DESIGN AND ANALYSIS OF AUTOMOTIVE BUMPER USING COMPOSITE MATERIALS

Y Sarath [1*] and T Muneiah[2]

[1]M.Tech research scholar, [2]Assistant Professor
Dept. of Mechanical Engineering, PBRVITS, Nellore, AP, India-524201.

ABSTRACT: - Automobile bumper subsystem is a frontal and rear structure of the vehicle that has the purpose of energy absorption during low velocity impact. The bumper beam is the main structure for absorbing the energy of collisions. Automotive bumper beam is one of the key systems in car. Bumper beam design to prevent or reduce physical damage to front or rear end of the Motor vehicle in collision conditions they protect the hood, trunk, grill, fuel, exhaust and cooling system as well as safety related equipment such as the parking light, head lamp and tail light etc. A good design of the car bumper must provide safety for passengers and should have low weight.

1. INTRODUCTION

Car accidents are happening every day. Most drivers are convinced that they can avoid such troublesome situations. Nevertheless, we must take into account the statistics – ten thousand dead and hundreds of thousands to million wounded each year. These numbers call for the necessity to improve the safety of automobiles during accidents. Automobile bumper subsystem is a frontal and rear structures of the vehicle that has the purpose of energy absorption during low velocity impact. The bumper beam is the main structure for absorbing the energy of collisions. Automotive bumper beam is one of the key system in car. Bumpers beam design to prevent or reduce physical damage to front or rear end of the Motor vehicle in collision conditions they protect the hood, trunk, grill, fuel, exhaust and cooling system as well as safety related equipment such as the parking light, head lamp and tail light etc. A good design of the car bumper must provide safety for passengers and should have low weight.

Car accidents are unpredicted, which happens every day. Nearly 1.3 million people die in road crashes each year, on average 3287 deaths a day. An additional 20 to 30 million are injured or disabled. These statistics are alarming and raises a concern over safety of passengers and car system. One of the safety features are in build in the front of automobile that is bumper beam system. Bumper became standard equipment of automobile in 1925. The uses of bumper has evolved from a mechanism being placed on the front and rear of the car to protect the body and safety features of motor vehicle from getting damage due to low speed collisions. They protect the hood, trunk, grill, fuel, exhaust and cooling system. They also protect the equipments such as parking lights, headlamps, tail lamps, radiator system and major engine part. Therefore, the bumper should be designed in such a way that they absorb major part of energy through energy absorbing device and transfer rest of it to chassis of automobile.

The simulation of motor vehicle is done for low velocity impact test, on the other hand, it should absorb all the energy excluding the energy absorbed by body panel, bumper over, reinforcement, radiator support, Et-cetera,. According to United Nations Economic Commission for Europe(ECE) Regulation number 42. Although, nowadays bumper is being designed more for aesthetics of motor vehicle rather than the actual functionality. The styling of bumper has become more important than structural design of the bumper. Nevertheless, the standards and regulations governing the design of the bumper should not be compromised in any circumstances. The study carried out by Federal Motor Vehicle Safety Standards and Regulations (FMVSS) highlights how the present day bumpers on motor vehicles are connected to the fenders rather than frame of the motor vehicle where it would be of more use and steady during low speed collision. The design of automobile parts and assemblies, components must be positioned with tight tolerances, so as to maintain automotive aerodynamics and functionality of components with respect to each other. Furthermore the support structures must not deform bumper components by applying unnecessary stresses. Therefore energy absorbing devices are installed in the bumper beam system. This device absorbs major part of energy during the impact and transfers rest to the surrounding.

Most automotive energy absorbers that are in the market today are designed to meet safety regulations with respect to individual geographic locations. North American markets will require that the design should satisfy FMVSS regulations that require the energy absorbers just to protect the car. The European and Asia Pacific markets have different set of requirements that focuses also on the safety of the pedestrian. However, the difficulties of designing a bumper system that is rigid enough to protect the vehicle and, at the same time compliant enough to protect a pedestrian raise questions as to whether these ideas are compatible.

2. LITERATURE REVIEW

- Alen John, Nidhi (2014)- They studied that Composites has the maximum stress value and it having the highest strength to weight ratio and producing low deformation as compared to Aluminium B390 alloy, Chromium coated and mild steel.

