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Effect of Cross-Sections Considering Material and Design Aspects in Automotive Chassis

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Abstract: *The framework for supporting the body and various parts of the automobile is served by the automotive chassis which has to withstand the twist, shock, vibration and other stresses and its caused due to the unexpected braking, speeding of the vehicle, dreadful road condition and centrifugal forces. The backbone of any heavy vehicle is the chassis which has to carry the maximum load for all designed operating conditions. In this paper design and analysis of heavy vehicle chassis is analyzed considering weight reduction which is the key intention of any automobile industries in today's fast changing world. The pertinent information of an existing heavy vehicle chassis of EICHER is considered for modelling and analysis with different polymer composite materials namely, S-glass /Epoxy, Carbon/Epoxy and non-varying C, I and Box type cross-sections subjected to the identical load as that of a steel chassis. The numerical results are validated with analytical calculation considering the stress distribution and deformation.*

Keywords: *Chassis, Carbon/Epoxy, Deformation, Non-varying cross sections, S-glass /Epoxy.*

I. Introduction

Automotive chassis is a skeletal frame on which mechanical parts like engine, axle assemblies, brakes, steering etc, are fastened. Automotive chassis or automobile chassis helps to keep an automobile rigid, stiff and unbending. The noise, vibrations and harshness of the automobile has to be minimized by the chassis a prime component of an automobile which provides the strength and stability to the vehicle under different conditions. The supporting frame which acts as backbone of any automobile, in which the engine, axle assemblies are fastened. Automotive frames are basically manufactured from steel, which holds the entire weight of an automotive vehicle. It provides strength needed for supporting the vehicular components and payload placed upon it.

During the time of manufacturing, the entire vehicle is flexibly molded according to the structure of chassis which provides strength needed for supporting the components of the vehicle and its payload. This paper describes the design and analysis of heavy vehicle chassis considering weight reduction as the prime objective of any automobile industries in today's fast changing world. Automobile chassis is usually made of light sheet metal or composite plastics. Composite materials a combinations of two materials in which one of the material is called the "matrix phase" is in the form of fibers, sheets, or particles and is set in the other material called the "reinforcing phase" which increases their internal damping capacity and leads to better vibration energy absorption within the material and results in reduced transmission of noise to adjacent structures. Many composite materials offer a combination of strength and modulus in comparison to any traditional metallic metals.

Many composite laminates have excellent fatigue strength to weight ratios and fatigue damage tolerances, hence it is considered as a major class of structural material and are either used or being considered as a replacement for metal in many weight-critical components in various industries. Composite materials with high damping capacity can be beneficial in many automotive applications where noise, vibration, and hardness are a critical issue for passenger comfort. The relevant information of an existing heavy vehicle chassis of EICHER is considered for design and analysis with different cross sections and for different combination of composites like Carbon/Epoxy and S-glass /Epoxy. The model of steel and polymeric composite heavy vehicle chassis was created in Pro-E and analysed with ANSYS for same load conditions. The best one is selected among the various combinations of composites and conventional steel chassis in terms of deflections and stresses.

II. Literature Survey

Considering C, I and Box type cross sections, is analyzed by employing a polymeric composite heavy vehicle chassis for the same load carrying capacity, with a reduction in weight of 73% to 80%[1]. The determination of the stresses in a truck chassis before manufacturing is important due to the design improvement and it is investigated [2]. Using sensitivity analysis the optimization of weight is performed for different cross sections and achieved 17% of weight reduction in the truck chassis [3]. The stress analysis of chassis using finite element analysis was performed using ANSYS. The same finite element model can be used for the fatigue analysis of the chassis. [4]. Investigation of the structural analysis & optimization of vehicle chassis with constraints of maximum shear stress and deflection of chassis under maximum load was performed [5]. The analysis using finite element techniques, weight of chassis frame can be optimized and it is feasible to analyse the modified chassis frame before manufacturing [6]. The model for vehicle that considers the elastic characteristic of frame was applied to the rear frame of articulated dump truck and it was confirmed that this analysis can be used to predict the bending and torsion stresses of frames [7]. The automotive chassis was optimized with constraints of maximum shear stress, equivalent stress and deflection of chassis under maximum load, also a sensitivity analysis is carried out for weight reduction [8]. The mathematical stress analysis of a platform integrated structure mounted on vehicle chassis designed for unconventional type of loading pattern was described [9]. The fatigue study and life prediction on the chassis in order to verify the safety of this chassis during its operation using Finite Element Method (FEM) was discussed in detail [10]. The modifications of existing bracket have resulted in reduction of stress values leading to safe design was investigated [11]. The structural analysis of the chassis frame is performed to check the vulnerable points having high magnitude stress at static load condition [12]. A detailed review was presented on the chassis design using FEA [13]. The stress analysis of heavy duty truck chassis was investigated for fatigue study and life prediction of components to determine the critical point having high stress [14, 15]. The static and dynamic load characteristics using Finite Element models are performed [16]. The analysis of chassis frame was done to improve its payload by adding stiffener at maximum stress region of chassis [17]. The effective method for dynamic stress analysis of structural components of bus systems is detailed [18]. To determine the characteristics of a chassis using ANSYS and reinforcement technique of optimization is carried out [19]. The static and dynamic load characteristics of chassis were investigated using Finite Element Analysis method [20, 21]. The structural analysis of chassis was investigated by replacing traditional materials with ultra light weight carbon fiber materials [22].

