Tensile properties of Renewable Diss Fiber /Polyester Composite

Mustapha BOUAKBA, Bahim ISSASFA, Mourad BOUKATEM and Abderrahim BELLOUFI
[1]Univ Ouargla, Fac. des Sciences Appliquées, Dépt. Génie Mécanique, Ouargla 30 000, Algeria
bouakba.mu@gmai.com , bouakba.mu@univ-ouargla.dz

ملخص : تعرض هده الدراسة نوع جديد من المواد المركبة المعزز بالألياف الطبيعية. تم فيها استعمال نبتات الديس التي تنمو بشكل كبير في دول البحر ألأبيض المتوسط. لقد درسنا الخصائص الميكانيكية لهذه الألياف بواسطة تجربة الشد حسب معاييرSTM . أثبتت النتائج المتحصل عليها أهمية هده الألياف مقارنة بالخصائص الميكانيكية التي تميز بعض الألياف النباتية مثل السيسال. تمت صناعة المواد المركبة من أجل ثلاث نسب مختلفة لأحجام الألياف 20٪، 30٪ و 40٪ وذلك من أجل دراسة تأثيرها على الخصائص الميكانيكية.

كلمات دالة : الألياف المتجددة ,نبات الديس , الألياف الطبيعية , المواد المركبة ,تجربة الشد.

ABSTRACT: This paper presents a novel composite material produced by a natural reinforcement subjected to tensile test. The used reinforcement is made of Diss fibers. The Diss (Ampelodesma mauritanica) is a Mediterranean wild plant. This fiber is characterized in tensile according to ASTM standard. The results obtained show that the fiber Young’s modulus and the stress at break are very interesting and are similar to those obtained for some natural fibers such as sisal fiber. The composite was developed to study by three differing volume fractions of 20%, 30 % and 40 %.

KEYWORDS: Renewable fibers, Diss, Ampelodesma mauritanica, natural fibers, composite, tensile.

RESUMÉ : Dans ce travail nous avons présente un nouveau matériau composite renforcé par des fibres naturelles. Le renfort utilisé dans cette étude est la fibre de Diss. Le Diss (Ampelodesma mauritanica) est une plante sauvage de la Méditerranée. La capacité de renforcement de ces fibres est investigue en traction selon la norme ASTM. Les résultats obtenus montrent que le module de Young et la contrainte à la rupture de la fibre sont très intéressants et sont similaires à ceux obtenus pour certaines fibres naturelles comme la fibre de sisal. Le composite étudie a été élaboré pour trois différents fractions volumique égale à 20%, 30% et 40%.

MOTS-CLÉS : fibres renouvelable, Diss, Ampelodesma mauritanica, fibres naturelle, composite, traction.

1. Introduction

In the recent years, many researchers took the challenges to replace the synthetic fibers by the renewable fibers in composites materials. Natural fibers have many advantages like good mechanical properties, lower density, and environmental impact [1, 2]. The main advantages to using natural fibers in composite are the low cost, low weight, biodegradable, ecological, and renewable. However, tow major reason limits the large using natural fibers reinforced composite. First, the tensile strength of natural fiber is very low compared to Synthetic fibers. The second is the water absorption [3]. This work aimed to use the Diss fiber in strengthening of composite material. The Diss (Ampelodesma mauritanica) is a wild plant, very fibrous over large parts of Mediterranean countries. To the best of the Author's knowledge, no previous attempt has been performed at manufacturing fibers for plastic reinforcement from the Diss plants.

In the present work, we investigated the tensile properties of the Diss fiber and the composite fabricated by a molding process. Two parameter Weibull distributions have been used to carry out statistical analysis on fiber strength and Young’s modulus.

2. Experimental Method

The studied composite material is made of a polyester matrix reinforced with Diss fibers. The Table gives these properties of the used matrix.

Table 1: Polyester unsaturated resin properties

Properties	Value	Unit
Density	1.2	g/cm^3
Young's modulus	500	MPa
Tensile stress at failure	30	MPa
Tensile strain at failure	2.5	%

The composite plates have been fabricated using a molding technique at low pressure equal to 3 Bars, with impregnation at room temperature (18 to 20°C). The unsaturated polyester resin has been hardened and catalyzed in percentage between 0.5 and 1 % in mass. After the matrix polymerization, structural composite plates are obtained with the dimension 400×400×2, and having a different fiber's volume fraction 20%, 30% and 40 %. The fiber volume fraction is affected by the geometric parameters of fiber arrangement within the fibrous structure, their orientation, and the spacing between fibers [5]. In this work the fiber volume fraction for these plates composites elaborated has been calculated according to ASTM D2854 standard as:

$$V_f = \left[\rho_m \times \frac{W_f}{\rho_m \times W_f + \rho_f \times W_m} \right] \tag{1}$$

Where ρ_m density of matrix, ρ_f density of fibers, W_m weight of matrix, W_f weight of fibers.

