MATERIALE PLASTICE
https://revmaterialeplastice.ro
https://doi.org/10.37358/Mat.Plast.1964

Synthesis and Experimental Investigation of Glass Fibre Epoxy/sawdust Composites for Flexural & Tensile Strength

PRAVEEN BARMAVATU[1]*, SONALI DESHMUKH[1]*, MIHIR KUMAR DAS[2], RADHAMANOHAR AEPURU[3], VENKAT REDDY RAGIREDDY[4],BANOTH SRAVANTHI[5]

[1]Department of Mechanical Engineering, Shri Jagdish Prasad Jhabarmal Tibrewala University (SJJTU), Jhunjhunu, Rajasthan, 333001, India
[2]School of Mechanical Sciences, Indian Institute of Technology Bhubaneswar, Argul, Jatni, 752050, India
[3]Facultad de Ingeniería, Departamento de Ingeniería Mecánica, Universidad Tecnológica Metropolitana, Santiago, Chile
[4]Department of Mechanical Engineering, Anurag University Hyedrabad, Telangana, India
[5]Department of Mechanical Engineering, Anurag College of Engineering, Kodad, 508206, India

***Abstract**: Every day, the need for composite materials grows. The physical and chemical characteristics of the constituent materials inside the hybrid composite impact the final structure. The rate at which these individual properties are sustained varies, but it has an impact on the final properties of hybrid composites. Sporting goods and lightweight orthopaedic components are made from hybrid composites. Glass fibre epoxy and sawdust are utilised to construct hybrid composites in this study, using glass fibre to epoxy resin ratios of (60:40, 60:39, 60:38, 60:37).The current research involves the creation of hybrid composites and their study for flexural and tensile strength under various load conditions. Applying resin and hardener, as well as inserting reinforcement, is repeated in the hand-layup manufacturing process to improve characteristics and create a laminate form. They improve fatigue and fracture resistance while providing dimensional stability and weight savings.*

***Keywords**: composites, fracture resistance, hand-layup process, reinforcing material, sawdust*

1.Introduction

The efficiency of energy sources is critical to society's technological advancements. The engineering material's qualities determine its effectiveness. When using these resources, we must keep the environment in mind. Natural fibres can be used to create eco-friendly materials. These fibres are readily available, inexpensive, have high specific strength, and are biodegradable, recyclable, and lightweight. Material with low weight and high rigidity is required in lightweight applications such as aircraft and aerospace. Pressure vessels must be corrosion resistant and strong to function well. Composite materials are capable of meeting these standards. Composites are materials that allow for the creation of a diverse range of qualities in a single material. Flexible qualities are seen in composite materials. Changes in the synthesis material can change the properties of composites. Composites are dependable replacements for traditional structural materials because of their flexibility. A composite material is made up of at least two chemically distinct materials separated by a different interface. A composite material is made up of two phases that come together to form a composite. There are two phases: matrix and reinforcement. In comparison to the reinforcement phase, the matrix phase is not as strong. As a result, reinforcement strengthens the matrix. Reinforcement materials come in a variety of forms, including fibres, particles, and flakes. Reinforcement essentially improves flexural strength. When compared to individual component phases, a composite material's combination of multiple components makes it superior. H. Ku et al. [1] improved the flexural capabilities of the composite by combining epoxy resin with sawdust. There are three different particle sizes used: < 425 µm, 425-600 µm, and 600-1180 µm. A precise percentage of sawdust with a particle size of 425µm can be used to achieve maximum flexural strength. If flexural strength is a key metric in composite properties, sawdust is a good choice. As a result, for the current experiment, we've chosen sieved sawdust particles with a particle size of less than 425 µm. T. Vaisanen et al. [2] conducted research on natural fibre polymer composite materials made using epoxy resin and forest, agricultural, and industrial waste.

