ANALYSIS OF TRUSS BRIDGE AND COST OPTIMIZATION BY USING HOLLOW SECTIONS

A THESIS

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Under the supervision

of

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MAY -2019

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"ANALYSIS OF TRUSS BRIDGE AND COST OPTIMIZATION BY USING HOLLOW SECTIONS"** submitted for partial fulfilment of the requirements for the degree of Master of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Kaushal Kumar Assistant Professor**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Signature of Student

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-May- 2019

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"ANALYSIS OF TRUSS BRIDGE AND COST OPTIMIZATION BY USING HOLLOW SECTIONS"** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in "Structural Engineering" and submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Sahil Bhatia(172657)** during a period from July, 2018 to May, 2019 under the supervision of **Mr. Kaushal Kumar,** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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

Date: - ………………………

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I, Sahil Bhatia would like to acknowledge my work on **"ANALYSIS OF TRUSS BRIDGE AND COST OPTIMIZATION BY USING HOLLOW SECTIONS".**

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ABSTRACT

Bridges are constructed for connection road, railway in the obstacle like canal, river, valley etc. truss bridges are the structure whose load bearing superstructure are made up of Truss. Truss usually transfer its load to single member to others members because of its rigid nature. In truss bridges solid section like angular section are expensive to construct and difficult to transport from one place to another. As we know hollow sections are economic structure having greater radius of gyration by which compressive strength increases.

In this research I take solid and hollow section for the comparison. Making economical bridge use of hollow section is the revolution. Design and the structural analysis for both the bridges are carried out in the ANSYS Work Bench software. The whole study is about to design and analyze the component of truss bridge having Angular section and then replace it by Hollow section after which compare their result. This is the software part after which for practical performance I design a prototype having a span of 1.2m for Angular section which further tested after which replaces it by Hollow section and then compare their result.

Keywords: Hollow Structural Sections, ANSYS, Fatigue test, Bridge Design.

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CHAPTER 1
INTRODUCTION

Bridges are the structure constructed for sporting the railway and road traffic or other moving Loads which are moving on Bridge. Bridges are constructed on obstruction which includes a river, channel, canyon, valley, avenue or railway. If a bridge is constructed to hold highway site visitors, its miles called a dual carriageway bridge. If, but, it's far built to carry railway site visitors, it's far referred to as a railway bridge.

In maximum part low weight metal structure were regularly prepare to the options which include pre-stress concrete and reinforce concrete. The benefits of steel shape had been its energy, economical and easy to transport and faster assembly. Steel structures were dismantling without loss to the reliability of the authentic shape. Most structural metal gadgets were prefabricated in a workshop with an advanced high-quality manage compared to In-situ production. Tolerance exact inside the Indian Standard codes for metal structural thing at some point of the fabrication erection had been small in comparison to comparable bolstered concrete structures. Steel also performs a vital function in composite creation together with reinforced and priestess concrete shape. With the development of metal as a construction cloth, the styles of metal sections had been also elevated. Among these sections, the Hollow structural sections (HSS) or Structural whole sections had been the maximum reliable one. Due to their first-rate functions, the utility of those sections in gift commercial marketplace has been pretty elevated.

1.1 Description on Truss Bridge

Bridge which superstructure is load bearing consist of steel is known as truss bridge having connecting normally forming shape triangular. The related factors may be puzzled from compression, tension or every so often each in reaction to dynamic loads. Steel bridges are one of the oldest sorts of modern bridges. The primary styles of steel bridges proven in this text have easy design which can be easily analysed by 19th and twentieth-century engineers. A Steel bridge is within your means to construct as it makes use of resources successfully.

1.2 Types of Truss Bridge

There are four types of truss bridges we construct

1. K Truss
2. Howe
3. Pratt
4. Warren
5. Vierendeel truss
6. Brown truss

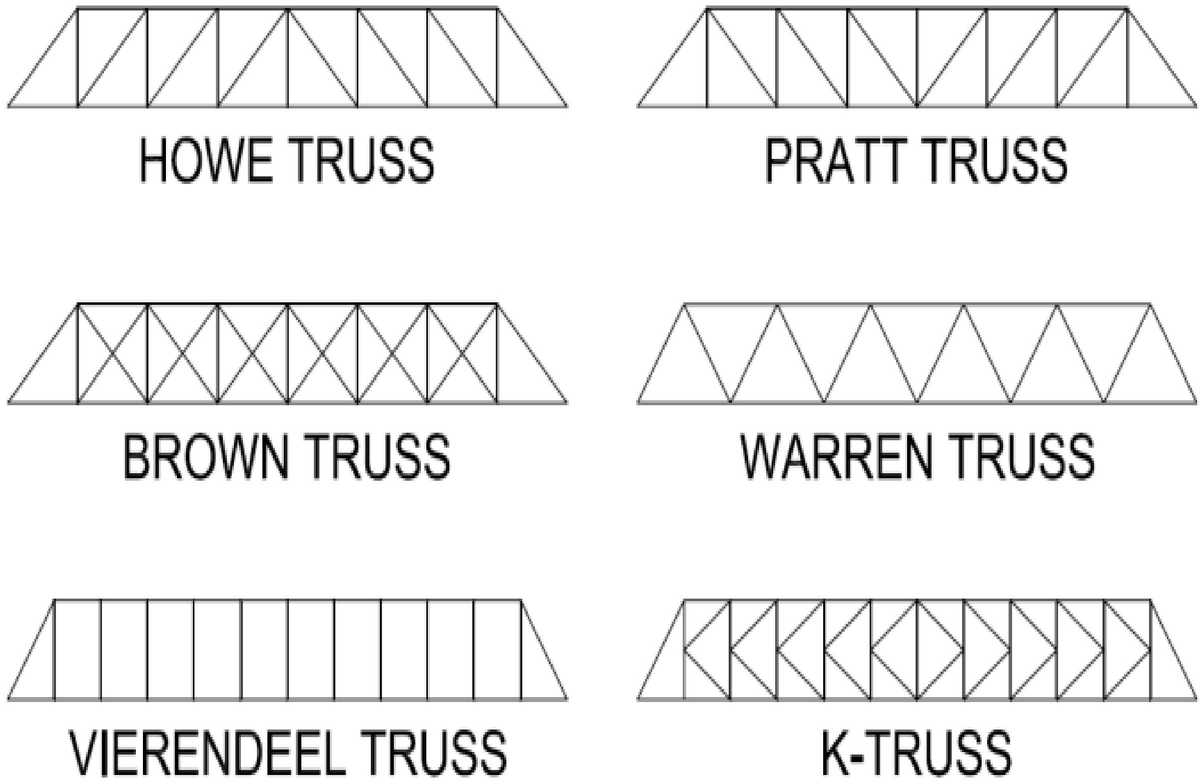

Fig 1.1 Various types of truss bridge(source- Book NrenderaTali)

1.3 Loading on truss Bridge

There are various loads which we are considering for competing stresses in the design of a bridge are following:

1. Erection forces
2. Racking force
3. Impact load
4. Dead load

5. Wind load
6. Seismic load
7. Live load
8. Thermal force
9. Forces on parapets
10. Longitudinal force
11. Forces due to curvature
12. Frictional resistance of expansion bearings

1.4 Truss Bridge Components

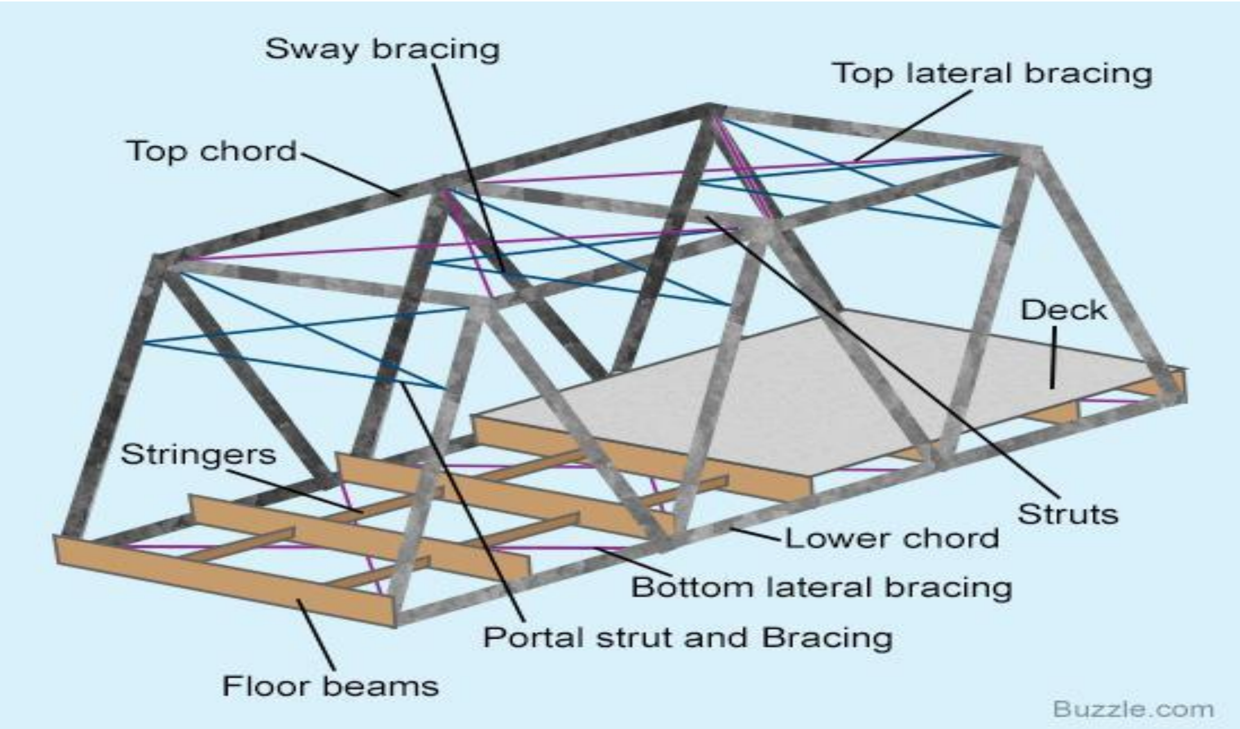

Fig 1.2 Different component in truss bridge (source- Book NrenderaTali)

Web member:

Web members are the members that could be diagonal or vertical in which compression and tension are depends on the type of the truss. “Post” is called when the members are in vertical compression and “hangers” are called when there is tension.

Top chords:

While we are done proportioning and detailing these members need special attention. In compression these members are highly stressed.

Cross bracing:

In distribution of the transverse load to the lateral system these bracing are provided. In this type of bracing the end support is provided to the top lateral bracing system.

Bottom Chords:

Bottom chords are the members which are highly stressed in tension. These members are also easily connected like riveting, bolting and welding.

Lateral bracing:

Lateral bracing is placed between the bottom and top chords of truss in pair.

End Post:

End post are those members which are placed in the end of the truss for caring the lateral forces in bridge bearing which is come from the top chord level.

Portal bracing:

The location of the portal bracing is in the end post. In top lateral bracing these bracing give end support.

1.5 Hollow section

A hollow structural section (HSS) is of metal type in which there is a hollow cross section. HSS (hollow structural section) may be of different shape like circular, rectangular, or square sections, despite the fact that other shapes including elliptical are also to be had. HSS (hollow structural section) is only self-possessed of structural steeper code. HSS (hollow structural section) is from time to time referenced as hollow structural steel. Rectangular and square hollow sections are also normally called tube metal or structural tubing. Hollow section which are of circular shape are known as steel pipe, although circular pipe are genuinely dimensioned and classed in a different way from hollow section (hollow section dimensions are based on outdoors dimensions of the profile; pipes also are synthetic to an exterior tolerance, albeit to a specific popular.) The corners of hollow section are have round in shape and have the circular radius which is about twice of wall thickness. There is uniform wall thickness across the segment

1.6 Use of hollow section in structure

Hollow sections are of different shape but particularly section having rectangular shape, are normally utilized in welded metallic frames where members are much taking loading. Circular and square hollow sections have extremely effective shapes for this a couple of loading as they've consistent geometry along two or more than cross-sectional axes, and hence uniform energy description. This makes them suitable alternatives for columns. However, the HSS has advanced resistance to lateral tensional buckling .The flat square surfaces of square HSS can ease production, and they're occasionally desired for architectural aesthetics in exposed structures, although elliptical HSS are getting extra popular in exposed systems for the equal aesthetic motives.

1.7 Function of Hollow Sections

Hollow sections gift a hanging benefit for use in building structures showing to fluid discharge, Air or water. There pull coefficients were lots decrease than the ones of everyday sections with sharp edges. Structures planned in hollow sections have a 20 to 50% smaller base to be covered than similar systems made up of using open sections. Many researchers have been completed to evaluate the probability of inner corrosion. These investigations, carried out in numerous international locations, show that inner corrosion does now not occur in sealed whole sections. Even in hollow sections which have been now not flawlessly sealed, internal corrosion become confined. If there was challenge approximately condensation in an imperfectly sealed hollow segment, a drainage hole can be made at a point where water cannot enter by way of gravity.

Different styles of programs are

1. Corrosion Protraction
2. Use of internal void
3. Concrete filling
4. Fire protection by water circulation

1.8 ANSYS Workbench

ANSYS might be universal purpose code, want to suggest connection of all department of vibration, physics, heat transfer, structural and magnetic force for purpose of engineer department. Functioning circumstances, allows checking in effective surroundings before producing prototypes of product. ANSYS code with its benchmark structure as seen and offers chance for taking solely required options. ANSYS will work integrated with alternative used engineering code on desktop by adding CAD and FEA affiliation modules. In this course first of all we are going to name the Finite component Method then we are going to begin to use ANSYS workbench code that is incredibly in style in finite component analysis programs. About ANSYS workbench program, we are going to use interface of the work bench, interface of the Mechanical and that we can find out how we will produce Mesh Models and that we also will name the small print of the Meshing Operations. And one amongst the vital factor is regarding during this subject shaping Contacts, Joints and Boundary Conditions.

After all this sort of vital data we are going to use Ansys workbench program with latest version nineteen for Static Structural analysis, Thermal analysis and Modal analysis. We are going to do countless example applications with Ansys workbench. We can begin learning from the beginning and that we will progress step by step thus it’s not necessary to understand something regarding the Ansys workbench code before this coaching. After this coaching course you'll learn he’s the Finite component Method, you'll be able to use the work bench interface, Mechanical interface, you'll be able coproduce correct Mesh Models, this is often one amongst the vital subject for doing a correct analysis, you’ll additionally learn outline contacts, joint and boundary conditions properly. When this coaching you’ll learn to try to static structural analysis, thermal analysis, modal analysis with Ansys workbench nineteen and you'll be able to connect these analyse stop every alternative once it's necessary.

1.8.1 Task which we can perform in workbench

1. Import models from CAD System
2. Conditioning models designed for simulations using the DesignModelar.
3. Performing FEA simulations with Simulation.
4. Optimising design using DesignXplorer or DesignXplorer VT.

1.9 Advantages of Hollow Steel Section

1) In Hollow Section there is higher strength as of weight ratio which means the weight of this section is less due to which cost is optimizing.
2) Hollow section are very useful as a support characteristics and in compression of structural member

3) In fire protection the Hollow section are very useful because it circulate the water in internal void in section due to which the temperature remain low in steel.
4) In bracing members of structure suited well due to the tensional strength of the Hollow Section.
5) In Hollow Section the internal void are present which can be used as the void which is filled by the concrete which helps in increasing the compressive strength.
6) Hollow section torsion constant is greater than 200 times in open section.
7) In Hollow Section there is transmitting of same torque undergoes less shear stress as compare to solid one.

1.10 Advantages of Angle section

1) In Angle Section there is 90 degree of bend which help it to resisting the bending due to its length.
2) Angle section is light weight, strong as compare to other section. Angle section is affordable in term of durability and strength as compare to other.
3) It can be used as economical project.
4) Angle sections are easy to work in structure because it is easy to handle. Bolting and joints are easy in this angle.
5) Availability of the Angle Section is Easy.
6) It's easy to reuse and recycle by melting and purifying into new forms, making it eco-friendly and sustainable.

1.11 Problem Statement

Truss bridges are mostly build-up of steel with conventional section which are mainly design and constructed as per the method are given. By this the cost of the brides are increase due to its increase in weight. So the hollow section is the best replacement for this problem. Hollow section are have better properties and economical in nature. So in this research we see the problems which are faced on applying the hollow section and the result are to be compared.

In my research I chose Pratt Truss Bridge which is further design and analyse in ANSYS Workbench by both Angular and Hollow rectangular Section.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Bridge production tends to occupy massive tasks that include the consumption of competencies linked to numerous engineering corrections such as civil, geology, electrical. So, adding the hard work of all worried should be careful. The preliminary plans are ready concerning the venture, inclusive of the traits demanded bridge; web spot info, and the necessity of assets. The bridge layout can be resolute by applying the type of bridge being constructed. The major classes of the bridges are beam, arch, truss, cantilever, and suspension. The beam bridge is one of the famous types. Bridges also can be classified via the deliberate use, like avenue and pedestrian pavement, rail bridge cloth to be used like steel or concrete, and stuck or moveable. Moveable bridges are constructed whilst the deliver height can be additional to the bridge floor. In such situations, the street has the capability to be lifted or pivoted, to allow marine visitors movement beneath it.

