LABORATOIRE DE THERMIQUE ET ÉNERGIE DE NANTES

Phénomènes de déconsolidation dans les stratifiés composites à matrice thermoplastique

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TPC manufacturing steps

matter

structure

Chemistry

Heat
No/low pressure

Prepregging

Layup

Consolidation

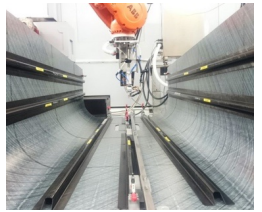
Post processing

Conformation

stamping

Assembling

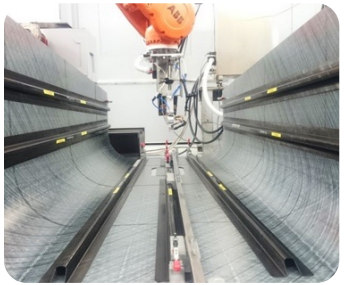
overmoulding

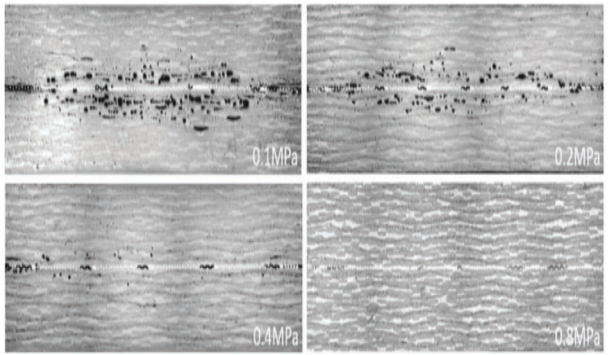


welding

Deconsolidation

Welding

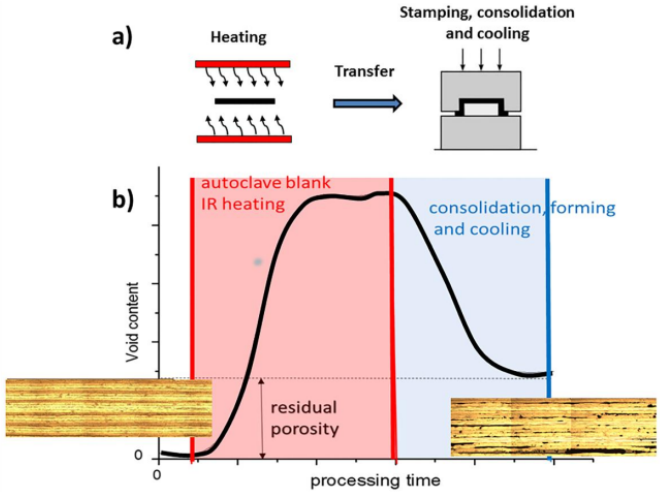




GF/PEI resistance welding

[Shi et al. 15]

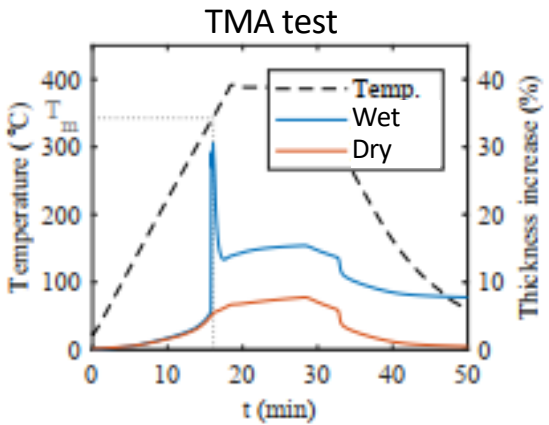
Thermo stamping



[Donnadei et al. 18]

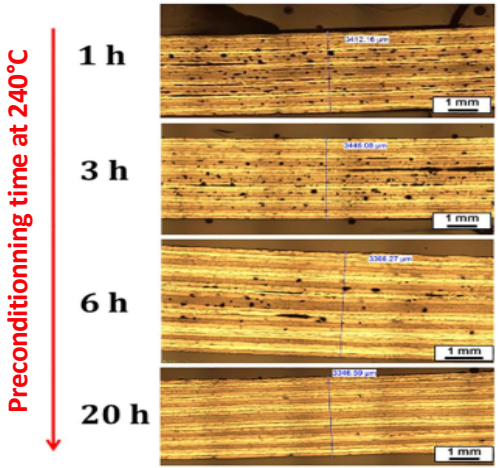
State of the art hypothesis

Moisture



[Slange et al. 18]

Residual stresses



[Donadei et al 18]

Motivation

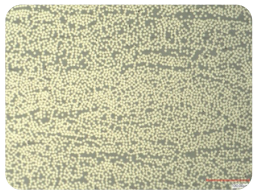
Understand and quantify deconsolidation

Need for characterization tools

Outlines

Material

Manufacturing



Moisture

Deconsolidation Benches

Microstructural in-situ analysis

Macroscopic parametric study

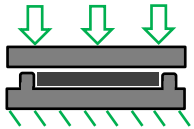
Laminate manufacturing

Material

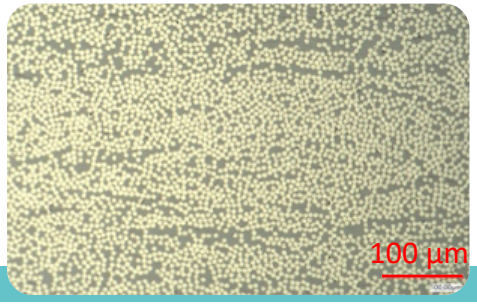
CF/PEKK (Toray Composites)
348 x 348 mm^2 x 2.90 mm
16 plies stack, UD, CP, QI

