IMPROVING THE STRUCTURAL EFFICIENCY OF STEEL TRUSSES

Fatema Trawadi
ME Student, Department of Civil Engineering, Trinity College of Engineering and Research Pune,

Prof. S.V.Shelar
Professor, Department of Civil Engineering, Trinity College of Engineering and Research Pune.

Abstract- Although structural steel is used to erect huge items such as skyscrapers due to its strength and ability to hold much more weight than other materials, it can also be used in smaller commercial buildings, homes, apartment, complexes and so much more. Structural steel can be used for ceiling and floor joist as well as for roofing providing more sustainability to the project. Using steel can help to create a stronger structure that is able to stand up to not only more weight but also higher winds providing more protection that other options. Choosing to work with steel will prove to help save time on any construction project. Since time means money then you will find that you'll be able to save on the allotted budget for the job. Steel comes precut and ready to use. There is no having to measure twice and cut once in order to create an efficient end result. You also don't have to deal with doing re-cuts when human error has reared its ugly head. Working with steel can simply be faster allowing workers to complete a project before an estimated time as well.

Keywords- Steel Structure, Optimization, Structural Efficiency, Steel Trusses.

1. INTRODUCTION

Structural hollow sections possess many advantages over open sections; structural efficiency when subjected to compression, reduced surface area, absence of sharp corners, aesthetic appeal. However, the structural efficiency of trusses formed from tubular steelwork may be compromised by the design of the joints between the chords and the bracing (web diagonal) elements. In order to prevent local failure at a node, the size/thickness of the chords and/or bracing elements may need to be increased above that required to resist the axial force in the member. Thus the amount of material used along the whole length of individual members is increased to avoid a local capacity problem.

1.1 Structural Efficiency

Strengthening joints between hollow sections is problematic as access to the inside of the tube is not possible. The design approach that has been adopted for many years is to size the members to resist the axial forces generated in the truss members and then check that the joints between the chords and braces have sufficient capacity without stiffening. Structural engineers face the challenge of designing structures that can support not only the weight of the structure itself but other loads as well, such as forces caused by people, furniture, snow, wind, and earthquakes. The structural framing system should be designed to carry these loads in an efficient manner. Because the cost of construction materials used to build a structural system is often based on the weight of the materials, it is cost effective to use the least amount of material necessary to provide a structure that can safely carry the applied loads .The most efficient structures are strong and lightweight. One measure of the cost effectiveness of a structure is structural efficiency.

Although structural efficiency can be defined in many ways, in this activity we will define structural efficiency ratings the ratio of the load applied to the structure to the weight of the structure itself. It is important to understand that in this definition, the maximum design load applied to the structure is not necessarily the maximum load that the structure can carry. In order to provide an efficient design, the structural engineer must design the structure to carry the loads that are anticipated to occur, called the design load. So efficiency is based on maximum design load, not on the actual load that the structure can carry, which may be much higher than the design load. Of course, often the most efficient structure will be one that has a maximum capacity equal to the maximum design load.

1.2 Efficiency of Structure Steel

Although structural steel is used to erect huge items such as skyscrapers due to its strength and ability to hold much more weight than other materials, it can also be used in smaller commercial buildings, homes, apartment, complexes and so much more. Structural steel can be used for ceiling and floor joist as well as for roofing providing more sustainability to the project. Using steel can help to create a stronger structure that is able to stand up to not only more weight but also higher winds providing more protection that other options. Choosing to work with steel will prove to help save time on any construction project. Since time means money then you will find that you'll be able to save on the allotted budget for the job. Steel comes precut and ready to use. There is no having to measure twice and cut once in order to create an efficient end result. You also don't have to deal with doing re-cuts when human error has reared its ugly head. Working with steel can simply be faster allowing workers to complete a project before an estimated time as well.

Some of the other ways that steel becomes a money saver is by recycling. Recycling steel can bring a pretty penny while working with other materials is only an expense. The future fees that may be spent on using options other than structural steel can be costly. If choosing wood, over time wood must be replaced due to rot, termites, weather damage and even molding. Steel is a permanent solution which makes it more cost effective. Over the life expectancy of a building steel will prove to be the money saving choice of materials in which to build with. From the architects or the designer's creative standpoint, structural steel offers them a canvas on which they are able to create anything they choose. The safety that steel provides allows them to be creative while still being confident in their ideas

1.3 Structural Design and Load Management

The heating load placed on HVAC system of a building can be reduced the Structural Engineering team, as pointed out in the book [1] ‘Factor 5: Transforming the Global Economy through 80% Improvements in Resource Productivity’:

Building orientation and external shading: The energy from the sun entering a building can be reduced through a focus on building orientation and shading. If appropriate the orientation of the building envelope should be set based on the solar gain of the site to balance heat entering the building during summer and winter. In the case where the building orientation is fixed due to site conditions the use of shading can reduce solar gain during summer and allow heat to enter the building during winter (using adjustable vertical shading for east and west facades)[2].

Roofs:

In our analysis we are comparing Steel roof truss with two more composite roof truss with the same load force Various loading capacity with **steel roof** truss and two more other **composite roof** truss total deformations, Equivalent stress are tabulated thereby i will conclude the steel efficiency

1.4 Aim and Objective of the Study

1.4.1 Aims and objectives

The aim of the structural design is to design the structure for stability, strength and serviceability. It must also be economical and aesthetic.

The primary objective of structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life. If improperly designed, elements of a structure would fail causing serious consequences such as large expenses or ultimately losses in lives which cannot be compared with any cost. Once the architectural engineer sets the function and layout of the structure, the role of the structural engineer begins which can be summarized in the following steps to develop a safe, functional and economic structures. The thesis aims to improve the efficiency of structures through developing new measures, examining some available measures, making good use of some existing measures and providing theoretical backgrounds for some effective measures based on the structural concepts.

The objectives of the study are:

1. Examine other material used 2D roof truss and create a static structure and find out the deformation and equivalent stress.
2. Develop static 2D roof truss structure with steel model find out the deformation and equivalent stress.
3. Compare the efficiency of the three types of steel namely Mild Steel Alloy Steel and Structural Steel.
4. Identify which one is having more efficiency out of the three types of 2D steel roof truss.
5. Finally 2D Steel and other mild steel alloy steel and structural steel deformation and truss output is tabulated.

2. REVIEW OF LITERATURE

Chotiga Choensiridamrong et.al in (2014)[2] presented two approaches to determine the optimal plane trusses using the particle swarm optimization. The two-stage optimization and the simultaneous topology-sizing optimization of plane trusses are investigated and compared. The matrix representation of both topology and element size is introduced and integrated into the standard particle swarm algorithm to enable higher flexibility and computational efficiency. The truss weight is to be minimized subject to stability, stress and deformation constraints. The results show that the simultaneous optimization provided much better solutions with higher expense of computational time.

HK Dhameliya et.al in (2014) [3] attempted to compare various truss configurations with same span, pitch, the spacing of truss regarding the weight aspects. All the trusses have been analyzed and designed by Staad Pro, software for the span 20 m which are the most common spans used in practices. From the parametric study, the most appropriate span will be formulated considering geometric shape, weight, economy and other criteria.

Jian-Ping Li et.al in (2014) [5] applied the species conserving genetic algorithm (SCGA) to search multiple solutions of truss topology optimization problems in a single run. A real-vector is used to represent the corresponding cross-sectional areas and a member is thought to be existent if its area is bigger than a critical area. A finite element analysis model has been developed to deal with more practical considerations in modeling, such as existences of members, kinematic stability analysis and the computation of stresses and displacements. Cross-sectional areas and node connections are taken as decision variables and optimized simultaneously to minimize the total weight of trusses. Numerical results demonstrate that some truss topology optimization examples have many global and local solutions and different topologies can be found by using the proposed algorithm in a single run and some trusses have a smaller weight than the solutions in the literature.