2.2 Paper Review

Cheng et al. [1] their study deals with the problem occurring in the hollow chord section which upon subjected upon loading results in the buckling of top flanges of chord member. For to overcome this, the concrete is moderately or fully filled in the welded T-joints and then the structure is analysed regarding the rigidities and having the load bearing capacity of the joints in structure. By partially filing of concrete in the joint, it results that the elastic rigidity becomes 15-17% greater than that of the hollow ones which further results in the good sectional strain property.

Cui et al. [2] their study deals with the fatigue damage that occurred due to the steel concentrations and weld stresses of a welded T-joint of a steel truss bridge. For overcome this, Corner Fillet Profile and Ultrasonic Impact Treatment are used and analysed experimentally. This includes the peak stress method because of its high applicability and good accuracy. As a result, it is concluded that use of both profiles results in increase in fatigue performance of the joints as 24% in case of CFP and 36% in UIT. And combination of both results in 60% increase in fatigue resistance.

Taylor et al.[3]Their study includes the fatigue strength of T-joint in a fully welded steel truss bridge on large scale on basis of notch stress approach through a experimental programme which then followed by the numerical analysis. Finite Element Analysis is done as regards the consequence of plate thickness and the whole radius on the efficient notch stress. Different specimen tested. But the specimen having butt weld to be condescending have slightly higher fatigue life than that of designed curve, and in the graph the critical location get changed from HS1 (hotspot) to HS2. As a whole, it is then concluded that the fatigue life designed curves are directly based mostly on large scale data, but can scale specimens too and it appears to be conservative in nature from a fatigue life point of view.

Pedro et al.[4] Their Study give us the current aims of the composite truss bridge which can be constructed for the railway and the road bridges. Composite truss bridges are the revolution in the bridge design which give the effective results and the strength are also good. In composite bridges the cables are connected with the girder of the truss and give full support to the bridge. For the high speed railway and in the bridges having large traffic are now constructed by the composite truss bridge. Span of these bridges are up to 540 m long. From the data the dynamic loading are now affect the bridges due to which load is increases day by day and chance for the brides to fail.

Liu et al. [5]In this study, the main focus is emphasises on the fatigue cracks that developed in the joints of steel truss bridge due to the long term dynamic loading. The model having the crack is analysed by the Finite Element Software – ANSYS. Intensity factor is the main term that is highlighted the most in this modelling. Modelling method is based on the idea of breakup the whole structure into the parts. Cracked part is separated from the main model by Boolean operation. And then the meshing of cracked and other part is implied. Values of stress intensity factor (SIF) that came out directly relates to the fatigue life estimation of the structure.

Josef Machacekaand Martin Cudejko [6] in this study with deference to the writer's earlier experimental research report in references, the numerical analysis and the Euro code move toward about dispersion. The main concern is loyal to elastic and elastic–plastic probability distribution of the flow corresponding to the design level of bridge loading and plastic collapse. The analysis covers both the average elastic frame 2D modeling of the shear link used by architects and the 3D GMNA (geometrically and materially non-linear analysis) using ANSYS software package. Results of the numerousness of models are equally equated and tackle with purveys of Euro code 4 for composite bridges. The non-linear sharing of the longitudinal shear, necessary for correct design of shear association of composite steel and concrete bridges (in both ultimate limit state counting fatigue and serviceability limit state) substantially depends on rigidity of the shear connection and compression of the shear connectors above truss nodes. These issues are analyzed in parametric statistic studies, pointed out and finally some recommendation for practical design is recommended.

Akio Kasuga [7] studied construction method which is developed a balance structure for more than 10years and then compares the single span bridge with suspension bridge. The construction of the concrete deck and steel truss in this structure are on the with a leg on each side of cables. During construction, the corresponding forces of these cables are distribute out into the ground, but after the result is carried for of the bridge, the forces are of pre-stressing for the concrete upper and lower transfer load. Using this way to bridge a bottomless valley produces profit in terms of both construction cost and sustainability. A bridge with single span requires fewer excavations than other bridge types, and the environmental collision of construction are utilizing by composite truss.

Frangopol et al. [8] their main purpose in this thesis to give study about the main truss system and in the USA the greatest category is the long span truss bridge having whole structure system. In long span bridge there is protection with components depends upon the probalistic and their organisation consistency .in the older time long span bridges are design according to the stress not counting there consistency. For the analysis part the reliability is based upon the distribution to the wind, live and dead loads .this type of bridges give us long time structural health monitoring where the number of data for input and response are composed. In the analysis the main factor which is provided is the conventional analysis part which is done in this thesis.

Mehrjoo et al. [9] tell us in open up new promise in Artificial Neural Network (ANNs) has promise in the field of inverse problems. For opposite trouble like structural recognition of huge structures (such as bridges) anywhere in situ calculated data are accepted to be inaccurate and frequently unfinished, ANNs give us greater promise. This study give us the estimation of the joints which are damage using a back propagation which is based upon the neural network. The method that was employed to conquer the issues associated with a lot of unknown parameters in a large structural scheme is the sub structural identification. The natural frequencies and form shapes were used as enter parameters to the neural network for damage recognition, mostly for the case with incomplete measurements of the mode shapes.

E Bhargavi and GVR Rao [10] said that in Asian nation and outside of Asia there is majority of truss bridges which are functionally obsolete or structurally deficient. There's a desperate have to be compelled to enhance the performance of those existing bridges by associate degree acceptable technique that ought to be economical and with minimum disturbance to the traffic. The aim of the current analytical work is to understand the result of Pre-stressing on the member forces, deflections and total weight of steel of a statically determinate 3sorts of trusses like Pratt sort (Type A), Warren truss (Type B), Lattice Truss (Type C).Pre-stressing method has remained accepted to improvement the performance of the truss. There is cable which is straight in the pre-stressed with high tensile cable and also its profile. The truss is examined for member forces and deflections exploitation STAAD professional package. From the obtained analytical results, it's seen that there's lucid improvement within the performance of the structure. Member forces are reduced considerably within the entire truss members and there's discount in deflection at the centre and material demand when pre-stressing.

Wardhana et al.[11] tell us about the life of the bridge is taken as one year (during Construction) to the 150 year. The main common cases of bridge failures were characterized to collision and flood. Flood and scour, with the key flood disaster in 1993, gave to the oftenest peak of bridge failures (almost fifty three of all failures). Bridge overload and lateral impact forces from trucks, barges/ships, and trains represent100th of the whole bridge failures. There is different primary are evaluated as maintenance, construction, detailing, and construction. Comparing created among 3 periods of corresponding studies (1977–1981, 1982–1988, and 1989–2000) disclosed nearly similar trends, with most failures occurring throughout the bridge's service life. Also, human-induced external events occurred of all told3periodshowever were most dominant within the initial and third periods. Technological advances in data systems have a good impact on information assortment and analysis.

Azizinamini [12] are said that in the examination for understand the behaviour of the ultimate load and the old truss brides which were transports for the steel truss bridge in structural laboratory. The initial step is to test the ultimate load for the testing of the bridges in exiting organization without any retrofit. The failure gives us progressively and there was ample warning earlier the failure. A major conclusion from ultimate load tests was that in inspecting old steel truss bridges one should pay very close attention to tension members that use forging.

Cho et al. [13] their researches meant to prove standard and reliability-based methods to the collapse cause calculation so a tosspot the results of H beam and installed on the failure of a steel span ended the Han dynasty stream in Korean Peninsula solely fifteen years once gap to traffic. Moreover, it's going to be discovered that each the out-dated and reliability-based S-N and linear elastic fracture mechanisms (LEFM) methods in terms of the predictable fatigue life and also the fatigue failure probability offer regarding similar and compatible results. This means that any of the responsibility method might be used as effective and rational methods for the measurable investigation of the progressive collapse causes, alongside the aids of standard S-N/LEFM fatigue analysis.

Lee and S.B [14] this paper is a case study of a collapsed bridge in west Virginia USA. This bridge had a Gerber suspended truss structure. Tests performed to check the reason for collapse were Chemical Composition, mechanical testing (chirpy v notch test), testing of welds (ultrasonic and x-ray testing), fatigue test(S-N curve), Chemical composition test suggested that quality of material was good. Mechanical testing indicates that material had sufficient capacity to resist brittle fracture even at temperature as low as -20’CWhile testing the welds it was found that penetration of welds was not sufficient-N curves also suggested that structure would not have failed if welds were penetrated to full depth.

Ventura et al. [15] said that results in this paper are carried from Colquitz River Bridge situated near Victoria for full scale tests performed on it. In 1992 the dynamic characteristics of the structure are determined. The length of bridge is 82.68m long, width of the deck is 11.89 m and thickness is 175mm of concrete deck are supported by the six continuous steel girders. Due to its typical nature this bridge is chosen for the testing. The location of bridge is excellent having site accessibility and high seismic risk. Tests performed by traffic vibration and the other sources for the dynamic loading calculation. The dynamic loading is calculated in 50 different locations of the deck, abutments and piers. By these tests the large number of data is collected which is further processed and analysed at the University of British Columbia. The data of principal modes of vibration are collected immediately after identification. In this bridge guild release pullback and ambient vibration tests which were conducted to verify the frequency determined from vibration test and to determine fundamental modes damping. The force in this test is about 90KN at a selected location are apply load after applying load quickly release for induce free vibration. By this test data is used for the further finite element mode of bridge to compute it after it used to determine the dynamic behaviour of specific components of bridge. All the data is collected by these tests are further used in response during the earthquake.

Shelley et al. [16] said that combined experimental and analytical analysis, lead for travelling objective, international situation measurement and analysis done for the bridge serviceableness. A connected word with definition used for important terms is obtainable. Non-destructive and harmful checking Field-calibrated analytical models, , area unit studied to grasp the important behaviour and performance of actual bridges and to quantify relative contributions of various stiffness and resistance mechanisms. Whereas our heuristic mental object has served North American nation well, additional rationalizing our bridge engineering apply is required to attain the optimum management of the main road transportation infrastructure necessary for continued advances within the next century.

ShivrajD.Kopare and. S. Upase[17] Tell us about the bridges and their strength. After providing the various load check their strength and the behaviour of the bridge like deflection, age etc. the main objective of this research is make an effective, economical, safety and the strength of the bridge. Scope of the research is to associate the parameter for the designing of the bridge. The main part is to take the thickness, depth and length of the bridge. Plate beam is discussed in use of steel in building and use to taking high load and proportioning of area is done easily. Steel structures have high strength, and weight of the steel structure is less than other structure. Plate beam in the thesis is taking as per IS 800:2007 and analysed in SAP 2000. After all this plate beam are getting good result.

Salawu and Williams [18] tell us about the loading on the structure. The main objective of thesis is the dynamic loading applied on the bridge or structure. To check the performance and behaviour by applying dynamic load on the structure and give the dynamic loading on the bridge is important in indignity bridges. Parameter of dynamic loads excitation forced, modal parameter like damping value, natural frequency, mode shape and other in the system parameter like damping matrices, stiffness and structural mass. There parameters are decide the performance of the bridge for dynamic loading check the static load. After satisfy static load the dynamic loading is provided

2.3 Summary of literature review

After the complete study of the journals and research paper, the conclusion is came as there is very less research which is done on this topic. In roof truss hollow section are generally used and are successful because it performs better as compare to angle section. By study the research papers I concluded that we can use hollow section in the bridges foe the better result as compare to the hollow section. Hollow sections are better in compression because its radius of gyration and the cost of the bridge also optimise.

2.4 Objective

The following are some of the prime objective of this study:

1. Comparative Analysis of truss bridge having two cross sections(Solid Section and Hollow section) in ANSYS Workbench
2. To optimizes the cost of the bridge.
3. Making Prototype of bridge for both Solid and Hollow sections and validating ANSYS results.

CHAPTER 3
METHODOLOGY

3.1 General

Bridges are the structure used to construct road, railway passage connection. They are constructed over any gaps like valleys, river, canal, etc. Method which is used in this research is to carry the design of truss bridge and analysis it having a span of 1.2m using the two different sections (Angle section and Hollow section). The performances of both the bridges are similar for achieving the result having ultimate goals of reducing the tonnage. Design and the structural analysis for both the bridges are carried out in the ANSYS Work Bench software. The whole study is about to design and analyze the component of truss bridge having Angular section and then replace it by Hollow section after which compare their result. This is the software part after which for practical performance I design a prototype having a span of 1.2m for Angular section after which replaces it by Hollow section and then compare their result. Hollow section are strong, having load bearing capacity, economical and strong as compare to Angular section.

The research is done in two parts-

i. By analyzing and comparing the displacement of different member in truss bridge in Hollow section And Angular section using the ANSYS software.
ii. By making the Prototype of the bridge having Angular and Hollow Section and comparing their result in same parameters.

3.2 Classifications on bridges

Brides are classifies as many ways depends upon their objective. As we know bridges are the structure which is built for the span a physical obstacle such as road, valley etc. construction of brides are done for providing passage over obstacle. Classification on bridges is discussed below:

3.2.1 On the basis of material:

i. Steel bridges: these types of the bridges are constructed in having long span where moving load is high. They are the primary materials which are used in arches, decks, suspension cables and in trusses.

ii. Concrete bridges: On the basis of material this type is most common used in construction of the bridges. In concrete type there are pre-stressed and reinforce types are bridges are common.

iii. Timber bridges: the structure of timber bridges are made up of wood. These are also called temporary bridges.

Fig. 3.1 Image of truss bridge

3.2.2 On the basis of life of bridge:

i. Temporary bridges: The constructions of these types of bridges are for short span for the use of short time like military bridges etc.

ii. Permanent brides: The lives of these types of bridges are 100 or more than that. Permanent bridge are mostly constructed where the life is depends upon their design, load taking capacity etc.

3.2.3 On the basis of Structural system :

i. Truss bridges: Members of this type of bridge is steel type truss member which resist forces axial in compression or in tension. The members are constructed in triangular shape.

ii. Beam having T structure: In this type live load is supported side by side in Reinforced Concrete Beam.

iii. Suspension bridges: these bridges are supported the main girders by vertical hangers which are carrying suspension cable support. These are constructed for long span and having high depth.

iv. Box-girder brides: in this the main girder having steel place whose girder multiple and single box beam fabrication.

v. Arch bridges: The shapes of the bridges are arch whose super structure is in arch shape. The compression load which is resist in axial compression are transfer by curved arch in abutment.

vi. Stayed cable bridges: High strength steel cables are connected with main girder of the bridge. One or more than one tower are constructed for connecting the cables to the tower which are based upon the length of the span.

3.2.4 On the basis of function:

i. Highway bridges: In this type there is vehicle traffic are calculated which is of trucks, Car , Buses, Tanks etc .in highway bridges there are also lane is provide as per Code like single , double etc.

ii. Railway bridges: Bridges which are constructed for the crossing of railway are known as railway bridges. These bridges are mainly constructed by steel truss.

iii. Combine bridges: Bridges which are constructed for both train and railway are called combine bridges. Two decks are provided in this type one is for rail and second for vehicle.

3.2.5 On the basis of Support Condition:

i. Simply Supported: hinged are simply supported in main girder or in trusses which is fixed in one end and other end is movable, equilibrium condition is provided for the analyzing of the support.

ii. Continuous Support bridges: the support in this type is continuous which is on main girder or Trusses .in this type the joints expansion are less by this the maintenance is low and it became economical.

iii. Rigid frame bridges: Sub-structure rigidly connected to the bridge main girder.

3.2.6 On the basis of Span length:

i. Short Span: These types of bridges have 50m length due to the short length it is called as short span bridges.

ii. Long Span: These types of bridges have 200m or more than 200m span length.

iii. Medium Span: the span length of this types of bridges are given between 50m to 200m. These are most common type of bridges.

