# Hybridization of Fiberglass and Banana Pseudo-Stem Fiber Reinforced Composite for the Production of a Car Bumper

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| Abstract | Case Studies |
|---|---|

Hybridization is one of the ways to increase the mechanical properties of reinforced composite materials. The intent of this study was to investigate the structure and materials employed for a light weight car bumper. In this paper an existing car bumper was used as a master model which was used to produce the scale size and full size mould for the production of hybrid reinforced composite. The production was carried out by hand layup process using different weight percentage of fiberglass/banana pseudo-stem fiber as reinforcement and polyester resin as matrix. Eighteen (18) specimens of scale size were produced and the optimal results obtained from the production were used to produce the full size car bumper. The mechanical properties like tensile, compression, flexural and impact tests were carried out on the eighteen (18) specimens and the optimal results obtained are tensile strength 34.76N/mm2, compression strength 131.37N/mm2, flexural strength 86.5 N/mm2 and impact strength 17.95KJ/m2 respectively. The same mechanical properties tests were carried out on the existing car bumper (ABS Plastic) and the results obtained are tensile strength 20.71N/mm2, compression strength 4.85 N/mm2, flexural strength 17.73 N/mm2 and impact strength 31.96 KJ/m2 respectively. In addition to mechanical properties tests conducted others characterizations like x-ray fluorescence (XRF), x-ray diffraction (XRD), Thermo gravimetric analysis (TGA), Fourier transform infrared spectroscopy (FTIR), Scanning electron microscopy (SEM), Water absorption and Slake durability index studies were also employed to obtain information about the crystal structure, chemical composition and functional group present in the hybrid fiber reinforced polymer composite produced. In comparing the results the fabricated car bumper shows significant improvement in mechanical properties than existing one. Therefore, it is based on the optimization results obtained that the weight percentage of 25% of synthetic and 5% of natural fiber was used to produce the full size of the car bumper. Weight comparison of similar car bumper was made and the results shows that alloy steel weight 12.2 kg, alloy aluminium weight 9.57 kg, ABS plastic weight 6.04 kg and hybrid weight 4.09 kg respectively.

**Keywords:** Fiberglass, Banana pseudo-stem, Polyester, characterization.

## 1.0    INTRODUCTION

The composites are well known to mankind since pre-historic period and were practiced as well. But with the development of polymers and polymer science, the concept and technology have undergone a sea change in the understanding of the basics like the role of matrix and reinforcement, bonding mechanism

morphological features and environmental effects etc.

Polymer composites due to their lightweight, chemical and corrosion resistance as well as heterogeneous composition provide unlimited possibilities of deriving any characteristics material behaviour. This unique flexibility in design tailoring and other characteristics, such as ease of manufacturing, high specific strength, stiffness, shape moulding, corrosion resistance, durability, adaptability and cost effectiveness, have attracted the attention of engineers, material scientist and technologists. The have becomes the materials of $21^{st}$ century to meet the requirement of space, missile, and marine and medical aid technologies [1].

An automobile bumper is a shield made of steel, aluminium, rubber, or plastic that is mounted on the front and rear of a vehicle. When a low speed collision occurs, the bumper system absorbs the shock to prevent or reduce damage to the car. The bumper is not capable of reducing the effect of impact at high speeds instead they are focused on mitigate injury to pedestrians struck by cars. In existing bumper, the weight is more. In the present trends the weight reduction has been the main focus of automobiles manufactures. Less fuel consumption, less weight, effective utilization of natural resources is main focus of automobiles manufactures in the present scenario. The above can be achieved by introducing better design concept, better materials and effective manufacturing process.
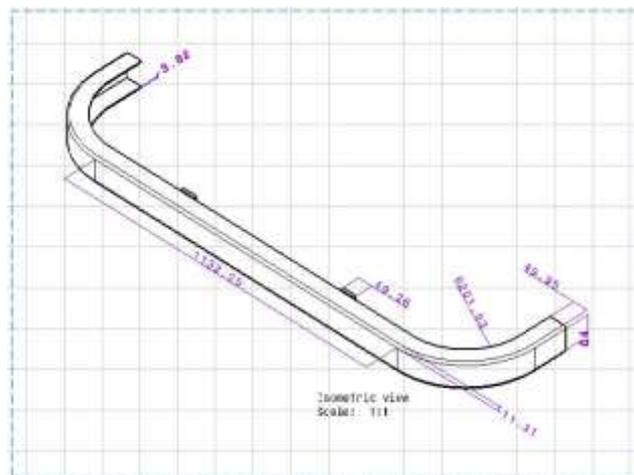


**Figure 1.1: Schematic drawing of a car bumper.**

The choice of materials for automotive car bumper and other vehicle components is one of the most important design parameters in automotive manufacturing. The type of material used has significant effects on the overall attractiveness of a vehicle which includes the aesthetics, cost, performance, emission levels and fuel economy. For vehicle manufacturers, weight is a very important factor in choosing materials for automotive components as it affects many other attributes, so active measures are recurrently taken to utilize lightweight materials for car components as much as possible [2]. Cost, however, is an important factor which is also taken into consideration in materials such as

aluminium, magnesium; carbon fibers are more expensive than the heavier materials such as steel and cast iron for reasons including abundance and ease of fabrication [3]. In the decision making process of the design, therefore, compromise is often met to balance both cost and weight requirements.

According to [4], the composition of steel in car component was about 75% in 1977 which reduced to 65% in 2010 due to increase in polymers and composite used mostly for interior components. To achieve the goal of reducing fuel consumption of new vehicles by a factor of two by 2035 [5], the US Department of Energy believes that the use of more lightweight

materials such as aluminium, magnesium and polymer/ composites will be required to push the composition of steel further down to 20% by 2035 [US Department of Energy, 2010]. Although aluminium is considered as the most common car material for lightweight purposes, plastics are much lighter but rarely used for structural components because of their lower mechanical properties compared to the metals. However, with adequate reinforcement, the polymeric composites formed can have similar mechanical properties of steel and aluminium such as high strength and toughness while maintaining their light weight. Composites are formed by specific arrangement or overlaying of a stronger material, e.g. metal fibers or flakes with a weaker material to form a new one. Most polymer composites are formed using fibrous reinforcement arranged in a continuous or non-continuous manner within a polymer matrix [6]. Common examples used are fibers of glass, carbon and aramid, to provide strength and stiffness of polymer matrices such as polyester, polyurethane, epoxy, polypropylene, polyethylene, nylon, etc. [7]. Polymer composites can also be formed by appropriately adding nanoparticles to a polymer matrix to form Nano composites which have higher performance composites with excellent mechanical and electrical properties and lighter weight [8]. Unlike ordinary plastics, polymer composites are useful for exterior and structural parts of a vehicle because of their reinforcements. They, therefore, have a major role to play in reducing vehicle weight and fuel consumption by replacing many steel components.