Pei-Ling Chen et.al in (2014) [1] proposed a theoretical basis for k-truss and uses it to design an algorithm based on graph-parallel abstractions. Their experiment results show that their method in the graph-parallel abstraction significantly out performs the methods based on Map Reduce in terms of running time and disk usage.

Seung kook Yun et.al in (2014) [7] presented a decentralized algorithm for the coordinated assembly of 3-D objects that consist of multiple types of parts, using a networked team of robots. They described the algorithm and analyze its convergence and adaptation properties. They partitioned construction in two tasks: tool delivery and assembly. Each task is performed by a networked team of specialized robots. They analyzed the performance of the algorithms using the balls into bins problem and show their adaptation to the failure of robots, dynamic constraints, multiple types of elements, and reconfiguration. They instantiated the algorithm to building truss-like objects using rods and connectors. They implemented the algorithm in simulation and show results to construct 2-D and 3-D parts. Finally, they described ahardware implementation of the algorithms, where mobile manipulators assemble smart parts with IR beacons.

Michael Fenton et.al in (2016) [4] applied grammatical evolution. It can represent a variable number of nodes and their locations on a continuum. A novel method of connecting evolved nodes using a Delaunay triangulation algorithm shows that fully triangulated, kinematically stable structures can be generated. Discrete beam-truss structures can be optimized without the need for any information about the desired form of the solution otherthan the design envelope. Their technique is compared to existing discrete optimization techniques, and notable savings in structure self-weight are demonstrated. In particular, their new method can produce results superior to those reported in the literature in cases in which the problem is ill-defined and the structure of the solution is not known a priori.

Mingli Wu et.al in (2016) [6] focused on the electromagnetic shielding performance of the steel truss bridge in electrified railway. The background of the study is based on the AC and DC railway systems which are running in parallel in the project of Dashengguan Bridge. The multi-conductors model including the steel truss bridge as well as the of the conductors of traction supply systems are constructed by the Q3D software. After that, the electrostatic voltage, induction electromotive force with and without the influence of steel truss bridge has been computed. By comparing the result fewer than two distinct conditions, the electromagnetic shielding performance of the steel truss bridge can be evaluated.

3. PROBLEM STATEMENT AND METHODOLOGY

3. 1Problem Statement

The main problem existing is that almost all the knowledge in light-weight structures comes from the performance of full-scale tests in laboratories. This tests, which might be very costly, are typically with static loads and not always satisfactory. Moreover, it is impossible to think in testing the complete structure of a building in a dynamic full-scale test, its cost would not be assumed by any company. Some of the disadvantages facing in the fixed point structure are:

1. Due to drying shrinkage and moisture expansion fixed point may crack. Therefore construction joints are provided to avoid these types of cracks.
2. Fixed point is weak in tension.
3. High Self weight of fixed point is not always favorable for seismic prone structures.
4. Sustained loads develop creep in structures.
5. If salts are present in the fixed point then it will results in the efflorescence in fixed point structure.

3.2 Methodology

Analytical methods often provide an understanding of a solution but they are only applicable to solve relatively simple problems. In contrast, numerical methods can be applied to a broad range of problems for providing a complete solution, but they are unlikely to give a general solution. Both analytical and numerical solutions are developed based on assumptions. Experimental methods do not require such assumptions and provide true solutions, but measurements can only be taken on selected locations. It can be noted that the three types of method are complementary. Therefore they have been used in the study for improving the efficiency of structures, with the analytical methods being considered first where possible.

3.2.1 How Energy Efficient are Structural Steel Buildings

A building construction is a long-term process which takes a long time, and a lot of materials are required to get finished. While constructing a building, as a vigilant contractor, you may have certain responsibilities towards the environment. It is essential for you to ensure that your construction activities do not harm the environment. So how can you make that happen? You can do it by using structural steel to make buildings.

3.2.1.1 Fast Construction

When you use structural steel for your building, the construction time is reduced considerably. Structural steel is pre-fabricated at a structural steel fabrication company and brought to the main construction site for assembly. This reduction in construction time expedites the process of building, thereby saving the energy consumption during construction.

3.2.1.2 Recyclable Material

Structural steel is an alloy which is 100% recyclable. This property of structural steel makes it an energy efficient material to be used in a building. When a structural steel building is demolished or renovated, the structural steel used in the building is completely recycled, leaving behind no wastage.

3.2.1.3 Saves Energy

Structural steel buildings are good insulators for heat and cold. This enables them to contain heat during winters and simultaneously keep the temperatures low during summers due to their insulating property. As the temperatures are maintained in a structural steel building, it helps save the energy used for heating or cooling the property.

3.2.1.4 Durable Material

Structural steel, though highly flexible, is still the most durable and sturdy material to work within the construction industry. This durability of the structural steel lowers the wear and tear in the building thereby, cutting down the repair, maintenance, and replacement energy requirements.

3.2.1.5 Resistant Material

Structural steel's durability is a known fact. This durability makes it a highly resistant material to external forces such as fire and earthquake. Structural steel building roof work is tested and made to protect it from the fire. The ductile and flexible nature of structural steel makes it bend rather than crumble during an earthquake. With the above-mentioned benefits, structural steel buildings are not just energy efficient but also the most strong and long lasting ones. The structural steel buildings are resistant in nature and can withstand the effects of external factors.

4. THEORETICAL CONTENTS

4.1 INTRODUCTION

Truss is very important for a construction, such as construction for roof, bridge and high-rise building. Truss can give high esthetic value for mega construction such as Eiffel Tower, Paris and for building like stadium for football in Europe. In architecture and structural engineering, a truss is a structure comprising one or more triangular units constructed with straight members whose ends are connected at joints referred to as nodes.

External forces and reactions to those forces are considered to act only at the nodes and result in forces in the members which are either tensile or compressive forces. Moments are explicitly excluded because all the joints in a truss are treated as revolute. Nowadays, the analysis of truss is concerned of many designers and consultants. The truss structures are required to be designed in such a way that they have enough strength and rigidity to satisfy the strength and serviceability limitation. In order to archive the minimum requirement, it is necessary to carry out an accurate analysis to investigate the reaction and stress that acting inside the member of the truss. When the load acting on a truss, the structure may deform and change to different shape or size. This can be a result of compression (pulling) stresses or tension (pushing) stresses inside the truss members. A truss is a structure composed of slender members joined together at their end points. Roof trusses in general, the roof load is transmitted to the truss by a series of purlins. The roof truss along with its supporting columns is termed a bent. The space between bents is called a bay Planar trusses lie in a single plane. Typically, the joint connections are formed by bolting or welding the end members together to a common plate, called a gusset plate Double cantilever truss or roof truss. The double cantilever truss or roof truss is used as a main structure to cover industrial buildings; it allows to build aisles with large spans. Walls , Panels, Slabs.

4.2 DEFINITION OF A TRUSS

A truss is essentially a triangulated system of (usually) straight interconnected structural elements; it is sometimes also referred to as an open web girder. The individual elements are connected at nodes; the connections are often assumed to be nominally pinned. The external forces applied to the system and the reactions at the supports are generally applied at the nodes. When all the members and applied forces are in a same plane, the system is a plane or 2D truss.

The principal force in each element in a truss is axial tension or compression.