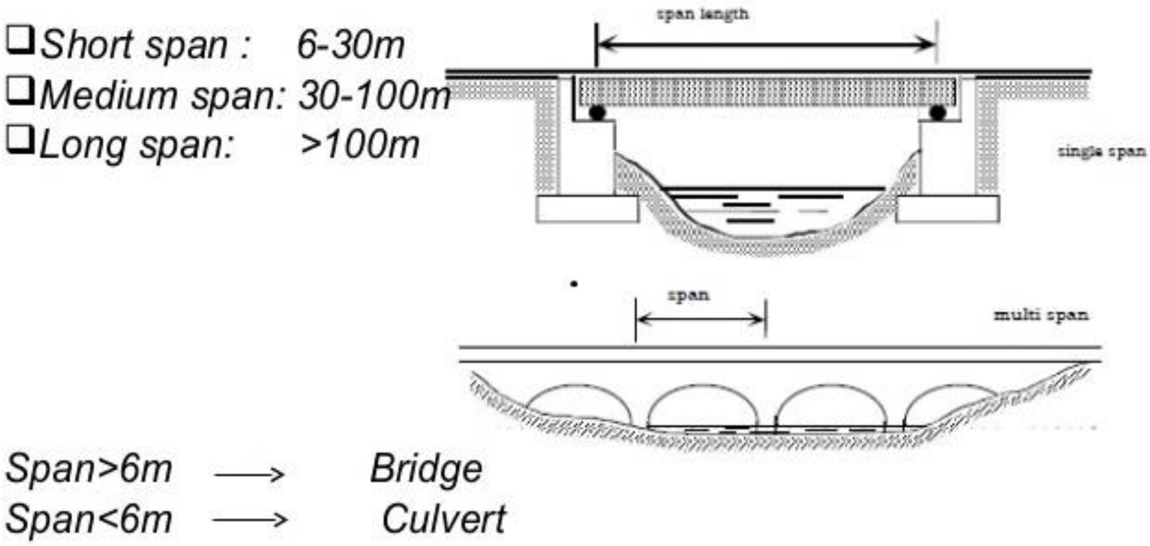

Fig. 3.2different span Length Bridge

3.3 Reason for Bridge failures

The reason for the failure of bridge is based upon material of the bridge like timber, steel, concrete, etc. In steel bridge most common failures are fracture, buckling, fatigue, shearing, corrosion and yielding. Others reason in the sub structure of the bridges during flood soil erosion happen due to which soil is settle and cause failure in both concrete and steel bridge. The most common failure of bridge is due to the deficiencies in design and defect in design, due to section loss there is overstress happen o the structural element, during construction there is failure happen, during earthquake, due to fire and lack of inspection causes bridge failure.

3.4 Distribution of load in Steel Truss bridge

In truss bridges load is transfer from all the members of the truss or all the nodes of the truss. Gravity load which is applied on the truss bridge is inducing by moving vehicle load which are transfer on the supporting piers. Loading is distributed by the condition which depends upon the span length or other members by seen all this we decide deck type. Frame of the steel bridge play an important role in the distribution of load in bridges by distribute load to the node.

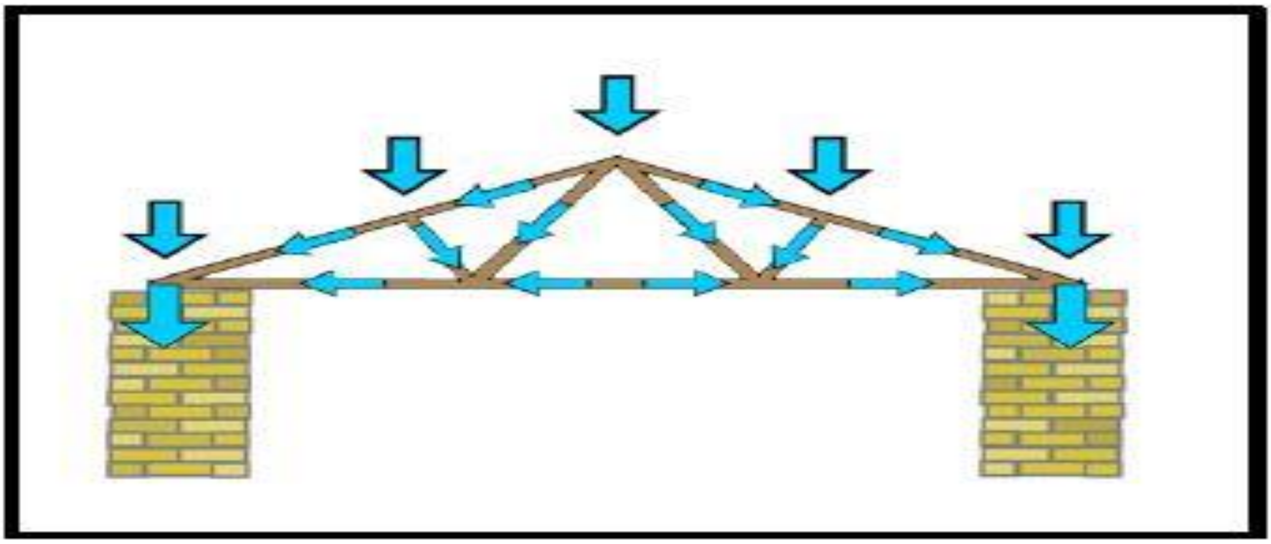

Fig 3.3 load distribution on truss bridge (source- Book NrenderaTali)

3.5 Loads on Bridges

When we construct a bridge we have to consider its environment and weight .by the nature of the bridge loads are decided on it. Various loads are act on the bridge but in my case I discuss about those loading which I take for analysis of bridge.

1. Live Load
2. Thermal forces
3. Dead Load
4. Impact load
5. Seismic load

3.5.1 Live Load:

Weight which is applied due to the vehicle movement and pedestrian movement are called as live load. Live load is load which changes with respect of time and load applied also changes. Example of live load is bike, cars, trucks, etc. moving on the bridge are calculated as live load. There are four type of IRC loading which is depends upon the location, purpose, and properties of bridge. Following are the type of loading which is given

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

1. IRC Class AA Loading

This loading is consists for both wheeled and tracked vehicle with dimension as shown in fig below. This type of loading are used in highway, railway etc. Bridge design in this type of loading is checked for the IRC class A loading.

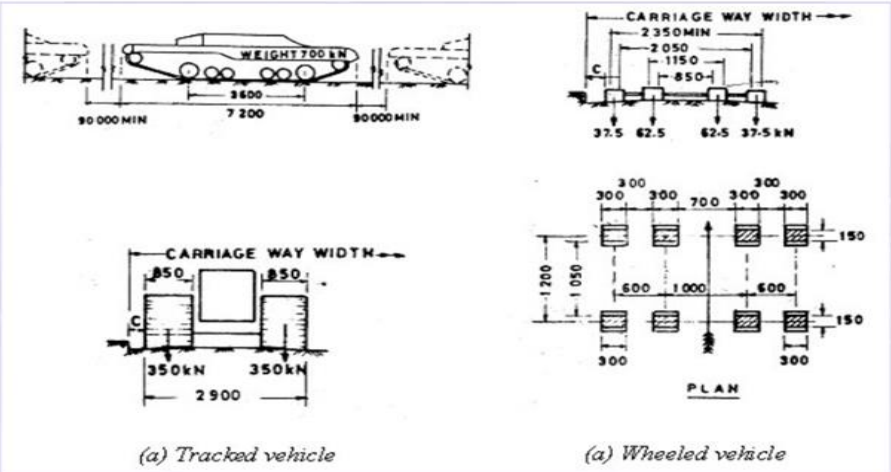

Fig 3.4 Imprint details of Class AA loading(source- IRC 6:2014)

2. IRC Class B Loading

Class B Loading is applied for the temporary structures like timber Bridge etc for the specified areas.

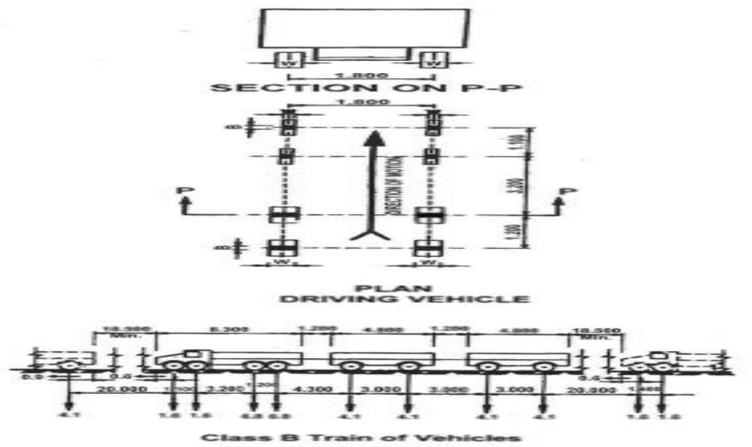

Fig 3.5 Imprint details of Class B loading(source- IRC 6:2014)

3. IRC Class A Loading

This type of loading is given for the two trailers having specified spacing and wheel load vehicle. Class A loading is used for designing purposes as well as for the confirming the bridges in upper class loadings.

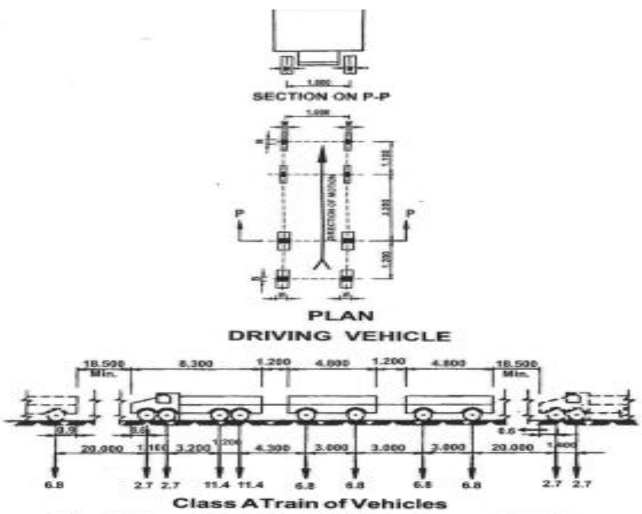

Fig 3.6 Imprint details of Class A loading (source- IRC 6:2014)

4. IRC Class 70R Loading

This Loading is used in the construction and design purposes for large span bridges or permanent bridges. This type is the heaviest type of loading in the IRC class. while designing we check further for the class A loading for certain conditions cause it generate high stresses in class A loading.

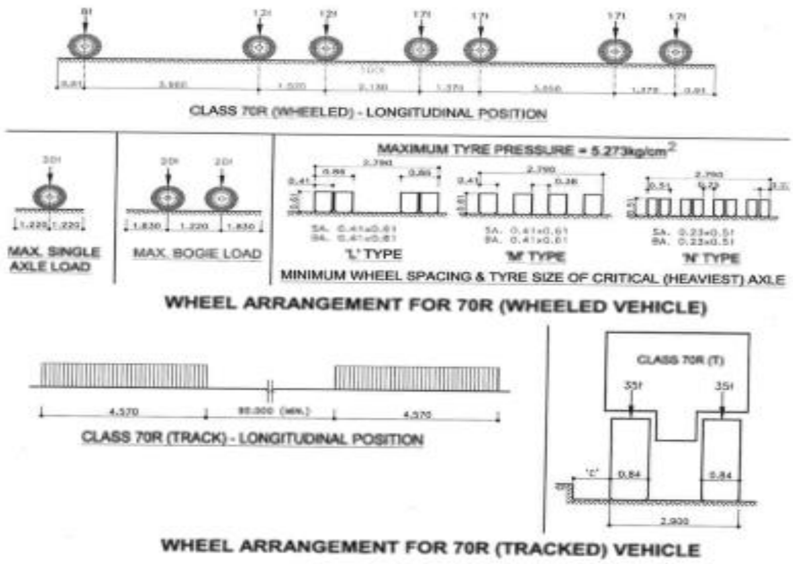

Fig 3.7 Imprint details of 70Rloading (source- IRC 6:2014)

As we studied different types of Loading in the IRC Class. I chose Class 70R loading for my Design Purposes because we design a bridge for the common stresses and applied the loading.

3.5.2 Thermal forces

When there is variation in the solar radiation, air temperature, etc., due to which there is changes occur in the bridge temperature which can be called as effective bridge temperature. Due to temperature there is contraction or expansion which cause load effects.

3.5.3 Dead Load:

The self-weight of the structure or the weight of other structure applied on the constant magnitude and which is permanently attached to the structure are called as Dead load. Assumption of dead load always taken as in designing of the bridge after the successful result we decide to construct the bridge. The designing of bridge according to dead load is done as the load is transfer to one member to next member by the total load is distributed. Slab of bridge is design in case of Road Bridge because stringer transfer load from slab to floor beam, in main girder the load is given from floor beams to stringer. By all these assumption we have to design the bridge according to structure weight, loading etc.

Table 3.1 various materials having dead load (IRC 6:2014)

Material	Dead Load(Kg/m^3)
Stone Masonry	1120
Timber	800
Concrete	2400
Macadam or Rolled Gravel	2240
Pavement	2400
Aluminium	2800
Steel	7844

3.5.4 Impact load

In design of bridge impact load have to be satisfied. There is a percentage of live load vehicle should be computes in impact factor. In static position load consider is less than that of the moving vehicle produce load. In live load there is increment which allows impact as live load percentage.

i. For loadings of 70R and class AA

a. Spans which have less than 9m length

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

Wheeled vehicles: there is exact 25% of span length taken

b. Span which have 9m and more length

For tracked vehicles: there is exact 10% of span length

For wheeled vehicles: up to 23m span length is taken for 25% and there is 23m curve for span

ii. For loadings of Class A and Class B Loads:

From the equation given below are determine the fraction impact. Span lengths having 3m to 45m these equations are used.

a. Steel bridges having $= \frac{9}{13.5+L}$

b. Reinforced Concrete Bridges having $= \frac{4.5}{6+L}$

Length of span is denoted by L.

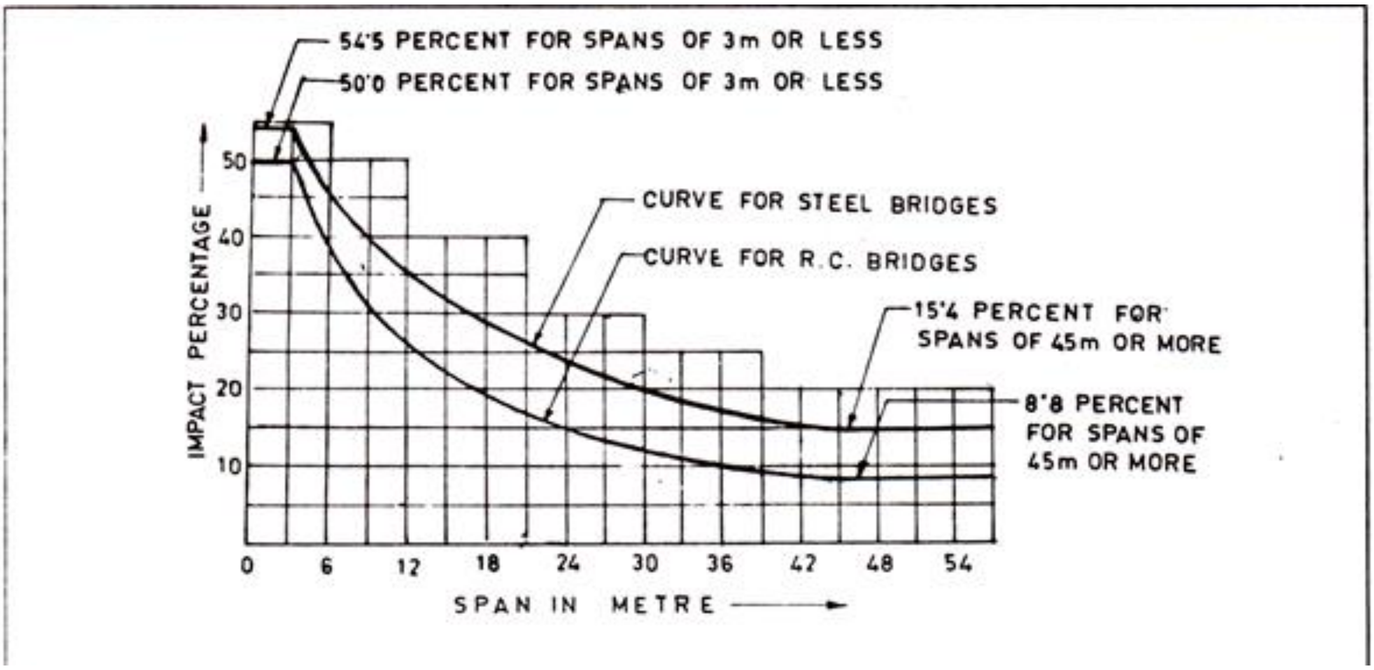

Figure 3.8 Impact percentage Curve (source- IRC 6-2014)

3.5.5 Longitudinal forces

For the longitudinal forces there are various provisions which are mention below

a. By driving vehicle acceleration forces are caused

b. Due to temperature change or other cause there is movement of bearing r resistance of friction which is offered.

c. From the effect of wheels breaking is resulting forces.

3.6 Truss bridges connection

Connection in truss members are of many type like riveting, welding, bolting etc. for the connection labour which construct trusses are skilled and have knowledge about the trusses connection. In railways riveting is provided but in other cases it is not as common. For the fatigue consideration riveting is used. But now the bolting and welding are done in most of the trusses. For the short span trusses there is connection which is provided in workshop and then transported to site and for long span welding and bolting is provided in site.

