Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/19884
DOI URL: http://dx.doi.org/10.21474/IJAR01/19884

ISSN NO. 2320-5407

RESEARCH ARTICLE

THERMOPHYSICAL AND MECHANICAL CHARACTERIZATION OF THIN POLYPROPYLENE SHEETS REINFORCED WITH RESIDUES AND FIBERS FROM CHAD'S BOIS BORASSUS (RÔNIER)

A. Malgnan Okim[1], E. Ngarguededjim Kimtangar[1], Alexis Mouangue Nanimina[2], B. Hinpere Wedjou[2] and G.E Ntamack[3]

1. University of N'Djaména, Faculty of Exact and Applied Sciences, Industrial Technology Studies and Research Laboratory.
2. Institut National Supérieur des Sciences et Techniques d'Abéché, Department of Mechanical Engineering, BP.130 Abéché, Chad.
3. Mechanics, Materials and Acoustics Group (GMMA), Physics Department, Faculty of Science, University of N'Gaoundéré, B.P. 454 Ngaoundéré, Cameroon.

……

Manuscript Info

Manuscript History
Received: 10 September 2024
Final Accepted: 19 October 2024
Published: November 2024

Key words:-
Composite Materials, Chad Rônier Wood Residues and Fibres, Thin Sheets, Thermophysical and Mechanical Properties

Abstract

The aim of this work is to determine the mechanical characteristics of thin polypropylene sheets reinforced with residues and fibres of Borassus wood from Chad for use in construction. Borassus is a palm tree whose wood is widely used in traditional and even modern construction in Africa for its mechanical strength and weather resistance. To do this, we formulated test specimens using different mass fractions (10%, 15% and 20%) of Borassus wood powder or fibres in the polypropylene matrix. After melting the polypropylene mixed with the powder or fibres, the specimens are produced under the effect of the compacting pressure in the mould. The moduli of elasticity obtained in three-point bending vary according to the type of composite : From 695.426 MPa to 824.87 MPa for FNTF ; from 495.140 MPa to 711.270 MPa for FNTM in the case of powders. From 323.194 MPa to 552.657 MPa for FibNTF ; from 506.475 MPa to 770.740 MPa for FibNTM in the case of fibres. Fracture stresses vary : from 29.061 MPa to 15.033 MPa for FNTF ; from 29.271 MPa to 20.378 MPa for FNTM in the case of powders. From 16.275MPa to 12.926 MPa for FibNTF ; from 16.100MPa to 15.008 MPa for FibNTM in the case of powders. Our results show an increase in moduli of elasticity and a decrease in bending fracture stresses when the levels of additives are increased, in line with the results of the literature. The composites developed in this way could be used in the construction of homes.

……

Introduction:-

In view of global warming and the environmental problems threatening our planet, a number of researchers have been working to develop ecological materials with a low impact on the environment. Composites made from wood fibres and powder and various types of polymeric matrices are an important class of bioproducts with a wide range of possible applications. Various studies have already shown that plant fibres and residues are not only cheap, but

Corresponding Author:-G.E Ntamack
Address:-Mechanics, Materials and Acoustics Group (GMMA), Physics Department, Faculty of Science, University of N'Gaoundéré, B.P. 454 Ngaoundéré, Cameroon.

also harmless to health and lighter. They also have very interesting mechanical and thermal properties. This explains why these fibres and residues are increasingly replacing synthetic fibres in many applications (Achouak & Lina, 2021).

AlMaadeed et al, (2014)investigated the effect of palm powder loading rate on the properties of palm powder reinforced low density polyethylene composites at different weight rates ranging from 10% to 70%. The results showed that Young's modulus and flexural strength increased with increasing filler content. Composites with a 70% powder content had the highest Young's modulus and flexural strength. The Young's modulus increases more than 13 times that of virgin LDPE (low-density polyethylene). The results also showed that the rate of water absorption increases with increasing thickness. These results show the importance of the quantity of material constituents as parameters influencing the properties of polymer/plant fibre composites (Naziha, 2015).

Panaitescu et al, (2007)studied the effect of filler content on the mechanical properties of PP/sisal fibre composites, and found that tensile strength and modulus of elasticity increased with increasing sisal fibre content. The modulus of elasticity doubles in the concentration range of:0, 5, 10, 15, 20 and 25%. Increasing the percentage of lignocellulosic reinforcements systematically improves the mechanical performance of wood/polymer composites(Adjou et al., 2013).

However, too much wood makes adhesion more difficult, leading to a drop in performance in some cases. In addition, there is a certain proportion of reinforcement beyond which major difficulties arise, particularly in terms of manufacturing methods.

Salim Bouhank (2017)studied the development of PVC/Spanish broom fibre composite materials in the case of formulation and characterisation in tensile and impact tests. As results, he obtained for Young's moduli : E_0=2100MPa, E_{10}=2300MPa, E_{20}=2400MPa, E_{40}=2900MPa). For fracture stresses, the following values were obtained :σr_0= 27MPa, σr_{10}=23MPa, σr_{20}=21MPa, σr_{40}=19MPa.

In this article, we present the formulation of various new materials based on the residues and fibres of Borassus wood from Chad. We will determine their characteristics, which make them the materials of choice, by means of three-point bending tests. We will also discuss the use of Borassus wood residues and fibres in terms of availability and their use in construction.

Methods and Materials:-

Materials used:-

The aim of this part is to enhance our local materials such as the residues and fibres of Borassus wood from Chad used as effective reinforcement in polymer matrices and to improve their mechanical and thermophysical properties(El-Abbassi et al., 2014).Of plant or animal origin, natural fibres are worth more than 40 billion dollars a year to the economy, with production of around 35 million tonnes in 2009(Touloum et al., 2012).The experimental material of BorassusAethiopum (rônier) comes from the rôneraie field of Canton Tchoua, a locality in the department of Tandjilé centre, about 25 km from Laï, the capital of the province of Tandjilé, situated between 9°18'36‘’ north latitude and 16°4'45‘’ east longitude.

