<u>EVALUATION OF TRAILER CHASSIS STRUCTURE FOR INCREASED STIFFNESS</u>

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A B S T R A C T

The establishment of CPEC is likely to increase the road transportation in Pakistan by many folds, where heavy duty trucks will play vital role in carrying goods from Pakistan's northern border to the Gawadar Port in south. The appropriate design of transportation vehicles will play a vital role in the life expectancy of these heavy duty trucks, which will be subjected to the tough conditions of Karakoram Mountain Range. Generally, heavy-duty trucks are designed to resist structure buckling with increased load carrying capacity. For this purpose, the truck beds are lowered to reduce the torsional effects.

The torsional effects on the vehicle chassis increase by many folds as the C.G. (Center of Gravity) of the pay load moves up beyond critical limit. For resisting these effects and to have an off-road capability, chassis frames are made from sandwiched multi-grade steel layers. The major structural member is usually the expensive grades of Ti precipitated steels such as B750L. The design of two-axle general purpose heavy duty chassis frame for 26 ton trucks and higher capacities need to be modified to best suit the loading conditions and applications in Pakistan.

Finite element analysis of the multi-layered multi-grade chassis frame steel structure was carried out for the selected heavy duty truck chassis. The obtained results were analyzed and alternate materials were sought as per our application which can provide a cost effective solution. Modifications of the structural members were carried out in order to reduce weight from the overdesigned regions; also over stressed regions were reinforced.

The design criteria of strength and stiffness were adopted. The results showed that the proposed trailer chassis structure for increased stiffness fulfills the design requirements. Maximum stresses and deformations for various cross-sectional chassis, which is derived in this work, is less than the conventional chassis.

Keywords: Trailer Chassis, Beam Section, Torsional Loadings, Bending Loadings

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List of Abbreviations

CG.. Center of Gravity
ML ....Multi-Layer Sections
CI ....C & I Sections
CB .... C & B Sections
CZ ....C & Z Sections
BI ....B & I Sections
BC .... B & C Sections
BZ ....B & Z Sections
IC ....I & C Sections
IB ....I & B Sections
IZ ....I & Z Sections
CPEC .... China Pakistan Ecnomic Corridor
Ti.. Titanium
A71..Multi-Layer Sections
REGN ....Registration
Dr...Doctor
DME ....Design of Manufacturing Engineering
SMME ....School of Mechanical and Manufacturing Engineering
FEM...Finite Element Method
etc...etcetera

CHAPTER 1: INTRODUCTION

Automobile lower body consists of tires, frame, engine suspension and driven line is called chassis. All the other parts of the vehicle are fixed on it [1]. The chassis frame should be strong to support these bodies parts and also remain rigid when higher shear stress and bending moment is produced at high speed. These frames should be light in weight and structure for reduction of fuel consumption [2]. However, the frame of vehicle dose not only to support the mechanical parts such as axle assembly, suspension, break and steering mechanism, but also stabilize and sustain the required correlation between steering mechanism and suspension. The greater the ability of chassis to absorb energy due to shock and impact load conditions, the lower will be the chances of injury [3]. Running commercial vehicle chassis **Figure 1-1** have to bear a lots of loads like running gear, engine power transmission to the axle. Therefore, chassis must be design that it become appropriate for all these problems [4].

Figure 1-1: Trailer Chassis

The critical points, where the maximum stresses act, can be recognized by using finite element method (FEM). The fatigue failure of the vehicle is a cause of these critical points. The magnitude of bending and torsional stresses estimates the life span of the variable chassis frame.

1.1 Types of Automobile Chassis:

The chassis of vehicle can be categorized in different forms which include:

1.1.1 Ladder Chassis:

It is conventional type of chassis which is still being used in SUV's. It has resemblance with the ladder chassis and consist of longitudinal main members and connection of the series of cross members.

1.1.2 Monocoque Chassis:

It is single piece chassis of vehicle which helps in the formation of whole shape of the vehicle. Parts of the monocoque chassis are assembled by welding. Steel plates monocoque chassis are very economical and appropriate for computerized production.

1.1.3 Backbone Chassis:

The backbone chassis are formed with rectangular/ circular hollow tubes. Material of the tube is glass fiber. These tubes connect the rear and front shaft of chassis. These chassis are best chassis in designing the small sports car. The process of manufacturing of the backbone chassis is very simple and economical.

1.2 Chassis Cross Sections:

1.2.1 Types of Cross Sections of Chassis:

When a vehicle moves on a plain and rough surface of the road, vehicle chassis face center of gravity (C.G.) shift, bending and torsional deformation. Due to the above circumstances the different types of cross section of chassis have been studies.

1.2.1.1 Solid round or rectangular box sections

A. Square solid bar
B. Round solid bar

1.2.1.2 Hollow round or rectangular box sections

D. Circular closed tube
F. Rectangular box section

1.2.1.3 Rectangular channeling such as 'C, I, Z, H and U sections

C. Round tube with longitudinal cut
E. C Section
G. Top hat Section
H. I Section
I. Channel flitch plate Section

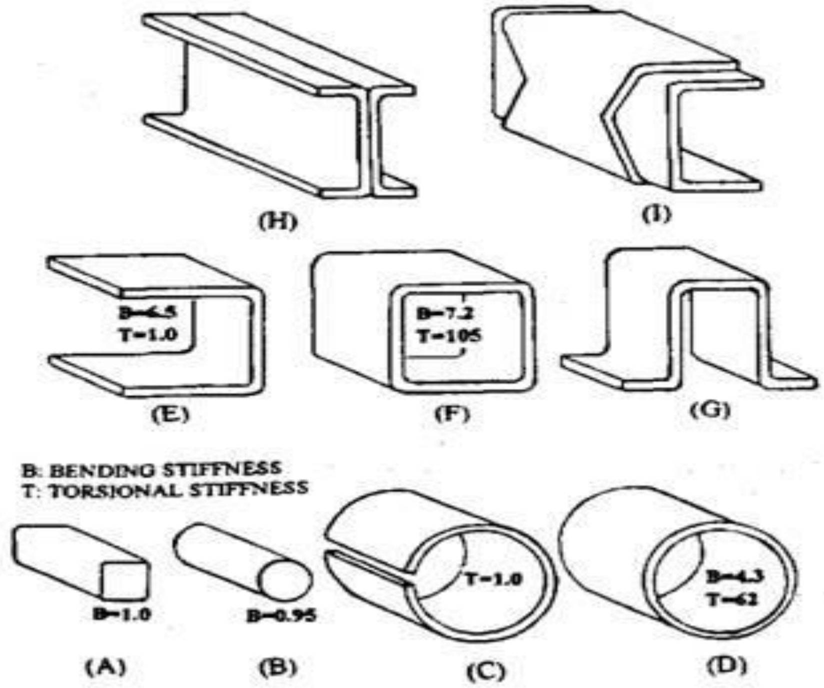


Figure 1-2: Types of Chassis Cross Section

Channel sections are more useful as compare to hollow tube sections in torsional rigidity. The chassis are not just rigid but a mixture of flexibility and rigid in some extent.

1.2.2 Main Member Bending Resistance

The chassis main members are the span of distance between front and rear axle, which intake maximum weight. The whole weight of vehicle is come on the main members who are transferred through suspension system.

For the comparison of bending stiffness of different sections have the thickness and cross sectional area is kept same **Figure 1-2:** Types of Chassis Cross Section**Figure 1-2** A to F. Seeing a stiffness/ rigidity of 1 for the solid square cross section, and the comparative bending rigidity for all other cross sections are,

Square rod	1.00
Round/ Circular rod	0.95
Circular hollow tube	4.30

Open C Channel Section	6.50
Square hollow tube section	7.20

Either hollow round or rectangular box sections or open channel section like C, I, Z, H and U sections give highest bending stiffness. During the analysis of bending stiffness of main member of chassis, the thickness and cross sectional area is kept same. An analysis of C section that is best section for main member was carried out. The designing of heavy loaded vehicle, two C sections or I section may be used. This double section is also called flitch frame in which two C sections are joined back to back which enable it for more bending stiffness.

1.2.3 Main and Cross-Member Torsional Resistance

Open channel main member show good resistance against bending but less against torsion. Combination of main and cross members of the chassis show good resistance against torsional deformation. In **Figure 1-2:** Types of Chassis Cross Section C to F section are analyzed. First, comparison of open channel section and closed circular section. Second, comparison between open channel section and closed hollow rectangular box section is made. It is conclude that later comparison show highest resistance against torsional deformation. Bearing in mind the open channel section has a resistance of 1 in this each case.

Round tube longitudinal cut	= 1.0
Closed hollow tube section	= 62.0
Open channel C section	= 1.0
Closed rectangular box section	= 105.0

1.3 Chassis Operating Conditions

Before the designing of the chassis of vehicle, the conditions of the roads are also taken under consideration. Usually, on the off road drive chassis frame face four different types of loading.

1.3.1 Vertical Bending:

If we support the chassis of vehicle at ends, front and rear axle and cast the load of passengers, luggage, engine etc. in the middle of front and rear axle then chassis main member will vertically bend from central area.

1.3.2 Longitudinal Torsion:

When the two wheels of vehicle at the section are on bump diagonally, the chassis will wrap in antagonize direction. The chassis main and cross members will imply longitudinal torsion. **Figure 1-3**, which twists the chassis of vehicle.

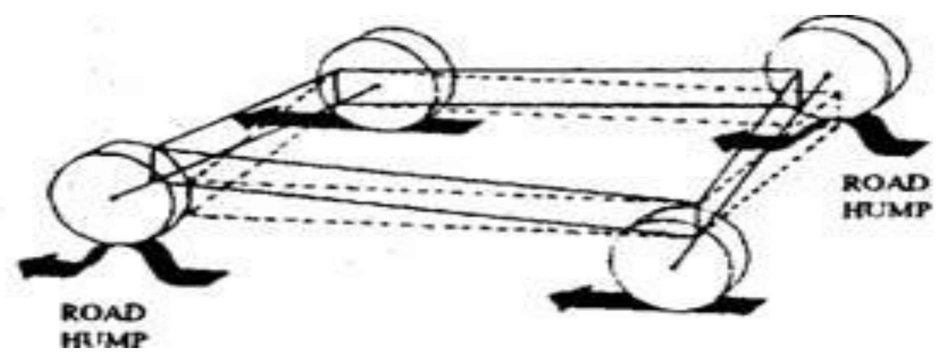


Figure 1-3: Longitudinal Torsion

1.3.3 Lateral Bending:

When the chassis of vehicle is manifest to lateral lead which can be side wind force, centrifugal turning force, camber of road or accident with any object, the chassis will move in the force of direction. Then chassis of vehicle will adopt a bow shape due to reaction for tires. Which would be opposite direction of lateral bending. As show in the **Figure 1-4**.

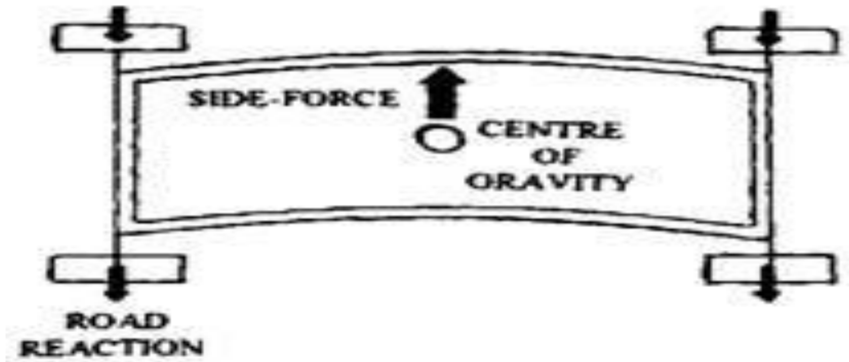


Figure 1-4: Lateral Bending

1.3.4 Horizontal Lozenging

When the chassis of vehicle is moving back and forth, the wheel manifest to the road indorses like road joints, road bumps and cold welds whereas the other diagonal wheel exert thrust. Due to above loading chassis rectangular shape deformation into parallelogram shape which is known as Lozenging.

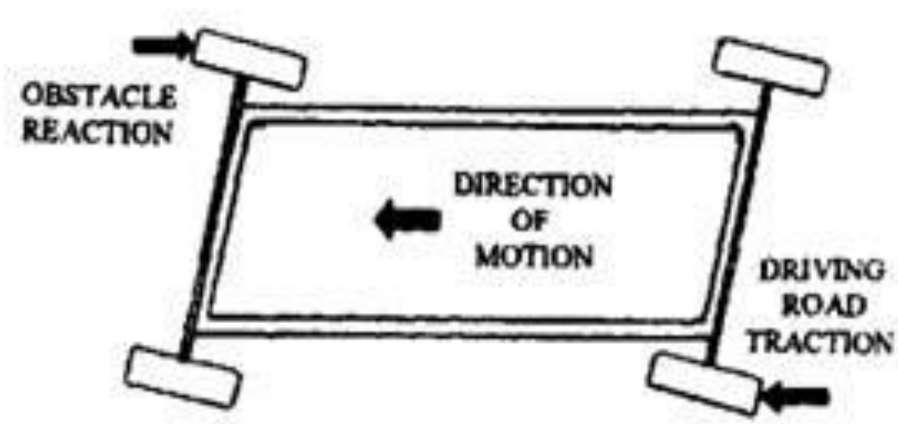


Figure 1-5: Horizontal Lozenging

1.4 Chassis Side and Cross Member Joints

By the joining the cross section and main members of the section, a single piece rectangular chassis is designed. Open channel sections are commonly used for cross members but for special applications sometimes closed hollow tube section are used. The single open or closed channel/ tube members do not own sufficient stiffness against torsion. But when joined together they form a relatively rigid structure capable of withstanding both bending the torsional loading. The attachment of the cross-members to the side channels needs special attention, because the junction points are subjected to maximum bending as well as torsional stresses. Commercial vehicle main members are generally made C section channel of cross section. Web section of C section channel resists all bending deformation and the upper and lower flanges save the web from collapsing through longitudinal and provide additional resistance to both bending and torsional stresses. Since the flanges or the outer regions of the web are the maximum stressed parts of the channel, any attachment should, therefore, preferably be in the web section. In actual practice, joints are made between flanges or a combination of both web and flange joints for convenience.

A. Top-hat-section cross-member joined to side-member flanges and web.
B. C channel section cross members with prolonged flanges connected to main member flanges.
C. C channel section cross member with the strengthen patch connected to main member of web.
D. ‘Top-hat’-section cross-member with alligator-jawed enforcement joined to both flanges and web.
E. Tubular-section cross-member with reinforcement flat bracket joined to side-member web.

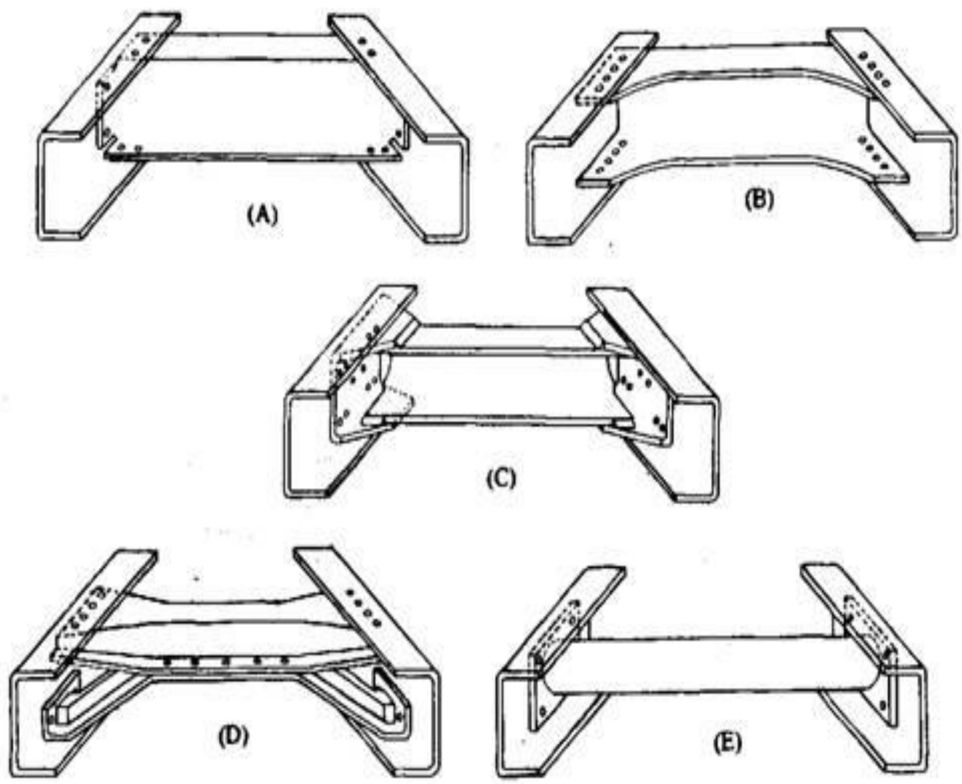


Figure 1-6: Chassis Side and Cross Member Reinforcement Joints

1.4.1 **Top-hat-section cross-member joined to side-member flanges and web**

A cross-member of ‘top-hat’ section joined between the web and both flanges. Sometimes just the web alone is joined, or alternatively the upper and lower flanges from the attachments. These joints are mostly used for light and medium-duty work.

1.4.2 C-section cross-member with extended flanges joined to side-member flanges

A pure channel-section flange joint and the cross-member flanges have been widened to provide reinforcement to the joint. This joint is used only for medium duty work.