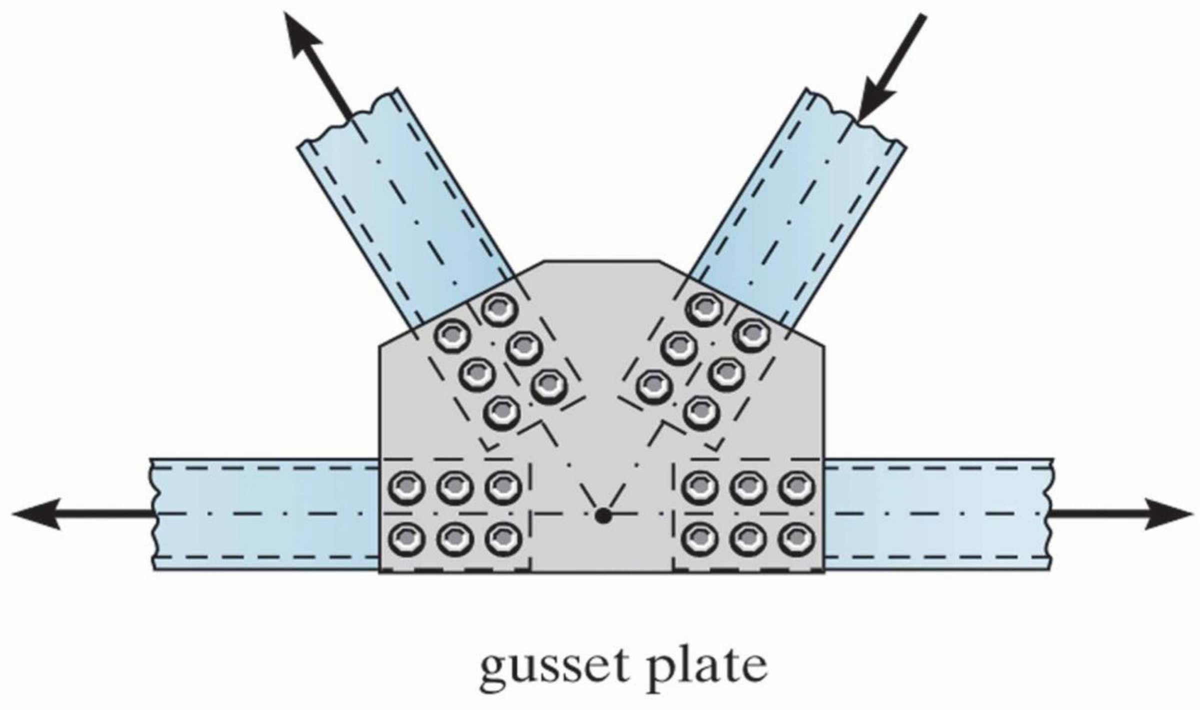

Fig 3.9 Truss Bridge joint

3.7 Design of Steel

Steel utilized in extension development is normally basic steel Confirming to IS: 2062(steel for universally useful) or IS: 8500(structural steel miniaturized scale alloyed) or IS11587 (structural climate safe steel). Steel secured by the above details contain: iron, a little level of carbon and manganese, and little amounts of alloying components to improve explicit properties of the last item, for example, copper, nickel, chromium, molybdenum and zirconium.

3.7.1 Steel stresses

i. Combined Stresses: in this members are subjected to the bending and axial forces are taken so that the portioning

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1 \quad \text{....3.1}$$

Where,

F_b = allowable bending stress

f_b = calculated bending strength

F_a = allowable axial stress

f_a = axial stress calculated

Due to the shear stress, bending and the bearing equivalent stress is calculated as,

$$f_e = \sqrt{f_b^2 + f_p^2 + f_b \times f_p + 3f_s^2} \quad \text{........... 3.2}$$

Where,

f_s = shearing stress

f_p = bearing stress

f_b = bending stress

There is 90 per cent of equivalent stress which is not exceeding more than that of yield stress.

ii. Basic permissible stresses*:* the value for the basic permissible stresses is extended by certain combination subjected to the increase limitation of the yield strength is not exceed 0.9.the stress in flexure and axial of permissible should take into effect of buckling. Under the live load , dead load with impact forces are taken from the table which is given below

Table 3.2 Steel having basic permissible stresses

S.No.	**Description**	**Permissible Stress**
1.	Shear	
	Maximum stress	$0.42f_y$
	Average stress	
	For $f_y \leq 250$MPa	$0.37f_y$
2.	Flexure;	
	In plates, flats and tubes	$0.65f_y$
	In girders and rolled sections	$0.61f_y$
3.	Axial Compression on effective width	$0.61f_y$
	For $f_y > 250$MPa	$0.34f_y$
4.	Bending stress on flat surface	$0.79f_y$
5.	Axial Tension on net area	$0.59f_y$

3.7.2 Limit for Load Deflection

In steel bridges the deflection due to load is an important issue. Deflection in bridges has to be in acceptable range in the limit load which pulls are attention because of the safety of the bridge.

For the deflection criteria there is a research done by Dr. Chung C. Fu of University of Maryland. In his research the multiple load behaviour on deflection is studied where the conclusion is the deflection in bridges due to load is L/1000 where span length is denoted by L.

3.7.3 Generals Details

i. Main Girder Spacing = the span spacing is not less than 1/20 of span having centre to centre of the main girder.

ii. Effective Span = the distance of the main girder effective span is distance between the centre of the bearing of the girder and distance of cross girder is between the main girder centre.

iii. Minimum sections = In bridge construction the thickness of the plate is 8mm and 6mm for main member and floor plates. Thickness should be increases 2mm if one side is not painting accessible. In ISA7550 specified the minimum size of the angle section. Main girder end angle is not less than three-quarter of cross girder thickness.

Fig.3.10 Image of angle section

Fig. 3.11 Image of Hollow section

iv. Effective depth = truss girder or plate effective depth is taken as distance of centre of gravity to lower to upper chords.
v. Deflection = the total deflection in plate girder, lattice girder and rolled steel beams is due to the live load, dead load. Impact load for the deflection is taken as 1/600 and for the live load impact should be 1/800. For cantilever arms 1/400 and 1/300 for the different span. Deflection of bridge gross are and gross moment should be taken.
vi. Minimum depth = following are the minimum depth value which are not be less than

Effective span for Trusses= 0.1

Effective span for plate girder and R.S joints= 0.04

For concrete and composite bridge,

Effective span for overall depth= 0.04

Effective span for girder and steel beam= 0.033

vii. Compression plates= plate width having unsupported is measured as adjacent of welds, bolt and rivet are connected to the plate having section not exceed 45t, where thickness is denoted by t. the plate unsupported project is measured from edge to the line of bolts and rivet and the 16t is the value for the connected plate.
viii. Effective sectional area = area of the member of effective section is the gross sectional flange having area deduction in bolt and rivet. Sum of section area is deducted for the maximum number of holes in right angle section to the member stress which is on right angle. The calculation of the holes is done by the whole actual diameter for rivet and diameter for bolt is 3mm have to be taken.
ix. Effective length of struts = the effective length is taken as the ratio of the value L/r for the purpose of calculation. Values for the length is to be taken as
   a) Restrain in direction and position effective held for both ends= 0.7L
   b) Restrain at one end and in position effective held is both end = 0.85L
   c) Restrained at one end in direction and position effective help but one the restrain is not happen on I direction at other end = 2L
   d) There is no restrain at one end and the position of effective held is both ends = 1L
x. Edge distance = at the centre of any bolt or rivet the minimum edge distance is taken as the 1.5 of the dia of the bolt or rivet.

3.8 Software Analysis of Prototype

In this part first we analyse the prototype in ANSYS Workbench. By analysing the bridge and calculate the rate of loading is applied on the bridge to deflection or how much the deflection is occurring in this prototype. Designing and analyses are done for both the bridges (Angular Section and Rectangular Hollow Section). After calculated the load by Analyses Bridge the practical part is done by making prototype of both the bridges and compare its result.

Step 1-In Design Modeller Create Geometry:

First I chose the warren truss for my prototype then after it length and other dimensions are calculated. While creating geometry of bridge structure the steps are done are given below:

a) In this step while taking care of the dimension we draw XY plane Geometry of the truss.

b) Then after drawing geometry the patterned are drawn at a distance which is equal to the bridge deck width.

c) After drawing patterned the nodes are created which then connected to the original geometry by drawing straight lines. After which floor beams are called bottom lines and top lateral struts.

d) Next step is to draw the deck which is rectangular surface body is drawn in ZX plane .thickness of slab is given by doing the proportioning.

e) After all the completion last step is to give imprint load to the deck slab according to dimension to the surface of the deck.

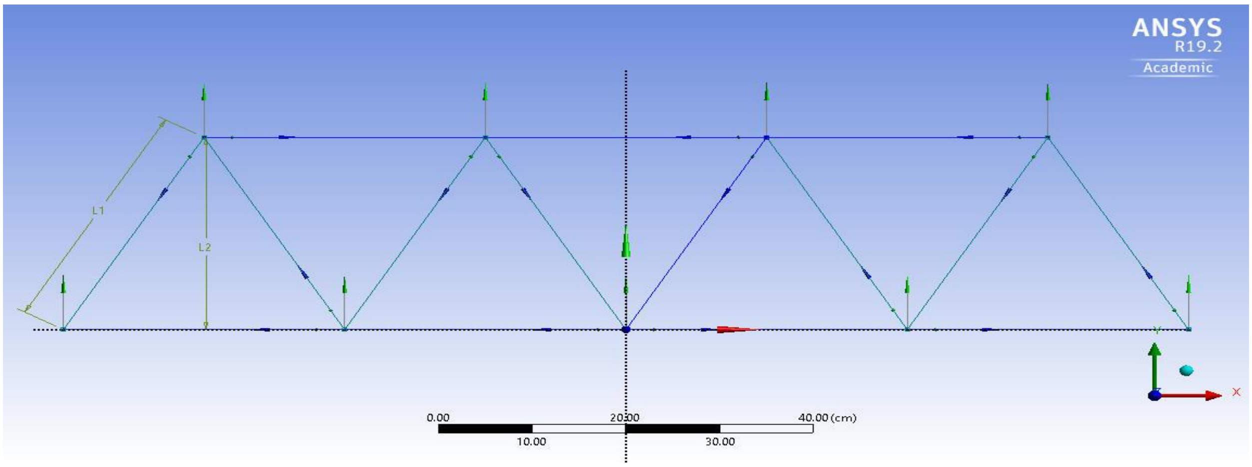

Figure 3.12 Geometry of line body of bridge

Here,

Vertical member length is $\mathbf{V_2}$ = 4m

Diagonal member length is $\mathbf{L_1}$ = 6.4m

Horizontal member length is $\mathbf{H_3}$=5m

Step 2-Cross Sections are Define:

In prototype of the bridge I take two cross sections one is Rectangular Hollow Section and second one is Angular section. First design Angular Section and computing its result, and same is done for Hollow Section. The dimensions of both the Sections are given below.

(i) Angular Section Detail:

The first section chose is Solid Section which is Angular in shape as shown in fig below.

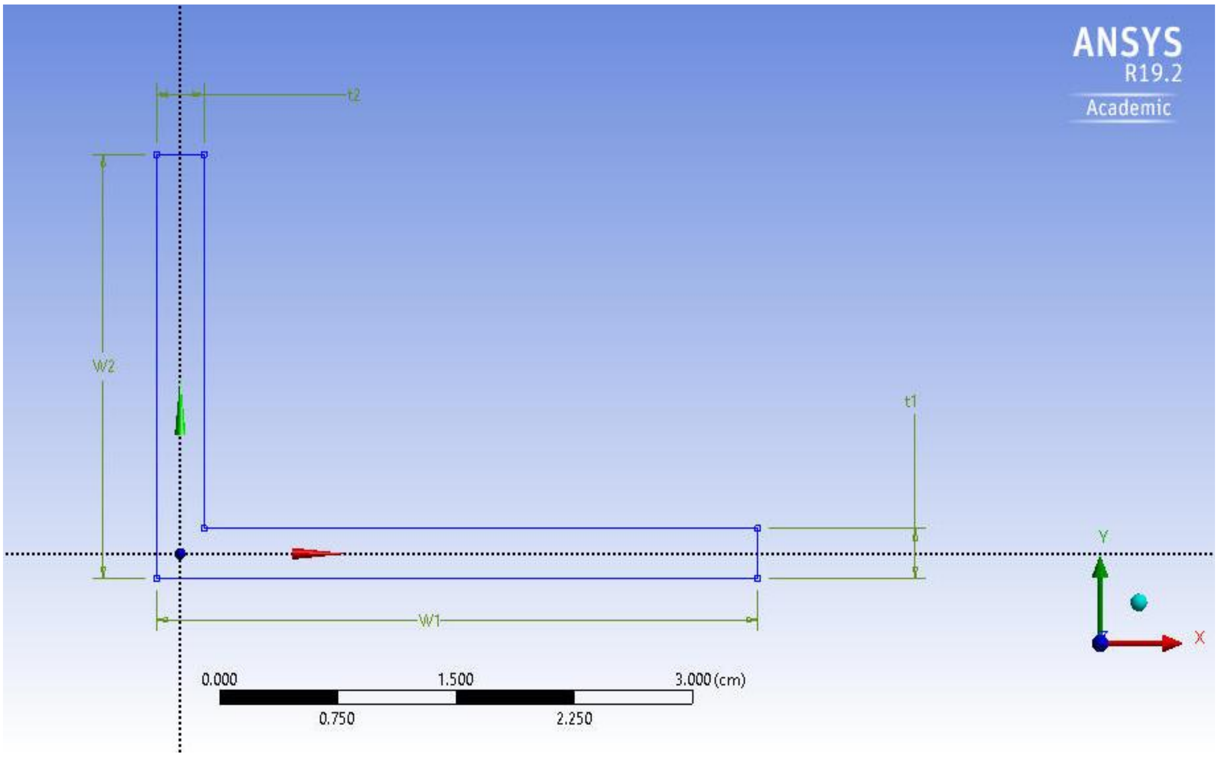

Figure 3.13 Cross section view having Angle section

Angular Section which I take in Prototype has unequal length so the Dimensions are:

Where,

Width of section (**W1**) = 3.81cm

Width of Section (**W2**) = 2.54cm

Thickness of the Angle Section is equal

T= 4cm

(ii) Hollow Section Detail:

The Second Section is taken as Hollow Section having Rectangular shape for equal load distribution to the Section. I chose Rectangular section as my Hollow section But having irregular width as equal to Angular Section. As we compare both the sections Hollow section ha less Weight as Compare to Angular Section. Dimensions of Hollow Section are given below:

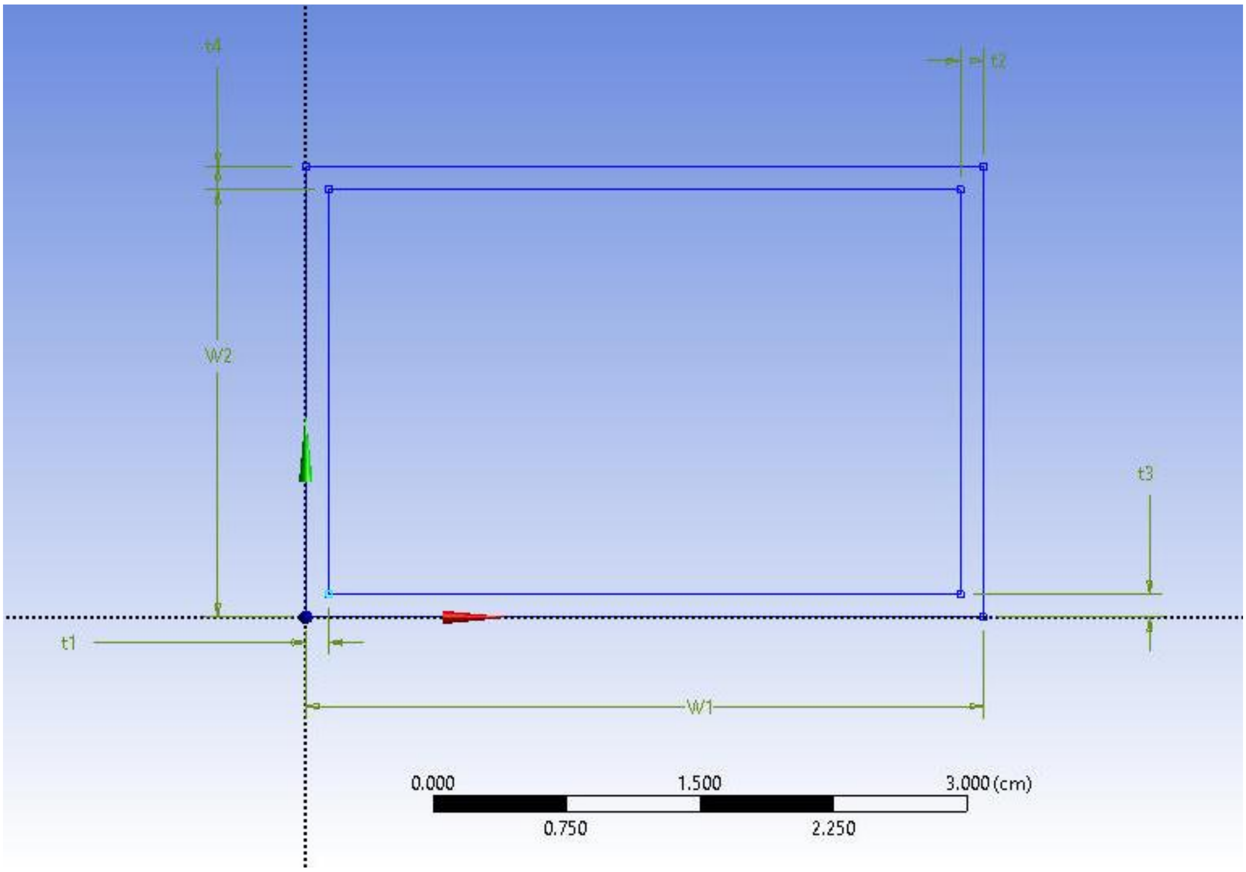

Figure 3.14cross section views having Hollow section

Where,

Width of the Section (**W1**) = 3.81cm

Width of Section (**W2)** = 2.54cm

Thicknesses of section are equal

T= 0.15

Step 3- Load Imprint Provided:

After completion of the Cross Section our next step is to provided static load and imprint load proportioning. In this we take 70R loading tracked vehicle imprint and proportioning it in prototype an apply load to the bridge for both the sections and compare their results.