The locality of Tchoua canton was chosen because of its high potential for roasting. The Borassus trees studied were male and female, around 30 to 40 years old, with a height of 11 m for the male and 9 m for the female, and diameters of 193 cm for the male and 188 cm for the female(NetodjiroAllarabeye, 2009).

The materials used to make the composites are plant reinforcements made of fibres and residues extracted from BorassusAethiopum wood (Tarek, 2019). To obtain the residues and fibres from Borassus wood, the following equipment must be used successively : an axe, an iron and wooden chisel, a wooden sledgehammer, a hoe and a grinder.

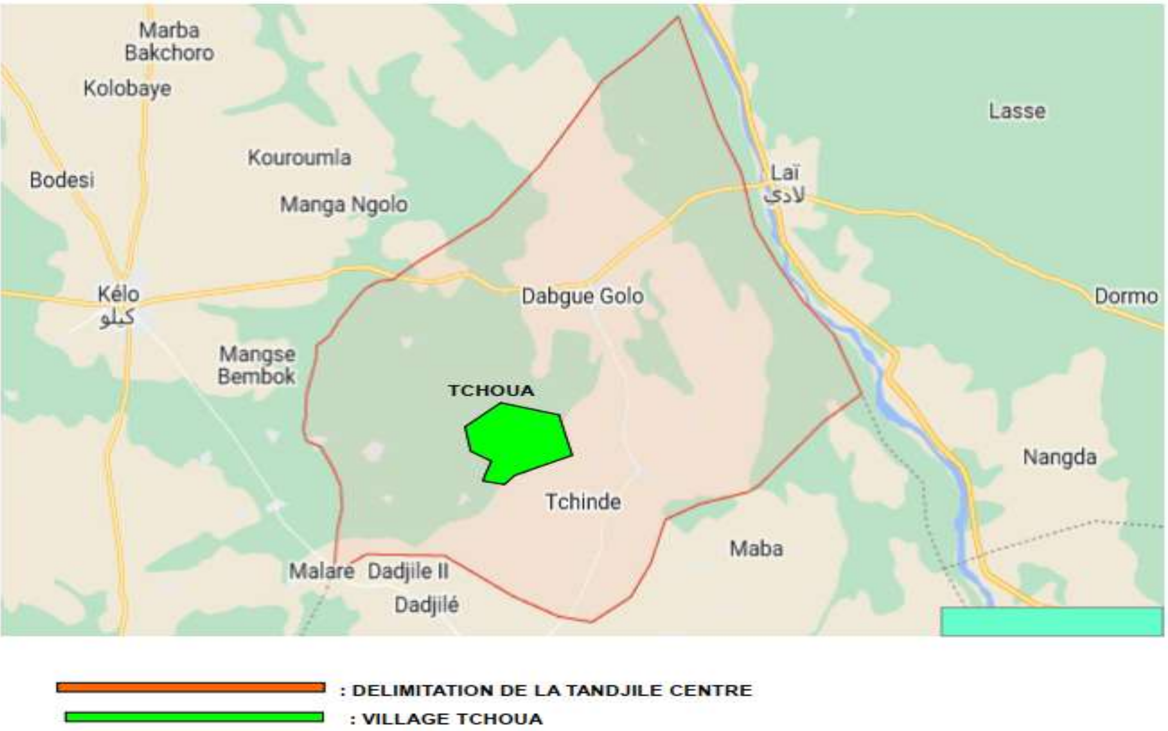


Figure 1:- Map of Tchoua Canton.

Photo 1:- Borassus wood splitting technique.

Photo 2:- Technique for recovering and conserving residues and fibres.

Pre-treatment of fibre

The fibres or residues were pre-treated by washing with tap water and then using distilled water as a solvent. After pre-treatment, the fibres and residues were dried in an oven at 100°C for 24 hours at the Institut de RechercheenElevage pour le Développement (IRED) laboratory in N'Djamena.

Photo 3:- Washing of residues with tap water (a), Calibration tray after washing (b), Washing with distilled water (c) at IRED in N'Djamena.

Photo 4:- Cleaning with distilled water (a, b and c), placing in the jar (d), placing in the oven (e), closing the oven and leaving the study (f and g) at 100°C for 24 hours of Borassus wood fibres.

Polypropylene matrix

The resin used for the experiments is from the homopolymer range of (REPSOL), registered as NRC (Djebloun, 2018). The thermoplastic matrix is polypropylene supplied by Raffinage de N'Djamena (NRC). Chad to manufacture polypropylene in the form of spherical granules 3 to 4 mm in diameter (Ragoubi, 2010). For reasons of cost and good transmission of forces to the reinforcement, the choice fell on a well-known polymer, polypropylene (PP). Polypropylene has good mechanical properties and also has good impact and corrosion resistance (Nguyen, 2016).

Shaping composite materials

In our study, the composite materials were made from polypropylene reinforced with BorassusAethiopum wood residues or fibres. Mixtures with different wood mass proportions range from: 10%, 15% to 20% (Samir, 2020).

Photo 5:- Bag (a) and Polypropylene grains (b).