## 2.0 MATERIAL AND METHOD

### 2.1 Materials

For the production of composite bumper, an already existing plastic bumper was used as a master model to produce the mould and the dimensions are assumed as same as that of master model for the production. The following materials were used during the course of this production:

i. Unsaturated polyester resin
ii. Fiberglass woven mat
iii. Banana pseudo-stem fiber reinforcement
iv. Cobalt naphthenate as accelerator and catalyst
v. Methyl ethyl ketone peroxide [MEKP] as hardener
vi. Release agent
vii. Already existing bumper as a master model
viii. Brush and/or roller, scissors
ix. Cleaning equipment- acetone, containers
x. Personal protective equipment [PPE], gloves, lab coat, safety glasses etc.

### 2.2 Method

The reinforced composite bumper was fabricated using the hand lay-up method. Prior to the composite preparation, a mould was produced using an existing bumper as a master model. The surface of the mould produced was well polished and a mould-releasing agent (waxpol) was applied on the surface of the mould to ease removal of the casted product. Unsaturated polyester resin (UPR) was thoroughly mixed with 1% by wt. Cobalt nephtbenate as accelerator and 1% by wt. MEKP as catalyst. On adding the catalyst or hardener the resin began to become more viscous until it reaches a state when it is no longer a liquid and has lost its ability to flow, this is the gel point. The resin continued to harden after it has gelled until it has fully hardened. This reaction itself is accompanied by the generation of exothermic heat, which, in turn, speeds the rate of reaction; this is known as the curing of the resin. The fibers (synthetic and natural) are cut and stacked in a specified shape are placed evenly (Discontinuous) inside the mold. Using a metallic roller, the air bubbles were carefully removed and the two fiber were allowed to wet completely. The mould was closed and the excess resin was allowed to flow out as flash by stabbing with hand brushes. The pressure was held constant during the curing process at room temperature for some minutes. After the curing process the composite produced was removed from the mould and finishing process was carried out on it. Table 2.1 below showed the weight percentage of the control factors.

### Table 2.1: WEIGHT PERCENTAGE OF CONTROL FACTORS

| Factors | Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|---|
| Weight of fiber glass (%) | 10 | 20 | 30 | 40 |
| Weight of Banana fiber (%) | 0 | 5 | 10 | 15 |



CASTED SCALE SIZE OF CAR BUMPERS

SCALE SIZE MOULD FOR THE COMPOSITE

FULL SIZE MOLD OF CAR BUMPER

CASTED FULL SIZE OF CAR BUMPER

## 2.3 CHARACTERIZATION OF HYBRID FIBER REINFORCED POLYMER COMPOSITE

The researchers utilized various analytical techniques to characterize and analyse the hybrid fiber reinforced polymer composite of the car bumper produced. Scanning electron microscopy (SEM) with Energy disperse x-ray spectroscopy (EDX) was used to study the microstructure and chemical composition of the car bumper. X-ray fluorescence (XRF) and X-ray diffraction (XRD) provided information on the elemental composition of mineralogical phases present in the car bumper respectively. Fourier transform infrared spectroscopy (FTIR) allowed for the identification of functional groups and molecular bonds within the samples while Thermo gravimetric analysis (TGA) measures mass change as a function of temperature. These analytical techniques were used to determine all the necessary parameters for this research work.

## 2.4 WATER ABSORPTION /EFFECTIVE POROSITY (BS 812)

Water absorption is influenced by the shape, size and disposition of the mineral grains, since these accounts for the volume of voids and their connections. Effective porosity is an important parameter that influences the strength and weather ability of rocks. It is different from true porosity in that it determines water absorption whereas true porosity or total porosity is a measure of pore volume both sealed and permeable.

BS. 812 (1967) recommends four methods by which water absorption/ effective porosity can be determined depending on the aggregate size. Method B which test material sizes between 38.10mm and 9.52mm was used. The sample was dried in an oven at a temperature of $105^0C \pm 5^0C$. This was then cooled in air tight desiccators and the weight determined. It was then immersed in distilled water in a gas jar for 24 hours, at a temperature of 20 to $25^0C$. Bubbles of air entrapped in the vessel and on the surface of the aggregate were removed by gentle agitation.

The drained sample was gently surface dried with an absorbent cloth until all surface moisture was removed. The sample was transferred to another dry absorbent cloth and spread on it in such a way that all the aggregate was exposed to the atmosphere (not direct sunlight or any other source of heat) to remove all films of water. This still damp sample was weighed.

## CALCULATION

Water absorption/effective porosity (%) = 100 (W2-W1)/W1

Where W1 = weight of damp aggregates

W2 = weight of oven dried aggregates

## 2.5 SLAKE DURABILITY INDEX (ASTM D4644-87)

The slake durability test first proposed by Franklin and Chandra (1972) is a test intended to assess the resistance offered by a sample to weakening and disintegration when subjected to one or more cycles of wetting and drying in a slaking fluid, usually water. It provides an index to describe the degree of material alterability and relate the properties of the rocks to that index.

The ASTM D4644-87 was adopted for this particular investigation.

The slake durability test apparatus consists of two drums, 100mm long and 140mm in diameter made of wire mesh having 2mm apertures. These are mounted in water bath half filled with water.

10 lumps of the material were selected and oven dried to a constant weight at the temperature of $105^0C$. The empty drums were weighed and their masses recorded. Then the weight of the drum with samples where ascertained and recorded.

The materials in the drums were subjected to rotation with a speed of 20 rotations per minutes in the water bath for a period of 10 minutes, after which they were taken to the oven to dry at a temperature of $105^0C$ thus, concluding one cycle. Two cycles have been recommended as one weathering cycle and the value of the dry mass after the 2nd cycle expressed as a percentage of the original mass is the slake durability index.

## CALCULATION

Slake durability index $(I_{d1})$ = (B-D)/(A-D) X 100

The test is repeated a second time and C was the final dry mass of the drum and residual sample.

Slake durability index $(I_{d2})$ = (c-d)/(a-d) X 100

Where D = mass of empty drum

A = initial dry mass of the drum and sample

B = the new mass of dry drum and sample after first cycle

C = final dry mass of drum and sample after second cycle.