Dimensions are given below:

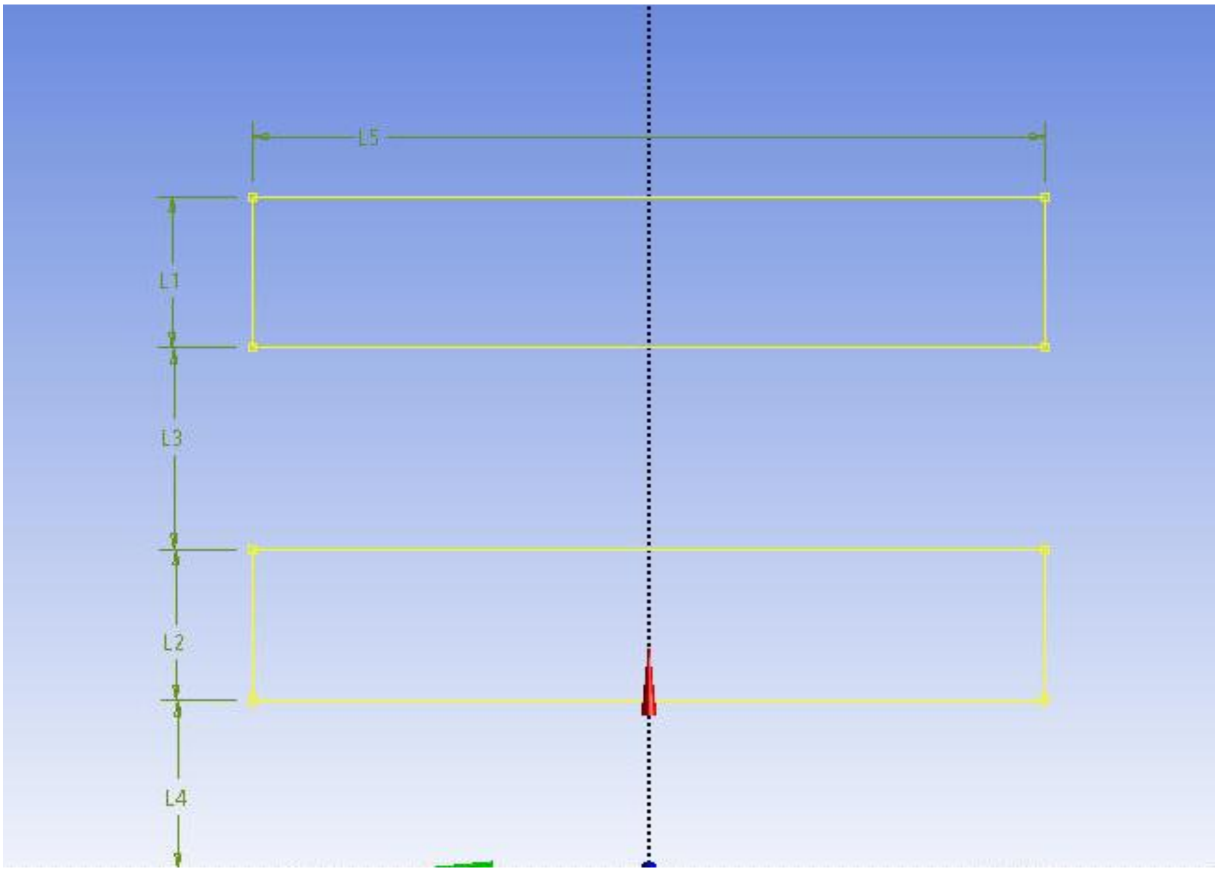

Fig. 3.15 Load imprint provided as IRC 70R loading view

There is two wheel length is given and the width of the wheel also taken by proportion. The value is come are:

Track width of the wheel (**L1** and **L2**) = 5cm

Loading imprint distance of space in it (**L3**) = 6cm

Distance between outer edge and the edge of the deck of track (**L4**) = 7cm

Track load length (L5) = 28cm

Step 4-Mesh Size Details:

Selection of mesh size in order to their convergence study which is conducted whose mesh size is varies from high point to low point and the total deformation is carried with different values. The final mesh size is taken as the deference mesh size is neglected.

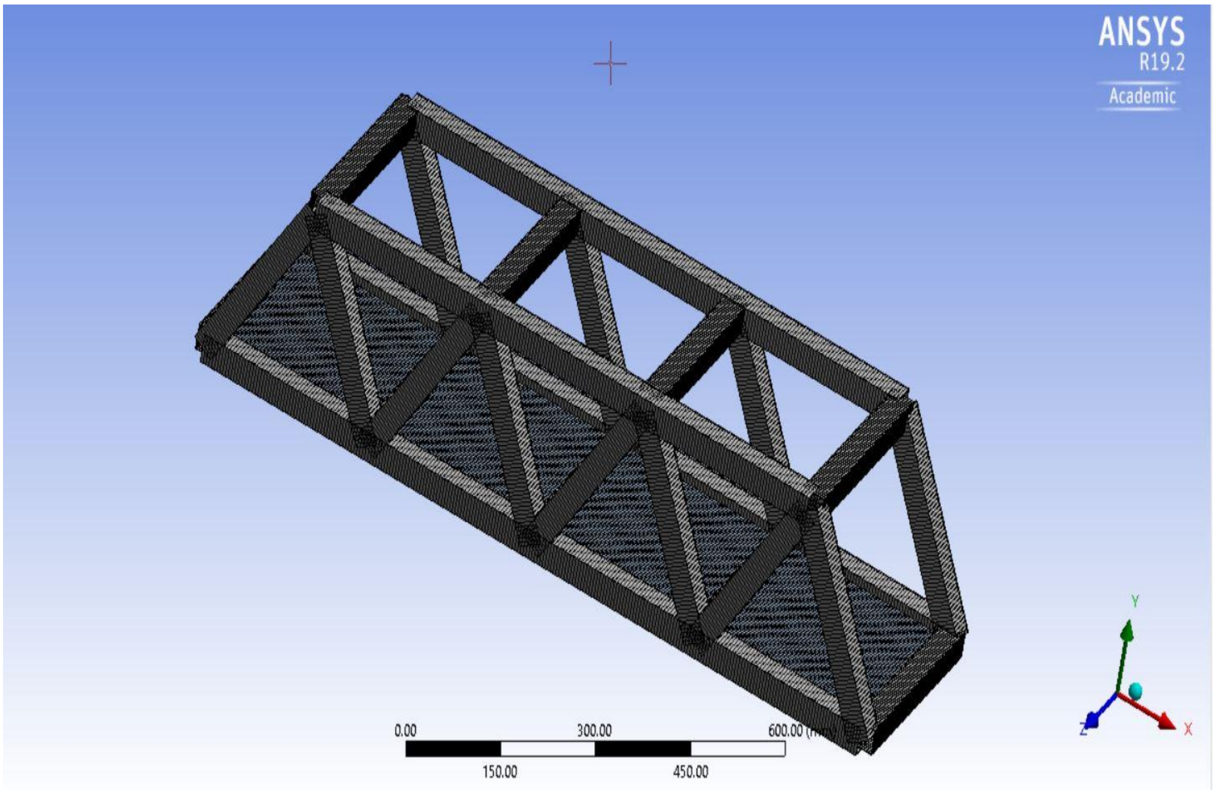

Fig.3.16 Geometry of meshing

From above graph the data is based upon mesh size having 265mm and the structure is analysed by using the mesh size of 25mm.we also take 10mm mesh type but in my case it take much time to solve it and analyse the result. By taking 25mm mesh size there is not a big difference in the result so i can take it as mesh size.

Step 5-Boundary Condition:

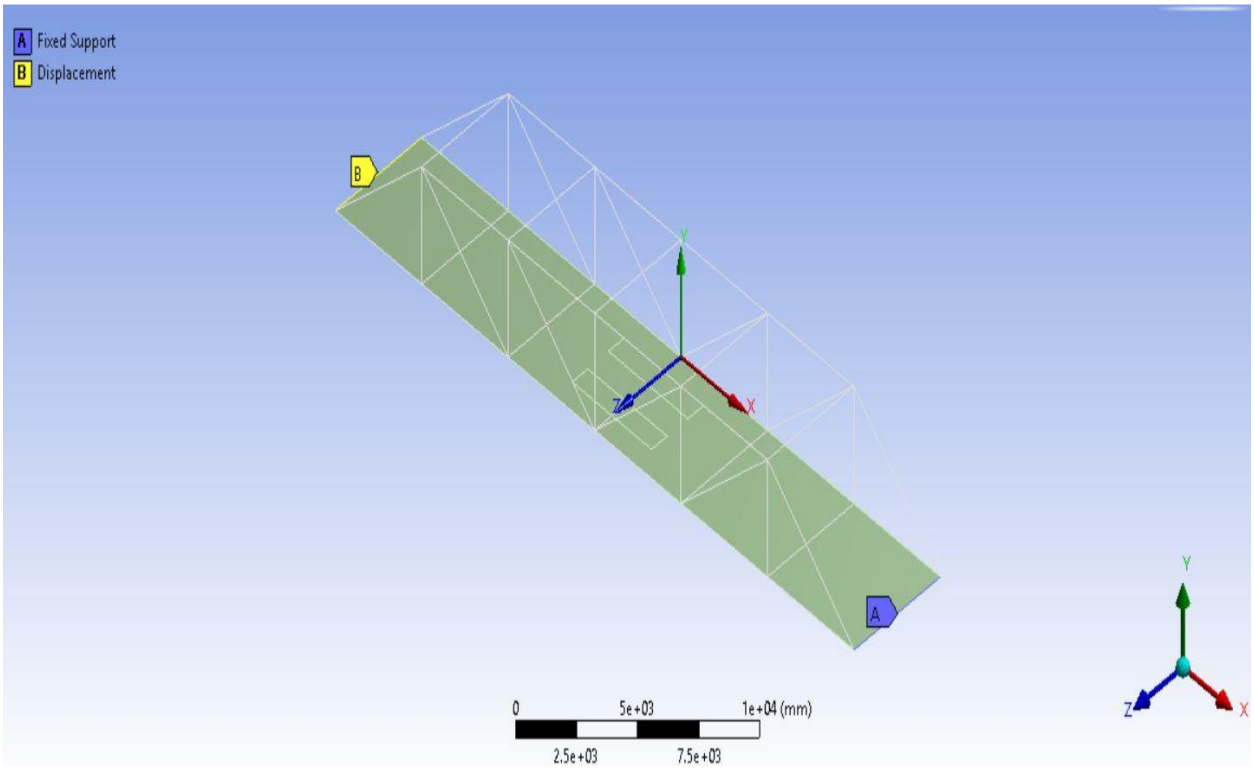

Fig.3.17 Geometry of supports in bridge

Roller support and the fixed support are provided where A represent Fixed support and B represent displacement support .in this one side having roller support and other having Fixed support. Y direction in this meshing is restrained.

Step 6- Elements used in ANSYS

Element type applied in ANSYS is plan controlled. During the Analysis of my bridge software used 5 types of elements.

Table 3.3 Types of element used by ANSYS Workbench

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

3.9 Prototype Bridge Testing

Design and analysis part of the prototype is done above in ANSYS workbench. Now the modelling of prototype is done by practically designing and then compares their result. Testing of the prototype is also done.

3.9.1 Plan of the Prototype Bridge

Plan for the testing of the prototype bridge is done by the plan as follows:

a) Truss configuration is decided first.
b) Structural model is drawn.
c) Stability and the static determinacy are checked.
d) Members are cut according to the dimensions.
e) Gusset plate is cut according to design.
f) Holes are drilled in gusset plate and members.
g) Parts of the members and gusset plate are assemble and built the bridge for both the sections.
h) Testing of both the bridges (Angular and Hollow Section) are done in Universal testing Machine.

(i) Configuration of Truss – In prototype we take truss same as we took on software testing of prototype bridge i.e. Warren truss.

(ii) Model of the Structure – First we are drawn the model on the paper and calculated their joints and members.

(iii) Checking the determinacy of the mathematical static determinacy. the condition is 2j=m+3 , where member are called m and structure joint are called j.in my condition there are 9 joints and have 15 members while putting these values in equation we get R.H.S and L.H.S having 18 . By this the determinacy and the stability is satisfied.

(iv) Then the cutting of members and gusset plate are done according to their dimensions in truss type Warren. Having equilateral triangle for all members is equally cut. Length is considered for all members are 30cm.

(v) The material for the gusset plate is taken as steel because we are consider the member stresses to be emphasize and to joints are made efficient to give the proper load distribution to the members.

(vi) After cutting all the members and gusset plate we drilled hole by 6.5mm for applying the bolt of 6mm in our structure.

(vii) After completion of the assembly of both the bridges having cross Section of Hollow Section and Angular section is tested in UNIVERSAL TESTING MACHINE.

3.9.2 Prototype of Bridge:

In this prototype there is angle Section which is used for making it and the connection of bolt are provided as 6nn of MS are provided. Deck of the bridge is made up of wood because while testing the bridge the members are stable and imprint load is provided equally. The connections are bolted and only one gusset plate are connected in one joint. The connection of the Angular Bridge is easy as compare to Hollow section. The assembly of Angle Section Bridge is easy and deck is placed properly on the bridge same are done with the Hollow section. Figure of the bridge is given below.

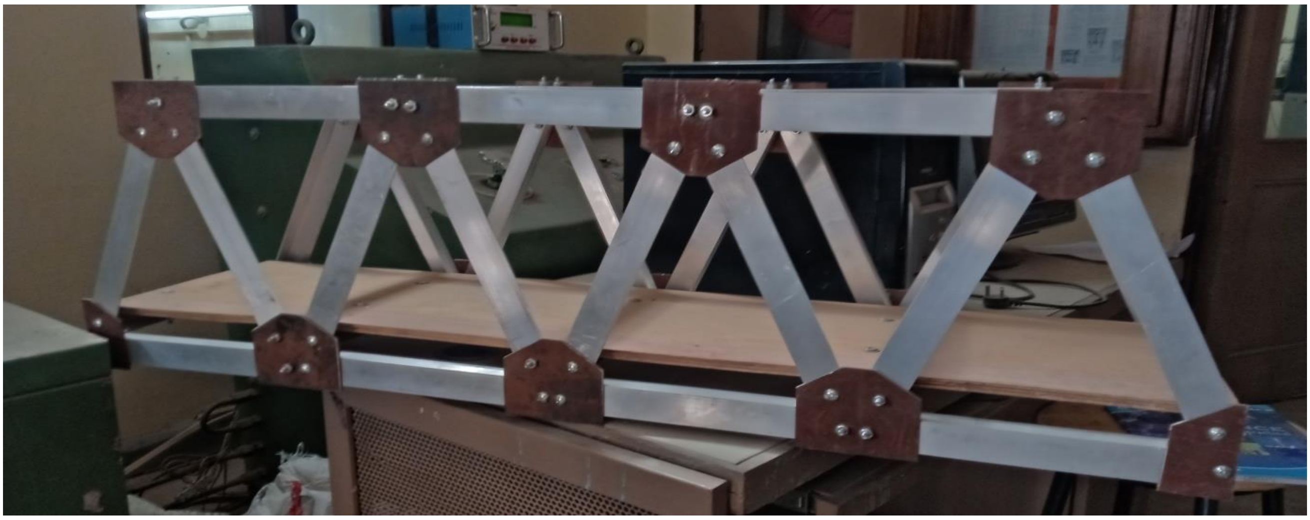

Figure 3.18 Image of prototype by taking Angle Section

Now my next task is to assemble the Hollow section by the steps which are given above. While assembling the members the only difficulty is occur on the joints. In Rectangular Hollow section there are two gusset plates are provided on the joints for give equal strength to the members. Due to which assembly of bridge take much time as compare to the Angle section Prototype. But in case of weight Hollow section give us less weight as compare to Angle section about 30 per cent of weight is less and the Cost of hollow section is decreases. The image of the Hollow section prototype is given below.