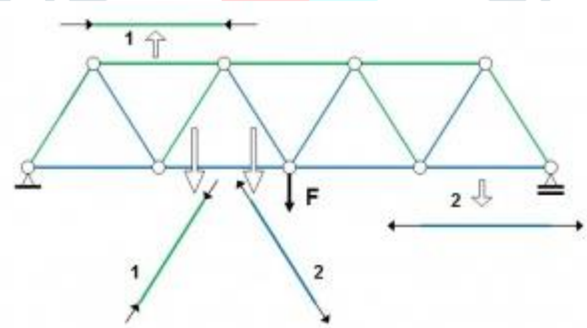


Fig1.1 Members under axial forces in a simple truss
1 - Compression axial force
2 - Tension axial force

4.3 USE OF TRUSSES IN BUILDINGS

Trusses are used in a broad range of buildings, mainly where there is a requirement for very long spans, such as in airport terminals, aircraft hangers, sports stadia roofs, auditoriums and other leisure buildings. Trusses are also used to carry heavy loads and are sometimes used as transfer structures. This article focuses on typical single storey industrial buildings, where trusses are widely used to serve two main functions:

- To carry the roof load
- To provide horizontal stability.

Two types of general arrangement of the structure of a typical single storey building are shown in the figure 1.2 below.

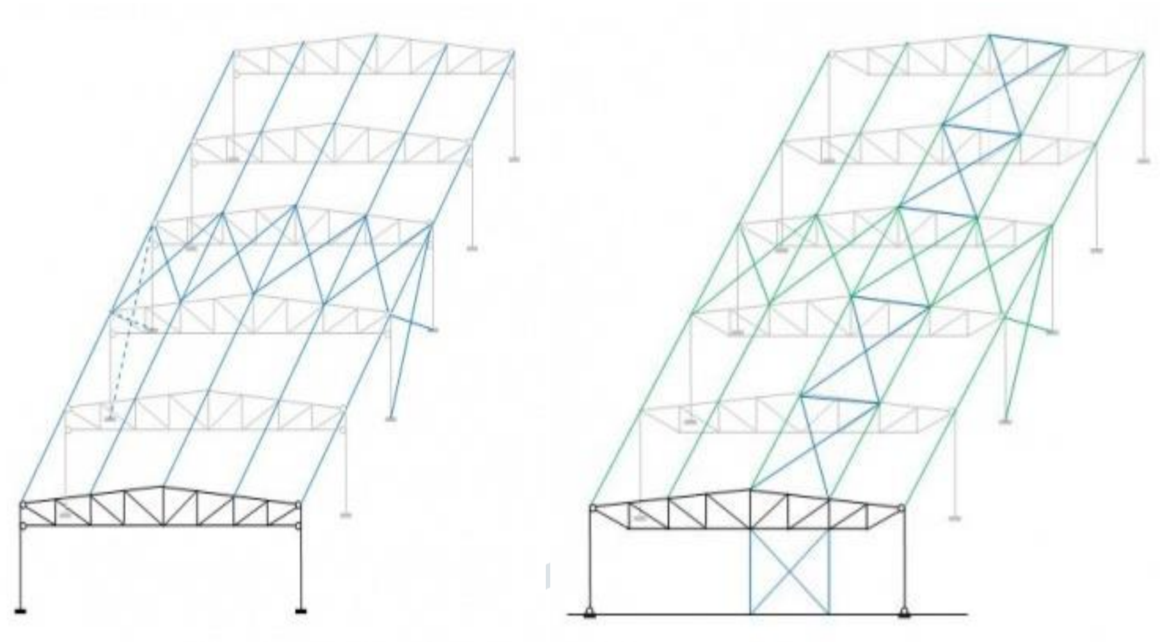


Fig 1.2 Typical truss building arrangements

In the first case (left) the lateral stability of the structure is provided by a series of portal trusses; the connections between the truss and the columns provide resistance to a global bending moment. Loads are applied to the portal structure by purlins and side rails.

In the second case, (right) each truss and the two columns between which it spans, constitute a simple structure; the connection between the truss and a column does not resist the global bending moment, and the two column bases are pinned. Bracing in both directions is necessary at the top level of the simple structure; it is achieved by means of a longitudinal wind girder which carries the transverse forces due to wind on the side walls to the vertical bracing in the gable walls. Longitudinal stability is also provided by a wind girder in the roof and vertical bracing in the elevations.

4.2 STEEL TRUSS

Steel is broadly used around the world for the development of workshops structures of various sizes. It is a flexible and powerful material that offers green and sustainable answers. Steel has long been known as the financial option for a variety of bridges. It dominates the markets for long-span bridge structure, workshops roof structures, footbridges, and medium span dual carriageway bridges. It is now increasingly more the selection for shorter span dual carriageway systems as properly. The connected elements
(usually directly) can be pressured from tension, compression, or now and again each in response to dynamic loads. These trusses can be made from wooden, steel or can be composite shape. In this thesis, metal trusses used for constructing bridges are considered. Steel has higher strength, ductility and durability than many different structural materials inclusive of fixed point or wooden. However metallic should be painted to prevent rusting [10]. Like other bridge sorts, there is each simple and continuous truss bridge. The individuals of a truss may be arranged in a nearly unlimited wide variety of ways, but the big majority of trusses encountered in bridge belong to one of the commonplace kinds listed under. Some of these commonplace varieties of trusses are the Baily truss, Warren truss, Warren truss with verticals, subdivided Warren truss, the Pratt truss, subdivided Pratt (Baltimore) truss, K truss, and the Howe truss. The essential participants of a roof truss are shown in determine 1.2.

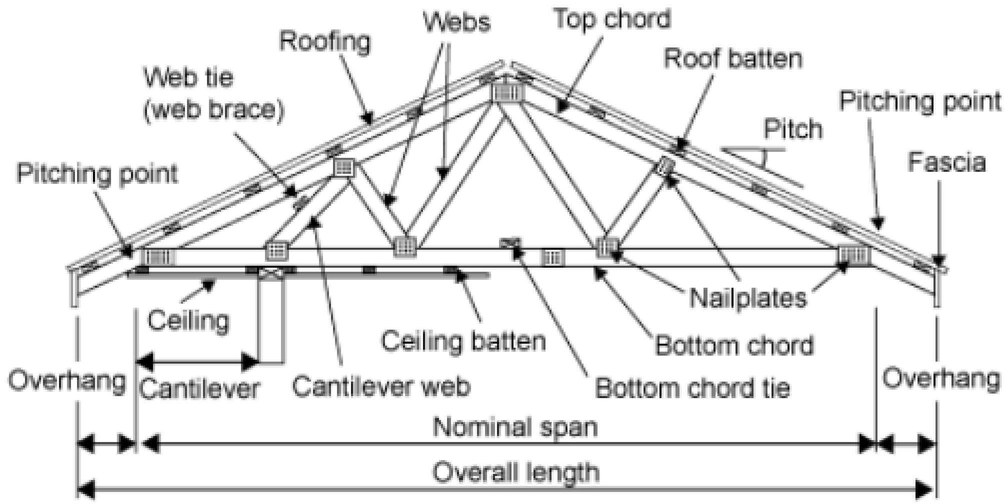
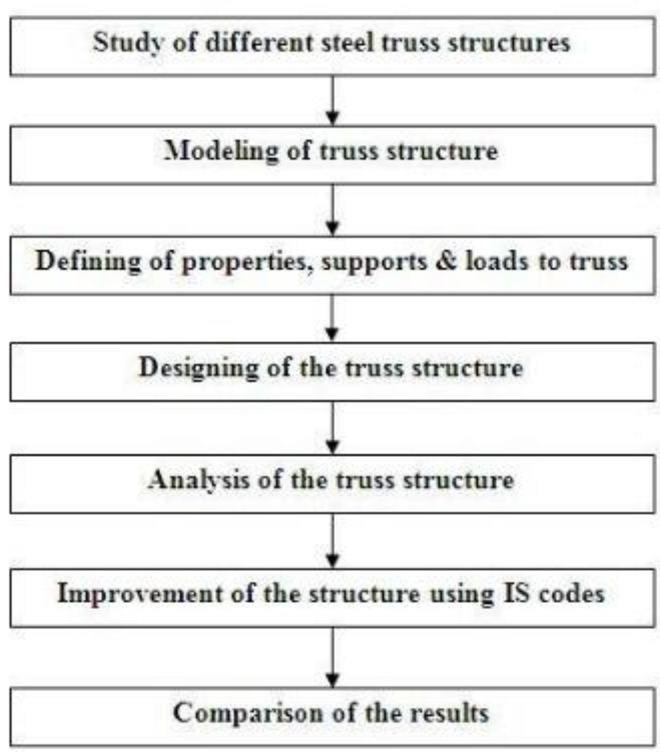