Consolidation

- Press (40 bar) - HP



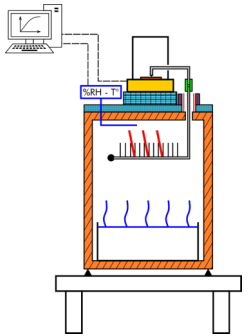
- Oven - VBO



Material

Manufacturing

Moisture

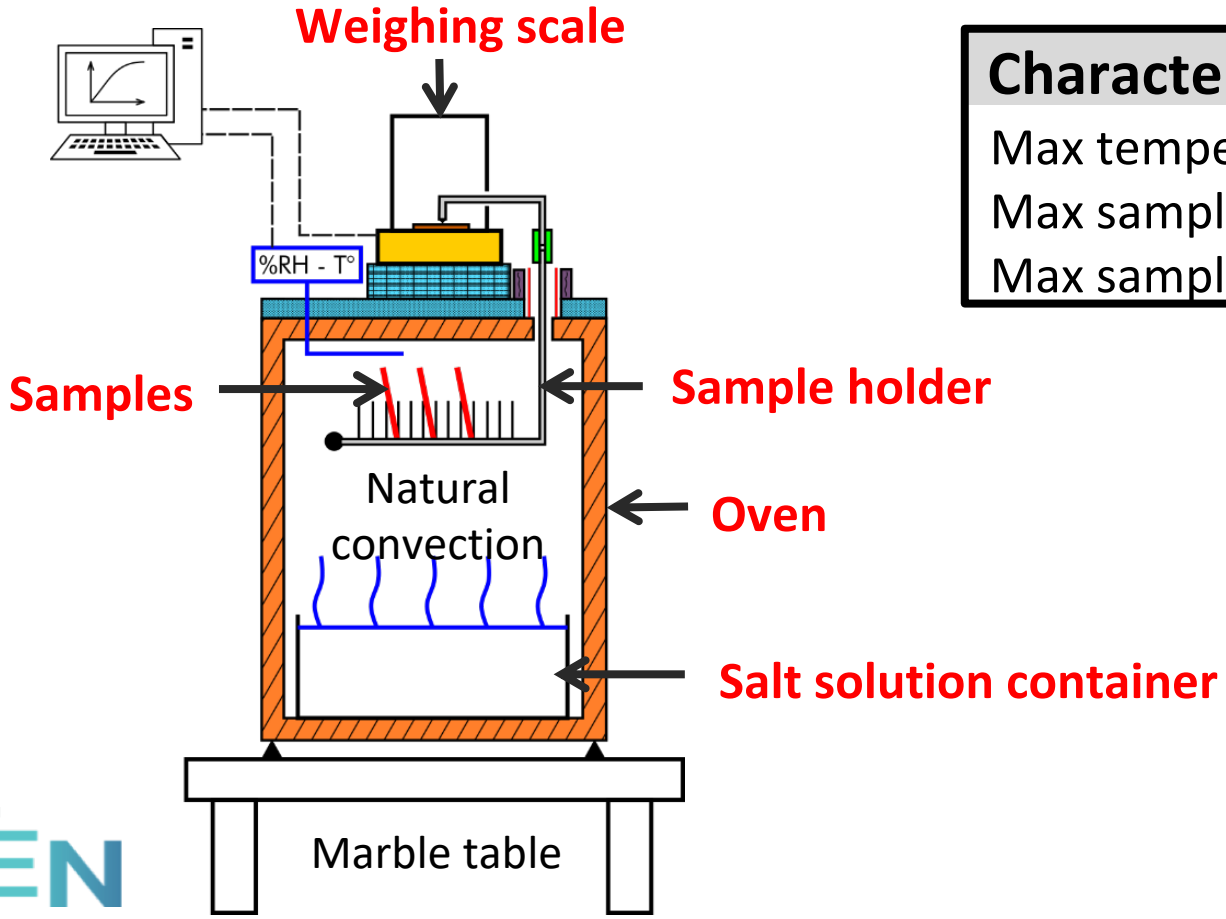


Deconsolidation Benches

Microstructural in-situ analysis

Macroscopic parametric study

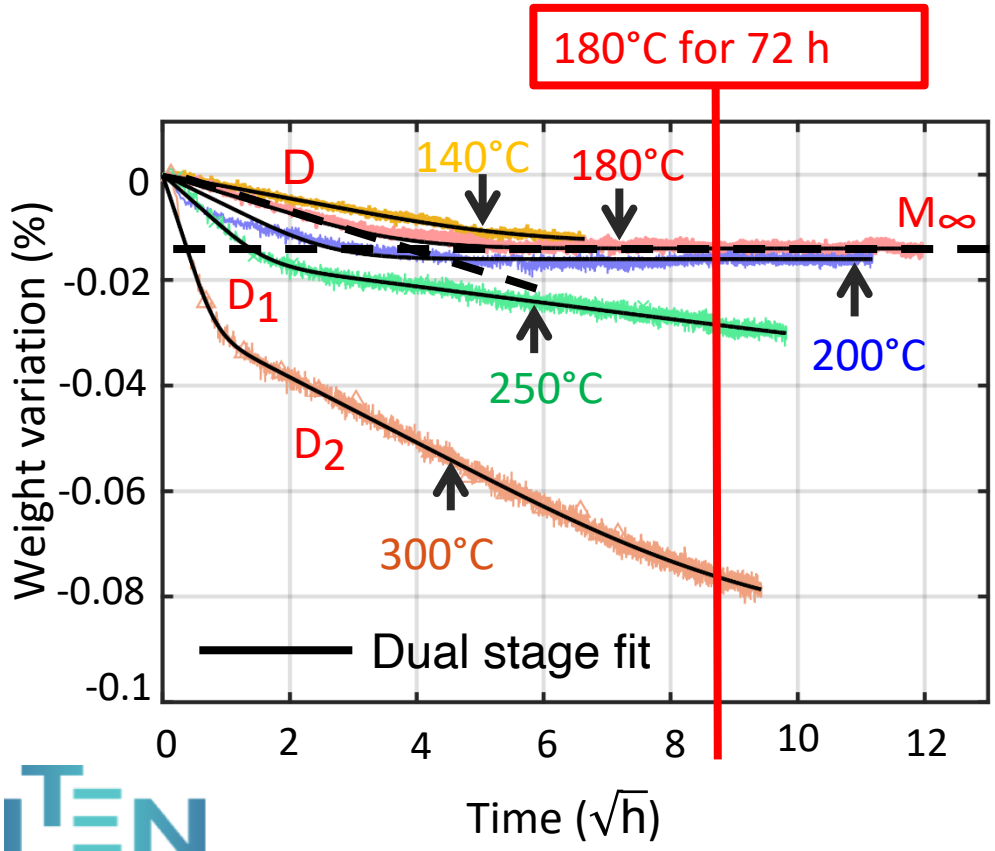
Moisture sorption/desorption bench



Characteristics

Max temperature: 330°C
Max sample weight: 36 g
Max sample size: 150 mm x 150 mm

[Amedewovo et al. Comp part B 23]



Dual stage model

$$\frac{\partial C_1}{\partial t} + \frac{\partial C_2}{\partial t} = D_1 \frac{\partial^2 C_1}{\partial^2 x} + D_2 \frac{\partial^2 C_2}{\partial^2 x}$$

T(°C)	D_1 (m²/s)	D_2 (m²/s)
140	1.45×10^{-11}	0
180	3.25×10^{-11}	0
200	6.39×10^{-11}	0
250	1.75×10^{-10}	1.99×10^{-12}
300	6.60×10^{-10}	4.93×10^{-12}

Thermal diffusivity α at 300°C:

2.6×10^{-7} m²/s $\alpha/D_1 \approx 400$

Material

Manufacturing

Moisture

Deconsolidation Benches

Microstructural in-situ analysis

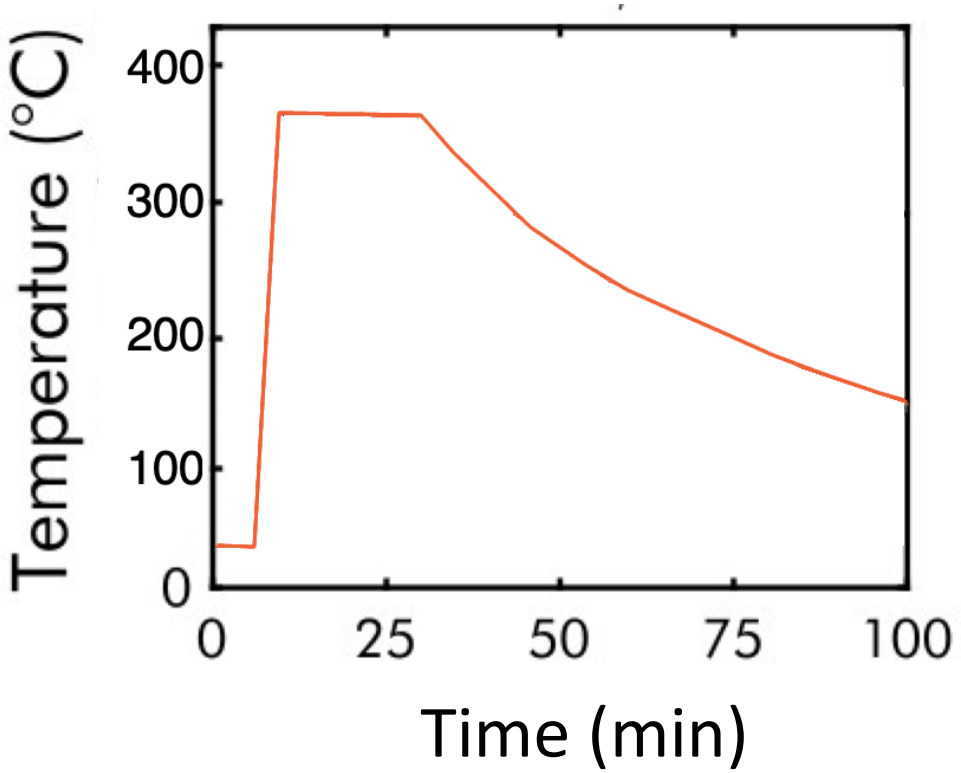
Macroscopic parametric study

Preconditionning

- Ambient storage
  (for 5 months → 0.02 % H2O)
- Water immersed
- Dried 180°C
- Annealed 250°C
- Rehumidified

[Amedewovo et al, ICCM Belfast 23, comp part A 24]