**email: praveen205.bps@gmail.com, sonali.deshmukh425@gmail.com*

The technique utilized is called hand -lay-up. When the material is evaluated for impact and flexural strength, it is discovered that both of these properties improve. It has also been shown that adopting hybrid approaches for composite development can increase mechanical properties [3-5]. M.R. Rahman et al. [6] found that raw sawdust treated with a benzene diazonium salt improved the mechanical qualities of the composite. Chemically treated sawdust interacts better with the filler matrix than untreated sawdust. It was discovered that after chemical treatment of the filler, the filler dispersed better with the PP matrix. Fibre has poor adherence to the matrix material, resulting in incompatibility and a loss in composite mechanical performance. According to the author, it is preferable to use treated filler material to avoid the disadvantages outlined above. As a result, sawdust that has been chemically treated with Benzene diazonium salt was employed in this experiment. For the manufacture of plastic composites made of sawdust and PET reinforced with a thermoplastic resin, Siddikur Rahman et al. [7] employed the cold pressing method. The density of sawdust PET composite increases as the percentage of sawdust increases, according to the findings. Sawdust increases moisture content and decreases modulus of elasticity by a factor of 40-70 and 40-70, respectively. Moorthy M. Nair et al [8] created natural fibre with the help of sawdust reinforcing and epoxy. Flexural, tensile, and hardness strength have been enhanced as a result of the research. K. Raju et al. [9] examined the mechanical characteristics of palm fibre/glass fibre and epoxy mixed hybrid composite laminates. The tensile strength of the composite is said to rise as the phase ratio of fibre particles increases. According to the results of the flexural test, hybrid fibre has more advantages than the already available composite. The hardness test revealed that composites can be used in situations requiring high strength but low weight. As a result, the palm fibre/glass fibre/epoxy hybrid composite is both eco-friendly and cost-effective. The tensile behaviour of glass fibre reinforced epoxy composites was investigated by Umamheshwar & Mahender [10]. At a 95% confidence level, it is discovered that the proportion of fibre has a greater impact on tensile strength. Sivakandhan et al. [11] investigated the coaxial tensile strength of jute/epoxy and sisal fibre/epoxy composites, finding that jute/epoxy outperformed sisal epoxy by 32 per cent. Sisal and jute fibres were chosen for reinforcement owing to their mechanical qualities, and epoxy resin (LY556 grade) and hardener (HY951) were used as the matrix and binder for the composite. Abdul Moudood et al. [12] tested the composite's tensile and flexural strength. They did this by exposing flax/bio-epoxy composites to various environmental conditions. The mechanical properties of flax/bio-epoxy composites are reduced by water ageing, as seen by a comparison of newly formed composite with this exposed composite. In example a, the composite is immersed in water until saturation, and in the case of b, the composite is subjected to a humid atmosphere until saturation, and tensile strength and modulus are reduced by around 9% and 57 percent, respectively. In the instance of a the reduction rate is only 0.8 percent, but in the case of b, the reduction rate is 3 percent. The flexural characteristics of composites are shown to be more severely affected by water. In comparison to a produced sample, water reduces flexural strength and modulus by 64% and 70%, respectively. N. Saba et al [13]. The addition of 40 to 50 percent Date palm stem fibre to epoxy composites enhances tensile strength, while greater addition decreases the mechanical characteristics of the composite. Chauhan et al. [14] looked at the influence of sawdust filler on the composite's tensile strength. The impact of particle size, sawdust type, and sawdust proportion has been studied. The regression model is created in this study to forecast the composite's tensile strength. The composite with 18 percent sawdust and a particle size of 550.83 m has a tensile strength of 18.72 MPa. Sawdust was employed in plastic-based hybrid composites by Mishra [15]. Maximum tensile strength, flexural strength, toughness, and hardness are achieved with 40 percent wt. glass fibre, 0 percent wt. sawdust, and 60 percent wt. epoxy in FRPs (Fibre-reinforced plastics). The tensile strength of a composite is reduced as the percentage of glass fibre is reduced. In the present study, a larger percentage of glass fibre is employed to achieve optimal tensile strength. In literature, there is only a small amount of research on the development of sawdust composites. As a result, the application of sawdust polymer-based composite material has a lot of potential. The current research focuses on the synthesis of sawdust composites and the evaluation of mechanical properties using computer techniques.

2. Materials and methods

2.1. Determination of required epoxy resin and glass fibre

We employed E-glass fibre in this composite production. This glass fibre has 54 percent SiO_2, 15% Al_2O_3, and 12% CaO. In the composite production process, LY556 glass-epoxy resin and HY951 hardner are utilised. Weights are measured precisely in grams using electronic weighing equipment. This equipment measures the weights of epoxy resin and glass fibres. Glass fibre and epoxy resin are mixed in different proportions to create these composites (60:40, 60:39, 60:38, 60:37).

