Self healing with lignified bio-fibers and fillings.

Bob W.N.J. Ursem[*] and Prof. Ir. A. Beukers[**] [Bob Ursem]: w.n.j.ursem@tudelft.nl
Botanic Garden/Biotechnology, Faculty of Applied Sciences[*]
Delft University of Technology
Faculty of Aerospace Engineering[**] Delft University of Technology,
Fellow DoshishaUniversity, Kyoto, Japan
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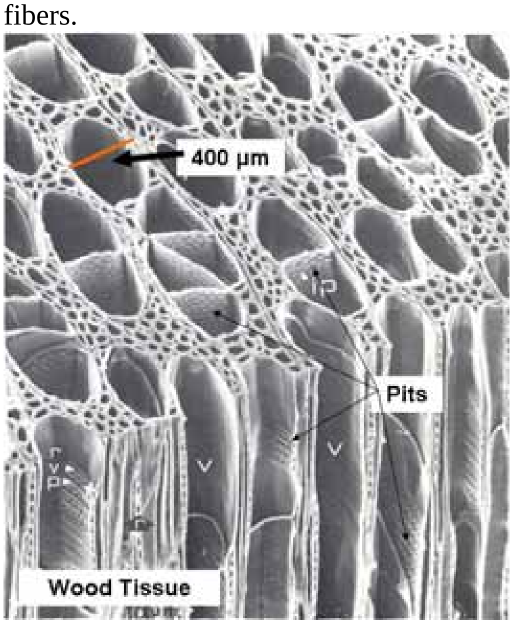
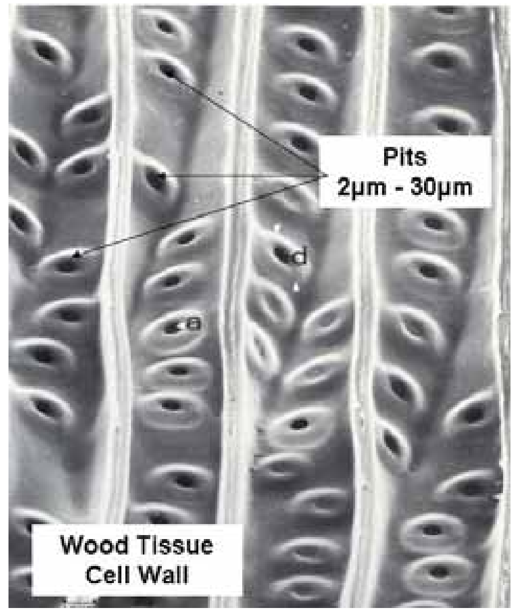
Wood fibers are known to be used as reinforcement in wood-polymer-composites (WPC) and wood-cement-bonded composites, but self healing aspects of bio-fibers and its fillings are still not been studied.
In self healing materials carriers are a major component for the transportation of polymers and other substances in composite materials. Furthermore carriers perform a major problem for the environment, because it is based on stratified layers of synthetic components.
Lignified bio-fibers allow a solution to this environmental problem as well as its capacity to incorporate polymers and other substances in many dimensions. These dimensions can range from nanometer scales up to macro meters, for instance in wood fibers.





Mechano-sorptive behaviour of biomaterials could be used to self-heal possible microcracks in cementitous materials. Biomaterials like wood fibers and cotton (tents made of cotton are known for their behaviour in rainy conditions) have the peculiar behaviour that when under stress the standard swelling and shrinkage behaviour changes. Under stress, during a wetting of the material, the strain in the fibers decreases, whereas the strain increases during drying of the material. This is known as the mechano-sorptive effect. The material incorporates a self-healing mechanism when hydrogen bonds are restored in a lower energy state during periods of wetting. This is caused by the cellulose chains having different micro-fibrillar angles in the different cell wall layers, leading to differential shrinking. An example of this restoring behaviour is shown in figure A.

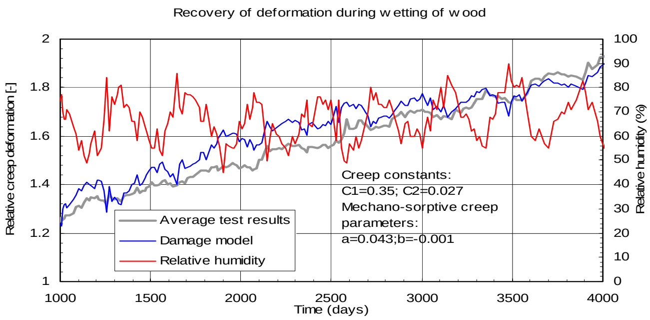
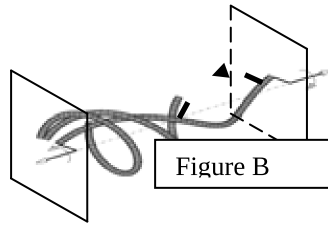


Figure A Deformation recovery due to increasing wood moisture content

During a thirteen year test period of wood under stress in a varying relative humidity there is a clear recovery of the deformation during wetting seasons. Damage models have been developed taking into account the effect of varying moisture content on the total deformation, showing the possibility of deformation recovery. This effect of wood fibers could be used as a recovery mechanism in cracked materials. Crack bridging fibers are stressed and could consequently be rewetted (artificially or naturally) restraining themselves and, during restraining, decreasing the crack width at the same time. A reduced crack width increases the probability of unhydrated cement pastes to cross the gap and further reduce the damage, especially since moisture allows for both the wood fiber as well as the cement paste to initiate chemical reactions. A further recovery of deformations may be created when wood fibers (or other bio-fibers) are unloaded and rewetted. Plastic deformations that have occurred during a previous mechanical loading can thus be recovered. The chemical kinetics involved in this effect allow for a restoration of the mechanical bond structure inside the wood cells. The mechano-sorptive recovery leads to decreased crack size.

Fibers obtained from lianas can reach length of up to 150 metres and are therefore a good option for incorporating them as reinforcing biofibers in concrete-like mixes and asphalt. They can easily be extracted and modified into spiralling fibers. When mixed with fresh concrete or asphalt, they can later function as gap bridging springs. The behaviour and mechanical properties of the spring will be altered when moisture enters. Because of atomic forces between the water molecules and the hydrogen bonds, contraction will occur with gap closing effects.
(Figure B).



The state of the art in auto reparable mechanisms is still never developed for bio based solutions in composite materials.

Natural lignified bio-fibers (fir, larch, pine, water lily and lianas) can also be used as carrier for substances which are released by trigger-mechanisms in order to heal cracks in materials. The

These fibers can store substances in their natural holes and also use the cell wall structure to host nanoparticles and release them when triggered for damage repair. For example, the reinforcement of fibers in cementitous materials and wood polymer composites can be filled with resins or iron-hydroxide and perform auto repairable mechanisms in microcracks in concrete and asphalt mixes. Resins (and latex) can provide similar auto repair mechanisms in other composite materials.

The study of lignified bio-fibers at Delft University of Technology has focused on the incorporation in all these carriers and the optimal types of carrier for self healing properties in various applications (concrete, asphalt, wood-plastics and other organic fiber boards). The result will be self healing composites for building applications and road pavements.

References

[1] Van de Kuilen, J.W. *'Duration of Load Effects in Timber Joints.'* PhD Theses, Delft University Press, Delft, The Netherlands, 1999

[2] Ursem, W.N.J. *'Anomalous growth patterns of South American lianas'* MSc. Thesis, Utrecht University, Utrecht, The Netherlands 1990