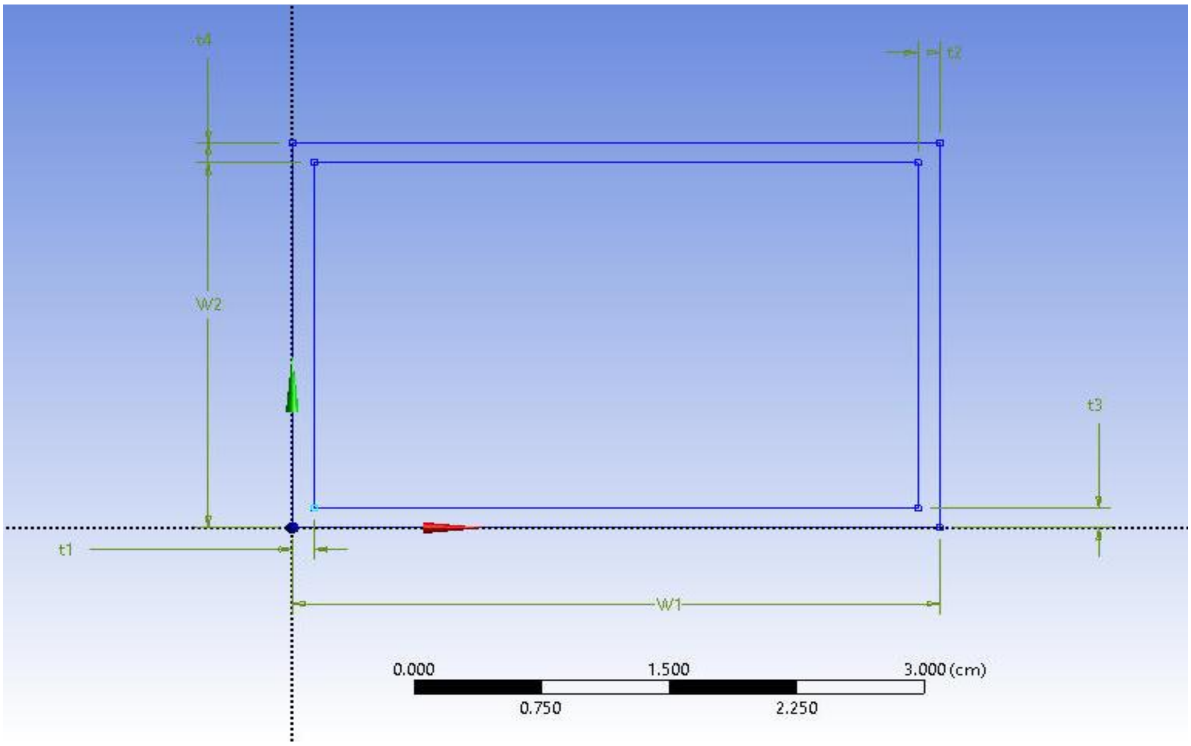


Figure 3.12 Cross Section view of hollow(rectangular) section.

W_1= 3.81 cm

W_2=2.54 cm

Where W_1 and W_2 are length and breadth of sides repectively is length of sides of the section.

All the thicknesses are equal so

T= 0.15

Where T is the thickness of the section.

Task 3 Providing Load Imprint:-

Proportionate load imprint values are found out and according to that load imprint is then provided.

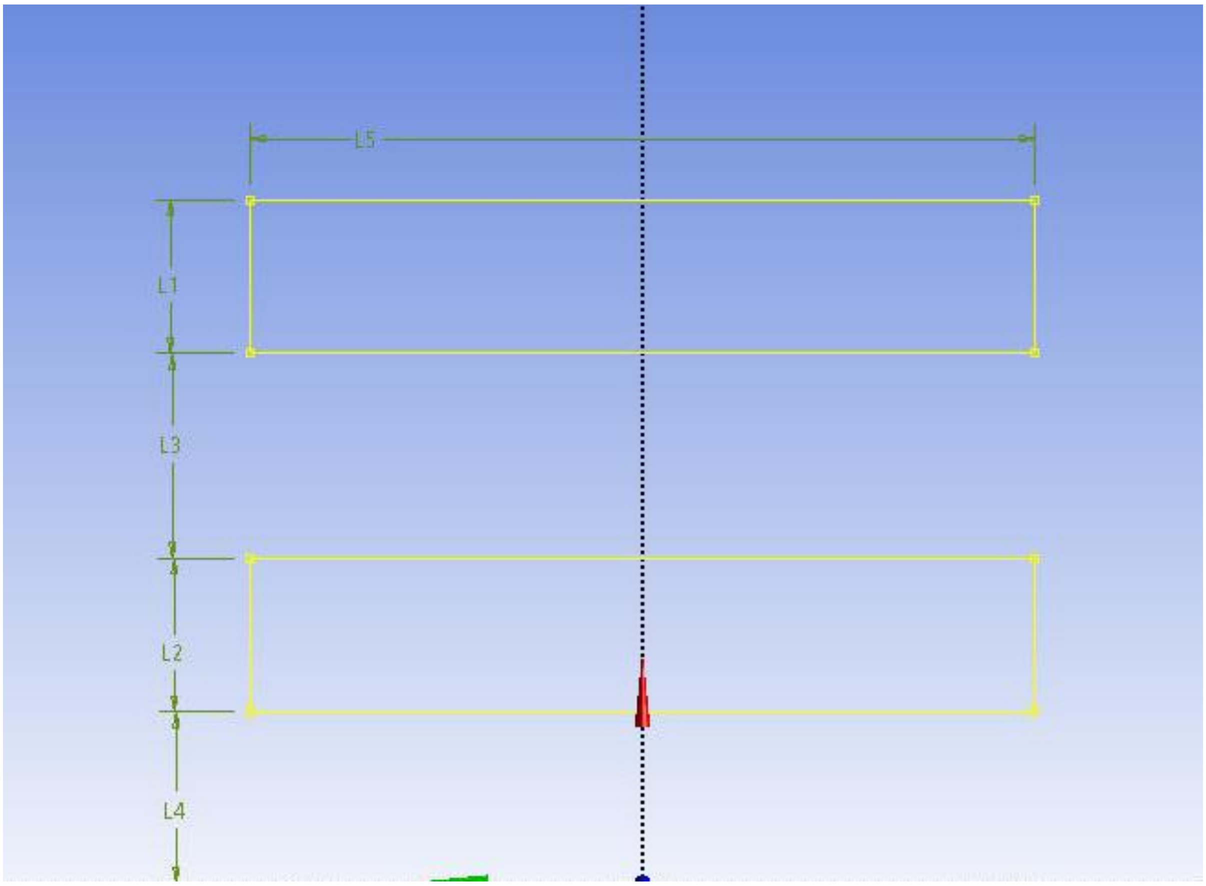


Figure 3.13 Load Imprint of IRC 70R proportionate load Drawn.

Here

L_1=L_2= Width of Track Load = 5cm

L_3= Distance Between Loading Imprints = 6cm

L4= Clearance Distance between edge of deck and outer edge of track = 7cm

L5= Length of Track Load= 28cm

Task 4: Selecting Mesh Size

In order to select the appropriate mesh size a Convergence study is conducted where mesh size is varied from high to low and Total Deformation behaviour was checked where difference in values became negligible Mesh Size was finalised and taken for the analyses of the results.