- Alen John, Sanu Alex (2014)- The objective of the study was to study desirable properties of polymer composite materials and compare with currently used materials.

- Nitin S. Motgi, S.B.Naik, P.R.Kulkarni (2013)- The objective was to study stress pattern of designed automotive bumper selecting suitable materials such as metals and composites. And comparing the results obtained. They found composite materials were more effective than metals.

- A.R. MortazaviMoghaddam, M.T. Ahmadian, Hosseinzadeh (2011)- They studied the structure, shape and impact condition of Glass Mat Thermoplastic (GMT) bumper and the results are compared with conventional metals like steel and aluminum. GMT showed very good impact behaviour compared to with steel and aluminum, which all failed and showed manufacturing difficulties due to strengthening ribs or weight increase due to use more dense material.

3. METHODOLOGY

- Study the literature related to bumper design and its performance improvement by referring to books, journal papers and related manuals.
- Obtaining design data of existing bumper model.
- D modeling of bumper model in CREO.
- Selection of bumper material in accordance with design.
- Theoretical calculation of impact force on bumper system.
- Analysis of part being designed using ANSYS
- Calculation of von-mesis stress and displacement and comparing the results obtained.

4. BUMPER DETAILS

- Effective length- 18cm
- Total length-60cm
- Thickness-5cm
- Effective breath-12cm
- Profile- c type

5. MATERIAL PROPERTIES

There are two main reasons why materials selection is required: firstly, to design an existing product for better performance, lower cost, increasing reliability and reduced weight and secondly, to select a material for a new product. Materials selection is a main product design consideration because product's overall performance is mainly affected and determined by materials selection process.

Table.1-Material Properties

SL.No.	Properties	Units	Structural Steel	Carbon Fibre	E- Glass Epoxy Fibre
1	Density	Kg/m3	7850	1500	1983
2	Young's Modulus	Mpa	200000	190000	700000
3	Poisson Ratio	-	0.3	0.25	0.25
4	Compressive yield strength	Mpa	250	200	600

6. IMPACT MECHANICS

Low speed collisions at 60kmph
Weight of car =1400kg
Weight of four passengers = 100kg
Total weight of vehicle in motion = weight of car + weight of passengers
= 1400 +400
= 1800kg
During collision the energy (work) is generated in form of kinetic energy, which is given by
Kinetic Energy= ½ m v2
Where m is the mass of the car, kg
v is the velocity of the car, m/s
Now, converting the velocity of car in m/s
v = 60 x 5/8 m/s
v = 16.67 m/s
On substituting the above value, we get the kinetic energy generated during the impact
Kinetic Energy = ½ x 1800 x 16.672
= 250100.01 Joules
This kinetic Energy is the work done during collision, therefore Kinetic Energy = Work Done (W)
Work Done (W) = 250100.01 Joules
To overcome the amount of kinetic energy generated, there should be a displacement of car components. Since, it is a frontal impact let us constrain the maximum displacement to 500 mm for passenger and other major component's safety.
As we know, the work done can also be calculated as,
W= F x d
Where W is energy, J
F is Force, N
d is maximum displacement of bumper,
250100.01 = F x 0.500
F= 250100.01/ 0.5
F= 500200.02 N
F= 500.2 KN
Therefore, during the frontal impact the car experiences the force of 500.2kN at the speed of 60kmph.This Force is equal to 28 times the G.

7. FINITE ELEMENT ANALYSIS OF TRUCK CHASSIS

7.1 BASIC CONCEPT OF FEM

The finite element method (FEM) is a computational technique used to obtain approximate solutions of boundary value problems in engineering. Simply stated, a boundary value problem is a mathematical problem in which one or more dependent variables must satisfy a differential equation everywhere within a known domain of independent variables and satisfy specific conditions on the boundary of the domain.

An unsophisticated description of the FE method is that it involves cutting a structure into several elements (pieces of structure), describing the behavior of each element in a simple way, then reconnecting elements at nodes as if nodes were pins or drops of glue that hold elements together . This process results in a set of simultaneous algebraic equations. In stress analysis these equation are equilibrium equations of the nodes. There may be several hundred or several thousand such equations, which mean that computer implementation is mandatory.

