

Mechanical properties of flax roving composites reinforcement

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Abstract

The work consists of analyzing three roving linen of different linear density (200 tex, 400 tex, 2000 tex) and three fabrics (satin, twill weave and plain weave) which were made on rapiere loom called Picanol. The purpose of the study is to analyze the mechanical properties of linen roving and the resulting composites that will be needed in the future to design a lightweight truss or structural frame.

1. Introduction

Construction is one of the largest markets for composites worldwide. A wide range of fiber reinforced composites are used in the construction industry for their benefits over traditional materials. The main advantages are: reduced weight, corrosion and rotting resistance, which can significantly reduce the durability of structures made of steel and wood. Lower operating costs are achieved because they do not need frequent repairs and maintenance. Lighter materials are easily assembled, which also reduces production costs. Composites give you more freedom of design, allowing you to produce different shapes and they can be used in many areas of the construction industry. They are well known as an effective solution for repairing structural defects and strengthening existing systems. [1]

Nowadays among the various organic materials, natural fibers are one of the potential cheap and environmentally friendly materials that may be an important component of polymer composites. In addition to ecological aspects, natural fiber reinforced composite products exhibit low density and high vibration absorption [2,3]. Flax fibers have greater strength compared to cotton, jute, hemp, and silk. Taking into account the lower density of flax fiber compared to fiberglass, the strength of both raw materials is comparable (Table 1).



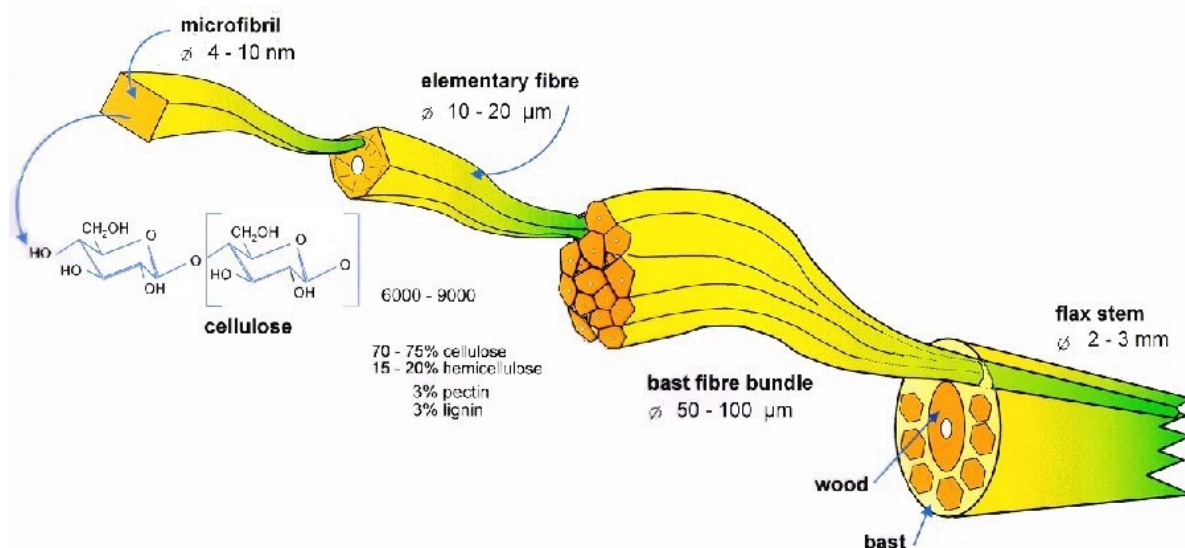


Figure 1. Flaxfibre structure[4]

Table 1. Density and strength of natural and noble fibres[5]

	Flax	Jute	Hemp	Ramie	Glass
Fibre Density, g/cm ³	1,45	1,3	1,48	1,5	2,5
Fibre strength,cN/tex	27-73	18-57	27-69	27-73	55-100