Table 1. %Weight ratios of glass fibre to epoxy resin and Sawdust

Sr. No	Ratio of Glass fibre	Ratio of Epoxy resin	Ratio of Sawdust
1.	60 %	40 %	0 %
2.	60 %	39 %	1 %
3.	60 %	38 %	2 %
4.	60 %	37 %	3 %

To determine the exact weight of material, glass fibre density is required. Density can be expressed in a variety of ways.

$$D = M/\mathrm{V} \tag{1}$$

where:
D=density, M=mass, V=volume
Fibre Density = 0.97 g/Cm³, Matrix Density= 1.125g/Cm³, Sawdust Density =1.1g/Cm³
Composite mould's volume is,

$$V_{(Composite\ mould)} = 300\times300\times5 \text{ mm}$$
$$= 30\times30\times0.5 \text{ cm} = 450 \text{ Cm}^3$$

$$V_{(Composite)} = V_{(Fibre)} + V_{(Matrix)} \tag{2}$$

$$V_{(Fibre)} = 60\%\, V_{(Composite)} = 60 \times \frac{450}{100} = 270 \text{ Cm}^3$$

As we know,

$$Density_{(fibre)} = \frac{Mass_{(fibre)}}{Volume_{(fibre)}} \tag{3}$$

Hence,

$$Mass_{(fibre)} = Density_{(fibre)} \times Volume_{(fibre)} \tag{4}$$
$$= 270 \times 0.97 = 261.9\ gm$$

$$V_{(Matrix)} = 40\% V_{(Composite)}$$
$$= 40 \times \frac{450}{100} = 180\ Cm^3$$

$$Density_{(Matrix)} = \frac{Mass_{(Matrix)}}{Volume_{(Matrix)}} \tag{5}$$

$$Mass_{(Matrix)} = Density_{(Matrix)} \times Volume_{(Matrix)} = 180 \times 1.125 = 211.5\ gm \tag{6}$$

For the ratio of 60:39:1 of Fibre: Resin: Sawdust,

$$V_{(Matrix)} = 39 \times \frac{180}{100} = 70.2\ Cm^3$$

$$Mass_{(Matrix)} = 1.175 \times 70.2 = 82.84\ gm$$

$$V_{(Sawdust)} = 1 \times \frac{180}{100} = 1.8\ Cm^3$$

$$Mass_{(sawdust)} = Density_{(sawdust)} \times Volume_{(Sawdust)} = 1.1 \times 1.8 = 1.98\ gm \tag{7}$$

The identical procedure and results are determined for the remaining two compositions, 60:38:2, and 60:37:3. The resin-to-hardener ratio is 10:1, which means that for every 100 g of epoxy resin, we need 10 g of hardener. The next step is to cut glass fibres according to the mould specifications after the weight determination process is completed.

2.1.1. Estimation of weights

Table 2. Estimation of weight

Sr. No	sawdust %	Fibre Wt. (gm)	Resin Wt.(gm)	sawdust Wt, (gm)
1.	0%	261.9	211.5	0
2.	1%	261.9	82.48	1.98
3.	2%	261.9	80.37	3.96
4.	3%	261.9	78.25	5.94
	Total wt.	1047.6	452.6	11.88

2.1.2. Preparation of sawdust

Benzene diazonium salt is used to chemically treat sawdust. To begin, it is dried at 105°C to remove excess moisture. It is stored in a sealed container to protect it from the effects of the environment. The mixture is then combined with a 50 mL solution of 5% NaOH. This solution is stored in the refrigerator for 10 min after adding sawdust to it. After that, a cooled Benzene diazonium salt solution is gently poured over the mixture. After 10 min of constant stirring, this is cleaned with soap and water and dried in the open.

2.2. Preparation of mould and specimen

Composite laminates are created on a hardwood mould with dimensions of 300x300 mm² for the test specimen, as illustrated in Figure 1. To fit inside the mould perfectly, glass fibre must be chopped into numerous layers, each measuring 250 x 250mm. The glass fibre may be cut with a regular blade. In addition, electronic weighing equipment can be used to determine the weight.