1.4.3 C channel section cross member with strengthen patch connected to main member of web

Main and cross members connected where the cross member has a lap welded end strengthening patch (triangular) bracket, connected to the main channel section web only. This method of joint reinforcement allows the flange to be out of holes, which generally serve as a point for stress concentration. These joints are widely used for heavy-duty trucks.

1.4.4 **'Top-hat'-section cross-member with alligator-jawed enforcement joined to both flanges and web**

A pinched two piece of cross member that open at the end to form an alligator jawed flange and web strengthened connection. This form of cross-member and alligator jawed enforcement joint to both flanges and web.

1.4.5 **Tubular-section cross-member with reinforcement flat bracket joined to side-member web.**

A circular tube section, the cross member with a welded rectangular end bracket connected directly to the main member web. Circular tube section cross members are specifically suitable for withstanding both bending stresses and torsional stresses are at resolute points, like spring yoke hangers and axle suspension pivoting supports.

1.5 Chassis main and Cross-member Clasping

A service life of a chassis structure also depends on the type of joints in which the various members are fixed together. Riveting, bolting, and lap welding are the three different methods of joining available.

A. Riveted joint
B. Bolted joint
C. Lap-welded Connections

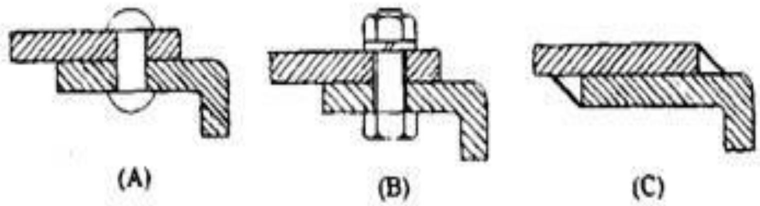


Figure 1-7: Chassis Side and Cross Member Fastening

1.5.1 Riveted Joints

Cold-riveted joints **Figure 1-7A** are most commonly used to connect two members. A unformed rivet has a shank and a head. To make the second head the shank spread out in a pair of any spaces of hole by forging process. of holes in the members to be joined, and occupies any clearance existing in the hole. These joints provide a moderately large compressive force between the plates so that relative movement is prevented.

1.5.2 Bolted Joints

For heavy-duty applications, the bolted joints **Figure 1-7B** are preferred, specifically if additional components are to be fastened, So the joints provide the compressive forces in between the member, so that the consistent friction forces stop the relative movement of these parts. If the bolted joints are not torque properly, they will lose because of continuous back and forth motion and flexing. This vibration could be the good reason of fatigue failure and heavy noises.

1.5.3 Welded Connections

Generally chassis side- and cross-members are not welded together. However subsections are frequently joined by lap welding. The problem with welded joints

Figure 1-7C is that they produce thermal distortion and, in case of the rigid frame, high stress concentration develops at the joints, which may eventually crack. Additionally, welding destroys any previous heat treatment around the joint thereby weakening the structure. Although precautions are available to prevent these problems but they are expensive to apply.

CHAPTER 2: Literature Review

In the chassis design, by reducing the weight of structure we can improve fuel ingestion and increasing loading capacity. For this purpose we need to take under consideration many parameters like, (1) Price, (2) Stiffness, (3) Dimensions of frame etc. Lots of work has been done on maturing the design principles of chassis. Automobile lower body consists of tires, frame, engine suspension and driven line is called chassis. Chassis acts as the footing for any vehicle [1]. The chassis frame should be strong to support the these bodies parts and also remain rigid when higher shear stress and bending moment is produced at high speed. These frames should be light in weight and structure for reduction of fuel consumption[2]. The prime function of vehicle chassis is to provide support to vehicle parts and components that are mounted on it. It also serves the function of maintaining the relationship of steering mechanism and vehicle suspension and also provides satisfaction **Figure 2-1**. The greater the ability of chassis to absorb energy due to shock and impact load conditions, the lower will be the chances of injury[3].

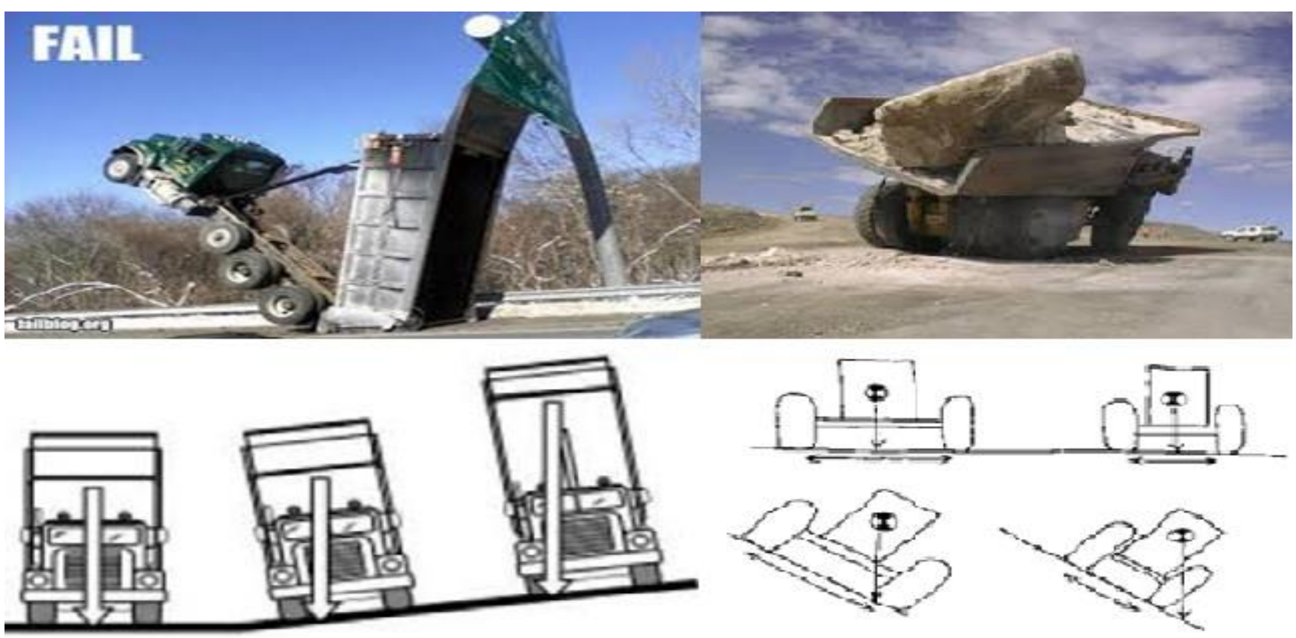


Figure 2-1: Failure Trailer Chassis Structure

2.1 Background

Scania AB is the leading truck developer in the world. They also develop and distribute assorted support system all around the world. Design and development of chassis require quite a big amount of computation. As designer require to iteratively check his model. Normally designing and testing is combined to linear models. But to accommodate non linear models massive amount of processing is required.. Software being used by Scania AB for this purpose is "Catia". The tool box used is GAS and (Catia Generative Assembly Structural). It can import file from CAD and assembly can be assembled in it.[9] Chassis frame design is of foremost importance because this is a part of truck that has to bear its load ad stable design of chassis means stable truck. Chassis design most important inputs is required payload by customer, speed required and conditions of driving. [10]. **Figure 2-2** show the chassis frame. Chassis frame has many characteristics;

A. Main members and cross members are mostly made by materials of Cast Iron (CI) and Steel with carbon.
B. C-Sections are mostly used as main member of the chassis
C. Cross member connect the both main members of chassis.
D. Rivets used to permanently connect the main and cross members of the chassis
E. Bolts used to temporarily connect the main and cross members of the chassis

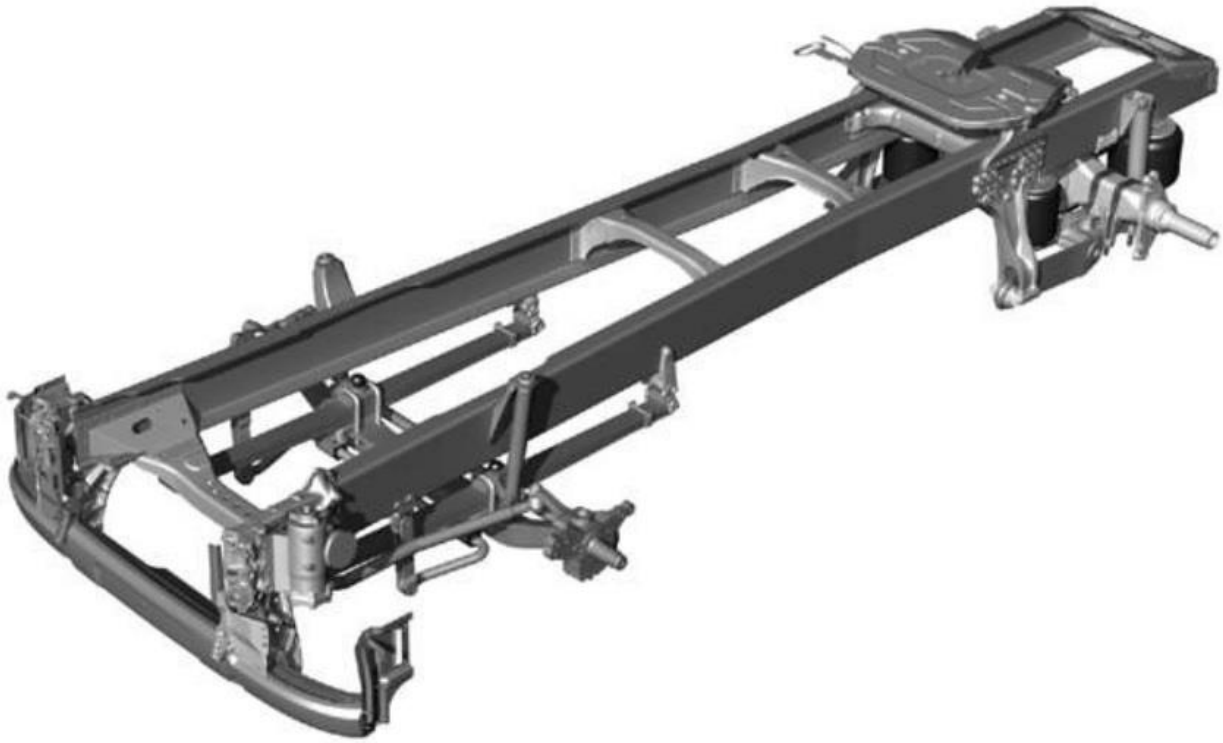


Figure 2-2: Chassis Frame

The first part provides a brief introduction to this research, which includes the motivation, scope of research and an overview of the research objectives. The second part provides literature background for this research, which includes extended finite element method (X-FEM), explicit crack front re-meshing method with FRANC3D program as example, fretting fatigue, mixed mode crack growth and crack growth simulation process with explanation for different fracture and crack growth criteria.

2.2 Motivation

The application of advanced simulation methods and fracture mechanics principles using an optimal simulation methodology to support root cause investigation was not found in the literature. The main motivation of this research was to,

2.2.1 Develop a new simulation methodology

Develop a new simulation methodology for computationally intensive full vehicle durability analysis and predict accurate crack growth behavior in heavy duty truck components.

2.2.2 Provide effective and optimal solutions

Provide effective and optimal solutions during root cause of failure analysis by including information of critical loads, failure mode, crack initiation and crack propagation cycles.

2.2.3 Improve agreement

Improve agreement between test failures and simulation results so as to close unresolved / unknown issues causing quality letdown.

2.2.4 Avoid loss of operational time

Avoid loss of operational time due to failures by improving product durability. Any loss of operational time of a machine / vehicle is often very expensive (both in repair cost and liability cost)

2.2.5 Improve product durability

Improve product durability by providing advanced simulation results upfront during early product development stage.

2.2.6 Improve confidence in using simulation methods

Improve confidence in using simulation methods for resolving root cause investigations. Motivation of this research is also driven by the fact that many test failures often are resolved in an ad-hoc manner without proper knowledge of failure mode and crack propagation behavior. Identifying crack initiation and crack propagation behavior will help avoid making costly repairs and provide optimal solutions.

2.3 Scope of Research

This research was focused on providing a detailed analysis of current simulation methods used in the heavy duty truck industry for the evaluation of trailer chassis structure for increased stiffness. The drawbacks and limitations of existing methods used in industry were demonstrated with case studies. A novel simulation method was developed and a detailed explanation of advantages and strengths of this process was described. The proposed simulation methodology for different sections are propagation simulation using ABAQUS program and analyzed different finite element models using ABAQUS solver. The full vehicle model static response was used for different section study for evaluating stiffness of component level model (contact definitions, pre-tension conditions and parabolic mesh refined to small element sizes) and the simulation process was semi-automated with multiple programs and scripts. The case studies were solved using proposed simulation process to identify maximum deformation and critical loads causing failure. These results were compared to the all different sections to show good correlation, thus validating the proposed simulation methodology.

2.4 Overview of Research Objective

The cross section area design is different for chassis frame for different load conditions of load in vehicles. The stiffness, stress and bending analysis is different for different cross section area of chassis frame.. From this analysis we can find out critical points for high stresses in chassis frame, made of side members and its attached series of cross members by FEM [5]. The truck chassis which is subjected to torsional loading due to road roughness. A numerical technique FEM is used and the obtained results show that the road excitation is the main disturbance and he determines the suitable mounting locations of chassis components. Some modifications are also suggested to reduce the vibration and to improve the strength of chassis [6]. For the static analysis, how to find the stiffness of chassis with the help of FEM (ANSYS) by applying bending and torsional loads [8]. The truck chassis which

to improve the load carrying capacity (stiffness) and reducing the failure against bending by adding stiffeners[9].The heavy vehicle frames which is dominated by warping torsions, because warping is inhibited in the joints where the cross–members are attached to the side–members. (They claimed: The Chassis rigidity, strength and stiffness can be statically analyzed by warping torsions. The method gives close agreement with experimental results.)[10]. On different (I, C & Box) cross sections of main member. (They Claimed: After compare the all sections, existing “C” sections is better than all the sections with respect to the Stress, Displacement, Strain and Shear stress except the weight. Weight can also be reducing by optimizing “C” section).[11] The reduction of stresses near the riveted joint of the chassis. (He concludes that stresses can be reducing by increasing the thickness or length or finding the optimum location of connecting plates.)[13]. FEA analysis of single and double chassis frame of truck and converted double frame chassis frame to single with the consideration of the criteria of strength and light weight. (They claimed: performance is improved, weight is reduce, strong connection is with stand high stresses)[12]. The maximization of wanted properties (Stiffness, Strength and Deflection) and minimization of unwanted properties like (Materials, Cost and Weight), with the help of Sensitivity Analysis(approximately same section modulus and flange width), frame web height to the change in thickness and vice versa. (Finding: In sensitivity analysis different cross section are used for stress analysis and we find a 17% weight reduction in the truck chassis)[13]. An existing heavy vehicle chassis of EICHER is considered for modeling and analysis with different polymer composite materials on different C, I and Box type cross-sections subjected to the identical load. (Based on the results it was inferred that carbon epoxy composites with “I” section has superior strength to withstand high load and induced low deformation and stress distribution when compared to steel and composite material and other cross sections.)[14].If you want to increase stiffness of chassis, add Box type cross members in the chassis.[15].The different cross section for chassis frame for different load conditions of load in vehicles. (Finding: The stiffness, stress and bending analysis is different for different cross section area of chassis frame. Besides these factors material of chassis frame is also important. From this analysis they can find out critical points for high stresses in chassis frame, made of side members and its attached series of cross members) [16].

CHAPTER 3: Methodology

In this thesis we are mainly focusing on the stiffness, strength and rigidity of chassis frame. For this purpose the truck vehicle chassis of BSK 46 Steel material subjected to same load is analyzed by "ABAQUS" software. Here four different vehicles chassis with different cross sections are modeled. These cross sections are C, I, Z and rectangular box type is subjected to same load conditions. The bending and torsional loading effects are compared for different cross sections. It is concluded from this finite element analysis (FEM) that C, I, Z and Box-Sections should be used as main member, while the Box and I-Section are mostly used as cross members in the chassis.