The tear strength of the linen fiber depends on the growth and processing conditions of the straw. The straw that is not treated has strong fibers but at the same time is thick and difficult to spin. The straw that is treated has weaker and shorter fibers due to the middle plate break between the filaments. [6]

Greater fiber length indicates better quality. Linen fibers are smooth. Higher anatomical indexes increase the physical-mechanical properties of the fiber, this leads to an increase in the breaking strength of the linen varieties. The properties of the composites depend on the mechanical properties of the textile products. An experiment was conducted to determine the effect of linear density of linen yarn on its strength and the weave used. Research will help to predict the mechanical properties of composites with this type of textile reinforcement in the future. The work consists of analyzing three roving linen of different linear density (200 tex, 400 tex, 2000 tex) and three fabrics (satin, twill weave and plain weave) which were made on rapier loom. The purpose of the study is to analyze the mechanical properties of linen roving and the resulting composites that will be needed in the future to design a lightweight truss or structural frame.

2. Materials

Three roving linens with different linear density were tested: 200 tex, 400 tex and 2000 tex. Further to the experiment, using these three linear densities, three fabrics were created on the rapierloom: satin, twill weave and plain weave fabric. The fabric shave 400 tex weft and 167 dtex polyester warp.



Figure 2. Flax roving plain a) 200 tex, b) 400tex, c) 2000tex

In all three fabrics the warp count was 320 threads / dm.

In the satin weave 4/1 step 2 the weft was 75 roving/ dm.

For a twill weave 1/3 diagonal weave S, the weft count was 71 roving / dm.

For plain weave 1/1 weft density was 66 roving / dm



Figure 3. Fabric structure a) satin, b) twill c) plain

In the satin and twisted weave the right and left sides were different. This was due to the difference in coverage, but in the plain weave both sides were the same. The composite was made using the above weaving code and using the vacuum bag method. The composite was made with a single layer and two layers. For a smooth surface, the fabric was laid flat on the glass, then poured with 1x10 epoxy resin with a hardener. Double layer composite was obtained by applying two fabrics of the same weave, placing them in the same direction on each other. Then the impregnated fabrics were applied sequentially with Teflon fabric, perforated foil and wadding. Then the whole package was sealed in a vacuum bag and subjected to a vacuum compression process, reaching a vacuum of 1 bar for 4 hours until the resin cured. After 24 hours the prepared single and double layer composites were removed from the vacuum bag and cut into samples of the appropriate size needed to perform bending rigidity tests.

3. Experiment

The experiment consisted of analyzing three different linen rovings of varying linear densities (200 tex, 400 tex, 2000 tex) and three different weave fabrics (satin, twill weave and plain weave) woven from a roving weft of 400 tex. The roving strength tests were carried out in accordance with EN ISO 2062 (Textile - Threads in Fertilizers - Determination of breaking strength and elongation at break of thread sections). In order to determine the breaking strength and elongation of roving linen, 50 repetitions were performed for each of the three types of linear density. The sample length was 25 cm. Fabric strength tests were performed in accordance with EN ISO 13934-1 (Textile - Flat Tensile Properties - Part 1: Determination of maximum force and elongation at maximum force using the strip method). In order to determine rupture strength and elongation of the fabric, 5 repeats were performed for the warp and weft respectively. The sample width was 5 cm. The distance between the jaws was 10 cm. All roving samples and fabrics were tested after conditioning for 48 hours at 24 ° C and 62% humidity. The samples were mounted vertically, centrally in the clamp of Instron's strength machine. The breaking force was determined by moving the beam at a speed of 250 mm / min until fabric breakage.