Rectangular prismatic specimens

The specimens were made in several phases using different techniques for making our specimens (Allegue et al., 2012). The process is used in the same way for polypropylene (PP), but the mixing time is very short (between 2 and 4 minutes) and the fibres are oriented in the direction of flow to obtain good mechanical properties and improved rigidity. After melting the PP in a container and mixing it with the Borassus wood powder for a heating time of 30 minutes. The first layer of PP is poured into the mould and the male or female Borassus wood fibres are spread over the paste in the mould before it is placed under compacting pressure for a maximum of 5 to 6 minutes and then cooled by circulating a stream of water for 2 minutes before it is removed from the mould. The various stages in the manufacture of the specimens are shown in Figure 2 below :

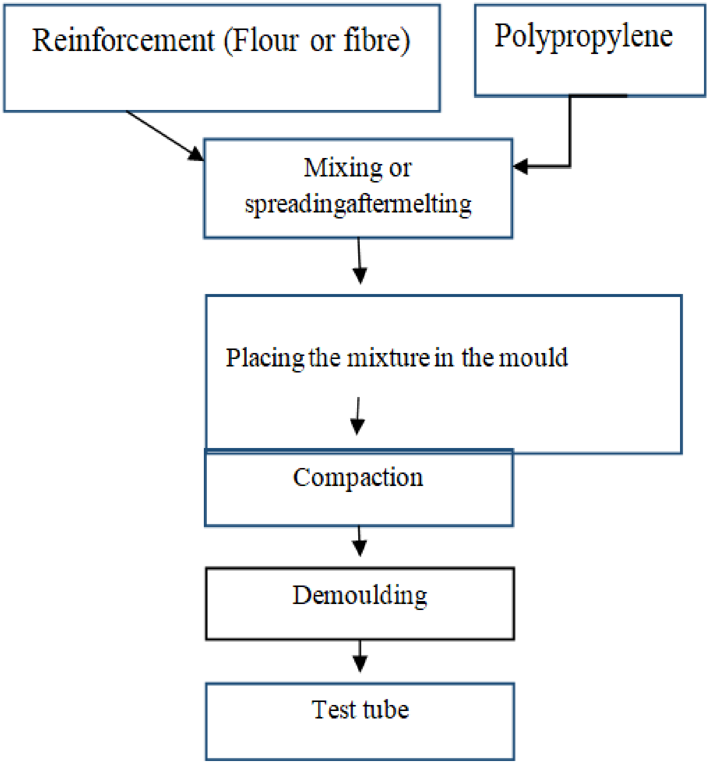


Figure 2:- Specimen production flow chart.

Results and Discussion:-

The results of the bending tests, showing respectively the development of deflection as a function of force (deflection-force), breaking strength and deformation as a function of the mass fraction of fibres and Borassus powder in the specimens, are shown in Table 1.

Table 1:- Summary of average results obtained for the three-point bending test.

Designation of test pieces		Average stress (MPa)	Average MOE (MPa)	Standard deviation of stress	MOE standard deviation (MPa)	Average strength (N)	Average arrow (mm)	Average deformation (%)	Standard deviation of Deformation
FNTF	10%	29,061	695,426	12,149	200,566	2056,667	4,144	0,040	0,005
	15%	25,703	715,502	1,215	116,506	816,667	2,724	0,022	0,003
	20%	15,033	824,873	8,771	95,336	1606,667	3,497	0,032	0,016
FNTM	10%	29,271	495,147	3,022	78,833	1364,333	4,401	0,041	0,006
	15%	21,618	680,713	7,610	249,024	1744,333	5,190	0,046	0,010
	20%	20,378	711,270	4,705	114,107	1063,000	3,684	0,030	0,004
FibNTF	10%	16,275	323,194	1,212	31,603	706,667	4,458	0,038	0,001
	15%	14,982	497,969	0,295	280,190	276,667	2,666	0,019	0,008
	20%	12,926	552,657	2,619	124,722	470,000	4,307	0,028	0,003

FibNTM	10%	16,100	506,475	1,903	84,097	690,000	4,034	0,031	0,007
	15%	15,532	530,544	2,198	120,815	583,333	4,657	0,032	0,009
	20%	15, 008	770,748	2,303	208,899	576,667	3,090	0,021	0,005
PP à 0%		14,785	547,380	2,001	79,906	961,500	2,913	0,027	0,0003

Figures 1, 2, 3 and 4 show the development of deflection-force, breaking strength and deformation as a function of the mass fraction of fibres and Borassus wood powder in test specimens.