Deconsolidation cycle



Material

Manufacturing

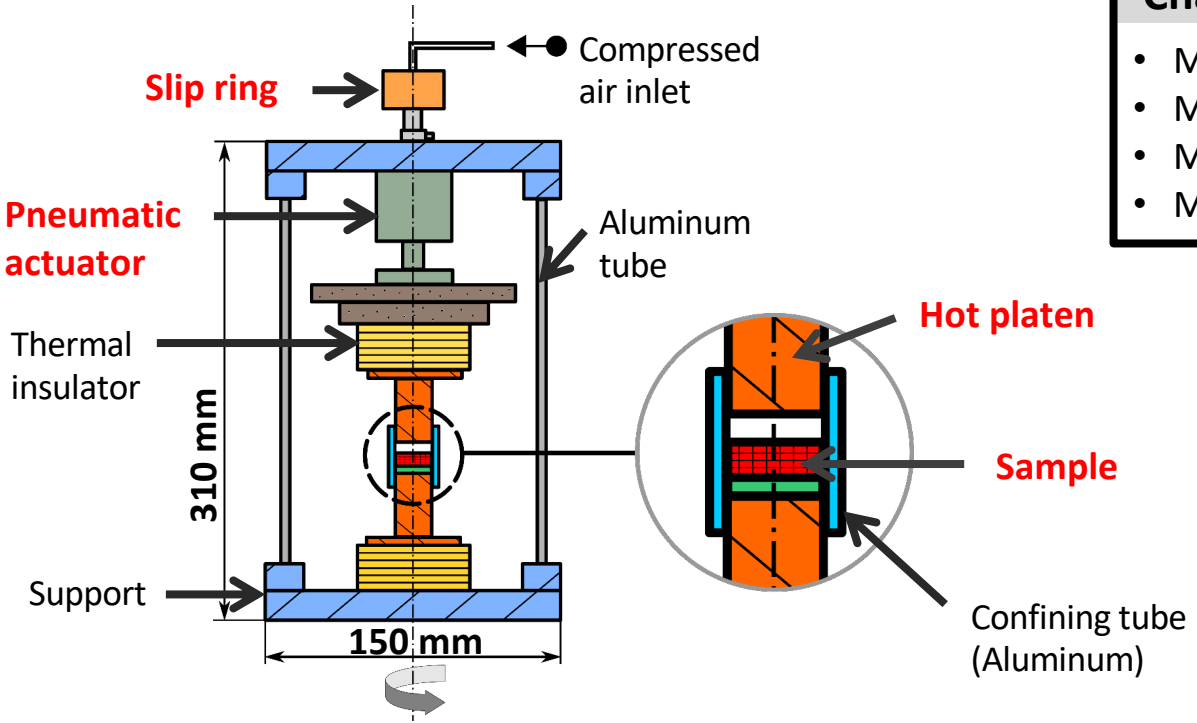
Moisture

Deconsolidation Benches

Microstructural in-situ analysis

Macroscopic parametric study

In situ Tomography Observation

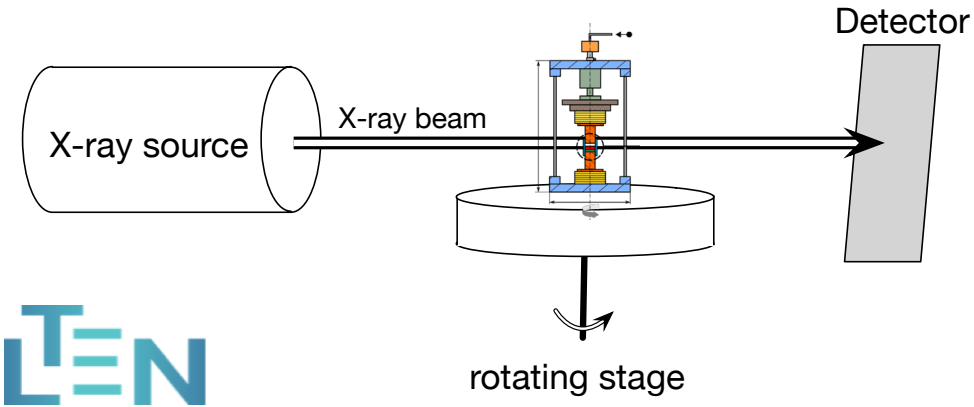


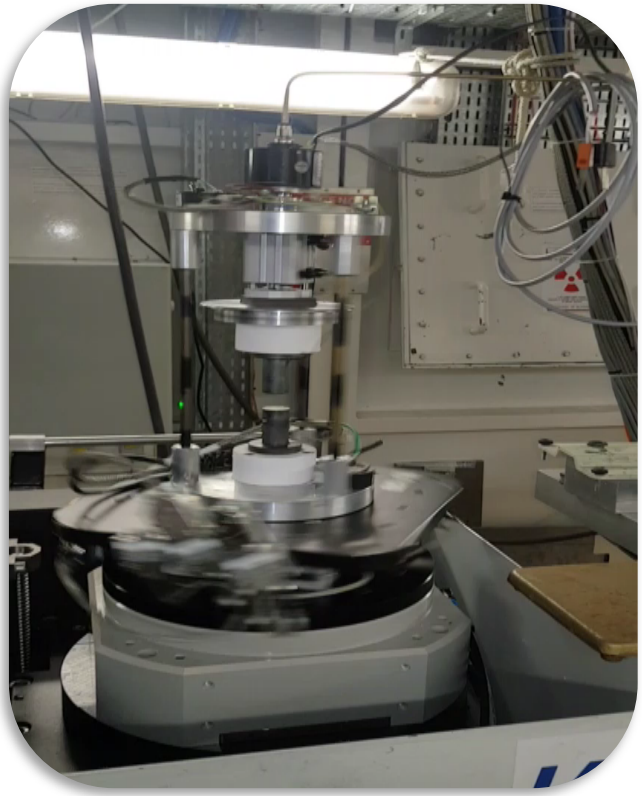
Characteristics

- Max temperature: 450°C
- Max heating rate: 2°C/s
- Max pressure: 1.2 MPa
- Max sample diameter: 20 mm