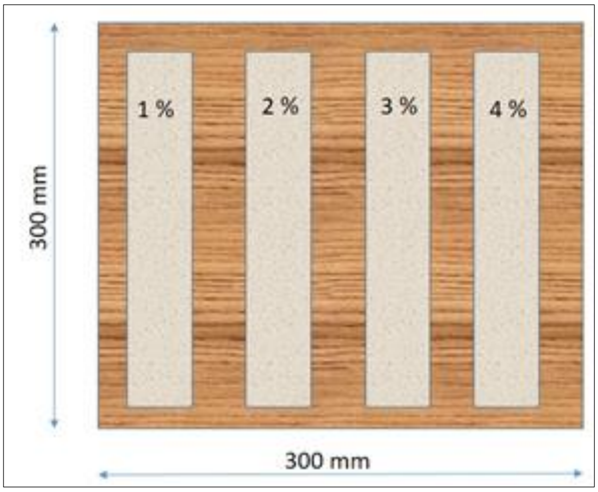

Figure 1. Wooden mould for composite preparation

Wax gel and Teflon film are used to keep the polymer from sticking to the surface. Wax gel is applied on a Teflon sheet. A Teflon sheet can be used to provide a good surface finish on the product. After curing, a PVA coating is applied. This is used to release the mould. In the area where the Teflon sheet is applied, a PVA coating is applied. On Teflon, PVA forms a thin coating. A thermosetting polymer in liquid form is combined with a hardener and put into a mould. Polymer is spread equally with a brush. The ratio of resin to hardner was preserved at 10:1. The resin is 100 g and the hardner is 10 g. These are combined right before the laminates are made. After 15-20 min, this mixer hardens and becomes unusable. The procedure of applying resin and hardener, as well as inserting reinforcement, is repeated for each layer of polymer and mat. The following stage is to add filler material after you've completed the required layer. Sawdust is added in ascending proportions to other compositions, i.e. 1 percent, 2 percent, and 3 percent. The technique is repeated until the desired thickness is achieved. Allow half an hour for it to settle. Apply weights to the mould after it has settled. In this scenario, a hardwood board is used to apply uniform pressure. Its measurements are 30 x 30 cm. It's positioned in such a way that it can provide consistent pressure. Any moulding's best physical qualities are developed at this stage. After the laminates have settled, they are left to cure for 12-16 h. After curing, the specimen is removed from the mould. For a better finish, surface grinding is used. Tensile and flexural testing is now performed on the material. Specimen dimensions are to be kept 250 x 25 x 2 mm for each test, which can be easily obtained by surface grinding.

Figure 2. Glass epoxy laminate specimen of varying compositions

3.Result and discussions

3.1. Tensile test

On a universal testing machine, tensile tests are done. For testing, test specimens with the above-mentioned Epoxy resin and glass fibre compositions were used. Table 3 shows the tensile strength of various blending combinations. The tensile strength of a material can be computed as follows:

$$S = \frac{F}{A} \quad (8)$$

where:

S= Breaking strength, F=Force applied that caused the failure, A= Cross-sectional area of the material.

Table 3. Tensile strength and flexural strength

Fibre %	Resin %	Sawdust%	Ultimate Tensile strength in N/mm²	Flexural strength in N/mm²
60	40	0	188.924	15.61
60	39	1	224.33	17.80
60	38	2	180.993	14.214
60	37	3	109.433	13.7