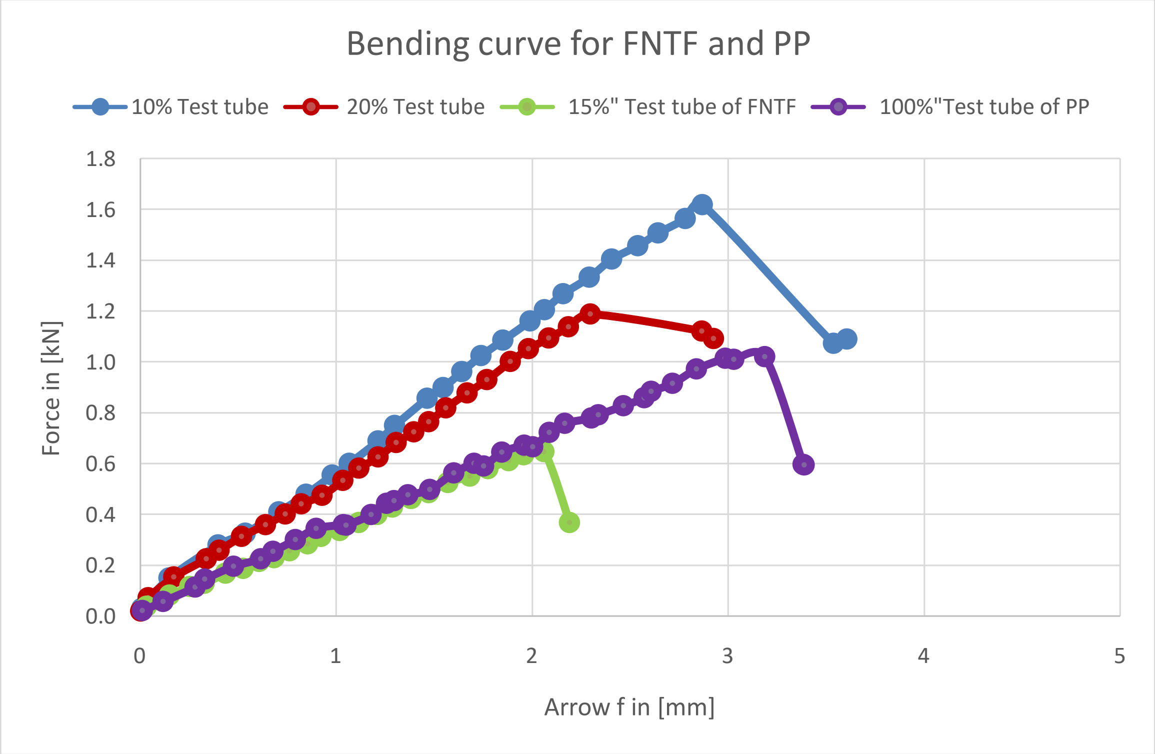


Figure 1:- Bending curve for FNTF and pure polypropylene (PP).

From the figures above, we can see that adding the powder as a filler increased the polymer resin, with the deflection reaching a value of 4.14 mm under a force of 2056.66N at 10%, a value of 2.72 mm under a force of 816.66 at 15% and a value of 3.49 mm under a force of 1606.66N at 20% for the untreated powder (flour) of female Borassus wood (Figure 1). For the untreated powder (flour) of male Borassus wood, we have a deflection of 4.40 mm at a force of 1366.33 N at 10%, a deflection of 5.19 mm at a force of 1744.33 at 15% and a deflection of 3.30 mm at a force of 1063.00 N (Figure 2).

The fibres have a deflection ranging from 2.66 mm to 4.45 mm for forces ranging from 276.66 N to 706.66 N in the case of untreated female Borassus wood fibres (Figure 3). And from 3.09 mm to 4.65 mm for forces varying from 576.66N to 690N (figure 4) for untreated fibres of male Borassus wood.

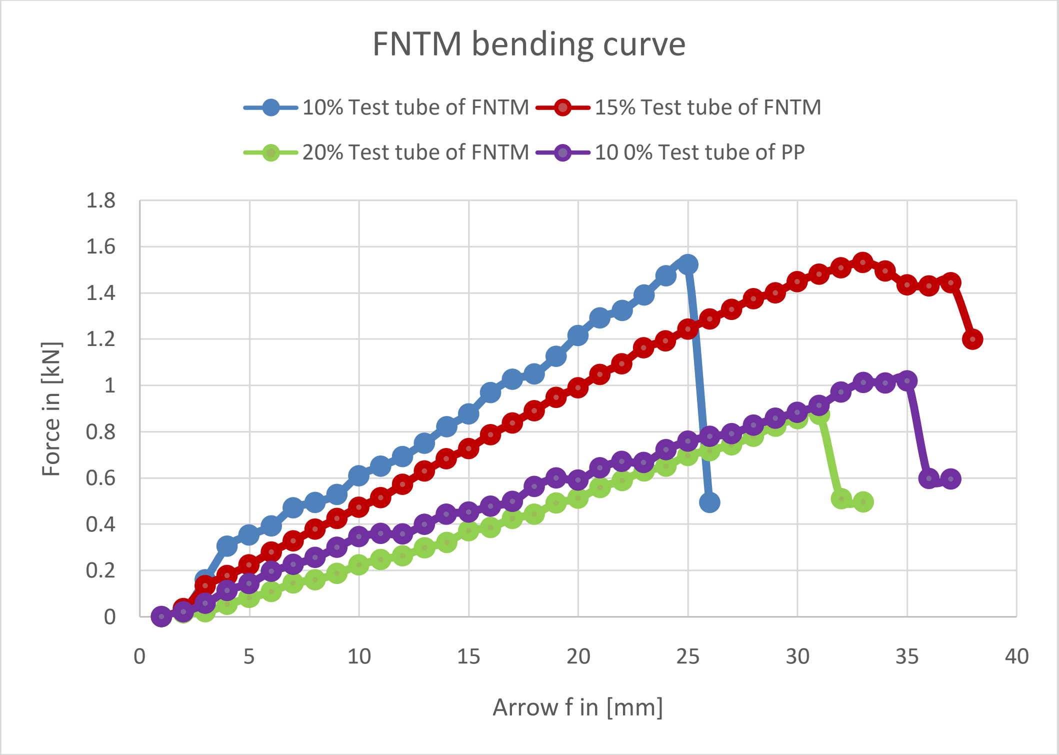


Figure 2:- Bending curve for FNTM of pure polypropylene (PP).