III. Specification Of Existing Heavy Vehicle Chassis

The specification of an EICHER 10.9 vehicle is exposed in the Appendix I .The capacity of truck is 78480N, total load acting on the chassis including truck capacity, weight of the body and engine is 117720N. The load acting on each beam is half of the total load acting on the chassis hence load acting on single beam is 58860N.

$$Stress\ \sigma = \frac{Mmax}{Zxx} \tag{1}$$

$$Y = \frac{wx(b-x)}{24EI}\left[x(b-x) + b^2 - 2(c^2 + a^2) - \frac{2}{b}\{c^2x + a^2(b-x)\}\right] \tag{2}$$

IV. Structural Analysis Of Heavy Vehicle Chassis

The dimensions of conventional steel heavy vehicle chassis (SHVC) are replaced with polymeric composite heavy vehicle chassis (PCHVC) for the numerical analysis. Since the properties of PCHVC vary with directions of fiber, a 3-D model of chassis is needed for analysis. The loading conditions are assumed to be static. The element has six degrees of freedom at each node translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. The finite element analysis is carried out on steel chassis as well as different types of polymeric composite heavy vehicle chassis [23]. From the analysis the stress distribution (Von-mises stress) and deformations were carried out. The load is applied on the chassis frame it is denoted as C, the total load of 117720N force is divided into two equal loads of 58860N and it is applied on each side bar it is denoted as A and B also the gravitational force is applied on the frame is 9806.6mm/s2 it is denoted as D.