3.1 Chassis Loadings

The Chassis generally experiences two types of loading, they are

a. Bending Loading
b. Torsional Loading

3.1.1 Bending Loadings:

In the bending loading, total weight of vehicles equipment luggage's and passenger is concentrated I the middle of its wheel base because chassis frame is supported at far ends by the wheel axial. Due to this weight the chassis, the main members sink into the middle region. See in the **Figure 3-1**(a)

3.1.2 Torsion Loadings:

When the front and the rear wheels, diagonally opposite move at the same time, two ends of the chassis are warped and deform in opposite direction. So that both main and cross members experience longitudinal torsion, which wrapped the chassis. See in the **Figure 3-1**(b)

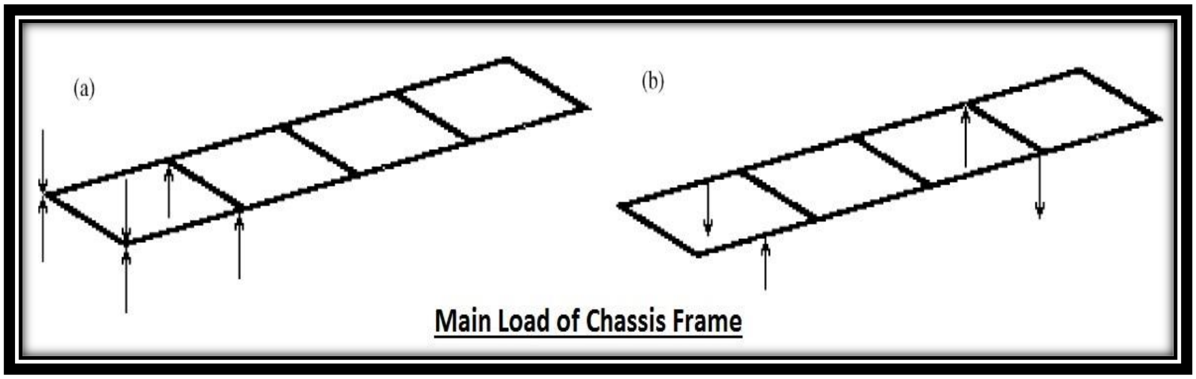


Figure 3-1: Chassis Loadings

3.2 Chassis Frame Understudy

The Loading Points and Boundary Conditions of the chassis are mentioned in the above **Figure 3-1**.For resisting the above mentioned loading and C.G. shift due to off-road drive, The following chassis frames are studied for finding best cross section for stiffness:

3.2.1 2-Axle Chassis having Single Section:

a. C – Section,
b. I – Section,
c. Z – Section
d. Box – Section,

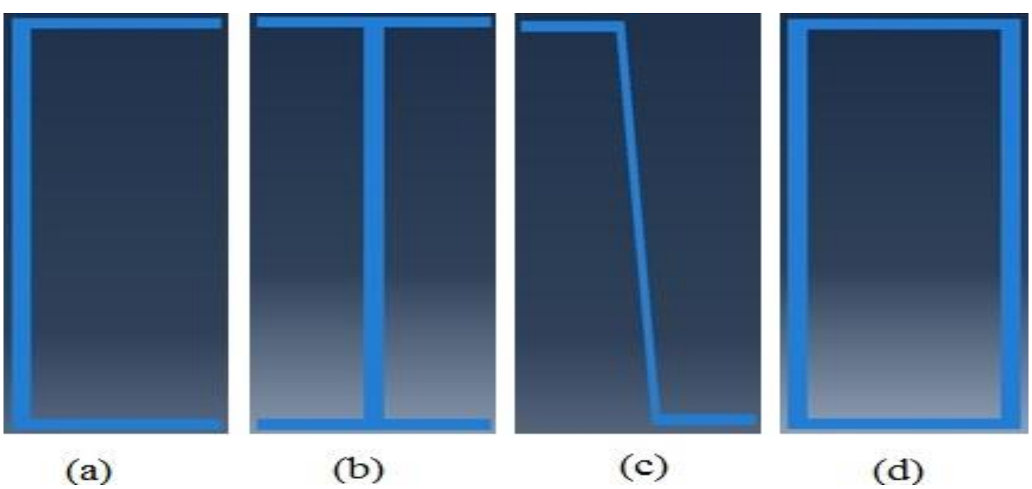


Figure 3-2: Chassis Single Sections

3.2.2 2-Axle Chassis having Double Section

a. CZ – Section
b. CI – Section
c. CB – Section
d. IZ – Section
e. IB – Section
f. IC – Section
g. BZ – Section
h. BI – Section
i. BC – Section
j. Combination of Different Cross Section with Multi-Layer – Section

Figure 3-3: Chassis Double Sections

3.3 Purpose

The objective of this dissertation is to evolve simple methods for models calculations which are in practice for design verification.

3.4 Goal

The main goal of this report is to give a approach based on finite element analysis (FEA) for designing chassis frame. With this approach recommendations, both effective analysis and model verification by comparison method is presented.

3.5 Problem Illustration

The bending and torsional loadings studied on a heavy vehicle dump truck under the vertical load. Different areas of chassis have been studied and a optimized model has been devised through analysis to obtain a required repeated frame design.

3.6 Limitations

Well posed restrictions are crucial in order to attain a depth of detail sufficient enough to be both comprehensible and universal so that the methodology presented herein can be mimicked on similar problems.

3.6.1 Limitation on physical levels for exploration

Due to software restrains, the analysis is limited to deformation and stress level values. The finding gives a better foundation for verification of cycle-to-failure estimations compared to theoretical models.

3.6.2 Limitation on material and deformation of models

For the above mentioned load case under consideration, it is better that analysis will be experienced for small deformations and linear stress-strain relationship. The results are I limitations good agreement with the assumptions.

3.6.3 Software limitation

ABAQUS is used to verify the analysis. Apart from these tools, no other tools are used for this type of problem very effectively. In this tool the trailer chassis is consider it is linear and material of the chassis is also symmetric.

3.6.4 Limitation on area of examination

The chassis main members and cross members deformation and stresses examine are our main goal and the rest geometry of the chassis are secondary importance.

3.7 Methodology

Scaia AB establish loads cases in Catia as a practice documents and make accurate calculation for precise design in a very short time save results for deformation and stresses. Furthermore, analyzing calculations are obtained for specific geometry. The following methodology is to evaluate the chassis structure for increased stiffness.

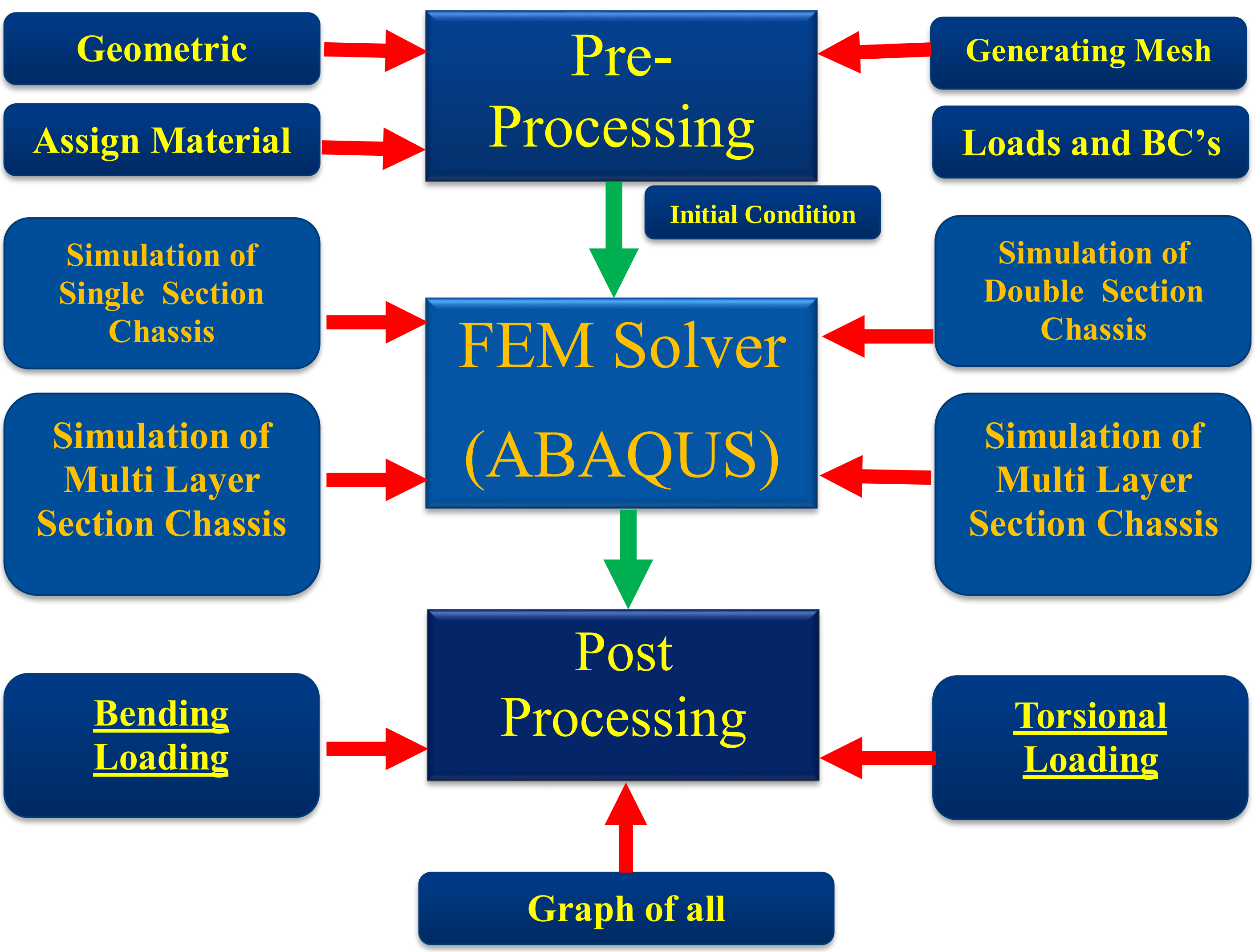


Figure 3-4: Methodology to evaluate stiffness of trailer chassis

CHAPTER 4: Case Study (Single Section Chassis)

In the present work, our main aim is to evaluate the trailer chassis structure for increased stiffness against torsional and bending loadings. For the validation of best section against above loadings different sections are analyzed, specifically I, C, Z and Rectangular Box sections. For the authentication the design is completed by applying the vertical loadings on the different chassis cross sections. In this chapter we only discuss the one case with the help of diagram other cases not shown diagrammatically because other all sections showing the same results as we discuss in the next chapter. All parameters kept constant for all cases like loading points, boundary conditions, same material properties, thickness of sections. Some important geometrical information shown in the following paragraph in details.

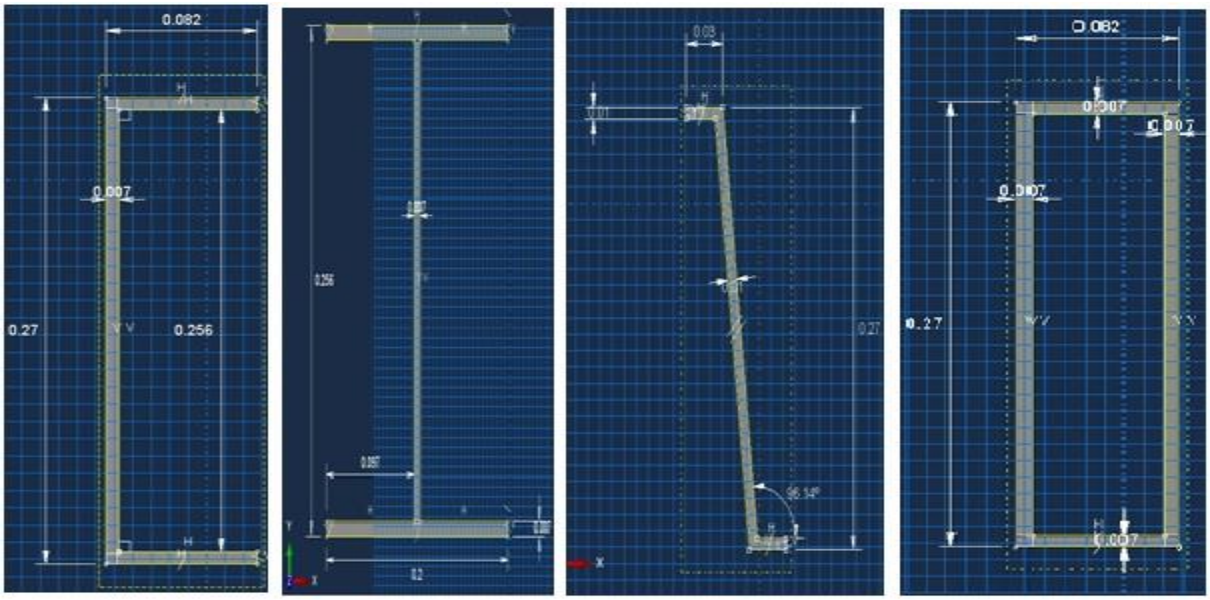
4.1 Dimensions of Sections

As we know that chassis of vehicle are made with the series of cross members and main members. The dimensions of main member and cross member sections, are given below for analysis of different chassis.

4.1.1 Dimensions of Side/ Main Members Sections

All the sections having the same thickness and same cross sectional area. The sizes are available in the following figure.

a. C – Section,
b. I – Section,
c. Z – Section
d. Box – Section



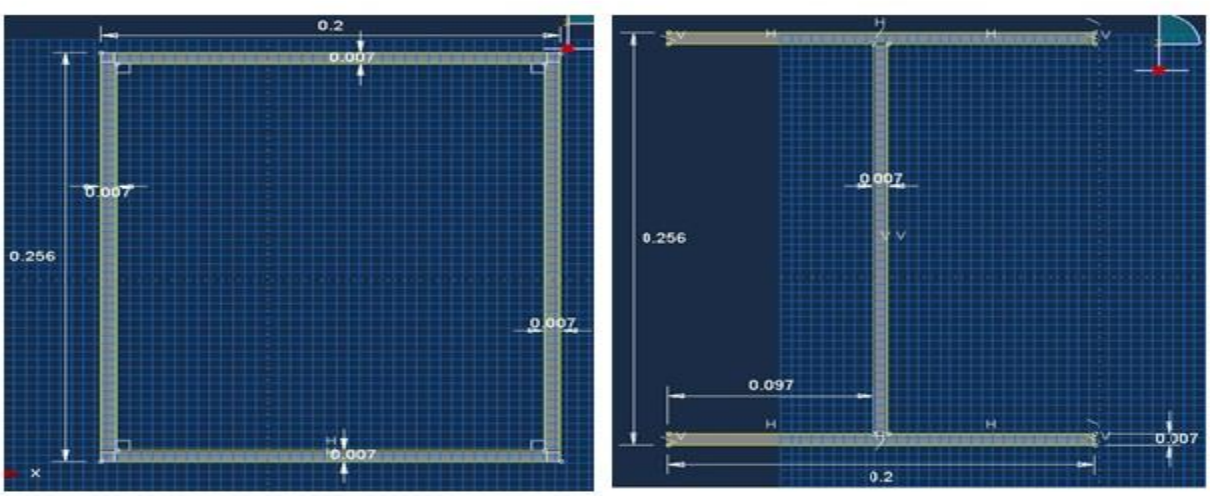
a b c d

Figure 4-1: Dimensions of main member section

4.1.2 Dimensions of Cross Members Sections

All the sections having the same thickness and same cross sectional area. The sizes are available in the following figure.

a. Box – Section,
b. I – Section,



a b

Figure 4-2: Dimensions of Cross Member Sections

4.2 Specification of the Single Section Chassis

All the basic sizes of chassis sections are in the following table:

Table 4-1: Specification of the Single Section Chassis

S/ No.	Description	Box-Section	C-Section	I-Section	Z-Section
1.	Overall Length (m)	7.085			
2.	Overall Width (m)	0.864			
3.	Overall Height (m)	0.270			
4.	Front Axle Distance from Origin (m)	1.350			
5.	Distance between two Axle(m)	5.650			
6.	Thickness of Section (m)	0.007			
7.	I-Type Cross Members (Qty: Nos)	03			
8.	B-Type Cross Members (Qty: Nos)	03			
9.	AREA (m^2)	0.00284	0.00294	0.00294	0.00312
10.	VOLUME (m^3)	0.0895	0.0689	0.0669	0.0668
11.	Overall Mass (Kg)	697.98	537.41	522.16	520.8
12.	Torsional Constant - J (m^4)	4.64e-4	4.64e-8	4.8e-8	4.7e-8
13.	Volume Centroid / Center of mass	1.65, -0.0872, 3.69	1.65,-0.0875, 3.77	1.65,-0.0875, 3.76	1.6, -0.0901, 3.8
14.	Centroid – Cx along x-axis (m)	0.0186	0.01814	0.041	0.0231
15.	Centroid – Cy along y-axis (m)	0.135	0.135	0.135	0.135
16.	Moment of Inertia along x-axis - Ix (m^4)	2.61e-5	2.96e-5	2.96e-5	2.57e-5
17.	Moment of Inertia along y-axis - Iy (m^4)	1.61e-6	1.64e-6	6.506e-7	1.65e-5
18.	Section Modulus along x-axis – Zx (m^3)	2.04e-4	2.04e-4	2.2e-4	2.12e-4
19.	Section Modulus along y-axis – Zy (m^3)	8.65e-5	8.6e-5	1.59e-5	8.62e-5
20.	Bending Load (N) along y-axis	26640 each Member			
21.	Torsional Load (N) along y-axis	188744 each Member			

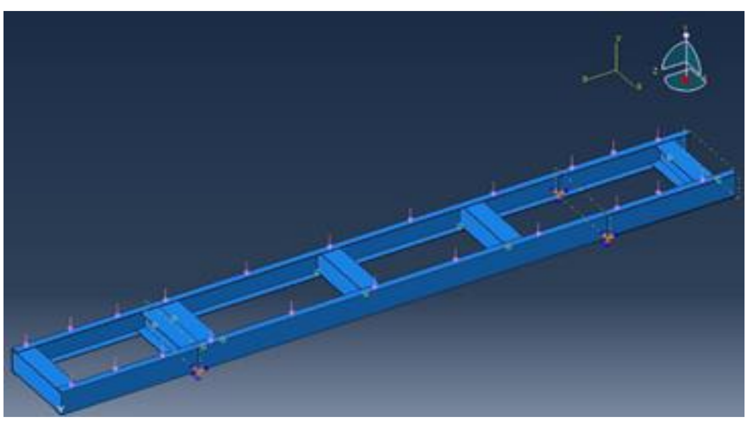
22.	Material: High Strength Steel (BSK 46)	Young Modulus = 2.0e+11 N/m^2, Poisson Ratio = 0.3, Density = 7800 Kg/ m^3, Yield Strength = 4.1e+8 N/m^2

4.3 Finite Element Model of the Chassis (Single Section)

Solid model of heavy vehicle chassis is done in ABAQUS design software. For further analysis of chassis design is also into ABAQUS. The meshing is done of Auto Fine Mesh element method and element size is 20.