7.2. A General Procedure for FEA

There are certain common steps in formulating a finite element analysis of a physical problem, whether structural, fluid flow, heat transfer and some others problem. These steps are usually embodied in commercial finite element software packages. There are three main steps, namely: preprocessing, solution and post processing. The preprocessing (model definition) step is critical. A perfectly computed finite element solution is of absolutely no value if it corresponds to the wrong problem. This step includes: define the geometric domain of the problem, the element type(s) to be used, the material properties of the elements, the geometric properties of the elements (length, area, and the like), the element connectivity (mesh the model), the physical constraints (boundary conditions) and the loadings.

The next step is solution, in this step the governing algebraic equations in matrix form and computes the unknown values of the primary field variable(s) are assembled. The computed results are then used by back substitution to determine additional, derived variables, such as reaction forces, element stresses and heat flow. Actually the features in this step such as matrix manipulation, numerical integration and equation solving are carried out automatically by commercial software.

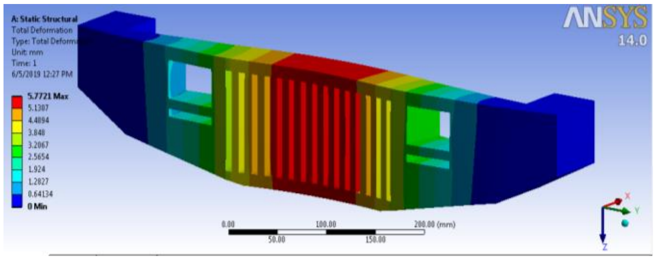
The final step is post processing, the analysis and evaluation of the result is conducted in this step. Examples of operations that can be accomplished include sort element stresses in order of magnitude, check equilibrium, calculate factors of safety, plot deformed structural shape, animate dynamic model behavior and produce color-coded temperature plots. The large software has a preprocessor and postprocessor to accompany the analysis portion and the both processor can communicate with the other large programs. Specific procedures of pre and post are different dependent upon the program.

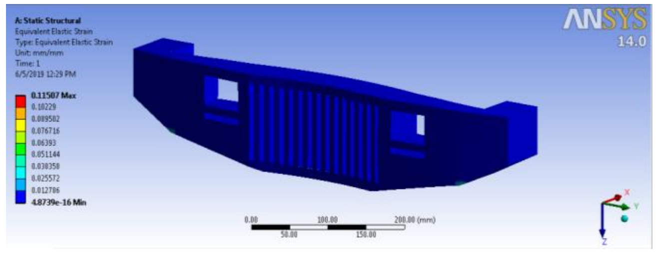
CARBON FIBRE GEOMETRY

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	F:\project 2019\CAR PUMBER\pumber_files\dp0\SYS\DM\SYS.agdb
Type	DesignModeler
Length Unit	Millimeters
Element Control	Program Controlled

Display Style	Body Color
Bounding Box	
Length X	100. mm
Length Y	600. mm
Length Z	120. mm
Properties	
Volume	2.3131e+006 mm^3
Mass	3.4696 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	1091403
Elements	634775
Mesh Metric	None
Basic Geometry Options	
Parameters	Yes
Parameter Key	DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	No
Attach File Via Temp File	Yes
Temporary Directory	C:\Users\sss\AppData\Local\Temp
Analysis Type	3-D
Decompose Disjoint Faces	Yes
Enclosure and Symmetry Processing	Yes

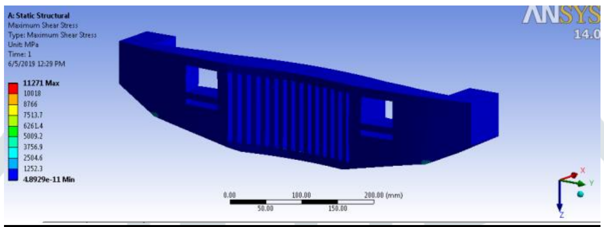
8. RESULTS AND ANALYSIS:





