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- Integrated structural analysis and design software packages, which generally work on finite element method for analysis and design, have been gaining popularity in the field of designing since they have reduced the tedious calculation process to a simple process of just giving input values. The result generated is according to the values entered without the consideration of the feasibility 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

I. INTRODUCTION

Composite materials have been used extensively to build truss structures owing to their remarkable properties. Composite truss structures have attracted tremendous research interests due to their superior strength and performances, and have been utilized in the construction of civil structures. Considerable efforts have been placed on the development and analysis of truss bridges, which usually consist of concrete and steel.

1.1 Introduction

Research works have been focused on material characteristics, truss joint design, and processing and construction of structural components. In the nineteenth century, composite trusses for aerospace applications were investigated [1-3], which are distinctly different from civil structures regarding materials, strength, stiffness, and weight. The effects of prestressed cables in composite structural system were studied [4]. In recent years, experimental study and numerical analysis have been carried out on composite space trusses with prestressed cables made of steel and compression members made of concrete [5,6]. The performances and characteristics of overall composite truss structures have been studied [7, 8]. Although publication works on composite trusses have been found in the literature, further investigation on systematic design and analysis of composite trusses containing pretensioned cables is needed.

1.2 Background

The time period of most useful structure may be very indistinct. This is because a structure may be most desirable in special components. This one of a kind aspects are called goals, and might as an instance be the weight, feel or stiffness of the shape. A numerical assessment of a positive objective is viable through a goal feature, which determines the goodness of the structure in terms of weight, value or stiffness. Of course, the optimization needs to be accomplished inside some constraints; otherwise, it’s a problem without a nicely described solution. Firstly, there are design constraints, like a constrained geometrical extension or restrained availability of various structural elements. Secondly, there are behavioral constraints at the structure that denotes the structural response under a sure load circumstance. Here may additionally, for example, limits on displacements, stresses, forces and dynamic reaction be looked after. Finally, there's one apparent call for that is valid for all structures, and it's far kinematical balance, in any other case they are mechanisms. This can be visible as a behavioral constraint. Structures that lie in the constraints are called viable answers to the optimization trouble.

1.3 Motivation

Optimization may be completed with appreciate to two or extra specific goal features. This is known as a multi-goal optimization (also referred to as multi-criterion or vector optimization). One example of this is Galante's (1996) try to discover a minimal weight of a truss using as few one-of-a-kind profiles as feasible. In multi-goal optimization, one fashionable goal characteristic may be prepared by using weighted elements of the concerned objective functions. Hence, by means of changing the weights, exclusive Optima are obtained. Other techniques for dealing with multi-goal optimization are also viable. When it comes to trusses, the optimization can be divided into 3 categories; sizing, shape and topology optimization; Sizing optimization refers to locating the most excellent cross phase area of every member of the structure; shape optimization manner optimizing the outer shape of the shape; and topology optimization describes the search for the fine inner connectivity of the participants. One manner of optimizing those three parameters is to take them into attention one at a time, beginning with the topology optimization, a so called multi-degree optimization method (additionally called layered optimization). It is obvious although, that this technique doesn't constantly offer the excellent global answer, for the reason that issues aren't linearly separable. One of the strengths of a genetic algorithm is that a simultaneous optimization of all three parameters can be executed [9].

1.4 Truss optimization

A truss is a structure of assembled bars, frequently arranged in a triangular shape. Theoretically, the bars in a truss are assumed to be related to each different with the aid of friction-loose joints. In actual-existence trusses even though, the joints are greater or much less stiff because of welding or screwing the bars collectively. Even with some stiffness inside the connections, a model with friction-free joints can correctly be used if the center of gravity axis

II. REVIEW OF LITERATURE

Vaibhav B. Chavan et. al. (1990) This research's objective was to estimate the economic importance of the Hollow Sections in contrast with conventional sections. This paper was carried out to find out the percentage economy accomplished using Hollow Sections so as to understand the importance of cost efficiency. The technique used in order to reach the objective involves the comparison of various profiles for different combinations of height and material cross -section for given span and loading conditions. The analysis and design phase of the project was done utilizing STAAD PRO V8i. The results of STAAD analysis were validated with the results of Manual analysis [12].

Davison and Birkemoe (1982) Determined that there are two residual stress gradients in the longitudinal direction, one across the tube face and around the cross section, denoted as membrane, and the other perpendicular to the tube face through the material thickness, denoted as bending. "The perimeter (membrane) residual stress gradient represents the variation in the mean value of the longitudinal residual stress [and] the through thickness (bending) residual stress gradient is the deviation from this mean value normal to the perimeter through the material thickness"[13].

Chotiga Choensiridamrong et.al in (2014)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) 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) 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)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) 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) 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) 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.

M.G.Kalyanshetti, G.S.Mirajkar, (2012) This research involves the economy, load carrying capacity of all structural members and their corresponding safety measures. Economy was the main goal of this study involving comparison of conventional sectioned structures with tubular sectioned structure for given requirements. For study purpose superstructure-part of an industrial building is considered and comparison is made. Research reveals that, up to 40 to 50% saving in cost is achieved for square and rectangular tubular sections [10].