V. Results And Discussions

5. 1. Structural Analysis of C - Channel Section

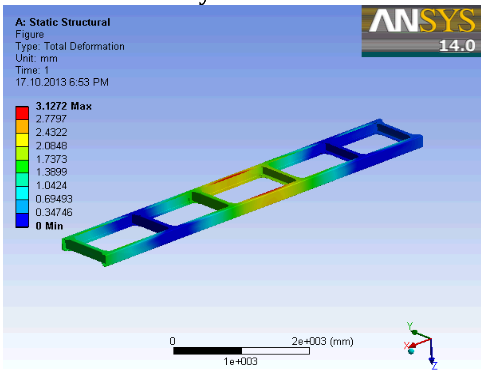

Figure 1. Deformation pattern for steel chassis channel

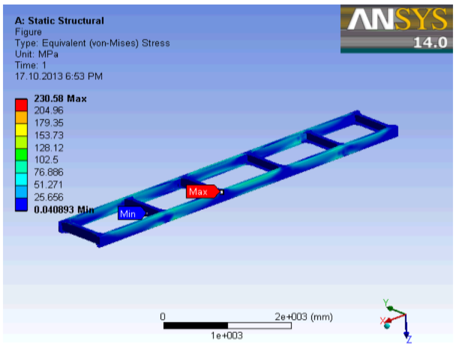

Figure 2. Stress distribution for steel chassis

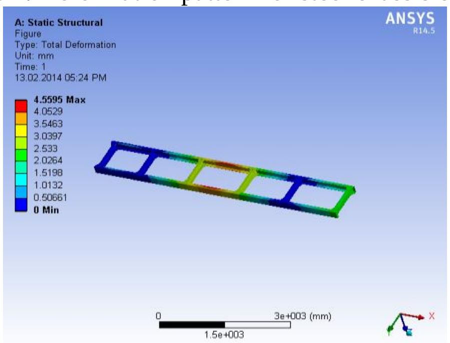

Figure 3. Deformation pattern for carbon/epoxy chassis

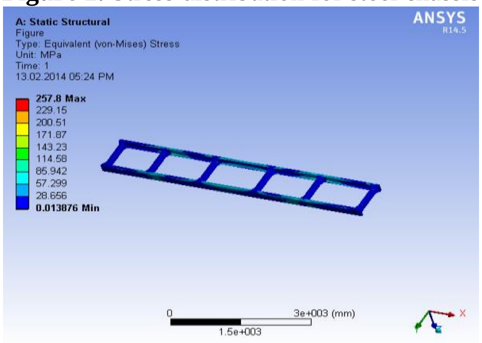

Figure 4. Stress distribution for carbon/epoxy chassis

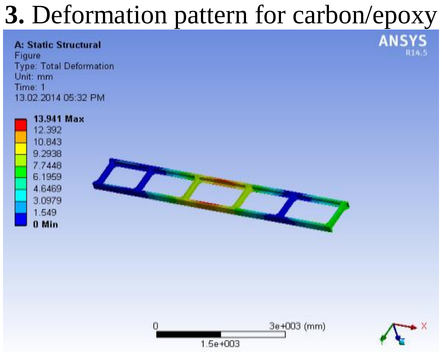

Figure 5. Deformation pattern for S-Glass epoxy chassis

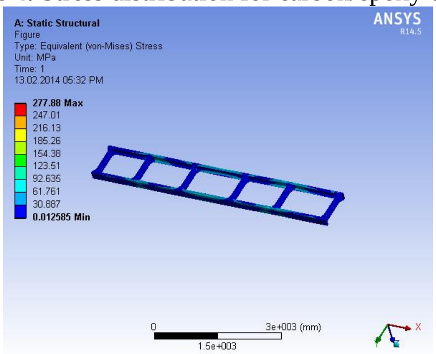

Figure 6. Stress distribution for S-Glass epoxy chassis

Fig. 1 to 6 illustrates the deformation and stress distribution pattern for the C-channel cross section. Figures 1, 3, 5 represent the deformation plot for the C-channel cross section for the different materials. Figures 2, 4, 6 represent the stress distribution for the C-channel cross section for the different materials.