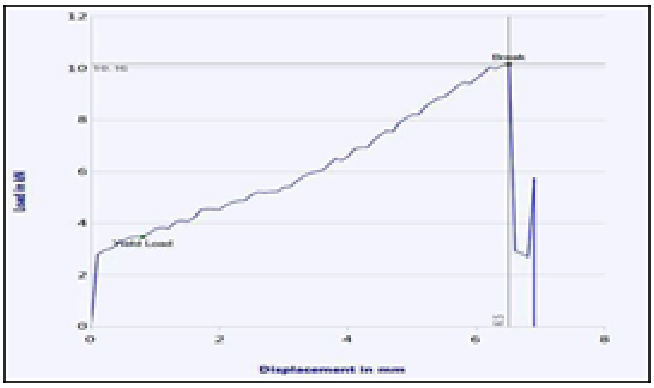

Figure 2. Tensile behaviour for 0% sawdust

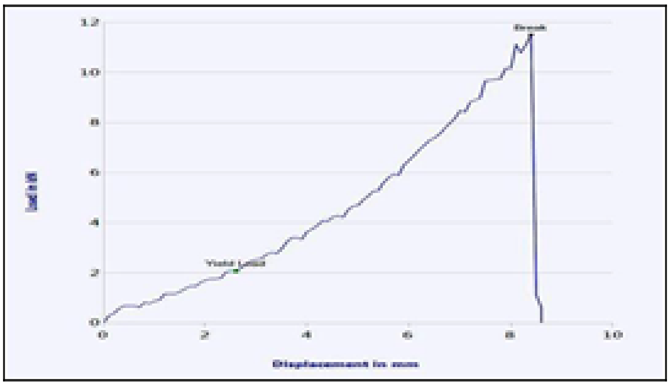

Figure 3. Tensile behaviour for 1% Sawdust

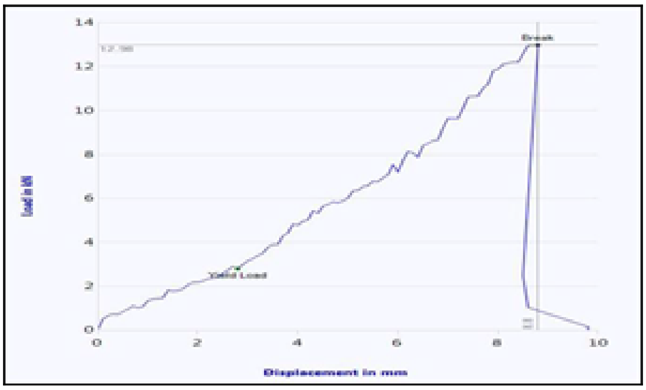

Figure 4. Tensile behaviour for 2% Sawdust

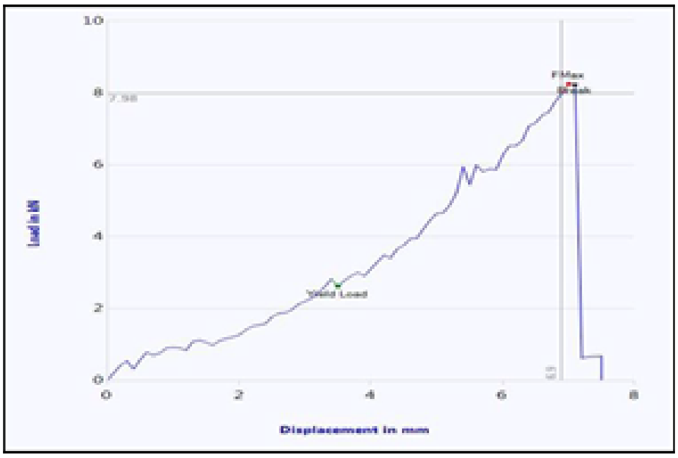

Figure 5. Tensile behaviour for 3% Sawdust

3.2. Flexural test

Flexural testing machine is used to calculate flexural strength. Three-point simply supported bending apparatus with precision dial gauge and digital load indication was used to test flexural strength. The test was repeated in the order of decreasing difficulty. The formula for calculating flexural strength is as follows:

$$Flexural\ Strength = \frac{3PL}{2BD^2} \quad (9)$$

P= Load applied (kg-s), L= Beam Span Length (mm), B= Specimen Width, D= Specimen Depth (Thickness of specimen). Table 3 shows the flexural strength of several epoxy resin and glass fibre compositions with varied sawdust percentages. Equation 2 is used to calculate flexural strength.