Trilok Gupta, Ravi K. S Harma, (2013) The research involves various kinds of industrial roof trusses by using computer software. It also involves the knowledge regarding steel roof trusses and the design philosophies with worked examples. From the observations they concluded that, the sections designed using limit state methods are more economical than the sections using working stress method. It was observed that the tubular section designed by limit state method was the most

III. 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.

IV. 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.

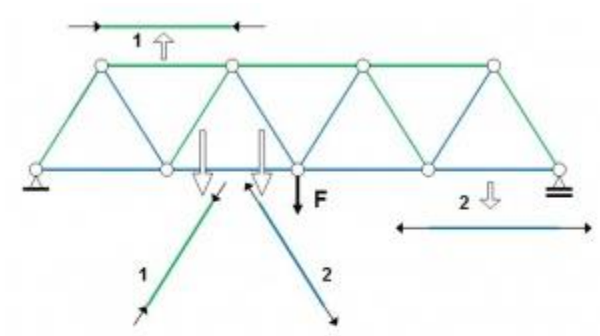


Fig1.1 Members under axial forces in a simple truss
1 - Compression axial force
2 - Tension axial force

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.

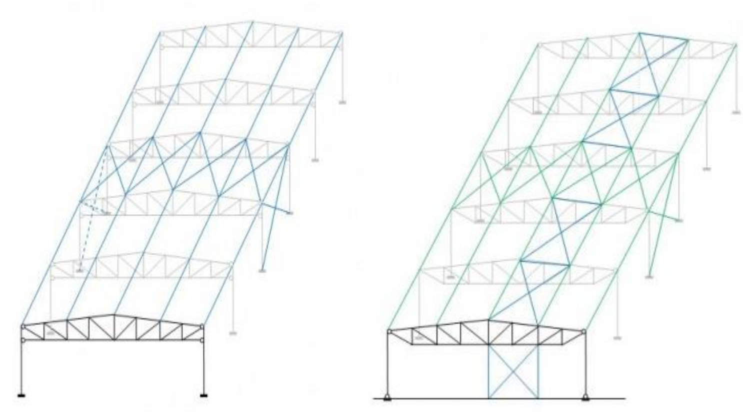


Fig 1.2 Typical truss building arrangements

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.

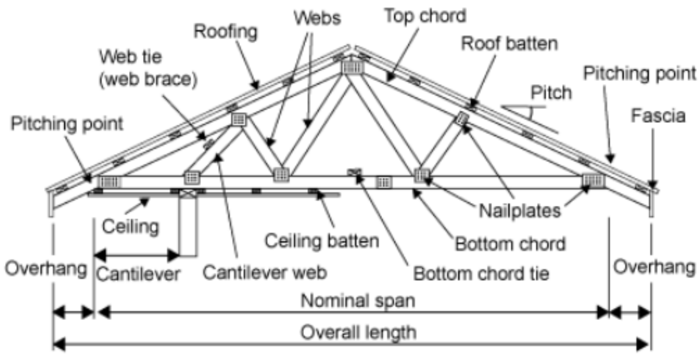
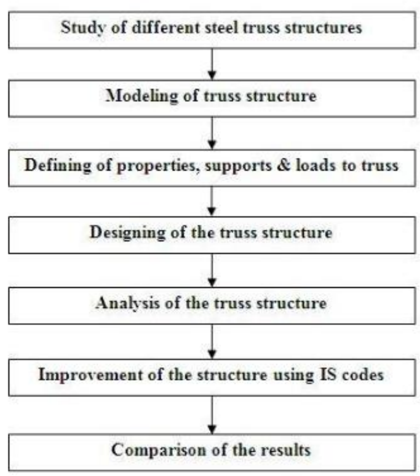


Fig1.1 Skeleton of a typical Roof truss

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.