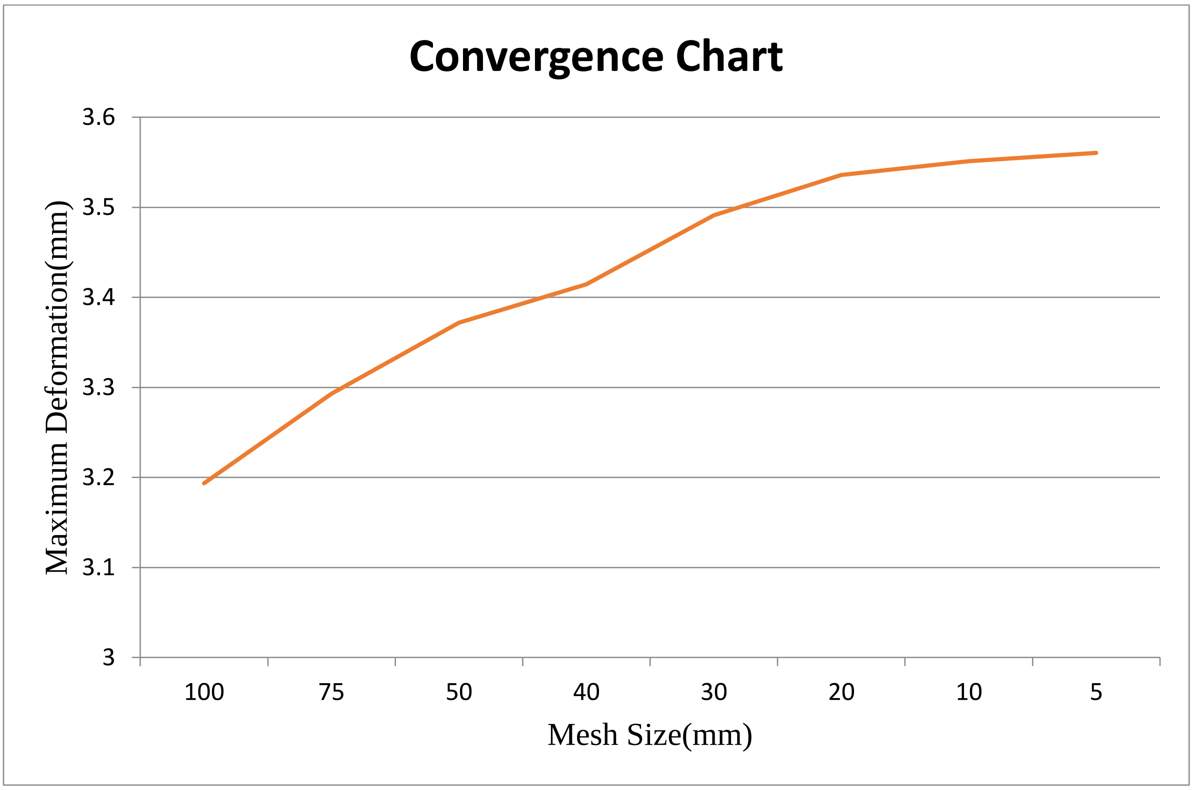


Figure 3.14 Convergence Graph.

So based upon the data from above graph mesh size of 25mm is taken and whole structure is analysed using mesh of size 25mm. 10mm mesh can also be taken but it takes very much time for the system to analyse the results and as there is not much difference between the results mesh size of 25mm is taken.

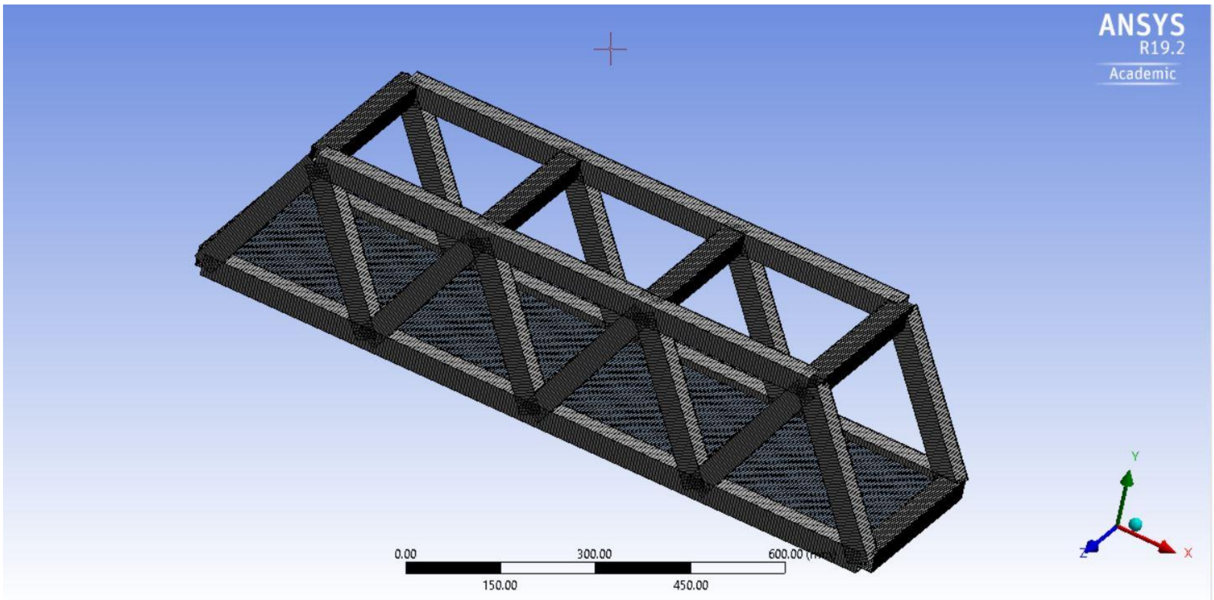


Figure 3.15 Meshed Geometry of the bridge.

Task 6: Boundary Conditions

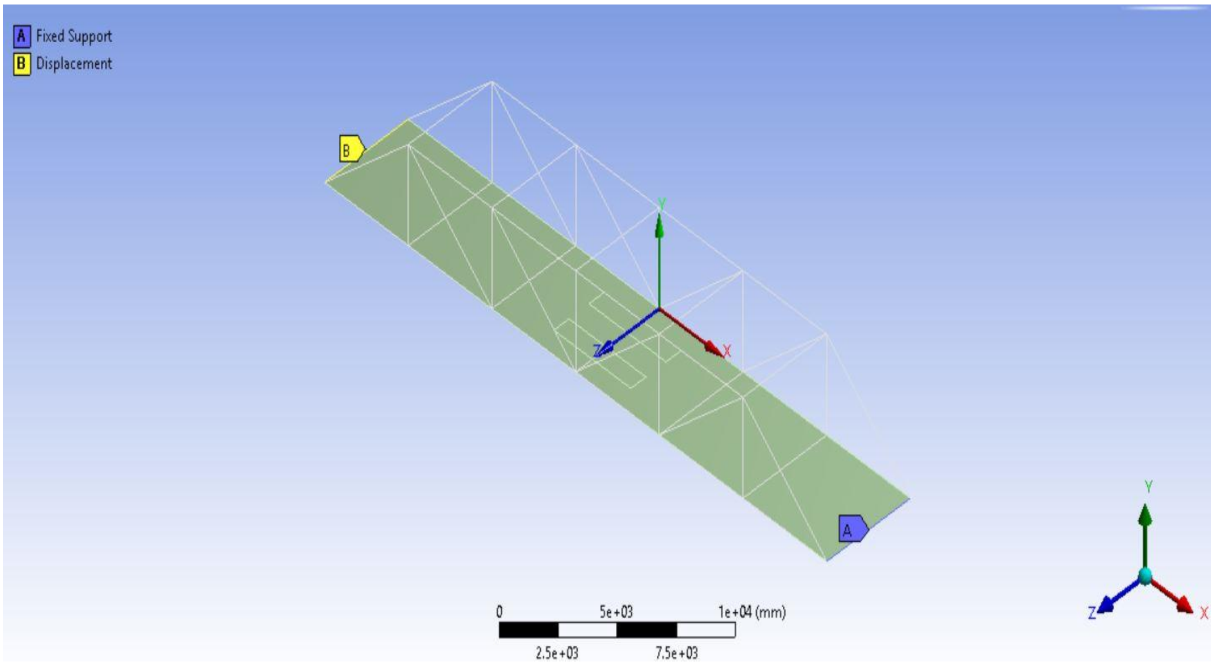


Figure 3.16 Supports provided in Bridge in software

Fixed support is provided on one side and roller support is provided at the other. From above figure we can see that A is representing fixed support and B is representing displacement support where Y direction is restrained.