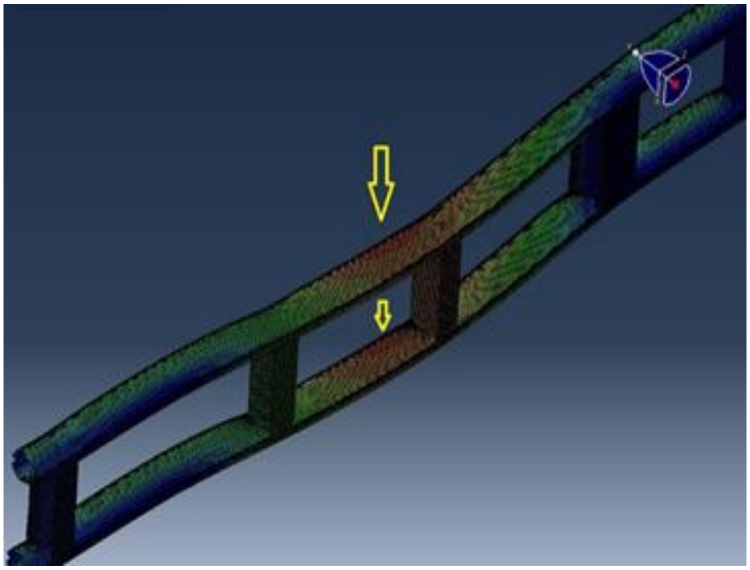
4.3.1 Single Section Chassis under Bending Loading Case:

For the analysis of chassis under bending loading we have to analyze all sections like C, I, Z and Rectangular Box type sections. The loading points, boundary conditions are same for all sections. The following figures are also showing the maximum deformation and maximum stresses areas. The results may be same for all similar type of loading cases. Deformations and stresses are same for all section, only one case is show in the following figures:



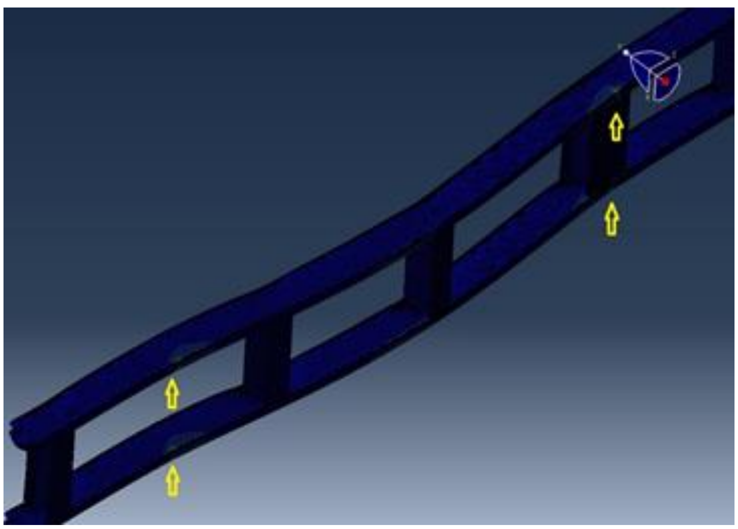
The Loadings points and Boundary Conditions are at main member of the chassis as shown in the figure. The loadings points as pressure load are veritically downward.

Figure 4-3: B.C's and Loading Points Single Section (Bending Case)



The maximum bending deformation is at the middle of the chassis, maximum are at main section of frame. As shown in the figure.

Figure 4-4: Total Deformation Single Section (Bending Case)



The maximum bending stresses are at the boundry points of main member of sections, as shown in the figure.

Figure 4-5: Equivalent (Von Mises) Stress Single Section (Bending Case)

4.3.2 Single Section Chassis under Torsional Loading Case:

For the analysis of chassis under torsional loading we have to analyze all sections like C, I, Z and Rectangular Box type sections. The loading points, boundary conditions are same for all sections. The following figures are also showing the maximum deformation and maximum stresses areas. The results may be same for all similar type of loading cases. Deformations and stresses are same for all section, only one case is show in the following figures:

The Loadings points and Boundary Conditions are at main member of the chassis as shown in the figure. The loadings points are veritically downward.

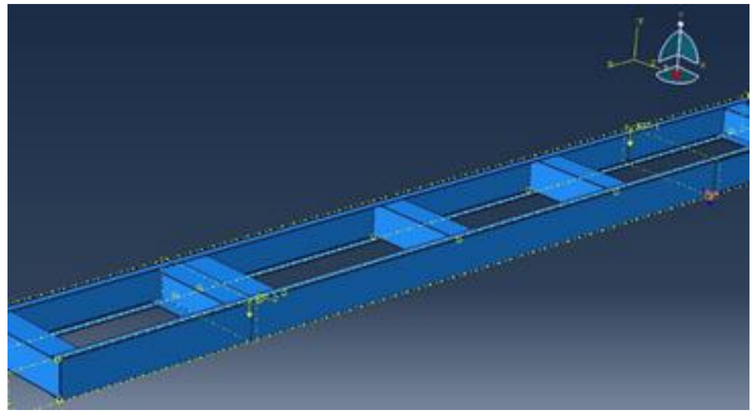


Figure 4-6: B.C's and Loading Points Single Section (Torsional Case)

The maximum tosional deformation is at the ends of chassis as shown in the figure.

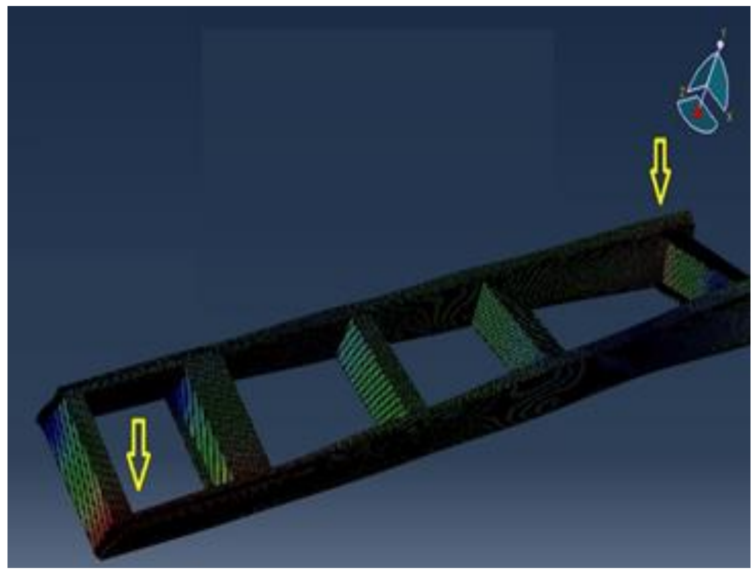


Figure 4-7: Total Deformation Single Section (Torsional Case)

The maximum torsional stresses are at the boundry points of main member of sections, and joints of main and cross members.as shown in the figure.

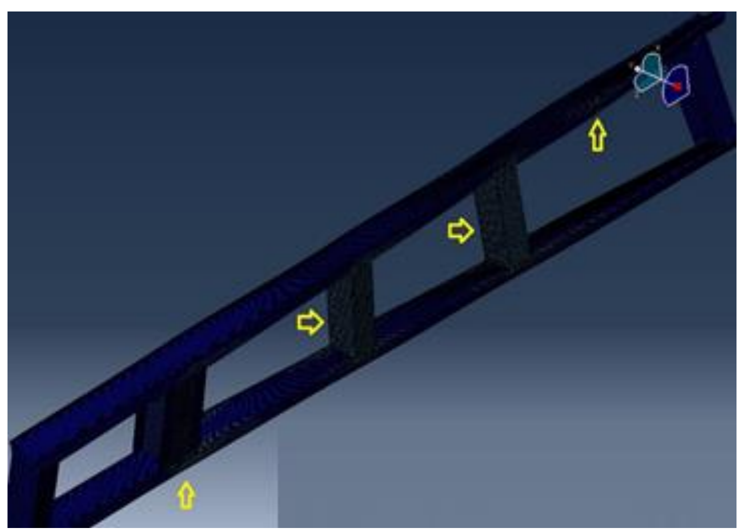


Figure 4-8: Equivalent (Von Mises) Stress Single Section (Torsional Case)

CHAPTER 5: Case Study (Double Section Chassis)

In the present work, our main aim is to evaluate the trailer chassis structure for increased stiffness against torsional and bending loadings. For increasing the torsional resistance against the torsional loadings, we have to design the double section chassis. For the design of double section chassis, we put one section of section main member to the other one as shown in the figure FIG……. for finding the best combination of double section chassis, we analyze different combination of C, I, Z and Box section. For the authentication the design is completed by applying the vertical loadings on the different chassis cross sections. The following table shows the parameters for the heavy vehicle chassis for double section chassis structure.

5.1 Specifications and Dimensions of double Sections Chassis

The dimensions of main member and cross member sections are same as we used in the single section chassis. We just place one chassis onto other for improving torsional deformations and stresses. The specifications and some important dimensions are shown the following table:

Table 5-1: Specification of the Double Section Chassis

Description	1	2	3	4	5	6	7	8	9	10
	CZ	CI	CB	IZ	IC	IB	BZ	BI	BC	ML
Overall Length (m)	7.085									
Overall Width (m)	0.864									
Overall Height (m)	0.54									
Front Axle Distance from Origin	1.350									
Distance b/e two Axle (m)	5.650									
Thickness of all Sections (m)	0.007									
I-Type Cross Members (Qty)	06									
B-Type Cross Members (Qty)	03									
VOLUME (m^3)	0.115	0.121	0.145	0.112	0.120	0.143	0.135	0.142	0.143	0.2324
Description	1	2	3	4	5	6	7	8	9	10
	CZ	CI	CB	IZ	IC	IB	BZ	BI	BC	ML

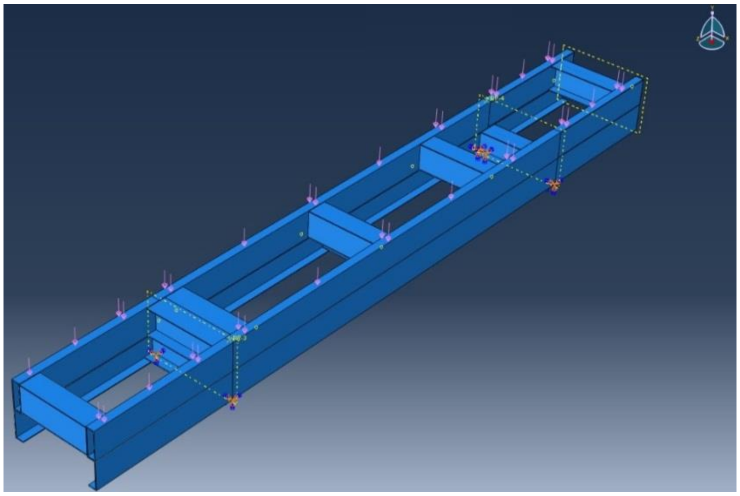
Torsional Constant - J (m^4)										
Overall Mass (Kg)	**894.41**	**943.86**	**1134.03**	**875.66**	**933.00**	**1115.29**	**1054.98**	**1104.43**	**1112.31**	**1812.47**
Volume Centroid / Center of mass	**1.65, -0.189, 3.68**	**1.65, -0.204, 3.67**	**1.65, -0.230, 3.65**	**1.65, -0.191, 3.67**	**1.65, -0.207, 3.66**	**1.65, -0.232, 3.64**	**1.65, -0.174, 3.64**	**1.65, -0.187, 3.63**	**1.65, -0.188, 3.63**	**-2849.16, -4.26, 17212.73**
Moment of Inertia about the center of mass (mm) (Ixx, Iyy, Izz, Ixy, Iyz, Izx)	**3901.3, 3984.9, 128.97, 1.48e-5, -13.11, 6.70e-6**	**4101.01, 4196.88, 149.04, -5.3e-6, 14.98, -9.9e-6**	**4912.4, 5033.4, 183.5, -3.8e-6, -18.05, -9.82e-6**	**3804.66, 3879.43, 119.40, 1.47e-5, -12.24, 6.22e-6**	**4028.96, 4123.22, 147.1, 3.53e-6, -14.15, -3.45e-6**	**4815.10, 4927.41, 173.77, -3.60e-6, -16.76, -9.08e-6**	**4541.39, 4641.96, 150.17, 1.7e-05, -9.35, 2.96e-06**	**4741.06, 4853.49, 170.69, -4.84e-6, -10.76, -8.58e-06**	**4765.83, 4885.34, 178.40, 4.76e-06, -10.93, -4.19e-06**	**7.89e+09, 8.03e+09, 2.37e+08, -0.521, 2921.54, -0.173**
Bending Load (N) along y-axis	**26640 each Member**									
Torsional Load (N) along y-axis	**188744 each Member**									
Material: High Strength Steel (BSK 46)	**Young Modulus = 2.0e+11 N/m^2, Poisson's Ratio = 0.3, Density = 7800 Kg/ m^3, Yield Strength = 4.1e+8 N/m^2**									

5.2 Finite Element Model of the Chassis (Double Section)

Solid model of heavy vehicle chassis is done in ABAQUS design software. For further analysis of chassis design is also into ABAQUS. The meshing is done of Auto Fine Mesh element method and element size is 20.

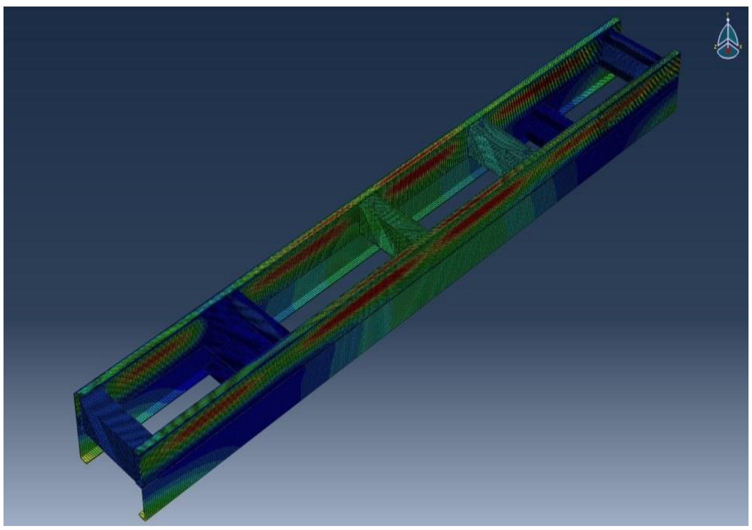
5.2.1 Double Section Chassis under Bending Loading Case:

For the analysis of chassis under bending loading we have to analyze all double sections like BC, BI, BZ, IC, IB, IZ, CB, CI and CZ sections. The loading points, boundary conditions are same for all sections. The following figures are also showing the maximum deformation and maximum stresses areas. The results may be same for all similar type of loading cases. Deformations and stresses are same for all section, only one case is show in the following figures:



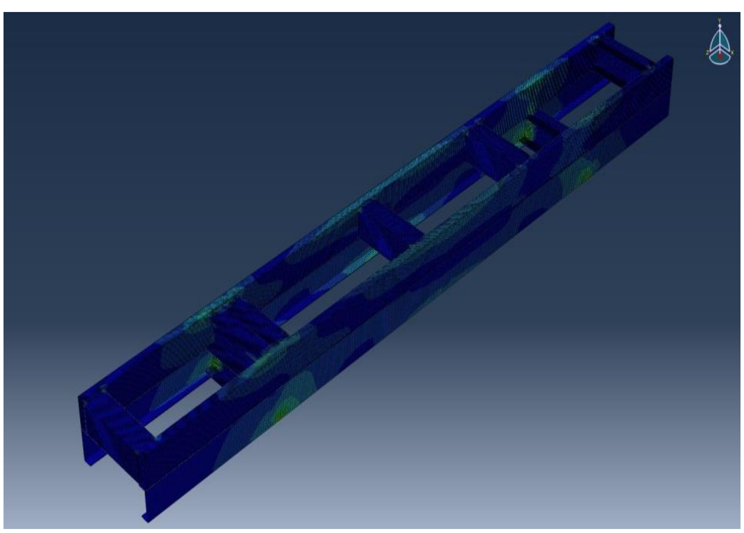
The Loadings points and Boundary Conditions are at main member of the chassis as shown in the figure. The loadings points as pressure load are veritically downward.

Figure 5-1: B.C’s and Loading Points Double Section (Bending Case)



The maximum bending deformation is at the middle of the chassis, maximum are at main section of frame. As shown in the figure.

Figure 5-2: Total Deformation Double Section (Bending Case)



The maximum bending stresses are at the boundry points of main member of sections, as shown in the figure.

Figure 5-3: Equivalent (Von Mises) Stress Double Section (Bending Case)

5.2.2 Double Section Chassis under Torsional Loading Case:

For the analysis of chassis under torsional loading we have to analyze all double sections like BC, BI, BZ, IC, IB, IZ, CB, CI and CZ sections. The loading points, boundary conditions are same for all sections. The following figures are also showing the maximum deformation and maximum stresses areas. The results may be same for all similar type of loading cases. Deformations and stresses are same for all section, only one case is show in the following figures:

The Loadings points and Boundary Conditions are at main member of the chassis as shown in the figure. The loadings points are veritically downward.

