Formulation and Study of Mechanical Behavior of an Innovative Material Manufactured Utilizing Local Resources and Polyester Resin

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Abstract

In recent years, the automobile and aeronautical industries have shown a growing interest in using composite materials for manufacturing sheet metal and chassis. This trend is largely motivated by the need to reduce pollution, improve fuel efficiency, and increase the recyclability of materials, while still meeting engineering normative requirements. The main goal of this research is to minimize the weight of vehicles or aircraft, while maintaining their rigidity and keeping the cost price within acceptable limits. A key driver of this work is the overarching objective of developing more efficient and/or equivalent parts and chassis to those currently in use. By exploring new materials and manufacturing techniques, we aim to improve the performance and sustainability of composite-based products in the automotive and aerospace industries.

Key words: frame, composite material, physical and mechanical characterization, plate laminate

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I. Introduction

In recent years, there has been a growing demand in both the automotive and aerospace industries for lightweight, high-strength materials that can withstand the extreme conditions of use while also reducing fuel consumption and emissions.[1] Composite materials, which are made by combining two or more materials with different properties, have emerged as a promising solution to these challenges.[2]

However, the manufacturing of composite materials can be expensive and resource- intensive, with many of the materials and processes involved in their production being sourced from overseas suppliers.[3] This has led many companies in the automotive and aerospace industries to explore the use of local suppliers and materials, both to reduce costs and toimprove their environmental sustainability.[4]

Recent developments in composite materials manufacturing, including the use of new materials and manufacturing techniques are helping to make the production of composite pieces for the automotive and aerospace industries more sustainable and cost-effective. [5] For example, a many study examined the use of sustainable natural fiber composites in aerospace applications, and found that these materials had significant potential for reducing the carbon footprint of the industry. [6] In another study, explored the use of 3D printing technology to manufacture composite parts for both the automotive and aerospace industries, demonstrating that this technology can significantly reduce lead times and costs. [7]

In this article, we will manufacturing a composite materials for use in the automotive and aerospace industries, with a focus on the economic, environmental, and local factors that can influence this process. We will examine the ways in which these innovations are helping to make the production of composite pieces more sustainable and cost-effective, and the potential for further advancements in this field. [8]

II. Experimental Procedures

II.1 Materials Used

The materials employed consist of a dune sand collected from the Bechar region (Taghit) and ground to a fineness module of 0.8 (CDS), an unground dune sand (DS), a ground clay (CC), and a binder made of a liquid polyester resin.

a b c

Fig.1. Used materials; a: DS; b: CDS; c: CC

Their chemical compositions are listed successively:

Tab.1. Chemical characteristics of DS [%]

Teneur%									
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	CI	TiO_2
86.02	0.89	0.16	0.16	-0.04	0.01	0.02	0.03	0 .015	0.03

Tab.2. Chemical characteristics of CDS [%]

Teneur%									
SiO_2	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**SO_3**	**K_2O**	**Na_2O**	**CI**	**TiO_2**
87.65	1.02	0.75	0.29	0.25	0.02	0.03	0.06	0 .018	0.04

Tab.3. Chemical characteristics of CC [%]

Teneur %									
SiO_2	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**SO3**	**K_2O**	**Na_2O**	**CI**	**TiO_2**
54.64	16.82	5.64	6.88	1.73	0.05	2.47	0.05	0 .018	0.04

The reinforcement used is in the form of injected flax fibers (fabric), as shown in figure (2).

Fig.2. Flax fiber (fabric).