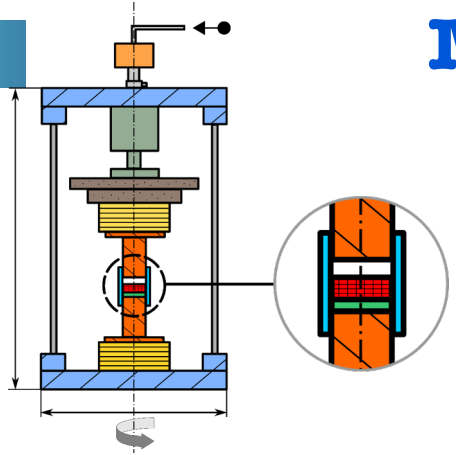
In the synchrotron

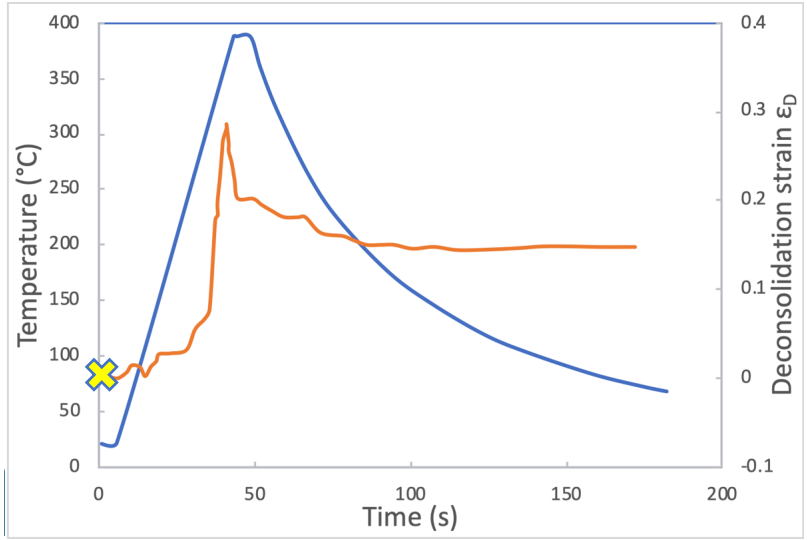
ID 19 - ESRF Grenoble

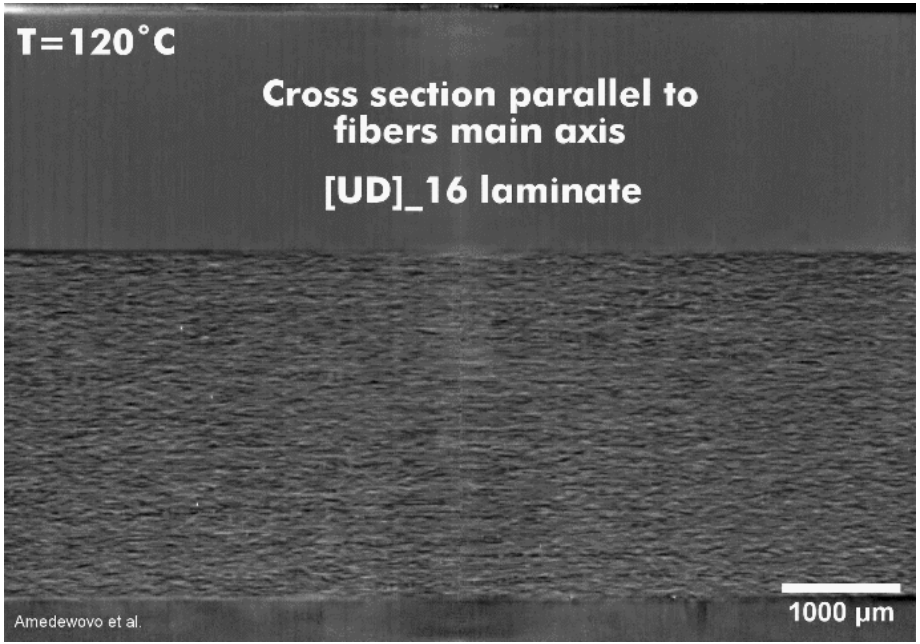


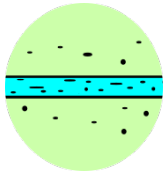


Microscopic observation

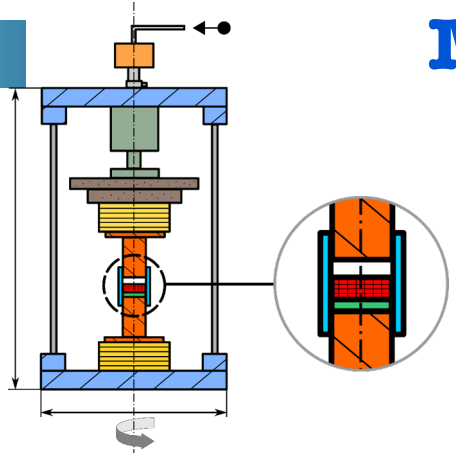


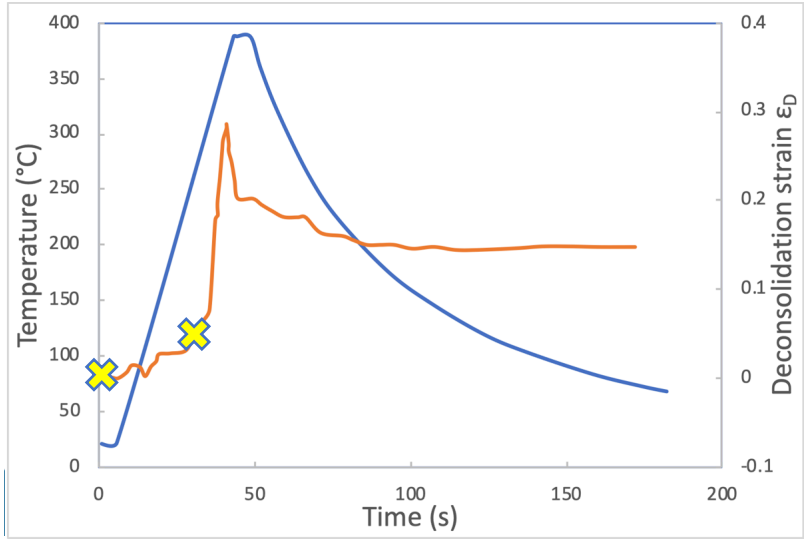


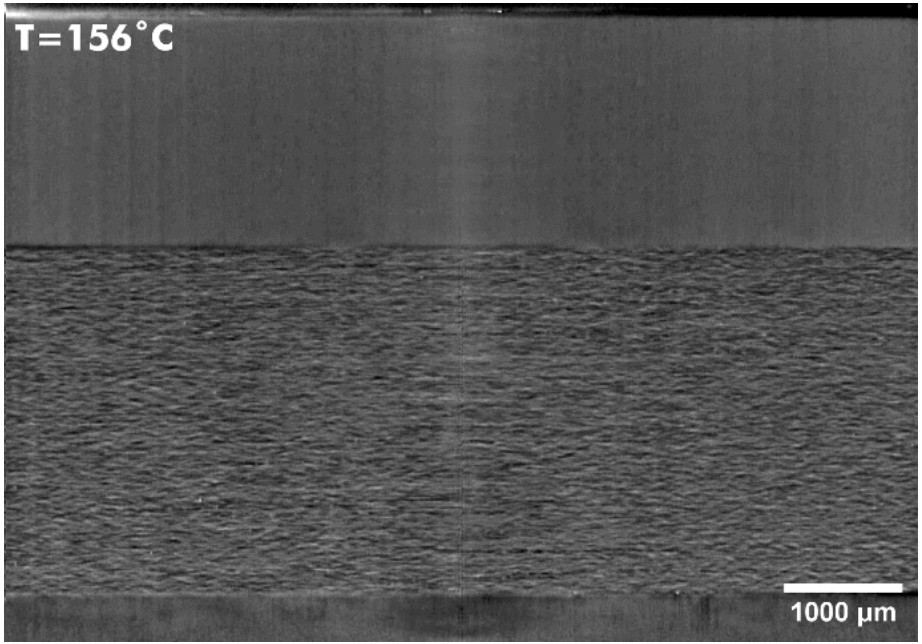


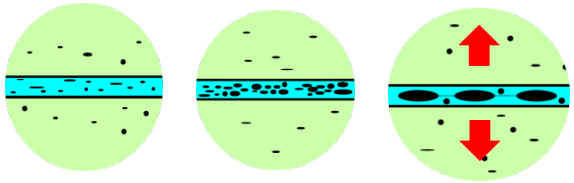


Microscopic observation

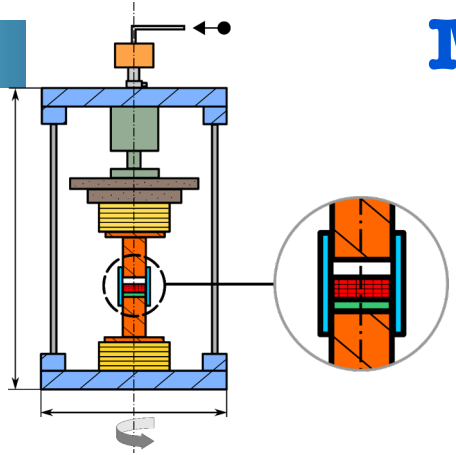