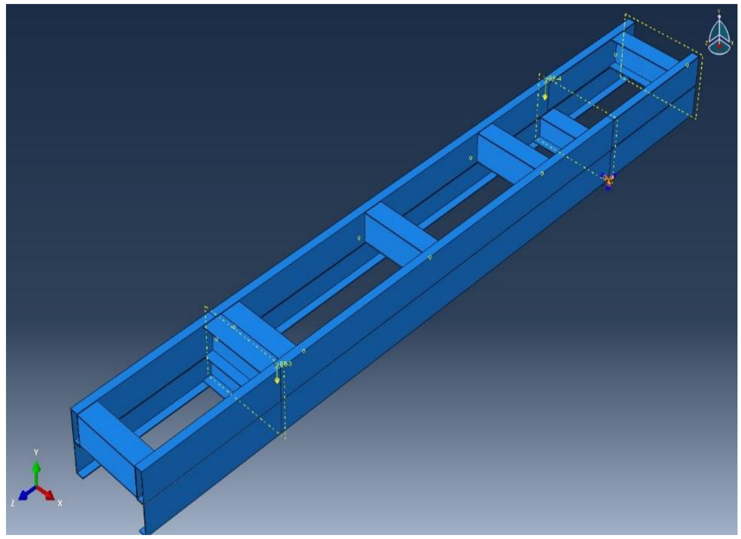


Figure 5-4: B.C's and Loading Points Double Section (Torsional Case)

The maximum tosional deformation is at the ends of chassis as shown in the figure.

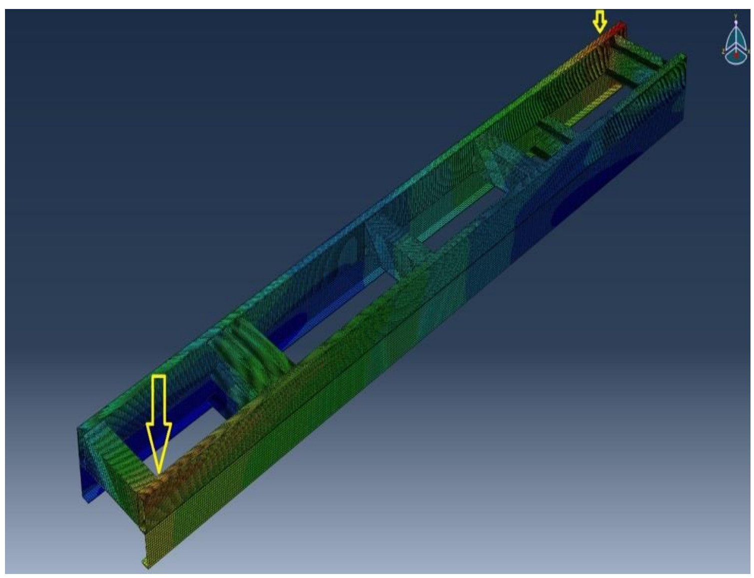


Figure 5-5: Total Deformation Double Section (Torsional Case)

The maximum torsional stresses are at the boundry points of main member of sections, and joints of main and cross members.as shown in the figure.

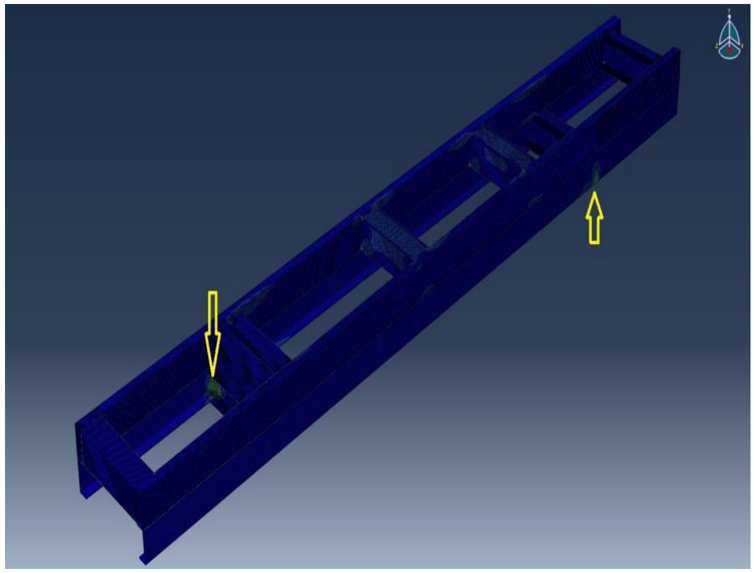


Figure 5-6: Equivalent (Von Mises) Stress Double Section (Torsional Case)

5.3 Multi-Layer Section Chassis (Double Section)

The multi-layer section chassis is a new form of double section chassis in this type of section we have to use multi-layers of section by putting up and down "C" and "Z" sections, for finding the best section for the design of chassis which is best against torsional loadings. The details geometry of ML section is shown in the following figure.

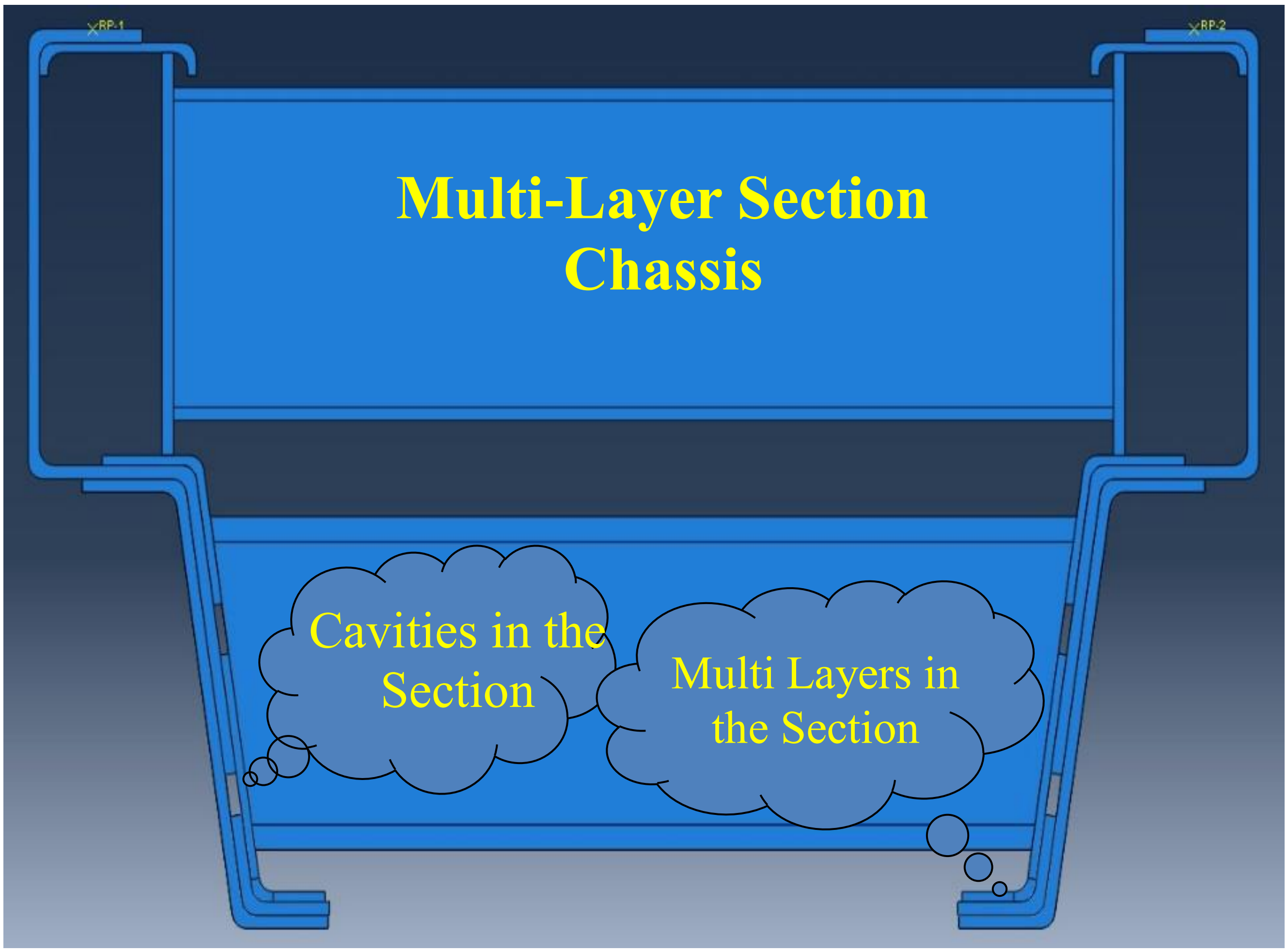


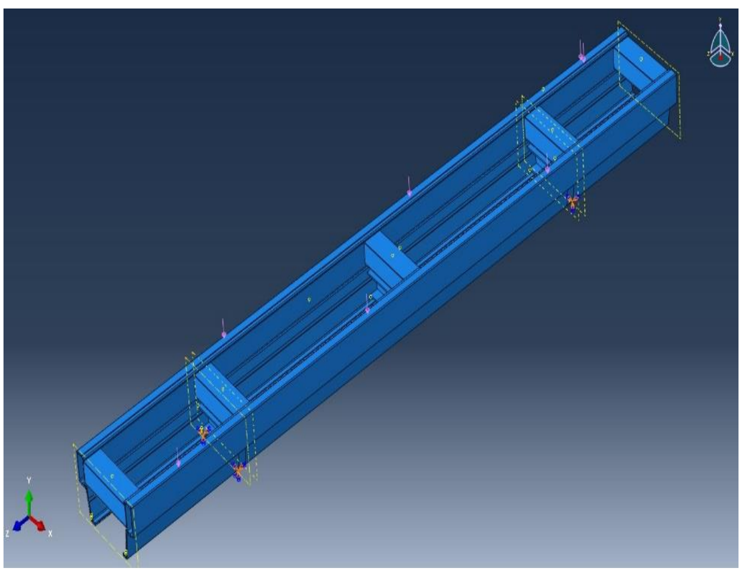
Figure 5-7: Multi-Layer Section

5.4 Finite Element Model of the Chassis (ML Section)

Solid model of heavy vehicle chassis is done in ABAQUS design software. For further analysis of chassis design is also into ABAQUS. The meshing is done of Auto Fine Mesh element method and element size is 20.

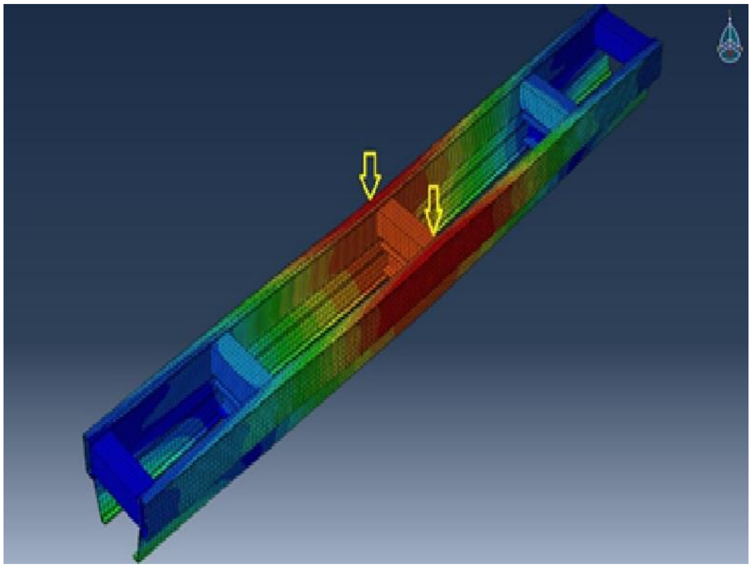
5.4.1 Multi-Layer Section Chassis under Bending Loading Case:

For the analysis of chassis under bending loading we have to analyze the ML section. The loading points, boundary conditions are same for all sections. The following figures are also showing the maximum deformation and maximum stresses areas. The results may be same for all similar type of loading cases. Deformations and stresses are same for all section, only one case is show in the following figures:



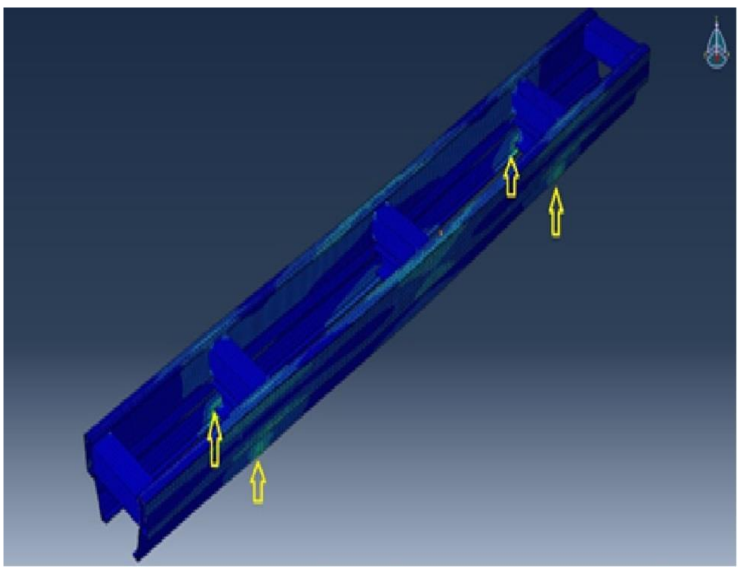
The Loadings points and Boundary Conditions are at main member of the chassis as shown in the figure. The loadings points as pressure load are veritically downward.

Figure 5-8: B.C's and Loading Points ML Section (Bending Case)



The maximum bending deformation is at the middle of the chassis, maximum are at main section of frame. As shown in the figure.

Figure 5-9: Total Deformation ML Section (Bending Case)



The maximum bending stresses are at the boundry points of main member of sections, as shown in the figure.

Figure 5-10: Equivalent (Von Mises) Stress ML Section (Bending Case)

5.4.2 Multi-Layer Section Chassis under Torsional Loading Case:

For the analysis of chassis under Torsional loading we have to analyze the ML section. The loading points, boundary conditions are same for all sections. The following figures are also showing the maximum deformation and maximum stresses areas. The results may be same for all similar type of loading cases. Deformations and stresses are same for all section, only one case is show in the following figures:

The Loadings points and Boundary Conditions are at main member of the chassis as shown in the figure. The loadings points are veritically downward.

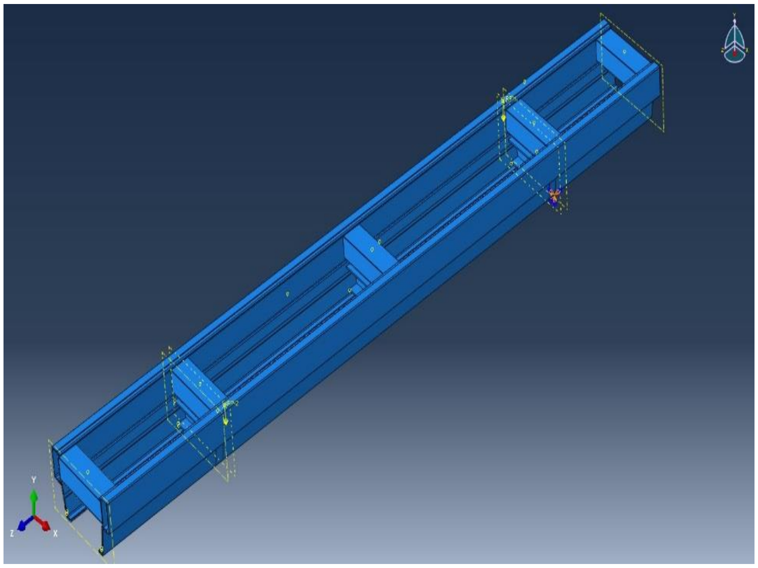


Figure 5-11: B.C's and Loading Points ML Section (Torsional Case)

The maximum tosional deformation is at the ends of chassis as shown in the figure.

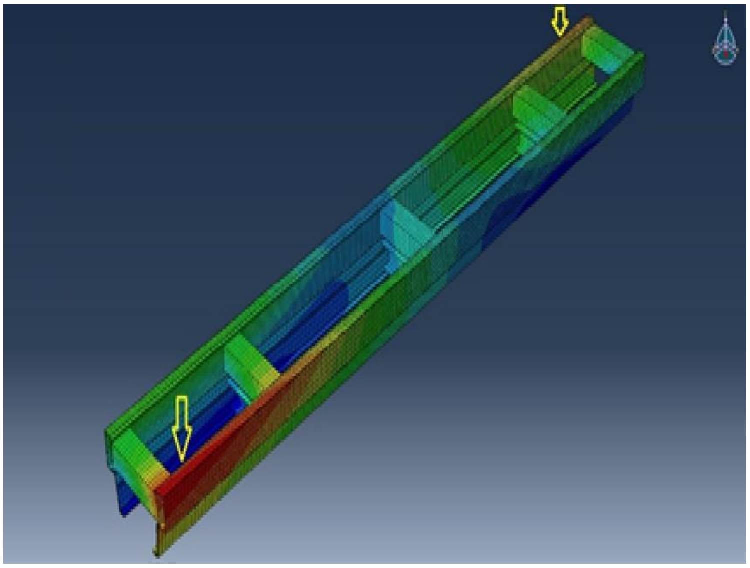


Figure 5-12: Total Deformation ML Section (Torsional Case)

The maximum torsional stresses are at the boundry points of main member of sections, and joints of main and cross members.as shown in the figure.