5. 2. Structural Analysis of I - Channel Section

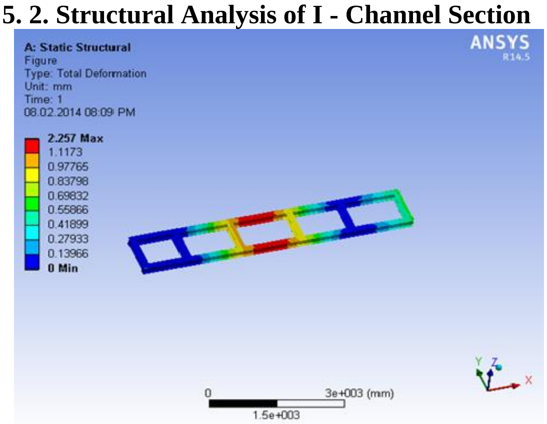

Figure 7. Deformation pattern for steel chassis

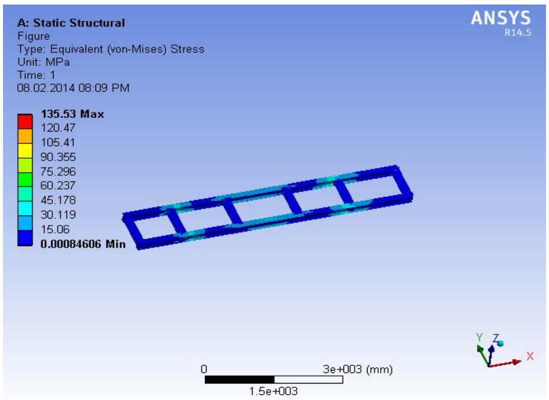

Figure 8. Stress distribution for steel chassis

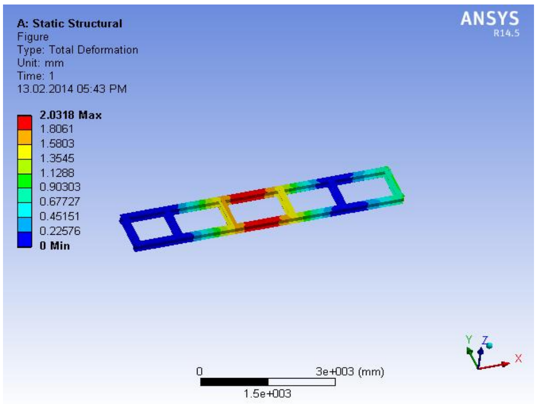

Figure 9. Deformation pattern for carbon epoxy chassis

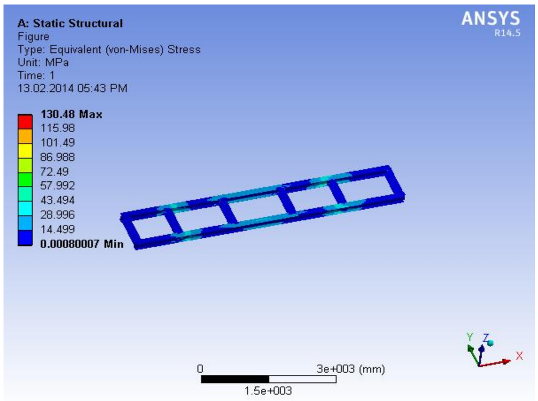

Figure 10. Stress distribution for carbon/epoxy chassis

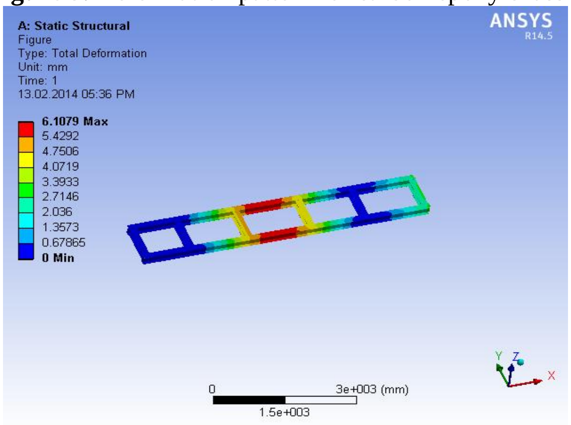

Figure 11. Deformation pattern for S glass epoxy chassis

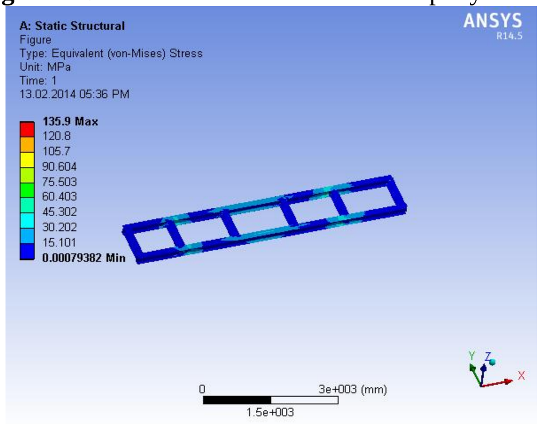

Figure 12. Stress distribution for S-Glass epoxy chassis

The deformation and stress distribution pattern for the I- Cross section is depicted in the Fig. 7 to 12. Fig. 7,9,11 represents the deformation plot for the I-channel cross section for the different materials.

