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Variability of the mechanical properties among flax fiber bundles and strands

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Abstract

This work analyzes the variability of the mechanical properties of flax fiber bundles and strands (a strand is the set of the bundles issuing from the same stem). A first remarkable result is that to obtain average values with good precisions about twenty randomly selected strands are sufficient. Moreover a comparative study of the fracture properties of bundles issued from different strands leads to the assumption that each stem is particular with special properties. A more detailed study shows that correlations exist between the sections of the strands and their mechanical properties. These trends are similar to those reported for unit fibers.

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Keywords: Flax fiber; Mechanical properties; Variability; Bundle; Strand

1. Introduction

One of the aspects that threaten the effective use of plant fibers in the field of structural composites is the great dispersion of their mechanical properties. Indeed, the dispersions observed on the unit fibers are very high compared to those of synthetic fibers [1,2] .The origins of this great variability are numerous, including: differentiated thickening of the walls of the fiber between the bottom and top of the stem [3], growth conditions [4,5], fiber extraction methods (6), volume of material tested [7,8,9] and the likely inadequacy of current methods for the mechanical characterization of plant fibers with particular morphology [10].

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Thus, it would be illusory to seek to manufacture mechanically reliable structural materials from these fibers. However, it should be noted that the basic reinforcement element in structural composites is not the unit fiber but the roving, i.e. a controlled assembly of unit fibers. Therefore, the entities whose properties dispersion is to be checked are fiber bundles or groups of bundles (the strands).

The issue of the variability of the mechanical properties of flax fibers is approached in this work from different points of view. First, we study the possibility of experimentally accessing with good accuracy to reliable average values of the mechanical properties of plant fiber bundles. We then show that the dispersion between stems originating from the same culture is much smaller than those reported for unit fibers. The volume effect of the test specimen on the mechanical properties is discussed in terms of the cross section area and the length of the strands.

2. Materials and methods

2.1. Materials

The study focused on the Arétha variety of flax grown north of Caen in 2012 (altitude 73.47 m), on thick silty soil (3 m). Between sowing and grubbing the precipitation rate and temperatures were favorable for flax growing. However, due to climatic disturbances later, harvesting was delayed (only 75% of the plots were harvested, in October instead of September as usually). All strands were taken from the middle zone of the plant in order to eliminate the additional variability related to the sampling zone [11,1,12].

2.2. Methods

A specific methodology was developed in the laboratory for uniaxial tensile testing bundles or strands of plant fibers [13]. This precaution is explained by the particular morphology of the bundles composed of unit fibers having an average length of 3 to 4 cm held between them by pectin bonds. The methodology included: parallelization of the bundles, their retention by averages of metallic shells and the use of a device which allows uniform clamping in the jaws.

The tests were carried out using Instron 5800R machine equipped with a load cell of capacity 2 kN at a deformation rate of 1% min^{-1}. The cross-section area of the strand was measured after mechanical testing by averages of image analysis software, transversely to the loading axis. It corresponds to the total area of the fibers in the clamping zone in the jaws.

3. Results and discussion

3.1. Representativeness of the average value of a mechanical property

The aim is to evaluate the number of strands to be tested in order to obtain an average of a mechanical parameter (ultimate deformation or strength) which converges sufficiently. The rupture of a strand occurs by the sequential ruin of the bundles that compose it (about 30). Taking the strands in their order of test, average of the considered mechanical property is calculated for the first i broken bundles. The number of bundles tested is sufficiently large when the addition of a new bundle no longer has an effect on the average, i.e. when the average over the first i bundles converges sufficiently towards the “real average” of the set.

In order to estimate the number of strands to be tested for evaluating the average ultimate deformation of a set of strands with a given precision, the convergence of the average deformation of the first i bundles is analyzed in Fig. 1. Knowing that each bundle contains about 30 unit fibers, by testing 10 strands 300 bundles (i.e. 9,000 unit fibers) are loaded in tension: this large number of bundles makes it possible to estimate the average ultimate deformation of a set with accuracy better than 2%. Precision is about 1% when testing 15 strands (see Fig. 1).