IV. RESEARCH METHODOLOGY



V. 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.

VI. 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.

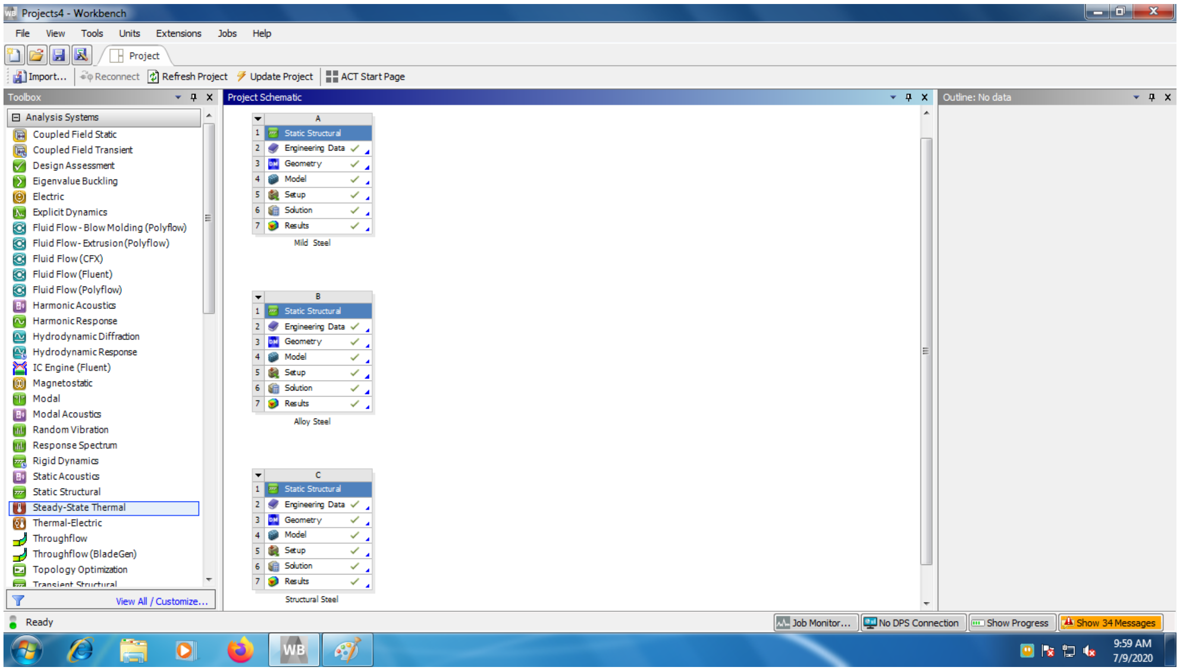