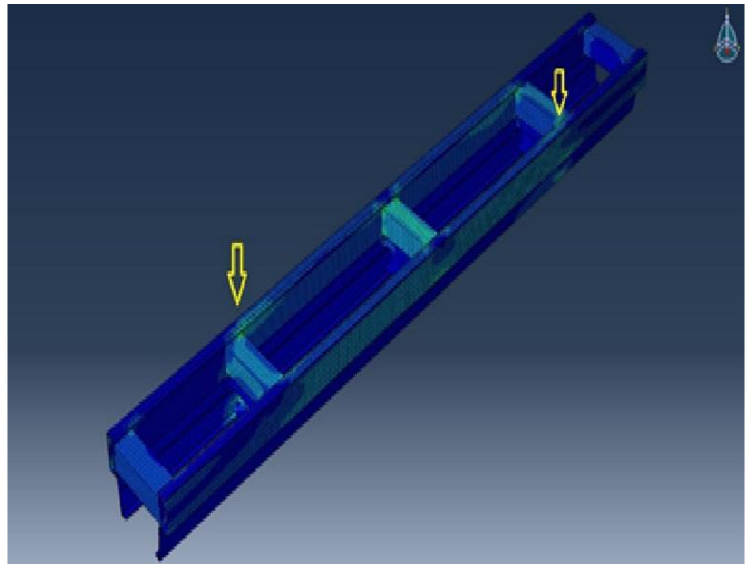


Figure 5-13: Equivalent (Von Mises) Stress ML Section (Torsional Case)

CHAPTER 6: Results, Discussion and Conclusions

As you know I discussed in the chapter - 1, the purpose of this report was to evaluate the trailer chassis structure for increased stiffness. In this circumstance, fourteen different sections are analyzed by using the finite element method (FEM) technique with the help of "ABAQUS" software. The above fourteen sections are analyzed under torsional and bending loading. The goal of my present research was to execute a bit by bit study on the finite element method (FEM) of the vehicle to a certain extent than for design purposes. The results discussed in the following paragraph separately each section.

6.1 Results and Discussion of Single Section Chassis:

According to above analysis of different single section chassis, we have to conclude the results and discuss about all single section chassis. I have to analysis the above mentioned chassis under torsional and bending loadings cases. We discuss the results in table and graphically and discussed which section has more resistance against deformation and stresses.

6.1.1 Sum up the results of all Single Section Chassis:

After viewing the all single section chassis, namely C, I, Z and Rectangular Box type sections, we conclude that "C-Section" less deform and also have a minimum stresses on it under bending loading case and "B-Section" show the less deformation and also have minimum stresses on it under torsional loadings. See the in details in the following table.

Table 6-1: Results of Single Section Chassis

S/ No	Description	Bending Loading Effects		Torsional Loading Effects	
		FEM U (Magnitude)	FEM Stress	FEM U (Magnitude)	FEM Stress
1.	Box-Section	4.9E-4	2.6E+9	1.1E-1	1.9E+9
2.	C-Section	2.8E-4	1.2E+7	3.1E-1	3.3E+9
3.	I-Section	6.3E-4	8.7E+7	3.3E-1	2.6E+9
4.	Z-Section	3.3E-4	4.5E+7	3.5E-1	3.7E+9

6.1.2 Graphical representation of the results (Single Section):

The results of single section chassis are presented graphically, deformations and stresses are discussed separately in the following paragraph.

6.1.2.1 Deformations of Single Sections Chassis:

The "I-Section" of the chassis showing the maximum deformation but "C-Section" Show the less deformation rather than all section under bending loadings.

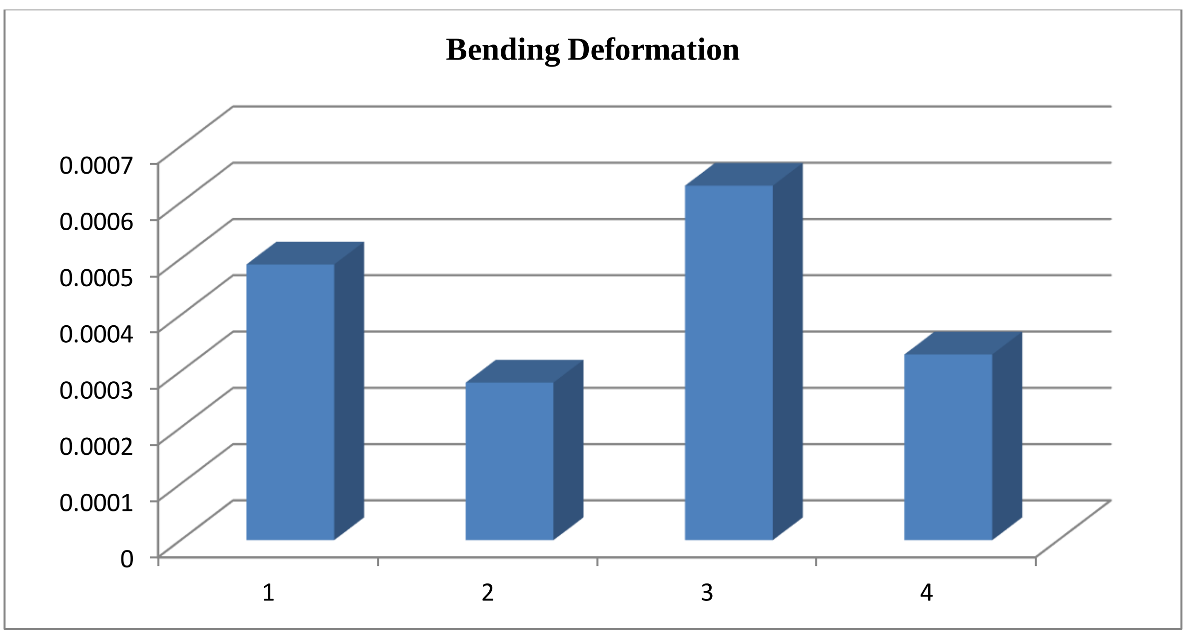


Figure 6-1: Graph of Bending Deformation (Single Section Chassis)

Cross Section	1	2	3	4
	Box-Section	C-Section	I-Section	Z-Section

The "Z-Section" of the chassis showing the maximum deformation but "Box-Section" Show the less deformation rather than all section under torsional loadings.

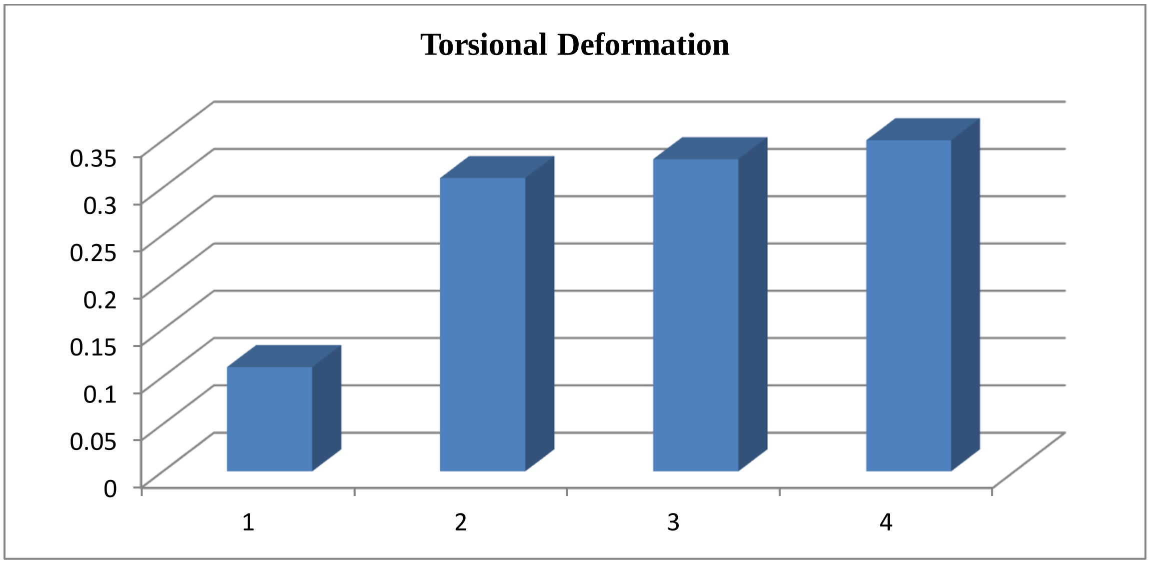


Figure 6-2: Graph of Torsional Deformation (Single Section Chassis)

Cross Section	1	2	3	4
	Box-Section	**C-Section**	**I-Section**	**Z-Section**

6.1.2.2 Stresses of Single Sections Chassis:

The "Box-Section" of the chassis showing the less resistance in stresses but "C-Section" Show the highest resistance in stresses and less deform rather than all section under bending loadings.

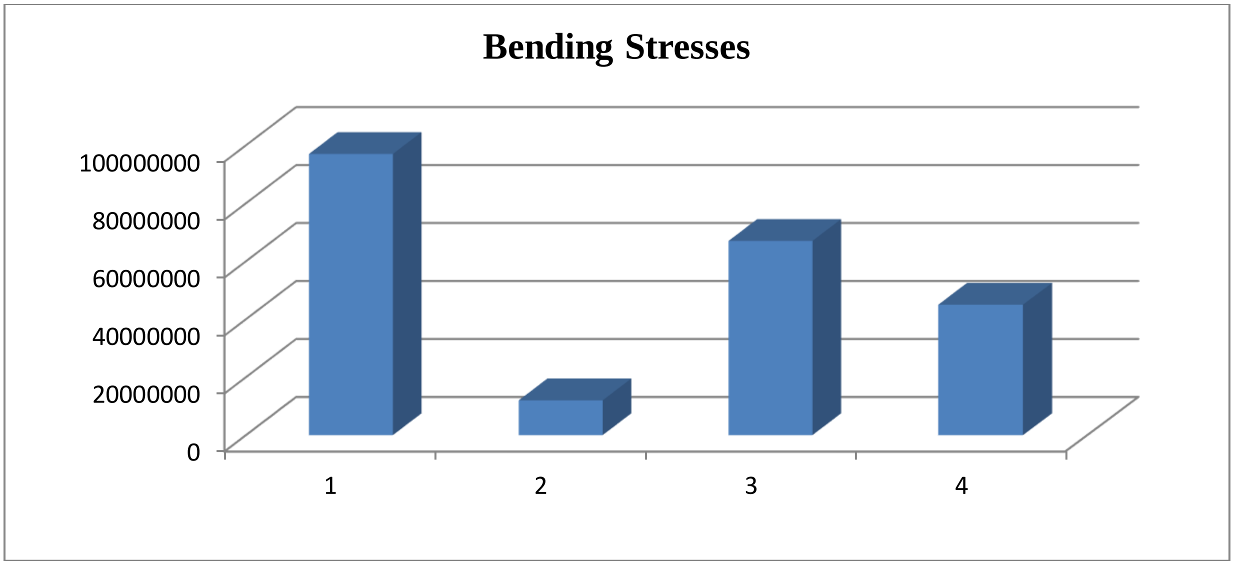


Figure 6-3: Graph of Bending Stresses (Single Section Chassis)

Cross Section	1	2	3	4
	Box-Section	C-Section	I-Section	Z-Section

The "Z-Section" of the chassis showing the less resistance in stresses but "Box-Section" Show the highest resistance in stresses and less deform rather than all other section under torsional loadings.

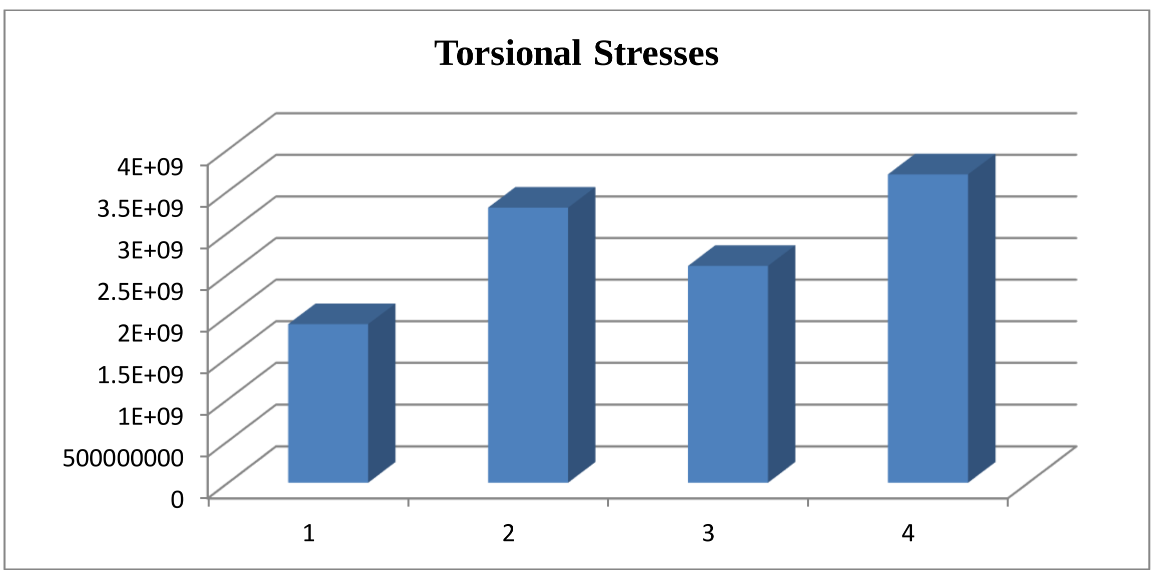


Figure 6-4: Graph of Torsional Stresses (Single Section Chassis)

Cross Section	1	2	3	4
	Box-Section	C-Section	I-Section	Z-Section

6.2 Results and Discussion of Double Section Chassis:

According to above analysis of different double section chassis, we have to conclude the results and discuss about all double section chassis. I have to analysis the above mentioned chassis under torsional and bending loadings cases. We discuss the results in table and graphically and discussed which section has more resistance against deformation and stresses.

6.2.1 Sum up the Results of all Double Section Chassis:

After viewing the all double section chassis, namely IC, IB IZ, CI, CB, CZ, BZ, BC, BI and ML type sections, we conclude that "ML-Section" less deform and "CI-Section" have a minimum stresses on it under bending loading case and "ML-Section" show the less deformation and also have minimum stresses on it under torsional loadings. See the in details in the following table.

Table 6-2: Results of Double Section Chassis

DOUBLE SECTION CHASSIS					
S/ No	Description	Bending Loading Effects		Torsional Loading Effects	
		FEM U (Magnitude)	FEM Stress	FEM U (Magnitude)	FEM Stress
1.	C & Z-Section	3.0E-4	1.4E+7	1.4E-1	3.2E+9
2.	C & I-Section	2.2E-4	2.2E+6	1.2E-1	3.5E+9
3.	C & B-Section	2.2E-4	3.6E+6	1.6E-1	2.7E+9
4.	I & Z-Section	4.9E-4	8.4E+7	1.0E-1	2.3E+9
5.	I & C-Section	2.0E-4	1.5E+7	5.9E-2	3.0E+9
6.	I & B-Section	1.9E-4	2.6E+7	1.3E-1	2.8E+9
7.	B & Z-Section	4.2E-4	2.3E+7	6.3E-2	1.9E+9

8.	**B & I-Section**	2.0E-4	1.8E+7	5.1E-2	2.3E+9
9.	**B & C-Section**	2.0E-4	1.2E+7	4.2E-2	2.1E+9
10	**Multi-Layer Section**	+5.4E-5	+8.3E+3	+8.8E-3	+7.0E+2

6.2.2 Graphical Representation of the Results (Double Section):

The results of double section chassis are presented graphically, deformations and stresses are discussed separately in the following paragraph.

6.2.2.1 Deformations of Double Sections Chassis:

The "IZ-Section" of the chassis showing the maximum deformation but "ML-Section" Show the less deformation rather than all section under bending loadings.

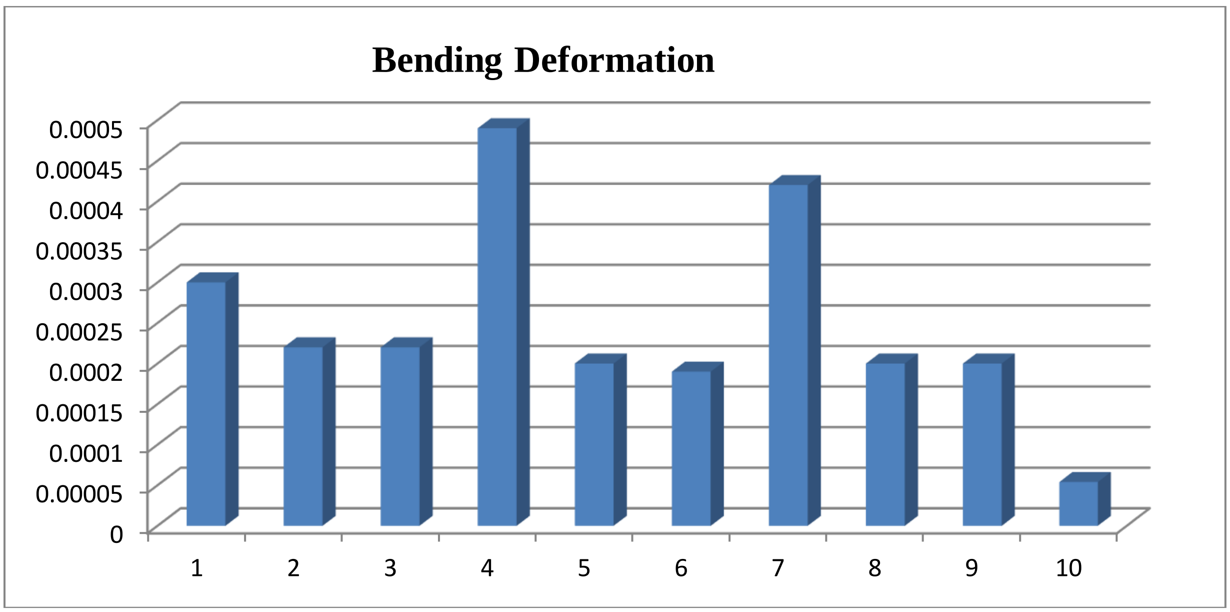


Figure 6-5: Graph of Bending Deformations (Double Section Chassis)

Cross Section	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	CZ	**CI**	**CB**	**IZ**	**IC**	**IB**	**BZ**	**BI**	**BC**	**ML**

➢ **Bending Deformation Increasing Trend**

ML<IB<IC<BI<BC<CI<CB<CZ<BZ<IZ

The “CB-Section” of the chassis showing the maximum deformation but “ML-Section” Show the less deformation rather than all section under torsional loadings.

