Structural Analysis of Light Duty Vehicle Roof Panel Made of Carbon Fiber and Sisal Fiber Composite Material

By

Abenezer Shimellis

A Thesis Submitted to

The Department of Mechanical Systems and Vehicle Engineering

School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Masters of Science in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia
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Advisor: Mr. N. Ramesh Babu (Ass. Prof)

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Approval of Board of Examiners

We, the undersigned, members of the Board of Examiners of the final open defense by **Abenezer Shimellis** have read and evaluated his thesis entitled "**Structural Analysis of Light Duty Vehicle Roof Panel Made of Carbon Fiber and Sisal Fiber Composite Material**" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement for the Degree of Masters of Science in Automotive Engineering.

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CANDIDATE'S DECLARATION

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Candidate	Signature	Date

This MSc Thesis has been submitted for examination with my approval as thesis advisor.

Advisor name	Signature	Date
Co-advisor name	Signature	Date

DEDICATION

I dedicate this project to God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. He has been the source of my strength throughout this program and on His wings only have I soared. I also dedicate this work to Adama Science and Technology University and to my families those encouraged me all the way and their encouragement has made sure that I give it all it takes to finish that which I have started. To my second mother Tsion Bushura, my best one Eyuel Mamo, Milto Eyuel, Hallelujah Eyuel (Mama) and Mo’a Eyuel; and also, to Madam Bekelech Fite who have been affected in every way possible by this quest. Thank you. My Mom for you all can never be quantified. God bless you.

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List of Acronyms and Abbreviations

3D	Three dimensional
ASTM	American standards for testing machines
Av	Average
CAD	Computer aided design
CF	Carbon fiber
CFRP	Carbon fiber reinforced plastic
CFSFC	Carbon fiber and Sisal fiber composites
DNC	Direct numerical control
ECAE	Ethiopian conformity assessment enterprise
FEA	Finite element analysis
FEM	Finite element methods
Gp	General Polyester
GVW	Gross vehicle weight
NaOH	Sodium hydroxide
PAN	Polyacrylonitrite
PEEK	Polyether-ether-ketone
PPS	Polyphenylene
SF	Sisal fiber
UTM	Universal testing machines

Nomenclatures

E	Young's modulus
F_{max}	Maximum force
g	gravitational force
GPa	Giga pascal
kg	kilo gram
km	kilometer
kN	kilo newton
L	Length
m	mass
M_b	Bending moment
mg	milligram
MPa	mega pascal
N	Newton
Pa	Pascal
Pcs	pieces
t	thickness
v	volume
W	Width
W_d	dry mass
W_m	water mass
W_w	wet weight
ρ	Density

ABSTRACT

The natural fiber reinforced composites are being used in various fields of applications that are contributing to the replacement of conventional metals such as structural steel, mild steel and many other materials which exposed the vehicles for high weight and low fuel efficiency. For this thesis work, the composite natural fibers with carbon fiber are being used due to their light weight, higher specific strength and non–abrasive which also have economical value. The hybrid composites with different fiber lengths and reinforcements may contribute a better role than those of single fiber composites. Carbon fiber and sisal fiber are the important fibers in automobile industries for manufacturing parts of the body, frame and vehicles interior components. This thesis work deals and focuses on the Structural analysis, Modeling, Design and evaluation of mechanical properties like tensile strength, compression strength, bending and water absorption of both carbon fiber and sisal fiber hybrid composites materials for further production of vehicles roof panel and replace the new composite material into the pre-existed conventional one. Composite materials are prepared by using general polyester resin, sisal fiber and carbon fiber. The sisal fiber was woven in mat structure with fiber orientation of $0^0/90^0$ *and* $\pm 45^0$ *and inserted at the middle layers between twill carbon fiber and molded together. The test specimens were prepared according to ASTM standard dimensions. From the test performed, the stress results obtained in tensile test of CFSFC of* $0^0/90^0$ *was 193 MPa which is higher than* $\pm 45^0$ *of 103 MPa. In the bending test the load in* $0^0/90^0$ *fiber orientation is 2506.7 N which is higher than the maximum load of* $\pm 45^0$ *orientation of 1620 N. In case of the compression test both* $0^0/90^0$ *and* $\pm 45^0$ *got the same stress of 7.7 MPa with maximum load of 23,253.3 N and 23,443.3 N loads respectively. In case of water absorption test,* $0^0/90^0$ *is better with water absorption of 2.91% which is lower than 3.67% of* $\pm 45^0$*. The modelling of roof panel was done using SOLIDWORK 2013 and the analysis was done using ANSYS 17.2. Both CFSFC and structural steel were found to be having equivalent stress of 9.1537 MPa with 1.4195 mm and 0.19895 mm of deformation respectively. Weight reduction of about 83 % was achieved by replacing conventional steel material with composite of carbon fiber and sisal fiber for roof panel.*

Keywords: Composite materials; Carbon fiber; Roof panel; Sisal fiber; Stress; Deformation.

1. INTRODUCTION

1.1. Background of the study

It is known as the pre-existed vehicles bodies are produced from conventional materials such as mild steel, structural steel and any other metallic materials which increase vehicles weight being very heavy and causes higher fuel consumption with associated higher levels of harmful emissions. The cost of conventional metals is high. Therefore, many researchers start to generate ideas to minimize the weight of the vehicle which may results in better fuel efficiency and lesser exhaust emission. To achieve the issues of weight reduction the better idea is introducing polymeric composite materials which are lesser in weight, abundantly available and can be molded into different shapes.

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel and epoxy reinforced with graphite fibers (Autar, 2006). The development of composite materials and their related design and manufacturing technologies is one of the most important advances in the history of materials. Research and engineering interest has been shifting from monolithic materials to Natural fiber reinforced polymeric materials. In the recent decades, natural fibers as an alternative reinforcement in polymer composites have attracted the attention of many researchers and scientists due to their advantages over conventional materials like metals and glass fibers. These natural fibers include flax, sun hemp, jute, sisal, Pineapple and many others (Nabi *et al.*, 1999). Natural fibers exhibit superior mechanical properties such as flexibility, stiffness and modulus compared to glass fibers (Kasama *et al.*, 2009).

Sisal Fiber is one of the most widely used natural fiber and is very easily cultivated. It is obtain from sisal plant that is a very strong and important leaf fiber. It is extracted from the leaves of the sisal plant and it is very hard. It is highly renewable resource of energy. Sisal fiber is exceptionally durable and a low maintenance with minimal wear and tear. Its fiber is too tough for textiles and fabrics. Sisal fiber is exceptionally durable with a low maintenance with minimal wear and tear, fully biodegradable, does not attract or trap dust particles and does not absorb moisture water easily, exhibits good sound and impact absorbing properties. And also, sisal fiber is applicable in shipping industries, used as a fiber core of the steel wire cables of elevators, and used in automobile industries with fiber glass in composite materials (http://textilelearner .blogspot.com).

In this thesis work it is aimed to replace the conventional materials to Carbon fiber and sisal fiber composites of light duty vehicles roof panel for the sake of weight minimization. And also, most of the studies on natural fibers are concerned with single reinforcement or reinforcement is conducted with other types of natural fiber. But, in this work the addition of natural fiber to the synthetic fiber to make the composite hybrid which is comparatively high strength, cheaper, lighter and easy to use was tried.

1.2. Statement of the problem

Weight reduction is now the main issue in automobile industries. Conventional materials used in vehicle structure are heavy causing higher fuel consumption and higher level of harmful emissions. Conventional materials like structural steel subjected to corrosion when exposed to moisture in the presence of air also suffer fatigue failure under repeated stresses and at higher temperatures. Research questions are as follows:

Is it possible to prepare composite material with carbon fiber and sisal fiber to replace conventional material in construction of vehicle roof panel?

Is it possible to achieve weight reduction of the vehicle using carbon fiber and sisal fiber composite? All these questions are answered in this thesis work.

1.3. Objectives

1.3.1. General Objective

The general objective of this thesis work is to design and analysis the light duty vehicle roof panel made of carbon fiber and sisal fiber composite material by varying fiber orientation which helps to reduce weight and fuel consumption of a vehicle.

1.3.2. Specific Objectives

The specific objectives are:

- ❖ To prepare composite materials using carbon and sisal fiber with varying fiber orientations.
- ❖ To test composite material for its mechanical properties.
- ❖ To model and analyze the roof panel using CAD and ANSYS software.
- ❖ To compare the composite material with conventional material.

1.4. Significance of the thesis

Natural fibers like Sisal fibers are abundantly available in our country Ethiopia. Due to its higher availability and simple to use, we can extract this fiber and make a composite material whether with a synthetic fibers or with other types of natural fibers. Because of sisal fiber is light weight, non-abrasive and non-corrosive material, it has great advantage in automobile industries to make different vehicles body parts alone or by mixing some other synthetic fibers like carbon fiber. The significance of this work is listed as follows:

- It helps in reduction of vehicle weight.
- It reduces the cost of vehicle body panels.
- Usage of composites in vehicle panels helps in reduction of fuel consumption.

1.5. Beneficiaries

Automotive industries, vehicle owners, researchers, society and country as a whole get benefitted with this work.

1.6. Scope of the study

This thesis work includes the preparation of composite material, testing for its mechanical properties, design and analysis of Toyota vitz roof panel made of composite material. Modelling of the roof panel with SOLIDWORK and analysis with ANSYS software also included.

1.7. Limitations

There is a shortage of literature related to carbon fiber and sisal fiber composite and also not much literature available about the usage of composite in the construction of light vehicle roof panel. Preparation of composite materials using hand layup process is very time consuming. Searching for mechanical testing machines like tensile, bending and compression test machines was another time consuming process. Due to an open molding system, getting an exact dimension for a molded specimen was somewhat challenging. And also, there is a shortage in well-organized work shop for sample preparation those used for the test.

1.8. Organization of the study

Chapter 1 deals on the introductory topics of background of the study, statement of the problem, general and specific objectives, significance of the study, scope of the study and limitations.

Chapter 2 discusses about the literature reviewed on structural analysis, Finite element analysis and Analysis of different vehicle components using ANSYS software. This chapter deals with reviewing of design and structural analysis of different Vehicle components for their bending, torsional and modal analysis. And also, this chapter includes the application and use/roles of composite materials for light duty vehicles.

Chapter 3 discusses about materials and methodologies of the thesis. Overall specification of vehicles such as weight specifications, engine specifications, roof panel and the material properties of steel and composite materials (Carbon fiber and Sisal fiber) are clearly described. The conceptual design parameters, discusses about light duty vehicle roof panel, basic issues in roof panel, classifies types of vehicle roof panel, material selection technics are considered, the detail explanations for composite materials are given and finally, fabrication of the sample of composite materials are also discussed. And also this chapter deals with the static analysis of roof panel design and development of 3D CAD model of light duty Toyota vitz vehicle roof panel for simulation, meshing and analysis of roof panel.

Chapter 4 The detailed discussion on the results obtained from mechanical testing and ANSYS analysis of the roof panel is included in this chapter. The results for simulation of static analysis of equivalent stress and deformation of roof panel for conventional steel and the hybrid of carbon fiber with sisal fiber are compared.

Chapter 5 deals with conclusion and recommendation depending on the result obtained from mechanical testing and analysis.

2. LITERATURE REVIEW

This chapter outlines some recent work and report published in literature on analysis of different vehicle components and analysis of carbon fiber composite material with varying fiber orientation. The mechanical behavior of a natural fiber reinforced composite depends on many parameters, such as fiber strength, fiber length, orientation, fiber-matrix interfacial bond strength etc. For better mechanical properties of composites a strong fiber matrix interface bond is important. Some surface modification to the fiber also improves the resistance to moisture induced degradation of the interface and the composite properties. In addition, factors like processing conditions or techniques have very significant influence on the mechanical properties of fiber reinforced composites.

2.1. Finite Element Analysis

Sivaraj *et al*. (2016) did the work on the structural Analysis of Ladder Chassis Frame for car Using ANSYS. In this paper, chassis frame maximum shear stress and deflections under maximum load are important criteria for design and analysis. In these projects, the analyzer calculated the von-mises stress and shear stress for the chassis frame and the finite element analysis has been done for the validation on the chassis frame model. The researcher takes certain material as Mild sheet steel, aluminum alloy and titanium alloy for the rectangular hollow box type to design chassis frame. Software used in this project, CATIA V5 for design purpose, HYPERMESH is used for meshing and ANSYS 16 is used for analysis.

Abhishek *et al.* (2014) have done the structural Analysis of Ladder Chassis for Higher Strength. As the investigator mentioned, important consideration in chassis design is to have adequate bending stiffness along with strength for better handling characteristics. Therefore, maximum shear stress and deflection are important criteria for the chassis design. This paper describes Structural analysis & optimization of vehicle chassis with constraints of maximum shear stress and deflection of chassis under maximum load. In the present work, this paper takes higher strength as the main issue, so the dimensions of an existing vehicle chassis of a TATA LP 912 Diesel BS4 bus is taken for analysis with materials namely Steel alloy (Austenitic) subjected to the same load. The four different vehicle chassis have been modeled by considering four different cross-sections. Namely C, I, Rectangular Box (Hollow) and Rectangular Box (Intermediate) type cross sections. For validation the design is done by applying the vertical loads acting on the horizontal different cross sections. Software used in this work Pro e 4.0 & Altair Hyper works 11.0.0.39 (Hyper mesh).

Indu *et al.* (2015) did the work with the Structural Analysis of Heavy Vehicle Chassis Using Honey Comb Structure. Automotive chassis can be considered as the backbone of any vehicle its principle function is to safely carry the maximum load for all designed operating conditions. This paper describes design and analysis of heavy vehicle chassis. Weight reduction is now the main issue in automobile industries. Traditionally most common material for manufacturing vehicle chassis has been mild steel, in various forms. Over time, other materials have come into use, the majority of which have been is steel and Aluminium. In this paper traditional materials are replaced with composite materials [S-glass epoxy and E-glass epoxy] using reverse engineering method. (Existing model, modified model, honey comb model). For validation the design is done by applying a single vertical loads acting on the chassis. And then Structural and, fatigue analysis will be carried out on three models to all materials and select the best material Impact analysis can also be done for the selection material in all models Software's used in this work solid works for modeling ANSYS 14.5 for analysis.

Chintada *et al.* (2015) did the analysis with ANSYS software on Structural Analysis of Eicher 11.10 Chassis Frame. According to the researcher, the strength is an important consideration in chassis design to have adequate bending stiffness for better handling characteristics. This paper is related with work performed towards the static structural analysis of the truck chassis in which study of the stresses developed and deformation of chassis frame of EICHER 11.10 has been done by considering three different materials like St52, Ni-Cr Steel and CFRP in each case. From the analysis the researcher conclude that, "CFRP is useful than St52 and Ni-Cr with its lesser deflection and stress when compared with the pre-existed one."

Shaik *et al*. (2016) did the work with "Modelling and Structural Analysis of Vehicle Chassis Frame Made of Polymeric Composite Material." In the present work of the researcher, the dimensions of an existing vehicle chassis frame of a MAHINDRA BOLERO vehicle is taken for modeling and analysis of a vehicle chassis frame with three different composite materials namely, Carbon/Epoxy, E-glass/Epoxy and S-glass/Epoxy subjected to the same pressure as that of a steel chassis frame. The design constraints were stresses and deflections. The researcher takes three different composite vehicle chassis frames and modeled by considering three different cross-sections. Namely C, I and Box type cross sections. For validation the design is done by applying the vertical loads acting on the horizontal different cross sections. The researcher carried out and used the software's in this work like PRO–E for modeling and ANSYS for analysis. From the results, it is concluded that the polymeric composite vehicle chassis is lighter and more economical than the conventional steel chassis with similar design specifications.

Archit and Dheer (2016) did the work with "Modelling and Analysis of a Chassis Frame by Using Carbon Fiber and E-Glass Epoxy as Composite Material: A Comparative Study." In this research firstly the researcher modeled the chassis frame of Eicher truck 11.0 in CAD software and has done the further analysis in ANSYS by using the composite material like carbon fiber and E-Glass Epoxy. Modal analysis is done to study the vibration characteristics of the chassis frame also to know the natural frequency of the chassis frame and further Harmonic analysis is done to know the von misses stress in the chassis frame at that natural frequency which incurs maximum deformation in chassis frame after that the results of all the three materials compare to know which is suitable material for the chassis frame. Finally the researcher conclude that, "The results of the harmonic analysis give a clear indication that the maximum stress induced is in steel and minimum stress induced is in composite material."

Azhar *et al*. (2017) the work is done on "Modeling and Analysis of Automobile Chassis Using Composite Materials." In this analysis describes design and analysis of automobile chassis. In this paper, model of chassis is done in Pro-E software and is imported to ANSYS. The model is meshed. The material properties are defined in pre-processing. Initially static analysis has done on the chassis using different materials, and then the modal analysis was done to obtain the mode shapes of the chassis. According to the researcher, its principle function is to undamaged carry the maximum load for all designed operating conditions. In this research work the researcher conclude that, "By using the layers for maintain same thickness of the chassis, and the displacement as well as stress values are reduced than using as single layer. So it will be better to take layers as single layer."

Vamsi *et al*. (2014) this paper is done on the title of "Modeling and Structural Analysis of Ladder Type Heavy Vehicle Frame." This paper describes modeling and structural analysis of conventional type heavy vehicle frame. Weight reduction is now the main issue for the analyzer.

In this work, the investigator takes the dimensions of an existing heavy vehicle frame of a TATA 1109 EX2 for modeling and analysis. In this work, the vehicle frame is initially modeled by considering ‘C’ cross section in SOLID WORKS 2011 and then it is imported to ANSYS 13.0. The analysis is done with three different composite materials namely Carbon/Epoxy, E-glass/Epoxy and S-glass/Epoxy subjected to the same pressure as that of a steel frame. The design constraints are stresses and deformations. So, after all based on the results it was inferred that Carbon/Epoxy polymeric composite heavy vehicle chassis has superior strength, less deformation, less normal stress and less weight compared to steel, E-glass/Epoxy and S- glass /Epoxy. So, the researchers conclude that it is better to use Carbon/ Epoxy as a material for frames of heavy vehicle chassis; so that the fuel consumption decreases for the vehicles.

Anurag *et al.* (2016) did the work on, “Design and Analysis of Chassis Frame.” This paper presents the study of the stress developed in chassis as well as deformation of chassis frame. The stress and deformation has been calculated for the chassis frame and the analysis has been done for the validation on the chassis frame. The model of the chassis has been developed in Creo (Pro-E) 2.0 and static structural analysis has been done in ANSYS WORKBENCH 15.0.

Ravi *et al*. (2012) this paper deals about “Modeling and Structural analysis of heavy vehicle chassis made of polymeric composite material by three different cross sections.” This paper describes design and analysis of heavy vehicle chassis. The analyzer main issue is weight reduction of a vehicle. In the present work, the dimensions of an existing heavy vehicle chassis of a TATA 2515EX vehicle is taken for modeling and analysis of a heavy vehicle chassis with three different composite materials namely, Carbon/Epoxy, E-glass/Epoxy and S-glass/Epoxy subjected to the same pressure as that of a steel chassis. The design constraints were stresses and deflections. The researcher mentioned three different composite heavy vehicle chassis have been modeled by considering three different cross-sections. Namely C, I and Box type cross sections by 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%. For validation the design is done by applying the vertical loads acting on the horizontal different cross sections. Software is used in this work PRO–E 5.0 for modeling, ANSYS 12.0 for analysis.

Vishal *et al.* (2014) this research is done on the title of "Structural analysis of ladder chassis frame for jeep using ANSYS." In this paper, the von-mises stress and shear stress calculation for the chassis frame and the finite element analysis has done for the validation on the chassis frame model of jeep. The researcher also takes certain material as mild sheet steel, aluminium alloy and titanium alloy for the rectangular hollow box type to design chassis frame of jeep by finding their mass density, yield strength, ultimate tensile strength, young's modulus, poison's ratio and share modulus. The software used in this paper for analysis is like finite element analysis to do the pre-processing, solution and post processing steps and ANSYS 14; and also CATIA V5 (product 1) for design purpose. At the end, the researcher concludes:-

i. The generated shear stresses are less than the permissible value so the design is safe for all three materials.
ii. Shear stress is found in minimum in aluminium alloy and maximum in mild sheet steel under given boundary condition.
iii. Von mises stress was found minimum in aluminium alloy and maximum in titanium alloy under given boundary condition.

Vishwanatha *et al.* (2018) has done the work on "Design and strength validation of front car bumper using composite material." The materials used for this analysis are carbon fiber reinforced plastic and epoxy resin having the composition of 60% of CFRP and 40% of epoxy resin. The binding polymer is a thermoset resin such as epoxy. In this work, a front car bumper is designed by using the software CATIA V5 R20 then imported into FEM package of NASTRAN in HYPERMESH. The researcher done various analysis such as modal (vibration) analysis, static analysis i.e. impact force analysis, stress analysis and strength analysis. The results are then compared with the conventional material such as steel. From all these analysis and comparison, the investigator concludes that, "the composite materials CFRP (Carbon Fiber Reinforced Plastic) and epoxy resin are suitable for use in the cars."