Fig 7.1 Start Page of Ansys Workbench

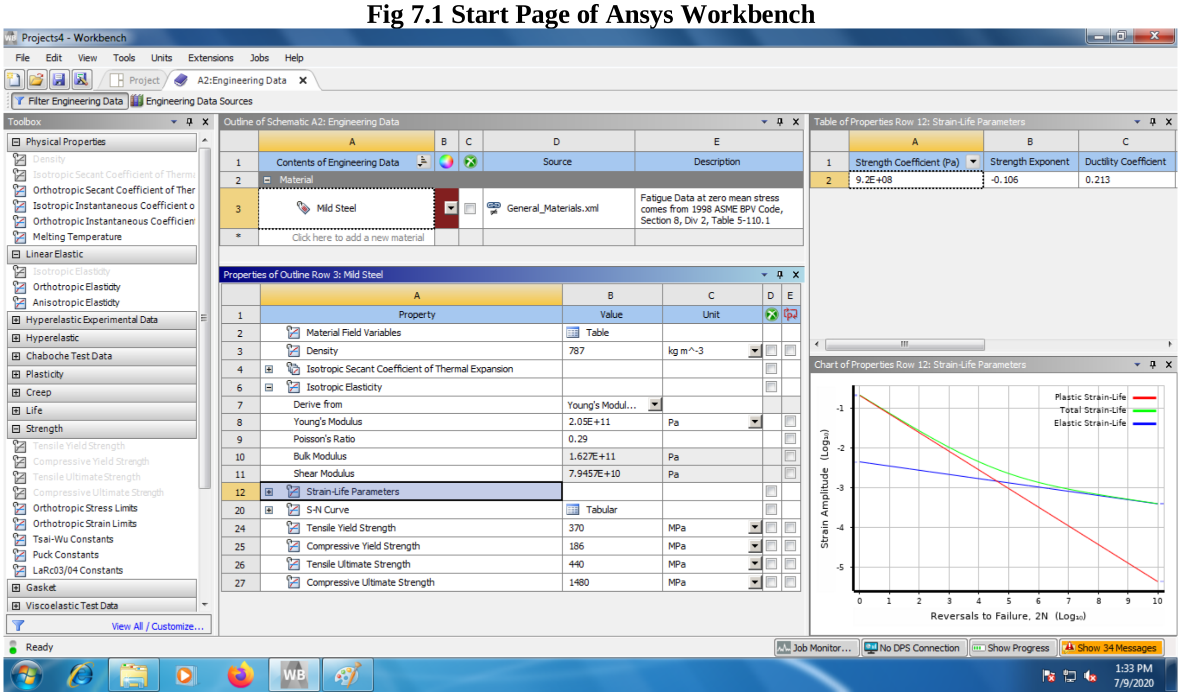


Fig 7.2 Engineering Data

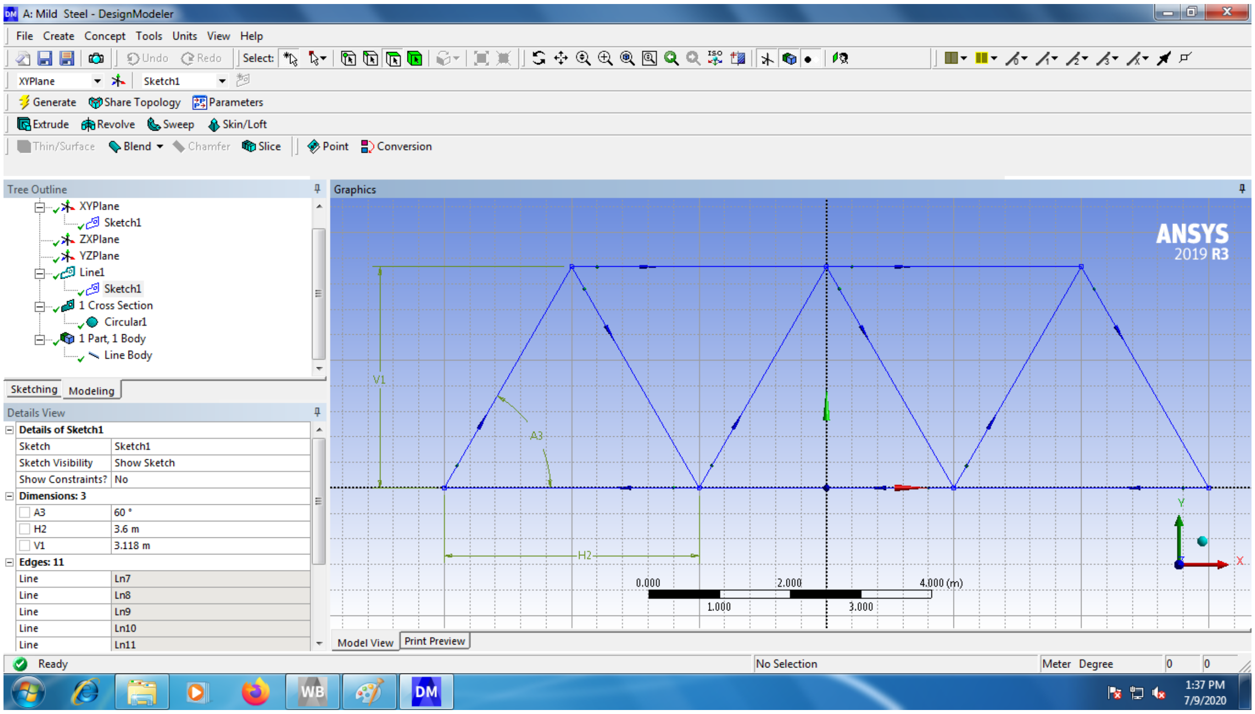


Fig 7.3 Geometry

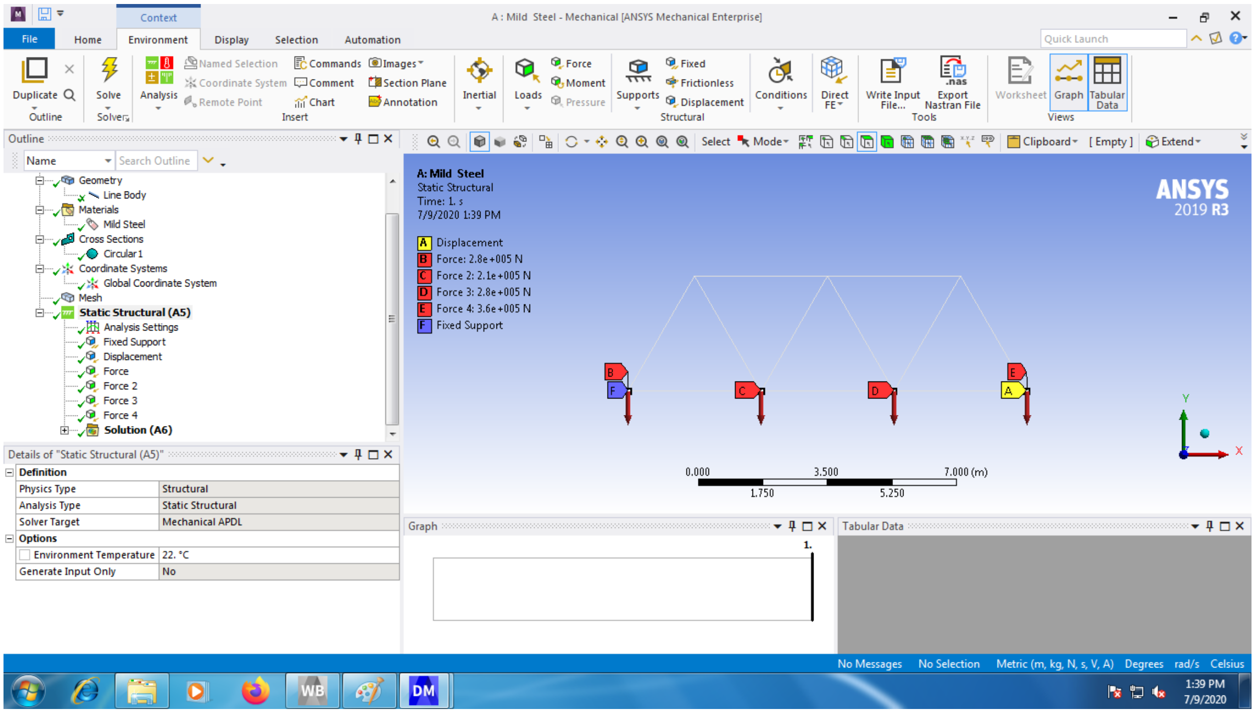