Task 6 Types of Elements Used: -

Element type used in ANSYS is program controlled. During the Analysis of our bridge software used 5 types of elements.

Table 3.4 Types of element used by ANSYS WorkBench

Element Name	Material ID	Element Type	Number of elements
SURF154	MAT_5-6	ETYPE_5-6	10
TARGE170	MAT_4	ETYPE_4	209
CONTAC175	MAT_3	ETYPE_3	49
SHELL181	Mat_2	ETYPE_2	219
BEAM188	MAT_1	ETYPE_1	326

3.10 Bridge prototype Testing

3.10.1 The Plan

For the testing of our bridge prototype model we worked upon the following plan: -

- Deciding a Truss Configuration first
- Drawing the structural Model
- Static determinacy and stability check
- Cut members according to the dimensions
- Make gusset plates
- Drilling the holes in members and gusset plates
- Assemble the parts and Build the Bridge.
- Test the bridge in Universal Testing Machine.

i. Truss configuration: - The truss types we taken was same as that of we took in case of software testing of small model i.e. Warren Truss

ii. Structural Model: - The structural model is drawn carefully on the paper and number of joints and member is calculated.

iii. Determinacy Check: -

Static determinacy mathematical condition is $2j = m + 3$

Where m is member number in the structure and j is number of joints in the structure.

In our structure we have 9 joints and 15 members putting this value in the equation we get value 18 in both L.H.S. and R.H.S. So, the stability and determinacy condition is satisfied mathematically.

iv. Members and gusset plates are then cut according to the dimension in warren truss length of all members is equal because it has equilateral triangles. Length of each member is 30 cm.

v. Gusset plates taken were made of steel because we wanted to emphasize on the member stresses so we needed to make joints more efficient that's why members of the structures were made up of aluminium and gusset plates were made up of Steel.

vi. Because we used the 6mm bolt in our structure we drilled the bolt hole of diameter 6.5mm.

vii. After assembling all the parts putting angle sections and hollow sections together we made two bridge models one of angle sections the other of hollow sections to test them in UNIVERSAL TESTING MACHINE.

3.10.2 Bridge prototype: -

Figure 3.17 Image of Model made using angle sections.

In case of model made up of angle sections single gusset plate is used and bolted connections are provided MS bolts of 6mm are provided.

Figure 3.18 Image of Model made using hollow sections.

In case of model made up of hollow sections joints are made using double gusset plates and MS bolts of 6mm diameter.

3.10.3 UNIVERSAL TESTING MACHINE

A Universal Testing Machine also known as universal tester is a machine used for testing the compressive and tensile strength of the materials. The "Universal" name signifies that it can perform many standard compression and tensile tests on materials, components and structures. Range of load varies from 0-1000KN.

Components of UTM

UTM mainly consist of two parts; (1) Loading Unit and (2) Control Panel

(1) Loading Unit It consists of a hard base at the centre of which is fitted with the cylinder and piston. A rigid frame which consists of upper cross head, lower table and the two straight columns that connected to the piston through a ball and socket joint. A pair of screwed columns mounted on the base pass through the main nuts to support the lower cross-head. Then this cross head is moved up and down with screwed columns that rotate by motor fixed at the base. Each cross-head has a tapered slot at the centre into which the pair of racked jaws inserted. Jaws are moved up or down with operating buttons provide in control panel.

(2) Control Panel The key components of control panel of UTM are hydraulic power unit, load measuring data logger and the control devices.

i. **Hydraulic Power Unit** It contains oil pump that driven by the electric motor and sump for hydraulic oil.

ii. **Load Measuring Unit** It consists a small cylinder in which piston moves up and down under the oil pressure. The overall accuracy of the machine mainly depends on the measuring unit.

iii. **Control Devices** Following are the control devices;

iv. **Electric Control Devices** These devices are present on the left side of panel in form of four switches. Lower cross head moves up and down by pushing these switches up and low respectively. And the other two switches are on and off for the hydraulic pump.

v. **Hydraulic Control Devices** These are the set of pair of control valve set on the control panel table. Right control panel is inlet valve that used as a pressure compensated flow control valve. While the hydraulic system on and this valve is in closed position, the oil flows in sump in backward direction. While opening of valve, causes oil to flow in a continuous manner into the main cylinder. Left valve is return valve. When this valve is closed, oil get pumped into main cylinder that results in the moving of main piston in upward direction. As loaded gets up then the specimen resist the moving of piston. Oil pressure in main cylinder then starts increasing until either load reaches maximum value or the specimen breaks down. A slow opening of this valve cause the oil to drain sump in backward direction and main piston to descent.

vi. **The Load Indicating Devices** This consists a range inflating dial. When the range adjusting knob is turned, the former move and sets itself to the selected range. The load on specimen at any stage is indicated by load pointer that moves over indicating dial of load.

Figure 3.19 Image of Universal Testing Machine.

3.10.4 LVDT as Deflection measurement devices

LVDT stands for Linear Variable Differential Transformer. It is an electrochemical Transducer and it converts the object's rectilinear motion by which it is attached mechanically into an electrical signal. It gives displacement value when connected to a Data Logger. In our project testing we have used LVDT to measure Deflection at the nodes. LVDT consists a core and the coil assembly. This coil assembly comprises of three wire wound coils of hollow shape. Inside of the coil is energised by the AC source. Magnetic flux generated by the main is attached to the two minor coils resulting AC voltage in each coil. The LVDT range includes; (0.02''), (0.02-0.32''), (0.32-4.0"), (4.0-20.0"), (±20.0")