Vijayan *et al.* (2015) this research is done on the title of "Design and analysis of automotive chassis considering cross-section and material." This paper describes design and analysis of heavy vehicle chassis as the prime objective of any automobile industries. The relative information of an existing heavy vehicle chassis of EICHER is taken for modeling and analysis by considering polymer composite materials namely, S-Glass Epoxy, and cross-section like C, I and Box type 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. The specification like the capacity of truck, total load acting on the chassis including truck capacity, weight of the body and engine of EICHER 10.9 is taken. The researcher takes into consideration of specification of heavy vehicle chassis and used the software called ANSYS for analysis. After the comparison between the existing conventional steel chassis and S-Glass Epoxy the researcher conclude that, "by employing S-Glass Epoxy composite heavy vehicle chassis for same load carrying capacity there is a reduction in weight when compared to steel but main downside is S-Glass Epoxy induces high deformation and stress distribution when compared to steel except in 'I' section. Based on the results it was inferred that steel with 'I' section has superior strength to withstand high load and induced low deformation and stress distribution when compared to S-Glass Epoxy composites material."

Tharun *et al.* (2017) the research is done on "Model and Analysis of car chassis using ANSYS." In this present work static load characteristics are analyzed using FE models. It is found that identifying location of high stress area, displacement and strain. Modal updating of car chassis model will be done by adjusting the selective properties such as different materials. Thus modeling of a car chassis is done in solid works 2016 software and analysis is carried out in ANSYS 14.5 work bench. Three different materials such as alloy aluminum alloy 6063-T6, ASTM A710 Steel and E-Glass are applied for the chassis. Stress, strain, displacement and maximum shear stress of each individual material is studied. From the results aluminum alloy 6063-T6 is showing less stress and displacement when compared to remaining materials.

Prashanth *et al.* (2017) this research deals about "Design and Analysis of Automobile Chassis by using Composite Material E-Glass Epoxy." In the present work an attempt is made to replace the chassis frame made up of steel with a composite material like E-Glass Epoxy. At first the chassis frame is modelled by considering c-cross section in CATIA V5 software and then it is imported to ANSYS13.0. The analysis is done on E-Glass Epoxy subjected to similar conditions as that of chassis made up of steel. The results are then estimated to finalize the best among two materials. The researcher set out the composition and mechanical properties of E-Glass epoxy. The stress pattern and displacement pattern has done using software ANSYS for both steel chassis and E-Glass epoxy chassis. After all analysis the researcher compares the stresses and deformation for steel and E-Glass epoxy and then concludes, “The weight reduction is 75% to 85%. On the basis of results it was observed that E-Glass Chassis has superior strength, decrease in deformation, normal stress, weight & fuel consumption compared to structural steel. Therefore, E-Glass Epoxy is most preferable for making chassis.”

Benjamin and Stalin (2016) did the work on the title of **“**Structural Analysis of Front-End Cross Bar of a TATA407 Chassis Frame.” This paper deals with the structural analysis of a front end cross bar which is replaced with Carbon Fiber Reinforced Polymer composite material. The front-end cross bar of a TATA407 vehicle frame is modelled using the CREO 2.0 modelling software and analyzed through ANSYS Workbench 14.5. The stress distribution and deflection results of the conventional steel and CFRP cross bars were compared. The strength-to-weight ratio has improved when CFRP is used. At the end, the researcher concludes that, “The carbon fibers are more suitable for most of the automotive applications. The replacement of the front-end cross bar only with CFRP has given better results than steel. Thus when we replace the conventional steel with CFRP, the deflection of the cross bar is reduced by 64.38% and the stress developed in the bar is reduced by 4.34%.”

Patel.V and Patel. R (2012) did **“**Structural Analysis of Automotive Chassis Frame and Design Modification for Weight Reduction.” They showed that the location of maximum Von Misses stress and maximum shear stress are at corner of side bar. They have done finite element analysis of existed chassis frame, design modification for weight reduction and finite element analysis of modified cross section and finally conclude that, “the weight is reduced by 6.68 % of the chassis frame. The maximum shear stress, maximum equivalent stress and displacement are also reduced respectively 12.14 %, 8.55 % and 11.20 %. It is clear that design is safe. And also, by using FEM software we can optimize the weight of the chassis frame and it is possible to analyze modified chassis frame before manufacturing.” The result shows the Von-Mises stress magnitude of critical point is 190.38 Mpa and the maximum shear stress magnitude is 106.08 MPa. The magnitude of maximum displacement is 3.0294 mm.

Kiran *et al.* (2014) works on **“**Structural Stress Analysis of an Automotive Vehicle Chassis.” In this dissertation work the researchers analyzed the monologue and ladder frame for static load condition with the stress, deflection and bending moment. In this paper the researchers deals with the static analysis of two different frame automotive chassis, the Chevy truck chassis shows the critical stress at the joints and it is being reduce by increasing the side member thickness, connection plate thickness and connection plate length were varied. Numerical results showed that stresses on the side member can be reduced by increasing the side member thickness locally. In this paper we have chosen one automotive chassis for the analysis which is to be done by using Finite Element Analysis (FEA) of the chassis design. In this paper the researcher used ANSYS for analysis and CATIA V5 R16 for modeling chassis. At the end, the researcher found that, for car and truck chassis the stress is higher at the joints.

Narayana *et al.* (2017) studies on the title of "Modeling and Analysis of Light Vehicle Chassis Made of Composite Material." In this paper the researchers attempt to replace the steel chassis with a composite material, and they have considered for the analysis work E-glass epoxy and S-glass epoxy subjected to the similar conditions as that of steel chassis. The modelling of chassis has been carried out by Pro-E Software V5.0 Package and static analysis has been carried out by ANSYS V 11.0 Software. The polymeric composite materials used in this work are: - E-Glass/Epoxy, S-Glass/Epoxy and Steel and also the researchers show the properties of these materials. In this paper the structural analysis is done with ANSYS 12.0 software. The stress and displacement patterns for S-Glass chassis, E-Glass chassis and steel chassis are done using ANSYS software. As the result obtained from ANSYS, the maximum stress was induced on steel chassis as compared with S-glass, E-glass epoxy and carbon epoxy chassis. Minimum stress was noted in carbon epoxy chassis. Maximum weight reduction of 38.8% can be achieved. The researchers concludes that, "By employing a polymeric composite light vehicle chassis for the same load carrying capacity, there is a reduction in weight of 30%~35.8%, natural frequency of polymeric composite light vehicle chassis are 35.82%~38.8% higher than steel chassis and 30~33.8% stiffer than the steel chassis and also, from the results it is observed that the polymeric composite heavy vehicle chassis is lighter and more economical than the conventional steel chassis with similar design specifications."

Ravindra and Belkar (2014) did the work on the title of "Performance Analysis of Carbon Fiber with Epoxy Resin Based Composite Leaf Spring." This paper describes design and analysis of composite mono leaf spring. In the present work, existing mono steel leaf spring of a light vehicle is taken for modeling and analysis. A composite mono leaf spring with Carbon/Epoxy composite materials is modeled and subjected to the same load as that of a steel spring. The design constraints were stresses and deflections. The composite mono leaf springs have been modeled by considering Varying cross-section, with unidirectional fiber orientation angle for each lamina of a laminate. Static analysis of a 3-D model has been performed using ANSYS 12.0. In this paper, the comparative analysis of Carbon/epoxy composite leaf spring and steel leaf spring is done by analytical, FEA using ANSYS 12. The result of FEA is also experimentally verified. Compared to mono steel leaf spring the laminated composite mono leaf spring is found 42% lesser stresses and weight reduction of 22.15% is achieved.

Mohd *et al*. (2012) performed the stress analysis of an actual low loader structure consisting of I-beams design application of 35 ton trailer. He used modeling software CATIA V5R18. The results of analysis revealed that the location of maximum deflection and maximum stress agrees well with theoretical maximum location of simple beam under uniform loading distribution. This study found out that there is discrepancy between the theoretical (2-D) and numerical (3-D FEA) results. It is observed that the maximum deflection pointed is situated in between BCl and BC2 with magnitude of 7.79 mm. The results of the numerical analysis revealed that the location of maximum deflection and maximum stress agrees well with theoretical maximum location of simple beam loaded by uniform force.

Monika and Razik (2013) carried out finite element analysis of truck chassis using ANSYS. In this project the work is performed towards the optimization of the automotive chassis with constraints of maximum shear stress, equivalent stress and deflection of chassis under maximum load. A sensitivity analysis is carried out for weight reduction. So a proper finite element model of the TATA 1612 chassis is to be developed by using actual parameter, the chassis is modeled in CATLA v5. FEA is done on the modeled chassis using the ANSYS Work bench12, the FEA is carried out for static, dynamic and shape optimization. Results obtained after the analytical approach for the chassis beam in terms of stress development is approximately closer to the FEA values. By reducing the height of the cross-member of chassis is found to be reduced by 8.72%.

Hemant *et al*. (2013) did stress analysis of automotive chassis with various thicknesses. They presented stress analysis of a ladder type low loader truck chassis structure consisting of C-beams design for application of 7.5 tons using FEM. The commercial finite element package CATIA version 5 was used for the solution of the problem. To reduce the expenses of the chassis of the trucks, the chassis structure design should be changed or the thickness should be decreased. Also determination of the stresses of a truck chassis before manufacturing is important due to the design improvement. In order to achieve a reduction in the magnitude of stress at critical point of the chassis frame, side member thickness, cross member thickness and position of cross member from rear end were varied. Numerical results showed that if the thickness change is not possible, changing the position of cross member may be a good alternative. Computed results are then compared to analytical calculation, where it is found that the maximum deflection agrees well with theoretical approximation but varies on the magnitude aspect. Finally they conclude that, "it is better to change the thickness of cross member at critical stress point than changing the thickness of side member and position of chassis for reduction in stress values and deflection of chassis."

Kurdi et al. (2016) this paper performed stress reduction of the chassis of single cab pickup truck using finite element methods (FEM). The first step was to evaluate and identify the critical area or maximum values of the static stress and its location. The second stage of this project was dealing with designing a new chassis based on the TATA model, and then the final stage was a validation of numerical results with both experiments and analytical calculation to get the desired chassis that have a strong and high quality design.

2.2. Experimental analysis

Anaidhuno *et al.* (2017) has done the work on "Evaluation of the mechanical properties and simulation of Sisal/Jute hybrid polymer composite failure in Automobile chassis panel." This project deals about evaluation of the mechanical properties and the simulation of Sisal/Jute hybrid polymer composite properties in comparison to a model metal steel automobile chassis panel. The structural simulation of the hybrid composite, stress/strain and displacement analysis are carried out by solid work explorer software. In this project the researcher compares the mechanical properties of Jute and Sisal fiber with mild steel. The investigator used Sisal/Jute Hybrid Polymer composite at 1:1, 1:2, 2:1 mixture ratio, 0.25, 0.35 and 0.45 volume fraction mixture using unsaturated polyester resin, Methylethylketone (Catalyst), Cobalt (accelerator), Vaseline (releasing agent). The fiber strands were reinforced with unsaturated polyester resin.

Different composite were fabricate for tensile, flexural, compression and hardness test. A researcher prepares samples with unsaturated polyester resin and test using universal testing machine and Tensometer (type W).

The researcher gives some of the assumption used for the analysis work are:-

(1) Fibers are not porous.

(2) The material property for all the constituents are attributed as isotropic material for both volumes.

(3) Fibers are uniform in properties with diameter.

(4) Inter-phase bonding is maintained between fibers and matrix.

(5) Perfect bond between fiber and matrix and no slippage.

(6) Fibers are perfectly aligned and arranged.

(7) Composite material is free of voids.

(8) Poisson's ratio of sisal/jute polymer composite = 0.1

(8) Poisson's ratio of mild steel = 0.29

Finally, the conclusion is given as "The sisal jute composite has a mass density of 1400 kg/m^3 compared to 7858 kg/m^3 of mild steel which a major advantage of light weight that aid their application in automobile body."

Suhas *et al*. (2014) Investigated on different Compositions of E-Glass/Epoxy Composite and its application in Leaf Spring. In this paper there was an attempt to study the mechanical properties of glass fiber reinforced plastic (GFRP) by varying volume percentage. The mechanical properties involved in the study are tensile strength, bending strength and impact strength. The results are compared for different loading conditions and a suitable composition is selected for the fabrication of mono composite leaf spring. The investigators prepare Glass fibers by varying their volume in different percentage. After the fabrication has done, the researcher conducts different tests like tensile test, Flexural test, Impact test, Static load test and the comparison results of load and weight of steel and composite material has done. The study concluded that the composite leaf spring had induced stresses much lower than that of steel leaf spring and the spring weight was nearly 44% lower when compared to steel leaf spring and also, comparative study made between composite and steel leaf springs with respect to weight and strength showed that composite leaf spring has more load carrying capacity and is lighter compared to Steel leaf spring.

Prashanth *et al*. (2012) did the work on influence of fiber orientation and thickness on tensile properties of laminated polymer composites. The objective of his research was to gain a better understanding of tensile properties of epoxy resin composites reinforced with glass fiber. The effect of fiber orientation & thickness of laminates has been investigated & experimentation was performed to determine property data for material specifications, the laminates were obtained by hand layup process. The laminates were cut to obtain ASTM standards. The test ready specimens were subjected to tensile loads on UTM machine. His research indicates that tensile strength is mainly dependent on the fiber orientation & thickness of laminated polymer composites.

He concluded that:

1. The laminated specimens with lesser thickness lead to more ultimate tensile strength irrespective fiber orientations.
2. Specimen sustain greater load in 90^0 orientation specimens than in other orientations.
3. Young's modulus of specimens increases with decrease in thickness.
4. Extension is minimum in case of 90° orientations and maximum in case 30° orientations.

Vinod and Sudev (2013) studied the effect of fiber orientation on the flexural properties of Pineapple leaf fiber reinforced bisphenol composites. The results revealed that, fiber orientation have great effect on the flexural properties of fiber reinforced polymer matrix composites. It can be seen that inclined oriented composites show better flexural strength (105.57 MPa) than Uni-directional and bi-directional oriented composites. Hence fiber orientation greatly influences the flexural strength of the Pineapple leaf fiber reinforced Bisphenol composite.

Channabasavaraju *et al*. (2013) evaluated tensile and flexural properties of glass, graphite and kevlar fiber reinforced polymer matrix composites. The results have showed the variation in the fiber types has significant effect on the tensile and flexural properties of composite materials.

Sandeep *et al.* (2014) found out the effect of fiber orientation on the flexural strength for pure glass/epoxy composite material is presented. The experimental results showed the difference in flexural strength in bidirectional glass fibers at $0\text{-}90^0$ and $-45\ +45^0$ orientation. From the experimental results the percentage difference in flexural strength for $0\text{-}90^0$ and $-45\ +45^0$

orientation fiber for 4 mm thick sample is 16.36 and for 6 mm thick sample is 32. Hence, the researcher concludes that, there is an effect of fiber orientation on the flexural strength of glass/epoxy composite material.

Kai Wei *et al.* (2018) did the work on “Preforming behaviors of carbon fiber fabrics with different contents of binder and under various process parameters.” In this work, preforming experiments and analysis were systematically conducted for typical carbon fiber fabrics to explore the influences of binder contents and process parameters on the preforming behaviors. The researchers clearly reveal that the binder content has remarkable influence on the preforming behaviors. Specifically, the increasing binder content will significantly enlarge the initial thickness and the compression distance and time. Besides, it is demonstrated that the relaxation ability is also enhanced with the adding binder. The binder can also lower the elastic recovery, and oppositely increase the viscoelastic recovery, leading remarkable increment of permanent deformation. It is found that the binder should not be unlimitedly added, since over adding binder can’t pronouncedly enhance the relaxation rate, and the content of 4 wt % is a relative optimal value for preforming process. We further reveal that the compression thickness can be reduced by lowering the compression speed.

Behrens *et al*. (2017) has done the work on “Forming and Joining of Carbon-Fiber-Reinforced Thermoplastics and Sheet Metal in One Step.” The scope of this research was to enable the combined forming, joining and impregnation of pre-impregnated FRP-sheets and sheet metal to steel-CFRP-steel-sandwich-parts in one process step. The researcher reveals that as forming and joining must be executed at temperatures above the melting point of the thermoplastic while the part removal must take place beneath this temperature, a heating concept for drawing tools was developed to enable short production cycles. Based on this research, a forming tool was constructed and hat profiles of steel-FRP-steel sandwiches were drawn successfully. Subsequently, the impregnation quality was investigated based on the process parameter tool temperature. Furthermore, the geometrical deviation of formed hat profiles was investigated.

Qiang *et al.* (2012) this paper aims to develop a multiscale approach for predicting three-dimensional elastic model of carbon twill weave fabric composite which will be applied to crashworthiness analysis of body structure of electric vehicle. The geometric parameters were obtained by measuring the microstructure of T300 carbon twill weave fabric composite through optical microscopy. The finite element model of representative volume element (RVE) in laminate composite was established to characterize the elastic properties of the materials using the homogenization technique. The numerical results of property were compared with those from uniaxial tensile and three point bending tests. Finally, the constitutive model of such composite was employed to crashworthiness analysis for electric vehicle body structure under the roof crash and side pole impact. The study indicates that the deformation behaviors of laminate calculated by using the elastic properties are in good agreement with tensile and bending experimental results with maximum relative errors of 4.04% and 7.79%, respectively. Meanwhile, a 28% savings of body weight is achieved using the carbon twill weave fabric composite compared to its predecessor made of glass fiber reinforced plastics (GFRP).

Badrinath and Senthilvelan (2014) investigates the comparatives on mechanical properties of Banana and sisal reinforced polymer based composites. In this work, sisal fiber and banana fiber have been used as the main reinforcing materials with epoxy resin as the matrix in order to increase the effectiveness of natural fibers. The investigator used sisal fiber and banana fiber as a reinforced material in polymer matrix composites. According to this paper the natural fiber composites were fabricated by hand layup method. The mechanical and physical properties have been studied for both the fibers by changing the orientation as uni-directional and bi-directional pattern with epoxy resin as a matrix material. Initially optimum fiber length and weight percentage were determined. The tensile, impact, flexural and water absorption test have been performed on these fabricated composites. Morphological analysis was carried out in tensile sample composites using SEM to analyze the fracture mechanism of both fibers. As the investigator conclusion, the comparison of tensile strength reveals that sisal 90^0 orientation fiber/epoxy composite has 56.5 Mpa exhibits higher tensile strength than sisal bi-directional fiber 16 Mpa.

John and Venkatanaidu (2004) in this paper, the variations of impact strength and compressive strength of unsaturated polyester based sisal/glass hybrid composites with fiber loading have been studied. The impact strength of these hybrid composites has been found to be higher than that of the matrix, whereas a marginal decrease was observed in the compressive strength of the hybrid composites over that of the matrix. The effects of NaOH treatment and trimethoxy silane (coupling agent) treatment on the impact and compressive properties of these sisal/glass hybrid composites have also been studied. No significant improvement in impact strength of the sisal/glass hybrid composites has been observed by these treatments, whereas a marginal increase in compressive strength of these hybrid composites has been observed. The researchers find out the compression strength of Sisal/Glass Hybrid Composites which is linearly increasing from 5.2 Mpa to 5.46 Mpa.

Bambach (2013) has done the work on "Fiber composite strengthening of thin steel passenger vehicle roof structures." This paper presents the novel approach of strengthening vehicle roof structure components by bonding carbon fibers to the steel surface. As the point of view of the researcher, such fiber strengthening systems have been shown to provide substantial increases in force and energy resistance for steel tubes under both axial crushing and pure bending. In this paper, the strengthening potential is assessed with a numerical study of two different passenger vehicles subjected to various roof crush test protocols. Numerical models of fiber composite strengthening systems are validated against experiments, and then applied to numerical models of the vehicles. Substantial improvements in the roof strength, and correspondingly the vehicles' roof strength to weight ratio, are demonstrated with the fiber strengthening technique. Comparisons are made with models of strengthening the roof structure components by adding steel rather than fiber composite, and the implications with regards to vehicle light-weighting are discussed. It is shown that fiber composite strengthening of vehicle roof structures has the potential to contribute to higher roof strengths and/or light-weighting in future vehicle fleets. And also the researcher conclude that, the potential of fiber-epoxy strengthening systems for vehicle light weighting has also been highlighted in the present study, where a 37–68% mass saving resulted with using fiber composite in place of added steel for equivalent roof strengthening.

Soroosh and Giovanni (2017) This paper presents a new design of the roof strengthening configuration in which sandwich material has been used. This type of configuration improves the energy-absorption capacity of the vehicle roof system and dissipated impact energy in a controlled manner. In reality, carrying out roof crush test is not cost effective, thus numerical analysis of vehicle roof crush test has been performed according to standard FMVSS 216 test. Sandwich structures with unidirectional carbon /epoxy composite face-sheets and Expanded Polypropylene (EPP) foam core have been used to model different configurations for vehicle roof structure. The effects of increasing the foam core density and face-sheets thickness on the energy absorption and strength-to-weight ratio (SWR) of vehicle roof structure have been investigated. Results revealed that, the optimized sandwich solution type 6 with the face-sheets of 0.8mm and foam core of 70 Kg/m3 density reduces the vehicle roof panel by 68% while it has almost the same structural performance with the steel solution having equal value of SWR. The researcher also investigates as the roof panel by itself absorbs about 12% of the total vehicle roof structure energy, in case of rollover accident.

Bhaskar *et al.* (2017) this paper deals about "Numerical and Experimental Modal Analysis of Car Roof Incorporating Viscoelastic Damper." The researcher extracts frequencies of car roof with viscoelastic damping conventional car roof by modelling using CATIA V5, meshed with meshing software Altair Hypermesh and analyzed using ABACUS software. The experimental modal analysis, FEA analysis of the conventional viscoelastic car roof was carried out for free – free conditional to evaluate the natural frequencies. On this paper the results from EMA and FEA were agreeing with each other. The investigator concludes that "the viscoelastic car roof revealed better NVH characteristics."

