

# Bio-composites for structural urban outdoor applications – A study of the impact of fiber content on the durability of flax fiber-reinforced epoxy composites

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Due to the current environment issues awareness, public authorities are looking for new ways to make the cities more appealing to the population. Therefore, the demand for ecological solutions for urban outdoor equipment is rising. Academic and industrial researches have a growing interest for bio-composites, in particular plant fiber-reinforced composites [1]. This makes them a good alternative to the usual fossil resource-consuming composite materials.

One major issue with plant fiber-reinforced composites, along with obtaining high fiber content, is their durability when exposed to water or moisture. In a previous work [2], losses in mechanical properties after water vapor sorption were observed. A change in the tensile behavior was also noted, in accordance with the observations on the plant fibers [3, 4].

As for immersion in distilled water at 23°C, some authors observed these losses of properties [5, 6], but also some contradictory results, highlighting the need of more investigations. In their works, Munoz and Garcia-Manrique [5] observed an increase of the ultimate tensile strength by around 30 %, but Scida *et al.* [6] observed a decrease of the ultimate tensile strength by around 10 %.

The purpose of this work is to analyze the impact of water sorption at 70°C in distilled water on the mechanical behavior of unidirectional flax fiber-reinforced composites obtained by thermocompression of 20 plies of 110 g/m<sup>2</sup> UD flax fibers (FlaxTape™ from Lineo<sup>®</sup>) manually impregnated by a DGEBA epoxy resin (SR 8500 with SZ 8525 hardener from Sicomin<sup>®</sup>). This study, which concerns two composites with different fiber contents, addresses the evolution of their microstructural and mechanical properties during and after saturation in distilled water at 70°C.

The properties of the two composites were measured under ambient conditions (23°C, 50 %RH) as the reference state. The first composite material, called “1 bar” as a reference to the processing pressure applied, exhibits a 37.7% volumetric fiber content. The second one, called “3 bars”, has a 51.1% volumetric fiber content. Parallelepiped samples of these two materials were immersed in distilled water at 70°C until the moisture equilibrium was reached. This equilibrium was achieved after 26 days of Fickian sorption and the water uptakes were around 12 % for “1 bar” and 15% for “3bars” (compared to samples stored at 23°C and 50 %RH).

In order to follow the evolution of stiffness and damping through the sorption process, modal analyses in free vibrations (through impulse response) were conducted at specific times of immersion. Tensile tests have been conducted (before and after immersion) on 3 kinds of unidirectional samples: 0° oriented fibers, 90° oriented fibers and 45° oriented fibers.

The first noticeable result of this work is the linear dependency between the modulus and the gain of mass of the samples. Indeed, the modulus decreases linearly with moisture uptake to half

its original value at saturation, with the same rate for “1 bar” and “3 bars” composites. These results are in accordance with the work of Le Duigou *et al.* [8] Also, the vibration damping ratio increases linearly with the water sorption and is more than doubled.

Then, it was found that the difference of stiffness between “1bar” and “3bars” composites before immersion, mostly due to difference in volumetric fiber content, disappears after immersion. Also, water sorption vastly reduces the stiffness and strength of the composites and non-linear tensile behavior appears. This non-linear behavior seems to be fiber-dependent since the “3 bars” composite was more affected.

The results in all fiber directions give a clear state of how these composites evolve with water sorption. However, work is in progress to complete these results through quasi-static tensile tests with unloads in order to characterize the visco-elasto-plastic behavior and through fatigue tests on immersed samples. Also, a numerical model is currently being developed in order to use these composites in structural urban outdoors applications.

## References

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