Fig1.1 Skeleton of a typical Roof truss

4.3 Analysis Of A Steel Roof Truss

Statistics show that the most frequent reason for the collapse of steel structures is instability. The essential problem in the design of steel roof trusses is proper estimation of the buckling length of the compressed upper chord. “In plane” buckling is rather good defined and related to node spacing. Much more problems arise with “out of plane” buckling, especially in the compressed chords of so-called “light” roofs. One of such cases is analyzed in this paper. The main aim is to show the influence of some usually neglected factors on the stability of the steel roof truss and give guidelines for designers.

5. RESEARCH METHODOLOGY



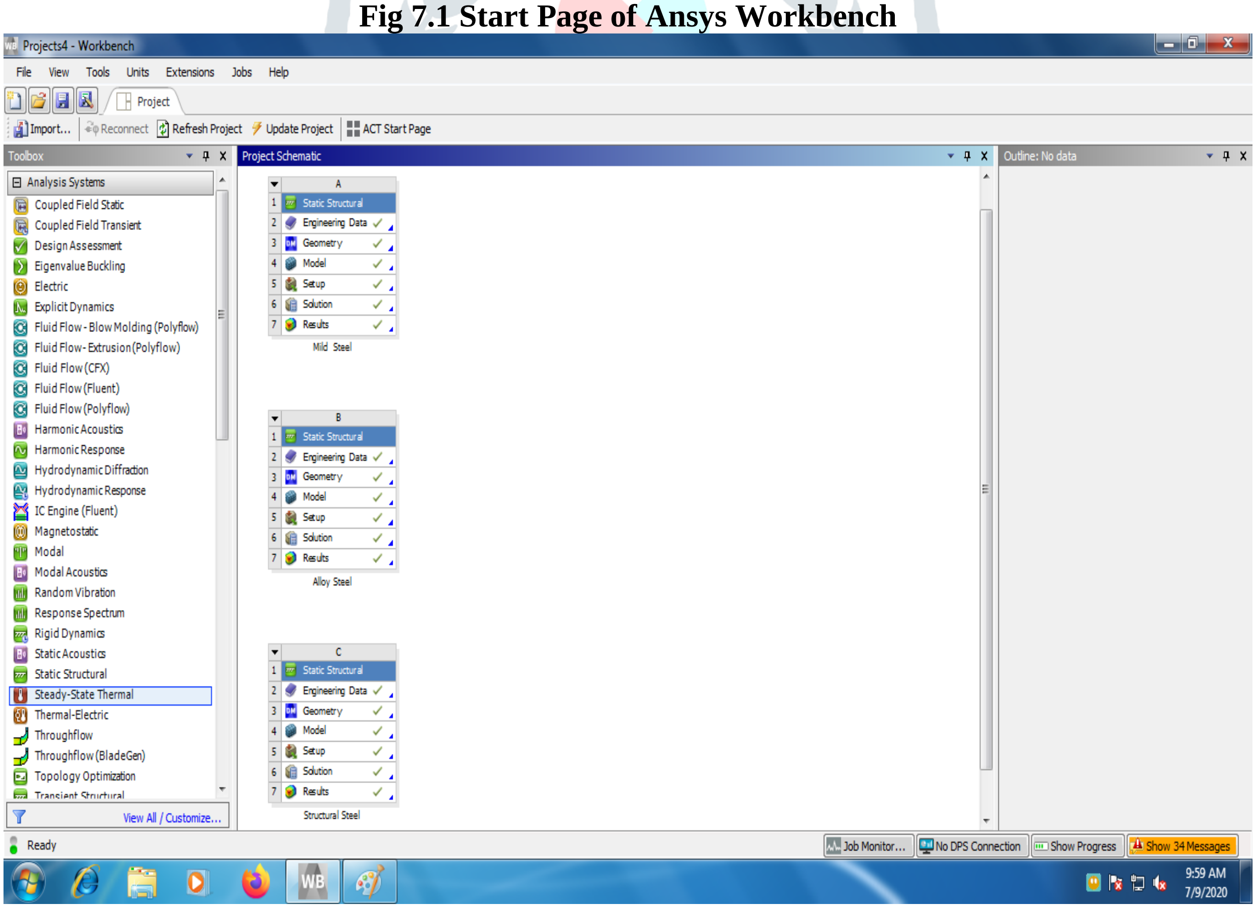
6. LIMITATIONS

1. Steel is an alloy of iron. This makes it susceptible to corrosion. This problem can be solved to some extent using anti-corrosion applications.
2. It has high maintenance costs as it has to be painted to make it corrosion-resistant
3. There are extensive fireproofing costs involved as steel is not fireproof. In high temperatures, steel loses its properties.
4. Buckling is an issue with steel structures. As the length of the steel column increases the chances of buckling also increases.
5. Steel has a high expansion rate with changing temperatures. This can be detrimental to the overall structure.

6. EXPERIMENTAL RESULTS

We have proposed to optimize the 2D steel truss configuration for increasing structural efficiency. We have tested the designed models using Ansys Software. Ansys has been developed specifically for multi-story commercial and residential building structures, such as office towers, apartments and hospitals. Ansys is a general purpose software with applications primarily in the building industry -commercial buildings, bridges and highway structures, industrial structures, chemical plant structures, dams, retaining walls, turbine foundations, culverts and other embedded structures, etc. We have designed three different steel truss namely Mild Steel, Alloy Steel and Structural Steel. The visual representation of all the three 2D steel truss designed are given below.