2.3. Summary of literatures

The summary of finding and conclusion of different literatures those related to this study are addressed as following to clearly indicate applicability of natural fibers, synthetic fibers and the work done on finite element analysis.

According to literatures, weight reduction and replacement of conventional vehicle body panel with composite materials are very common issues aim to increases the fuel efficiency and reduce the harmful exhaust emission. The composite materials also provide high riding quality. The reduction of weight, the reduction of developed stress and improvement of working life can be achieved using different composite materials in place of steel. Most literature reported that automobile roof panel mainly depends on two factors. The first one is mechanical properties like tensile strength, compression strength and bending (flexural) strength. The second one is physical properties like density, the measure of the relative heaviness of natural fiber composite with constant volume. The ply arrangement has its own factor in composite materials. Among each arrangement $0^0/90^0$ ply arrangement has higher tensile and bending strength.

2.4. Properties and application of sisal Fiber

Sisal Fiber is one of the most widely used natural fiber and is very easily cultivated. It is obtain from sisal plant that is a very strong and important leaf fiber. It is extracted from the Leaves of the sisal plant and is very hard. The plant known formally as Agave sisalana. These plants produce rosettes of sword-shaped leaves which start out toothed, and gradually lose their teeth with maturity. Each leaf contains a number of long, straight fibers which can be removed in a process known as decortication. During decortication, the leaves are beaten to remove the pulp and plant material, leaving the tough fibers behind. The fibers can be spun into thread for twine and textile production, or pulped to make paper products (http://textilelearner.blogspot.com)

Figure 2.1: a. Sisal plant. b. Sisal fiber. (http://textilelearner.blogspot.com).

Sisal fiber is fully biodegradable, green composites were fabricated with soy protein resin modified with gelatin. Sisal fiber, modified soy protein resins, and composites were characterized for their mechanical and thermal properties. It is highly renewable resource of energy. Sisal fiber is exceptionally durable and a low maintenance with minimal wear and tear. Its fiber is too tough for textiles and fabrics. It is not suitable for a smooth wall finish and also not recommended for wet areas (http://textilelearner.blogspot.com).

The fine texture of Sisal takes dyes easily and offers the largest range of dyed colors of all natural fibers. Zero pesticides or chemical fertilizers used in sisal agriculture. It is a stiff fiber traditionally used in making twine, rope and also dartboards Sisal fiber is manufactured from the vascular tissue from the sisal plant (Agave sisalana). It is used in automotive friction parts (brakes, clutches), where it imparts green strength to performs, and for enhancing texture in coatings application (http://textilelearner.blogspot.com).

2.4.1. Properties of Sisal Fiber

1. Sisal Fiber is exceptionally durable with a low maintenance with minimal wear and tear.
2. It is Recyclable.
3. Sisal fibers are obtained from the outer leaf skin, removing the inner pulp.
4. It is available as plain, herringbone and twill.
5. A sisal fiber is Anti-static, does not attract or trap dust particles and does not absorb moisture or water easily.
6. The fine texture takes dyes easily and offers the largest range of dyed colors of all natural fibers.
7. It exhibits good sound and impact absorbing properties.
8. Its leaves can be treated with natural borax for fire resistance properties (http://textilelearner.blogspot.com).

2.4.2. Use/Application of sisal fiber

From ancient time's sisal has been the leading material for agricultural twine because of its strength, durability, ability to stretch and resistance to deterioration in saltwater.

1. Sisal is used commonly in the shipping industry for mooring small craft, lashing, and handling cargo.
2. It is also surprisingly used as the fiber core of the steel wire cables of elevators, being used for lubrication and flexibility purposes. Traditionally sisal was the leading material for agricultural twine or baler twine. Although this has now been overtaken by polypropylene.
3. It is used in automobile industry with fiberglass in composite materials.
4. Other products developed from sisal fiber include spa products, cat scratching posts, lumbar support belts, rugs, slippers, cloths and disc buffers. Sisal is used by itself in carpets or in blends with wool and acrylic for a softer hand (http://textilelearner.Blogspot .com).

2.5. Automobile roof

An automobile roof or car top is the portion of an automobile that sits above the passenger compartment, protecting the vehicle occupants from sun, wind, rain, and other external elements. Because the earliest automobiles were designed in an era of horse-drawn carriages, early automobile roofs used similar materials and designs.

2.5.1. Types of roof

a. A convertible or cabriolet: A convertible or cabriolet is a passenger car that can be driven with or without a roof in place. The methods of retracting and storing the roof vary between models. A convertible allows an open-air driving experience, with the ability to provide a roof when required. The majority of convertible roofs are a folding construction made from cloth. Other types of convertible roofs include retractable hardtops (often constructed from metal or plastic) and detachable hardtops (where a metal or plastic roof is manually removed and often stored in the trunk).

Figure 2.2: Convertible car.

b. Hard tops: A hardtop is a rigid form of automobile roof, which for modern cars is typically constructed from metal. A hardtop roof can be either fixed (i.e. not removable), detachable for separate storing or retractable within the vehicle itself.

i) A detachable hardtop is a rigid, removable roof panel that is often stored in a car's trunk/boot.

ii) A retractable hardtop (also known as coupé convertible or coupé cabriolet) is a type of convertible that forgoes a folding textile roof in favor of an automatically operated, multi-part, Self-storing roof where the rigid roof sections are opaque, translucent, or independently operable.

Figure 2.3: Detachable hard top.

iii) The pillar less hardtop is a hardtop with no B-pillar which is often styled to look like a convertible. If window frames are present, they are designed to retract with the glass when lowered. This creates an impression of uninterrupted glass along the side of the car.

A pillar less hardtop is inherently less rigid than a pillared body, requiring extra underbody strength to prevent shake. Production hardtops commonly shared the frame or reinforced body structure of the contemporary convertible model, which was already reinforced to compensate for the lack of a fixed roof.

Hardtops tend to be more expensive and collectible than sedan models of the same vehicle.

Some hardtop models took the convertible look even further, including such details as simulating a convertible-top framework in the interior headliner and shaping the roof to resemble a raised canvas top. Some models adopted modified roof styling, placing the B pillars behind tinted side window glass and painting or molding the outer side of each pillar in black to make them less visible, creating a hardtop look without actually omitting the pillar.

Figure 2.4: A pillar less hardtop.

c. Sun roof

An automotive sunroof is a movable (typically glass) panel that is operable to uncover a window in an automobile roof, which allows light and/or fresh air to enter the passenger compartment. Sunroofs are either manually operated or motor driven, and are available in many shapes, sizes and styles. While the term sunroof is now used generically to describe any glass panel in the roof, the term "moon roof" was historically used to describe stationary glass panes rigidly mounted in the roof panel over the passenger compartment. Previous terms include Sunshine Roof, Sliding Head and Sliding Roof.

Figure 2.5: Typically glass panel (sun roof).

d. T-top

A T-top is an automobile roof with a removable panel on each side of a rigid bar running from the center of one structural bar between pillars to the center of the next structural bar. The panels of a traditional T-top are usually made of auto grade safety glass.

Figure 2.6: T-top panel.

e. Targa top

Targa top is a semi-convertible car body style with a removable roof section and a full width roll bar behind the seats. The rear window is normally fixed, but on some targa models, it is removable or foldable, making it a convertible-type vehicle. Any piece of normally fixed metal or trim which rises up from one side, over the roof and down the other side is sometimes called a targa band, targa bar.

Targa tops are different from T-tops, which have a solid, non-removable bar running between the top of the windscreen and the rear roll-bar, and generally have two separate roof panels above the seats that fit between the window and central t-bar.

Figure 2.7: Targa top roof panel.

f. Vinyl roof

Vinyl roof refers to a vinyl covering for an automobile's top. This covering was originally designed to give the appearance of a convertible to models with a fixed roof, but eventually it evolved into a styling statement in its own right.

Figure 2.8: Vinyl roof.

3. MATERIALS AND METHODS

In this chapter, the details of the materials used for the preparation of composite material, equipment used for testing the specimens and software used for designing and analysis of roof panel are given. For preparation of composite material, the materials like carbon fiber, sisal fiber, gp resin, hardener, wax, etc. were used. For testing the specimens tensile test, bending test and compression test machines were used. For designing and analysis SOLIDWORK and ANSYS software were used. The roof panel of Toyota vitz 1.0f vehicle which is most widely used in Ethiopia was selected for the work. These vehicles are generally imported from Japan. The specifications of the vehicle are given in table 3.1.

Table 3.1: Specification of the Vehicle. (https://carfromjapan.com)

Drive system	FF	Steering	--
Doors	5	Weight (kg)	970
Riding capacity (Person)	5	Wheel Base (mm)	2510
Length (mm)	3885	Tires front tread (mm)	165/70R14
Width (mm)	1695	Tires rear tread (mm)	165/70R14
Height (mm)	1500	Minimum turning radius (m)	4.5 m
Engine vitz specification			
Engine model	1KR-FE	Puissance maxi tr/mn (kW[ps]/rpm)	69 ps (51 kW)/6000rpm
Cylinder configuration	-	Couple maxi (Nm[kg-m]/rpm)	9.4 kg . m(92N . m)/4300 rpm
Super charger			

3.1. Materials

Table 3.2: Materials used in the preparation of composite material.

S No.	Materials	Quantity
1	Twill carbon fiber	2 sq. meter
2	Sisal fiber	20 kg
3	Hardener (resin catalyst)	2 liter
4	Bonding resin for both carbon fiber and sisal fiber	13 liter
5	Mold release wax	1 kg
6	NaOH (Sodium hydroxide)	500 mg
7	Anti-oxides (M-600)	2 liter
8	Distilled water	10 liter
9	PVA	0.5 liter

3.1.1. Carbon fiber

Carbon fibers, more than all other fibrous reinforcements, have provided the basis for the development of PMCs as advanced structural engineering materials. Carbon fibers are commercially available with a variety of tensile moduli ranging from 207 GPa on the low side to 1035 GPa on the high side. In general, low modulus fibers have lower specific gravities, lower cost, higher tensile and compressive strengths and higher tensile strain to failure than high modulus fibers. Among the advantages of carbon fibers are their exceptionally high tensile strength to weight ratios and tensile modulus to weight ratios, very low CTEs (which provide dimensional stability in such applications as space antennas) and high fatigue strengths. The disadvantages are their low impact resistance and high electric conductivity, which may cause shorting in unprotected electrical machinery. Their high cost has so far excluded them from widespread commercial application. Carbon fibers are widely used in aerospace and some applications of sporting goods, taking advantages of the relatively high stiffness to weight and high strength to weight ratios of these fibers (Autar, 2006). Carbon fiber was selected for this work and it was purchased from China. The figure 3.1 below shows the Twill carbon fiber that was purchased for specimen preparation by combining with natural fiber called sisal fiber.

Figure 3.1: Twill carbon fiber.

3.1.2. Sisal fiber

Sisal fiber is one of natural fibers that are abundantly available in our country Ethiopia. Most of the people use this fiber for different purposes like for tightening different materials, for home partition construction purpose by mixing with gypsum, tightening water pipe for preventing water from leakage, etc. For this project the extracted (Sisal fiber) SF is purchased from Bako town which is located 251 km towards western direction from Addis Ababa.

Figure 3.2: Sisal fiber.

3.1.3. General polyester resin

Gp resins are the most commonly used resins. They are low molecular weight organic liquids containing epoxide groups. Epoxide has three members in its ring: one oxygen and two carbon atoms. The reaction of epichlorohydrin with phenols or aromatic amines makes most epoxies. Hardeners, plasticizers, and fillers are also added to produce gp with a wide range of properties of viscosity, impact, degradation, etc. Properties of gp at room temperature are given in Table 3.3 below (Autar, 2006).

Table 3.3: Properties of gp at room temperature (Autar, 2006).

S No.	Properties	Gp resin	units
1	Specific gravity	1.28	-
2	Young’s modulus	3.792	GPa
3	Ultimate tensile strength	82.74	MPa

General polyester resin is the most common type of matrix material. Although gp is costlier than other polymer matrices, it is the most popular PMC matrix. More than two-thirds of the polymer matrices used in aerospace applications is gp based. The main reasons why gp is the most used polymer matrix material are:

- High strength
- Low viscosity and low flow rates, which allow good wetting of fibers and prevent misalignment of fibers during processing
- Low volatility during cure
- Low shrink rates, which reduce the tendency of gaining large shear stresses of the bond between gp and its reinforcement
- Available in more than 20 grades to meet specific property and processing requirements

Polymers are classified as thermosets and thermoplastics. Thermoset polymers are insoluble and infusible after cure because the chains are rigidly joined with strong covalent bonds; thermoplastics are formable at high temperatures and pressure because the bonds are weak and of the van der Waals type. Typical examples of thermoset include epoxies, polyesters, phenolics, and polyamide; typical examples of thermoplastics include polyethylene, polystyrene, polyether–ether–ketone (PEEK), and polyphenylene sulfide (PPS). The differences between thermosets and thermoplastics are given in the following table (Autar K. Kaw, 2006).

Table 3.4: The difference between Thermoplastics and Thermosets (Autar K. Kaw, 2006).

S No.	Thermoplastics	Thermosets
1	Soften on heating and pressure, and thus easy to repair	Decompose on heating
2	High strains to failure	Low strains to failure
3	Indefinite shelf life	Definite shelf life
4	Can be reprocessed	Cannot be reprocessed
5	Not tacky and easy to handle	Tacky
6	Short cure cycles	Long cure cycles
7	Higher fabrication temperature and viscosities have made it difficult to process	Lower fabrication temperature
8	Excellent solvent resistance	Fair solvent resistance

The gp resin which is used for this project is purchased from the local market of Addis Ababa gurd shola area, Ethiopia. Different kinds of gp resins are used for different kinds of composite material production.

Figure 3.3: General polyester Resin.

3.1.4. Hardener (catalyst)

During the process of molding for the composition of carbon fiber and sisal fiber, we need the hardening and curing agent called hardener or catalyst which used to cause a chemical reaction without changing the resin’s chemical composition. By adding this hardener to the gp resin the chemical reaction of gp resin is initiated and changing from semi liquid form to solid form. The curing agent is applied in the ratio of 10:1 of gp resin and hardener respectively during mixture that spilled between every layer of the fibers (Ashish kumre, 2017). The hardener (catalyst) that used for this project is purchased from local market that located in Addis Ababa Ethiopia.

3.1.5. Mold Release Wax

Mold releaser wax is a releaser which helps to reduce the friction that may happen between the molding surface plate and the molded materials that makes to separate (detach) each other easily after the molding process has taken place for 24 hours. This mold release wax may be in the form of cream or semi-fluid that paints on the surface. In this project cream type mold release wax was used.

Figure 3.4: Mold release wax.

3.1.6. Sodium hydroxide (NaOH)

Sodium hydroxide used in this project is pellet in form which is solid in its structure and white in color with the size of 500 gm which is produced in Alphax chemical industry, India. This chemical also named as caustic soda which has the molecular formula of NaOH. It is applicable in many industries like textile, soap, detergent, paper and etc. NaOH used in this project is measured within measuring tool and mixed with 10 liters of distilled water for removing the debris and dirt particles. And also it is purchased from local market.

Figure 3.5: Sodium hydroxide.

3.1.7. Distilled water

Distilled water is water that has been boiled into vapor and condensed back into liquid in a separate container. Impurities in the original water that do not boil below or near the boiling point of water remain in the original container. Thus, distilled water is one type of purified water that used to remove the debris and impurities from any materials needs to soak in water. In this project the purpose of distilled water is to remove the unwanted impurities and debris from sisal fiber after mixing it with NaOH and soak the sisal fiber in it.

Table 3.5: Consumable materials.

S No.	Consumable materials	unit	Quantity
1	Gloves	pcs	50
2	Respiratory	pcs	02
3	Permanent marker	Pcs	02
4	Small paint brush	Pcs	07
5	Safety glass	Pcs	01
6	Masking tape	pcs	01
7	Rags	kg	02
8	Stir sticks	Pcs	02
9	Sanding paper	pcs	04
10	Nail	kg	01
11	Scissor	Pcs	01

3.2. Process of sample preparation for Composite

The carbon fiber and sisal fiber is woven with $0^0/90^0$ and $\pm 45^0$ to prepare the specimen which has a dimension of 400 mm width and 500 mm length. The chart given below (Figure 3.6) shows the steps followed in preparation of the specimen.

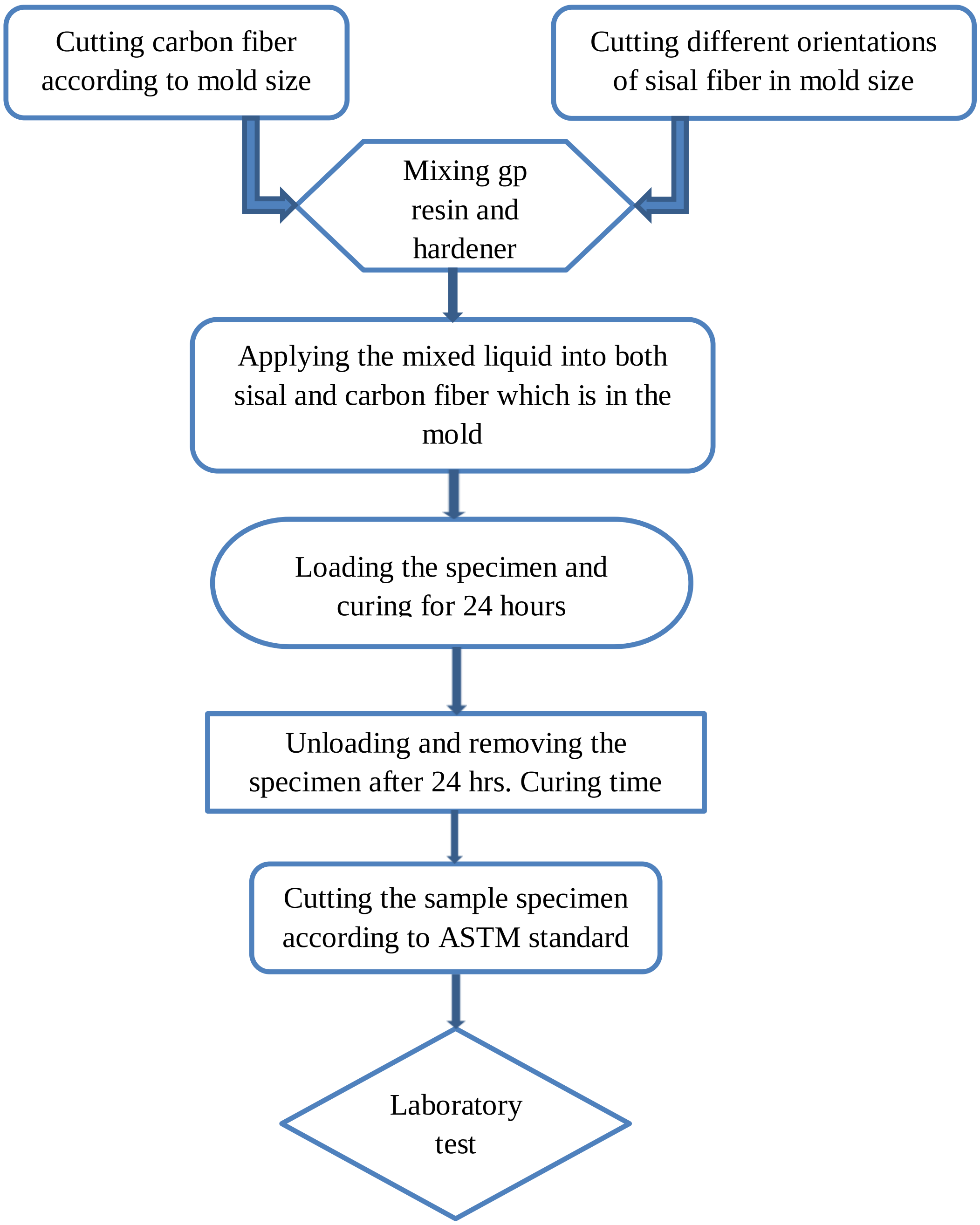


Figure 3.6: Preparation of composite materials.

To prepare the specified specimen, the first step for reinforcing polymer composite is soaking the Sisal fiber into the mixture of 10 liters of distilled water and 8 gram of sodium hydroxide (NaOH) solution for 24 hours for the sake of removing dirt particles, impurities and to improve its mechanical properties. Figure 3.7 shows weighing of NaOH with digital balance.

Figure 3.7: Measurement of NaOH using digital balance.

The solution was prepared by mixing NaOH with 10 liters of distilled water. Figure 3.8 shows the soaking of sisal fiber in NaOH solution.

Figure 3.8: Soaking the sisal fiber in base solution.

After thoroughly washing, the sisal fiber was dried in the sun light (Figure 3.9).

Figure 3.9: Drying sisal fiber in sun light.

The dried sisal fiber was woven on the weaving plate with 0^0,90^0 and ± 45^0 fiber orientation for preparing the specimen for test.

Figure 3.10: 0^0/90^0 of woven sisal fiber.

Figure 3.11: ± 45^0 of woven sisal fiber.

The woven mat was used for preparing the molds in combination with carbon fiber layer using gp resin and hardener on the molding plate. For both molds two layers of carbon fiber was placed at the top and bottom with single middle layer of sisal fiber mat with different orientations.