In this experimental study, an empirical method based on the principle of sand and clay saturation points with resin was used to optimize the formulation. To achieve saturation of the different mixtures, the resin content was varied step by step. The percentage of resin was chosen based on the weight of the different mixtures. According to a previous study, a resin content of 30% (by weight) was found to be sufficient to saturate the sand [8]. However, in our case, the experimental resin content of 30% was found to be insufficient, as non-saturation of the sand was observed (unwanted part). A value of 34% was found to be better suited. At a resin content of 38%, a very liquid paste indicating over-saturation was obtained. We therefore opted empirically for a mean value between 34% and 38%: 35% was adopted. [9]

To prepare the mixtures, all molds were cleaned and prepared to ensure satisfactory molding. In the first step, approximate amounts of (CDS, DS and CC) were taken, and then 35% of their total weight of polyester resin and 2% of the resin weight of hardener were added separately to each powder. They were then mixed using a mixer until the desired shape was obtained. After that, themixture was pressed for each mixture in a steel mold with dimensions of 40x40 X 160 mm.

II.2 Preparation of our mixtures using woven flax fiber:

After the ambient temperature treatment for 24 hours, we demolded the molds. We prepared our mixtures based on woven flax fibers. After preparing the mixtures, it turns out that mixture 2 (CC) gives the best results for tensile strength by flexion. This mixture is then taken as a reference in this work. The rectangular fabric of length 160 mm and width 40 mm is cut into strips as indicated in the figure. For the fabrics placed in the test specimen, a layer is spread within the thickness of the test specimen as shown in the figure. The operation is carried out by spreading the first layer of mixture to half of the thickness,and then the fiber fabric is deployed on the surface of the previous layer. The second layer is spread on the already deployed mixture until the mold is filled (figure 3).

Fig.3. Flax fiber (fabric).

III. Experimental Tests

Test Specimens Two types of test specimens were used: prismatic specimens with dimensions of 4 × 4 × 16 cm^3 for the three-point bending tensile test, and half-specimens obtained after flexural rupture for compression tests.

III.1 Bending Test

This test allows for the determination of the flexural tensile strength and is applied exclusively to prismatic specimens with dimensions of 4x4x16cm^3. The supports are made up of steel rollers. The test is conducted until rupture on a bending machine designed for this purpose. The calculation of the flexural tensile strength, Rf is given by the following formula:

$$Rf = (3PL) / (2bh^2) \qquad (1)$$

Where:

P: the force at the moment of specimen rupture,L: the distance between the supports, b: the width,

h: and the height of the specimen.

III.2 Compression Test

The purpose of this test is to determine the compressive stress that leads to the crushing of a half- specimen. The tests were conducted at a slow and constant loading rate of 2.4 kN/s of displacement of the upper platen on a press with a capacity of 300 kN. The compressive strength is calculated using the following formula:

$$\sigma = P/S \quad (2)$$

P: is the compressive force at the moment of sample rupture, S: the cross-sectional area of the sample.

Fig.4: Flexural test set-up

IV. Results and Discussions

Table 4 summarizes the measured values of the mechanical strengths obtained in bending andcompression for the 3 mortar samples.

Tab. 4. Mechanical Strengths of Mixtures.

	S D	CDS	CC
Flexion	19,20	21,74	23,67
Compression	101,5	106	119,6

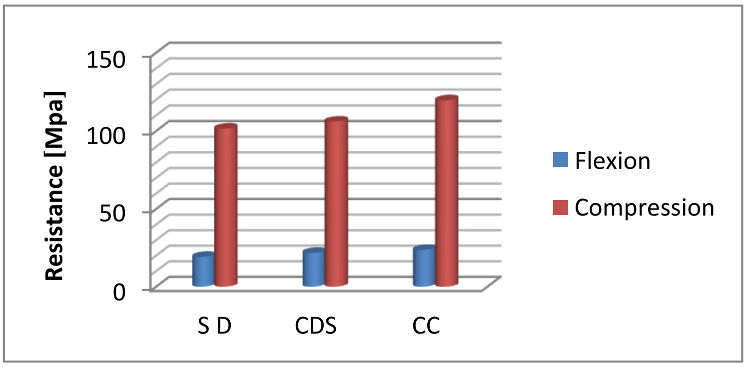

Fig. 5: Flexural Tensile and Compressive Strengths of Mixtures.