5. 3. Structural Analysis of Box Channel Section

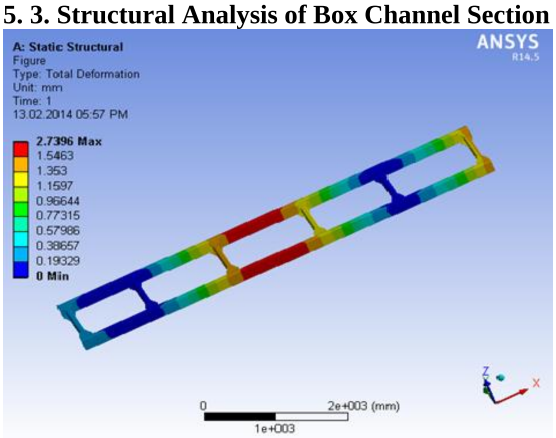

Figure 13. Deformation pattern for steel chassis

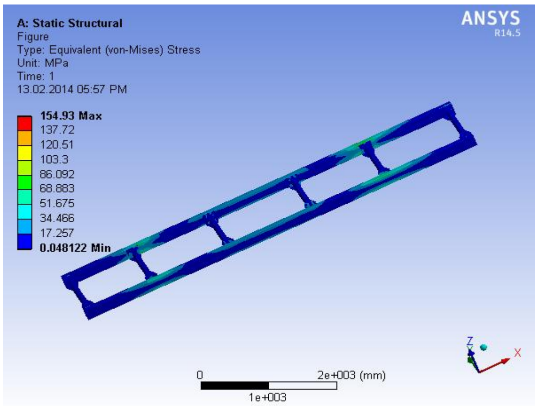

Figure 14. Stress distribution for steel chassis

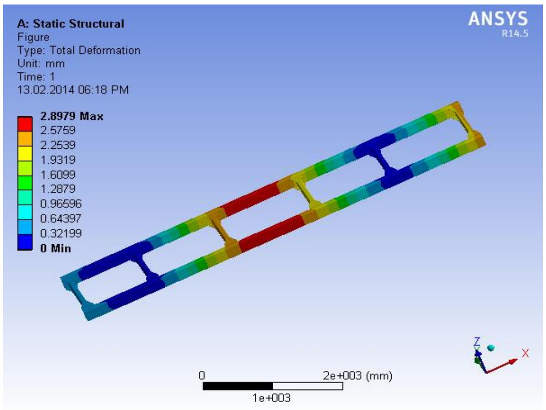

Figure 15. Deformation pattern for carbon epoxy chassis

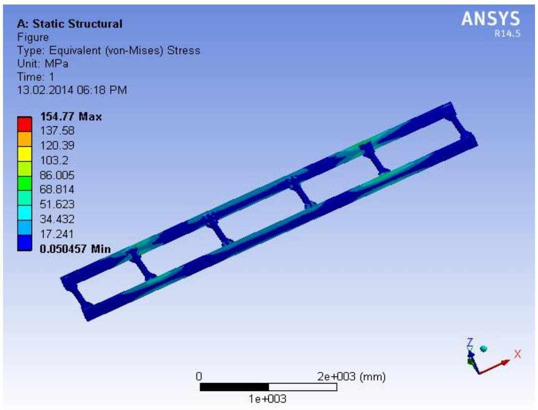

Figure 16. Stress distribution for carbon/epoxy chassis

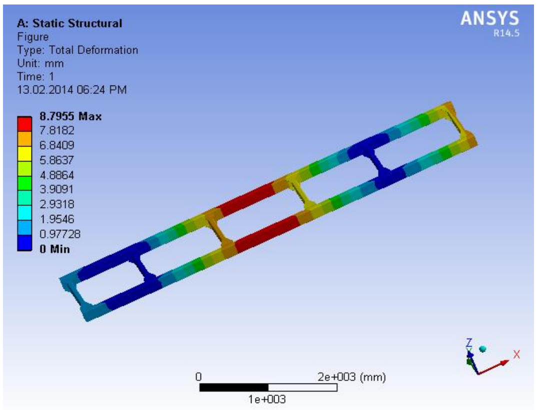

Figure 17. Deformation pattern for S glass epoxy chassis

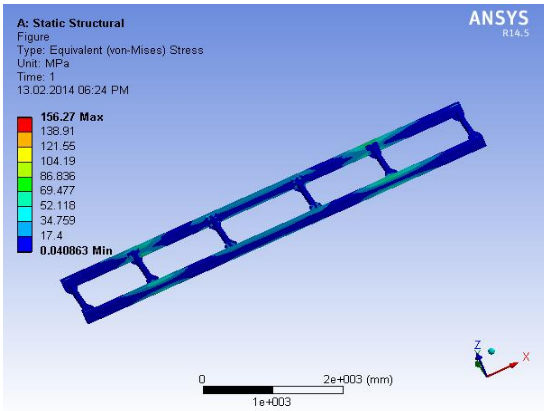

Figure 18. Stress distribution for S-Glass epoxy chassis

Fig. 8, 10, 12 represents the stress distribution for the I-channel cross section for the different materials. The deformation and stress distribution pattern for the Box- Cross section is depicted in the Fig. 13 to 18. The deformation plot for the Box- cross section for the different materials is shown in Fig. 13, 15, 17. The stress distribution for the Box-cross section for the different materials is shown in figures 14, 16, 18. The analytical results of stress distribution and deformation computed using equation 1 and 2 tabulated in the Table 1. Table 1 show the stress distribution and deformation values for materials and cross section of different materials and compared with the analytical values. It can be inferred from the tabulation that the magnitudes of the deformation and stress are very closer to analytical results in comparison with the numerical results.