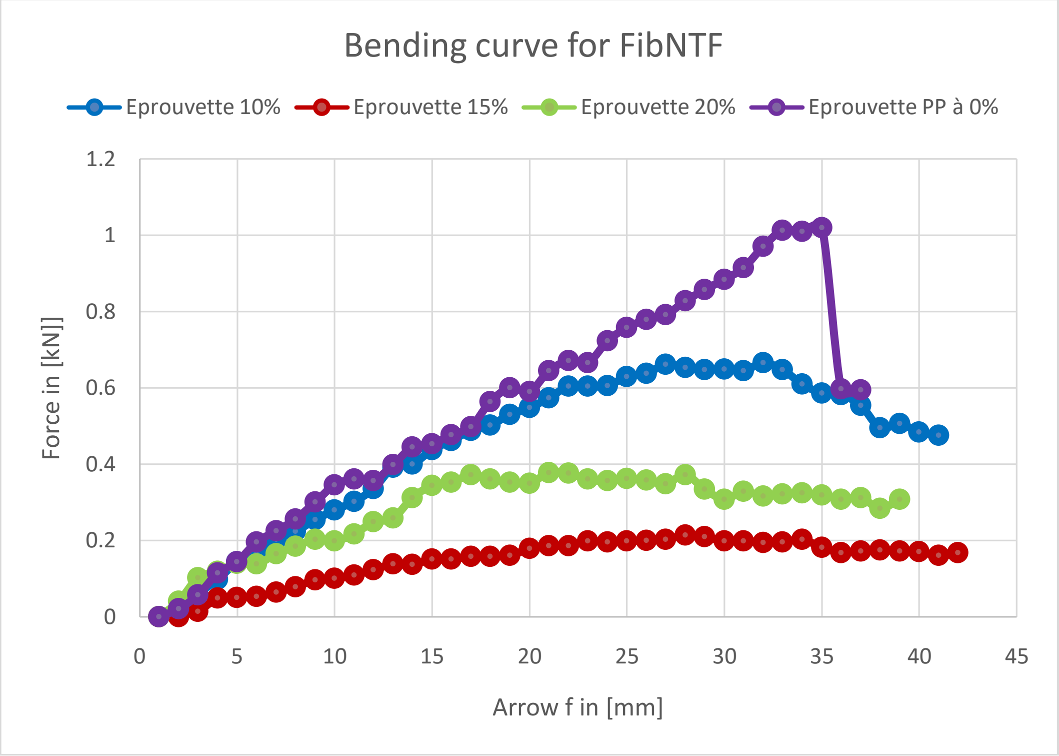


Figure 3:- Bending curve for FibNTF and pure polypropylene (PP).

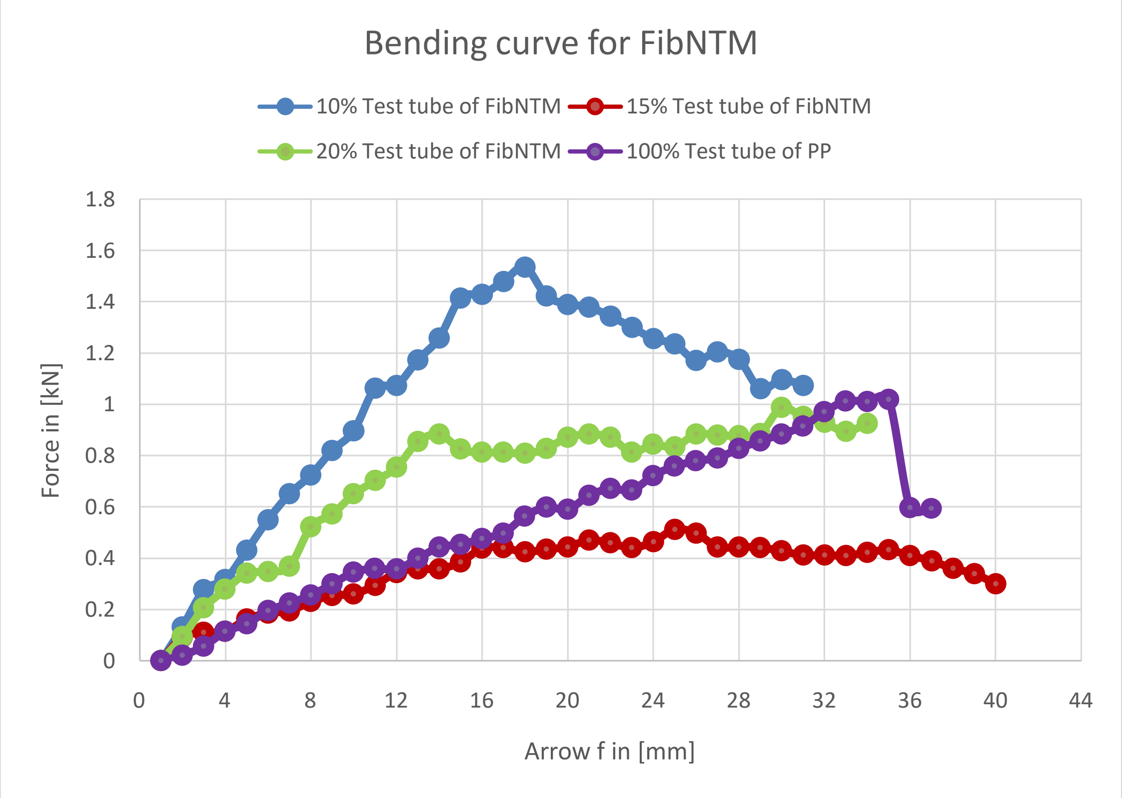
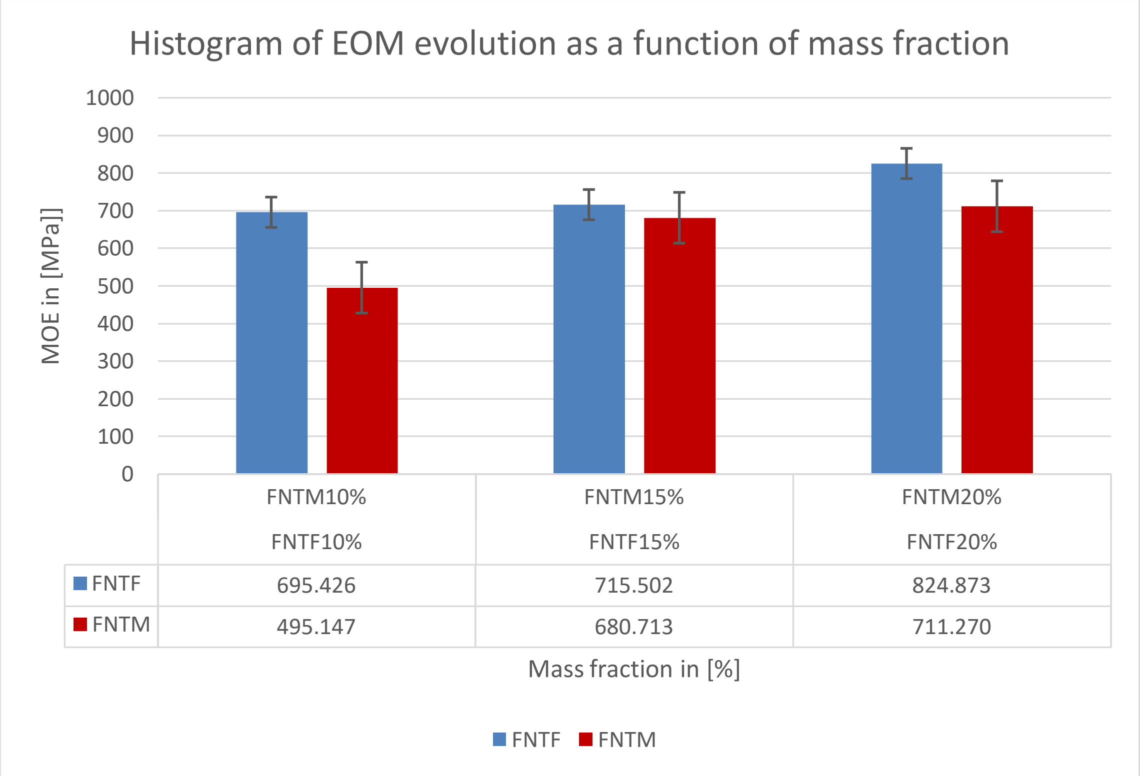