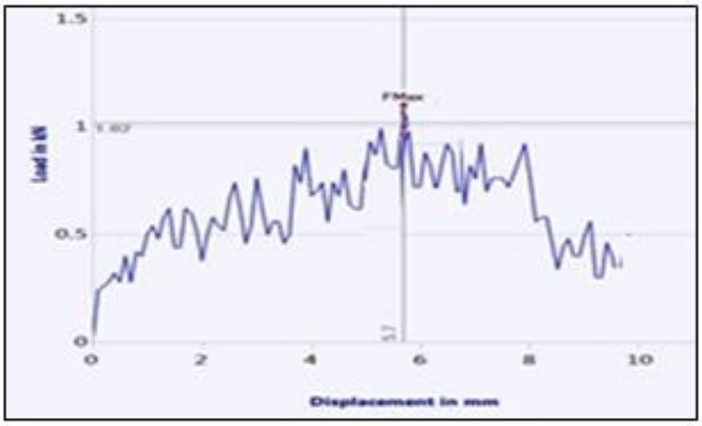

Figure 6. Flexural behaviour for 0% SAWDUST

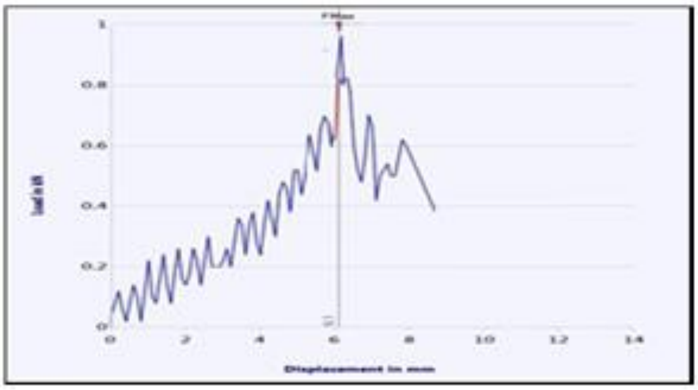

Figure 7. Flexural behaviour for 1% SAWDUST

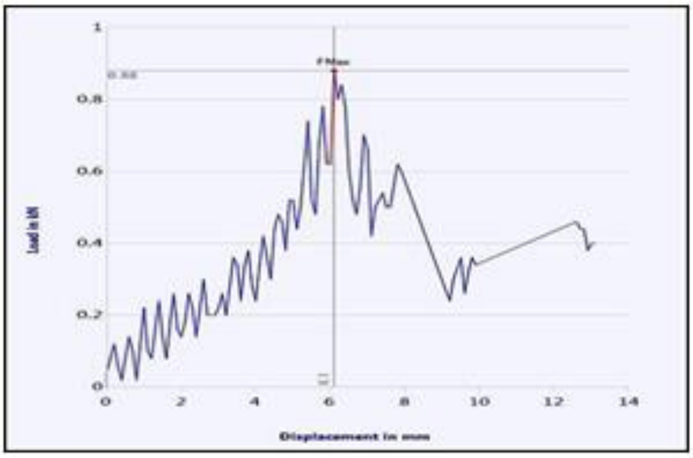

Figure 8. Flexural behaviour for 2% SAWDUST

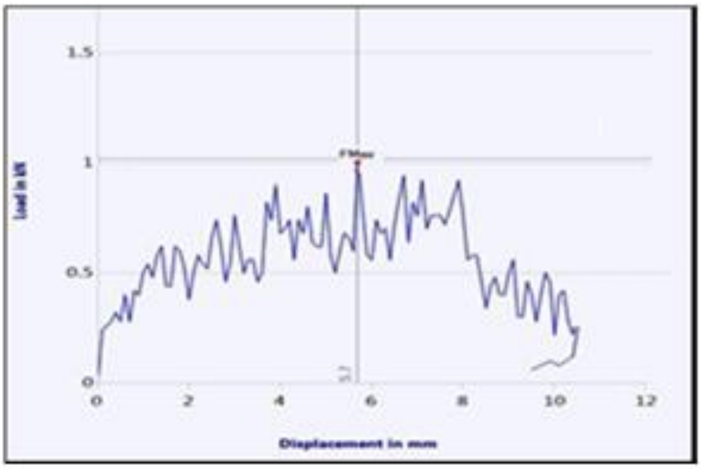

Figure 9. Flexural behaviour for 3% SAWDUST

4.Conclusions

Tensile and flexural strength of the hybrid composite are assessed. The analysis resulted in the following conclusions:

a. Tensile strength

-a high percentage of epoxy resin and a low amount of sawdust can be used to achieve great tensile strength. Fewer amounts of epoxy and a high percentage of sawdust can be used to make a low-tensile-strength composite material;

-the results demonstrate that composite material with 2 percent and 3 percent sawdust has lower tensile strength than 0 percent and 1 percent sawdust.

b. Flexural strength

-as the percentage of sawdust increases up to 1%, the flexural strength of the composite increases.