Table 1. Deformation and Stress Distribution Values

CROSS SECTION	MATERIAL TYPE	STRESS DISTRIBUTION		DEFORMATION (MM)	
		NUMERICAL	ANALYTICAL	NUMERICAL	ANALYTICAL
C	Steel	230.58	235.0789	3.1272	3.214
	Carbon Epoxy	257.80	235.0789	4.5595	4.312
	S-Glass Epoxy	277.88	235.0789	13.941	13.561
I	Steel	135.53	133.64	2.2570	2.349
	Carbon Epoxy	130.48	133.64	2.0318	2.195
	S-Glass Epoxy	135.9	133.64	6.1079	6.530
BOX	Steel	154.93	155.06	2.7396	2.833
	Carbon Epoxy	154.77	155.06	2.8979	2.713
	S-Glass Epoxy	156.27	155.06	8.7955	8.912

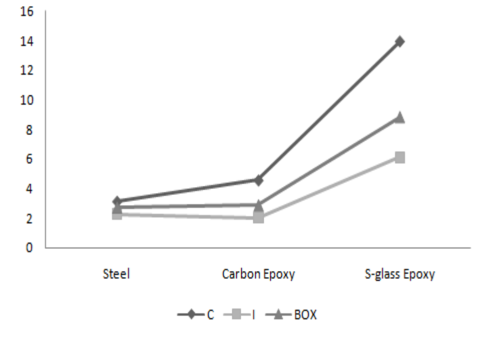	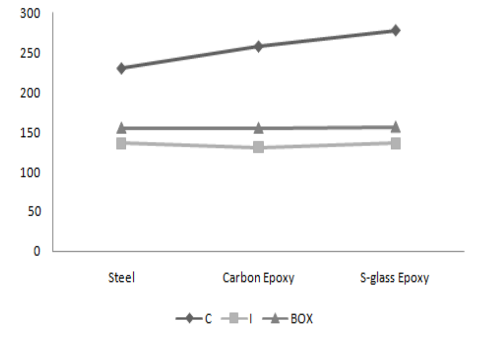
Figure 19. Deformation curve	**Figure 20.** Stress distribution curve

The magnitude of stress and deformation are greater when compared to other polymer composites. When compared with C and Box cross sections the I cross section induces very low stress and deformation. Carbon epoxy and S-glass epoxy material of C and BOX cross section as high stress and deformation when compare to I cross section [24]. Fig. 19 and 20 indicates the deformation and stress distribution curve for the analysis performed on various materials with cross sections like steel, carbon epoxy and S-glass epoxy composite. From the above curve it is clear that S-glass epoxy has high deformation and stress distribution when compared to carbon epoxy polymeric composite and steel. Carbon epoxy and steel chassis gives almost nearer value especially 'I' cross section. But carbon epoxy polymeric composite induces very low level of deformation and stress distribution when compared with steel. I-Cross section provides low deformation and stress distribution when compared to other cross sections like C and Box. Carbon epoxy composites have low weight when compared to steel.

VI. Conclusion

The existing heavy vehicle chassis of EICHER is taken for design and analysis with different cross sections for different materials like Carbon/Epoxy and S-glass /Epoxy composites is performed. The model of the chassis was created in Pro-E and analysed with ANSYS for same load conditions. After analysis a comparison is made between existing conventional steel chassis and composite materials in terms of deflections and stresses, to select the best one. The results of the steel and polymeric composites material with cross section C, I, and Box are performed. It is inferred that by employing a carbon epoxy composites heavy vehicle chassis for same load carrying capacity, there is a reduction in weight when compared to steel. Carbon epoxy induces low deformation and stress distribution when compared to S-glass epoxy composite material and steel especially in 'I' section. 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.

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Appendix – I

Specifications of heavy vehicle chassis

PARAMETERS	VALUE
Material of the chassis	Steel 52
Chemical composition	0.20%C, 0.50%Si, 0.9%Mn, 0.03%P and 0.025%S
Side bar of the chassis	200mm x 76 mm x 6mm
Cross bar of the chassis	180mm x 75 mm x 4mm
Front Overhang (a)	935 mm
Wheel Base (b)	3800 mm
Rear Overhang (c)	1620 mm
Young’s modulus E	2×10^5 N / mm^2
Poisson Ratio	0.3
Radius of Gyration R	100 mm
Width of the chassis	80 mm