## 3.0    RESULTS AND DISCUSSION
## 3.1 RESULTS

For designing the hybridized composite car bumper, the technique of reversed engineering was adopted. An already existing plastic bumper was used as master model and the dimensions are assumed as the same as that of plastic bumper for fabrication. The fabricated hybridized composite car bumper was subjected to standard mechanical properties according to the lay down procedures of ASTM standards for plastics. The mechanical properties studied are tensile, flexural, compression and impact strength respectively.

## 3.2 Tensile test

The tensile tests were performed according to the ASTM standard on the eighteen (18) specimens using universal testing machine and the results obtained are shows in table (3.1) below. The specimens dimension are (19.7*18*5mm) with load cell of 10KN and crosshead speed of 20mm/min. The stress-strain curve is shows in figure (3.1).

**Table 3.1:    Results: Tensile Strength (N/mm²)**

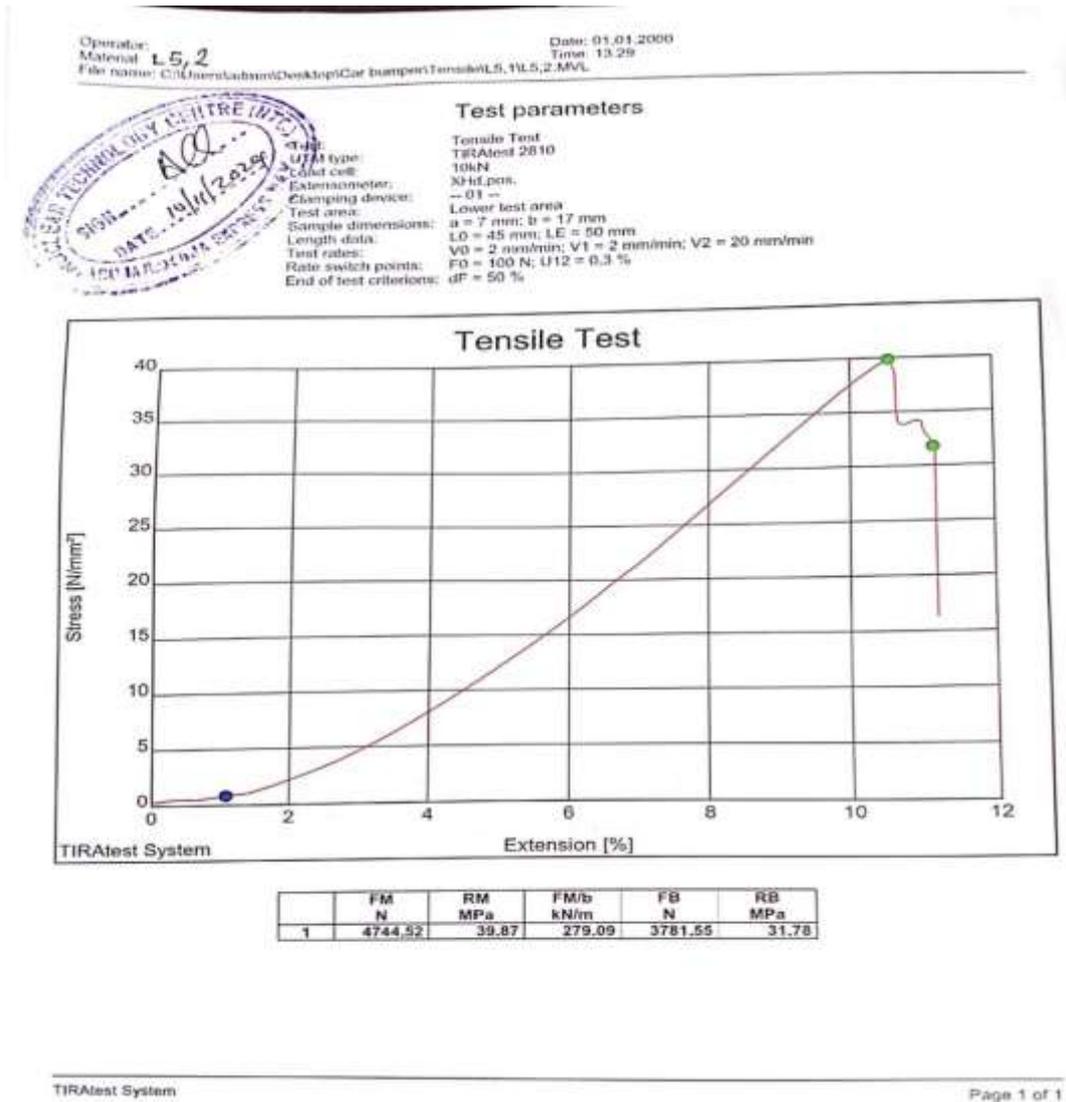| Specimens | L0, 1 | L0, 2 | L0,3 | Average | Optimal Result |
|---|---|---|---|---|---|
| Level0 | 6.11 | 18.88 | 37.15 | 20.71 | Fourth |
| Specimens | L1, 1 | L1, 2 | L1, 3 | | |
| Level1 | 17.00 | 21.38 | 17.00 | 18.46 | Fifth |
| Specimens | L2, 1 | L2, 2 | L2, 3 | | |
| Level2 | 30.04 | 14.26 | 31.55 | 25.28 | Third |
| Specimens | L3, 1 | L3, 2 | L3, 3 | | |
| Level3 | 26.97 | 33.93 | 37.15 | 32.68 | Second |
| Specimens | L4, 1 | L4, 2 | L4, 3 | | |
| Level4 | 6.84 | 11.25 | 11.01 | 9.7 | Sixth |
| Specimens | L5, 1 | L5, 2 | L5, 3 | | |
| Level5 | 33.67 | 39.87 | 30.74 | 34.76 | First |

**Figure 3.1 Tensile stress-strain curves**

### 3.3 Compressive test

Universal testing machine was used for the tests according to the ASTM standard in all the eighteen (18) specimens with the crosshead speed of 10mm/min. and load cell of 10KN. The stress-strain curve is shows in figure (3.2) and details results are in table (3.2).