The bending rigidity of the composites produced was tested according to PN-EN ISO 14125 by 3 point bending method. The tests were carried out at a speed of 5 mm / min. Samples were cut in accordance with the applicable standard for Class III material, unidirectional transverse reinforced composites. The length of the samples was 60 mm, the distance of the supports 40 mm, the width of 15 mm. The sample thickness for a monolayer composite was about 1 mm and for a two-layer composite it was in the range of 1.6 mm to 2.1 mm (table 2). For each variant, 5 measurements were made. The bending stress was calculated using the equation $\sigma_f = \frac{3F}{2bh^2}$ where σ_f is the bending stress expressed in mega pascals (MPa), F is the load in Newtons (N), L is the span in millimeters (mm) H is the thickness of the fitting in millimeters (mm), b is the width of the fitting in millimeters (mm).

Deformation on the outer surface of the fitting is calculated by the formula $\varepsilon = \frac{6sh}{L^2}$ where ε is the deformation on the outer surface of the body expressed by a dimensionless ratio, s is the deflection arrow in (mm), h is the thickness of the fitting in millimeters (mm), and L is the span in millimeters (mm).

4. Analysis of measurements results

The results of the study on the specific strength of roving and elongation at break are given in Table 2.

Table 2. Mechanical properties of roving linen.

	200tex	400tex	2000tex
Strength, cN/tex	4,62	4,33	2,98
Standard deviation for strength	1,33	1,22	1,18
Elongation %	0,86	1,00	1,03
Standard deviation of relative elongation	0,13	0,13	0,18

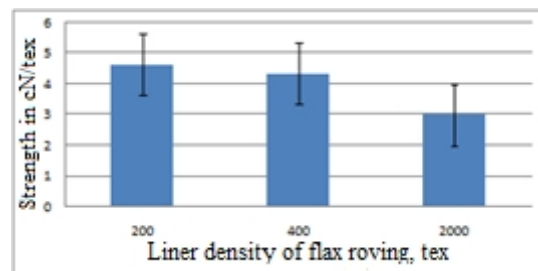


Figure 4. Flax roving strength cN/tex

As can be seen in Figure 4, the strength of the roving linen decreases as the linear density increases. The strength standard deviation of the roving linen with a linear density of 200 tex is equal to 1.33 cN / tex, 400 tex is equal to 1.22 cN / tex, 2000 tex is equal to 1.18 cN / tex. Elongation at break rises with increasing linear density of the roving linen. The results of the specific strength testing and elongation at fracture are given in Table 3.

Table 3. Strength and elongation in breakage point of woven fabrics.

		Stain weave	Twill weave	Plain weave
Strength N/cm	Warp	76,7	58,1	77,6
	Standard deviation	14,8	6,1	16,4
	Weft	114,7	108,3	77,1
	Standard deviation	2,4	9,7	19,3
Elongation %	Warp	21,5	22,5	18,1
	Standard deviation	3,0	1,7	2,1
	Weft	1,8	1,8	1,4
	Standard deviation	0,3	0,3	0,3

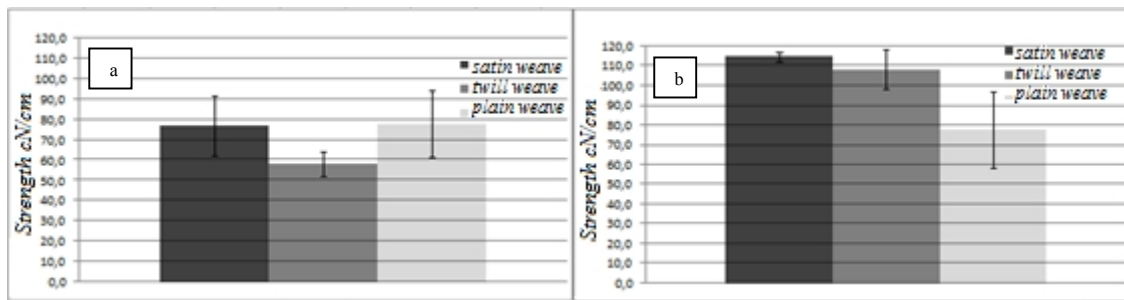


Figure 5. Fabric strength depending on weave and standard deviation a) Warp b) Weft

The strength of the plain weave along the weft direction is the lowest in comparison to the satin and twill. The satin weave fabric has a similar strength value along the weft to the strength of the twill weave fabric, while the plain weave fabric has the lowest strength. The strength properties of the satin weave and plain weave along the warp direction are very similar. The lowest strength along the warp direction was the twill fabric. Table 4 shows the results of the bending rigidity of the produced composites

Table 4. Composite properties depends on weave.