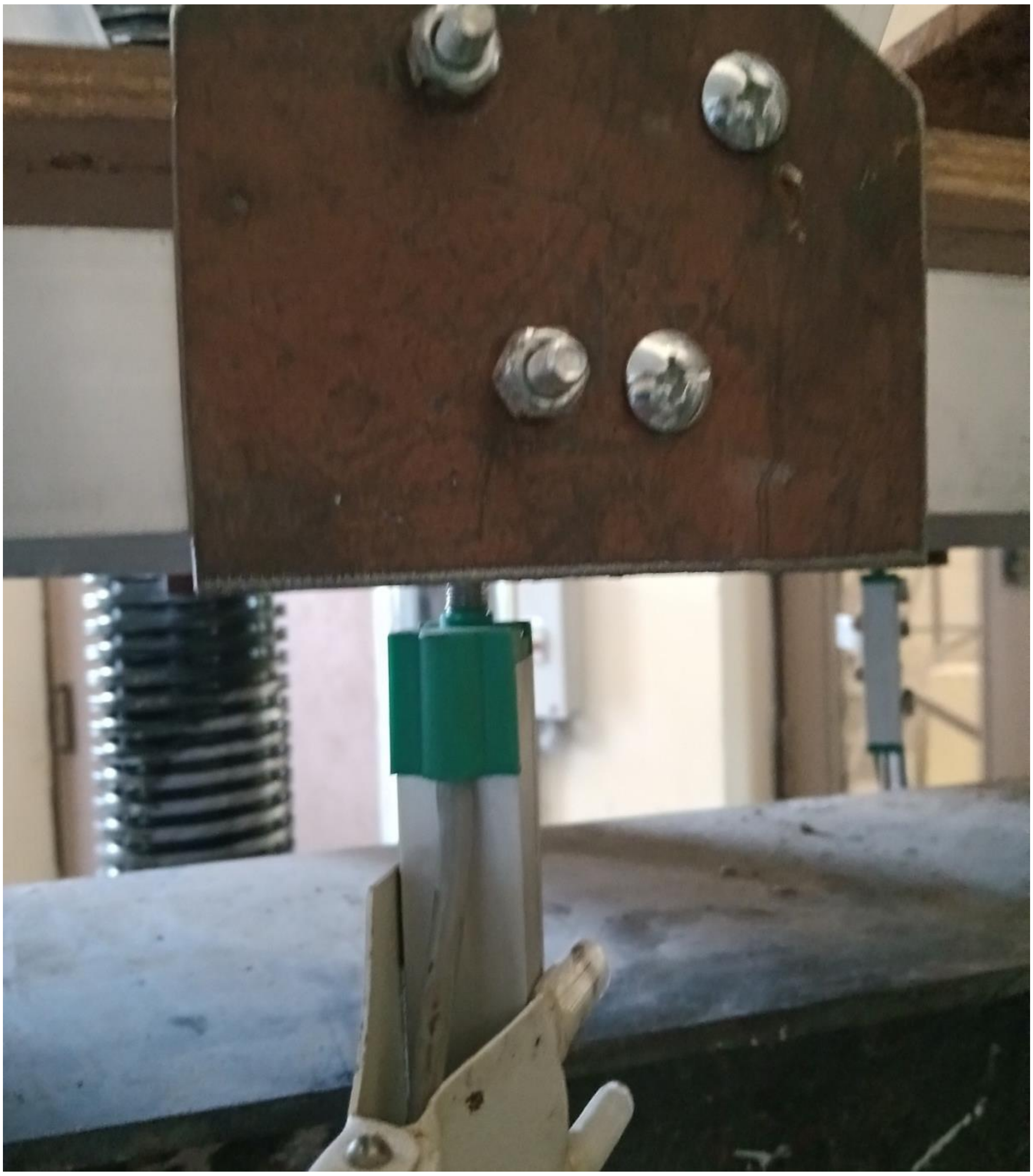


Figure 3.20 LVDT attached at a node.

3.10.5 Data logger The Universal Data Acquisition System (UDAS) includes the configuration and the data acquisition software. It consists of 16 sensor inputs in any combination or mix. Software of UDAS includes a GUI configuration utility that allows to set the sensor type, channel, gain range and all the other input parameters. LVDT attached at the back side of UDAS. When load is applied LVDT send signals to data logger which record the result. f

Figure 3.21 Data Logger

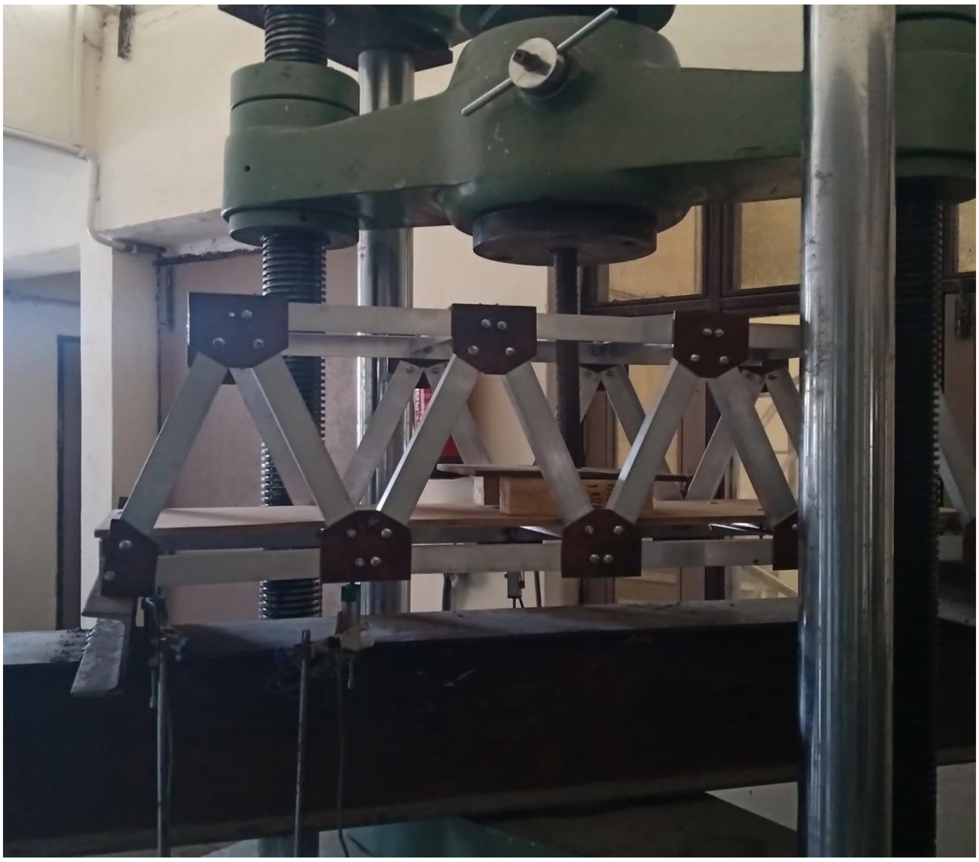


Figure 3.22 final testing arrangement

It can be seen clearly in the figure that LVDTs are provided one at the corner one at the centre and one at the node between corner node and central node.

3.10.6 Loading Arrangements

Two wooden blocks according to the dimensions calculated by proportioning with respect to IRC 70R loads were placed over the deck with suitable clearance distance and spacing between two tracks and load is applied centrally by a thick plate which is ultimately distributed equally over both cuboids and in this way we were able to provide load proportionate to IRC design load in our model. Because load in UTM is applied from the bottom we had our deflection at the corners and we had to make the central part fix to finally calculate relative displacement. So to make central part of the bridge fix in Y direction we used a big iron rod that extends from plate to the upper part of UTM.

Figure 3.23 Image of Load Imprint provided on the deck of bridge prototype

3.10.7 Support system

As UTM applies load from the bottom we made a proper support system using an I-section so that when UTM starts load is applied at the supports deflection occurs at the corners and centre remains as it is and after the testing deflection at the centre can be calculated relatively by assuming deflections at supports to be zero and solving for deflection at centre.

Figure 3.24 support system used in bridge Testing

Support system is made rigid so that the participation of support system on total deflection is negligible. On a huge I-section to channel sections are placed in such a way that it supports the corners of the bridge prototype while testing.

CHAPTER-4

RESULTS

4.1 Results for the Bridge tested in software: -

Bridge was tested in ANSYS WorkBench software and results were analysed on the basis of below mentioned result parameters. The comparison of values for solid section and hollow section is made.

The figures given in this section tells the areas according to the values. Areas with red colour are having maximum value and areas with blue colour are having minimum value of the result parameter.

(i) Total Deformation: -

Table 4.1 Maximum, Minimum and Average Total Deformation values.

Section	Solid	Hollow
Minimum Total Deformation	0	0
Maximum Total Deformation	1.7432mm	1.4474mm
Average Total Deformation	0.6636mm	0.64161mm

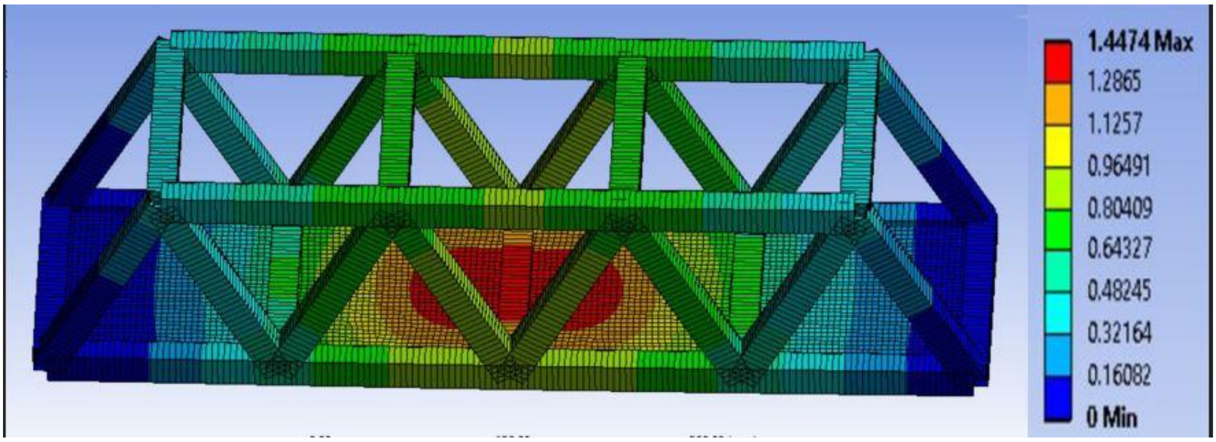


Figure 4.1 Areas of Total Deformation according to the values.

