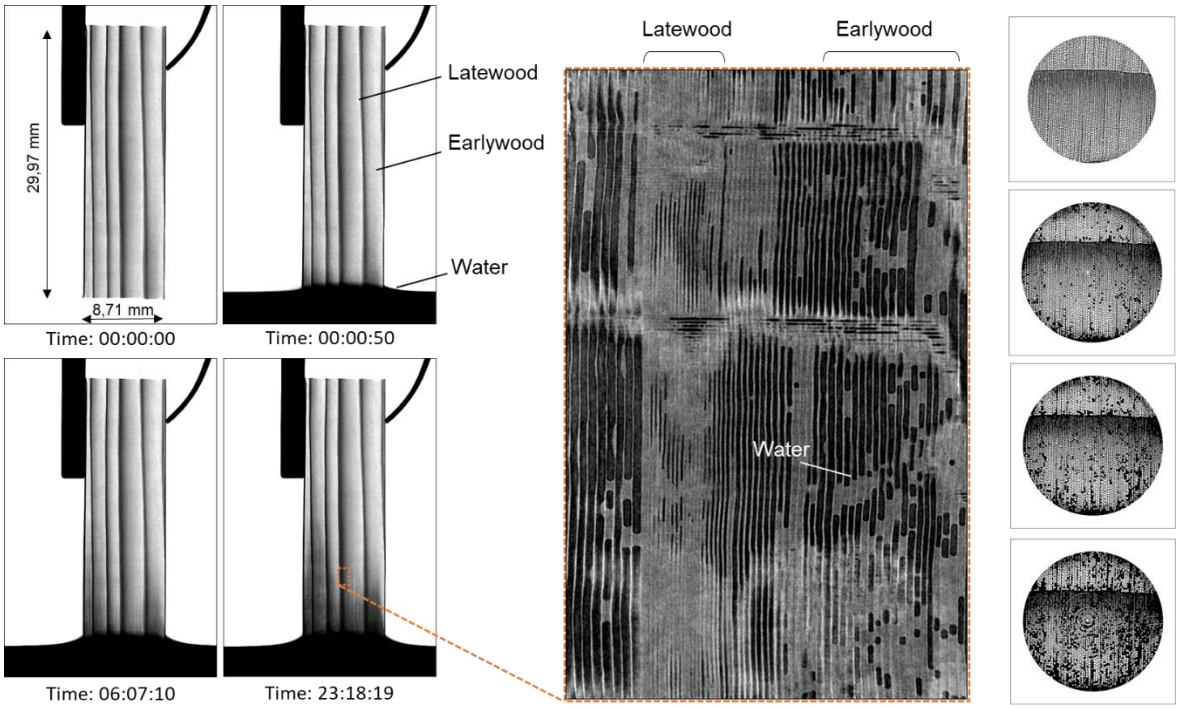
WaterUnWood



Free Water migration within Unsaturated Wood

Principle investigator: Romain Rémond (MCF-HDR) - LERMAB (Enstib-UL)

Collaboration: Julien Colin et Patrick Perré (Laboratoire LGPM (CentraleSupelec)) et de Benoit Martin et Damien Lathuillière du LERMAB

Context — The number of high-rise wooden buildings is currently growing significantly with the democratization of CLT panels. However, the structural elements of these buildings are particularly exposed to external climatic conditions during the construction phase. To ensure their durability over their expected lifespan, the required drying time have to be known after a rain shower and before closing the timber structures. This question involving coupled heat and mass transfer, can be investigated through numerical tools.

Objectives — Using X-ray imaging, this work aims at providing experimental data to validate the capacitive prediction of computational models simulating heat and mass transfer in porous media. This technique proved its great potential in observing the liquid water migration in building materials and offers more information than standard gravimetric methods. The main challenge of X-ray imaging is to distinguish water from lignocellulosic material. Two complementary methods are proposed. Both use a last generation nano-tomograph (RX Solutions Easy XL Ultra 150-160), suitable from high resolution imaging to fast imaging.