Total Deformation

Equivalent Elastic Strain



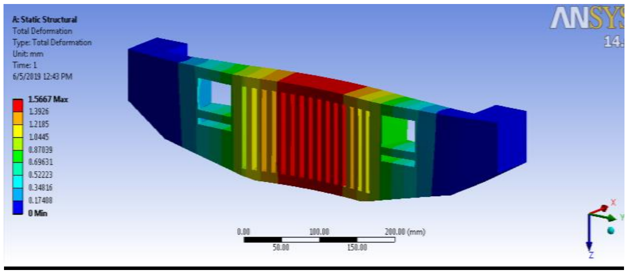
Maximum Shear Stress

Object Name	*Total Deformation*	*Equivalent Stress*	*Equivalent Elastic Strain*	*Maximum Shear Stress*
State	Solved			
Scope				
Scoping Method	Geometry Selection			
Geometry	All Bodies			
Results				
Type	**Total Deformation**	**Equivalent (von-Mises) Stress**	**Equivalent Elastic Strain**	**Maximum Shear Stress**
Minimum	**0. mm**	**8.5265e-011 MPa**	**4.8739e-016 mm/mm**	**4.8929e-011 MPa**
Maximum	**5.7721 mm**	**20731 MPa**	**0.11507 mm/mm**	**11271 MPa**

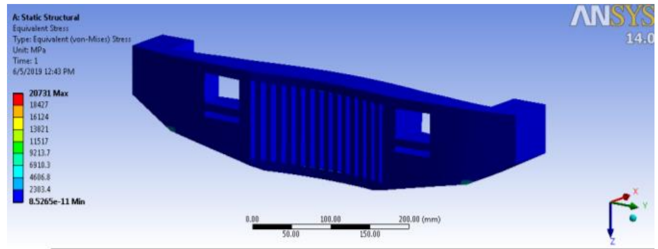
Epoxy E-Glass

Properties	
Volume	2.3131e+006 mm³
Mass	4.5868 kg
Scale Factor Value	1.

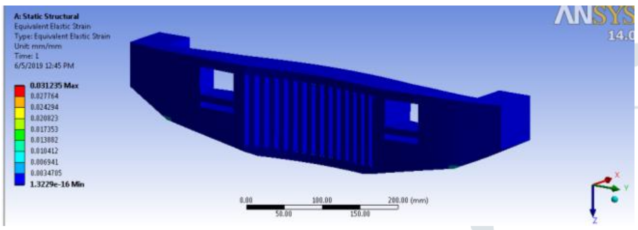
RESULTS



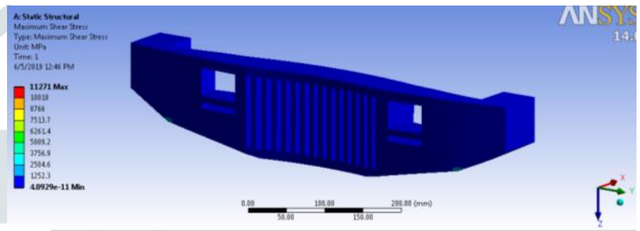
Total Deformation



Equivalent Stress



Equivalent Elastic Strain



Maximum Shear Stress

RESULTS

Object Name	***Total Deformation***	***Equivalent Stress***	***Equivalent Elastic Strain***	***Maximum Shear Stress***
Results				
Minimum	**0. mm**	**8.5265e-011 MPa**	**1.3229e-016 mm/mm**	**4.8929e-011 MPa**
Maximum	**1.5667 mm**	**20731 MPa**	**3.1235e-002 mm/mm**	**11271 MPa**

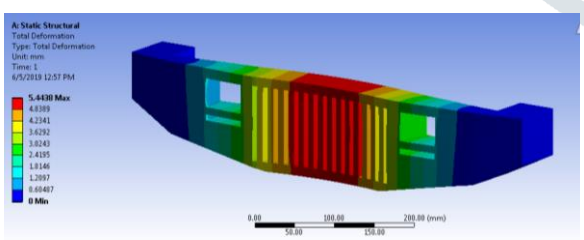
STRUCTURAL STEEL

Object Name	*Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Structural Steel
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	100. mm

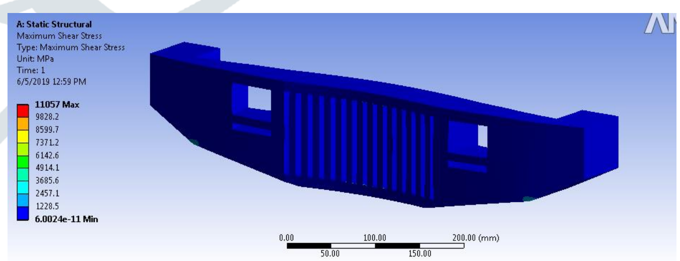
Length Y	600. mm
Length Z	120. mm
Properties	
Volume	2.3131e+006 mm³
Mass	18.157 kg
Centroid X	12.74 mm
Centroid Y	0.32684 mm
Centroid Z	-26.637 mm
Moment of Inertia Ip1	6.095e+005 kg·mm²
Moment of Inertia Ip2	29457 kg·mm²
Moment of Inertia Ip3	5.9786e+005 kg·mm²
Statistics	
Nodes	1091403
Elements	634775
Mesh Metric	None