**Table 3.2: Results: Compressive Strength (N/mm²)**

| Specimens | L0, 1 | L0, 2 | L0,3 | Average | Optimal Result |
|---|---|---|---|---|---|
| Level0 | 4.84 | 6.61 | 3.09 | 4.84 | Six |
| Specimens | L1, 1 | L1, 2 | L1, 3 | | |
| Level1 | 116.89 | 110.43 | 139.12 | 122.14 | Second |

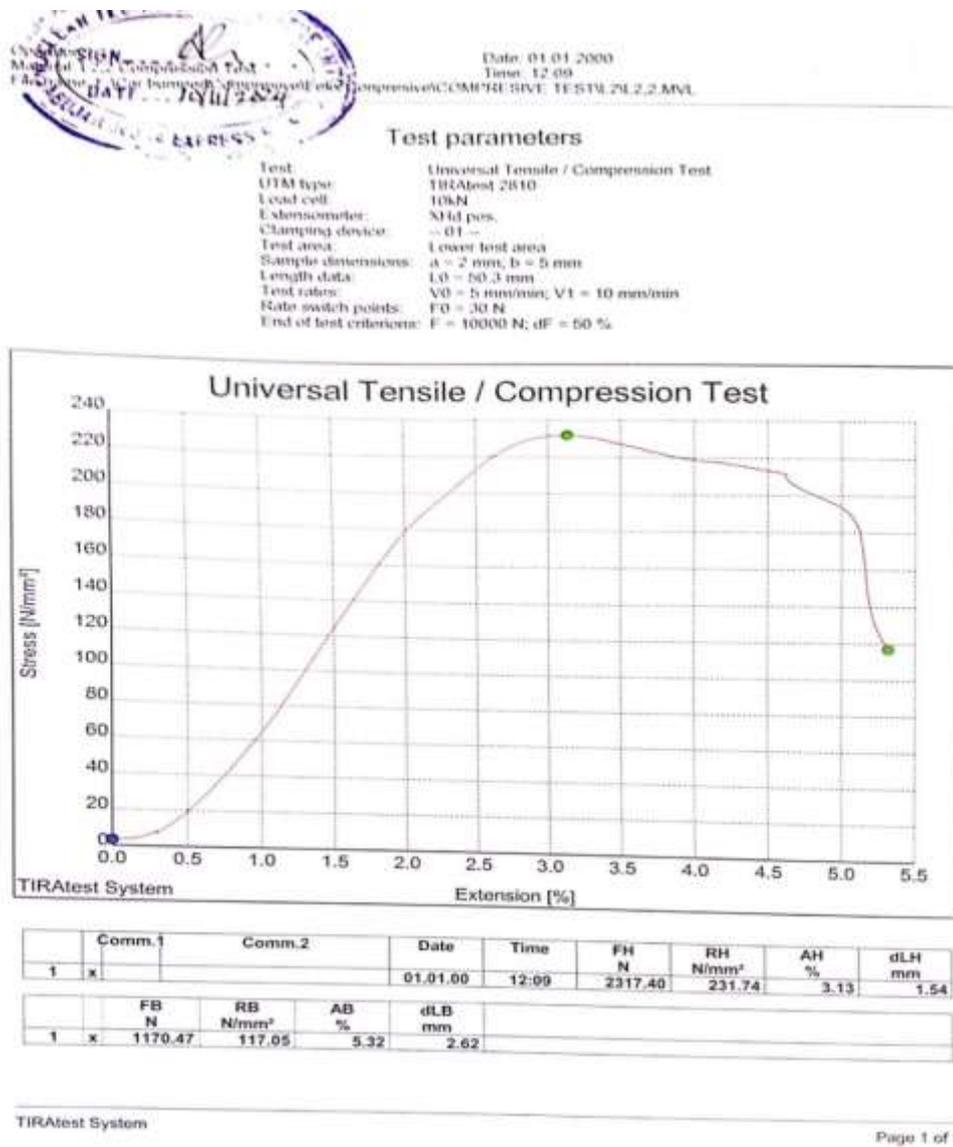| Specimens | L2, 1 | L2, 2 | L2, 3 | | |
|---|---|---|---|---|---|
| Level2 | 68.16 | 231.74 | 94.20 | 131.37 | First |
| Specimens | L3, 1 | L3, 2 | L3, 3 | | |
| Level3 | 8.22 | 29.38 | 4.65 | 14.08 | Fifth |
| Specimens | L4, 1 | L4, 2 | L4, 3 | | |
| Level4 | 62.86 | 192.84 | 76.83 | 110.84 | Third |
| Specimens | L5, 1 | L5, 2 | L5, 3 | | |
| Level5 | 68.16 | 94.15 | 66.94 | 76.41 | Fourth |



**Figure 3.2 Compressive stress-strain curves**

## 3.4    Impact test

The purpose of impact testing is to measure a material's ability to resist impact often as one of the determining factor in the service life of the material. Impact test is a standardized high strain rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition. Impact testing commonly consists of charpy and izod specimen configuration.  Impact test method was conducted according to the ASTM standard on the eighteen (18) specimens with specific dimension and defined notches were prepared and the results obtained are shows in table (3.3).

**Table 3.3:    Results: Impact Strength (KJ/m$^2$)**

| Specimens | L0, 1 | L0, 2 | L0,3 | Average | Optimal Result |
|---|---|---|---|---|---|
| Level0 | 31.364 | 32.245 | 32.261 | 31.957 | First |
| Specimens | L1, 1 | L1, 2 | L1, 3 | | |
| Level1 | 31.364 | 19.851 | 2.640 | 17.951 | Second |
| Specimens | L2, 1 | L2, 2 | L2, 3 | | |
| Level2 | 22.396 | 23.589 | 5.240 | 17.075 | Fourth |
| Specimens | L3, 1 | L3, 2 | L3, 3 | | |
| Level3 | 16.986 | 9.290 | 15.756 | 14.011 | Fifth |
| Specimens | L4, 1 | L4, 2 | L4, 3 | | |
| Level4 | 16.669 | 2.551 | 18.706 | 12.642 | Six |
| Specimens | L5, 1 | L5, 2 | L5, 3 | | |
| Level5 | 21.042 | 14.033 | 17.40 | 17.492 | Third |

## IMPats 15 Manufactured by ATS FAAR Spa ITALY
### Laboratory: POLYMER, GIF

| Test code | 02 | Date Tue 05/11/24 13:00:06 |
|---|---|---|
| OPERATOR | USMAN IM, ADAMU, GADU | |

**TEST CONDITIONS**

| | |
|---|---|
| Material code | EE |
| Supplier | |
| Conditioning | |
| Testing Temperature | 23 |
| | |
| Standard | ISO179 |
| | |
| Notch type | |
| Thickness [mm] | 6.63 |
| Width [mm] | 18.03 |
| | |
| Equipment type | Pendulum |
| SERIAL No. EQUIPMENT | 20008380 |
| SERIAL No. HAMMER | 0232.060 |
| Energy at free swing [J] | 1.639 CORRECTION OFF |

| | Normal Valued | Test Values |
|---|---|---|
| Energy [J] | 2.000 | 1.996 |
| Speed [m/s] | 2.900 | 2.419 |
| Angle [deg] | 150 | 150 |