3.2.1. Preparation of general polyester resin and hardener

Gp resin and hardener (catalyst) should have to be mixed in a recommended ratio for the sake of preparing the required composite material. The ratio of the mixture of general polyester resin and hardener is 10:1 respectively. The mixture has to be mixed thoroughly for fifteen minutes for proper mixing. Then immediately it should be applied on fiber layers.

3.2.2. Hand layup and molding

Hand lay-up molding is used for the production of parts of any dimensions such as technical parts with a surface area of a few square feet, as well as medium square feet. But this method is generally limited to the manufacture of parts with relatively simple shapes that require only one face to have a smooth appearance (the other face being rough from the molding operation). It is recommended for small and medium volumes requiring minimal investment in molds and equipment. Hand layup process is shown in figure 3.12.

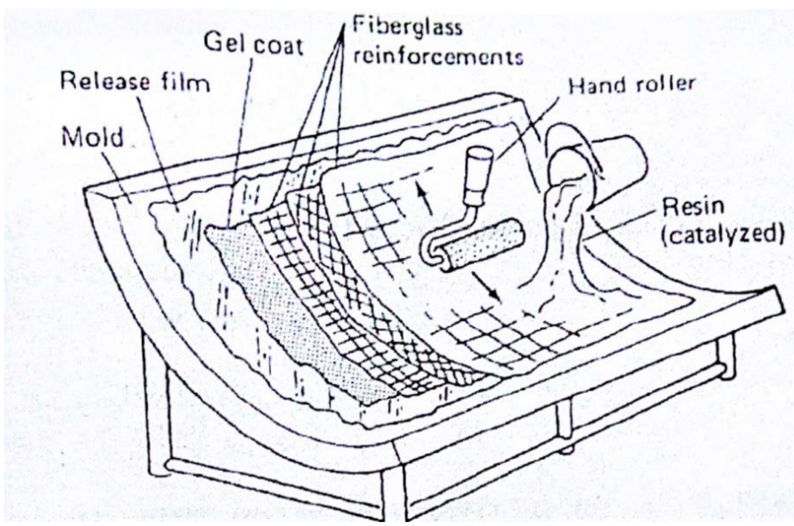


Figure 3.12: Hand lay-up techniques of composites (Autar K. Kaw, 2006).

In this molding system that shown in figure 3.13 below there are two layers of carbon fiber which placed at bottom and top of the middle sisal fiber by three layering system and placed these fibers under loads until its required curing time. The mold was cured for 24 hours under the load applied.

Figure 3.13: Loaded and molded composite.

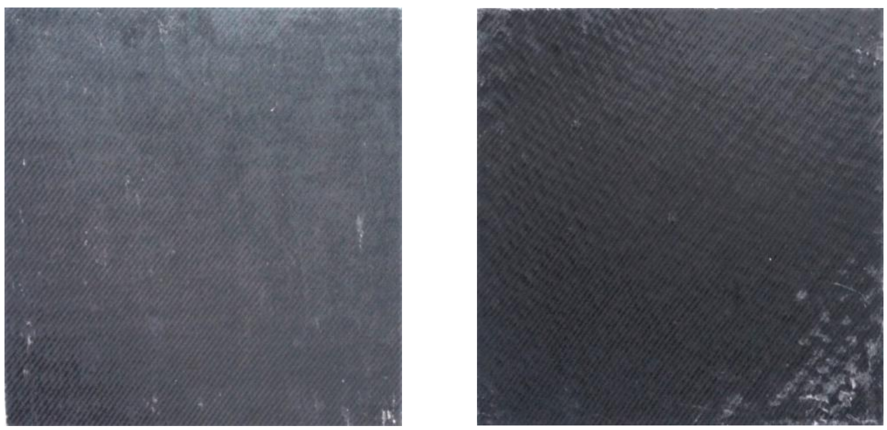


Figure 3.14: Prepared composite materials with different orientations of the fiber.

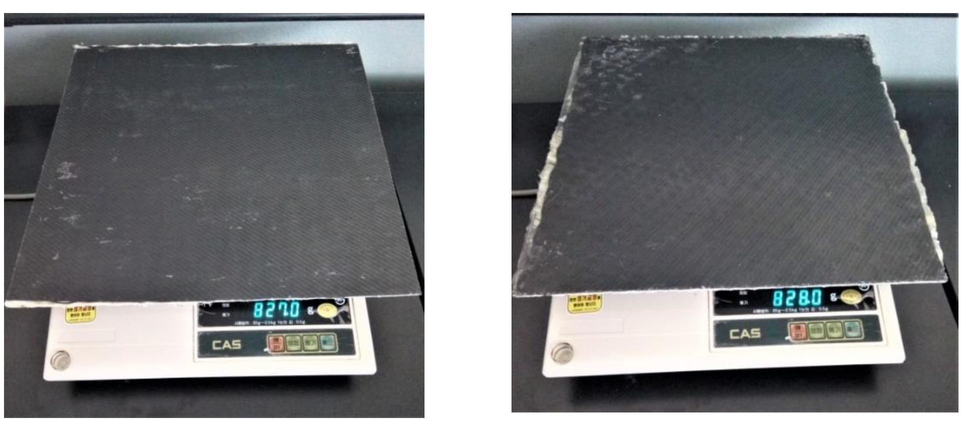


Figure 3.15: Weighing of $\pm 45^0$ and $0^0/90^0$ of composite material.

Table 3.6: The mass of composite materials.

CF and Sisal Orientation	Twill carbon fiber (g)	Sisal fiber (g)	Total composite mass in gram
$\pm45^0$	108	165	828
0^0, 90^0	108	165	827

3.3. Specimen preparation for mechanical testing

The specimens for tests were prepared by cutting using Jig saw as per ASTM standards (Figure 3.16).

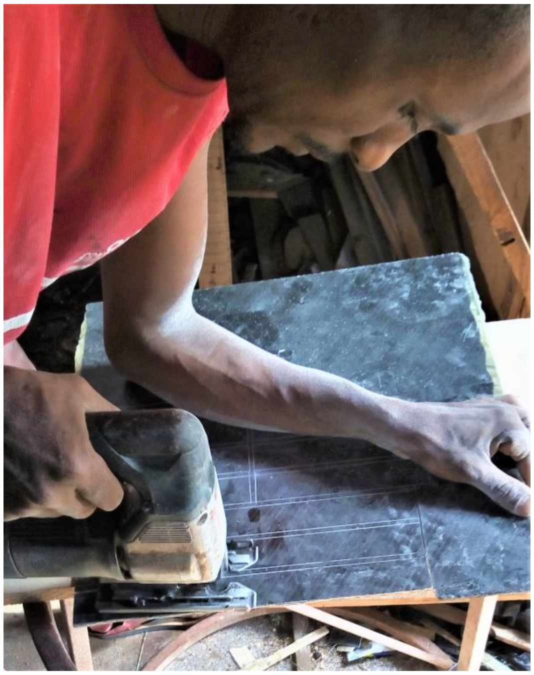


Figure 3.16: Cutting specimen with Jig saw.

3.3.1. Specimen for tensile test

The specimens required for tensile test were prepared with standard dimensions as per ASTM: D638 standards. Jig saw cutter was used to cut the fabricated hybrid composites as per the required dimensions of 300 mm length, 30 mm width with 4mm thickness. The specimens are shown in figure 3.17. The tensile test was conducted using universal testing machine. The tensile stress verses strain data was recorded.

Figure 3.17: Specimen for tensile test.

3.3.2. Specimen for compression test

Six specimens were prepared for compression test i.e, three for $0^0/90^0$ and three for $\pm45^0$ according to the ASTM D3039/D3039M standard of 155 mm length, 30 mm width with 4 mm thickness as shown in the figure 3.18 below.

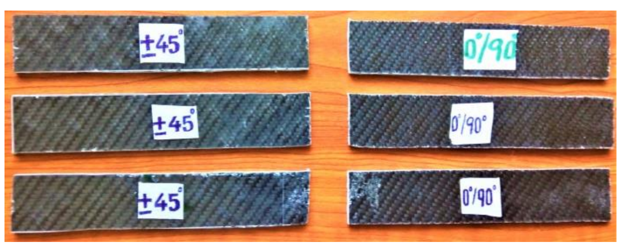


Figure 3.18: Specimen for compression test.

3.3.3. Specimen for bending test

The bending test indicates the force required to bend the specimen at three point loading condition. This test is useful to know whether this prepared material has the tendency to resist the loads without breaking. This test was performed with bending test machine on a specimens prepared according to ASTM D3039D/D3039M standard to measure bending strength of the composite. For this test six specimens were prepared with three $0^0/90^0$ and three $\pm45^0$ fiber orientation in 127 mm length, 30 mm width and 4 mm thickness.

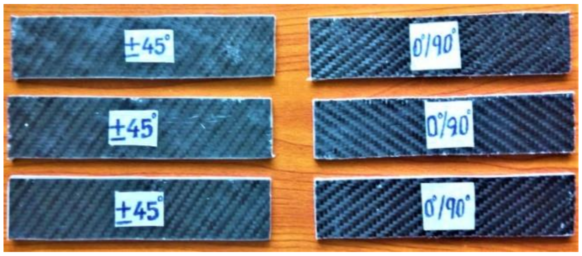


Figure 3.19: Specimen for bending test.

3.3.4. Specimen for water absorption

The basic need for measuring water absorption is to know the tendency of water absorption of the composite material from the surrounding. The specimens were prepared with two different angle orientations of $0^0/90^0$ and $\pm45^0$. Three specimen were prepared for each angle orientation with ASTM C220 standard of 30mm length, 20 mm width and 4mm thickness (figure 3.20). Before measuring the water absorption all six specimens were weighed for their dry weight and then soaked them into the tap water. Then after soaking the specimen for 5 days in tap water, the specimens were weighed to know the amount of water absorbed. The rate of water absorption was calculated using the following equation.

$$\text{Water absorption \%;} \quad Wm = \frac{Ww - Wd}{Wd} * 100\% \tag{3.1}$$

Figure 3.20: Water absorption samples.

3.4. Finite Element Analysis

An automobile roof or car top part coverage is the portion of an automobile that sits above the passenger compartment, protecting the vehicle occupants from sun, wind, rain, and other external elements. The process includes the steps like, modeling the roof panel of the selected vehicle, importing the model into ANSYS, meshing the model, applying boundary conditions and loads and analyzing the model. The analysis was done for equivalent stress and deformation.

In this analysis, the specification of Toyota vitz 1.0f model is selected. The dimensions of the vehicle roof panel were measured. Its length is 1500mm (1.5 m) long and its width is 1290 mm (1.29 m). The modeling of the roof panel was done by Solid work 2013 software and the analysis was done by ANSYS workbench 17.2.

By using ANSYS 17.2 software it is important to analyze static and dynamic behavior of roof panel by determining stress and deformation as well as natural frequencies and mode shapes.
This analysis was mainly focused on static analysis of vehicle roof panel. The static analysis was performed by assuming the vehicle is at rest and static loads are applied with different load cases.

3.4.1. Design analysis

To analyze the design the drawings must be drawn in user friendly software and they must be converted into a 3D model. This 3D model must be imported into an analyzing medium where it is structurally or thermally analyzed to sustain the need. Different steps involved in designing a component are:

1. Part drawing
2. Modeling
3. Structural analysis

3.4.1.1. Part Drawing

Part drawing is a document that includes the specifications of the part to be produced. Generally the part drawings are drawn to have a clear idea of the model to be produced.

3.4.1.2. Modeling

It is the process of developing a modal representation of any three dimensional surface of object via specialized software. The product is called a 3D model. There are three basic types of three dimensional computer geometric modeling methods.

i. Wire frame modeling
ii. Surface modeling
iii. Solid modeling

i. Wire Frame Modeling

A wire frame model is visual presentation of a 3 dimensional or physical object used in 3D computer graphics. It is created by specifying each edge of the physical object where two mathematically continuous smooth surfaces meet, or by connecting an object's constituent vertices using straight lines or curves. The object is projected on to a display screen by drawing lines at the location of each edge. The wire frame format is well suited and widely used in programming tool paths for DNC (Direct Numerical Control) machine tools.

ii. Surface modeling

These models are with no thickness. These models are widely used in industries like automobiles, aerospace, plastic, medical and so on. Surface models should not be confused with thick models that are models having mass properties. The only difference between the solid model and the surface model is solid model will have mass properties.

iii. Solid Modeling

A solid model of an object is a more complete representation than its surface (wireframe) model. It provides more topological information in addition to the geometrical information which helps to represent the solid unambiguously. There are different software those are used for generating these solid models like Solid works and Pro.E. In this project the roof panel was modeled by using SOLID WORKS 2013. The roof panel was modeled in part module by using different commands like extrude, rotate, fillet, extrude cut etc..,

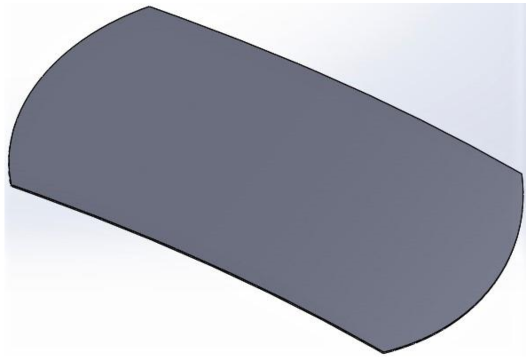


Figure 3.21: Roof panel drawing.

3.4.1.3. Structural Analysis

Structural Analysis is a key part of the engineering design of structures. The present roof panel model was converted into IGES format and it was then imported to ANSYS Workbench 13.0.There are various steps that are to be followed in analyzing a component structurally. They are:

1. **Mesh generation:** is the practice of creating a mesh, a subdivision of a continuous geometric space into discrete geometric and topological cells.

Figure 3.22: Mesh generation.

2. **Fixed support (Boundary condition) and load:** The boundary condition prevents one or more; flat, straight or curved faces from moving or deforming. The fixed support is available for Explicit dynamics, Harmonic response, Modal, Static structural, and Transient structural. In this thesis work static structural was conducted with surface and edge supported. After the boundary condition was applied, the force that acts on the body was inserted. The required force was applied to the surface with point load application.

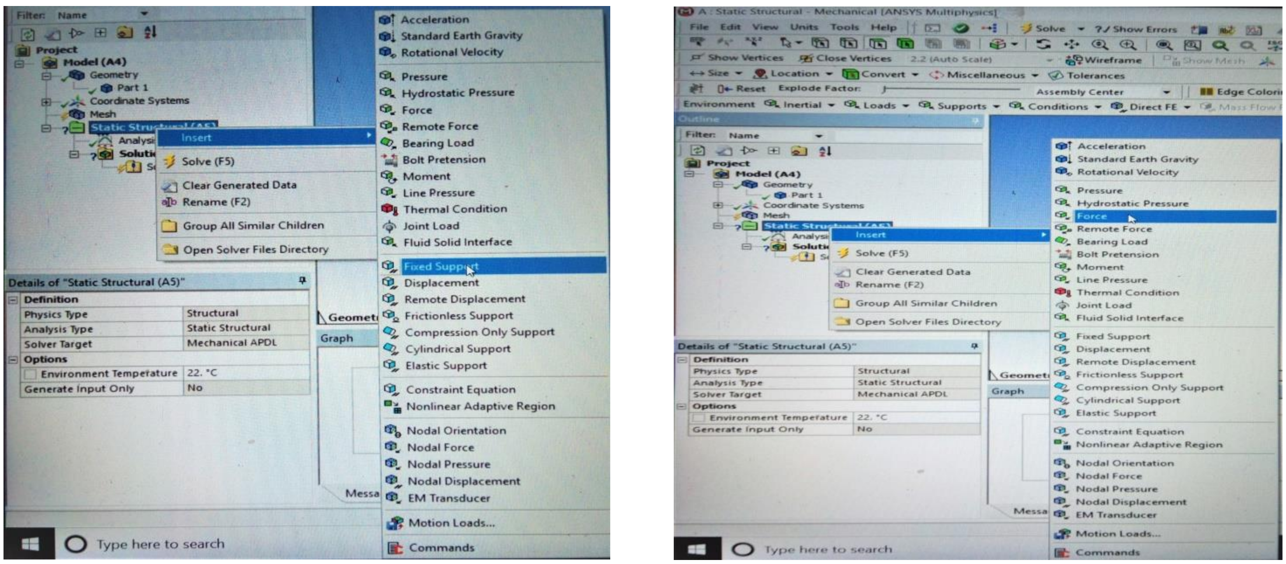


Figure 3. 23: Fixed support and load application.

3. **Evaluating result:** After applying boundary condition and load on the model provided, the results of both Equivalent (von-mises) stress and deformation was selected. As shown in figure 3.24 below, the equivalent stress was evaluated by right clicking on solution button, inserting stress and finally, equivalent (von-mises) stress was selected. The same is true for evaluating deformation; but the only difference is at insertion button deformation was selected and then total deformation was inserted.

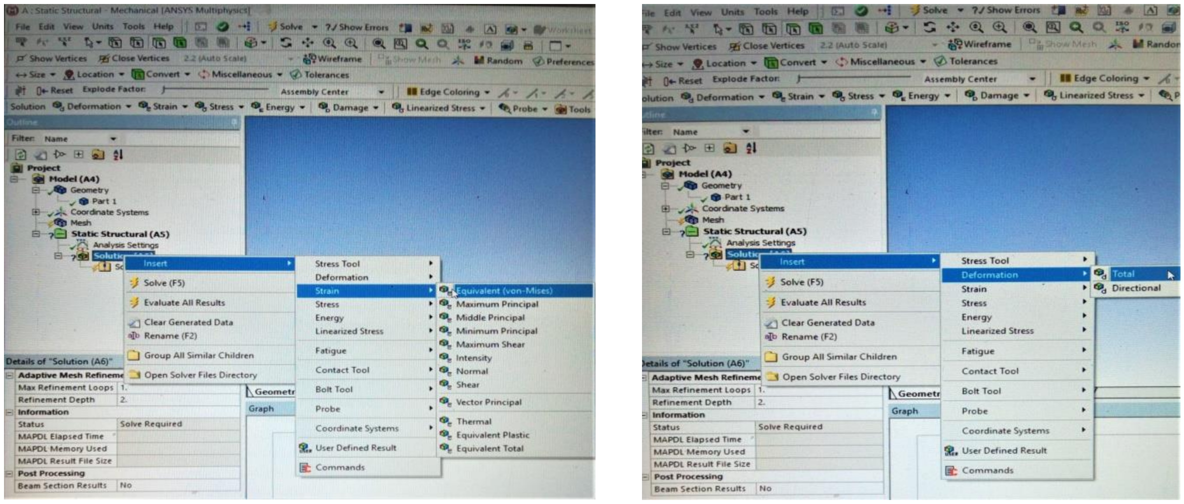


Figure 3.24: Equivalent stress and deformation.

The results of the analysis are used to verify a structure's fitness for use, often saving physical tests.

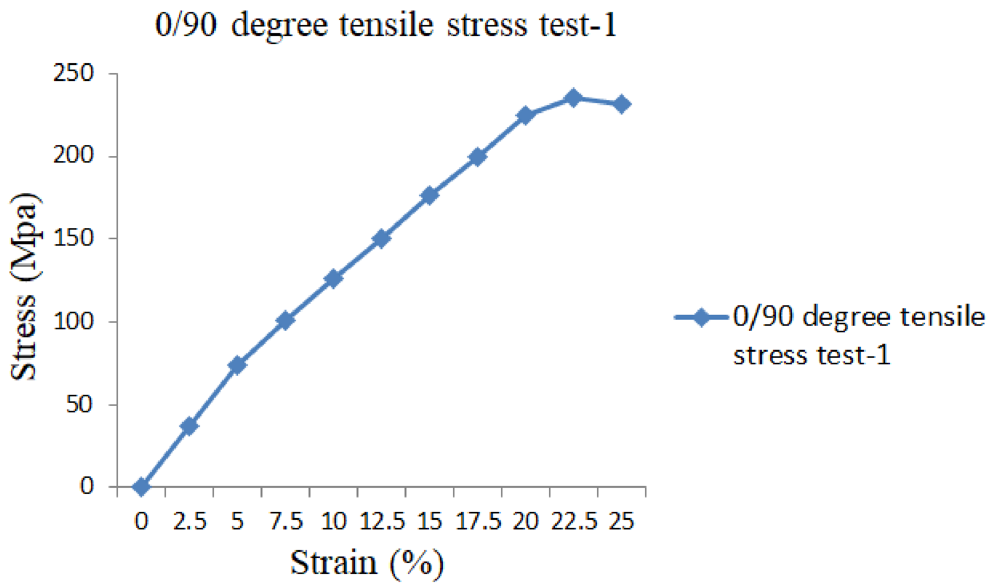
4. RESULTS AND DISCUSSIONS

4.1. Test result of the specimen

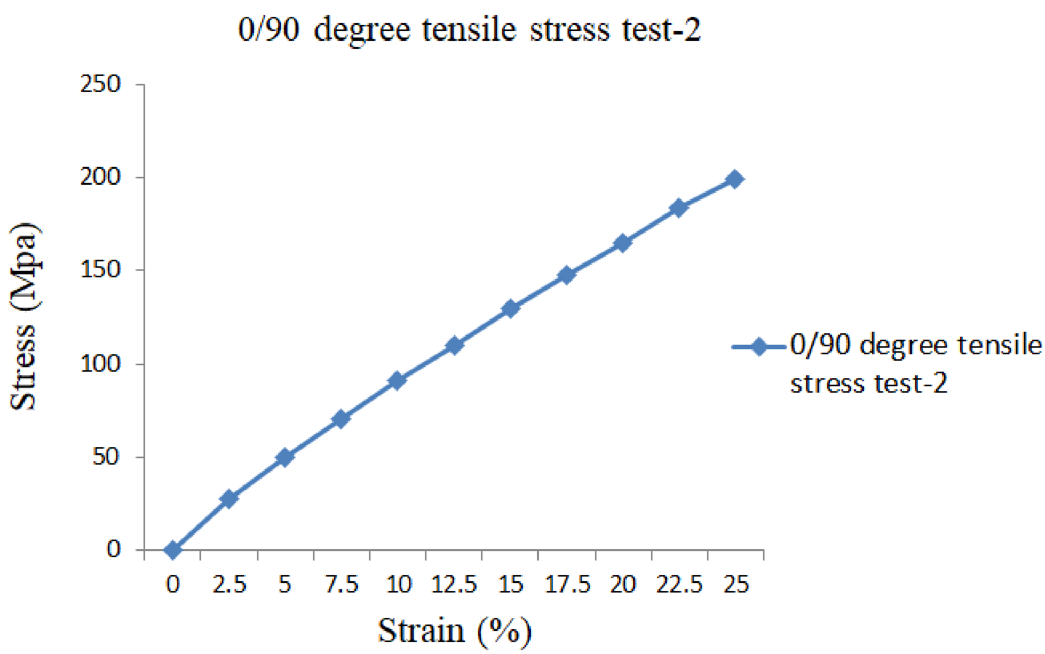
4.1.1. Tensile test result

The basic advantage of tensile test is to evaluate tensile properties of CFSFC internal structure. For the test of tensile strength there were six (6) specimens prepared with varying fiber orientation of $0^0/90^0$ and $\pm45^0$. Three specimens were tested for each orientation. All specimens have the dimensions of 300mm length, 30mm width and 4mm thickness. At the time of testing the tensile strength of CFSFC the specimens are placed in the jaws of UTM grip and the axial load is applied within both side of the specimen and finally, the applied load tends the specimen to fracture as shown in the figure 4.1 below. The tests were conducted at Ethiopian conformity assessment enterprise.