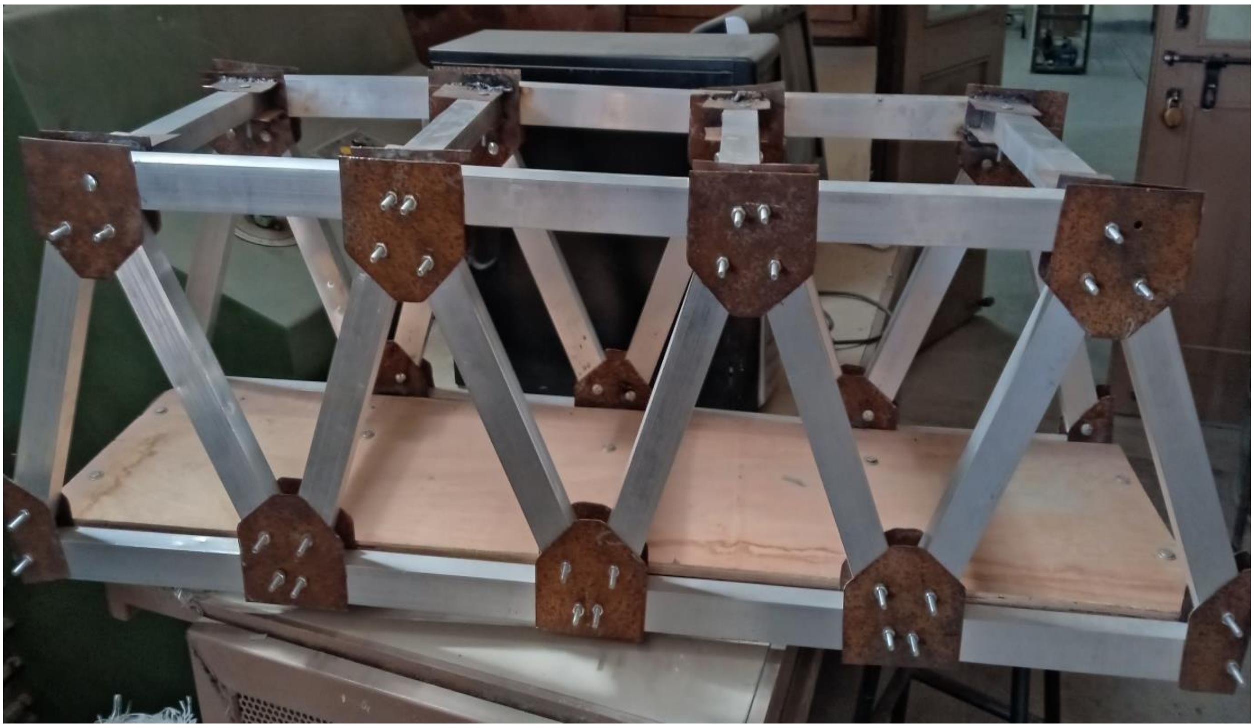

Figure 3.19 Image of prototype by taking Hollow Section

3.9.3 Universal Testing Machine

Universal testing machine is a machine which is used for the testing of the tensile and compressive strength of the material. By its name this is signifies that Universal means to perform standard tensile and compression test on structure, component and material. The capacity or range of the UTM (Universal Testing Machine) is varies load from 0-1000KN.the working of the UTM(Universal Testing Machine) is first the specimen or structure are placed on the platform of the machine and after placing it the top most part of machine is set or placed on the specimen by the control of machine. After proper fixing the specimen, load is applied by the machine in display loading and deflection details are shown. After breaking the specimen load is stopped and the reading is taken.

In testing of truss bridge we applied load on the bridge by imprint and then deflection on the nodes of the bridge are checked. This procedure is done for both the bridges (Hollow Section and Angle Section).as we know in UTM load is given from bottom to upside. So I have to make a support structure by which load is transfer to bridge and testing is done.

Figure 3.20 Universal Testing Machine Image

Component of Universal Testing Machine

Universal Testing Machine is differentiating in two parts: (1) control panel (2) Loading Unit

1) **Control panel:** Control panel in Universal Testing Machine is the data logger, hydraulic power unit, control devices and the measuring load data in the panel.
2) **Loading unit:** In Universal Testing Machine there is a plate in the middle of the machine having platform of hard base consist of piston and cylinder. There is redid frame consist of lower table and cross head in upper.

3.9.4 Linear Variable Differential Transformer (LVDT) as Deflection Measurement

Linear variable differential transformer is an electrochemical transducer and is used to measure the deflection of the specimen by attaching it on the specimen, structure etc. In bridge testing it play an important role because it is used to measure the deflection of nodes. LVDT is provided on the bottom of the nodes and it transfers the signal to data logger and gives the results' use 3 LVDT in my nodes for testing 1^{st} is on the corner,2^{nd} is on the centre and last one is on the nodes between centre and corner. IN fig we see the nodes are connected with LVDT

Figure 3.21 Image of Linear Variable Differential Transformer attached to node.

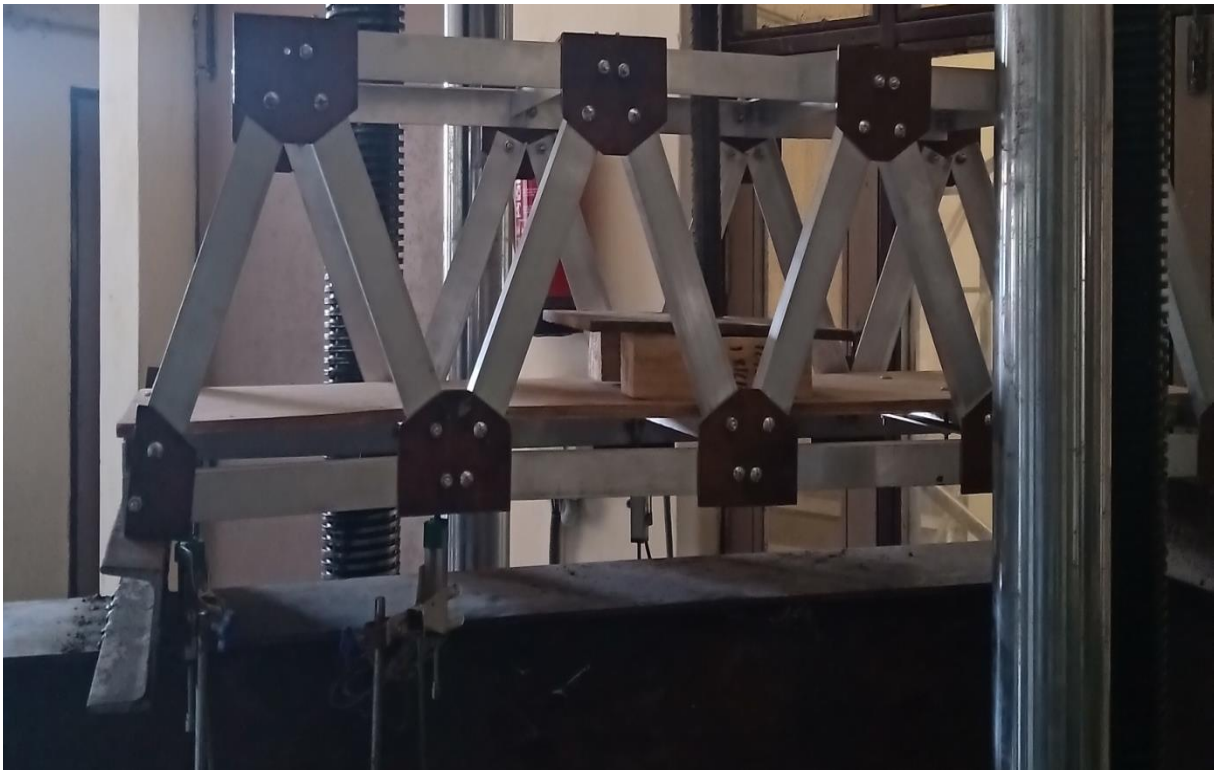

Fig. 3.22 Image of LVDT attached to three nodes

From the above fig we see the LVDT is attached on the different nodes for measuring deflection. these are attached to the Data Logger .and when the load is applied on bridge LVDT start sending the signal to the Data Logger after which Data Logger give the deflection reading of every node. By this I test the deflection of prototype.

Data logger: data logger is the part in the LVDT testing machine. Data logger is digital display where 15 channels are attached in it. Data logger receives the deflection, load etc from the LVDT and after which it display the result. Results are also saving in pen drive by attaching in the port.

Fig. 3.23 Image of Data logger

3.9.5 Arrangement for Loading

In Universal Testing Machine I made arrangement for the loading distribution of the bridge. The dimension of the imprint is taken and making the wooden cuboids by calculating the proportioning as seen in IRC 70R loading tracked vehicle. Wooden cuboids are placed on the deck of bridge having spacing and clearance between the two tracks. Loading on the cuboids are distribute by putting thick plate having ultimate distribution. Then after all this the load is applied on the steel plate then transfer to wooden cuboids to deck of the bridge

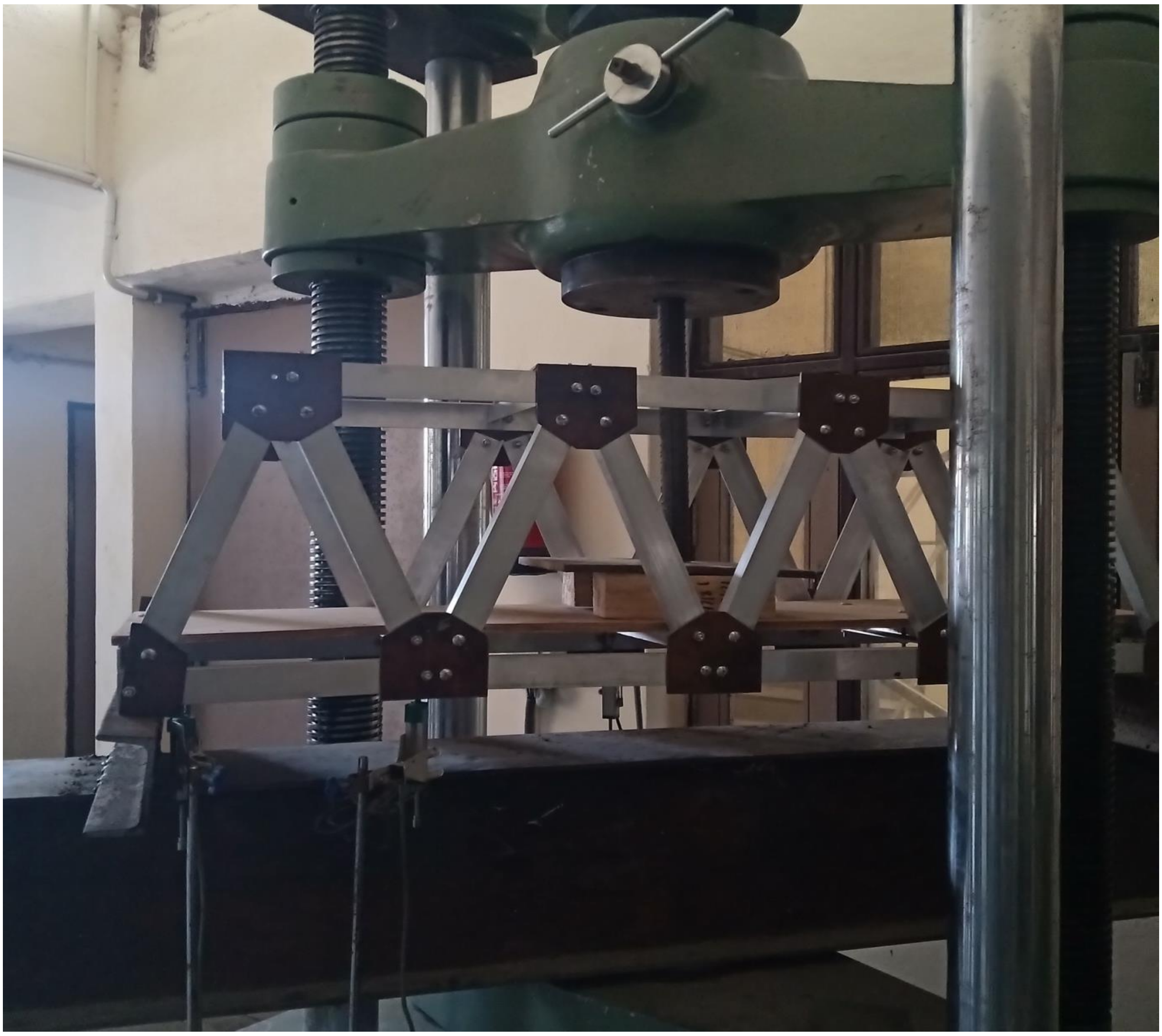

Fig. 3.24 Image of bridge in UTM

3.9.6 Support System in Universal Testing Machine (UTM)

As I discuss above Universal Testing Machine load distribution is from bottom and it is difficult to test prototype in this loading condition so i have to make support system using I-section.

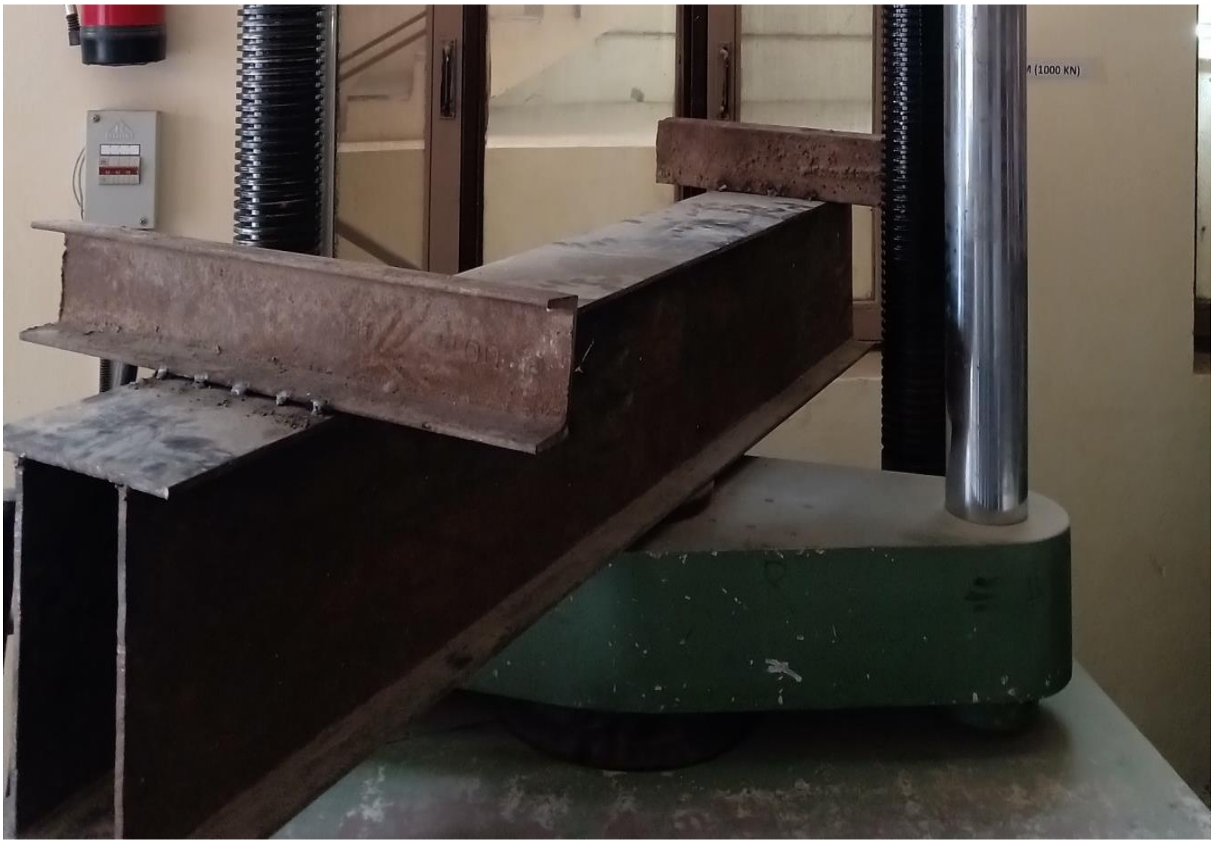

Fig. 3.25 Image of Support system in UTM

By the above figure we saw that I – section is placed on UTM for the bridge testing in which C- section is welded on I-section for supporting the lower part of the bridge on it. Bu taking bridge on it the load is transfer from the section to the bridge and the proper load is distributed by which we are calculated the total deflection of the bridge.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results of the Bridge tested in software

In ANSYS Workbench Software Bridge was tested and results were analysed on the basis of result parameters mentioned below. Solid and hollow section comparison values are made. Area according to the values is given in the figures. Area having blue colour are minimum value and area having red colour have maximum value of result parameter.

(i) Total Deformation

Table 4.1 Minimum, average and maximum total deformation result.