Comment

**TEST RESULT**

| Test n. | Resilience KJ/m$^2$ | Absorbed Energy % | Absorbed Energy J | Condition |
|---|---|---|---|---|
| L.0.1 | 31.364 | 99.8 | 1.991 | N |
| L.0.2 | 32.245 | 99.5 | 1.985 | N |
| L.0.3 | 32.261 | 99.5 | 1.986 | N |
| AVERAGE | 31.957 | 99.6 | 1.987 | |
| ST. DEV | 0.419 | 0.1 | 0.003 | |
| L.1.1 | 31.364 | 99.8 | 1.991 | N |
| L.1.2 | 19.851 | 100.1 | 1.999 | N |
| L.1.3 | 2.640 | 12.9 | 0.259 | N |
| AVERAGE | 17.951 | 70.9 | 1.416 | |
| ST. DEV | 11.803 | 41.036 | 0.818 | |
| L.2.1 | 22.396 | 100.1 | 1.999 | N |
| L.2.2 | 23.589 | 100.1 | 1.998 | N |
| L.2.3 | 5.240 | 19.9 | 0.398 | N |
| AVERAGE | 17.075 | 73.4 | 1.465 | |
| ST. DEV | 8.383 | 37.807 | 0.755 | |
| L.3.1 | 16.986 | 100.3 | 2.001 | N |
| L.3.2 | 9.290 | 100.3 | 2.001 | N |
| L.3.3 | 15.756 | 100.3 | 2.001 | N |
| AVERAGE | 14.011 | 100.3 | 2.001 | |
| ST. DEV | 3.376 | 0.000 | 0.000 | |

| | | | | |
|---|---|---|---|---|
| L.4.1 | 16.669 | 100.1 | 1.999 | N |
| L.4.2 | 2.551 | 100.3 | 2.001 | N |
| L.4.3 | 18.706 | 95.2 | 1.901 | N |
| AVERAGE | 12.642 | 98.5 | 1.967 | |
| ST. DEV | 7.184 | 2.358 | 0.047 | |
| L.5.1 | 21.042 | 100.1 | 1.999 | N |
| L.5.2 | 14.033 | 100.3 | 2.001 | N |
| L.5.3 | 17.40 | 100.3 | 2.001 | N |
| AVERAGE | 17.492 | 100.2 | 2.000 | |
| ST. DEV | 5.724 | 0.094 | 0.0009 | |

C=Completely broken    N= Non break    P=Partial break    H=Hinge    E=nEcking

## 3.5 Flexural test

There are two methods of determine the flexural properties of materials: three point loading system and four point loading system. In the present work three point loading bending test was carried out on the eighteen (18) test specimens as per ASTM standard with specimens' dimension of (50*25.3*3.8). The flexural test was conducted on the universal testing machine with load cell of 10KN and

crosshead speed of 10mm/min. The experimental study of the eighteen (18) specimens is given in table (3.4) and the stress strain curve is shows in figure (3.4).

**Table 3.4: Results: Flexural Strength (N/mm²)**

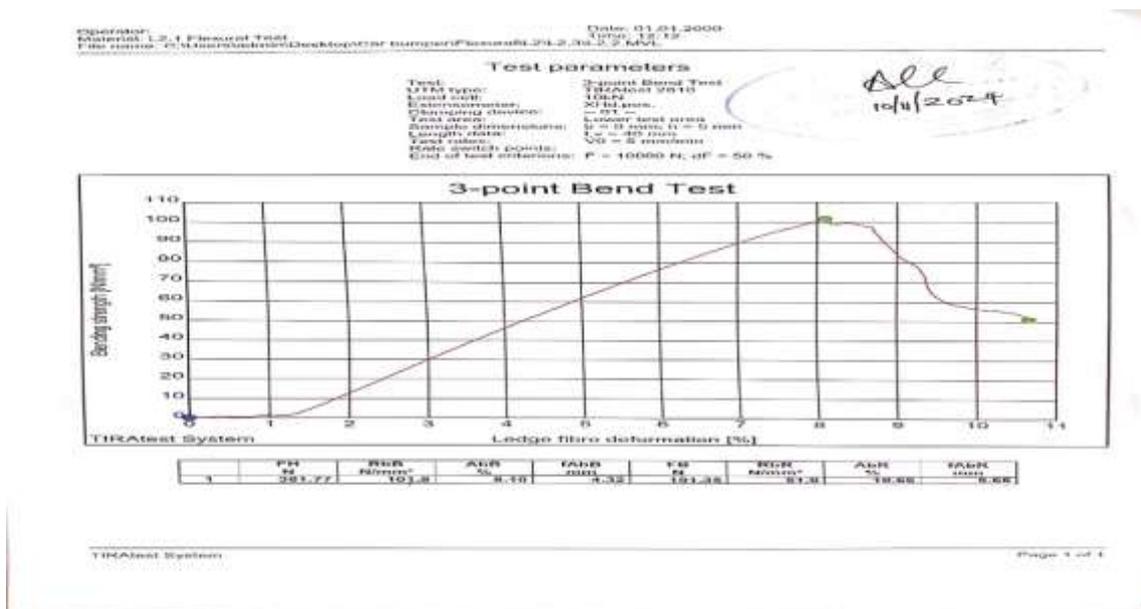| Specimens | L0, 1 | L0, 2 | L0,3 | Average | Optimal Result |
|---|---|---|---|---|---|
| Level0 | 12.0 | 13.6 | 27.6 | 17.73 | Six |
| Specimens | L1, 1 | L1, 2 | L1, 3 | | |
| Level1 | 70.5 | 35.6 | 6.9 | 37.7 | Third |
| Specimens | L2, 1 | L2, 2 | L2, 3 | | |
| Level2 | 101.8 | 90.4 | 67.4 | 86.5 | First |
| Specimens | L3, 1 | L3, 2 | L3, 3 | | |
| Level3 | 78.1 | 54.8 | 94.7 | 75.87 | Second |
| Specimens | L4, 1 | L4, 2 | L4, 3 | | |
| Level4 | 17.2 | 27.9 | 31.7 | 25.6 | Fifth |
| Specimens | L5, 1 | L5, 2 | L5, 3 | | |
| Level5 | 42.7 | 33.8 | 32.0 | 36.17 | Fourth |