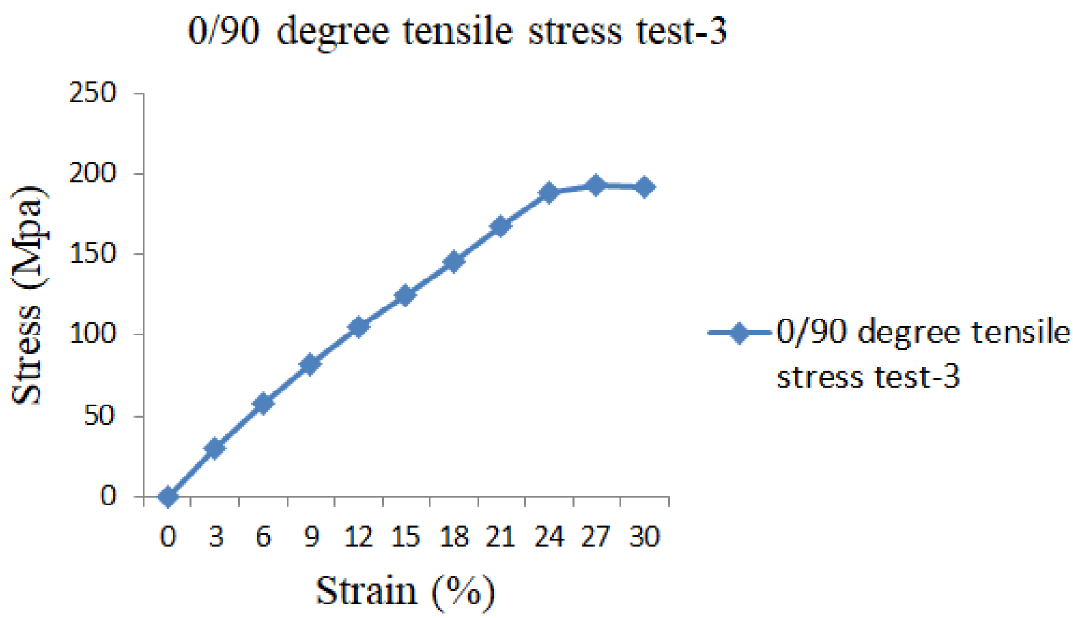
Figure 4.1: Fractured specimens after tensile test.



i. $0^0/90^0$ tensile strength test-1



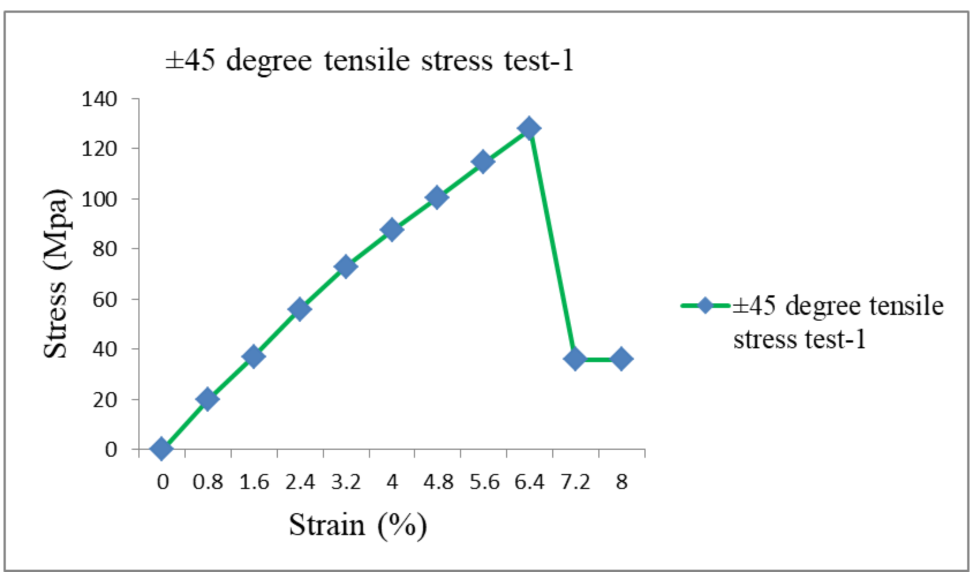
ii. $0^0/90^0$ tensile strength test-2



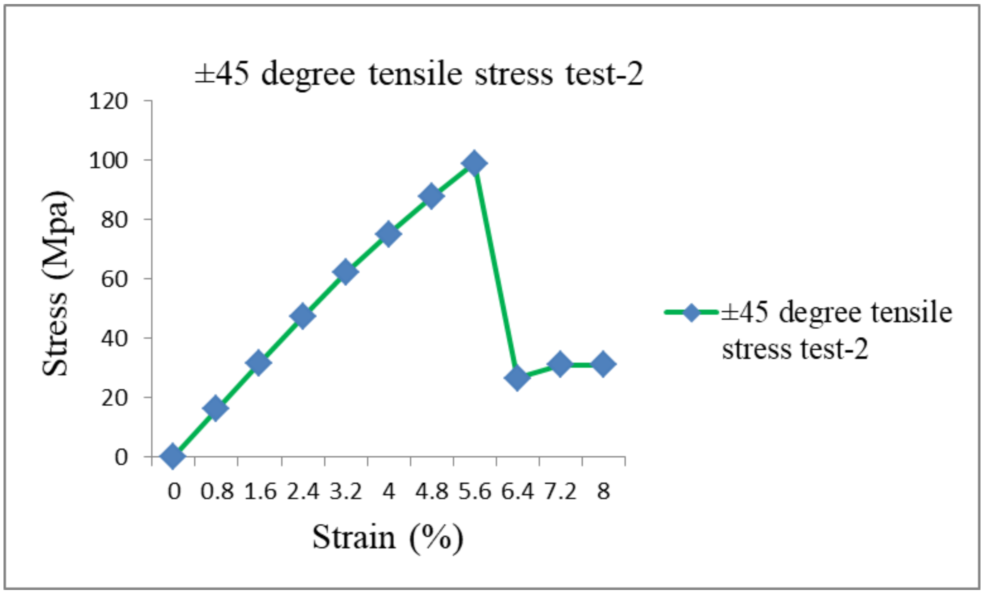
iii. $0^0/90^0$ tensile strength test-3

Figure 4.2: Tensile strength test of $0^0/90^0$ fiber orientation composite.

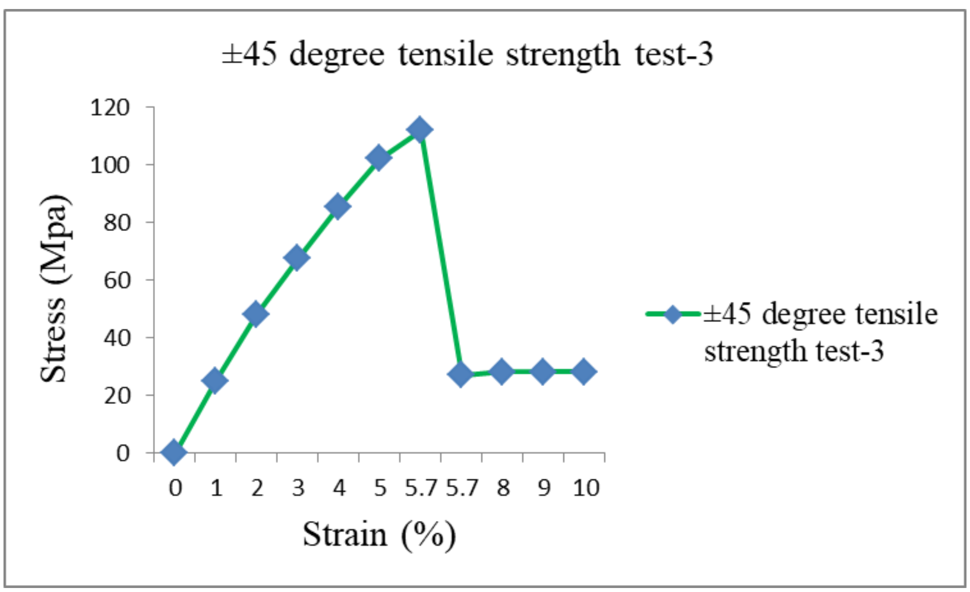
From the tensile test conducted on $0^0/90^0$ fiber orientation composite, the tensile strength found to the 214 MPa, 186 MPa and 178 MPa for test-1, test-2 and test-3 respectively.



i. $\pm 45^0$ tensile strength test-1



ii. $\pm 45^0$ tensile strength test-2



iii. $\pm 45^0$ tensile strength test-3

Figure 4.3: Tensile strength test of $\pm 45^0$ fiber orientation composite.

From the tensile test conducted on $\pm 45^0$ fiber orientation composite, the tensile strength found to the 119 MPa, 88 MPa and 102 MPa for test-1, test-2 and test-3 respectively.

The tensile strength values which were found from the tensile test are tabulated in Table 4.1.

Table 4.1: Tensile strength for composite with different fiber orientations.

Fiber orientation	Maximum tensile strength (MPa)			Average result (MPa)
	Test-1	Test-2	Test-3	
$0^0/90^0$	214	186	178	193
$\pm45^0$	119	88	102	103

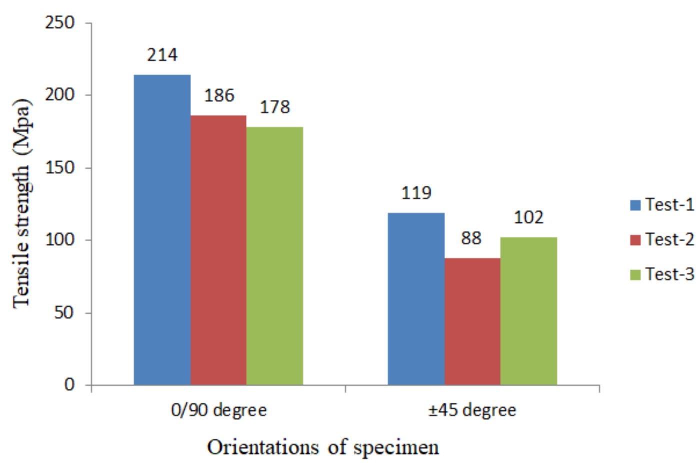


Figure 4.4: Tensile strength of specimen.

The figure 4.4 shows the tensile strengths found in three trials of each orientation of $0^0/90^0$ and $\pm45^0$. Figure 4.5 shows the average values of tensile strength for orientation of $0^0/90^0$ and $\pm45^0$.

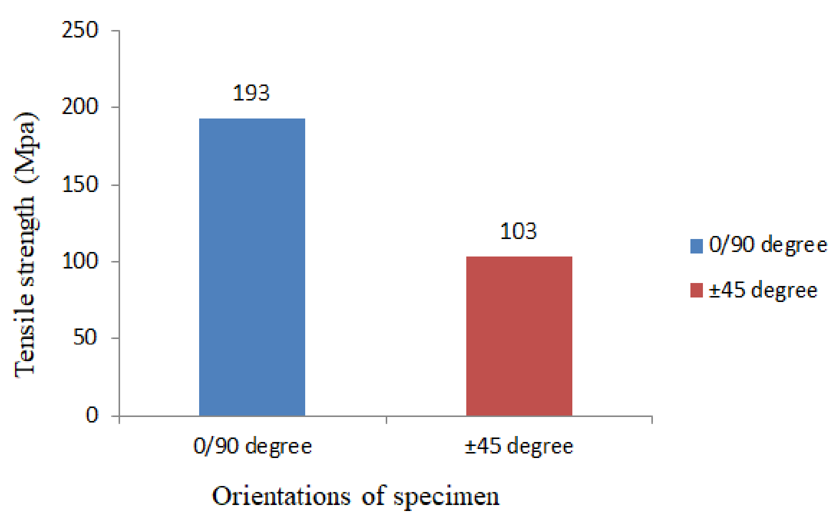


Figure 4.5: Average tensile strength of specimen.

As it is observed from tensile test result the $0^0/90^0$ of CFSFC has a higher tensile strength value. So, $0^0/90^0$ orientation is more suitable for light vehicle roof panel which is subjected to tensile stress. The young's modulus of $\pm45^0$ is found to be higher than $0^0/90^0$ orientation (Table 4.2).

Table 4.2: Tensile stress, elongation and Young's modulus.

Orientation	Samples	Thickness (mm)	Max. tensile force (kN)	Tensile stress (MPa)	Tensile strength (Mpa)	Uniform Elongation (%)	Young's modulus (Mpa)
$0^0/90^0$	Test-1	4	13.14	235.4	214	21.3	1105.2
	Test-2	4	12.33	198.9	186	24.9	798.8
	Test-3	4	14.93	193.4	178	25.1	770.5
$\pm45^0$	Test-1	4	10.01	129	119	6.6	1954.5
	Test-2	4	7.51	98.8	88	5.5	1796.4
	Test-3	4	8.95	111.8	102	5.6	1996.4

Discussion on tensile test

From the results it is found that the orientation of the fiber in a composite prepared has the great influence on tensile strength. It is found that the tensile strength of 0/90 degree is more than ±45 degree. Fiber exhibits more tensile strength in the direction of its fiber length. In other directions the tensile strength of the fiber observed to be less. The tensile strength of 0/90 degree is found to be 193 MPa while for ±45 degree it is 103 MPa. The observed tensile strength of these specimens of same orientations may be due to manual errors during specimen preparation. Due to usage of better composition of the materials the tensile strength achieved is observed to be higher than the tensile strength reported 56.5 MPa in the literature (Badrinath *et al.*, 2014).

4.1.2. Results of bending test

The purpose of bending test is to measure the force required to bend the specimen under three point loading conditions. The result of this test used to identify and select the specimen for an automobile roof panel and also other body parts that will support loads without breaking down.

The bending test of the prepared specimen was also performed by using universal testing machine with recommended ASTM standards for measuring the bending strength of the composite material. The test was conducted on three specimens prepared for each $0^0/90^0$ and $\pm45^0$ orientations.

Table 4.3: Specimens bending strength.

Orientations of Fiber	Maximum bending load (N)			Average (N)
	Test-1	Test-2	Test-3	
$0^0/90^0$	3070	1930	2520	2506.7
$\pm45^0$	1700	1280	1880	1620

The maximum bending load found in each test and the average values are given in the table 4.3. It is observed from the above table $0^0/90^0$ orientation of CFSFC have the maximum bending load of 2506.7 N than other orientation.

Maximum bending stress was calculated as follows.

Section modulus, $$W_b = \frac{w \times t2}{6} \tag{4.1}$$

Maximum bending moment, $$M_{bmax} = \frac{Fmax \times L}{4} \tag{4.2}$$

Maximum bending stress, $$\delta max = \frac{Mbmax}{Wb} \tag{4.3}$$

Figure 4.6: Bending test

The maximum bending load, the maximum bending stress, section modulus and the maximum bending moments are given in the table 4.4.

Table 4.4: Bending stresses, deflection and bending moment.

Orientation of CFSFC	Specimen	Length (mm)	Width (mm)	Thickness (mm)	F_{max} (kN)	W_b (mm^3)	$M_{b\ max}$ (N.mm)	δ_{bmax} (N/mm^2)
$0^0/90^0$	Bending-1	127	30	4	3.07	80	97,472.5	1218.4
	Bending-2	127	30	4	1.93	80	61,277.5	765.97
	Bending-3	127	30	4	2.52	80	80,010	1000.13
$\pm45^0$	Bending-1	127	30	4	1.70	80	53,975	674.7
	Bending-2	127	30	4	1.28	80	40,640	508
	Bending-3	127	30	4	1.88	80	59,690	746.13

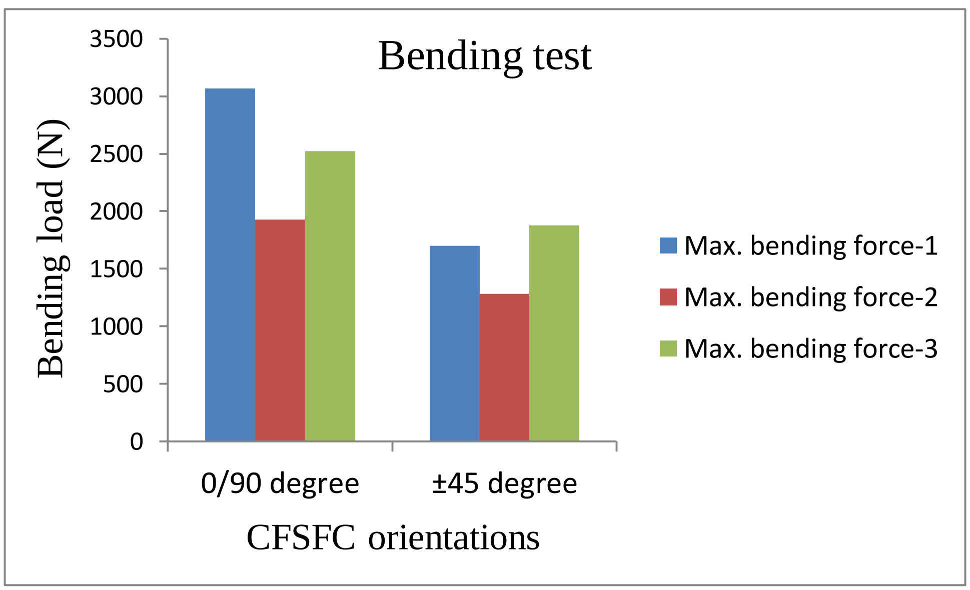


Figure 4.7: Specimens bending load.

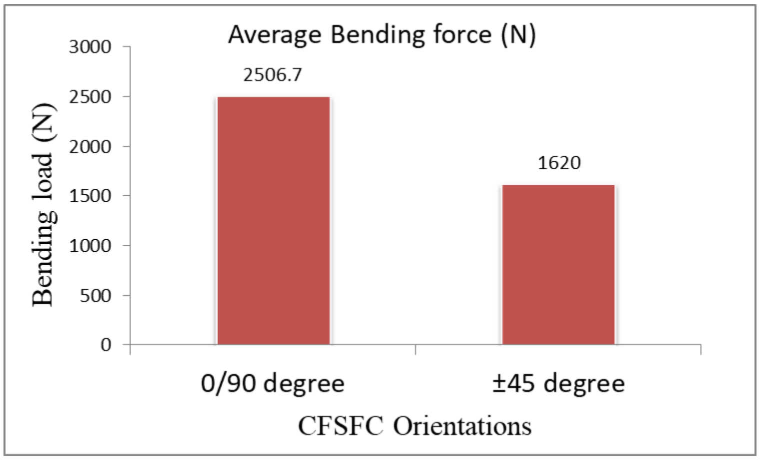


Figure 4.8: Average bending load.

The prepared specimen was tested for bending load condition with UTM which is located in Adama Belay Ab cable factory plc. Three specimens are prepared for each orientation and tested for bending load condition. As we have seen from the result shown above the 0/90 degree specimen have more bending strength than $\pm 45^0$ orientation. Because of its good bending load, the 0/90 degree orientation is used for manufacturing automobile body parts than other orientations.

Discussion on bending test

Table 4.5: shows the average bending strength test result of CFSFC.

Table 4.5: CFSFC average bending load.