Fig 7.1 Start Page of Ansys Workbench



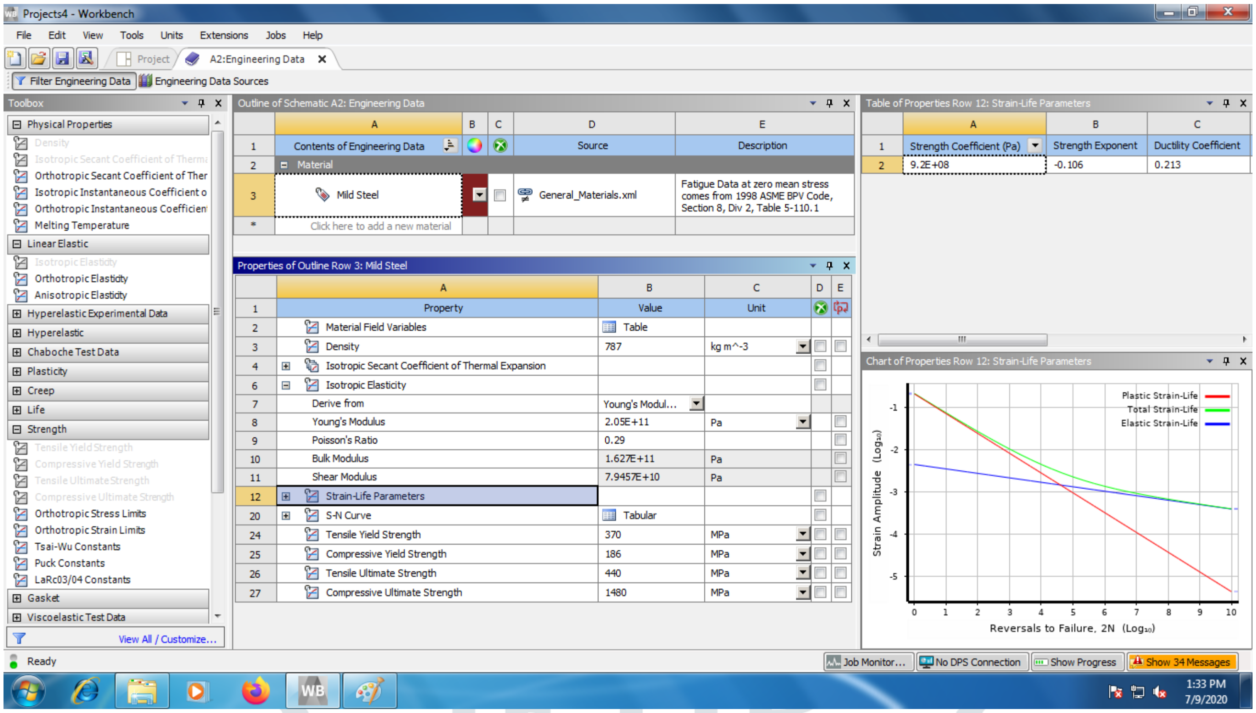


Fig 7.2 Engineering Data

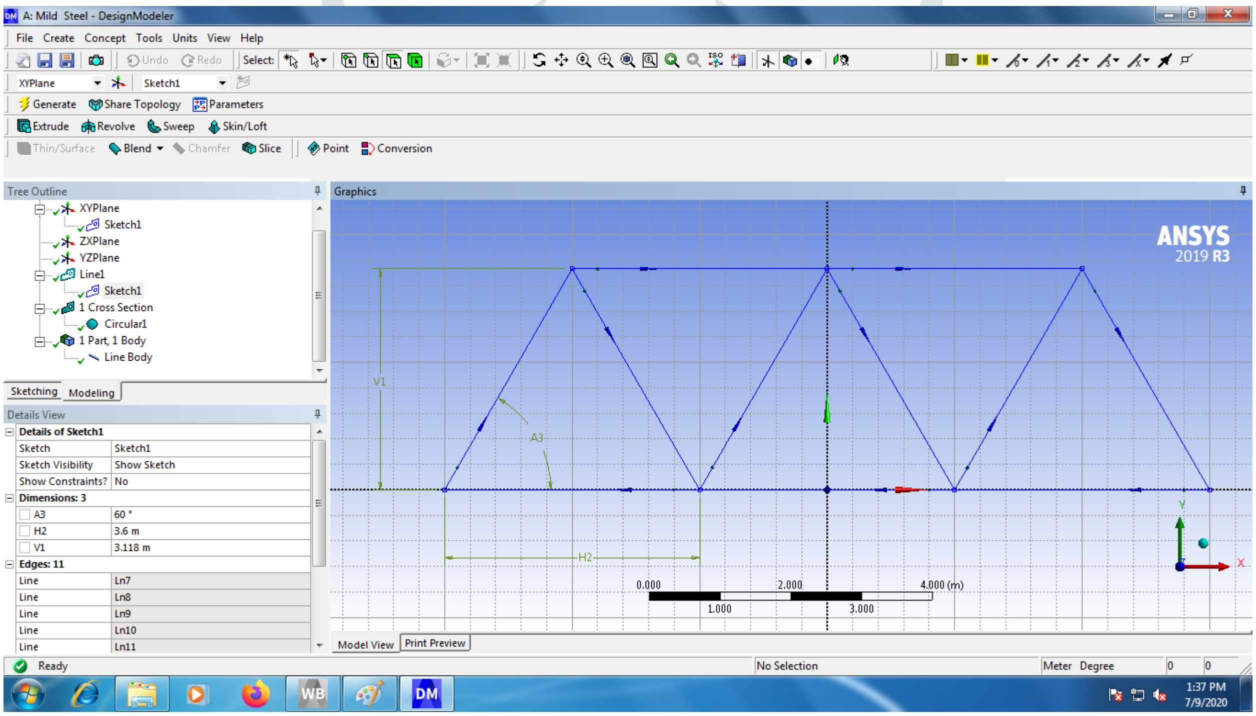


Fig 7.3 Geometry

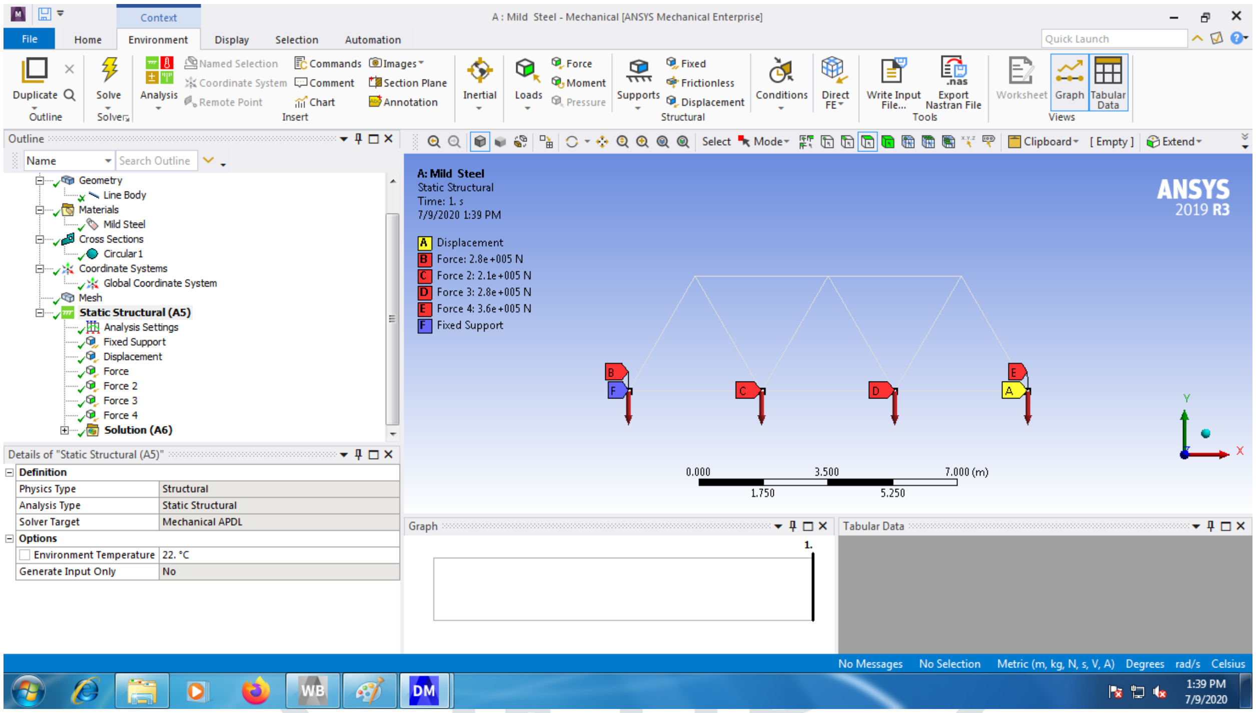


Fig 7.4.Static Structural Model

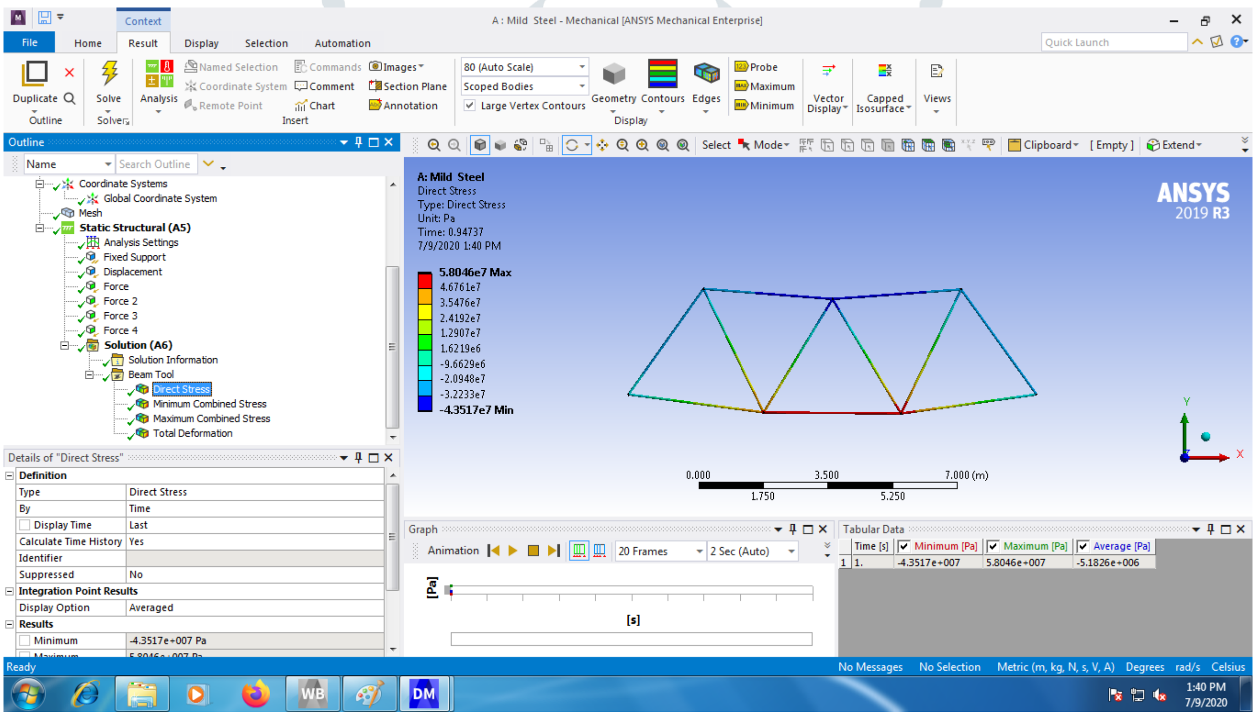


Fig.7.4 Static Structural Model

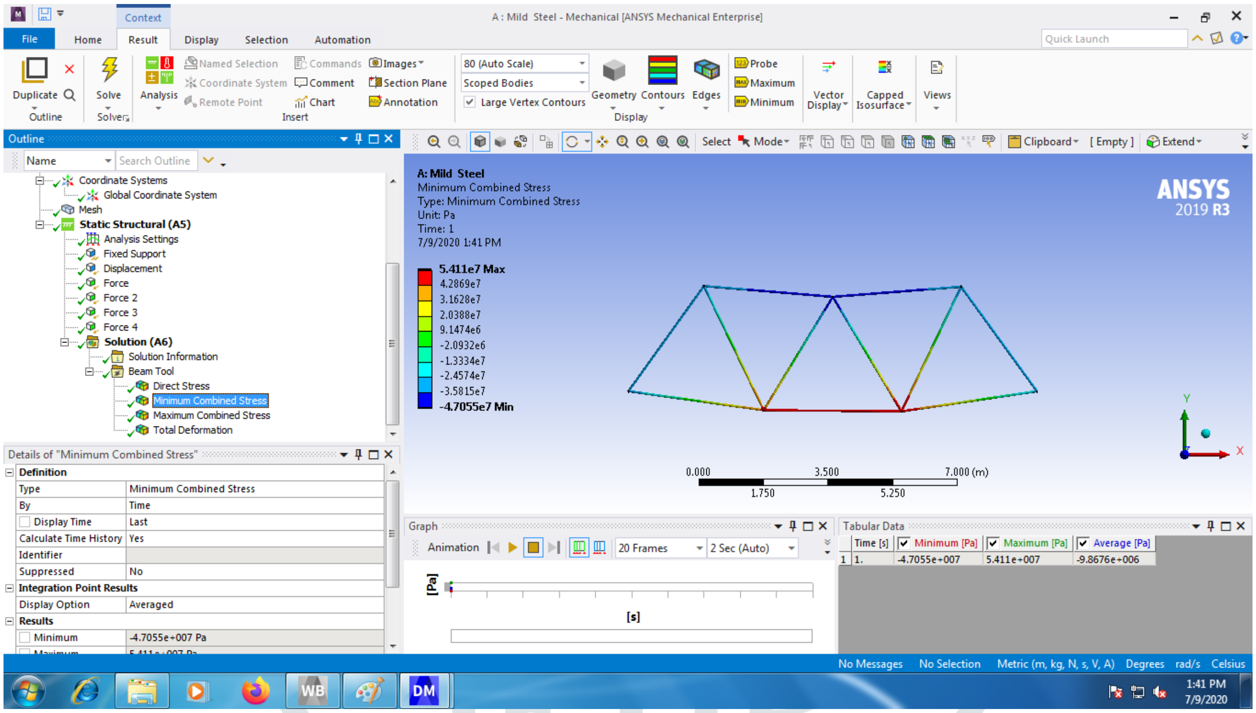


Fig.7.5 Direct Stress

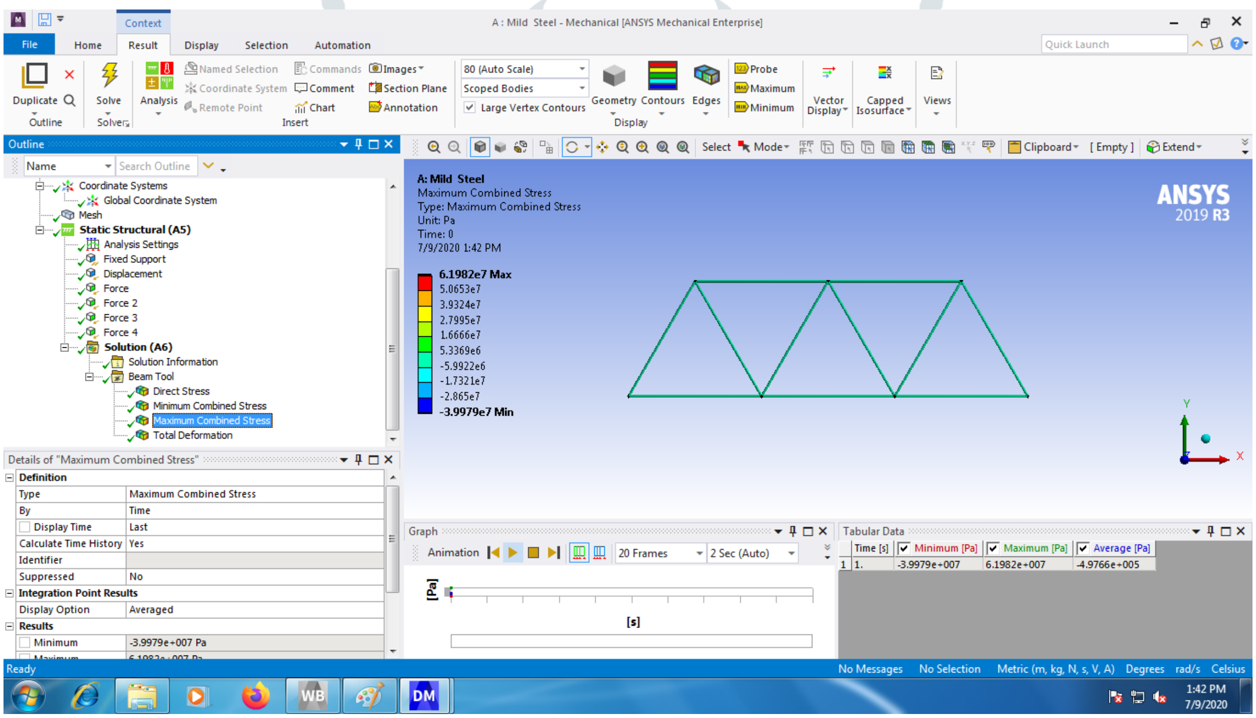


Fig.7.6 Maximum Combine Stress

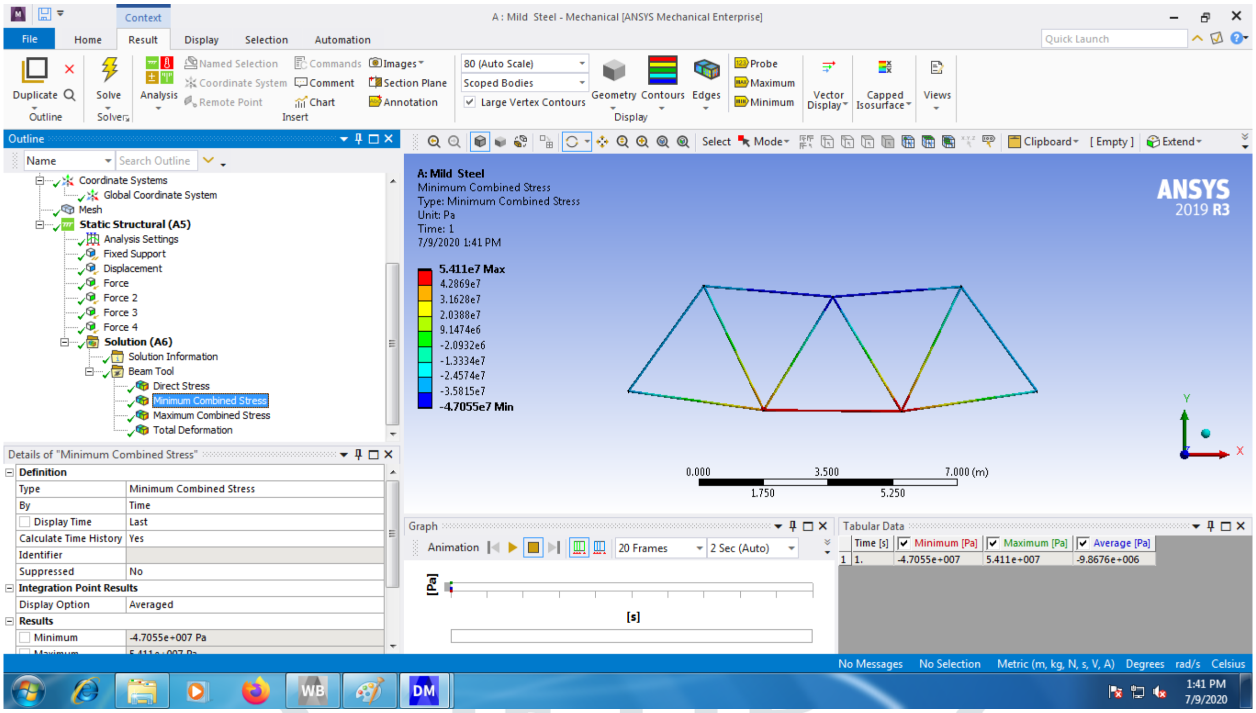


Fig.7.7 Maximum Combine Stress

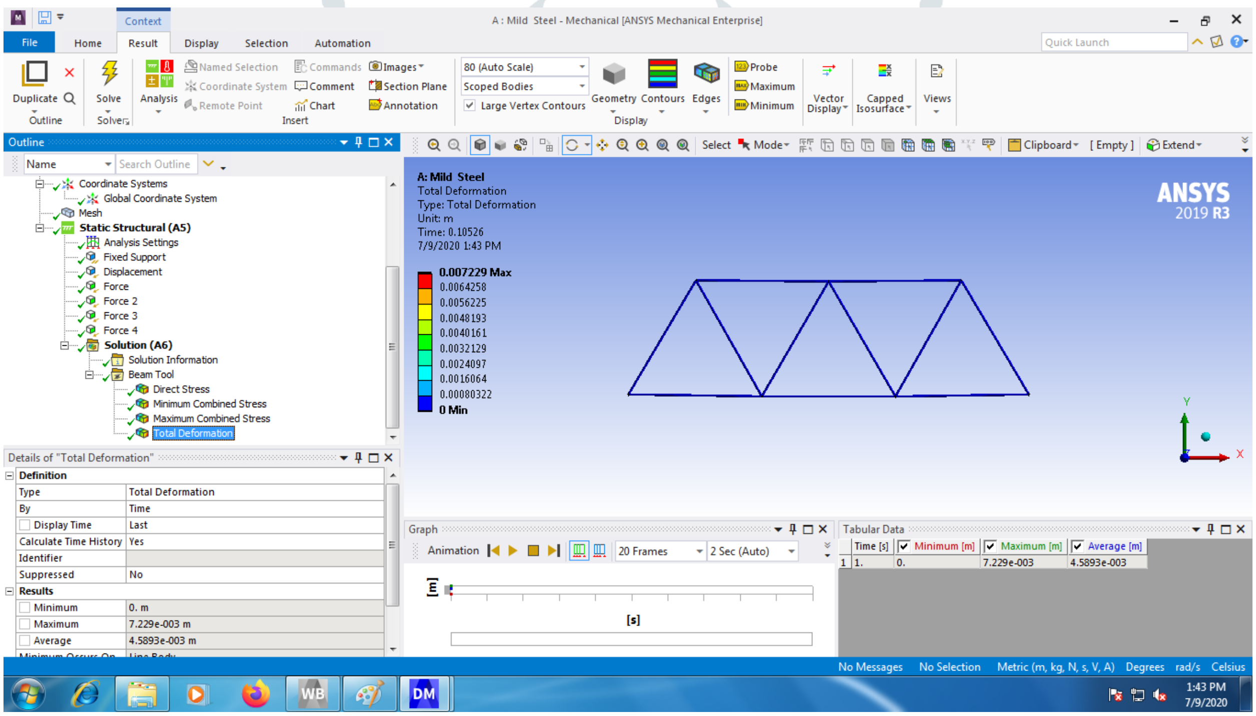


Fig.7.8 Total Deformation for Mild Steel

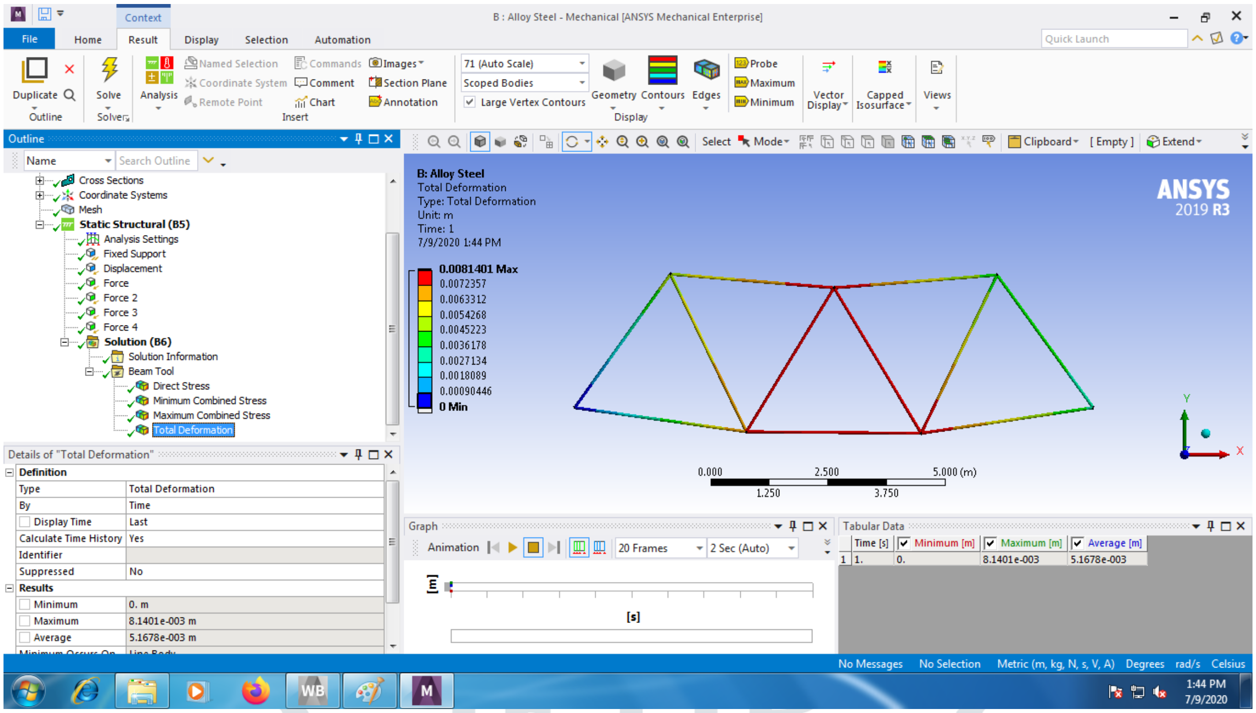


Fig.7.9Total Deformation for Alloy Steel