2. 1. Density of Diss-fiber Measurements

The density of these fibers is carried out by the Pycnometer method for five specimens at a room temperature. The mean value of this density is equal to 0.85 g/cm^3. This result is a very interesting compare to other natural fibers. For example the density of the sisal fiber is equal to 1.2 g/cm^3, and the density of glass fiber is equal to 2.4 g/cm^3. The use of Diss fibers in reinforced plastic fiber can be save in one m^3 a weight equal to 350 Kg from the sisal fibers, and save a weight equal to 1550 Kg from the glass fibers. From another point of view we can economize about 30 % and 64.58 % of the cost compared to the price, which cost him, the use of sisal fibers and glass fibers respectively.

2. 2. Fibers and Composite Tensile

A total of 50 fibers was tested at a room temperature with a fiber length of 250 mm. The tensile properties of the Diss fibers are determined experimentally according to ASTM standard D3039. The experiments are carried out with a single column ET traction machine equipped with a 10 KN load cell, with a velocity equal to 15 mm/min in order to get a total time test of 20 ± 3 s. During the axial loading, the short fiber appears the high scatter behavior. The behavior makes the analysis of results difficult [4]. For avoided this difficulty our fiber tests have a length equal to 250 mm. The studied composite plates with a two different volume fraction and two fibers length mentioned above have been subjected to axial loading according to the ASTM D3039 standard, with a constant speed of 2 mm/min. The test specimens have a length of 250 mm, a width of 25 mm and a thickness of 2 mm. five specimens have been tested for each volume fraction and for each fiber length.

2. 3. Statistical analysis with Weibull distribution

The following equation show the Weibull distribution with two parameters has been used to determine the dispersion of the tensile strength and the Young's modulus:

$$P(\sigma) = 1 - \exp\left\{-\left(\frac{\sigma}{\sigma_0}\right)^m\right\}, \qquad \sigma > 0,\ \sigma_0 > 0,\ m \tag{2}$$

Where $P(\sigma)$ is the probability of survival of the parameter σ, m is a shape parameter or the Weibull modulus related to the dispersion of the data and σ_0 is an average value of σ [4]. The probability of failure value for each strength was defined as:

$$P = \frac{i - 0.5}{n} \tag{3}$$

Where:
$i =$ 1, 2, 3, . . . , n
$n =$ total number of specimens tested

In order to define the average value of Young's modulus and strength tensile is necessary to follow these steps:

Step 1: For each strength Calculate $Y_p = \ln\{\ln[1/((1-P)]\}$ (4)

Step 2: Plot the calculated Y_P vs. $ln\sigma$.

Step 3: Use a linear least-squares method to fit a straight line to the data. The slope of this line is equal to m, and its intersection with the $ln\sigma$ axis is equal to $ln\sigma_0$.

3. Results and Discussion

The typical Load–Displacement curve for a Diss fiber is shown in Figure 1. The Diss fiber subjected to tensile load has a similar behavior when compared to other natural fiber shown in the open literature.

The Young's modulus of the Diss fiber is calculated by:

$$E = \frac{\sigma}{\varepsilon} \tag{5}$$

Where ε is the strain calculated by $\varepsilon = \frac{u}{L}$, with u : represent the displacement of the crosshead, and L is the length of the fiber. The stress is calculated as:

$$\sigma = \frac{F}{S} \tag{6}$$

Where F is the load; and S is the cross section of these fiber used in this study.

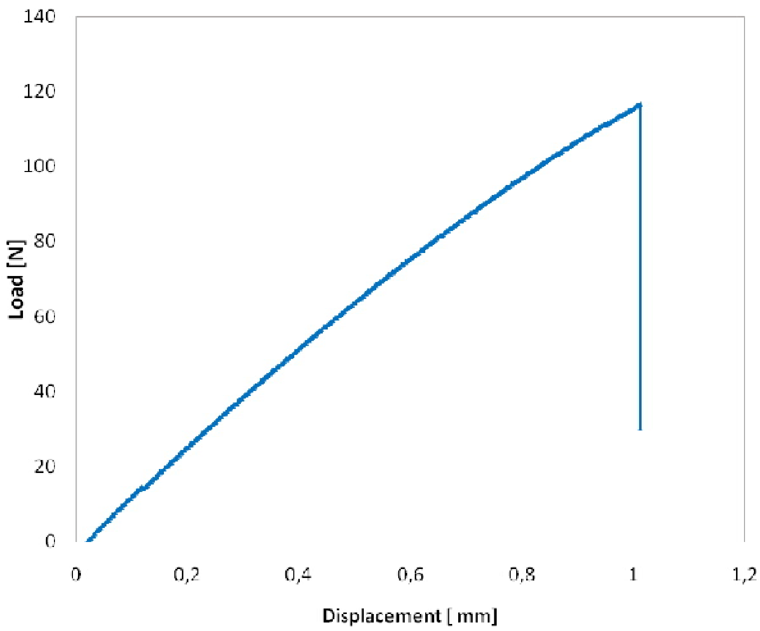

Figure 1 : Typical Load–Displacement curve for a Diss fiber.