Fiber orientation	Average bending (N)
$0^0/90^0$	2506.7
$\pm 45^0$	1620

As we have observed from the above table there was the comparison of bending load is performed. In this test result the 0/90 degree has 2506.7 N better bending results than ±45 degree with 1620 N. So, for the vehicles body part especially for those subjected to more bending stresses it is better to use 0/90 degree orientation materials made of carbon fiber and sisal fiber composites. Different authors have investigated the bending strength of composite materials.

According to the investigation of (Ramesh *et al*., 2012) the bending load was 3 kN with 14.2 mm displacement. From the test done in this thesis the maximum bending load found to be 2.5 kN with displacement of 1.1 mm.

4.1.3. Results of Compression test

For compression test also six samples were prepared as per the standard dimensions, three specimens for each $0^0/90^0$ and $\pm45^0$ orientations. The compression test was conducted in Belay-Ab cable factory plc. which is located in Adama. The dimension of a sample is prepared according to ASTM D3039/D3039M standard with 155 mm length, 30 mm width and 4 mm thickness.

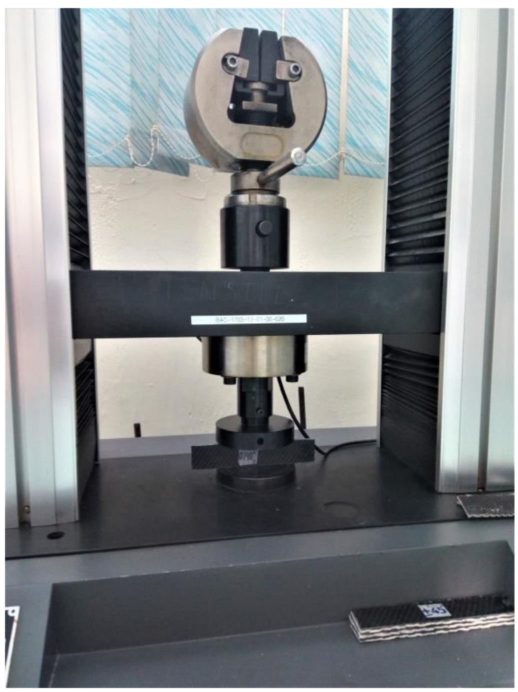


Figure 4.9: Compression strength test using UTM.

The result of compression test that performed by UTM is given in the table 4.6.

Table 4.6: Compression load of specimens.

CFSFC orientation	Maximum compression load (N)			Average value (N)
	Test-1	Test-2	Test-3	
$0^0/90^0$	25,640	12,390	31,730	23,253.3
$\pm45^0$	18,110	25,240	26,980	23,443.3

From the table 4.6, it is observed that the composite with $\pm45^0$ fiber orientation has higher compressive load than $0^0/90^0$ orientation.

Table 4.7: Compressive strength of specimen.

CFSFC orientation	Maximum compression strength (MPa)			Average value (MPa)
	Test-1	Test-2	Test-3	
$0^0/90^0$	8.5	4.1	10.5	7.7
$\pm45^0$	6.0	8.4	8.9	7.7

As we observe from table 4.7, the compressive strength of $0^0/90^0$ and $\pm45^0$ are equal. So, both are equally strong in compression.

Table 4.8: Maximum compressive load, compressive strength and deformation.

Orientations	Specimens	Thickness (mm)	Max. comp. strength (Mpa)	Max. load (kN)	Deformation (mm)
$0^0/90^0$	Test-1	4	8.5	25.64	2.37
	Test-2	4	4.1	12.39	2.60
	Test-3	4	10.5	31.73	1.86
$\pm45^0$	Test-1	4	6.0	18.11	2.60
	Test-2	4	8.4	25.24	1.74
	Test-3	4	8.9	26.98	1.70

As we have observed from table 4.8, the result of maximum compressive load, strength and deformation are obtained by using UTM. In case of the maximum load $\pm45^0$ angular orientation has the highest compressive load when compared to 0/90 degree orientation but, for the parameter of compressive strength both $0^0/90^0$ and $\pm45^0$ are equal.

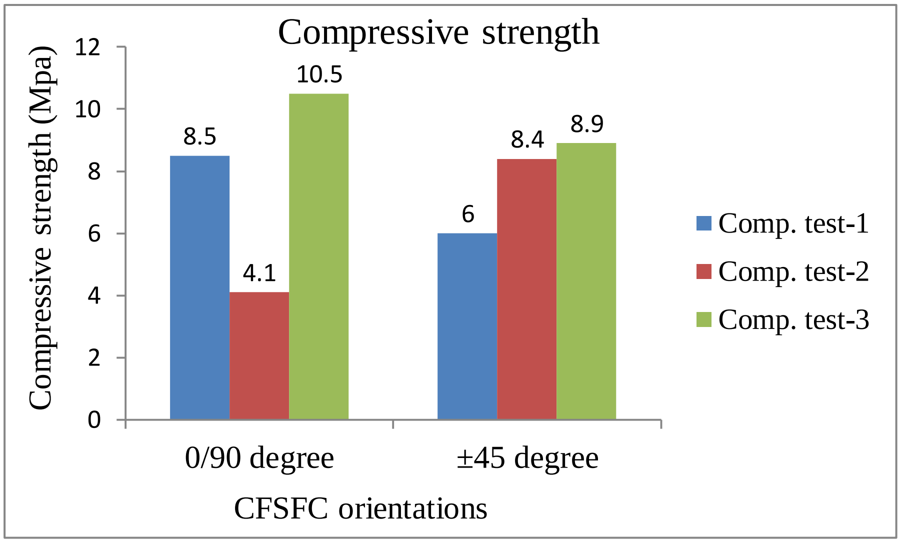


Figure 4.10: Compressive strength.

The figure 4.10 shows compressive strength of different angular orientation of CFSFC.

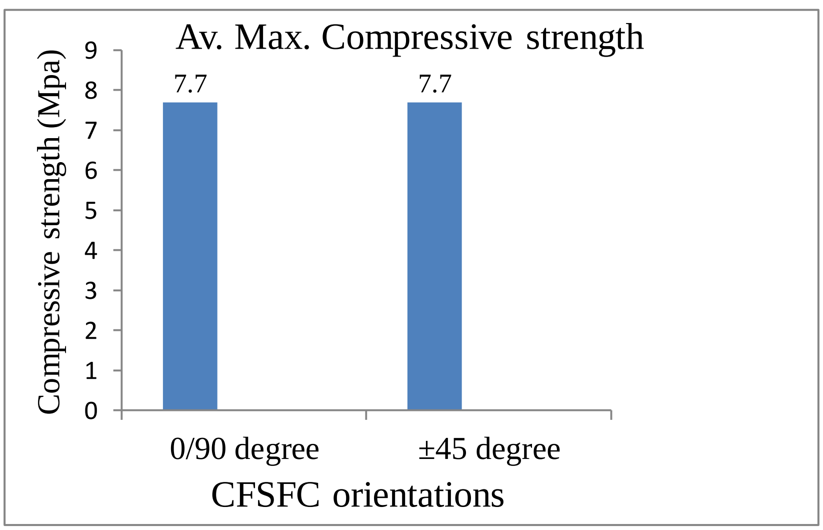


Figure 4.11: Average compressive strength.

As we have seen from figure 4.11 of average compressive strength of both $0^0/90^0$ and $\pm45^0$ angular orientations are equal.

Discussion on Compression test

From the result obtained in the compression test between the carbon fiber and sisal fiber with the orientation of $0^0/90^0$ and $\pm45^0$ both of different specimen has got the same values of 7.7 MPa of compression strength. So, with this value we can conclude that, we can use either $0^0/90^0$ or $\pm45^0$ for manufacturing of vehicles body parts.

4.1.4. Water absorption tests

The test of water absorption is used to know how much water is absorbed by the specimen within the period of five days immersion of composite materials in the tap water tank. The mass of the specimen was measured before immersion in water and also measured after immersion for 5 (five) days. Three specimens for each fiber orientation were tested and average value was considered. The % (percent) of water absorption was calculated as follows (Badrinath, 2014);

Water absorption %; $$Wm = \frac{Ww - Wd}{Wd} * 100\%$$

Where: w_m - water absorption

w_d - dry weight

w_w – wet weight

Figure 4.12: Weighing the mass of the specimen.

Figure 4.13: Sample of CFSFC immersed in water.

Table 4.9: Average dry and wet mass of the specimens.

Fiber orientation	Mass of water absorption (g)						Average (dry)	Average (wet)
	Sample-1		Sample-2		Sample-3			
	Dry	Wet	Dry	Wet	Dry	Wet		
$0^0/90^0$	3.23	3.32	3.11	3.19	2.95	3.05	3.09	3.18
$\pm45^0$	2.13	2.22	2.26	2.33	2.16	2.24	2.18	2.26

Water absorption was calculated by using wet mass and dry mass and then multiply by 100%.

Where: - w_{m1}: first wet mass of $0^0/90^0$ and $\pm45^0$ orientations

d_{m1} : first dry mass of $0^0/90^0$ and $\pm45^0$ orientations

w_{m2} : second wet mass of $0^0/90^0$ and $\pm45^0$ orientations

d_{m2} : second dry mass of $0^0/90^0$ and $\pm45^0$ orientations

w_{m3} : third wet mass of $0^0/90^0$ and $\pm45^0$ orientations

d_{m3} : third dry mass of $0^0/90^0$ and $\pm45^0$ orientations

According to equation (3.1), water absorption for all orientation is calculated as:

$$W_1 = \frac{Wm1-dm1}{dm1} * 100\%$$

$$W_2 = \frac{Wm2 - dm2}{dm2} * 100\%$$

$$W_3 = \frac{Wm3 - dm3}{dm3} * 100\%$$

Table 4.10: Water absorption (%).

Orientations	W1	W2	W3	Av. Water absorption (%)
$0^0/90^0$	2.78	2.57	3.38	2.91
$\pm 45^0$	4.22	3.09	3.7	3.67

Discussion of water absorption test

From the result obtained from the water absorption test, 2.91% of water is absorbed by 0/90 degree orientation after immersion for 5 days. The result of this water absorption becomes good when we compare with the same work which different authors has done. According to the investigation of (R.Badrinath, et al. 2014) the water absorption values of 0/90 degree becomes 4.07% in ordinary water test which is higher than my finding. So the water absorption reduced due to better composition of the materials.

4.2. Finite element analysis

4.2.1. Mass of roof panel

Mass is the basic properties of the object. Here the mass of roof panel is compared for two materials such as structural steel and Carbon Fiber and Sisal Fiber Composite (CFSFC) Materials. Mathematical equation for the mass calculation is:

Mass = Volume × Density

$$M = v \times \rho \tag{4.4}$$

Mass of the CFSFC = 19.48 g

Volume = length × width × thickness

$$V = l \times w \times t \tag{4.5}$$

V = 127 mm × 30 mm × 3.8 mm

$V = 14478\ mm^3 = 1.4478 \times 10^{-5}\ m^3$

From equation (4.4) $\rho = \frac{m}{v} = \frac{0.01948}{0.000014478}$ (kg/m^3) = 1345.5 kg/m^3 (density of CFSFC)

From given data of solid work mass property the total volume of the roof panel is 0.00445 m^3.

A. Mass of structural steel roof panel

We know density of steel = 7850 kg/m^3 (Vishal, F. et al, 2014)

Volume of roof panel = 0.00445 m^3

Total mass of roof panel = 7850 kg/m^3 × 0.00445 m^3 = 34.93 kg

B. Mass of CFSFC

We have density of CFSFC = 1345.5 kg/m^3

Volume of roof panel = 0.00445 m^3

Total mass of roof panel = 1345.5 kg/m^3 × 0.00445 m^3 = 6 kg

When heavy weight materials are replaced by lightweight materials it is possible to reduce the weight of vehicles and increase the payload carrying capacity. Here using Carbon Fiber and Sisal Fiber Composite Materials (CFSFC) there is a reduction in weight of 28.93 kg, which is of 83 % weight reduction.

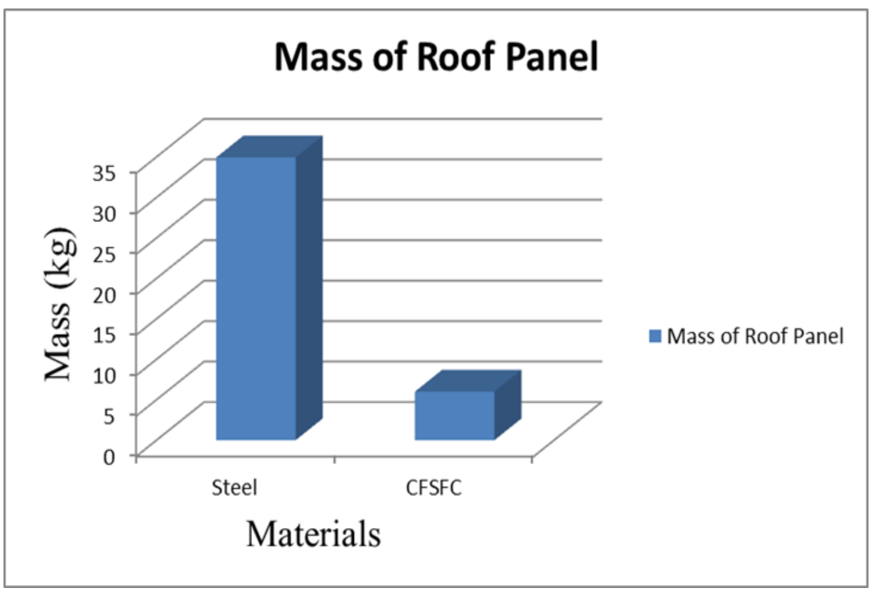


Figure 4. 14: Mass of roof panel.

4.2.2. Mesh Generation

The process for generating a mesh consists of three general steps:

1. Set the element attributes
2. Set mesh controls (optional)
3. Meshing the model

From the above listed types of mesh generation it is not mandatory to set mesh control because the default mesh controls are appropriate for many models. The program will use the default setting to produce meshing if no mesh controls are specified. To use the better quality of free mesh we can use the smart size features. The meshing was done on the model with 4988 numbers of nodes and 675 numbers of elements. The sizing of meshing was done with fine relevance center and higher smoothing.

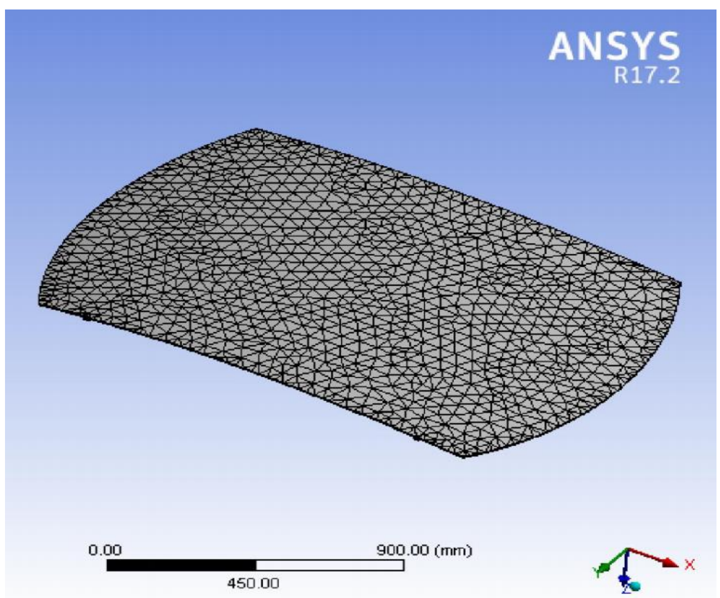


Figure 4.15: Meshing of the model.

4.2.3. Boundary condition and load application

On this step we have to fix the support for analyzing the material. The load application is the major part in the analysis of a component. There may be different types of loads like Uniformly Distributed Load, Uniformly Varying Load and Point Load.

From the vehicle specifications

Vehicle weight = 970 kg

Riding capacity (person) = 5.

Assume the average weight of the passenger is 60 kg and $5 \times 60 = 300$ kg

So, totals GVW = 970 + 300 = 1270 kg

Area of roof panel = 4.46 m^2

$$\text{Total load, } W = m \times g \tag{4.6}$$

$W = 12458.7$ N

The total load applied at the center = 12458.7 N

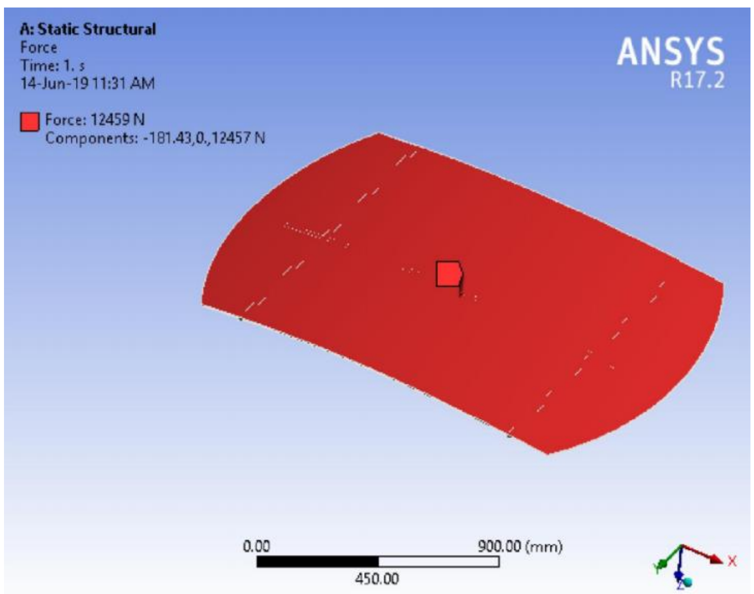


Figure 4.16: Fixed support and load application.

4.2.4. Equivalent stress and Deformation at different boundary condition

A. Stress distribution of Structural steel

It is a physical quantity that expresses the internal forces that neighboring particles of a continuous material exert on each other. For instance, when a solid vertical bar is supporting a weight, each particle in the bar pulls on the particles immediately above and below it. These microscopic forces are actually the average of a very large number of intermolecular forces and collisions between the particles in those molecules. There are many types of stresses developed in a component. The roof panel was analyzed by considering the equivalent stress (Vamsi *et al.*, 2014). The figure 4.17 below shows the stress distribution when the boundary conditions were applied on the lower parts of cross and longitudinal member support and at the edge.

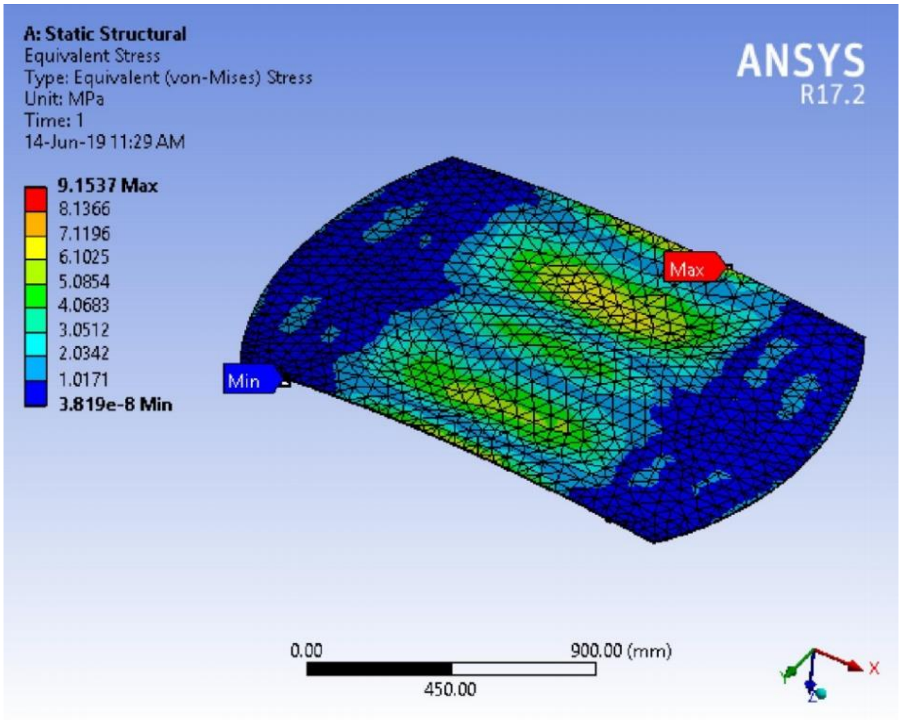


Figure 4.17: Equivalent von-mises stress distribution of structural steel.

The maximum equivalent stress 9.1537 MPa and minimum of 3.819×10^{-8} MPa was obtained from the above analysis. The yield stress of Structural steel is 225 Mpa, so the equivalent stress is less than the yield stress.

B. Deformation of structural steel

When an object is subjected to loading its shape may be changed temporarily or permanently due to applied force. This change in shape is called deformation. If the object deforms permanently it is called plastic deformation or failure. If it deforms temporarily it is called elastic deformation. While analyzing a roof panel, it has to deform elastically within the maximum loading limit so that the design is safe. The values of deformation obtained in ANSYS 17.2 for structural steel are shown in figure 4.18 below.