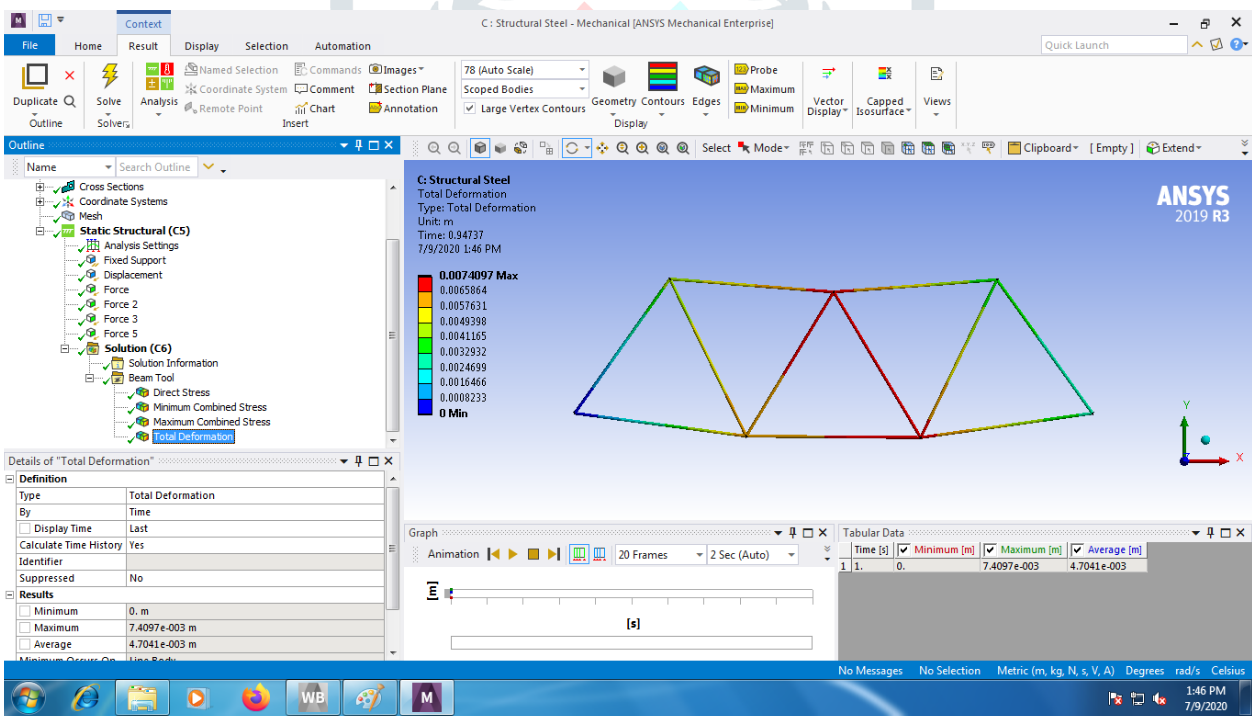


Fig.7.10 Total Deformation for Structural Steel

The designed steel truss structures are analyzed for increasing structural efficiency with different parameters. The results obtained for the designed Mild steel, Alloy Steel and Structural Steel are tabulated below:

	Direct Stress	Minimum Combine Stress	Maximum Combine Stress	Total Deformation
Mild Steel	Minimum = -4.3517e7 Maximum = 5.8046e7 Average = -5.1826e6	Minimum = -4.7055e7 Maximum = 5.411e7 Average = -9.8676e6	Minimum = -3.9979e7 Maximum = 6.1982e7 Average = -4.9769e5	Minimum = 0 Maximum = 7.229e-3 Average = 4.5893e-3