Section	Solid	Hollow
Maximum Total Deformation	1.7432mm	1.446mm
Average Total Deformation	0.6636mm	0.6106mm
Minimum Total Deformation	0	0

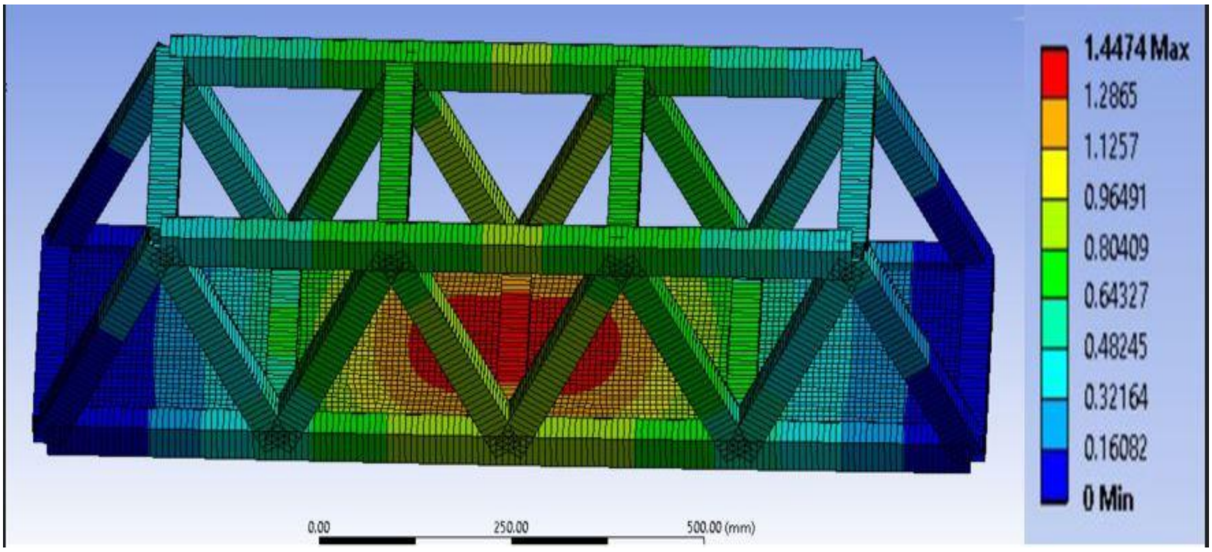

Fig. 4.1 total area deformation

By the table of total deformation hollow section has less deflection as compare to the solid deflection. Hollow section performs better than solid section.

(ii) Axial Force

Table 4.2 Minimum and maximum axial force values.

Section	Solid	Hollow
Maximum Axial Force	5584.3 N	5395.5 N
Minimum Axial Force	−9845.6 N	−9802.9 N

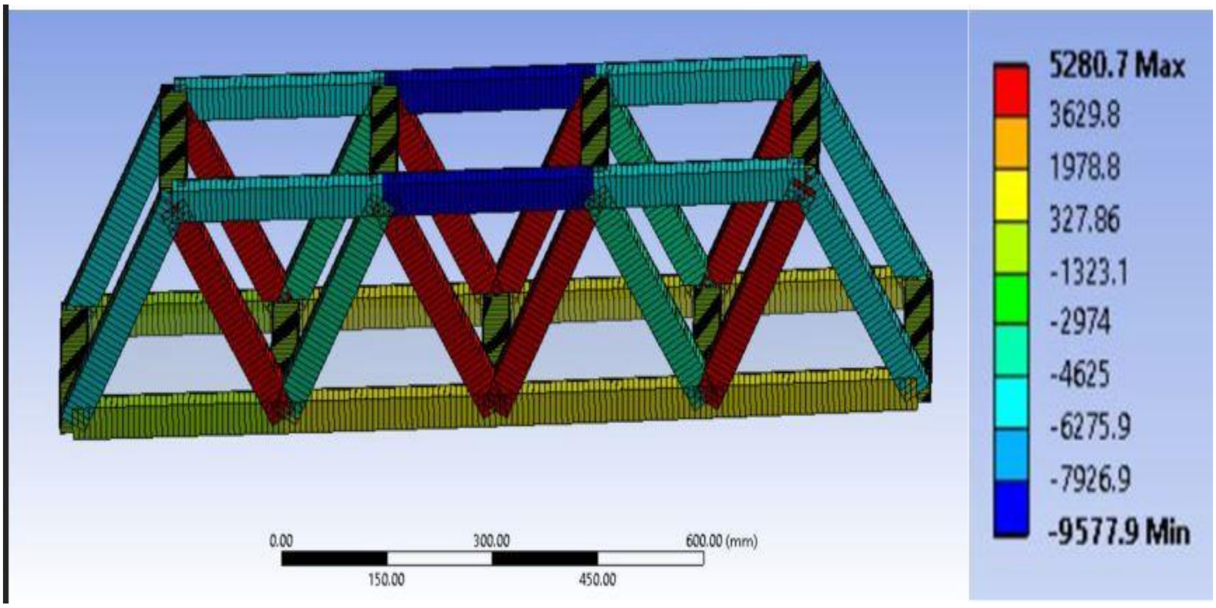

Fig. 4.2 total area of axial force

From the above table the axial force in solid section is applied less than that of the Hollow section.

(iii) Equivalent Stress

Table 4.3 Minimum, average and maximum equivalent stress results.

Section	Solid	Hollow
Maximum Equivalent Stress	45.145MPa	31.955MPa
Average Equivalent Stress	15.426MPa	11.020MPa
Minimum Equivalent Stress	0.815MPa	0.393MPa

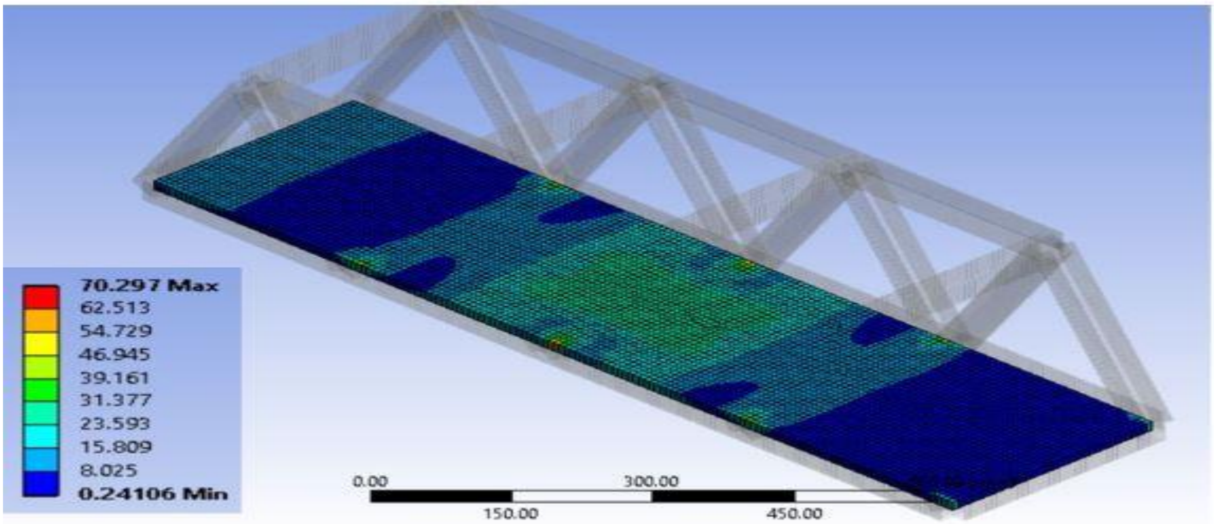

Fig. 4.3 total area of equivalent stress

From the above table equivalent stress in Hollow section is less than the Angle section.

(iv) Force Reactions

Table 4.4 values of force reaction for both the supports

Section	Hollow Section		Solid Section	
	Roller support	Fixed Support	Roller support	Fixed Support
X-Axis	$-$	1.7978×10^{-9}	$-$	1.3410×10^{-8} N
Y-Axis	9660.6 N	10018 N	9718 N	10159 N
Z-Axis	0	2.2154×10^{-6}	0	2.990×10^{-6}N
Total	9660.6N	10018 N	97198N	10159 N

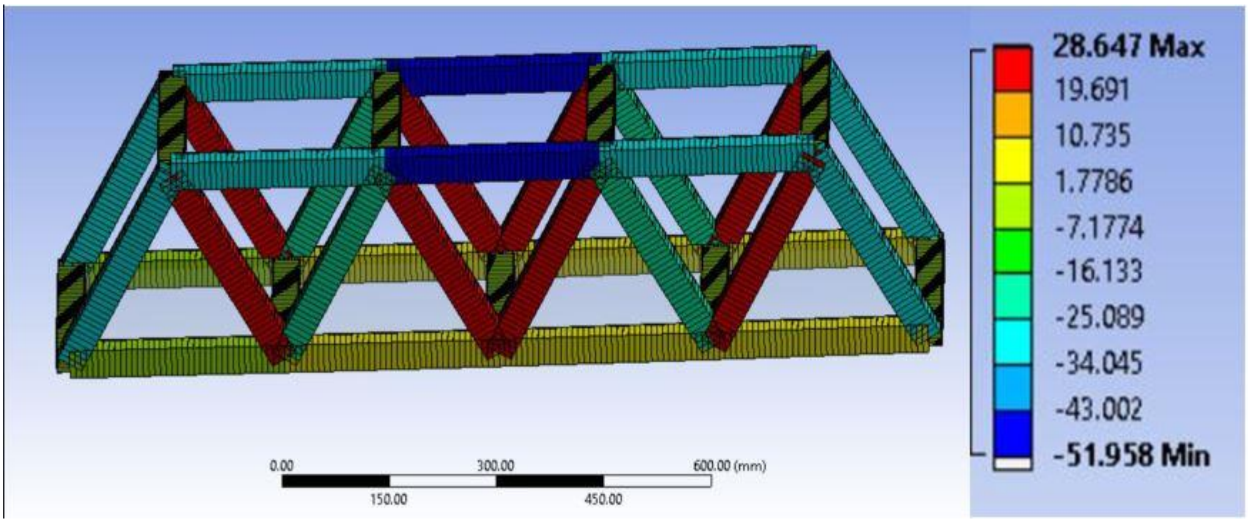

Fig. 4.4 Areas of Maximum Combined Stress

(v) Minimum and Maximum combined Stress

Table 4.5 values of force reaction for both the supports

Section	Hollow Section		Solid Section	
	Min. Combined	Max. Combined	Min. Combined	Max. Combined
Minimum	$-64.525\ MPa$	$-46.994\ MPa$	$-103.99\ MPa$	$-48.886 MPa$
Average	$-13.825 MPa$	$2.766\ MPa$	$-17.069\ MPa$	$4.663\ MPa$
Maximum	$28.11\ MPa$	$63.393 MPa$	$30.054\ MPa$	$102.01\ MPa$

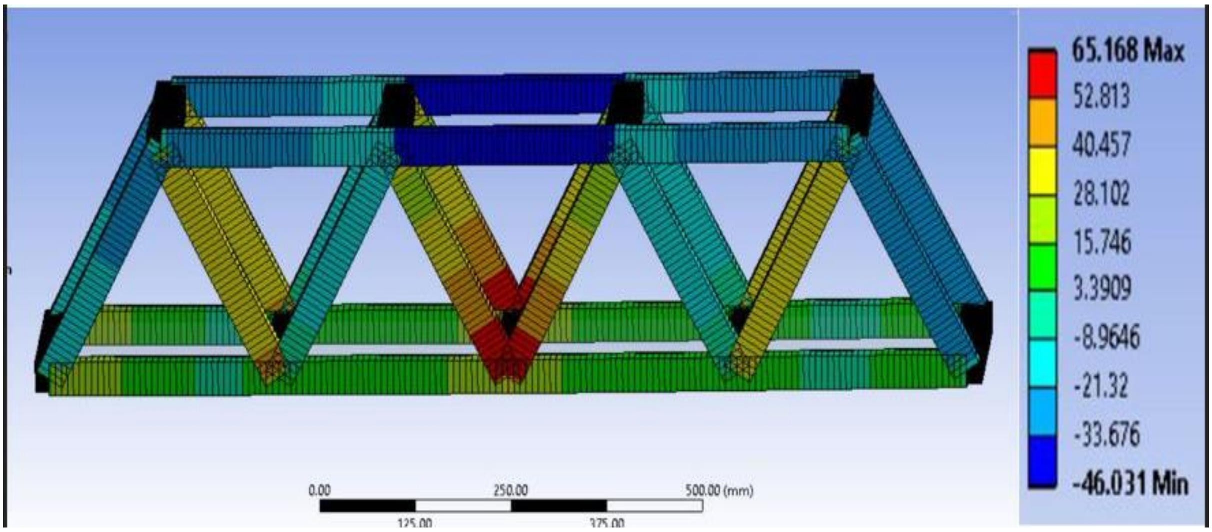

Fig. 4.5 Areas of minimum and maximum combined stress

(vi) Direct Stress in Beam

Table 4.6 values of direct stress in beam

Section	Solid	Hollow
Maximum Direct Stress	$30.772 MPa$	$27.274\ MPa$
Average Direct Stress	$-5.6168 MPa$	$-5.5297\ MPa$
Minimum Direct Stress	$-54.261\ MPa$	$-53.183 MPa$

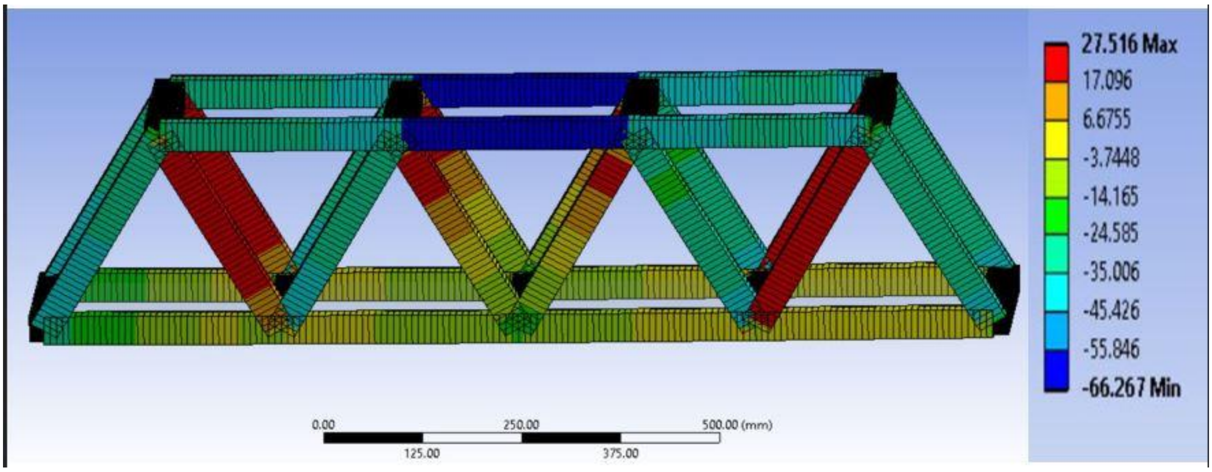

Fig. 4.6 Areas of direct stress

4.2Prototype bridge tested in UTM results

We have three LVDT readings of deflections while testing our bridge in UTM with respect to load for both hollow and solid sections. The result which is come is in the following table

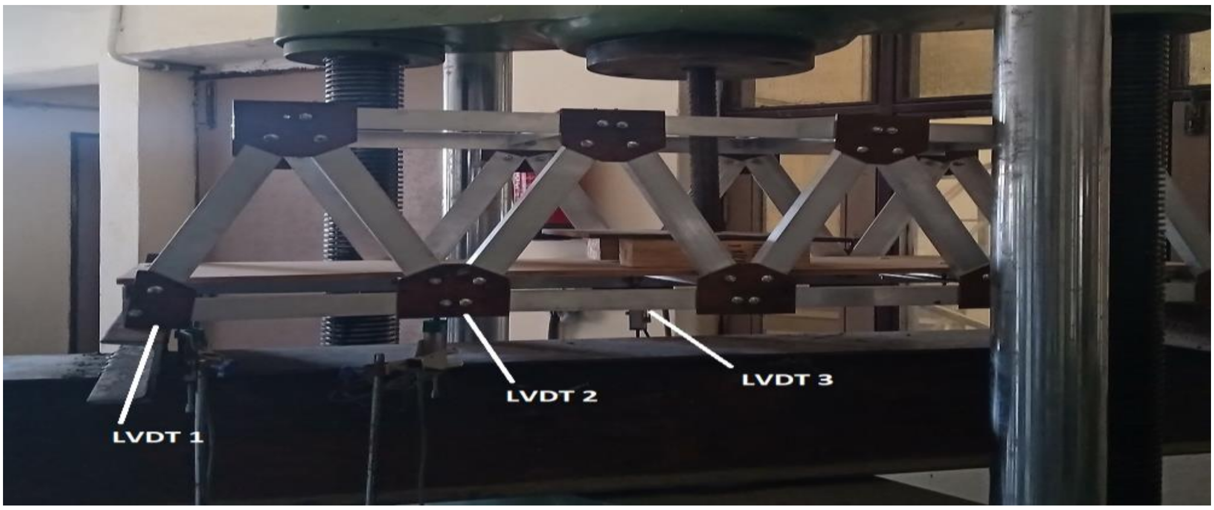

Fig. 4.7 Image of LVDT attached on nodes

Table 4.7 Readings of LVDT of bridge testing

Solid				Hollow			
Load (KN)	LVDT1 (mm)	LVDT2 (mm)	LVDT3 (mm)	Load (KN)	LVDT1 (mm)	LVDT2 (mm)	LVDT3 (mm)
2	0.0001	-	-	2	-	-	-
4	0.0005	0.0002	-	4	0.0001	-	-
6	0.001	0.0009	-	6	0.0008	0.0003	-
8	0.0016	0.001	-	8	0.001	0.0009	-
10	0.0019	0.0014	-	10	0.0012	0.001	-
12	0.21	0.0016	-	12	0.0019	0.0012	-
14	0.71	0.62	0.38	14	0.0022	0.0015	-
15	2.2	2.15	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