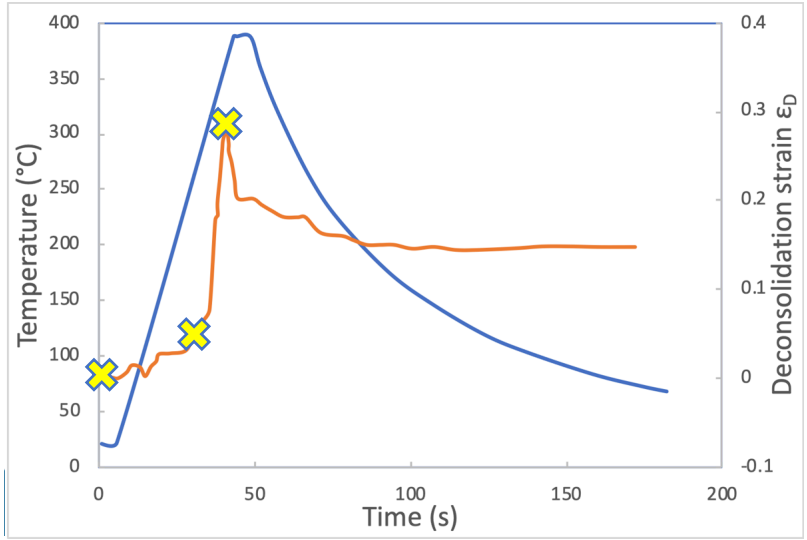


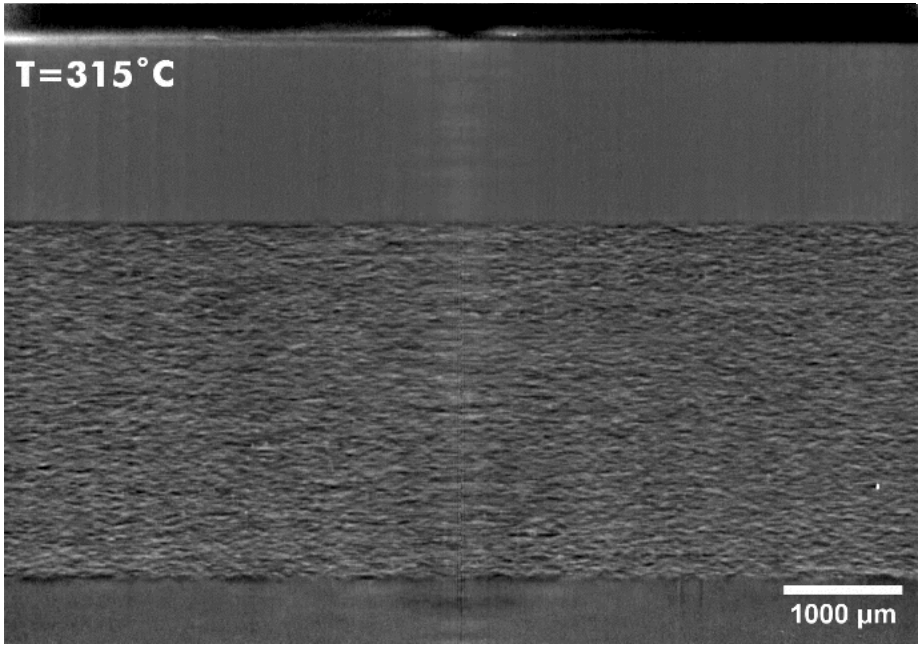


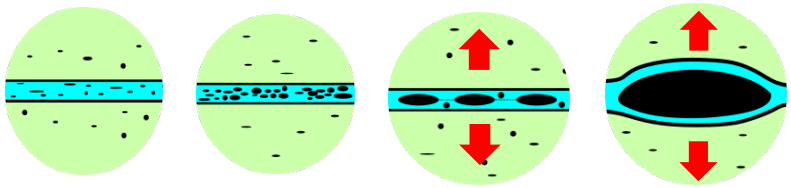


Microscopic observation

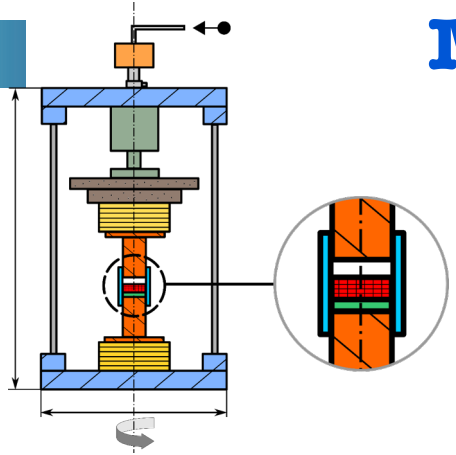


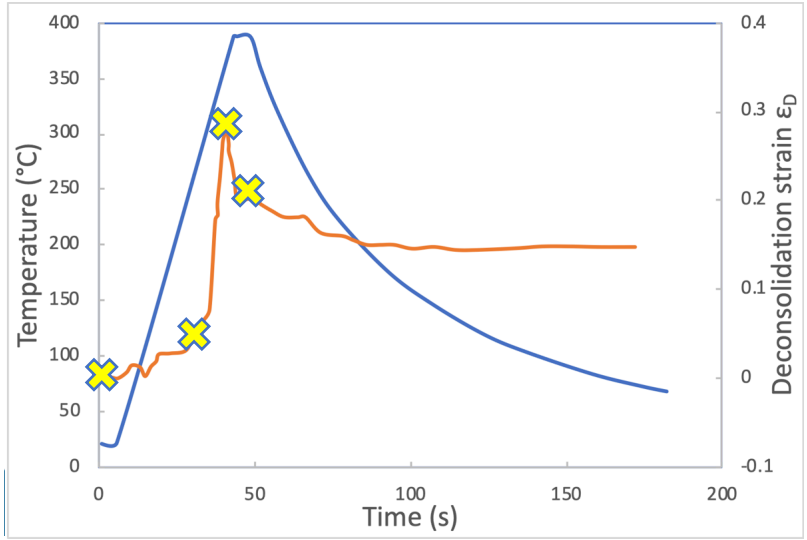


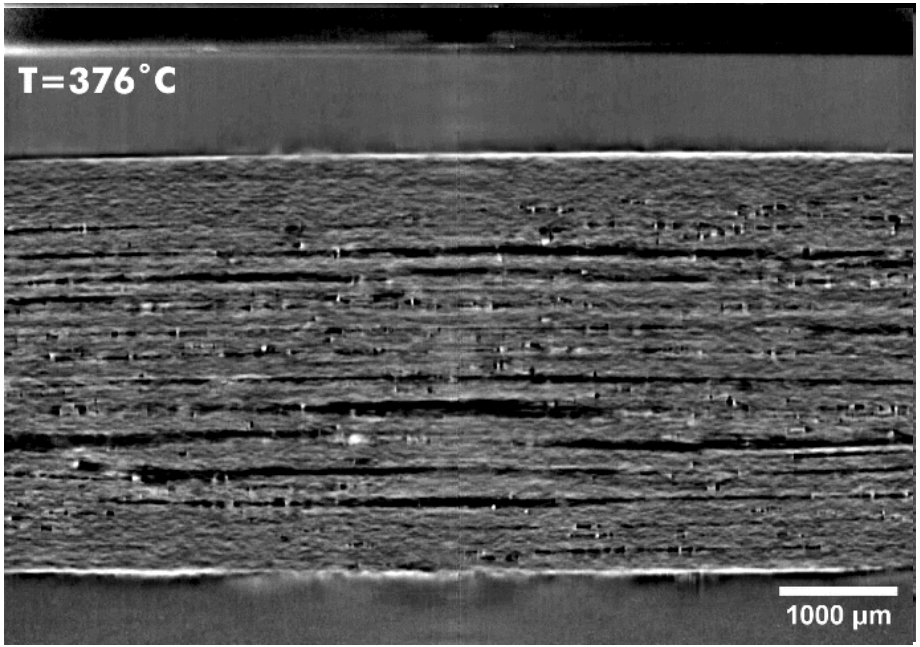


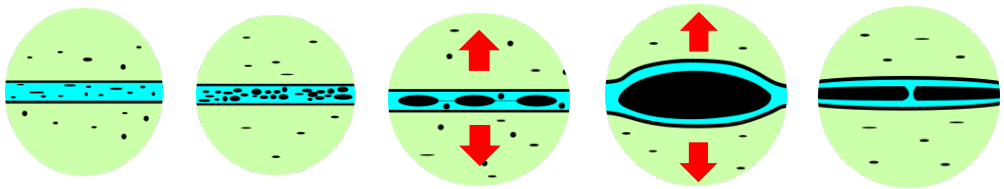


Microscopic observation

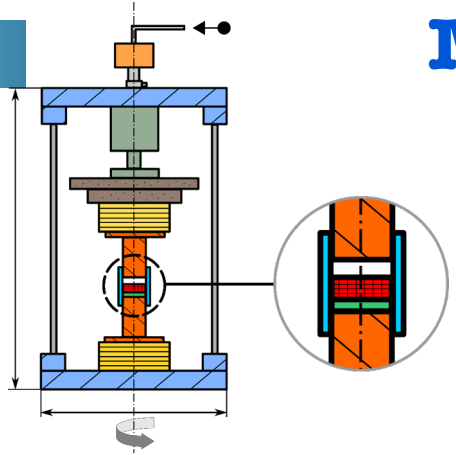


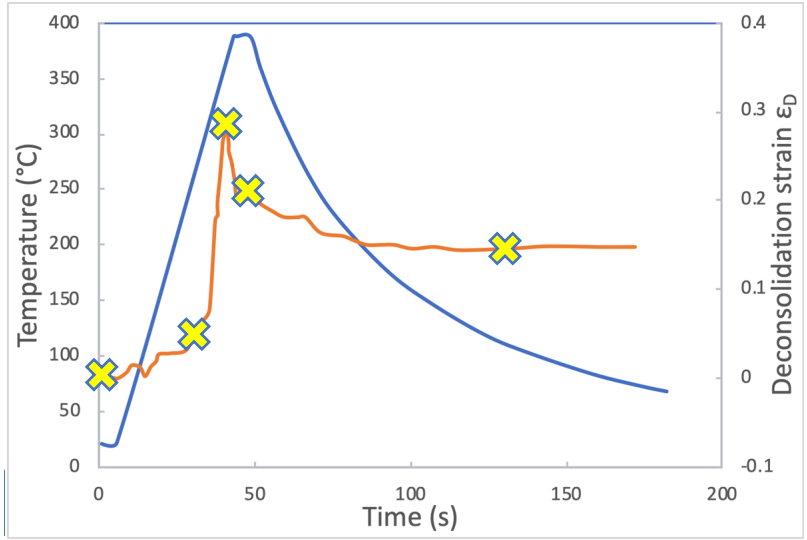


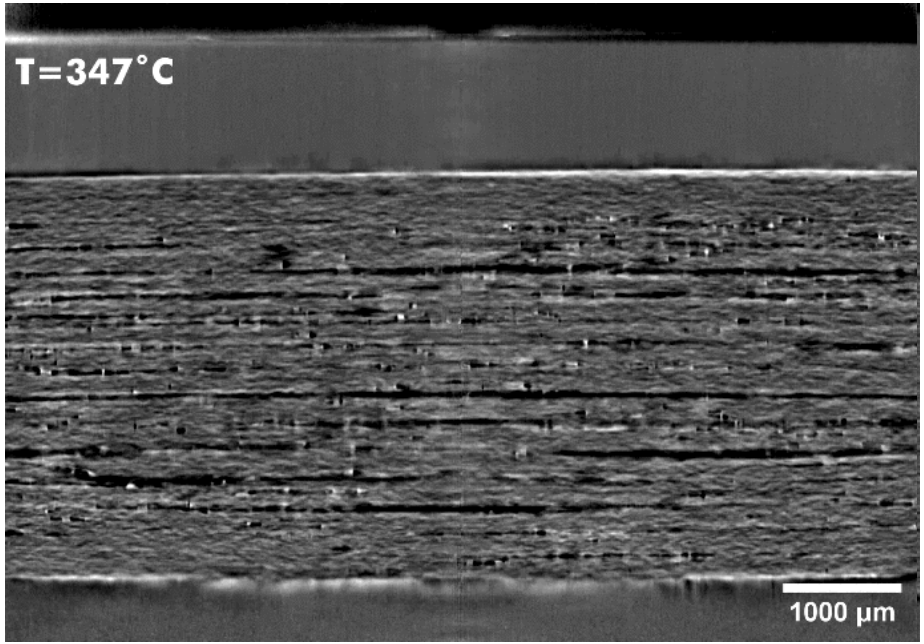