Fig 7.4.Static Structural Model

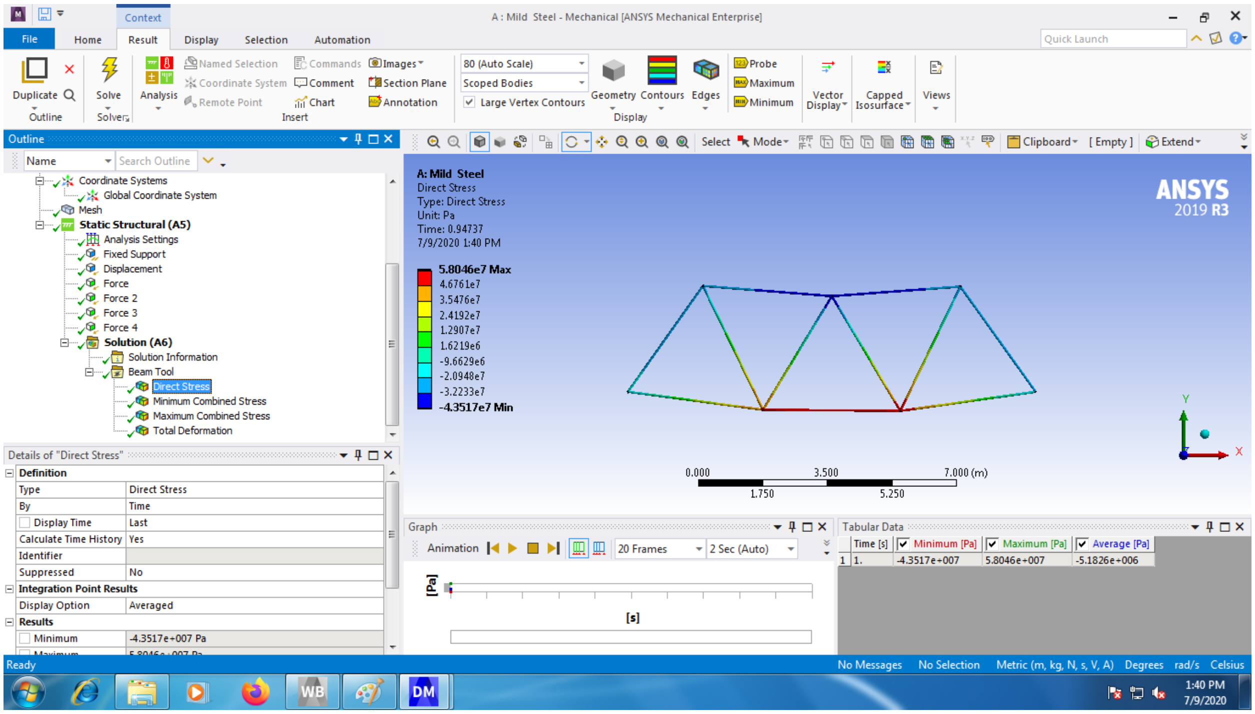


Fig.7.4 Static Structural Model

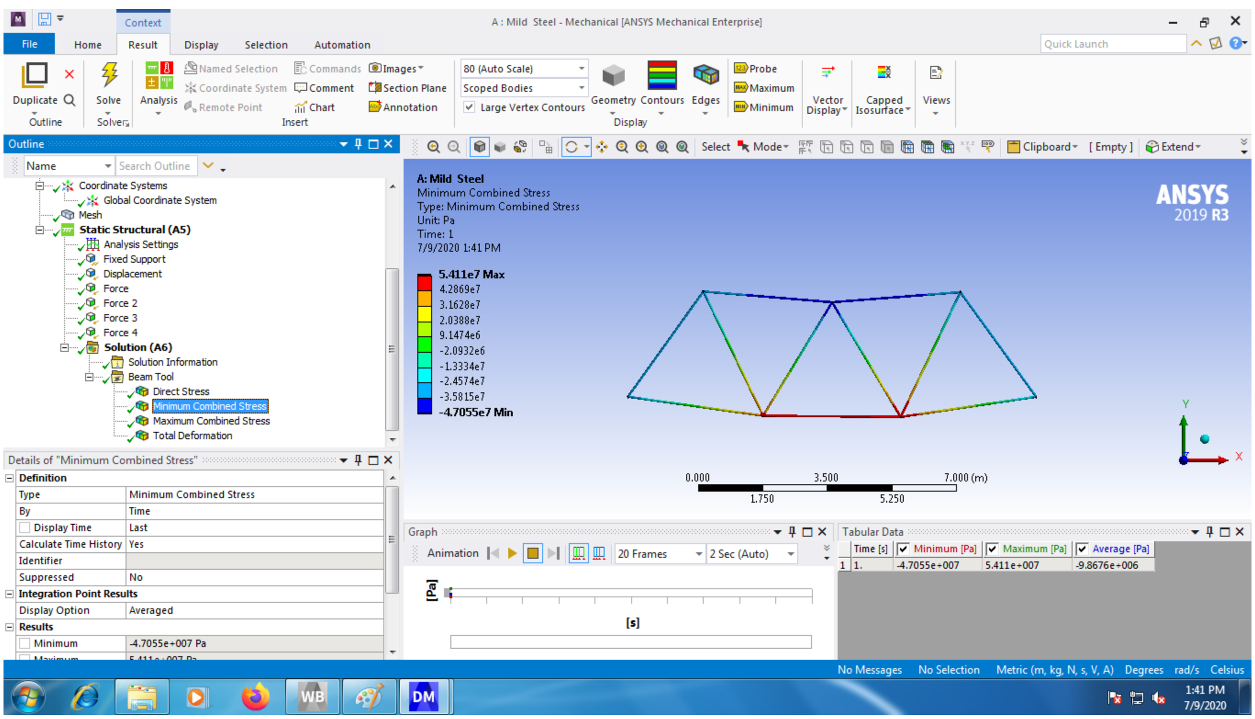


Fig.7.5 Direct Stress