Figure 4:- Bending curve for FibNTM and pure polypropylene (PP).



	FNTM10% FNTF10%	FNTM15% FNTF15%	FNTM20% FNTF20%
FNTF	695.426	715.502	824.873
FNTM	495.147	680.713	711.270

Figure 5:- Histogram of EOM type - FNTF and FNTM mass fraction.

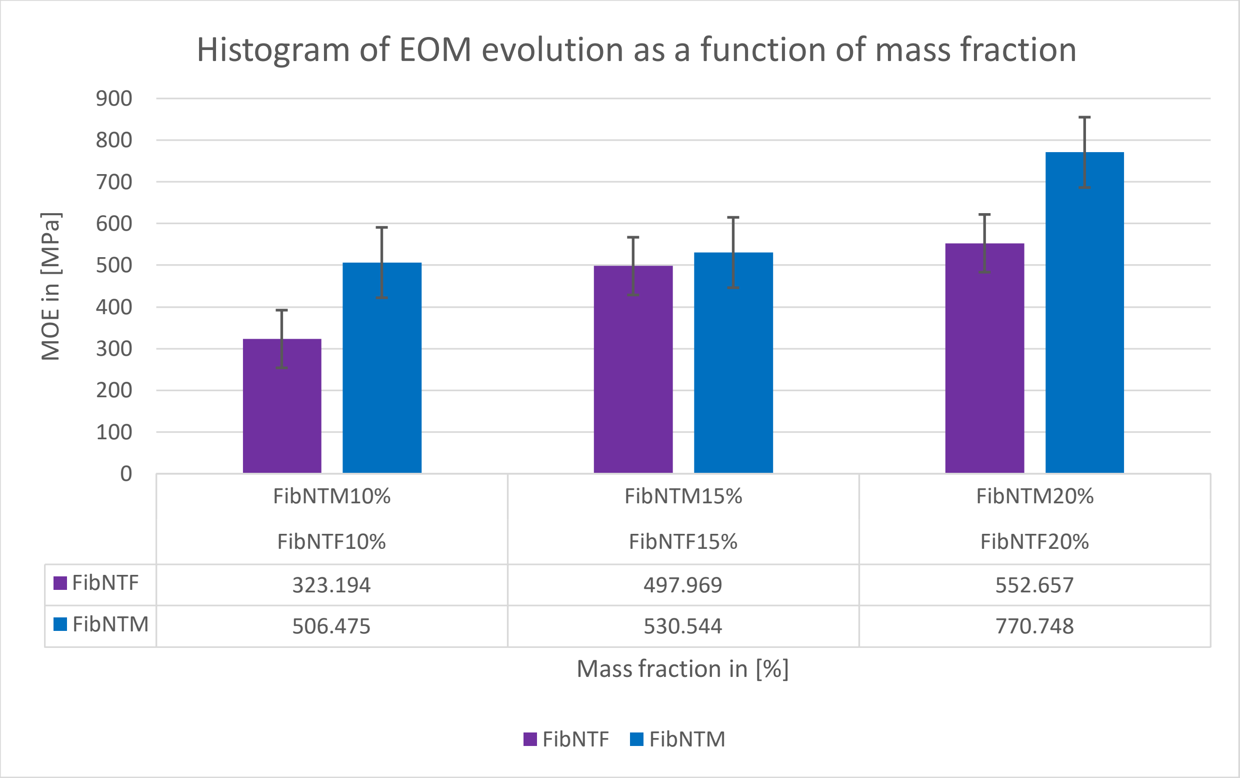


Figure 6:- Histogramme du type MOE- fraction massique de FibNTF et FibNTM.