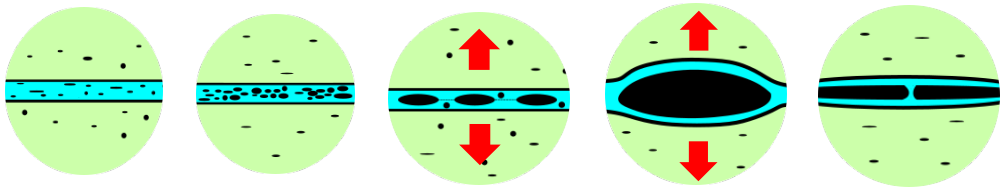


Microscopic observation









Material

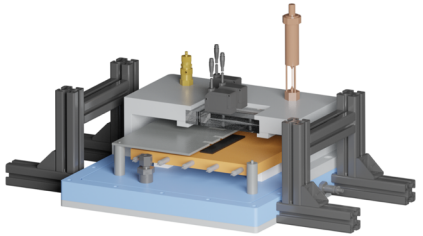
Manufacturing

Moisture

Deconsolidation Benches

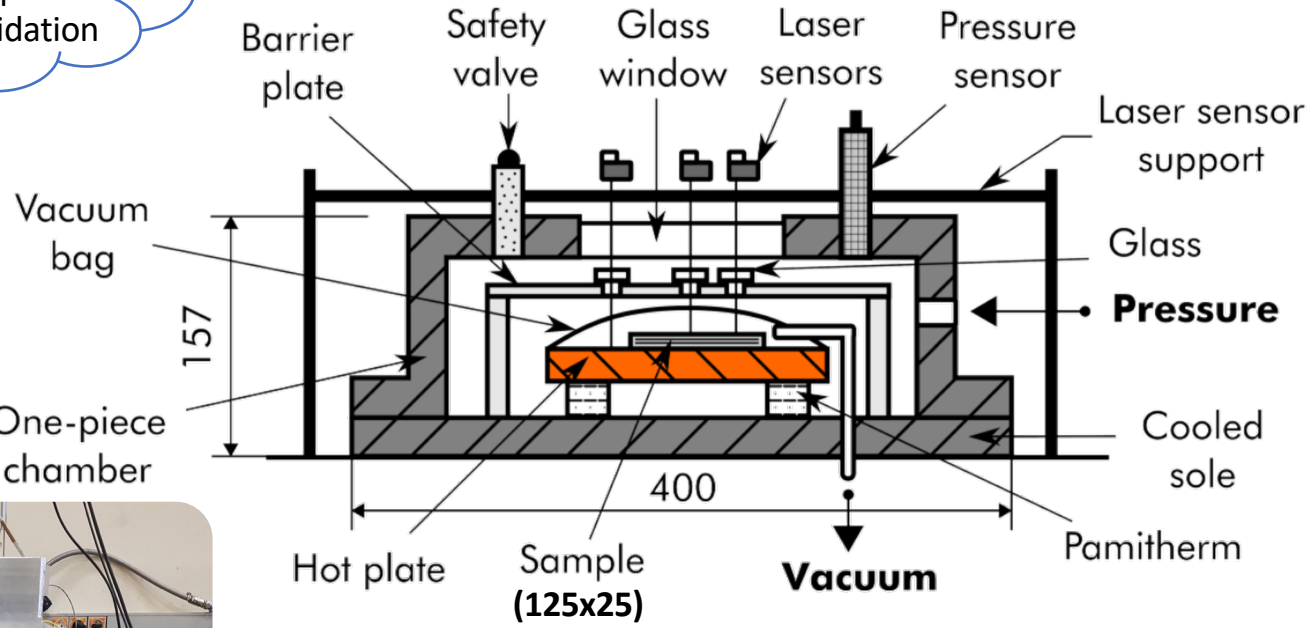
Microstructural in-situ analysis

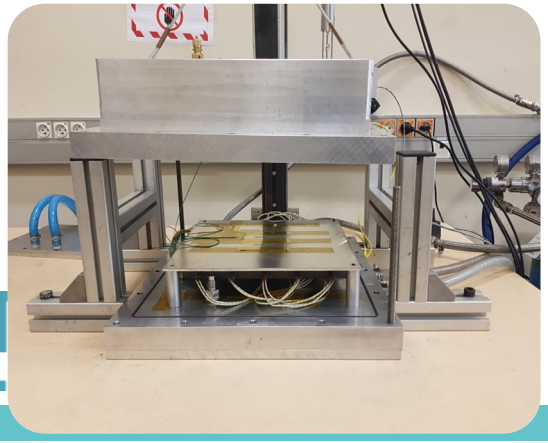
Macroscopic parametric study



Continuous in-situ COmposite DEConsolidation

CODEC bench



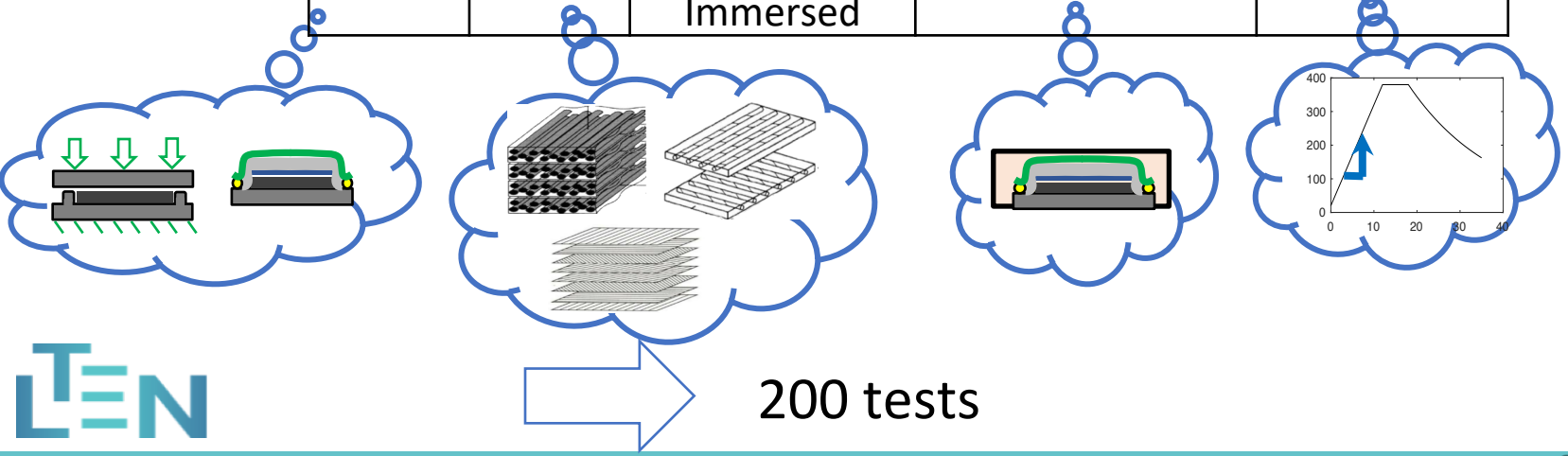


Up to 450°C
Up to 10 bars
Up to 60°C/min

[Amedewovo et al. Comp part A 23]