Loads

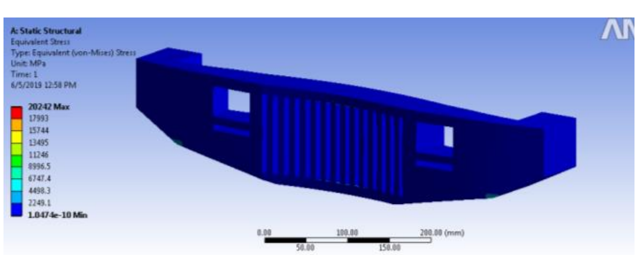
Object Name	*Fixed Support*	*Force*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	8 Faces	1 Face
Definition		
Type	Fixed Support	Force
Suppressed	No	
Define By		Components
Coordinate System		Global Coordinate System
X Component		5.002e+005 N (ramped)
Y Component		0. N (ramped)
Z Component		0. N (ramped)



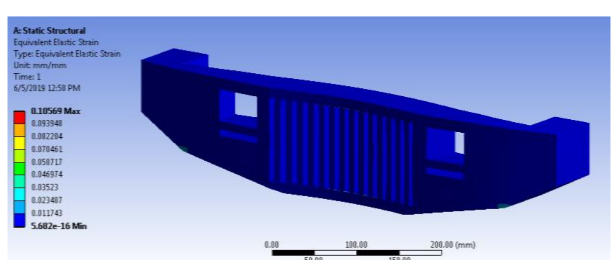
Total Deformation



Equivalent Stress



Maximum Shear Stress



Equivalent Elastic Strain

Results:

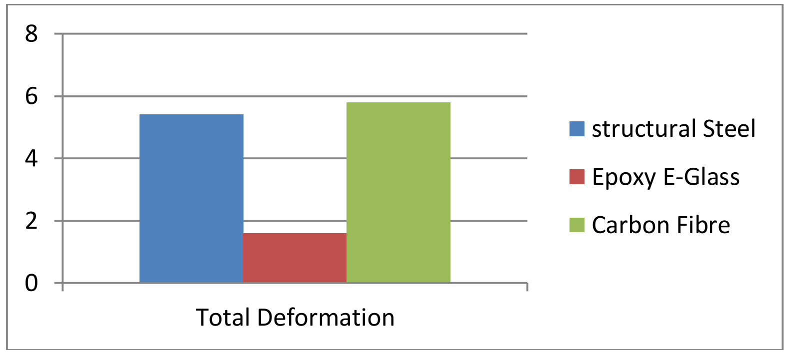
Object Name	*Total Deformation*	*Equivalent Stress*	*Equivalent Elastic Strain*	*Maximum Shear Stress*
Results				
Minimum	**0. mm**	**1.0474e-010 MPa**	**5.682e-016 mm/mm**	**6.0024e-011 MPa**
Maximum	**5.4438 mm**	**20242 MPa**	**0.10569 mm/mm**	**11057 MPa**

Tabular analysis

Material	*Total Deformation*	*Equivalent Stress*	*Equivalent Elastic Strain*	*Maximum Shear Stress*
STRUCTURAL STEEL	**5.4438 mm**	**20242 MPa**	**0.10569 mm/mm**	**11057 MPa**
Epoxy E-Glass	**1.5667 mm**	**20731 MPa**	**3.1235e-002 mm/mm**	**11271 MPa**
CARBON FIBRE	**5.7721 mm**	**20731 MPa**	**0.11507 mm/mm**	**11271 MPa**