**Figure 3.4 flexural stress-strain curves.**

**Table 3.5   Summary of Best Experimental (fabricated) Results**

| Description | ABS Plastic | Hybrid Composition | Reinforcement Ratio |
|---|---|---|---|
| Tensile ($N/mm^2$) | 20.71 | 34.76 | 50:20 |
| Compression ($N/mm^2$) | 4.85 | 131.37 | 20:5 |
| Flexural ($N/mm^2$) | 17.73 | 86.5 | 20:5 |
| Impact ($KJ/m^2$) | 31.957 | 17.951 | 10:0 |

## 3.6   RESULTS OF CHARACTERIZATION OF HYBRID FIBER REINFORCED POLYMER COMPOSITE FOR THE CAR BUMPER PRODUCED

The characterization results obtained are as follows:

### 3.6.1   X-RAY FLUORESCENCE (XRF)

The chemical composition of hybrid fiber reinforced polymer composite for the car bumper were determined through x-ray fluorescence analysis (XRF). The chemical composition are shown in table 3.6

**TABLE 3.6 CHEMICAL COMPOSITION OF HYBRID CAR BUMPER**

| COMPONENT | MOLE % |
|---|---|
| $SiO_2$ | 9.430 |
| $Fe_2O_3$ | 0.563 |
| CaO | 82.927 |
| $AL_2O_3$ | 3.621 |

The results indicate that the samples primarily composed of calcium based minerals, with Cao percentage of 82.927%. Iron, silicon and aluminium based minerals are present in smaller amount with $SiO_2$ of 9.43%, $Fe_2O_3$ of 0.563% and $Al_2O_3$ of 3.621%.

### 3.6.2   X-RAY DIFFRACTION (XRD)

Table 3.7, shown x-ray diffraction (XRD) analysis of hybrid fiber reinforced polymer composite for car bumper produced.

**Table 3.7 XRD Analysis of hybrid reinforced polymer composite**

| Phase Name | Formula | figure of merit | space group | DB Card Number |
|---|---|---|---|---|
| Fitchtelite | C19 H34 | 0.655 | 4:P1211 | 00-047-2500 |

| Chaoite | C | 0.917 | 147:P-3 | 00-022-1069 |
|---|---|---|---|---|
| Marialite | (Na3.21 Ca0.68 | 0.956 | 87:14/m | 01-070-6156 |
| Silicon Oxide | Si $O_2$ | 1.037 | 62:Pmcn | 00-035-0063 |

The table above detailed the mineralogical analysis of the car bumper. The results reveal the presence of several key minerals, fichtelite ($C_{19}H_{34}$) a principal constituent of the polymer composite is identified with a figure of merit of 0.655 and belonging to the space group of 4:P1211. Others minerals identified are chaoite (C), marialite (Na3.21Ca0.68K0.11) and silicon oxide ($SiO_2$) with different figure of merit and space group respectively. Fig. 3.5 showed the results of XRD of the hybrid fiber reinforced polymer composite.
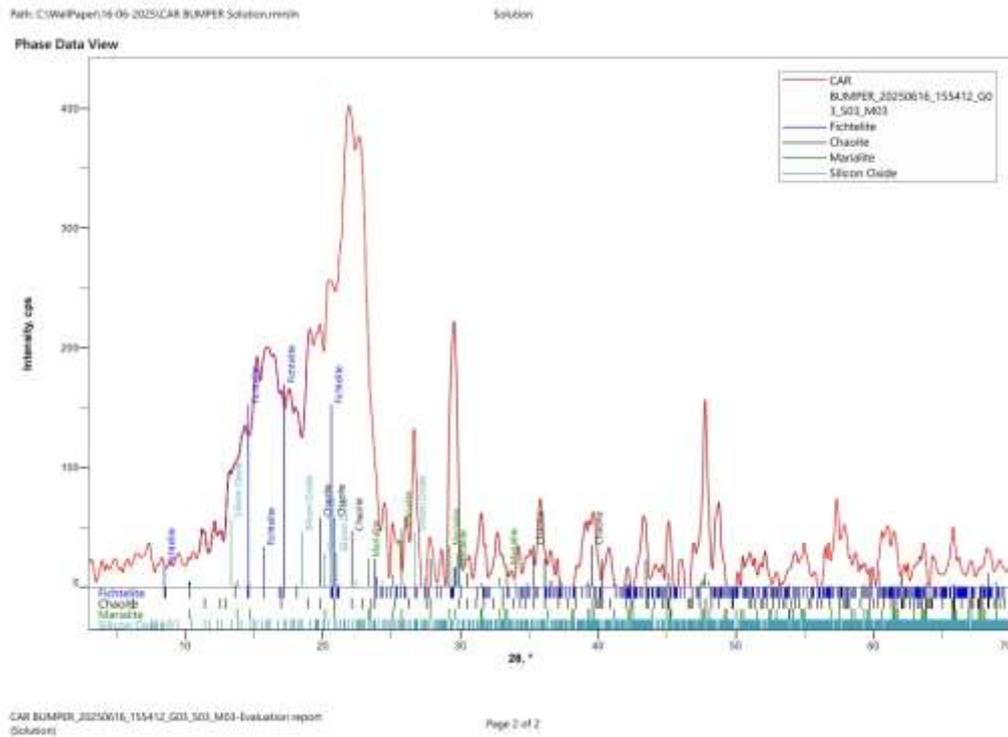


Fig. 3.5 XRD Pattern for Hybrid Fibre Reinforced Polymer Composite

### 3.6.3  THERMO-GRAVIMETRIC ANALYSIS (TGA)

In this test, initially the sample has no change in its mass up to $100^0C$ from room temperature. From $100^0C$ it has deviated from its original mass and there is a slight decrease in its mass up to $200^0C$ from where the slope of the graph has an increased in its negatively, which determines, increase in the rate of change in mass up to $300^0C$, this decrease in mass up to this point denotes the evaporation of volatile substances from the specimen. So, the sample has low rate of mass change for a certain scale of temperature from $300^0C$ to $500^0C$ there is a decrease in the mass of the specimen drastically, which indicates