Test matrix

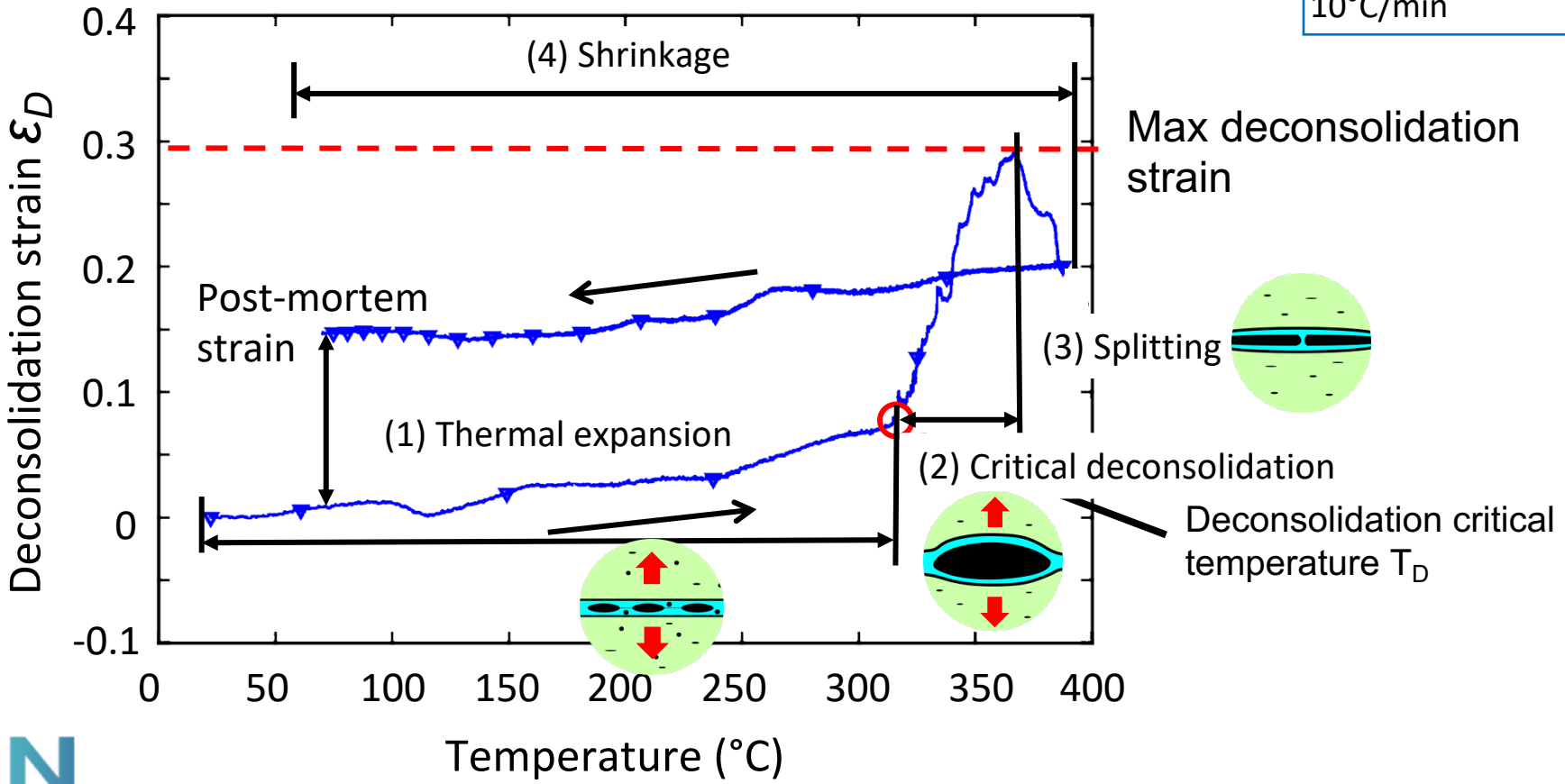
Initial laminate			Deconsolidation	
Process	**Layup**	**Conditionning**	**Counterpressure**	**Heating rate**
HP VBO	UD CP QI	Dried Annealead Ambient storage Immersed	No pressure 1 bar 3 bar 5 bar	5◦ C/min 10◦ C/min 60◦ C/min