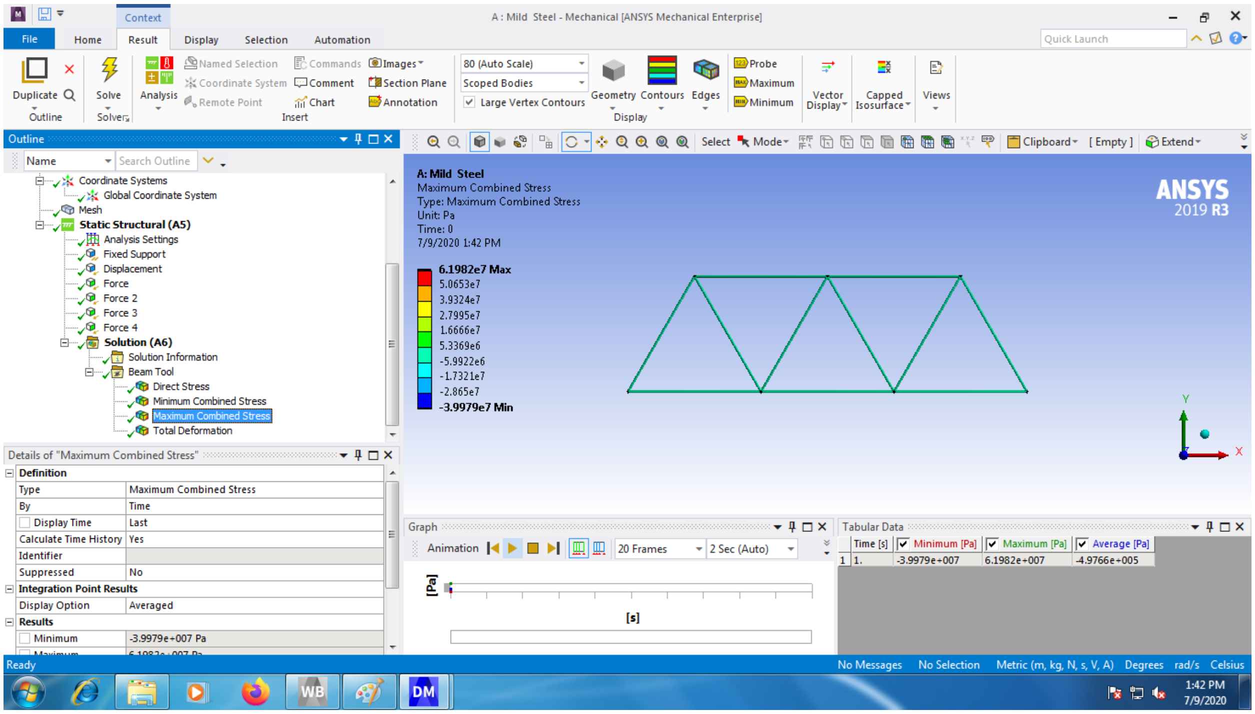


Fig.7.6 Maximum Combine Stress

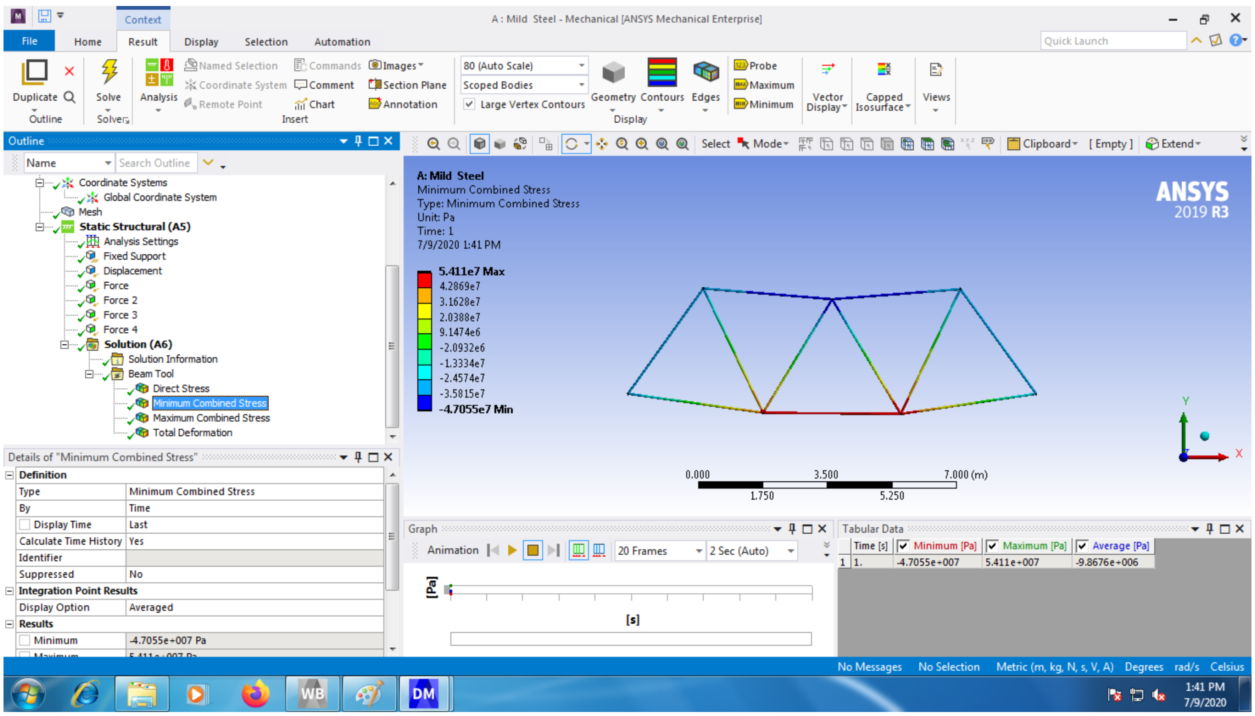


Fig.7.7 Maximum Combine Stress

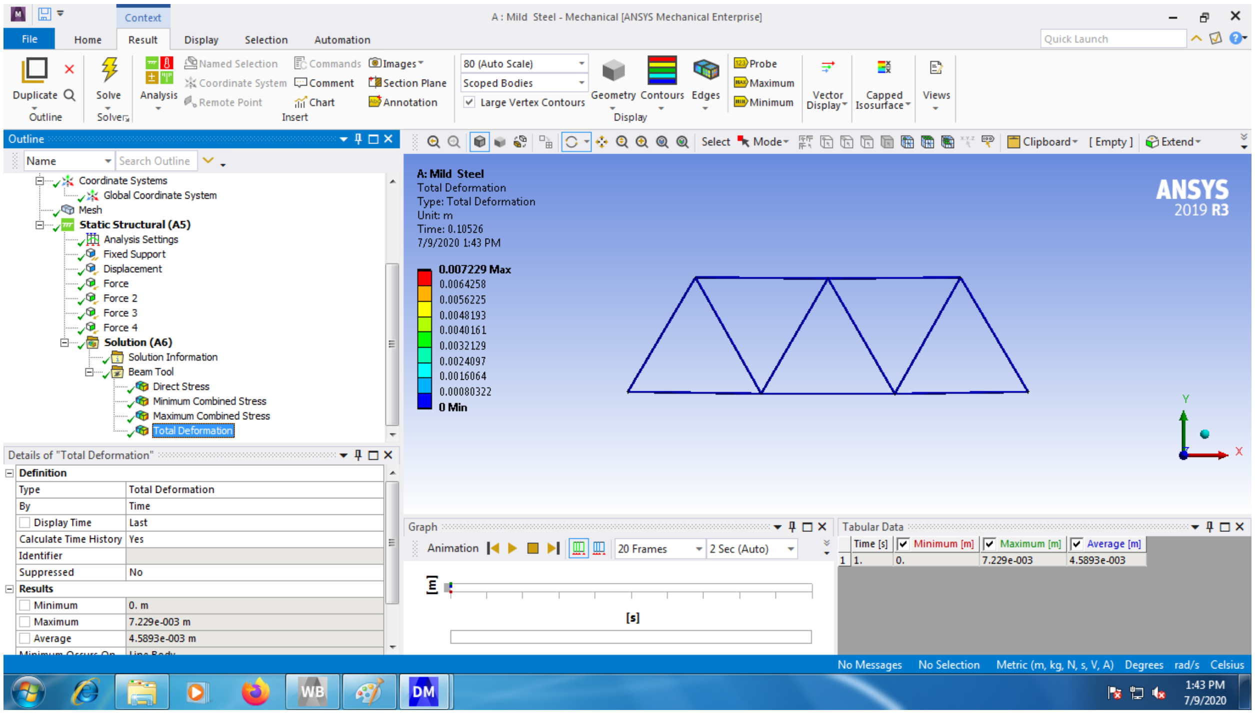