Approach — The first method is based on 3D imaging. For that purpose, one end of a small wood cylinder is submitted to liquid water and scans are performed at several elapsed times. High-resolution scans were selected (voxel size 1 µm) to clearly define the anatomical structure of wood. The liquid water in a slice can then be estimated, by image processing, as the proportion of lumen cells filled with water. However, the drawback of this protocol is the long time required per scan, which limits the method to slow evolutions of the MC field.

To assess the fast water imbibition in longitudinal direction, another protocol was developed, based on 2D projections, allowing high frequency imaging. As the anatomical structure cannot be observed in this case, a rigorous treatment of the X-ray beam attenuation was implemented to determine MC.

Key results —

- Non-homogeneous liquid water migration within annual ring growth
- Fast liquid water front in the early stage following by linear contant increased of moisture content
- No preferential migration between earlywood and latewood as mentioned in other studies
- Wood rays play an important role in the liquid migration of water via the cross-field pits
- Contact angle within the lumens which confirm cell wall affinity with water.

Main conclusions including key points of discussion — Two complementary methods were developed to access the liquid water migration in wood. The first one allowed to measure quantitatively moisture distribution evolution after a rigorous treatment of the X-ray beam attenuation. The second method, using a high-resolution 3D reconstruction, highlighted the role of wood rays on liquid migration within the porous network.

Future perspectives —

- Future experimental work will focus on water migration (drying-wetting) in radial direction of wood with much more permeable species.
- Such experimental data obtained from 2D imaging will be analyzed by an inverse method using the TransPore model for identification of the relative permeability expression of wood.
- Improve the quality of prediction of computational model of heat and mass transfer: prediction of biodegradation risks, wood drying, moisture fields in building walls, composite wall design, etc.

Valorisation ***(scientifique*** *: publications, chapitre d'ouvrage, présentation lors de conférences,…signaler d'éventuels prix)* ***; économique*** *: enveloppe Soleau, brevet, licence,… ;* ***diffusion*** *: communiqué de presse, interview,…)*

Titre	Nom de la conférence ou du journal	Lieu		Date		Type
Dynamique des transferts d'humidité au sein du bois lamellé croisé (CLT): mesures par tomographie X et modélisation numérique	Journée Scientifique Matériaux de Construction Biosourcés	France	Champs sur Marne	Mars	2018	Poster
Measuring moisture content distribution in wood during imbibition by micro-tomography	Physics of drying	France	Marne la Vallée	Novembre	2018	Communication orale
Dynamique des transferts d'humidité au sein du bois massif et des panneaux lamellés croisés : mesures par tomographie X	Les journées Jeunes Chercheurs Transfrontalières	France	Reims	Avril	2019	Communication orale
Water migration in wood during imbibition assessed by X-ray imaging	Nordic Symposium on Building Physics	Estonie	Tallin	Juin	2020	Communication orale
En outre un article sur ces travaux est en cours de rédaction, il sera soumis avant le printemps 2020, probablement dans Building and Environment - Journal - (Elsevier)						

Effet levier du projet

Le financement de ce projet (post-doc, déplacements, fonctionnement) a permis de complémenter le travail de thèse de B. Martin (Thèse ADEME-LERMAB-LGPM) en ajoutant des résultats nouveaux sur la migration de l'eau liquide dans l'épicéa. Les résultats obtenus avec ce nano-tomographe de dernière génération nous montrent pourquoi les modèles utilisant des formulations macroscopiques échouent dans la prédiction de l'imbibition d'eau au sein de l'Epicéa. Le cheminement de l'eau est en effet complexe et hétérogène au sein du plan ligneux en raison du manque de connections intervasculaires (ponctuations fermées après séchage) et l'intervention des rayons ligneux comme élément de pontage dans le cheminement. Ceci nous amène à revoir les ambitions initiales sur la capacité des modèles macroscopiques à pouvoir prédire la reprise d'humidité au sein de l'épicéa. En outre, ces résultats et les outils développés donnent de nouvelles perspectives pour les travaux à venir.