(ii) Equivalent Stress:-

Table 4.2 Maximum, Minimum and Average Equivalent Stress Average values.

Section	Solid	Hollow
Minimum Equivalent Stress	$0.5966 MPa$	$0.241 M$Pa
Maximum Equivalent Stress	98.254 MPa	70.297 MPa
Average Equivalent Stress	15.427 MPa	11.135 MPa

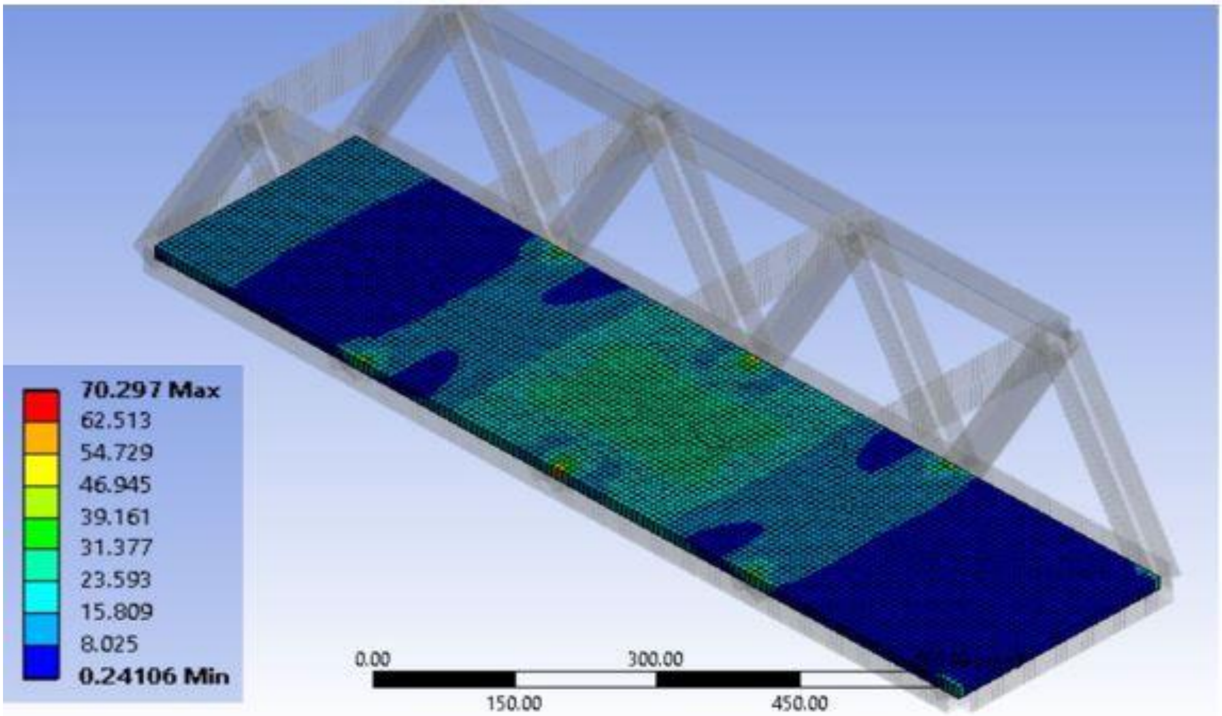


Figure 4.2 Areas of Equivalent Stress according to the values

(iii) Axial Force

Table 4.3 Maximum, Minimum and Average Axial force values.

Section	Solid	Hollow
Minimum Axial Force	−9846.6 N	−9577.9 N
Maximum Axial Force	5585.3 N	5280 N

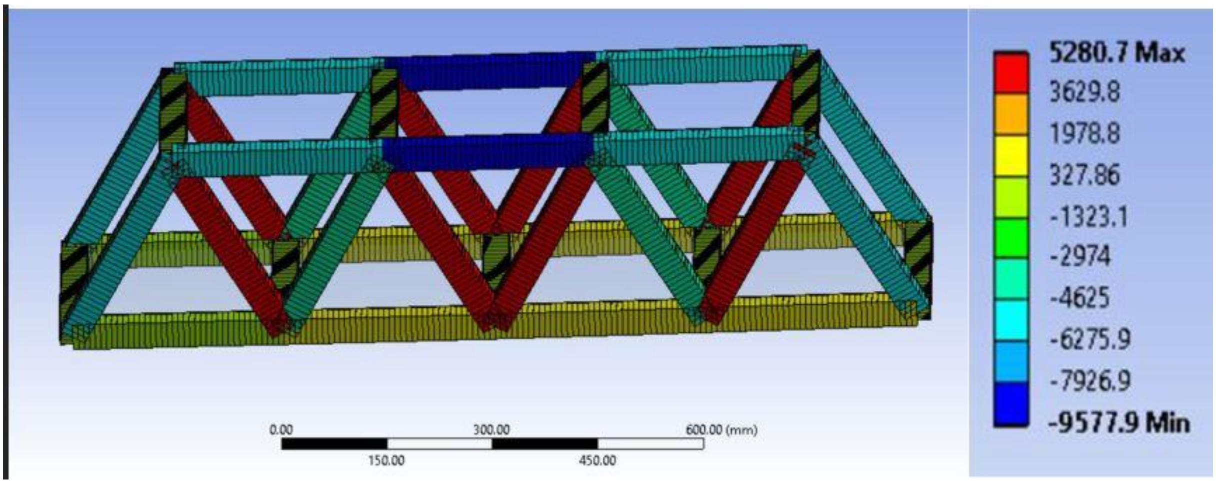


Figure 4.3 Areas of Axial Force according to the values

(iv) Force Reactions:

Table 4.4 Force reaction values for both the supports.

Section	Solid		Hollow	
	Fixed Support	Roller support	Fixed Support	Roller support
X-Axis	1.4412×10^{-8} N	0	1.8979×10^{-9}	0
Y-Axis	10160 N	9719 N	10019 N	9660.7 N
Z-Axis	$.2.992 \times 10^{-6}$N	0	2.3155×10^{-6}	0
Total	10160 N	9719 N	10019 N	9660.7N

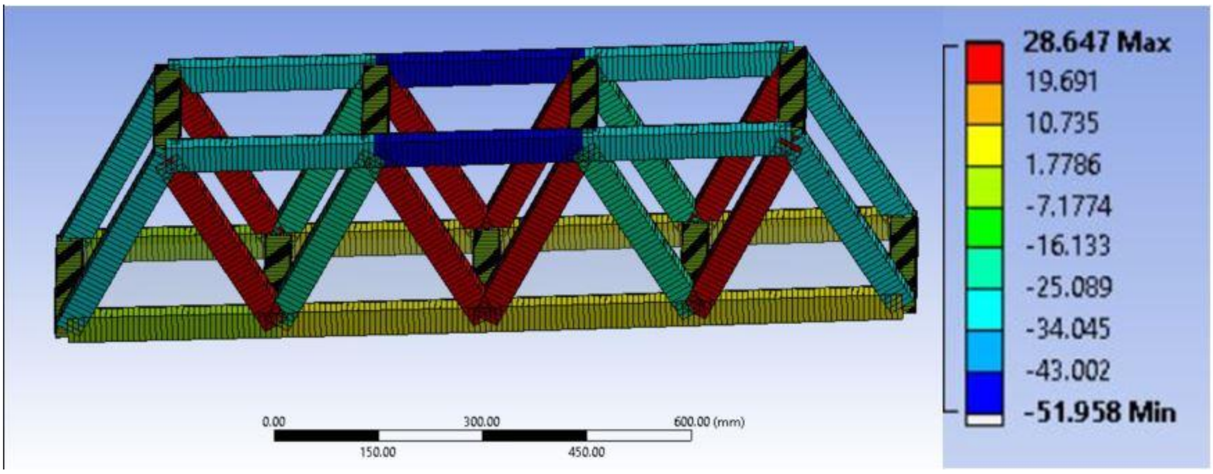


Figure 4.4 Areas of Direct Stress according to the values

(v) Direct Stress in Beams:

Table 4.5 Maximum, Minimum and Average Direct stress values in beams.