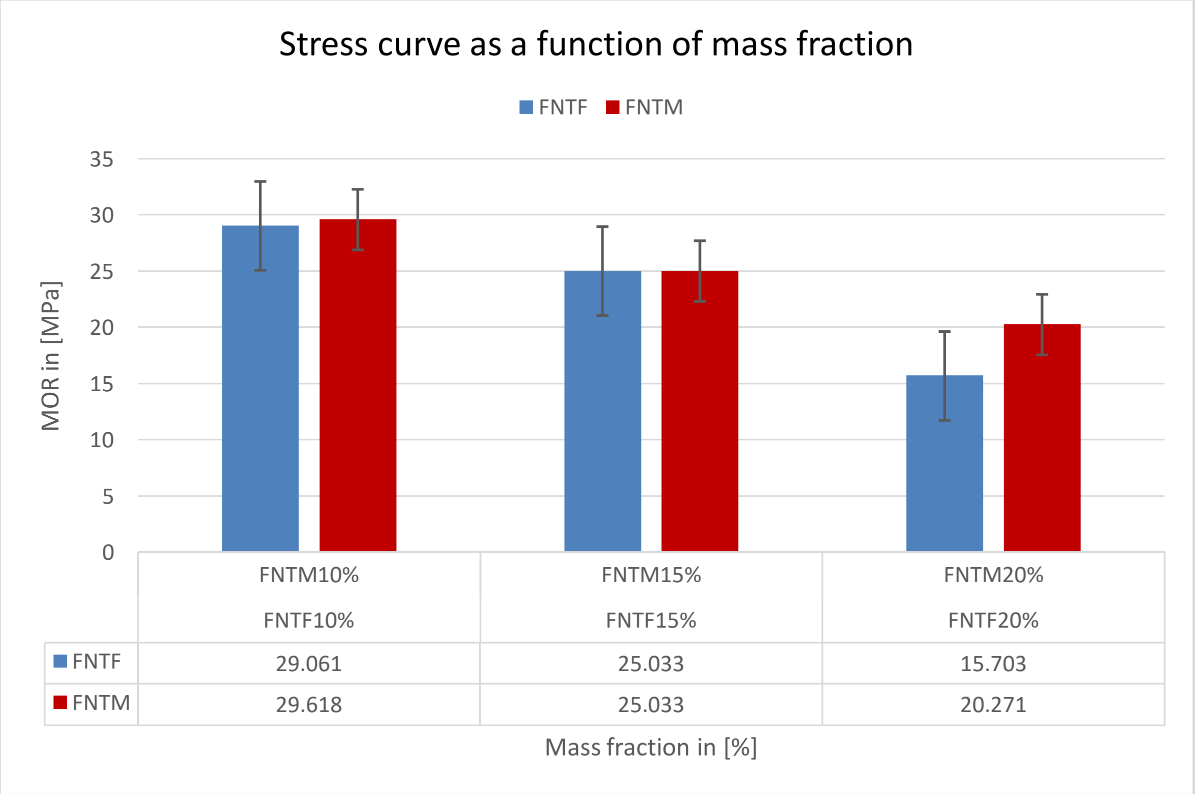


Figure 7:- Mass stress-fraction type curve for FNTF and FNTM.

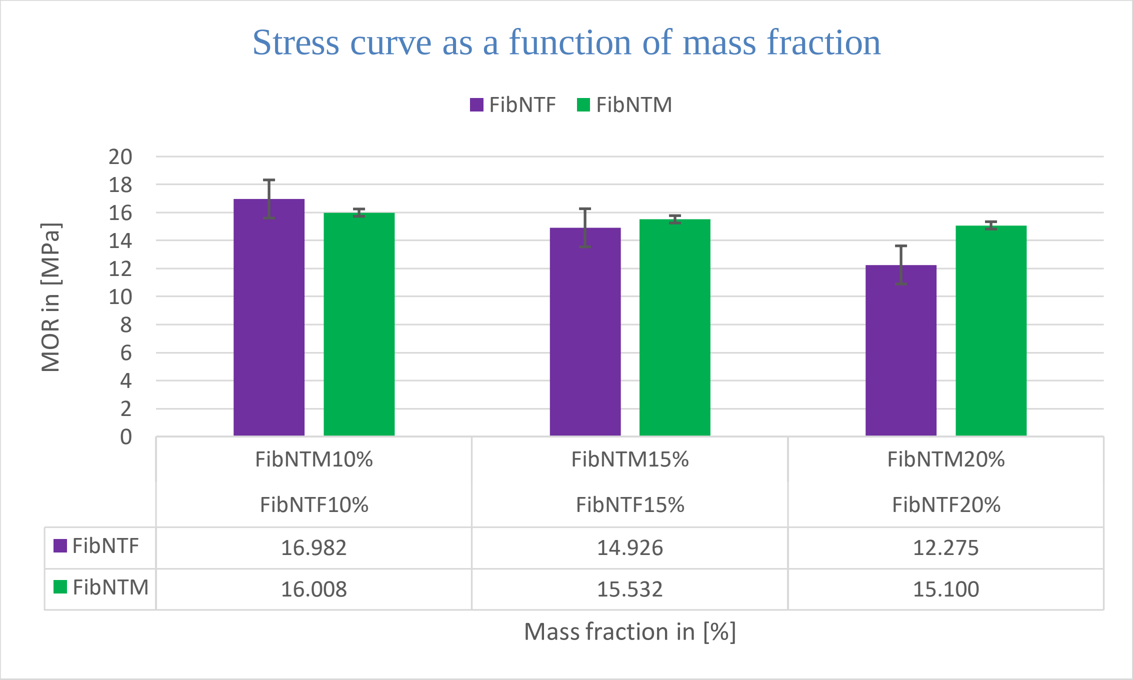


Figure 8:- Mass stress-fraction type curve for FibNTM and FibNTF.

We can see from the diagrams in Figures 5, 6, 7 and 8 that the moduli of elasticity have irregular values depending on the mass fraction of Borassus wood fibres or powder. Composites of untreated female Borassus wood powder (flour)(FNTF) and untreated male Borassus wood powder (flour) (FNTM) have a modulus of elasticity that ranges from 495.14MPa to 824.87 MPa while untreated female Borassus wood fibre (FibNTF) and untreated male Borassus wood fibre (FibNTM) have a modulus of elasticity that ranges from 323.19MPa to 770.74 MPa : these results are consistent with those of(Guidigo, 2017).

We can state that the mass fraction of the powder improves the mechanical bending characteristics of Borassus wood more than fibres reinforced with the polypropylene matrix. The value of the modulus of elasticity in bending increases with the addition of Borassus wood powder or fibres. The untreated Borassus wood powder helps the polymer matrix resist bending stress. Untreated Borassus wood powder helps the polymer matrix resist bending stress. The improvement in mechanical properties is significant : for a value of 20% of the Borassus wood powder (flour) (both female and male), the modulus of elasticity is 824.87MPa for the female and 711.27MPa for the male.