After calculating these results of deformation are shown in the graph

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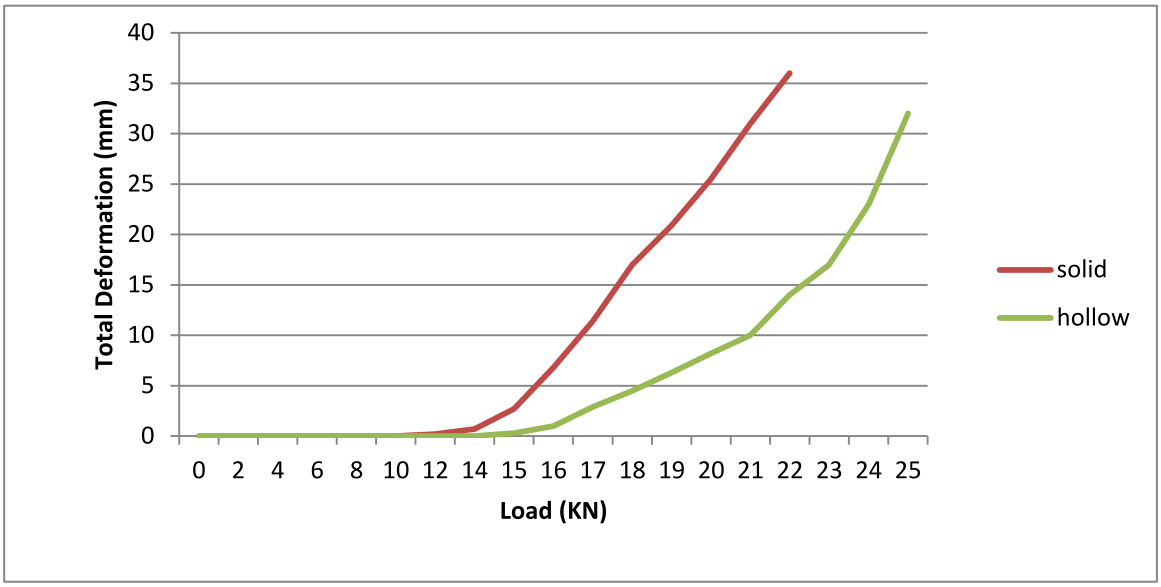


Fig.4.8 comparison of deformation of node 1

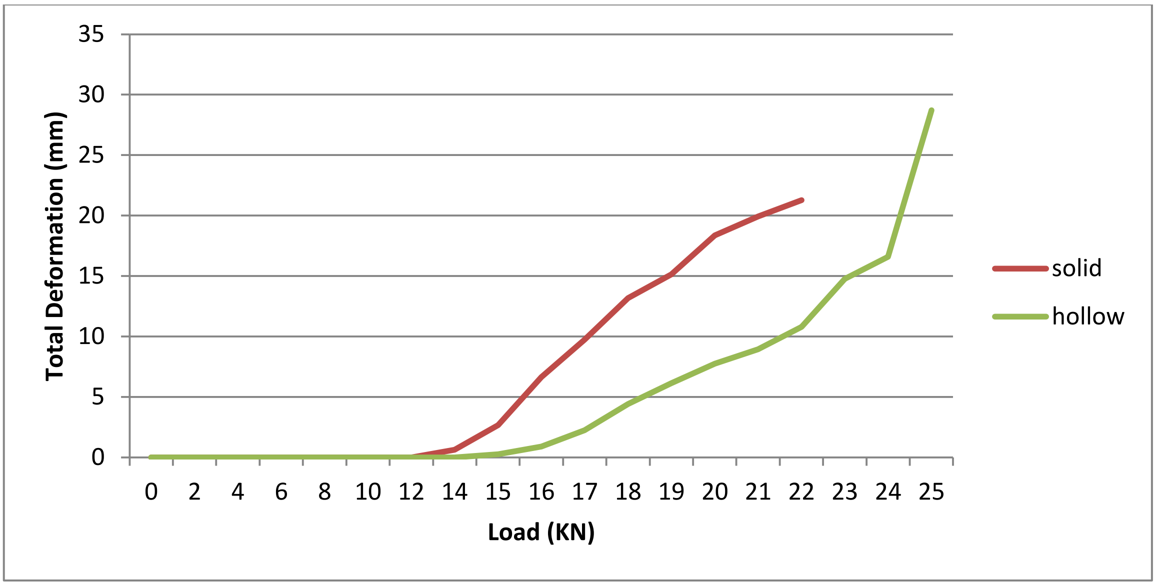


Fig. 4.9 comparison of deformation of node 2

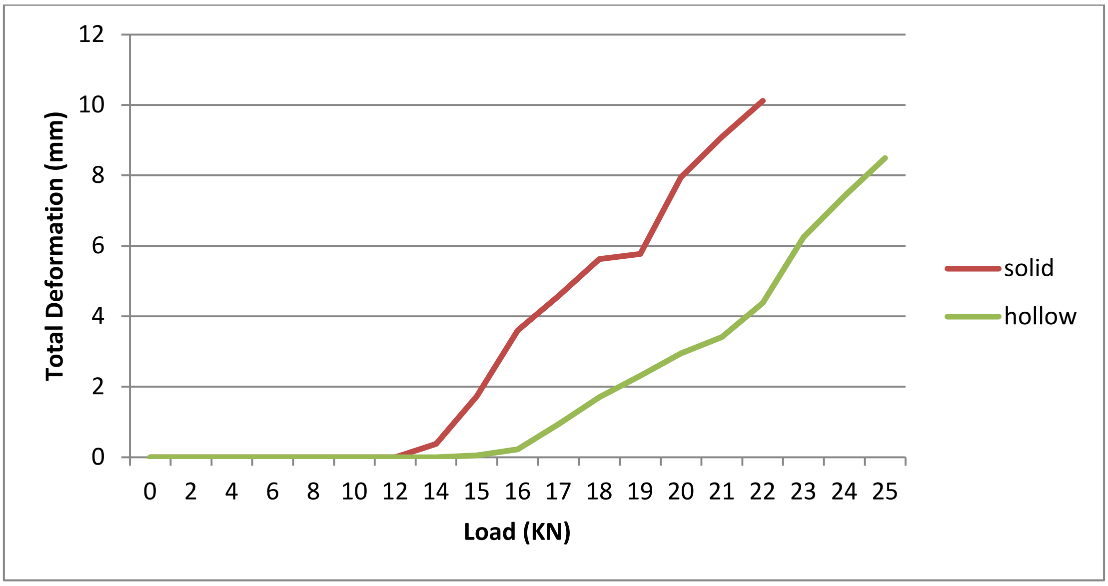


Figure 4.10 comparison of deformation of node 3

From the above graphs results tell us about the success of the hollow section. According to practical part and software part load taken more in hollow section and for deformation part hollow section less deform as compare to solid section.

Load failure values in both sections:

- Hollow sections = 23.5 KN.
- Solid Sections =19.3 KN.

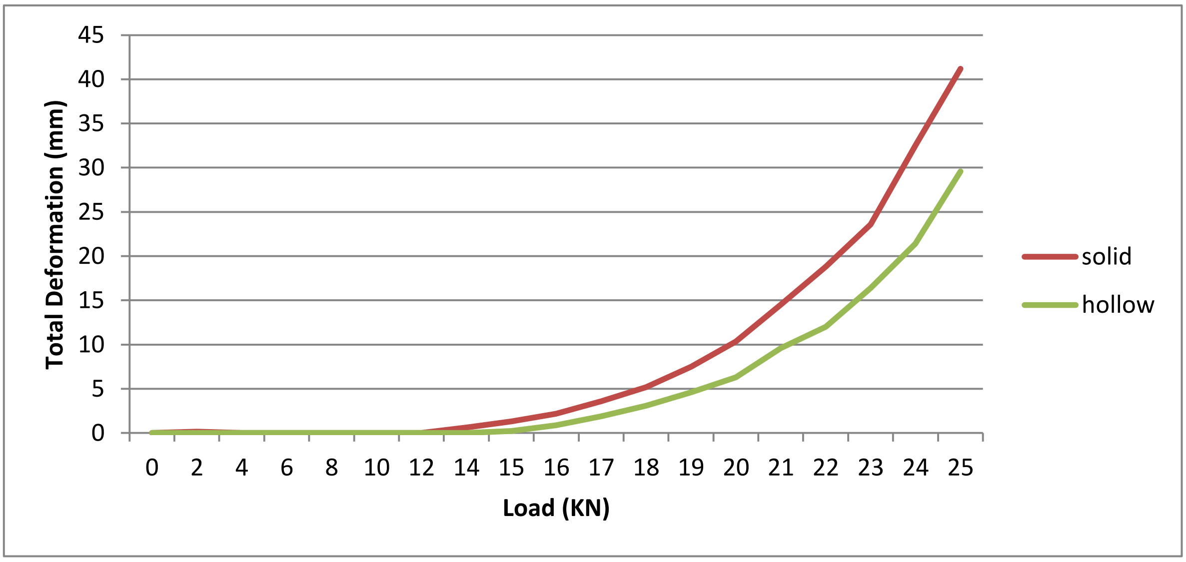
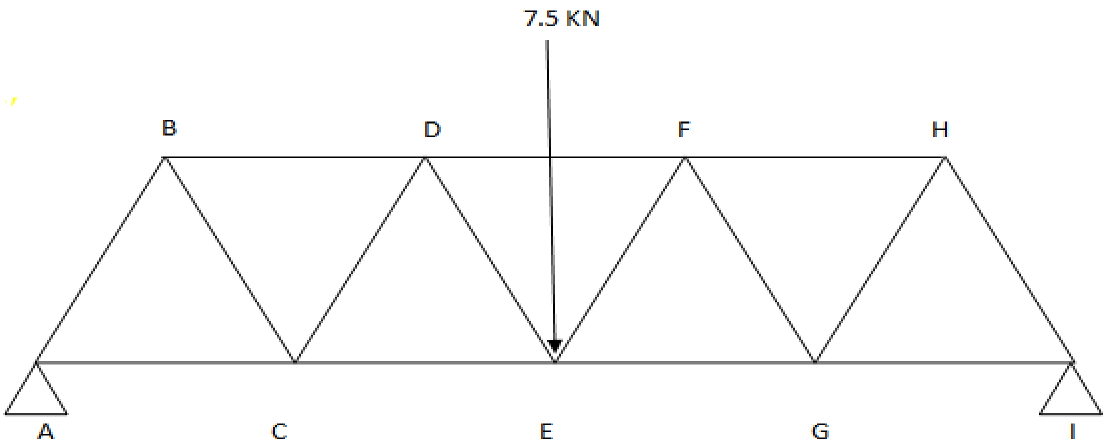


Fig. 4.11 total Deformation comparisons

4.3 Comparison of Results



There is a method for find out axial forces for the joints are known as Analytical method. By using this method I find out the different axial forces in prototype for both the bridges (Angle section and Hollow Section). In prototype there is an angle between two members which is 60^0 after all this I find out the axial forces in different members

Dimensions of bridge:

Length of total span= 120cm

Aluminium Modulus of Elasticity = 69GPa

One member length= 30cm

Calculation table for the direct stress of different member are given below:

Table 4.8 For different members direct stress calculated for prototype.

Members	Forces(KN)	Direct Stress(MPa)	
		Hollow	Angle
AB	-4.23	23.56	24.15
AC	2.155	11.33	12.10
BC	4.23	23.56	24.15
BD	-	-	-
CD	-4.23	23.56	24.15
CE	5.67	30.15	32.22
DE	4.23	23.56	24.15
DF	-4.23	23.23	24.15

In next part deflection is calculated for both the bridges (Angle section and Hollow Section). Method which is used to calculate deflection is virtual load method with the help of this method I calculate deflection in different nodes in both bridges. Results of the calculation are in the table:

Table 4.9 Results of Deflections in different nodes

Different Nodes	Deflection in Nodes(mm)	
	Hollow	Angle
A	-	-
C	1.04	1.35
E	1.57	1.90
G	1.04	1.44
I	-	-

In this part all results which are taken from ANSYS software and analytically values which we are calculated above for the deflection and load are compared and check the error percentage for both the bridges.

Table 4.10 Results Comparison between software values and calculated values

Results Parameter	Software		Prototype		Error Percentage	
	Hollow	Solid	Hollow	Solid	Hollow	Solid
Maximum Axial Force (KN)	5.28	5.58	5.77	5.77	9.28%	9.28%
Maximum Deflection (mm)	1.44	1.74	1.57	1.9	9.7%	9.19%
Maximum Direct Stress (Mpa)	28.65	30.77	32.13	32.36	5.15%	5.03%

From the above result we see that the Hollow section performs better as compare to Angle section. As we know Hollow section successfully used in construction roof trusses but there is less work is happen in bridges so I decide to make a bridge prototype compare it with the angle section for checking the results. In project my first part is to analyse both the bridges having Angle section and Hollow section and compare their results. Analyse of bridges is done in ANSYS workbench software. After analysing both the bridges result is on the side of Hollow section in Hollow section deformation is less as compare to the Angle section but this is the software part.

To check practically that it is possible to construct bridge with Rectangular Hollow section I make prototype for both the bridges having Angle section and Hollow section. While making prototype it is easy to make angle section bridge because it attach only one gusset plate in joints but in Hollow section two gusset plate attached. Testing of bridge is done in UTM in which the load is applied by imprint and gave the deflection for both the bridges. Rectangular Hollow section less deform as compare to Angle section because In rectangular section load distribute whole section but in Angle section load distribution is in Two sides. Hollow section successfully done its work and it is used in bridge construction. In the figure below we see the deflection in both the sections.

Fig. 4.12 Deformation in Angle section after testing

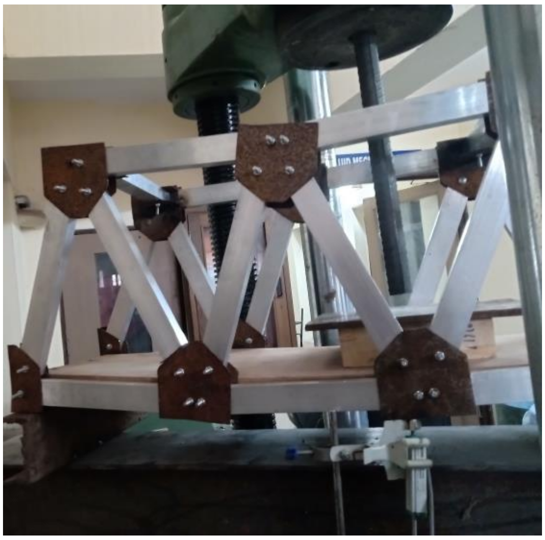


Fig. 4.13 Deformation in Hollow section after testing

CHAPTER 5

CONCLUTIONS AND FUTURE SCOPE

5.1 Conclusions

Analysis of truss bridge by replacing Angle sections with Hollow sections are discussed in this project. In truss bridges solid section like angular section are expensive to construct and difficult to transport from one place to another. As we know hollow sections are economical structure having greater radius of gyration by which compressive strength increases.

In this Project my first part is to analyse both the bridges having Angle section and Hollow section and compare their results. Analysis of bridge is done in ANSYS workbench software. After analysing both the bridges result is on the side of Hollow section in Hollow section deformation is less as compare to the Angle section but this is the software part. To check practically that if it is possible to construct bridge with Rectangular Hollow section I make prototype for both the bridges having Angle section and Hollow section. While making prototype it is easy to make angle section bridge because it attach only one gusset plate in joints but in Hollow section two gusset plates attached. Testing of bridge is done in UTM in which the load is applied by imprint and gave the deflection for both the bridges.

Rectangular Hollow section less deform as compare to Angle section because In rectangular section load distribute in whole section but in Angle section load distribution is in Two sides. Hollow section successfully done its work and it is used in bridge construction. In the figure below we see the deflection in both the sections.

From the above study I have drawn following conclusions:

1. On the various parameters results are taken such as axial force, deformation, direct stress, combined and equivalent stresses when solid section are replace by hollow section the outcome is good and results are more efficient than Solid section.
2. In truss bridge rectangular Hollow section perform better than Angle solid section.
3. Hollow section is 30-35 percent more economical than Solid section.
4. In software analysis values collected is more than that of the values collected by prototype testing because of the loss in unloading material, rolling of section and during transportation.

5.2 Scope for Future

1. In this study short span is used for the testing for future large span is used for the research.
2. Hollow sections made up of hexagonal or circular are used for the improvement in the results by increase in the life of truss bridges.
3. For increase the properties of section use of concrete or other cheaper material fill in hollow section.
4. In this research static loading is taken for the further study dynamic loading can be taken.

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