Fig.7.8 Total Deformation for Mild Steel

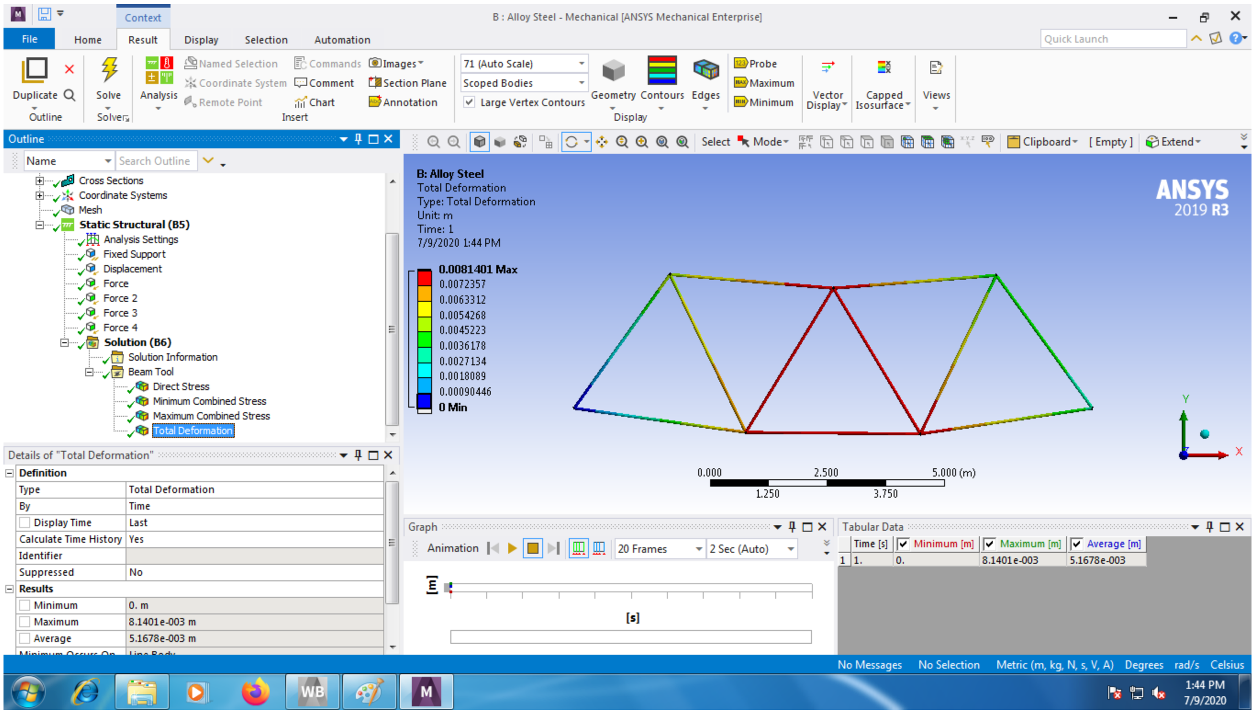


Fig.7.9Total Deformation for Alloy Steel

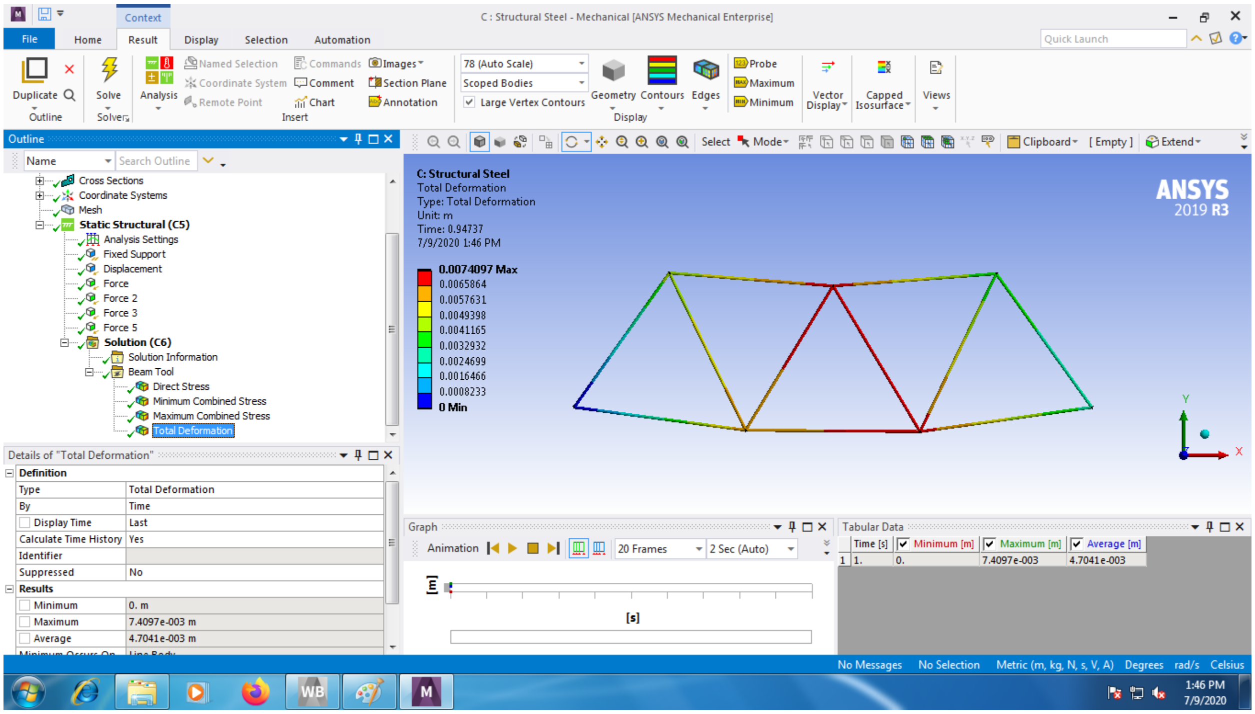


Fig.7.10 Total Deformation for Structural Steel

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

VII. 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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