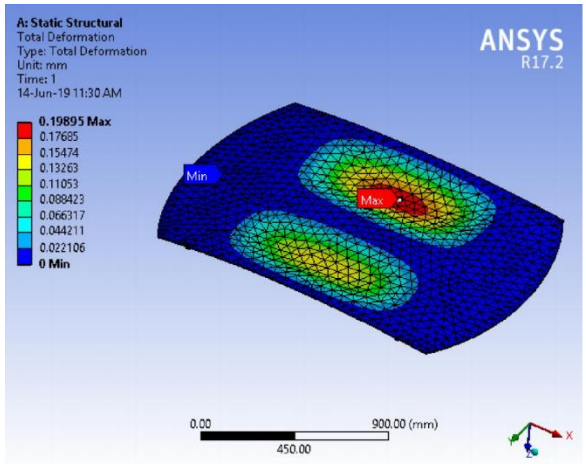


Figure 4.18: Total deformation of structural steel.

The maximum and minimum deformation 0.19895 mm and 0 mm is obtained respectively.

C. Stress distribution of carbon fiber and sisal fiber composites

The equivalent or von-mises stresses are considered for analyzing of the roof panel and its respective stress distribution are shown in the figure 4.19 below.

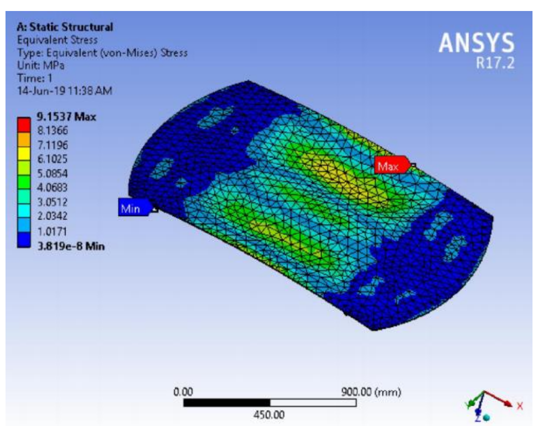


Figure 4.19: Equivalent von-mises stress of CFSFC.

The maximum equivalent stress of carbon and sisal fiber composite roof panel is 9.1537 MPa. The ultimate strength of carbon fiber and sisal fiber composite is 193 MPa which is more and more greater than the equivalent stress developed.

D. Deformation of carbon fiber and sisal fiber composite

The maximum deformation of carbon fiber and sisal fiber composite material of roof panel is 1.4195 mm as shown on figure 4.20.

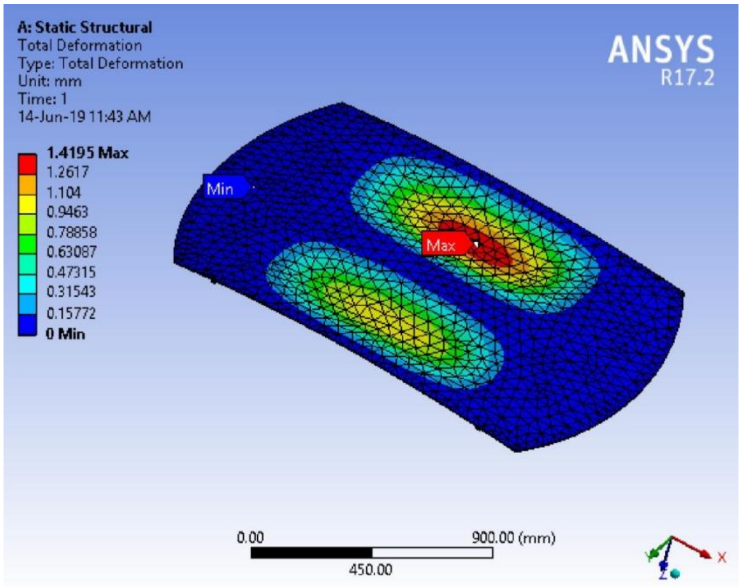


Figure 4.20: Total deformation of CFSFC.

From the result analysis of equivalent von-mises stress and deformation of both structural steel and composite of carbon fiber and sisal fiber were obtained. The values are given in the table 4.11 given below.

Table 4.11: Comparative analysis of structural steel and CFSFC roof panel.

S. NO	Parameters	Structural steel	CFSFC
1	Equivalent stress	9.1537 MPa	9.1537 MPa
2	Deformation	0.19895 mm	1.4195 mm

The figure 4.21 shows the stress distribution when the boundary condition are applied on the lower surface of roof panel.

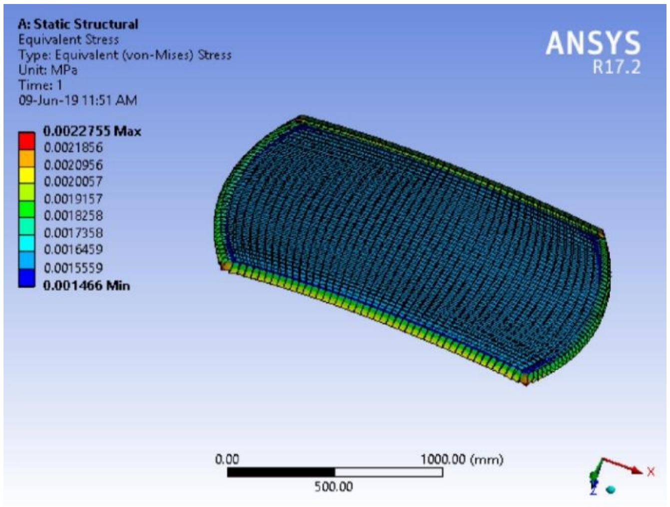


Figure 4.21: Equivalent von-mises stress distribution of structural steel.

The maximum equivalent stress 2275.5 Pa and minimum of 1466 Pa is obtained from the above analysis. In this case, the equivalent von-mises stress developed is very less and making the lower surface fixed is not safe.

The total deformation of the structural steel roof panel when the lower surface is fixed is shown in the figure 4.22.

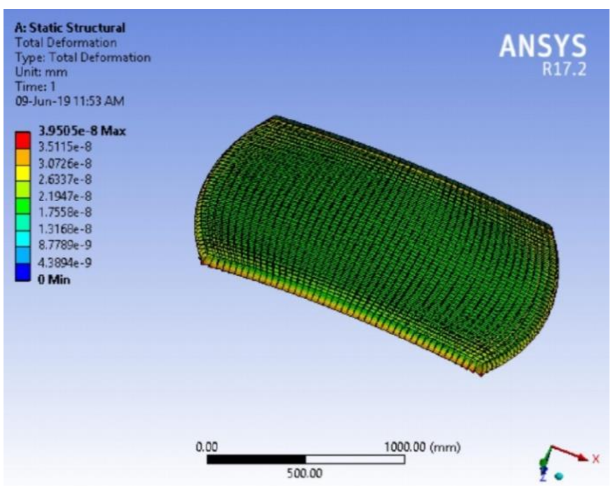


Figure 4.22: Total deformation of structural steel.

The maximum deformation is 3.9505×10^{-8} mm as shown in figure 4.22 above.

The equivalent or von-mises stresses are considered for analyzing of the roof panel and its stress distribution is shown on figure 4.23 below when the lower surface of roof panel is taken as a fixed support. The maximum equivalent stress of carbon and sisal fiber composite made roof panel is 22755.5 Pa. The ultimate strength of carbon fiber and sisal fiber composite is 193 MPa which is more and more greater than the equivalent stress developed (figure 4.23).

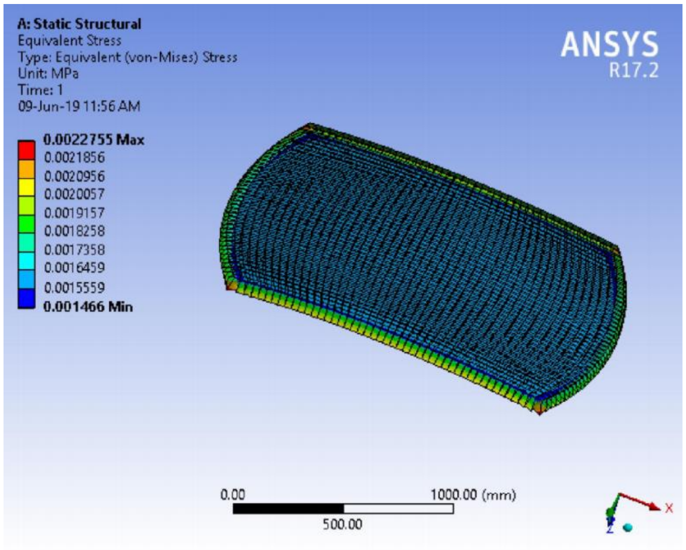


Figure 4.23: Equivalent von-mises stress of CFSFC.

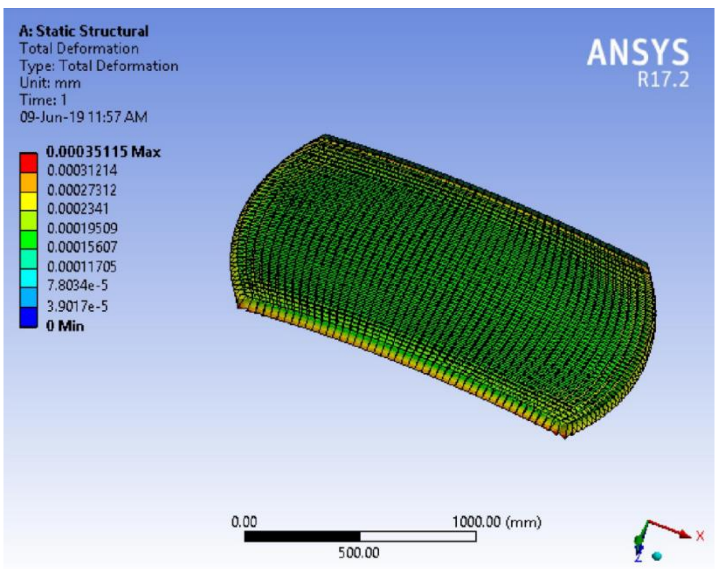


Figure 4.24: Total deformation of CFSFC.

The maximum deformation of carbon fiber and sisal fiber composite material of roof panel is 3.5115×10^{-4} mm when the lower surface of the roof panel is fixed (Figure 4.24).

From the analysis of equivalent von-mises stress and deformation of both structural steel and composition of carbon fiber and sisal fiber with lower surface fixed, their value are done by using ANSYS 17.2 and finally their comparative values are given in the table 4.12.

Table 4.12: Comparative result of a lower surface fixed support.

S. NO	Parameters	Structural steel	CFSFC
1	Equivalent stress	2275.5 Pa	2275.5 Pa
2	Deformation	3.9505×10^{-8} mm	3.5115×10^{-4} mm

The purpose of static structure analysis is to know the developed equivalent (von-mises) stress and deformation of vehicle roof panel for both structural steel and CFSFC materials. The analysis of equivalent stress and deformation was performed by ANSYS 17.2 for analyzing the stress developed and deformation of the model. For the analysis, two types of boundary condition were performed with 12458.7 N applied force. With the fixed bottom surface the value obtained for structural steel was 2275.5 Pa and 3.9505×10^{-8} mm equivalent stress and deformation respectively while CFSF composite materials obtained 2275.5 Pa and 3.5115×10^{-4} mm equivalent stress and deformation respectively. Another analysis has done by fixing the edge, longitudinal and side members of the roof panel support. With this boundary condition, structural steel obtained 9.1537 MPa with 0.19895 mm equivalent stress and deformation while CFSFC material obtained 9.1537 MPa with 1.4195 mm equivalent stress and deformation respectively.

5. CONCLUSSIONS AND RECOMMENDATIONS

5.1. Summary

Most of the time vehicle bodies are manufactured from conventional materials such as mild steel, structural steel and any other metallic materials which exposed the vehicles for higher load and fuel consumption. Nowadays, for the sake of weight minimization the researcher starts to replace the metallic parts of vehicles body into composite materials. Due to heaviness of materials used in automobile industries, increase in weight and less fuel efficiency was the great problem for vehicle manufacturers. Recently, these problems are getting solution by replacing conventional materials into composite one. This work concerned on structural analysis of light duty vehicle roof panel made of carbon fiber and sisal fiber composite materials by varying fiber orientations which helps to reduce weight and fuel consumption of a vehicle. This thesis conducted on the experimental analysis of carbon fiber and sisal fiber using general polyester resin and hardener. The tensile, bending, compression and water absorption test was conducted on prepared specimens. The roof panel was modeled by SOLIDWORK 2013 and the structural analysis was done using ANSYS 17.2. Under experimental analysis, $0^0/90^0$ was performed a good result in tensile, bending and water absorption were both are obtained equal values in compression test. In case of finite element analysis, both CFSFC and structural steel obtained equal values in equivalent (von-mises) stress with different deformation results.

5.2. Conclusions

5.2.1. Specimen testing

The carbon fiber and Sisal fiber composite samples were fabricated with two different orientations of $0^0/90^0$ and $\pm45^0$. The hybrid composite specimens were tested for tensile, Bending, Compression and also the water absorption. Based on the results obtained, the following conclusions are drawn:

- ❖ The result indicated that the $0^0/90^0$ orientation of CFSF composite shows tensile strength with the range values in between 178 MPa to 214 MPa with the average result of 193 MPa which makes this orientation higher than that of $\pm45^0$ orientation having the values in between 88 MPa to 111 MPa with average values of 103 MPa.

- With the test result of bending strength, the CFSF composite materials of $0^0/90^0$ orientation is capable of having the maximum bending strength with 1.1 mm displacement and 2.51 kN load when it is compared with that of $\pm45^0$ orientation of having bending strength with 1.31 mm displacement and 1.62 kN load.
- The results shown from the compression test of CFSF composites with $0^0/90^0$ and $\pm45^0$ orientation are remain the same with 7.7 MPa.
- The water absorption test result of $0^0/90^0$ and $\pm45^0$ orientation obtained that 2.91% and 3.67% of water absorption values respectively. $0^0/90^0$ orientation has lower absorbing tendency than that of $\pm45^0$ orientation.
- By considering all results of mechanical and physical laboratory test of tensile, bending, compression and water absorption result drawn above it is better to manufacture vehicle roof panel from 0/90 degree orientation of CFSF composite materials.
- By employing a composite of carbon fiber and sisal fiber to the light vehicle for the same volume of roof panel, there is a reduction in weight of 83% comparing with structural steel. From the result, it is observed that the CFSF composite light weight vehicle roof panel is lighter and more economical than the conventional steel roof panel with similar design specifications.
- Finally, as we understand from the result obtained, these CFSF composite materials can be used in automobile companies for different application of body parts.

5.2.2. FEM analysis

In the work of analysis, the light duty vehicle was modeled using SOLID WORK 2013. Static structural analysis was done on the roof panel using ANSYS work bench 17.2. For carbon fiber and Sisal fiber composite materials, the finite element analysis result shows that the equivalent stress for structural steel and carbon fiber with sisal fiber composition are 9.1537 MPa. In this case, both structural steel and CFSFC have the same equivalent (von-mises) stress of 9.1537 MPa. And also, the result of total deformation for structural steel and CFSFC are 0.19895 mm and 1.4195 mm respectively.

Table 5.1: Equivalent stress and deformation of roof panel.

S No.	Materials	Equivalent stress (MPa)	Total deformation (mm)
1	Structural steel	9.1537	0.19895
2	CFSFC	9.1537	1.4195

Although the magnitude of stress developed on the roof panel of each material for a particular load case is the same, the total deformation value is different. The maximum deformation is obtained on CFSFC than structural steel for the same load case. This is due to less stiffness of composite materials than steel i.e., the material with more stiffness exhibits less deformation. But, the strength and stiffness to weight ratio of composites are higher.

Generally, by employing a composite of carbon fiber and sisal fiber to the light vehicle for the same volume of roof panel, there is a reduction in weight of 83% comparing with structural steel.

Table 5.2: Weight comparison of structural steel and CFSFC.

S No.	Materials	Weight (kg)	Saved weight (kg)	Weight reduction (%)
1	Structural steel	34.93	--	--
2	CFSFC	6	28.93	83

5.3. Recommendations

- ✓ It was a big problem getting a mechanical testing machine to conduct tensile, compression and bending tests. Because of that, our time is spent by finding such testing machine searching at different places of Addis Ababa and country side. Our university should have to solve this problem by facilitating such kind of basic machine for next up coming generations.
- ✓ Due to an open molding system, getting an exact dimension for a molded specimen was somewhat challenging. So, if it is possible the next researcher should have to use such vacuum bagging molding system for sake of getting an exact dimension of molds.
- ✓ Cultivate sisal fiber plants is very use full due to their highly usage for manufacturing vehicle’s body parts by mixing either with other natural fiber or synthetic fiber.

- ✓ Finally, it is good to recommend the automobile body manufacturing companies to manufacture vehicles roof panel and any other body parts by using carbon fiber and natural fiber composites for the sake of reducing vehicles weight and improving fuel efficiency.

5.4. Future works

- ✓ Because of the manual extraction of sisal fiber is very hard, there was a big challenge preparing a specimen on time. So, it is recommended for the next researcher to design and fabricate mechanically operated machine for sisal fiber extraction purpose.
- ✓ Vehicle roll over analysis is not done in this work. So, the next researcher should take part to analyze vehicle roll over analysis.
- ✓ It is also recommended to conduct composition analysis parallel with that of orientation analysis.
- ✓ By mixing a carbon fiber with any other natural fibers the next researcher can analyze and design vehicle chassis frame and any other parts.
- ✓ The dynamic analysis of the roof also to be done by the future researcher.

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APPENDIXES

A. Experimental data

i. In this appendix, the laboratory experimental data sheet which is collected from Ethiopian conformity Assessment Enterprise during tensile test is found with values and detail information.

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Ethiopia Conformity Assessment Enterprise

ቁጥር (No.) 218/16.2/100288/19
ቀን (Date) 03 JUN 2019

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To: Abenezer Shimellis
Adama

On you request dated May 30, 2019 you have requested for the analysis on Carbon fiber and sisal fiber composite material.

Accordingly, the analysis is completed as per your request and hence you find the report attached here with.

Regards,

Tesfaye Solomon
Head, Branch Coordination and Customer's Service

THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA
ETHIOPIAN CONFORMITY ASSESSMENT ENTERPRISE

Enc: 2 Page of test reports MTR/2155-56/11

CC. ECAE

- Customer's Service
  Addis Ababa

ወደ ላቀ ብቃት የሚያደርስ!
Moving you forward!

ECAE ኢትምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No. TLD/F5.10-1	
		Copy No: -	Rev No: 1
Title:	TEST REPORT ይህ የናሙና ፍተሻ ሪፖርት እንጂ ሰርተፍኬት አይደለም	Page No: 1 of 1	Effective Date: 1Jan 13

Report No: MTR/2155/11
Test order No: ---

1	Name and address of client	Abenezer Shimellis Tel: +251-922-68-28-41, Adama
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	30/05/2019
5	Client's sample code	Adama Science & Technology University
6	Laboratory designated sample No.	11262076
7	Type of sample	Carbon & sisal fiber composite 0/90^0
8	Test method	As per client's agreement
9	Test date(s)	03/06/2019
10	Date of Submission of test report	03/06/2019

L.D.S No.	Test No.	Test Result Tensile strength (Mpa)
11262076	1	214
	2	186
	3	178
Average		193

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory
2. Sample prepared and submitted by customer.

Test report authorized by, Name Liyew Wudie Position Analyst I Sign

11145 011 6 46-05-69, Fax. 011 6 45-97-20, E-mail info-cs@eca-e.com Web site: www.eca-e.com
BOLE SUBCITY, WOREDA 6
ADDISABABA, ETHIOPIA

ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No. TLD/F5.10-1	
		Copy No: -	Rev No: 1
Title:	TEST REPORT ይህ የናሙና ፍተሻ ሪፖርት እንጂ ሰርተፍኬት አይደለም	Page No: 1 of 1	Effective Date: 1Jan 13

Report No: MTR/2156/11
Test order No: ---

1	Name and address of client	Abenezer Shimellis Tel: +251-922-68-28-41, Adama
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	30/05/2019
5	Client's sample code	Adama Science & Technology University
6	Laboratory designated sample No.	11262077
7	Type of sample	Carbon & sisal fiber composite ± 45^0
8	Test method	As per client's agreement
9	Test date(s)	03/06/2019
10	Date of Submission of test report	03/06/2019

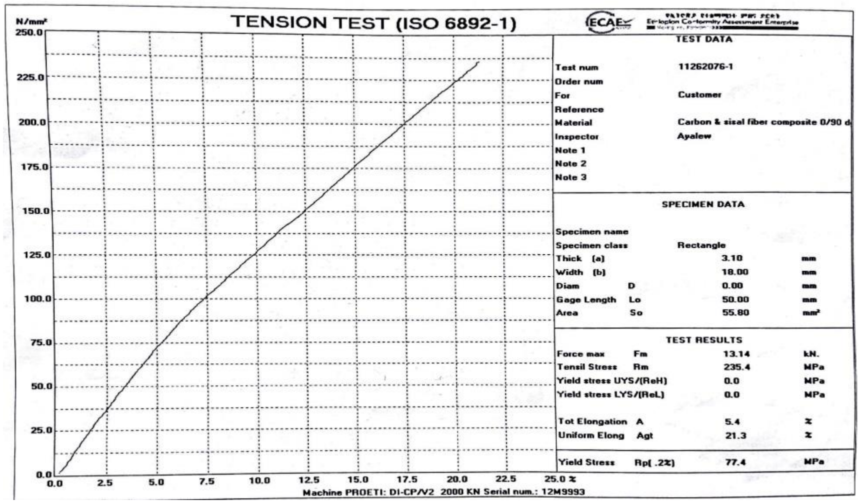
L.D.S No.	Test No.	Test Result Tensile strength (Mpa)
11262077	1	119
	2	88
	3	102
Average		103

Remark:

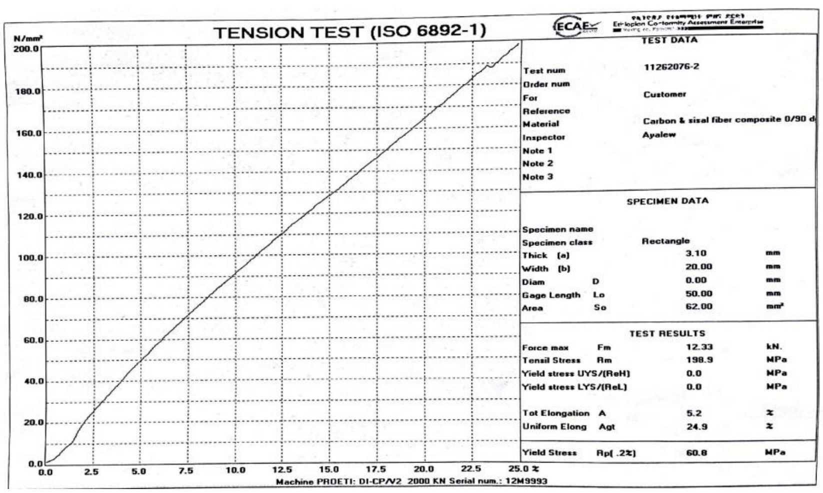
1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory
2. Sample prepared and submitted by customer.