It appears that the measured values exhibit a characteristic dispersion of heterogeneous granular materials. However, this is lower than the dispersion typically observed in concretes or mortars. Nonetheless, this is still lower than what is generally observed in mortars.

Influence of Fiber Fabric on the Strength of Our Mixtures:

The obtained results for compressive strength and flexural tensile strength in this type of reinforcement are summarized in Table 7.

Tab 7: Mechanical Strengths of Fiber-Based Mixtures (Fabric).

R [MPa]	DS	CDS	CC
Flexion	23,64	26,11	30,71
Compression	107,75	117	132,7

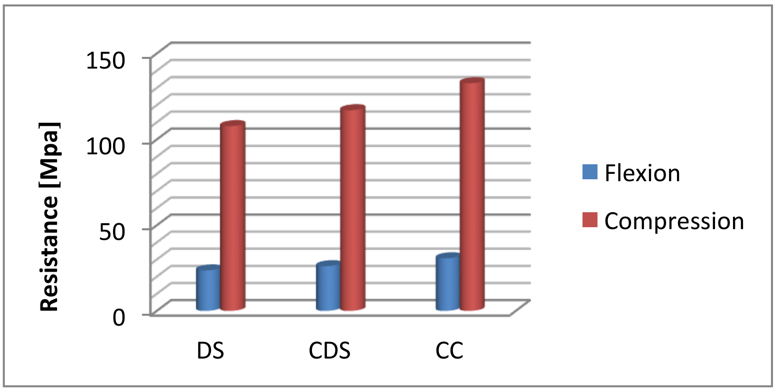

Fig. 6: Influence of Fiber Fabrics on Flexural Tensile Strength and Compression Strength of Mixtures.

The results obtained in compression and tension for fiber-reinforced mixtures (fabric) indicates that the mechanical strengths in flexural and compressive modes increase. A slow increase in flexural tensile strength is observed compared to a rapid increase in compressive strength.

V. Conclusions:

Resin mixture is a material that can be utilized in various fields such as the automotive and aerospace industries, among others. The approach adopted aimed at optimizing a formulation to achieve high mechanical characteristics (flexural and compressive tensile strengths). In our case, wechose a resin content of 35% as the saturation point with 2% hardener content relative to the resin percentage. The crushed dune sand mixture emerged as the optimal blend for use in the manufacturing of automotive and aerospace components.

Reinforcement with flax fiber (fabric) enhances the mechanical performance of resin mixtures.

Abbreviations DS: Dune Sand

CDS: Crushed Dune Sand

CC: Crushed Clay

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REFERENCES

1. dipenkumarrajak, d. D. Pagar, a. Behera&padeep l. Menezes. Role of composite materials inautomotive sector: potential applications, 10december 2021.
2. Awal A.A., Mohammadhosseini H. 2016. Green concrete production incorporating waste carpet fiber and palm oil fuel ash. Journal of Cleaner Production .
3. Carbone composites and cars –technology watch 2012 .In Reinforced plastic ,January /February 2013.
4. Leszek Gardynski, JacekCaban,DaliborBarta, Research of composite materials used in the construction of vehicule bodywork. 3 septembre 2018.
5. Nagma Zerin, Patrick Quinlan, Leonardo Simon, Optimum formulation design of natural fiber-reinforced composites (nfrc) for automotive applications
6. Muhammad Yasir Khalid, Ans Al Rashid, Zia UllahArif,waqasahmed,natural fiber reinforced composites: sustainable materials for emerging applications, july 2021.
7. Samit Chakraborty ,Manik Chandra Biswas ,3d printing technology of polymer-fiber

composites in textile and fashion industry: a potential roadmap of concept to consumer, 15 septembre 2020.
8. LeszekGardynski,JacekCaban,DaliborBarta, Research of composite materials used in the construction of vehicule bodywork. 3 septembre 2018.
9. Ghania Mirouzia, Bachir Redjela, Raoul Jauberthieb, Formulation et comportement mécanique de micro-bétons à matrice de résine polyester, 14 Novembre 2012.