The epoxy has high flexural strength because of the low amount of sawdust. The flexural strength of epoxy with a higher percentage of sawdust is reduced;

-when compared to 2 percent and 3 percent sawdust, 0 percent and 1 percent sawdust had higher flexural strength;

-as a result, increasing the sawdust percentage above 1% will not increase the tensile or flexural strength.

References

1.H. KU, M. DONALD, F. CARDONA, M. TRADA, Flexural properties of sawdust reinforced epoxy composites post-cured in microwaves, J. Compos. Mater. 46, (2012), 2879-2890

2.T. VÄISÄNEN, A. HAAPALA, R. LAPPALAINEN, L. TOMPPO, Utilization of agricultural and forest industry waste and residues in natural fibre-polymer composites: a review, *Waste Manag*, 54, (2016), 62-73

3.M.K. GUPTA, R.K. SRIVASTAVA, Mechanical properties of hybrid fibres-reinforced polymer composite: are views, Polym. Plast. Technol. Eng. 55 (2016) 626-642

4C. DONG, Review of natural fibre-reinforced hybrid composites, *J. Reinf. Plast. Compos*. 37 (2018) 331-348

5.T.P. SATHISH KUMAR, J. NAVEEN, S. SATHEESH KUMAR, Hybrid fibre reinforced polymer composites - a review, *J. Reinf. Plast. Compos*. 33 (2014) 454-471

6M. REZAUR RAHMAN, M. NAZRUL ISLAM, M. MONIMUL HUQUE, Influence of fibre treatment on the mechanical and morphological properties of sawdust reinforced polypropylene composites, *J. Polym. Environ*. 18 (2010) 443-450

7.K.S. RAHMAN, M.N. ISLAM, M.M. RAHMAN, et al., Flat-pressed wood plastic composites from sawdust and recycled polyethylene xterephthalate (PET): physical and mechanical properties, *SpringerPlus* 2 (2013) 629

8.M.M. NAIR, S.M. KAMATH, N. SHETTY, Study on tensile and hardness behavior of sawdust impregnated on short coir fibre reinforced epoxy composite, *Indian J. Adv. Chem. Sci. s1* (1) (2016) 118-121, ISSN 2320-0898

9.K. RAJU, M. BALAKRISHNAN, Evaluation of mechanical properties of palm fibre/glass fibre and epoxy combined hybrid composite laminates, Mater. Today: Proc. (2019)

10.R.S. UMAMHESHWAR-RAO, T. MAHENDER, Mechanical properties and optimization of processing parameters for epoxy, glass fibre reinforced composites, *Mater. Today: Proc*. (2019)

11.C. SIVAKANDHAN, G. MURALI, N. TAMILOLI, L. RAVIKUMAR, Studies on mechanical properties of sisal and jute fibre hybrid sandwich composite, Mater. Today: Proc. (2019)

12.YUNG-CHUAN CHIOU, HSIN-YIN CHOU, MING-YUAN SHEN, Effects of adding grapheme nanoplatelets and nanocarbon aerogels to epoxy resins and their carbon fibre composites, Mater. Design 178 (2019)

13.N. SABA, OTHMAN Y. ALOTHMAN, ZEYAD ALMUTAIRI, M. JAWAID, WAHEEDULLAH GHORI, Date palm reinforced epoxy composites: tensile, impact and morphological properties, J. Mater. Res. Technol. (2019)

14.SHAILENDRA SINGH CHAUHAN, NAGENDRA KUMAR MAURYA, SHASHI PRAKASH DWIVEDI, Effect of particle size and weight percent of different wood dust on the tensile strength of glass fibre Epoxy/Saw dust composite using RSM, Materials Today: Proceedings Elsevier Ltd, (2021).

V.R. MISHRA, Utilization of waste saw dust in development of epoxy resin hybrid green composite, Materials Today: Proceedings (2019)

Manuscript received: 28.11. 2021