Test report authorized by, Name Liyew Wudie Position Analyst I Sign.

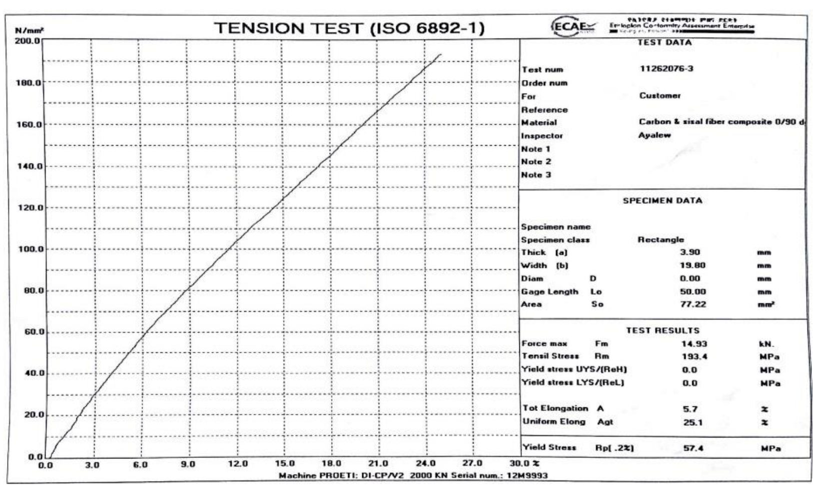
✉ 11145 ☎ 011 6 46-05-69, Fax. 011 6 45-97-20, E-mail info-cs@eca-e.com Web site: www.eca-e.com
BOLE SUBCITY, WOREDA 6
ADDISABABA, ETHIOPIA



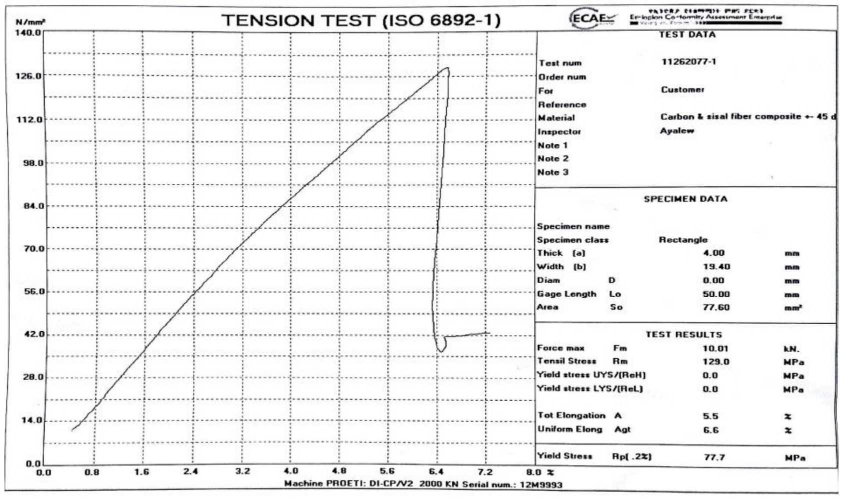
a. 0/90 degree tensile test-1 with max. Values of 214 Mpa.



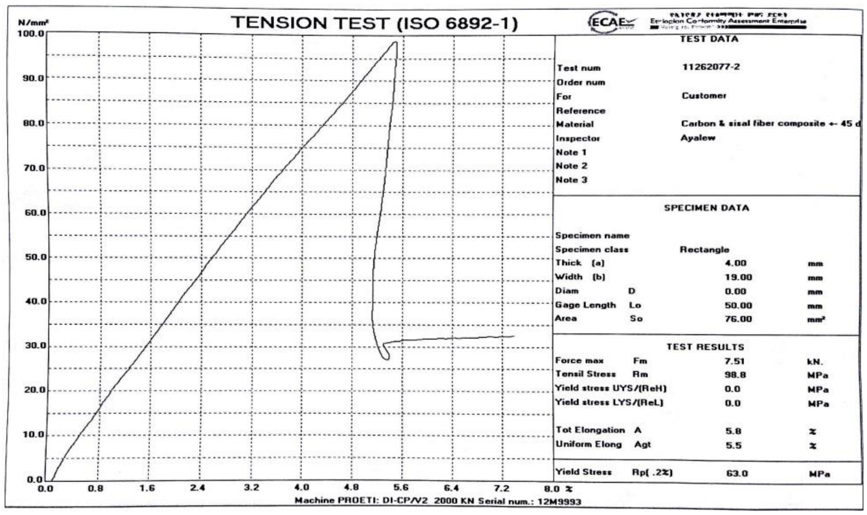
b. 0/90 degree tensile test-1 with max. Values of 186 Mpa.



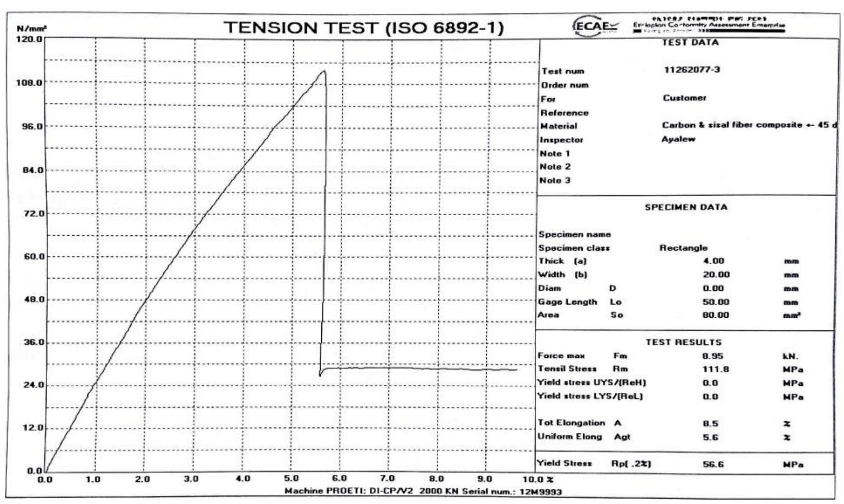
c. 0/90 degree tensile test-1 with max. Values of 186 Mpa.



a. ± 45 degree tensile test-1 with max. Values of 119 Mpa.



b. ± 45 degree tensile test-2 with max. Values of 88 Mpa.

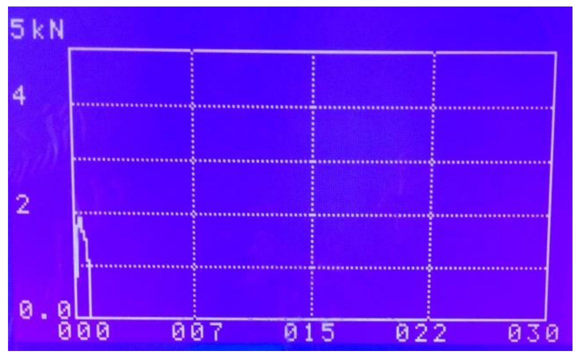


c. ± 45 degree tensile test-3 with max. values of 102 Mpa.

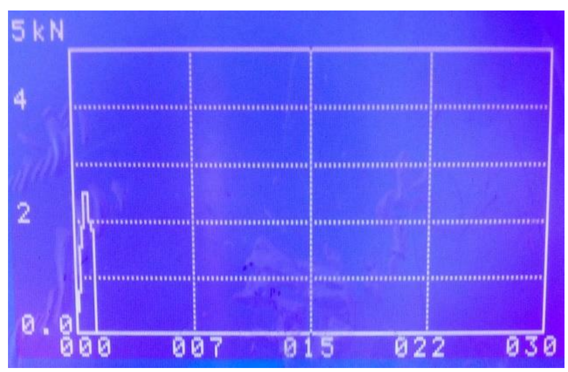
Bending strength test data which is taken from Belay-Ab cable plc.

i. Bending result of 0/90 degree

a. Table and graph of specimen-1

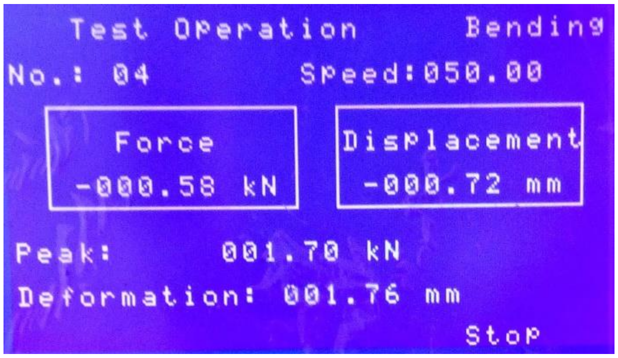


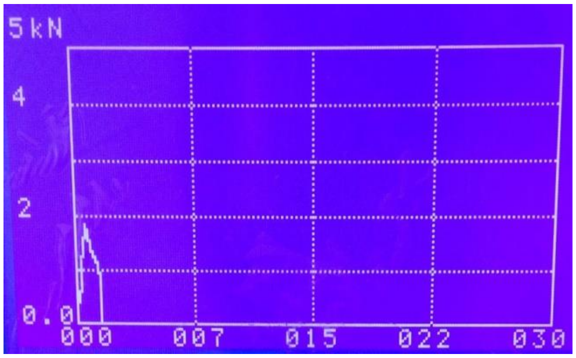
b. Table and graph of specimen-2



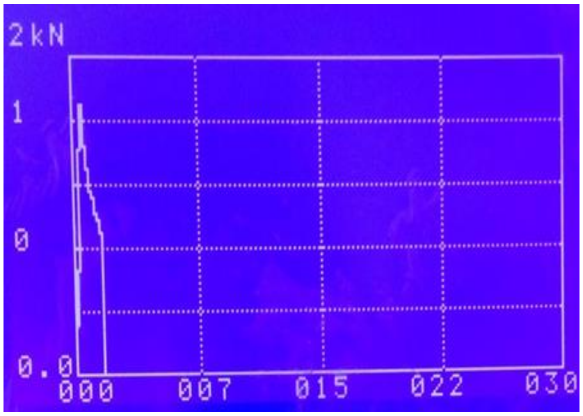
c. Table and graph of specimen-3

ii. Bending result of ± 45 degree

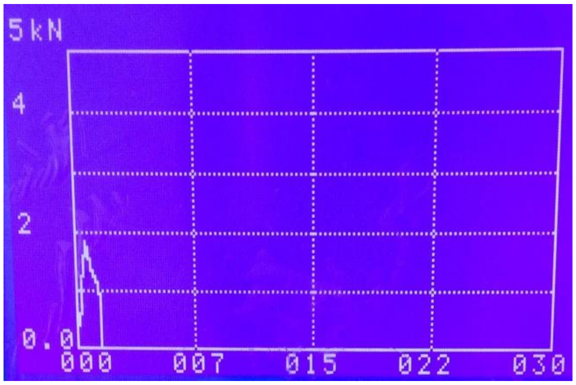




a. Table and graph of specimen-1



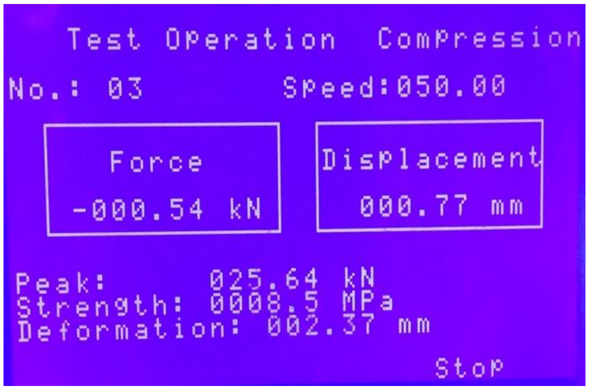
b. Table and graph of specimen-2

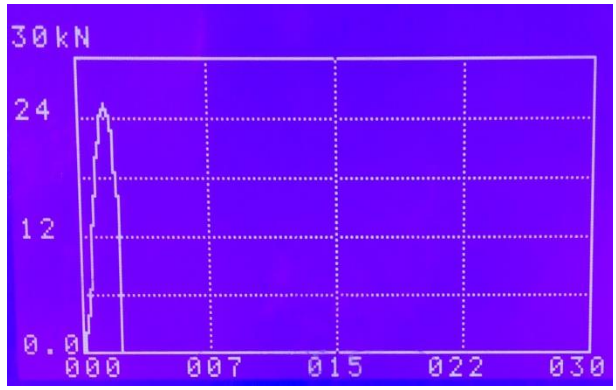


c. Table and graph of specimen-3

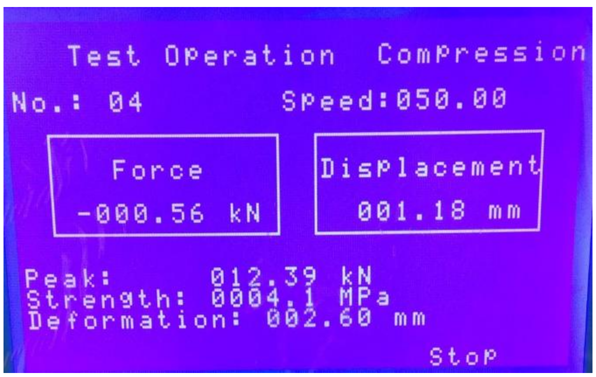
Compression strength test data which is taken from Belay-Ab cable plc.

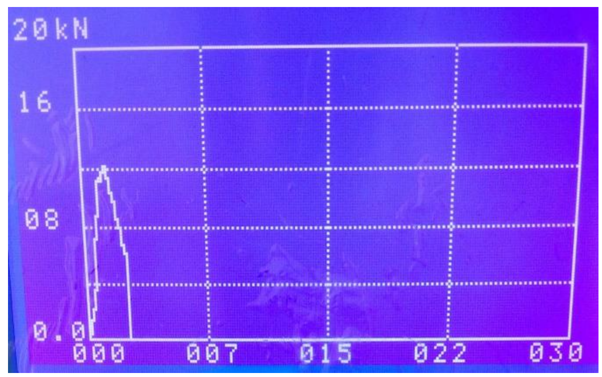
i. Compression result of 0/90 degree



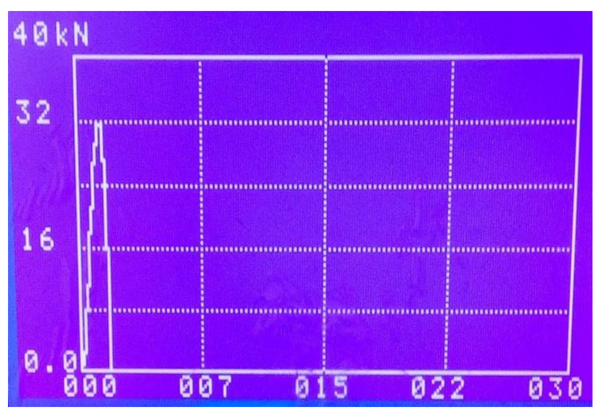


a. Table and graph of specimen-1



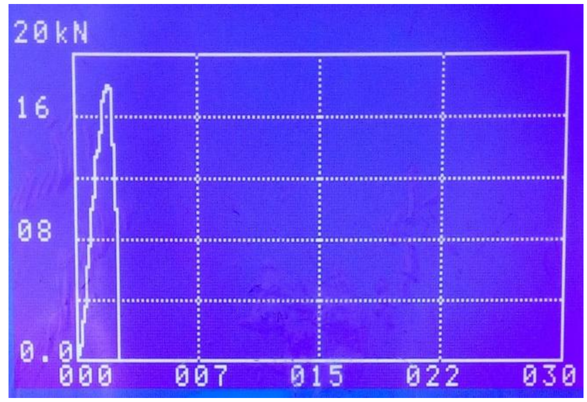


b. Table and graph of specimen-2

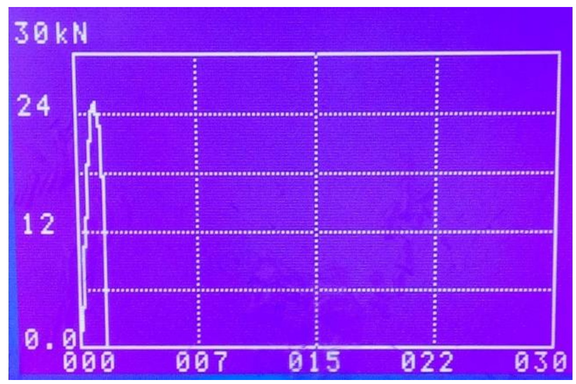


c. Table and graph of specimen-3

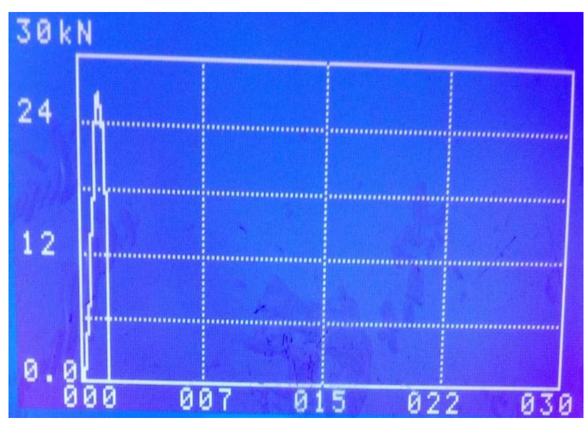
ii. Compression result of ± 45 degree



a. Table and graph of specimen-1



b. Table and graph of specimen-2



c. Table and graph of specimen-3

B. Pictures.

C. Cost estimation

S No.	Items	Quantity	Cost (Birr)
1	Carbon fiber	2 m^2	2400
2	Sisal fiber	2 kg	200
3	Gp resin	12 kg	1620
4	Hardener	0.5 kg	260
5	PVA	0.5	420
6	Mold release wax	1 pack	520
7	NaOH	1 pack	150
8	Distilled water	22 liters	220
9	Gloves	17 pcs	204
10	Small paint brush	1 pcs	25
11	Nails	0.25 kg	25
12	Scissor	1 pcs	15
13	Labor	7 days	1400
	Total cost		7459

According to the information gathered from MOENCO, the current price of Toyota vitz model roof panel which is imported from Japan is 15,000 birr. But, to manufacture roof panel with the same volume it may cost 7459 birr. With this cost estimation, it is obvious that the cost of the roof panel is reduced by 7541 birr.

D. Fuel saved

S No.	Weight comparison		Fuel consumption (km/liter)
1	Original weight	1270	18
2	Reduced weight	1241.07	18.41

Due to weight reduction of roof panel, the fuel consumption is reduced by 2.28 % with the replacement of structural steel roof panel into carbon fiber and sisal fiber composite material.

Mass properties of CFSFC materials

Mass properties of PP
Configuration: Default
Coordinate system: -- default --

Density = 1345.5 kilograms per cubic meter

Mass = 5.991626 kilograms

Volume = 0.00445309 cubic meters

Surface area = 4.4645226 square meters

Center of mass: (meters)
X = 0.75120299
Y = 0.64043286
Z = 0.31965483

Principal axes of inertia and principal moments of inertia: (kilograms * square meters)
Taken at the center of mass.
Ix = (0.99994845, 0, 0.01015356) Px = 0.78996832
Iy = (0, 1, 0) Py = 1.5000145
Iz = (-0.01015356, 0, 0.99994845) Pz = 2.2864156

Moments of inertia: (kilograms * square meters)
Taken at the center of mass and aligned with the output coordinate system.

Lxx = 0.7901226	Lxy = -1.3e-007	Lxz = 0.01519348
Lyx = -1.3e-007	Lyy = 1.5000145	Lyz = 4e-008
Lzx = 0.01519348	Lzy = 4e-008	Lzz = 2.2862614

Moments of inertia: (kilograms * square meters)
Taken at the output coordinate system.

Ixx = 3.8598331	Ixy = 2.8825417	Ixz = 1.4539366
Iyx = 2.8825417	Iyy = 5.4933442	Iyz = 1.2265905
Izx = 1.4539366	Izy = 1.2265905	Izz = 8.1248623