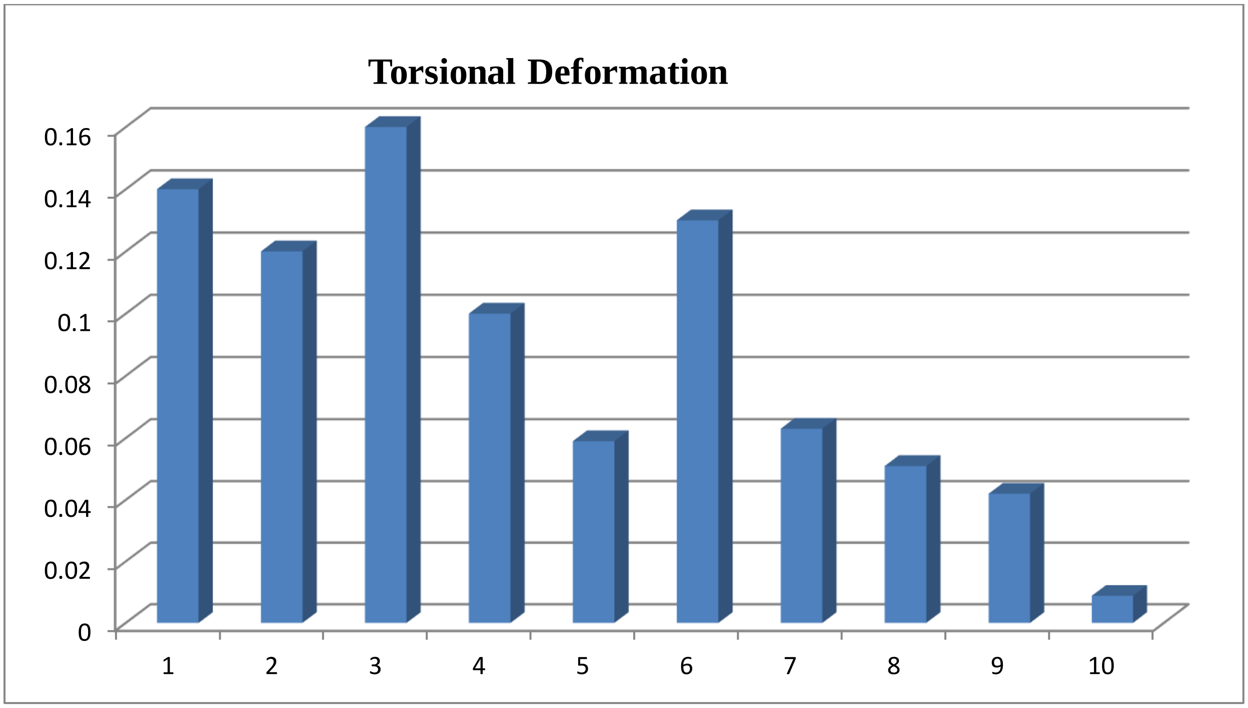


Figure 6-6: Graph of Torsional Deformation (Double Section Chassis)

Cross Section	1	2	3	4	5	6	7	8	9	10
	CZ	CI	CB	IZ	IC	IB	BZ	BI	BC	ML

- **Torsional Deformation Increasing Trend**

ML<BC<BI<IC<BZ<IZ<CI<IB<CZ<CB

6.2.2.2 Stresses of Double Sections Chassis:

The “IZ-Section” of the chassis showing the less resistance in stresses but “CI-Section” Show the highest resistance in stresses and less deform rather than all section under bending loadings. “ML-Section” has not a major difference with “CI-Section”, means “ML-Section” deformation is very minimum.

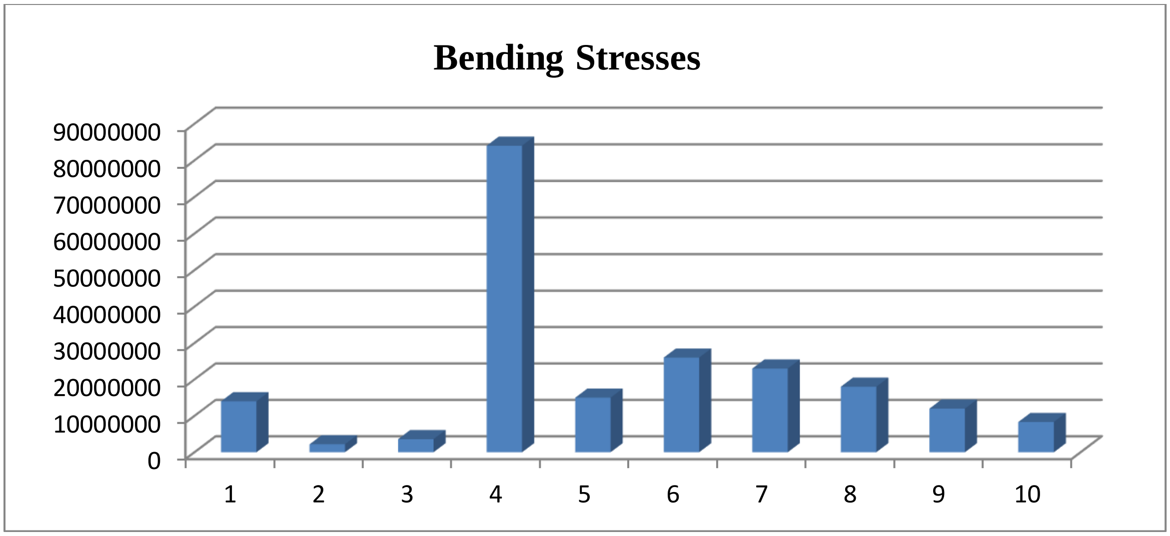


Figure 6-7: Graph of Bending Stresses (Double Section Chassis)

Cross Section	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	CZ	**CI**	**CB**	**IZ**	**IC**	**IB**	**BZ**	**BI**	**BC**	**ML**

The "CI-Section" of the chassis showing the less resistance in stresses but "ML-Section" Show the highest resistance in stresses and less deform rather than all other section under torsional loadings.

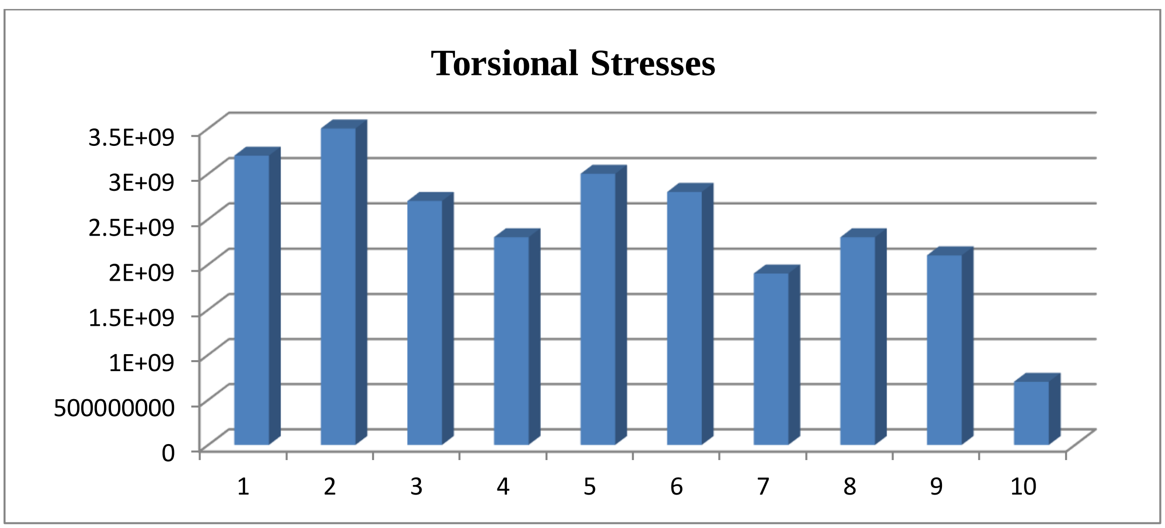


Figure 6-8: Graph of Torsional Stresses (Double Section Chassis)

Cross Section	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	CZ	**CI**	**CB**	**IZ**	**IC**	**IB**	**BZ**	**BI**	**BC**	**ML**

6.3 Comparison the Single and Double Section Chassis:

According to above analysis of different section of chassis, we have to conclude the results and discuss about all single and double section chassis. I have to analysis the above mentioned chassis under torsional and bending loadings cases. We discuss the results in table and graphically and discussed which section has more resistance against deformation and stresses.

6.3.1 **Results and Discussion of** All Section Chassis (**Bending Case**):

The results of single and double section chassis are presented graphically against bending loadings. Deformations and stresses are discussed separately in the following paragraph.

6.3.1.1 Deformations for All Sections of the Chassis:

The "I-Section" of the chassis showing the maximum deformation but "ML-Section" Show the less deformation rather than all section under bending loadings.

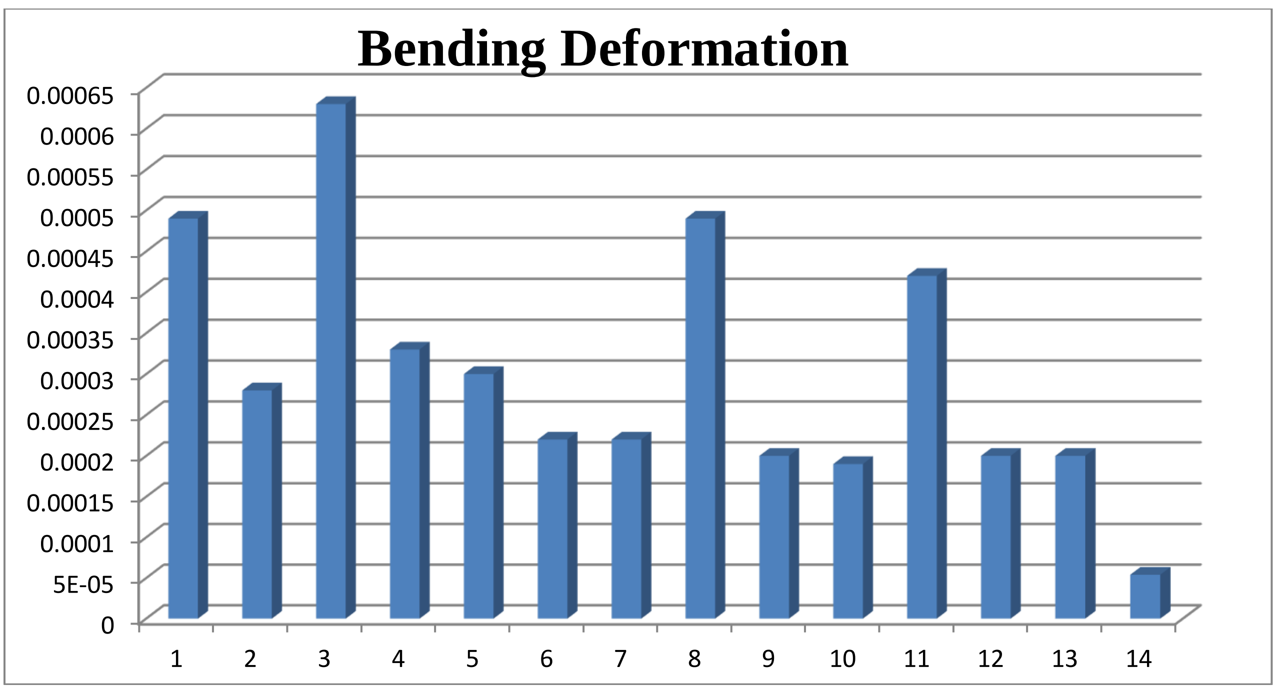


Figure 6-9: Graph of Bending Deformations (All Section Chassis)

Cross Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	B	C	I	Z	CZ	CI	CB	IZ	IC	IB	BZ	BI	BC	ML

6.3.1.2 Stresses for All Sections of the Chassis:

The "Box-Section" of the chassis showing the less resistance in stresses but "CI-Section" Show the highest resistance in stresses and less deform rather than all section under bending loadings. "ML-Section" has not a major difference with "CI-Section", means "ML-Section" deformation is also very minimum.

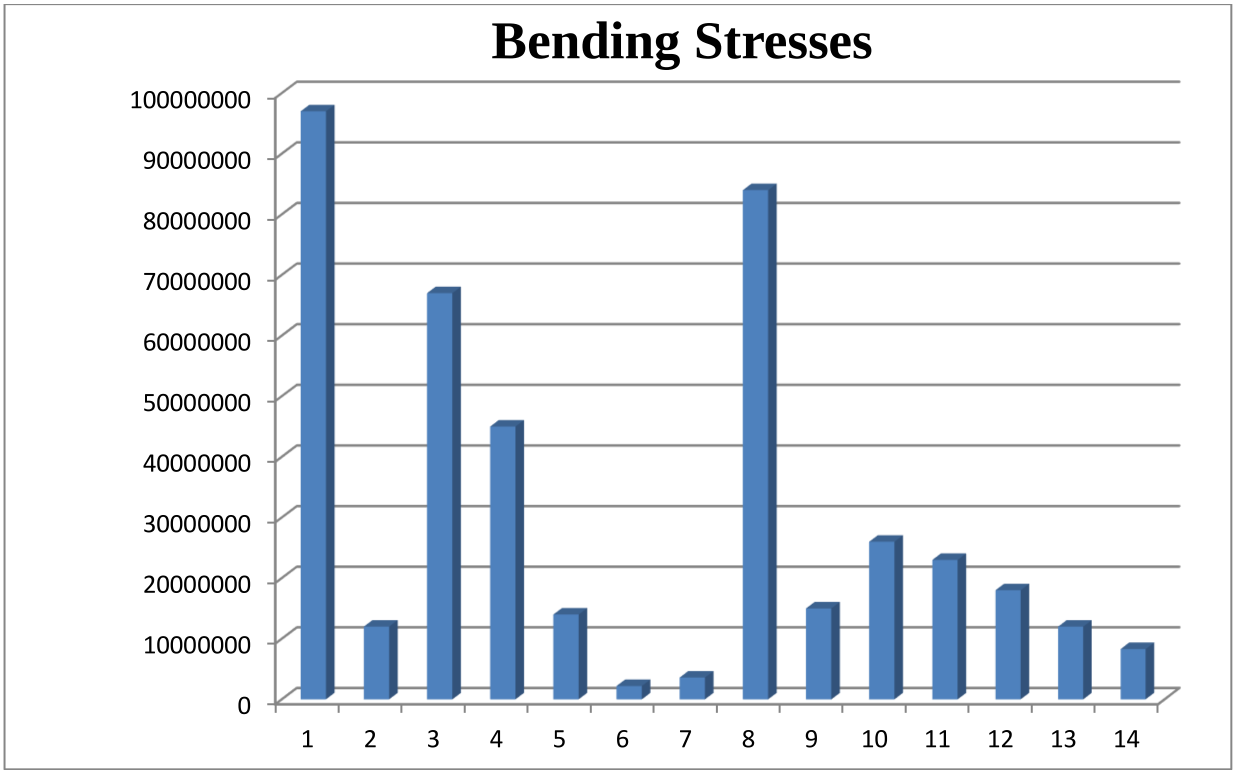


Figure 6-10: Graph of Bending Stresses (All Section Chassis)

Cross Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	B	C	I	Z	CZ	CI	CB	IZ	IC	IB	BZ	BI	BC	ML

6.3.2 Results and Discussion of All Section Chassis (Torsional Case):

The results of single and double section chassis are presented graphically against torsional loadings. Deformations and stresses are discussed separately in the following paragraph.

6.3.2.1 Deformations for All Sections of the Chassis:

The "Z-Section" of the chassis showing the maximum deformation but "ML-Section" Show the less deformation rather than all section under torsional loadings.