Directions	Weave type								
	Plain			Twill			Satin		
	Monolayer warp	weft	Doublelayer weft	Monolayer warp	weft	Doublelayer weft	Monolayer warp	weft	Doublelayer weft
Thickness mm	0,9	0,9	1,6	1,0	1,0	2,0	1,0	1,0	2,1
Bending Stress MPa	13,36	54,68	126,48	34,93	58,68	123,89	38,10	60,64	121,09
St. Dev for Bending stress MPa	0,80	1,09	6,20	4,06	2,21	6,85	4,00	3,82	8,60
Deformation in maximum stress	0,028	0,031	0,038	0,036	0,036	0,045	0,038	0,035	0,046
St. Dev for deformation	0,004	0,004	0,001	0,004	0,005	0,001	0,003	0,003	0,002

The research was carried out in the Department of Mechanical Engineering of the Technical University of Lodz. In the case of monolayer composites, for each of the three weaves 5 samples were cut along the warp and 5 along the weft. For the bilayer composites 5 specimens were cut along the weft. The support distance was 40 mm. The test speed was 5 mm / min. The surface of the fitting in contact with the loading pin was 2 mm. The INSTRON 4485 was used for the test.

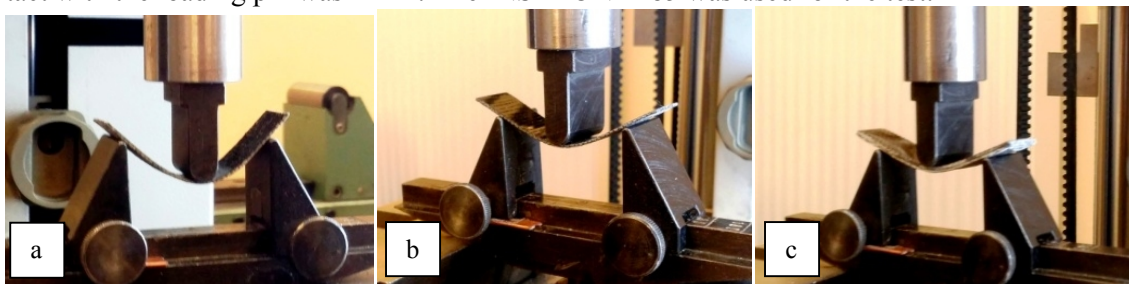


Figure 6. Banding way for a. Warp, b. Weft, c. Doublelayer weft.

Analyzing the bending process of the composite samples, in the case of the monolayer samples a smooth deflection occurred (Fig.6a, b), whereas in the case of double layer composites a violent cracking and fracture occurred at the maximum deformation (Fig.6.c).

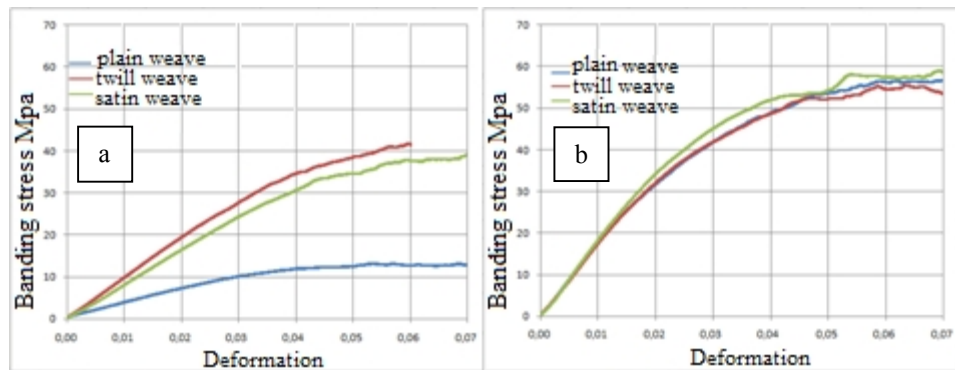


Figure 7. Bending rigidity for monolayer composites a. Warp, b. Weft.