Alloy Steel	Minimum = -4.3517e7 Maximum = 5.8046e7 Average = -5.1826e6	Minimum = -4.7055e7 Maximum = 5.411e7 Average = -9.8676e6	Minimum = -3.9979e7 Maximum = 6.1982e7 Average = -4.9769e5	Minimum = 0 Maximum = 8.1401e-3 Average = 5.1678e-3
Structural Steel	Minimum = -4.3517e7 Maximum = 5.8046e7 Average = -5.1826e6	Minimum = -4.7055e7 Maximum = 5.411e7 Average = -9.8676e6	Minimum = -3.9979e7 Maximum = 6.1982e7 Average = -4.9769e5	Minimum = 0 Maximum = 7.4097e-3 Average = 4.7041e-3

Table I. Output Results of Mild Steel, Alloy Steel and Structural Steel using Different Parameter

CONCLUSION

The study shows how to improve the efficiency of particular types of structure using three mechanics concepts, which are “the smaller the internal force, the more direct the internal force path, and/or the more uniform the internal force/stress distribution, the stiffer the structure”. The study concentrates on making good use of existing measures, developing new measures, providing a theoretical background to existing measures and abstracting general principles from available efficient measures for achieving more efficient structures. After analysis of the three types of 2D steel truss output parameters are tabulated. From the tabulated output it has been observed that 2D Mild steel truss out performs with minimum Deformation hence increasing the structural efficiency.

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