the evaporation of resin and hardener mixture which attached to the fibers of the specimen. The final amount of traces left over at $888.4^0$C is the amount of pure fiber present in the sample.Fig. 3.6 shown TGA analysis for Hybrid Fibre Reinforced Polymer Composite
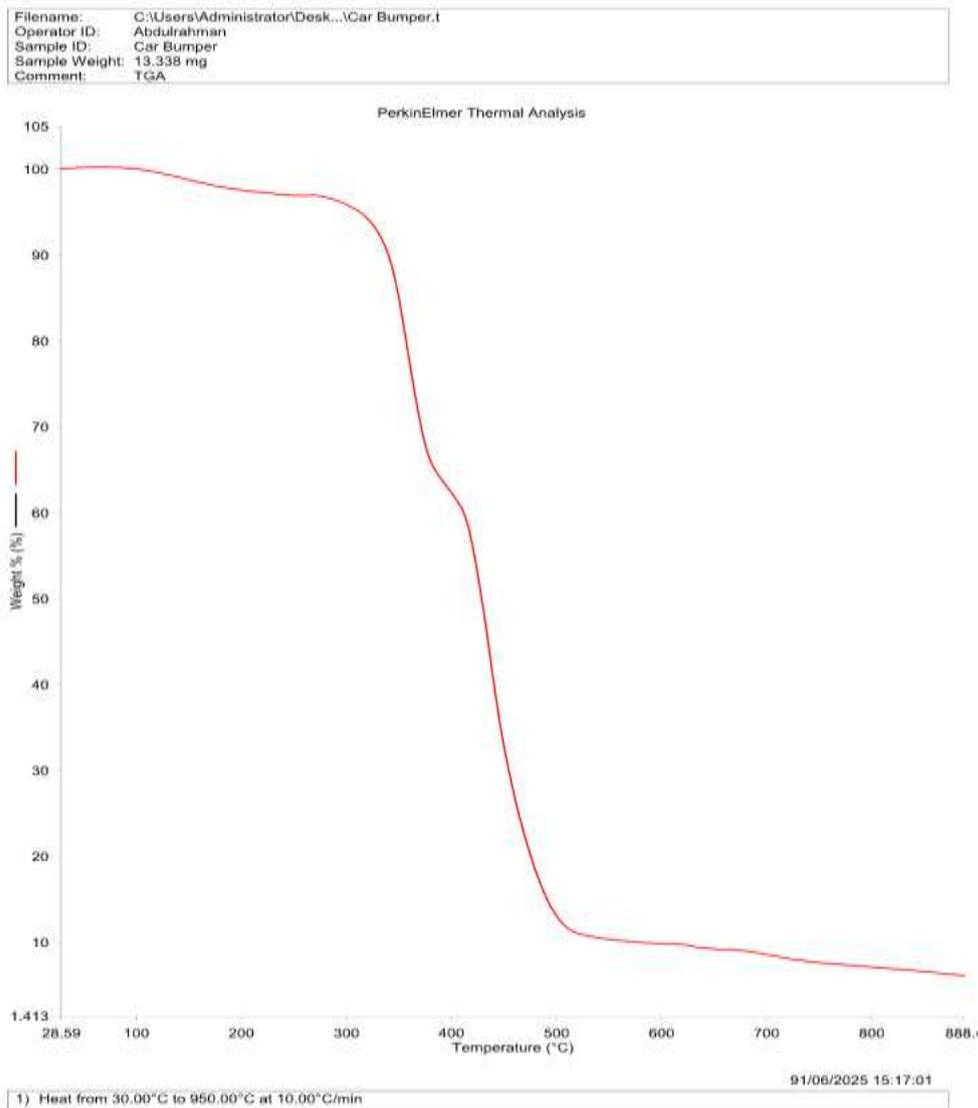


Fig. 3.6 TGA Analysis of Hybrid Fibre Reinforced Polymer Composite

### 3.6.4 FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR)

The Fourier transform infrared spectroscopy (FTIR) of the hybrid fiber reinforced polymer composite for the car bumper exhibits several prominent peaks that indicate the presence of functional groups in its crystal structure. The most prominent peaks are found at 3025.28 cm-1. Wavenumbers had shifted due to mixing fibers with the matrix. Wavenumbers shifts were noted at 1492.10 cm-1 and 694.80 cm-1 respectively.

Figure 3.7 shows the FTIR analysis of the hybrid car bumper.

Fig. 3.7 FTIR Spectra of Hybrid Fibre Reinforced Polymer Composite

### 3.6.5 SCANNING ELECTRON MICROSCOPY (SEM)

The micrograph focused on the concentration of various elements there in. It was observed that carbon (C) is the most abundant element in it with an atomic concentration of 90.27% and a weight concentration of 71.07%. This aligns with the highest content containing carbon (C) as detected by XRD and XRF analyses. Calcium (Ca) is the second most prevalent element present in the bumper, with an atomic concentration of 6.58% and weight concentration of 17.29%. Manganese (Mn) on the other way round has a minor presence in the car bumper with an atomic concentration of 0.10% and weight concentration of 0.37% others elements such as sodium (Na), potassium (K), Barium (Ba), titanium (Ti), zinc (Zn), sulphur (S), phosphorus (P), chlorine (Cl), silver (Ag), tin (Sn), and zirconium (Zr) shows negligible concentration in the analysis. Fig. 3.8 showed the SEM micrograph of hybrid car bumper.
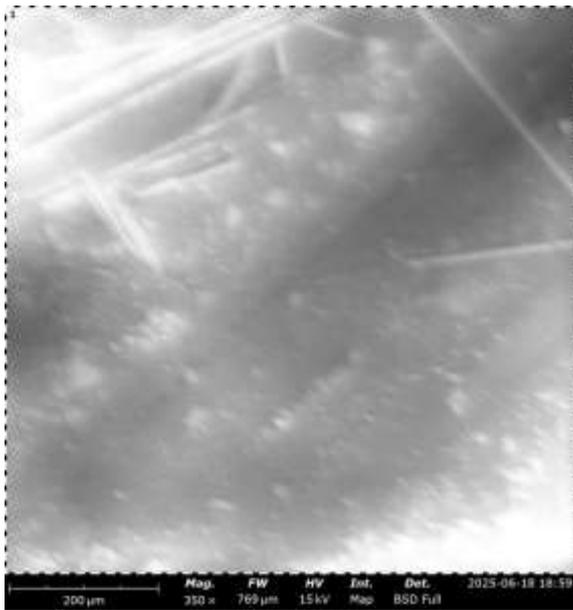
| Element Number | Element Symbol | Element Name | Atomic Conc. | Weight Conc. |
|---|---|---|---|---|
| 6 | C | Carbon | 90.27 | 71.07 |
| 20 | Ca | Calcium | 6.58 | 17.29 |
| 38 | Sr | Strontium | 1.29 | 7.43 |
| 13 | Al | Aluminium | 1.03 | 1.82 |
| 26 | Fe | Iron | 0.42 | 1.54 |
| 12 | Mg | Magnesium | 0.30 | 0.48 |
| 25 | Mn | Manganese | 0.10 | 0.37 |
| 11 | Na | Sodium | 0.00 | 0.00 |
| 19 | K | Potassium | 0.00 | 0.00 |
| 56 | Ba | Barium | 0.00 | 0.00 |
| 22 | Ti | Titanium | 0.00 | 0.00 |
| 30 | Zn | Zinc | 0.00 | 0.00 |
| 16 | S | Sulfur | 0.00 | 0.00 |
| 15 | P | Phosphorus | 0.00 | 0.00 |
| 17 | Cl | Chlorine | 0.00 | 0.00 |
| 47 | Ag | Silver | 0.00 | 0.00 |
| 50 | Sn | Tin | 0.00 | 0.00 |
| 40 | Zr | Zirconium | 0.00 | 0.00 |