Table 2 illustrate the average value of the tensile properties of the Diss fibers obtained by the Wiebul distribution a tow parameters. The tensile modulus and strain at failure and Stress at failure for this Diss fiber shown similar values when compared to sisal fiber presented in literature [4].

Table 2: Tensile properties of the Diss fiber

Tensile properties	Average value	Variation ratio (%)	Confidence interval at 93%
Young Modulus (GPa)	8.5	28.5	[7.5 : 10.5]
Stress at failure (MPa)	105	30	[80 : 115]
Strain at failure (%)	2	32	[1.8 : 2.65]

Figures 3 and 4 shows the average results from the axial load measurements carried out on a series of five composite samples for each fiber volume fraction (V_f). The average value of the tensile strength and the tensile modulus for the V_f equal to 30%, is around 102 MPa and 3.5 GPa, with a standard deviation corresponding respectively to 2.7 % and 5% of the mean value. The tensile strength for these Diss fibers reinforced composites with a V_f equal to 30 % is 1.30 times higher than the one measured from the composite plates has a V_f equal to 20 %, and 1.27 times higher than the one measured from the composite plates have a V_f equal to 40 %.

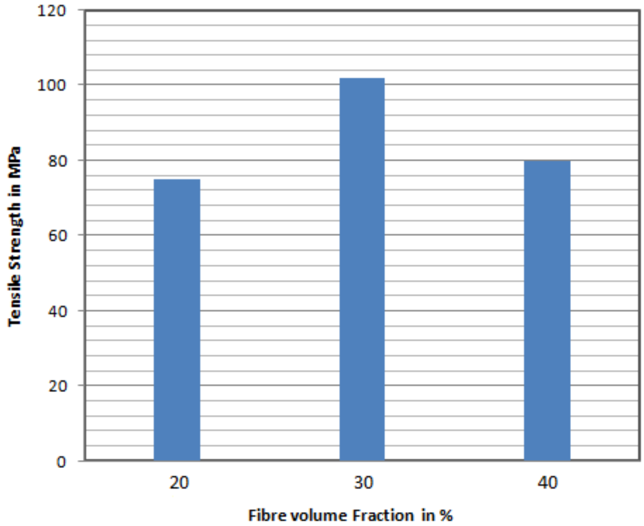

Figure 2: Effect of fiber volume fraction on the tensile strength for the Diss / Fiber Reinforced composite.

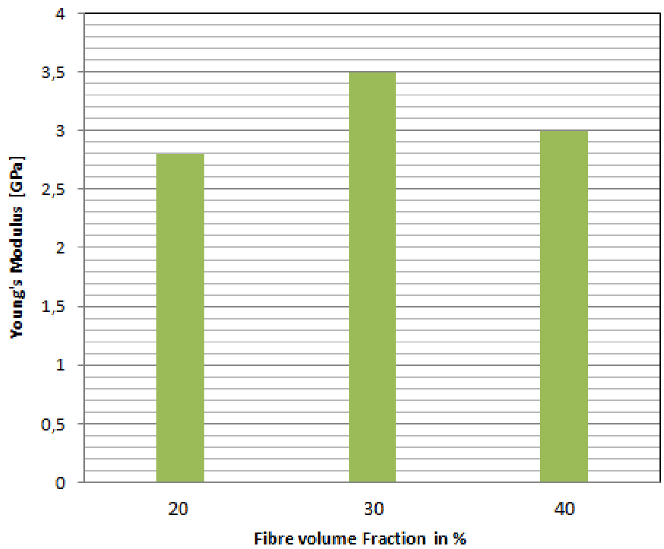

Figure 3: Effect of fiber volume fraction on the Young Modulus for the Diss / Fiber Reinforced composite.

4. Conclusion

The Diss fiber and composites evaluated in this paper demonstrate the following characteristics:

The Diss fiber has an excellent property and a similar behavior compared to other fiber shown in open literature.

1- The tensile modulus, strain at failure and Stress at failure for this Diss fiber shown similar values when compared to sisal fiber presented in the open literature [4].

2- The composite elaborated have a V_f equal to 30 % show the highest tensile strength and tensile modulus compared to the other prepared by the V_f equal to 40 % and 20%.

3- The use of the natural fiber causes to low price, low weight, biodegradable ecological, and renewable.

References

[1] Bouakba M., Bezazi, Boba K, Scarpa F. et Bellamy S.; *Composites Science and Technology,* Vol. 74, 150–159 (2013).
[2] Ben Brahim S. et Ben Cheikh R; *Composites Science and Technology*, Vol. 67, 140 -147 (2007).
[3] Wambua P., Ivens J. et Verpoest I.; *Computer Science and Technology*, Vol. 63, 59–64(2003).
[4] Belaadi A., Bezazi A., Bourchak M., Scarpa F. et Zhu C; *Composites: Part B,* Vol. 67, 481–489 (2014).
[5] El Messiry.; *Alexandria Engineering Journal,* vol. 52, 301–306 (2013).