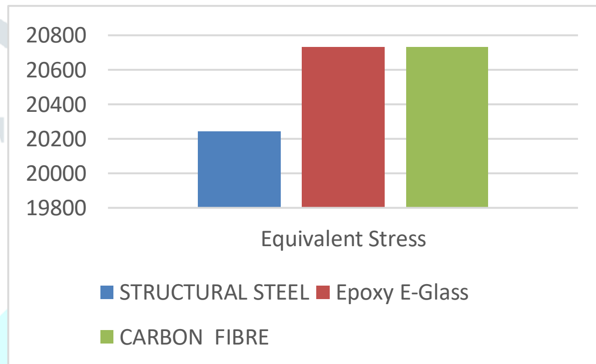
GRAPHICAL ANALYSIS

	Total Deformation
STRUCTURAL STEEL	**5.4438 mm**
Epoxy E-Glass	**1.5667 mm**
CARBON FIBRE	**5.7721 mm**



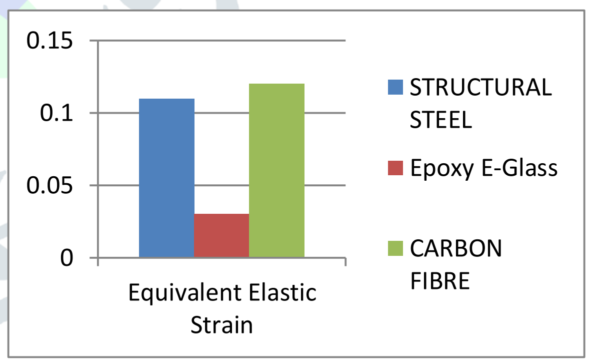
Equivalent Stress

	Equivalent Stress
STRUCTURAL STEEL	**20242 MPa**
Epoxy E-Glass	**20731 MPa**
CARBON FIBRE	**20731 MPa**



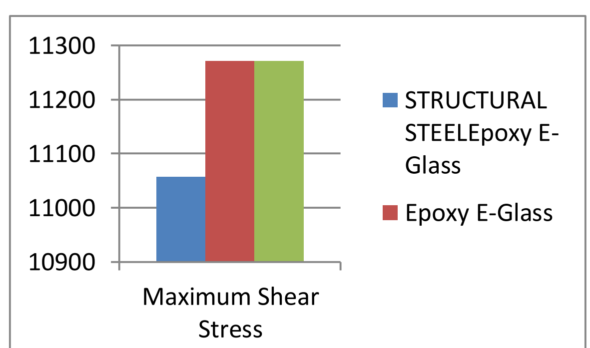
EQUIVALENT ELASTIC STRAIN

	Equivalent Elastic Strain
STRUCTURAL STEEL	**0.10569 mm/mm**
Epoxy E-Glass	**3.1235e-002 mm/mm**
CARBON FIBRE	**0.11507 mm/mm**

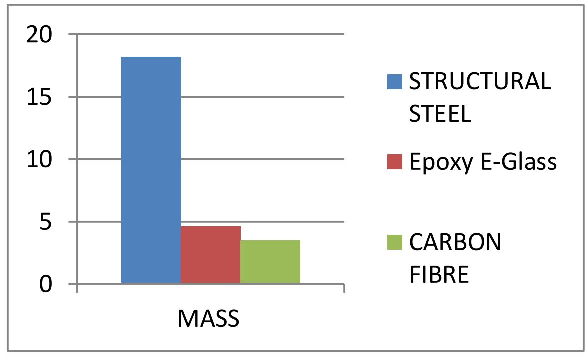


Maximum Shear Stress

	Maximum Shear Stress
STRUCTURAL STEEL	**11057 MPa**
Epoxy E-Glass	**11271 MPa**
CARBON FIBRE	**11271 MPa**



	MASS in Kg
STRUCTURAL STEEL	**18.2**
Epoxy E-Glass	**4.6**
CARBON FIBRE	**3.5**



MASS

9. CONCLUSION

From above the results it was analyzed that which composite material is best to replace the metallic/ conventional bumpers it was found that both the composite materials are safe to replace with heavy metallic bumpers. Epoxy E Glass performed very well in the analysis but this composite material is very costly as compare to other metal used in auto vehicle chassis frame which incur some extra cost on the consumer when cost will not be the factor. And E-Glass Epoxy fibre also showed well results rather than steel. The results of the analysis give a clear indication that the maximum stress induced is in steel and minimum stress induced is in composite material. And the Mass of the bumper beams can be reduced by more than 76%.

10. REFERENCES

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