Fig. 3.8 SEM Micrograph of Hybrid Fibre Reinforced Polymer Composite

### 3.6.6   WATER ABSORPTION AND SLAKE DURABILITY INDEX TEST

The result of water absorption and slake durability index test are shown in table 3.8

### TABLE 3.8 WATER ABSORPTION/SLAKE DURABILITY INDEX

| S/NO | Water absorption/Effective Porosity (%) | Slake durability index $(1_{d2})$& |
|---|---|---|
| 1. | 0.95 | 99 |
| Remarks | Low water Absorption | High Durability |

The physical properties of the hybrid fiber reinforced polymer composite for the car bumper which includes water absorption test was determined with high accuracy of (0.95%). The slake durability index test resulted in a remarkable 99% recovery of the specimen with a minimal loss of 1% which is well within the standard value. This indicates that the reinforced composite under study is exceptionally durable.
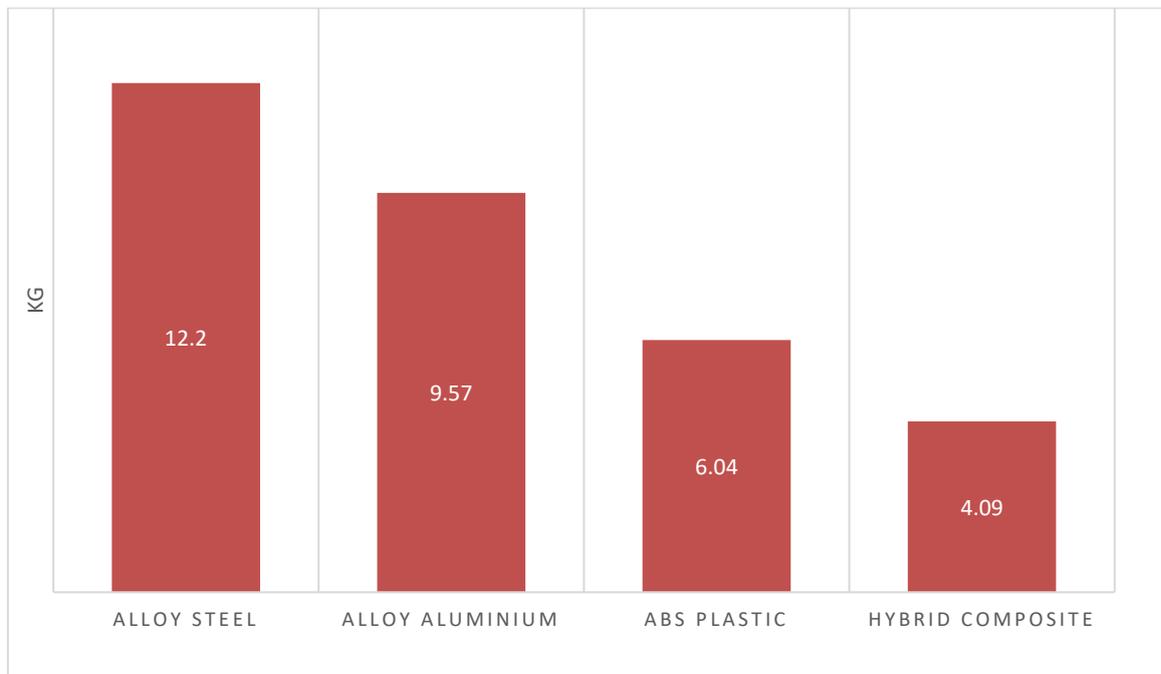
**Figure: 3.9 Weight comparison**

## 3.6    Discussion

Hybrid composite was successfully fabricated using hand layup technique. The tensile, compressive, impact and flexural strength tests were done using universal tensile machine, weight (pendulum) impact testing machine and three point bend test and the results obtained was showed in table 3.1, 3.2, 3.3 and 3.4 above respectively. The optimum graph chart was showed in figure 3.1, 3.2, 3.3 and 3.4 above respectively. From the eighteen (18) specimens produced, four tests were conducted on each specimen who makes it seventy two (72) tests that was carried out. The optimal average results obtained are tensile strength 34.76 $N/mm^2$, compression strength 131.37 $N/mm^2$, and flexural strength 86.5 $N/mm^2$ and impact strength 17.95 $KJ/m^2$ respectively. Also the test was conducted on the existing ABS plastic car bumper and the results obtained are tensile strength 20.71 $N/mm^2$, compression strength 4.85 $N/mm^2$, flexural strength 17.73 $N/mm^2$ and impact strength 31.96 $KJ/m^2$ respectively. The outcomes showed significant improvement in the mechanical properties on the experimental work. From the experimental results shown above, it was observed that the increase in weight percentage of fibers improves the mechanical properties. Therefore, it is based on the optimization results obtained that the weight percentage of 25% of synthetic and 5% of natural fiber was used to produce the full size of the car bumper. In addition to mechanical properties tests conducted others characterizations like x-ray fluorescence (XRF), x-ray diffraction (XRD), Thermo gravimetric analysis (TGA), Fourier transform infrared spectroscopy (FTIR), Scanning electron microscopy (SEM), Water absorption and Slake durability index studies were also employed to obtain information about the crystal structure, chemical composition and functional group present in the hybrid fiber reinforced polymer composite produced. Weight comparison figure 3.9 of similar car bumper was made and the results shows that alloy steel weight 12.2 kg, alloy aluminium weight 9.57 kg, ABS plastic weight 6.04 kg and hybrid weight 4.09 kg respectively.

## 4.0    Conclusion

The mechanical properties like tensile, compression, impact and flexural strength of a hybrid reinforced composite are studied. With

increased in the percentage of fibers the mechanical properties increases. Mechanical properties increase up to certain level and then decreases with respect to fiber loading. Surface treatment of fibers improves the strength and bonding between the matrix and fibers which leads to improve the properties. Hybridization reduces the usage of synthetic fibers and it gives the better mechanical properties.

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