The stress along the warp direction was the highest for the twill weave composite, lower for satin, and three times lower for linen weave. These differences are due to the number of warp threads compared to the number of weft threads in the weave.

When studying the stress along the weave, regardless of the type of weave, the values overlap and the differences between them on the graph are very small. The greatest stiffness along the weft has the satin weave composite. Small differences in bending stiffness along the weft direction can be explained by the fact that a weft thread of 400 tex does not have enough weft threads in the fabric. The affect of the number of warp and weft threads could only be observed with a thin warp of linear density 167 dtex, and the amount of warp and weft threads affected the bending stiffness (Fig. 7a). When combining a thin warp and a thick weft, the number of warp threads tends to be larger than the number of weft threads and depends on the weave used.

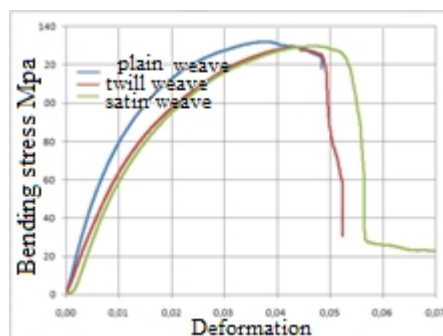


Figure 8. Bending stress for double layer weft.

The stress of double layer composites tested along the weft is approximately twice as large as that of single layer composites. The graph for the fabric with satin and twill weave overlap each other, however the plain weave has a higher stiffness (the stiffness module is higher). The maximum rigidity for the plain weave is similar to the rigidity of the satin and twill weave. When the stress for satin weave is at its greatest, the deformation is maximum.

5. Conclusion

The following conclusions were drawn when examining three roving linens of different linear weights and three basic weaves:

- within crease in linear density the strength of the roving linen decreases,
 - increase in linear density increases the elongation of the roving linen,
 - the strength along the weft of the linen fabric is lower compared to the twill weave fabric and the satin weave fabric,
 - satin weave fabric has a similar strength value along the weft to the strength of the twill weave fabric, while the plain weave fabric has the lowest strength,
 - The strength of the fabric along the weft direction is considerably higher compared to the strength of the test fabric along the warp, even though the warp yarn count is more than four times greater.
 - The elongation at breaking point in the weft direction of the plain weave is lower compared to the twill weave and satin weave, however the differences between twill and satin are small.
- Satin weave fabrics and twill weave have similar elongation values along the warp. Plain weave fabric is characterized by the highest value of warp elongation at breaking point.

After studying the composites of three different strands and two variants of the number of layers, the following conclusions were drawn:

- The bending stress of the composites along the warp is highest for twill weave fabric, smaller for satin weave fabric, and three times smaller for linen fabric because this weave has the largest number of warp threads,
- Differences in the bending stress of the composites along the weft, regardless of the type of weave, are statistically insignificant. This is due to the fact that the thick weft has a similar number of weft threads for each weave pattern used,
- the highest stiffness along the weft among the samples tested is the satin weave composite
- Double layer composites studied along the weft are characterized by twice as much stress than in monolayer composites,
- the stiffness of the two-layer composite studied along the weft of satin and twill weave is similar, however the highest stiffness is found in the plain weave fabric composite. These differences are due to the fact that the number of warp threads is large compared to the number of weft threads.

These studies are an introduction to the planned research on fabric structure and also multiaxial structures. The research will help to create and predict the mechanical properties of composites which can be used for textile reinforcement as lightweight trusses or frameworks in the future.

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