Section	Solid	Hollow
Minimum Direct Stress	$-54.262\ MPa$	$-51.958 MPa$
Maximum Direct Stress	$30.773 MPa$	$28.647\ MPa$
Average Direct Stress	$-5.6169 MPa$	$-5.5298\ MPa$

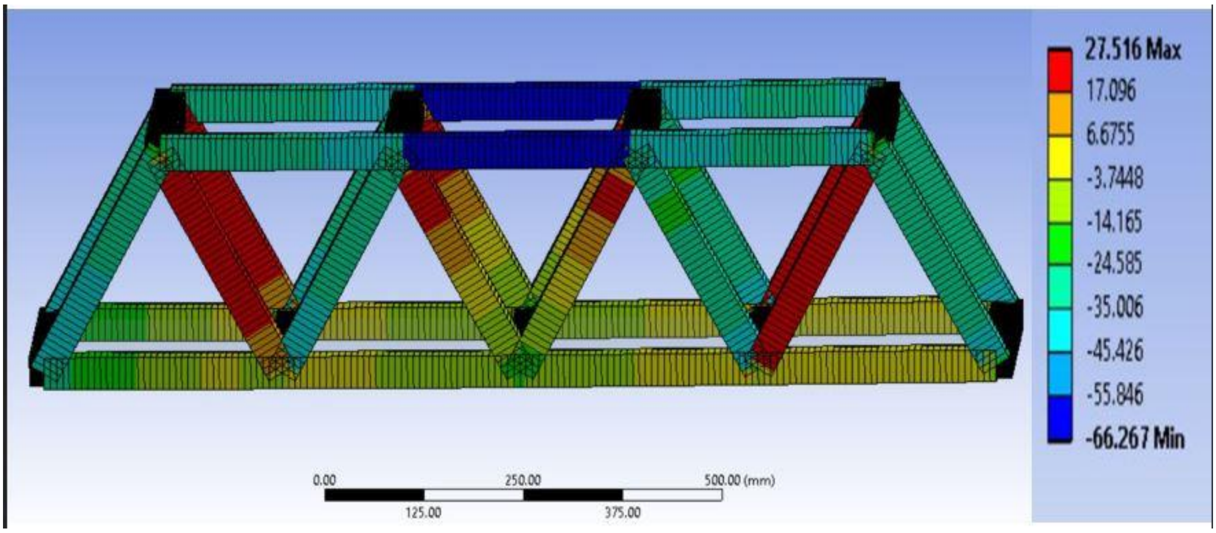


Figure 4.5 Areas of Minimum Combined Stress according to the values

(vi) Maximum & Minimum Combined Stress: -

Table 4.6 Maximum, Minimum and Average Combined stress values in beams.

Section	Solid		Hollow	
	Max. Combined	Min. Combined	Max. Combined	Min. Combined
Minimum	$-48.886 MPa$	$-103.99\ MPa$	$-46.031\ MPa$	$-66.267\ MPa$
Maximum	$102.01\ MPa$	$30.054\ MPa$	$65.168 MPa$	$27.516\ MPa$
Average	$4.663\ MPa$	$-17.069\ MPa$	$2.766\ MPa$	$-13.825 MPa$

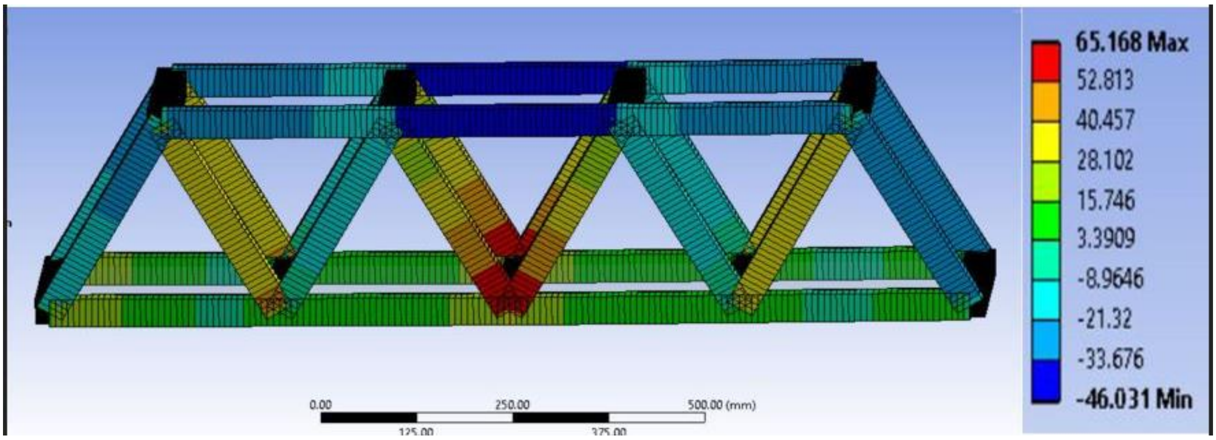


Figure 4.6 Areas of Maximum Combined Stress according to the values

4.2 Results for Bridge Prototype Tested in UTM

After testing our bridge in UTM we have 3 LVDT readings of deflection with respect to the load for both solid and hollow sections. The values are given in following table.