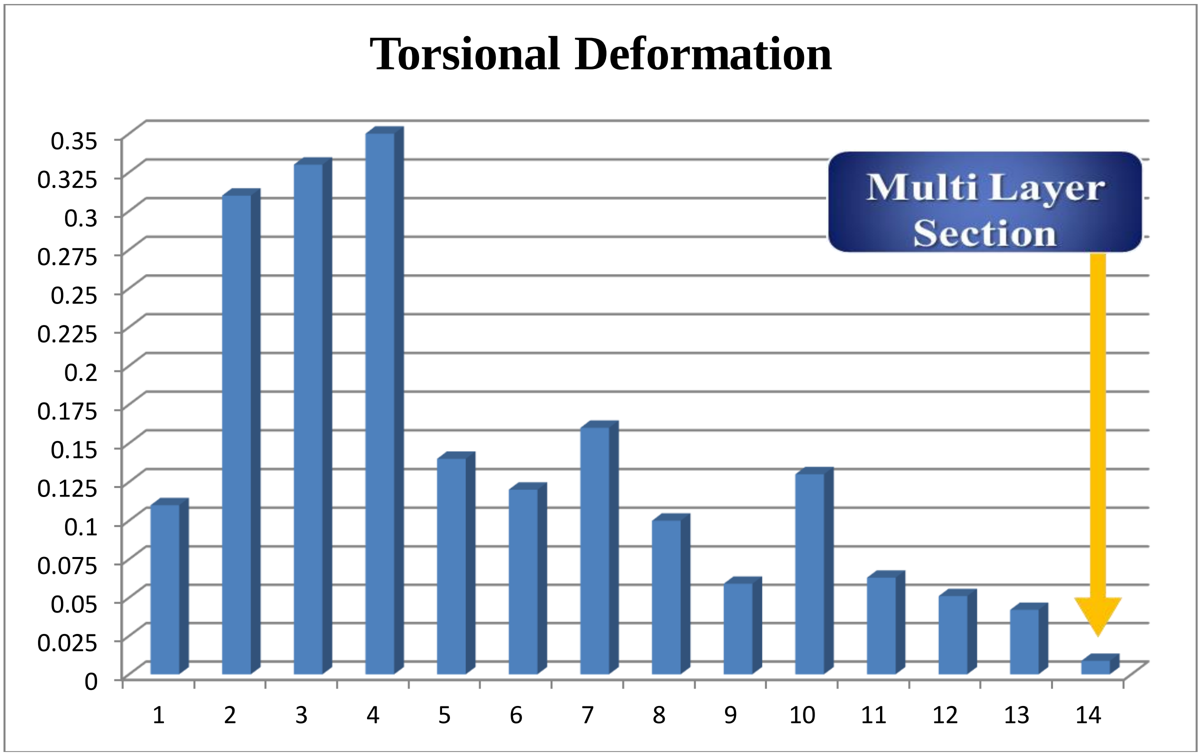


Figure 6-11: Graph of Torsional Deformation (All Section Chassis)

Cross Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	B	C	I	Z	CZ	CI	CB	IZ	IC	IB	BZ	BI	BC	ML

6.3.2.2 Stresses for All Sections of the Chassis:

The "Z-Section" of the chassis showing the less resistance in stresses but "ML-Section" Show the highest resistance in stresses and less deform rather than all section under torsional loadings.

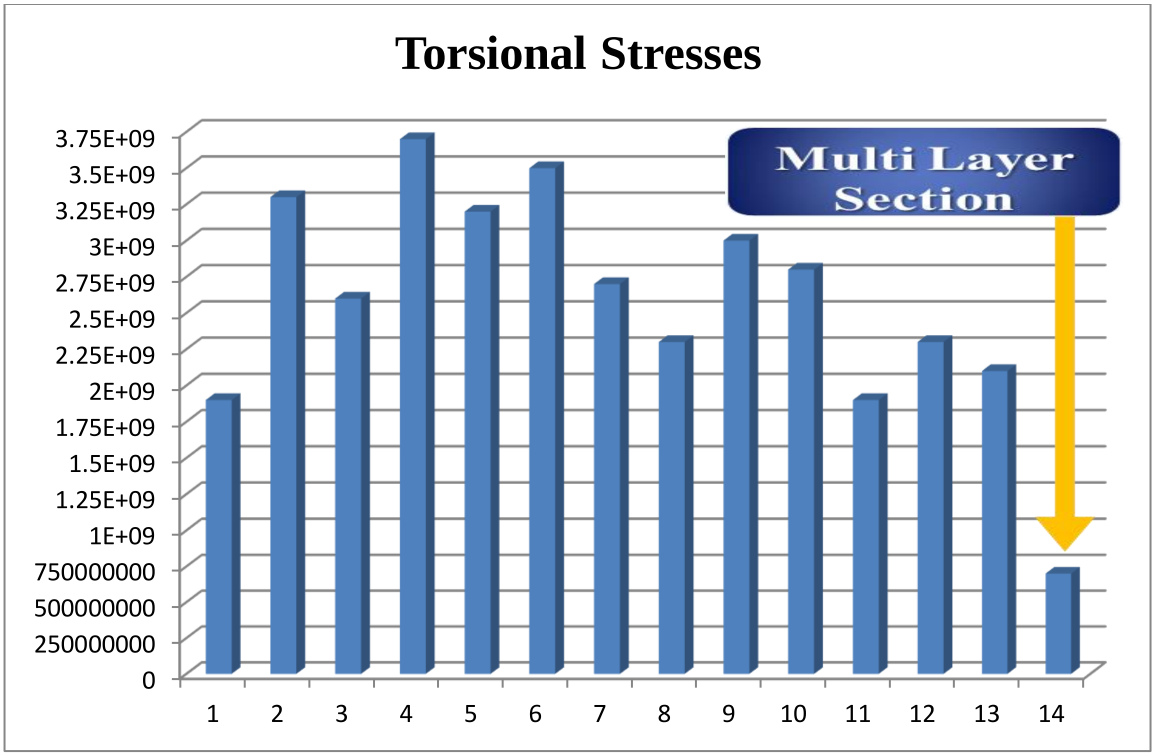


Figure 6-12: Graph of Torsional Stresses (All Section Chassis)

Cross Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	B	C	I	Z	CZ	CI	CB	IZ	IC	IB	BZ	BI	BC	ML

6.4 Comparison between Bending Verses Torsional Deformation:

For finding the best optimize section for torsional and bending deformation against bending and torsional loadings, that's why we need to compare bending and torsional deformation graphically by setting scale. For finding the best optimize section for torsional and bending deformation with respect to mass, that's why we need to compare bending and torsional deformation graphically by setting scale with mass of chassis. All the above comparisons discussed separately I the following graph.

6.4.1 **Bending Deformation Vs Torsional Deformation for All Section** Chassis:

For the finding the best section of trailer chassis structure against bending deformation verses torsional deformation for all section of chassis. We conclude that for increased stiffness of trailer chassis structure, the best section is in Multi-Layer Section. This section is the best and optimized section against bending and torsional loading as we can see in the following figure.

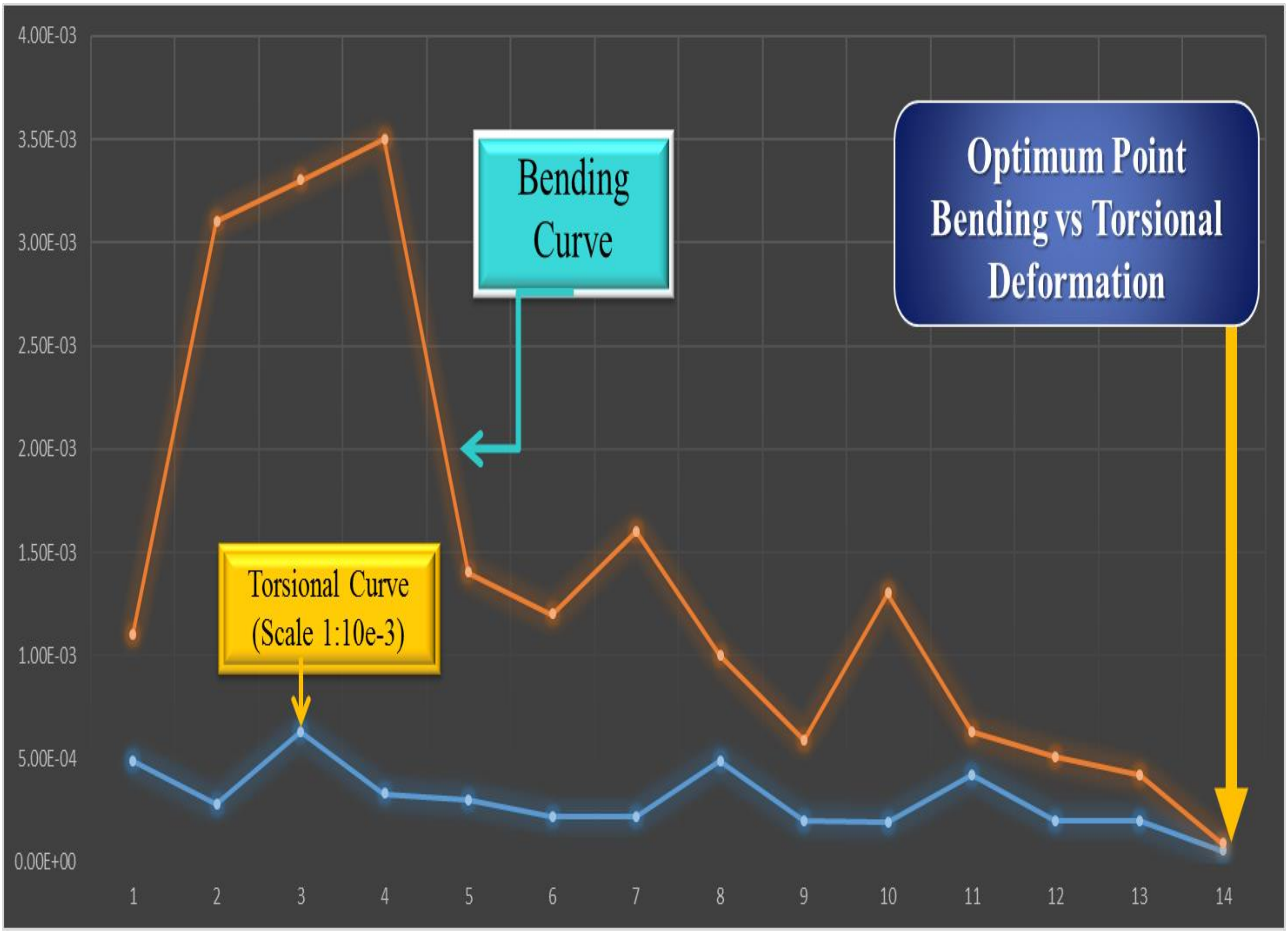


Figure 6-13: Graph of Bending Vs Torsional Deformations (All Section Chassis)

Cross Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	B	C	I	Z	CZ	CI	CB	IZ	IC	IB	BZ	BI	BC	ML

6.4.2 Bending ad Torsional Deformation Verses Mass for All Section Chassis:

For the finding the best section of trailer chassis structure against mass verses deformation. We conclude that for increased stiffness of trailer chassis structure, the best section is in between the section no. 13 and 14 (BC Section and Multi-Layer

Section). This section is the best section against bending and torsional loading as we can see in the following figure.

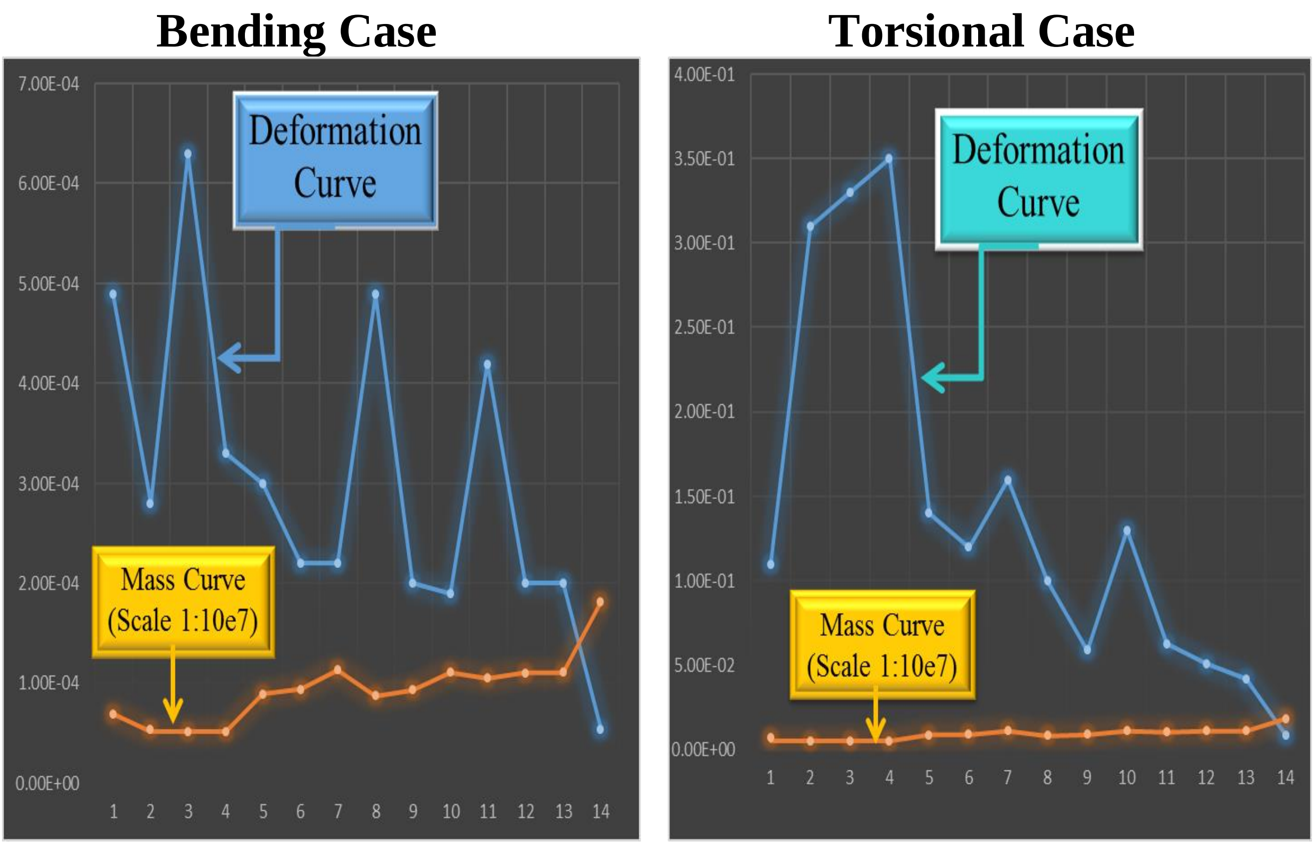


Figure 6-14: Graph of Bending and Torsional Deformation Vs Masses (All Section Chassis)

Cross Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	B	C	I	Z	CZ	CI	CB	IZ	IC	IB	BZ	BI	BC	ML

6.5 Conclusion:

For conclusion the results of above all cases are conclude separately according to chassis section types.

6.5.1 Single Section Chassis:

- "C" section is better than all other sections in terms of Bending Stress & Displacement, because it works as a cantilever beam under loading.

- “Box” section is better than all other sections in terms of Torsional Stress & Displacement, because any close section is best under torsional loading.
- Due to the lack of proper clamping the “I” section and “Box” section are not used for the practical applications.
- Due to the lack of proper clamping the “I” section and “Box” section are not used for the practical applications.

6.5.2 **Double Section Chassis**:

- Double section chassis have more resistance against torsional loading because lager the polar moment of inertia, less the chassis will twist.
- Double section chassis there is no major change against bending loading because the area moment of inertia is no change in this section, which characterizes a beam's ability to resist loading.
- If the points of forces act near the centroid of any cross section then it will show less deformation, that’s why double section chassis show the less deformation under torsional deformation and stresses.
- Due to increase of section modulus of double section chassis show less torsional deformation and stresses.
- In the double section chassis, the addition of three cross members as bending support of other new added main members. Theses sections show the less deformation against bending and torsional load.

6.5.3 **Multi-Layer Section Chassis**:

- It is best optimized design with respect to material.
- Multi-Layer Chassis is best for both torsional and bending loading cases.
- Gap in between the layer is suit for Compression Stresses.

- Multi grade layer Section is more stiff and rigid as compare to other single and double section.

6.6 Recommendation of Future Work:

In this report, different section of chassis of vehicle has been discussed for the increasing the stiffness of trailer chassis structure under torsional and bending loading cases in detail. Furthermore, some future work is recommended that we cannot do for this project. Recommended future work on this Multi-Layer section is acquired that is the following bulleted items into considerations;

- Simulate the all sections chassis by using different material.
- Simulate the all above sections for more than two axle chassis.
- Experimental Work is required on this section.

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ABSTRACT

The establishment of CPEC is likely to increase the road transportation in Pakistan by folds, where heavy duty trucks will play vital role in carrying goods from Pakistan's Northern border to the Gawadar Port. The appropriate design of transportation vehicles will play a vital role in the life enhancement of these heavy duty trucks, which will be subjected to the tough conditions of Karakoram Range. Usually, the heavy duty trucks are design to resist structure buckling with increased load carrying capacity. For this purpose, the truck beds are lowered towards ground in order to reduce the torsional effects.

The thermo-mechanically treated high strength steels like HSLA A710 are employed for manufacturing of chassis frame. Such materials like A710 provide an optimal solution for structures that have to mainly encounter bucking loads, however their performance reduce by large under the torsional loads. The terrain in the northern areas of Pakistan will subject the vehicles to extreme torsional loads for which appropriate design considerations must be carried out.

The torsional effects increase the vehicle chassis by folds as the C.G. (Center of Gravity) of the pay load moves up beyond critical limit. For resisting these effects and also to have an off-road capability, the extreme chassis frames are made from sandwiched multi-grade steel layers. Model analysis of the multi-layered multi-grade chassis frame steel structure will be carried out for the available heavy duty truck chassis. The obtained results will be analyzed and alternate materials will be sought as per our application which can provide an optimal cost effective solution. Modification of the structural members will be carried out in order to reduce weight from the overdesigned regions; also over stressed regions will be reinforced. A final comprehensive report will be prepared with the recommendations, and the simulation data will also be shared with the project awarding agency.

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