We note that the modulus of elasticity in bending varies very little with increasing fibres in Borassus wood: it is 552.65 MPa for the female and 770.74 MPa for the male. These results are in line with those of (Mechraoui, 2018).

Conclusion:-

Nowadays, plant fibres and residues are the focus of research into how to alleviate the environmental problems our planet is suffering from in the production of building materials. But if they are to be used wisely as building materials, their mechanical properties must be mastered. In this context, the fibres and residues of Borassus wood, which is available in large quantities in Chad, were incorporated into the polypropylene matrix for mechanical characterisation. Once the formulations had been made and the specimens produced using different proportions of Borassus wood residues and fibres, the three-point bending strengths were determined. These strengths vary from 29.061 MPa to 15.033 MPa of FNTF ; from 29.271 to 20.378 MPa of FNTM for powder. From 16.275MPa to 12.926 MPa of FibNTF ; from 16.100MPa to 15.008 MPa of FibNTM for fibres. These results were used to determine the moduli of elasticity and the stresses at break obtained from the experiments are in agreement with the results in the literature.

Acknowledgements:-

I would like to express my sincere thanks to DrNakorNargaye, head of the laboratory at the Institut de RecherchеenElevage pour le Développement (IRED), Mr DJEKOURBOUAYON Honoré and Ms Amina MOUSTAPHA HISSEIN, technicians at the IRD laboratory in N'Djamena.

Conflict of interests

The authors declare no conflict of interest with respect to the publication of this article.

References:-

1. Achouak, A., & Lina, A. (2021). Elaboration et caractérisation des matériaux composites polyéthylène PE/ Farine de bois [Memoire de Master]. Université Mohamed Khider de Biskra.
2. Adjou, E. S., Amamion, H., Tchobo, F. P., Aissi, V. M., &Soumanou, M. M. (2013). Extraction assistée par enzyme du jus de la pulpe fraîche du rônier (Borassus aethiopumMart.) acclimaté au Benin : Caractérisation physico-chimique et microbiologique. International Journal of Biological and Chemical Sciences, 7(3), 1135-1146.
3. Allegue, L., Zidi, M., &Sghaier, S. (2012, mars 19). L Propriétés mécaniques des composites polypropylènes renforcées de fibres de posidonie.
4. AlMaadeed, M. A., Nógellová, Z., Mičušík, M., Novák, I., & Krupa, I. (2014.). Mechanical, sorption and adhesive properties of composites based on low density polyethylene filled with date palm wood powder. http://hdl.handle.net/10576/31898
5. Bouhank, S. (2017). Elaboration de matériaux composites PVC/fibres de Genêt d'Espagne : Formulations et caractérisations [PhD Thesis]. http://dspace.univ-setif.dz:8888/jspui/handle/123456789/1045
6. Djebloun, Y. (2018). Contribution à la caractérisation des matériaux composites renforcés de fibres végétales [PhD Thesis, Université Mohamed KHIDER BISKRA]. http://thesis.univ-biskra.dz/id/eprint/3951
7. El-Abbassi, F., Ayad, R., Kebir, H., Sabhi, H., Buet, S., &Assarar, M. (2014). Elaboration, analyse et modélisation mécanique numérique d'agro-composites à base de fibres courtes d'alfa. MATEC Web of Conferences, 11, 01039. https://www.matec-conferences.org/articles/matecconf/abs/2014/02/matecconf_cmss2013_01039/matecconf_cmss2013_01039.html
8. Guidigo, J. (2017). Caractérisationphysico-mécanique d'un composite bois polymère ; Physical and mechanical characterization of wood polymer composite. http://www.theses.fr/2017LORR0229/document
9. Mechraoui, A. (2018). Sandwich composite de mousses polymères. https://hdl.handle.net/20.500.11794/21348
10. Naziha, Z. (2015). Elaboration de composites à base de PEBD: Etude des effets du taux de charges et des interactions à l'interface [PhD Thèse]. FERHAT ABBAS, SETIF-1.
11. NetodjiroAllarabeye. (2009). Caractérisation structurale, Physico-chimique et Mécanique du rônier Sous la direction de : Encadreur principal : Dr. NGARGUEUDEDJIM Kimtangar, Maître Assistan [Memoire de Master]. Institut Universitaire des Sciences et Techniques D'ABECHE (IUSTA).
12. Nguyen, D. C. (2016). Caractérisation de l'interface fibre/matrice : Application aux composites polypropylène/chanvre [Phdthesis, Université de Technologie de Troyes]. https://theses.hal.science/tel-03361756
13. Panaitescu, D. M., Iorga, M., Vuluga, Z., Donescu, D., Dan, M., &Serban, S. (2007). L'effet de l'interface dans les composites de fibres naturelles et de matières plastiques [Article revu]. Institut National de Recherche et Développement en Chimie et Pétrochimie Bucarest.
14. RAGOUBI, M. (2010). Contribution à l'amélioration de la compatibilité interfaciale fibres naturelles/matrice thermoplastique via un traitement sous décharge couronne [Thèse de doctorat]. Henri Poincaré Nancy 1.
15. Samir, A. (2020, septembre 23). Effet du traitement de surface sur les propriétés physico-chimique de composite PVC. http://archives.univ-biskra.dz/bitstream/123456789/18181/1/Amraoui_Samir.pdf
16. Tarek, D. (2019). Elaboration et caractérisation de composites bio-sourcés à base de fibres de palmier dattier.[PhD Thesis]. http://archives.univ-biskra.dz/handle/123456789/24690
17. Touloum, F., Benchabane, A., & Kaci, A. (2012). Valorisation des fibres naturelles de renfort pour matériaux composites. [Article revu] de Cergy-Pontoise.