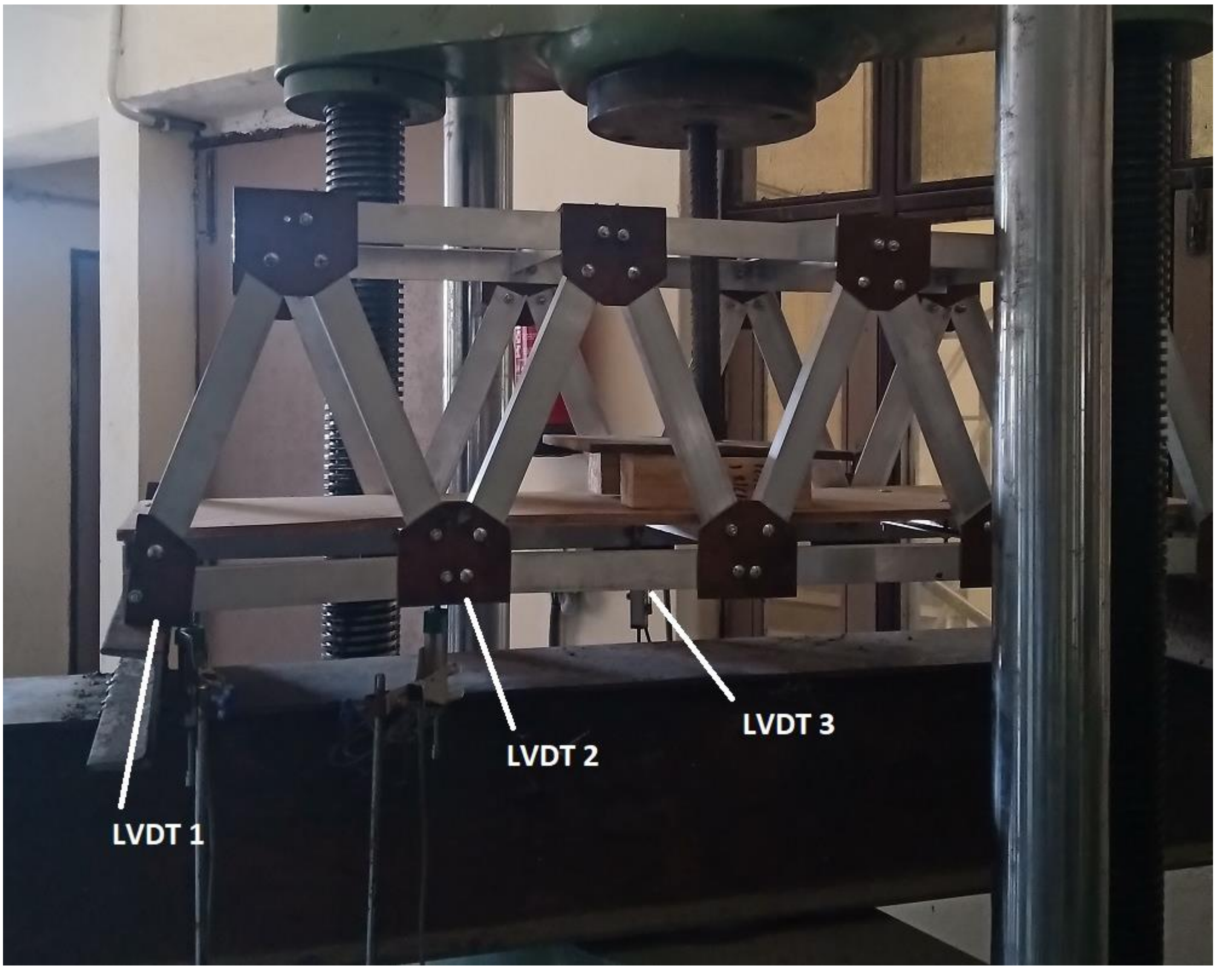


Figure 4.7 Locations of LVDTs

Table 4.7 LVDT readings recorded at the time of testing.

Solid				Hollow			
Load (KN)	LVDT1 (mm)	LVDT2 (mm)	LVDT3 (mm)	Load (KN)	LVDT1 (mm)	LVDT2 (mm)	LVDT3 (mm)
1	0	0	0	0	0	0	0
2	0	0	0	2	0	0	0
4	0.005	0	0	4	0	0	0
6	0.008	0.001	0	6	0.0075	0.0005	0
8	0.01	0.0065	0	8	0.019	0.001	0
10	0.098	0.066	.005	10	0.09	0.05	0.002
12	0.2	0.09	0.07	12	0.13	0.08	0.009
14	0.7	0.62	0.38	14	0.22	0.16	0.01
15	2.7	2.65	1.73	15	0.3	0.25	.05
16	6.8	6.63	3.6	16	1	0.89	0.22
17	11.4	9.73	4.58	17	2.9	2.24	0.94
18	17	13.16	5.62	18	4.5	4.42	1.7
19	20.9	15.14	5.77	19	6.3	6.14	2.31
20	25.5	18.36	7.95	20	8.2	7.75	2.95
21	31	19.92	9.09	21	10	8.93	3.41
22	36	21.27	10.12	22	14	10.8	4.38
23	-	-	-	23	17	14.77	6.24
24	-	-	-	24	23	16.6	7.41
25	-	-	-	25	32.02	28.72	8.49

Now we are going to analyze these results with the help of graphs.

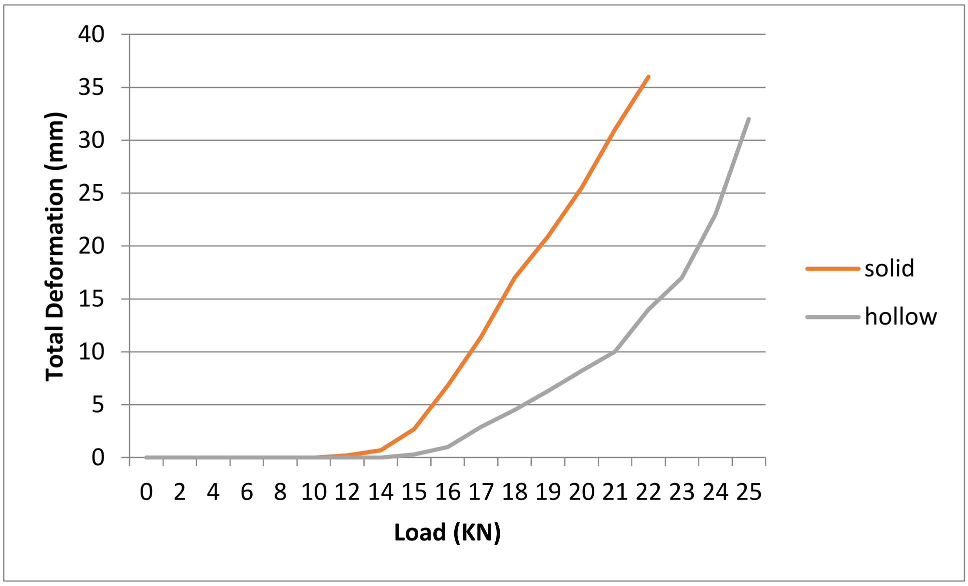


Figure 4.8 Deformation comparisons at node 1 with respect to load

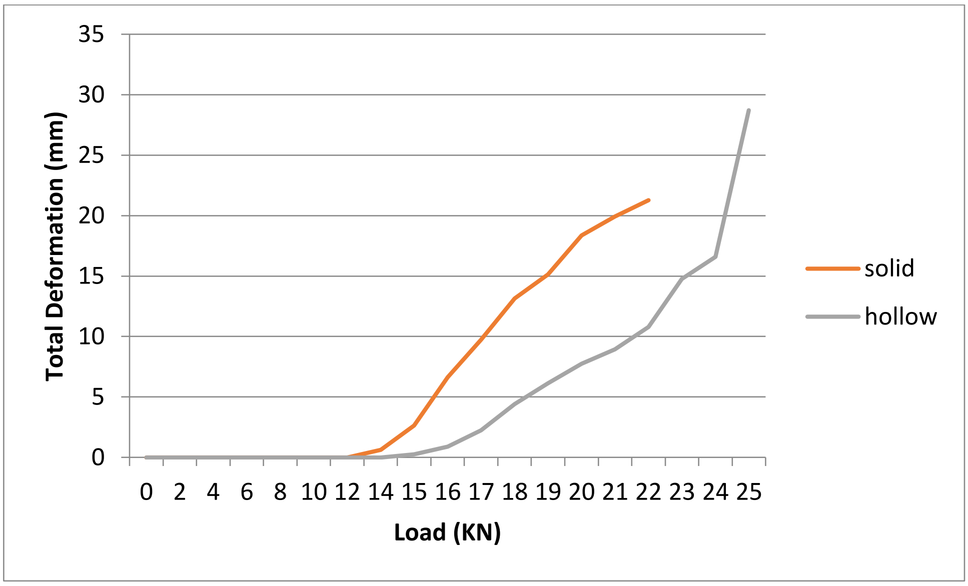


Figure 4.9 Deformation comparisons at node 2 with respect to load

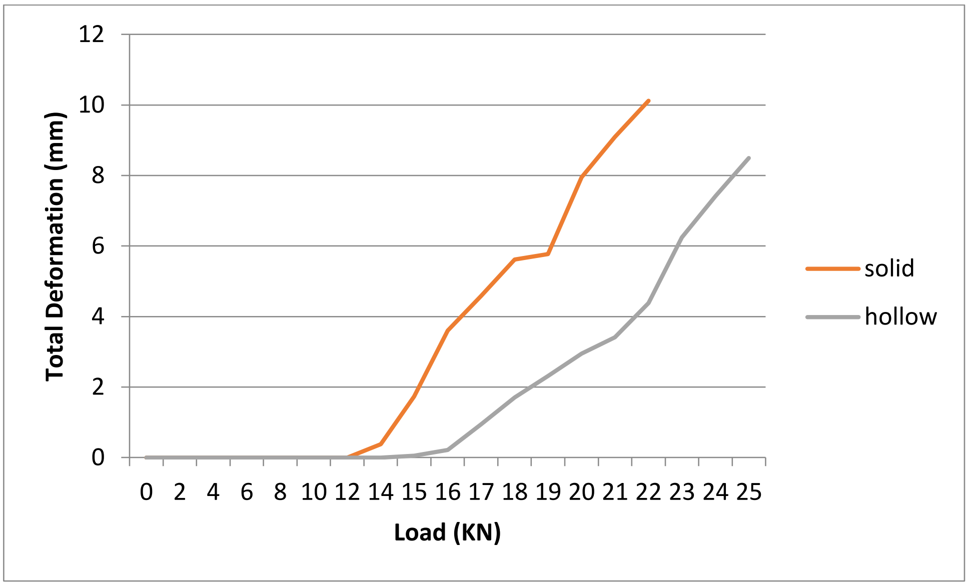


Figure 4.10 Deformation comparisons at node 3 with respect to load

From above graphs it can be clearly seen that hollow section is taking more load than solid section for same deformation value.

Failure load value for the bridges is as follows:

- Solid Sections : 19.4 KN.
- Hollow sections : 23.7 KN.

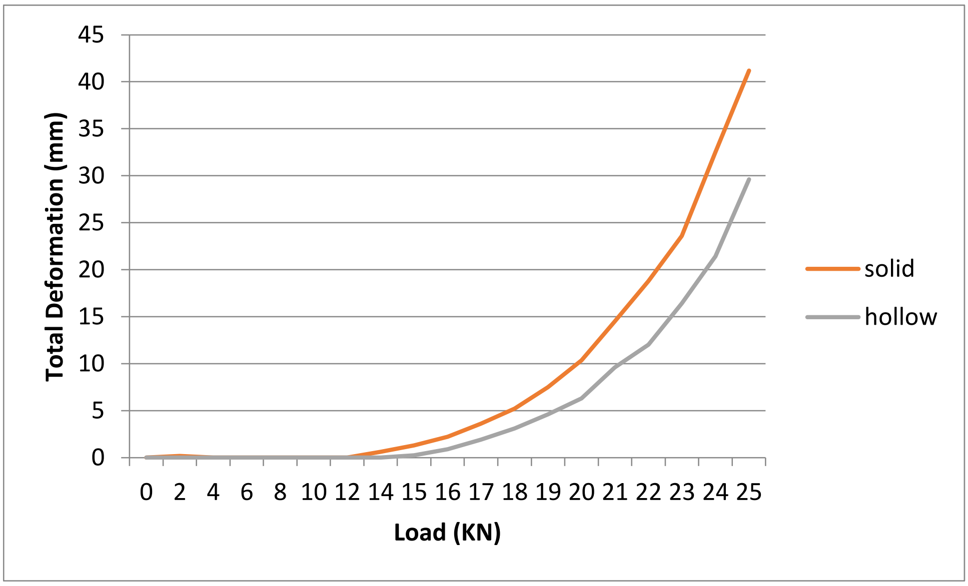


Figure 4.11 Total Deformation comparison from the results collected from ANSYS.

4.3 Results Comparison:

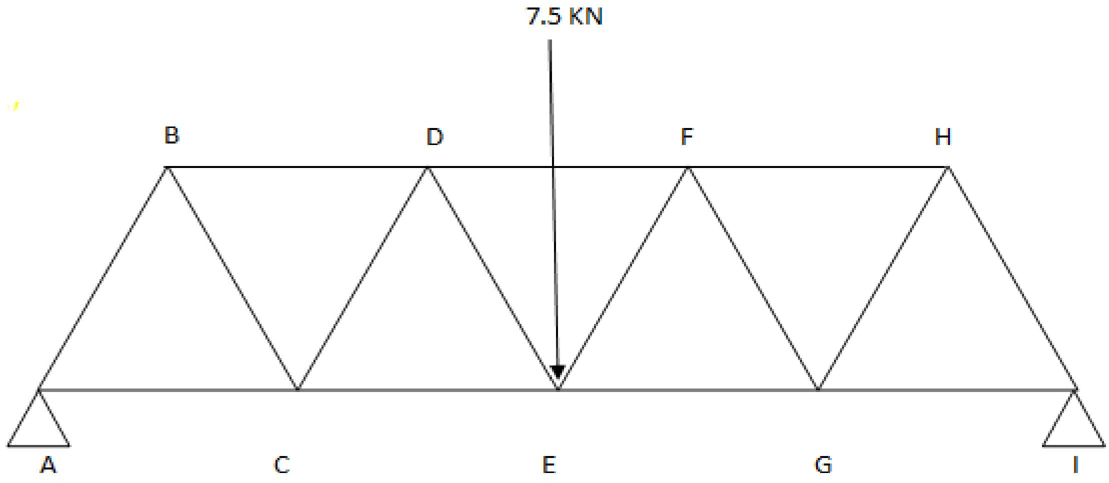


Figure 4.12 Bridge geometry with location of load at the centre.

By Analytical method we find out the axial force for the prototype having Angle and Hollow section using method of joints. Angle between any two members is 60°.

Length of one member = 300mm

Total span length = 1200mm

Modulus of Elasticity of Aluminium = 69GPa

Table of calculation is given below:

Table 4.8 Calculated Direct stress for various members of prototype.

Member	Forces(KN)	Direct Stress(MPa)	
		Angle	Hollow
AB	-4.33	24.25	23.66
AC	2.165	12.13	11.83
BC	4.33	24.25	23.66
BD	0	0	0
CD	-4.33	24.25	23.66
CE	5.77	32.32	30.13
DE	4.33	24.25	23.66
DF	-4.33	24.25	23.33

Deflection on the nodes has been calculated by using virtual load method. The calculation results are given bellow

Table 4.9 Deflection values at nodes.

Nodes	Deflection(mm)	
	Angle	Hollow
A	0	0
C	1.45	1.05
E	1.91	1.58
G	1.44	1.04
I	0	0

In this section values of all the result parameters from software and values derived analytically for prototype on the basis of load and deflection are compared.

Table 4.10 Results Comparison between software values and calculated values

Result Parameter	Software		Prototype		Error Percentage	
	Solid	Hollow	Solid	Hollow	Solid	Hollow
Maximum Deflection (mm)	1.74	1.44	1.9	1.58	9.19%	9.7%
Maximum Direct Stress (Mpa)	30.77	28.65	32.36	32.13	5.03%	5.15%
Maximum Axial Force (KN)	5.58	5.28	5.77	5.77	9.28%	9.28%

CHAPTER-5

CONCLUSIONS

5.1 Conclusions

This project discussed the comparative analysis of steel truss bridge by replacing solid sections with hollow sections. The theory suggested that hollow sections are better than solid sections and project was aimed at making that comparison in case of truss bridges because every year many new bridges are made and solid sections are being used in most of the bridges. If hollow sections are used instead of solid sections more durable bridges can be made and also the tonnage can be reduced.

Steel is being used worldwide on railways and road bridges successfully and the reason is its inherent better strength quality, weld ability, good resistance against toughness. Use of steel in structural application has played a very important role in reducing weight of structure.

Introduction of bridges made up of hollow sections in railways and highways will be a good decision for the up gradation and cost saving. The superiority of hollow sections is clearly indicated in ANSYS analysis results and results collected from prototype testing.

From our study we have drawn following conclusions.

1. The various results taken on various result parameters such as total deformation, axial force, direct stress, equivalent and combined stresses show that hollow sections when replaced to solid sections shows good results and are more efficient than solid sections.
2. Rectangular solid sections perform better than the angle sections in Truss Bridge.
3. Hollow sections can replace solid sections efficiently while reducing the tonnage of the Truss and saving money ultimately.
4. Values collected from prototype testing are a bit lower than the values collected from the software analysis. The reason is losses during construction, losses during rolling of sections, losses during transportation and losses caused during loading and unloading of materials.

5.2 Future scope of research.

1. The present study was done in a very short span of time testing of more prototypes made up of circular or hexagonal sections and analysing results in depth can give much more improvements and though advanced research on this topic cost can be decreased further while increasing the life of truss bridges and other truss structures.
2. Hollow sections can be filled with concrete or other cheaper materials to further increase the properties of section and increase the durability of structure.
3. Also in place of static loading dynamic loadings can be taken into consideration all it needs is suitable loading arrangement.
4. Analysis of different type of truss bridges such as sub divided truss, cantilever truss bridge, arch bridge and continuous bridge truss.
5. Using another computer software program to design and analysis process for bridges.

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