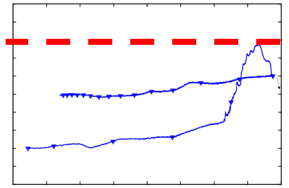
200 tests

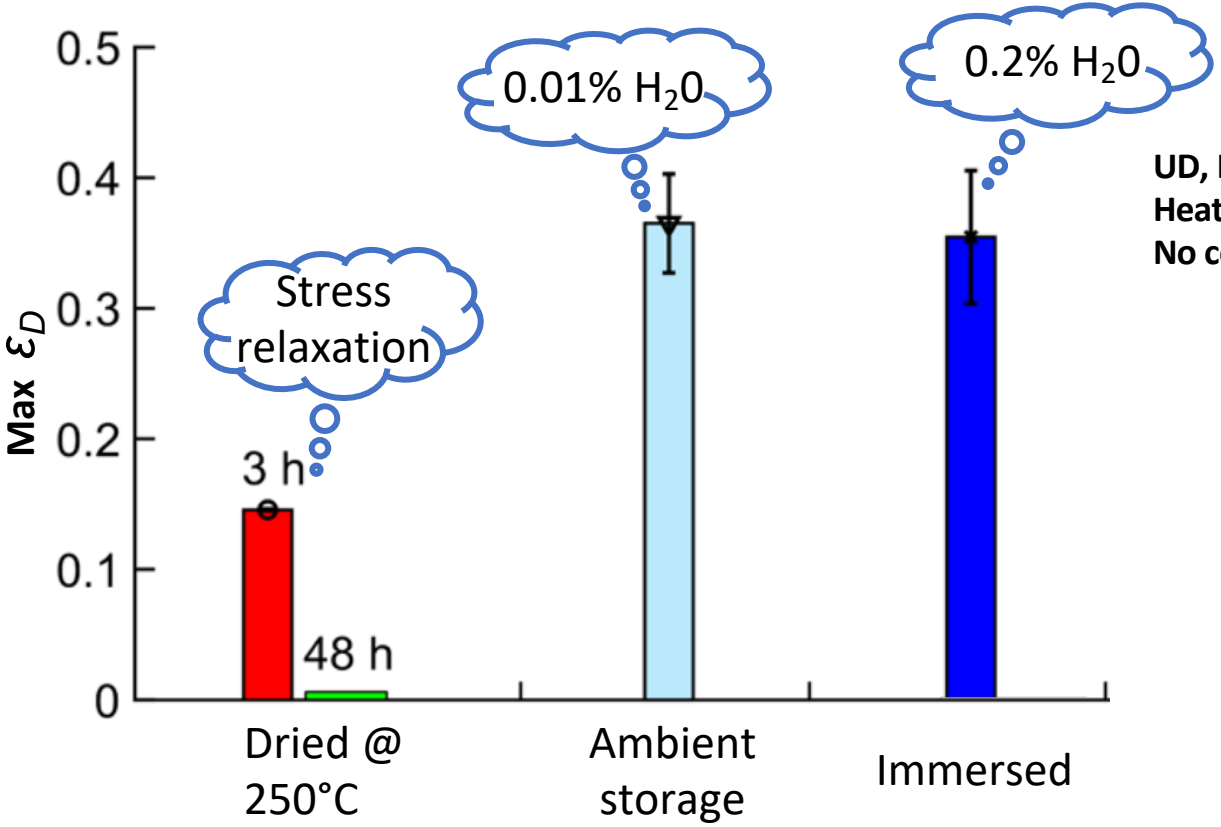
Deconsolidation graph

Press consolidated, Dried, no pressure, 10°C/min

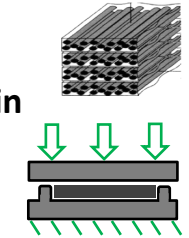


Moisture and residual stress

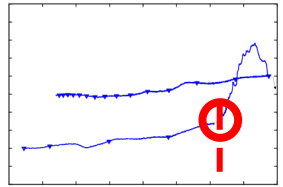


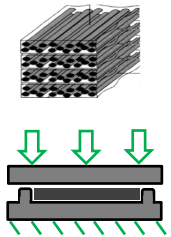


UD, HP
Heating rate =10°C/min
No counter pressure

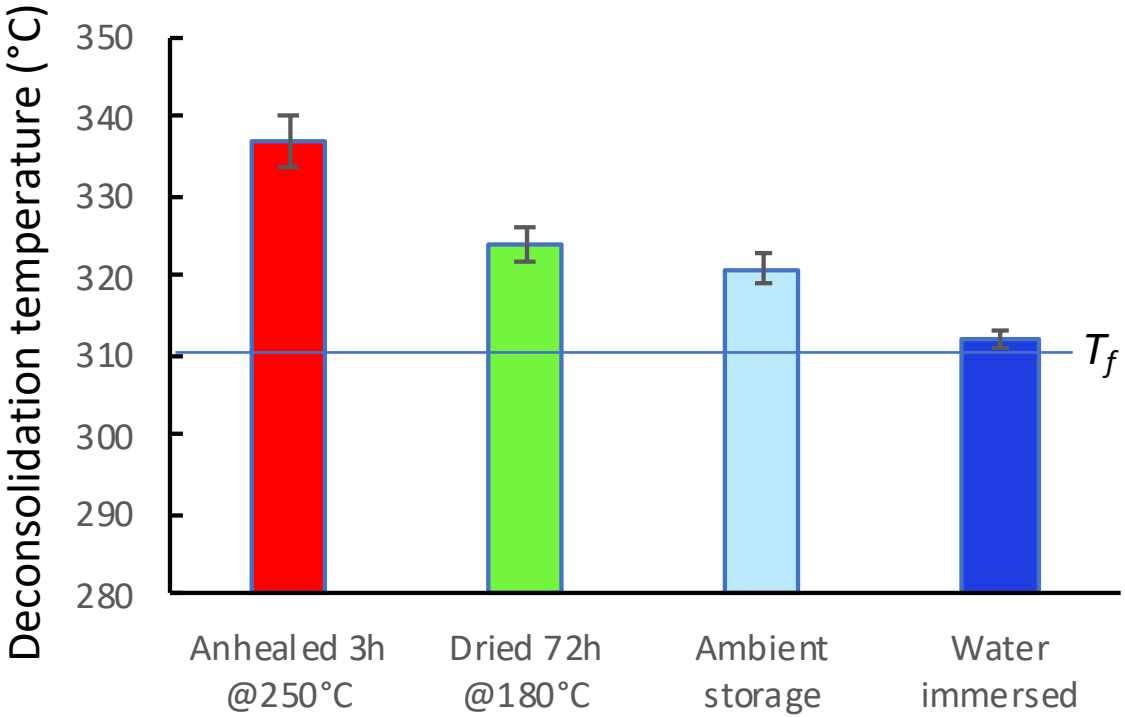


Effect of Moisture



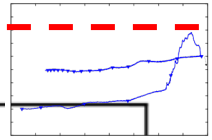


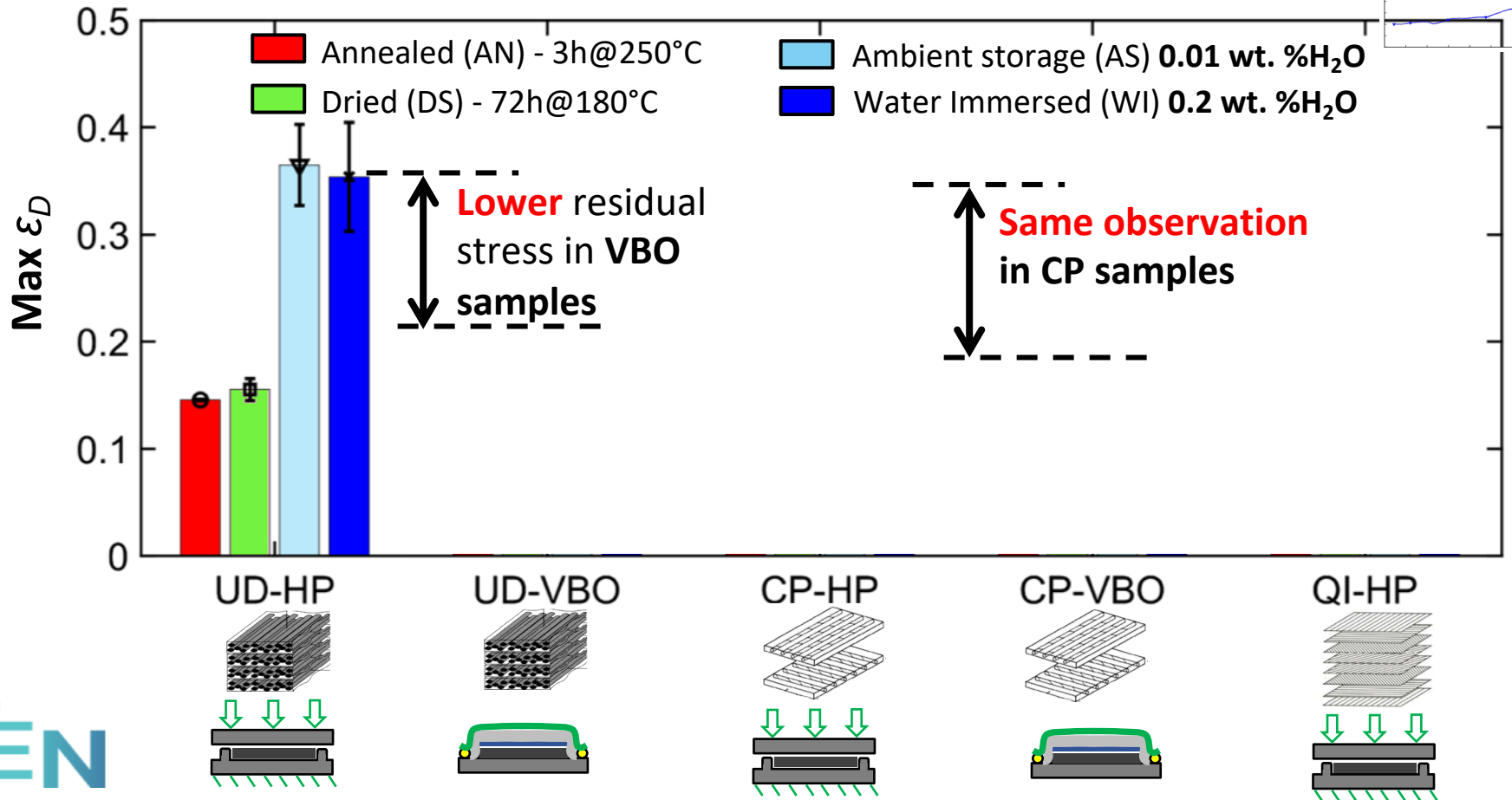
UD, HP
Heating rate =10°C/min
No counter pressure



Moisture makes deconsolidation happen sooner (colder)

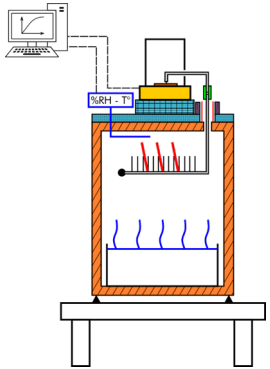
Hot press vs VBO

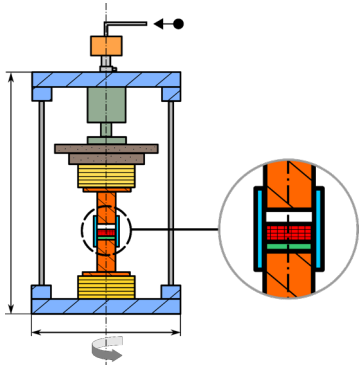


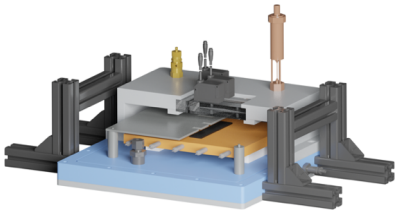


Conclusions

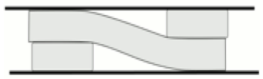
Thermoplastic laminates deconsolidation characterization tools were developped





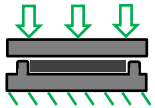


Phenomenological results



Preconditionning reduces catastrophic deconsolidation

Moisture makes deconsolidation happen sooner



Deconso HP > Deconso VBO whatever the layup

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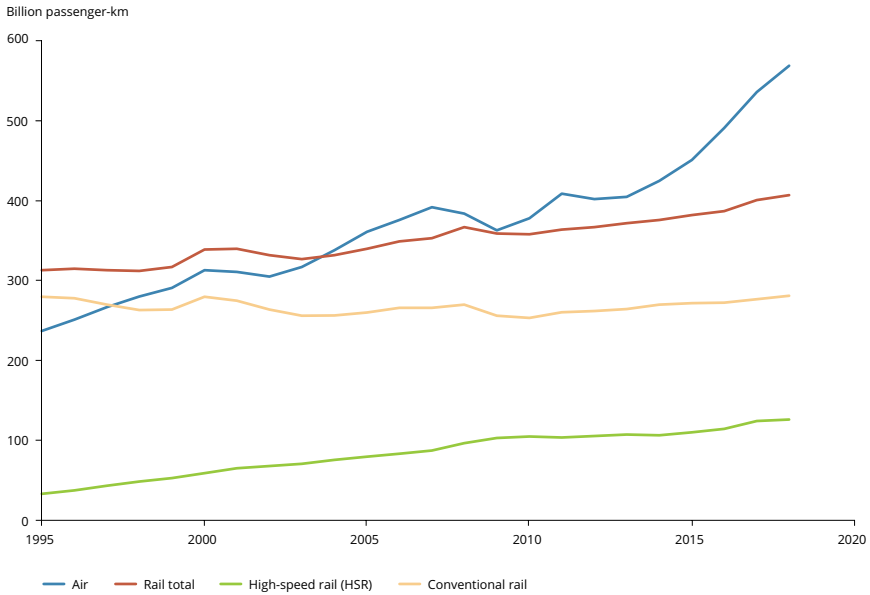
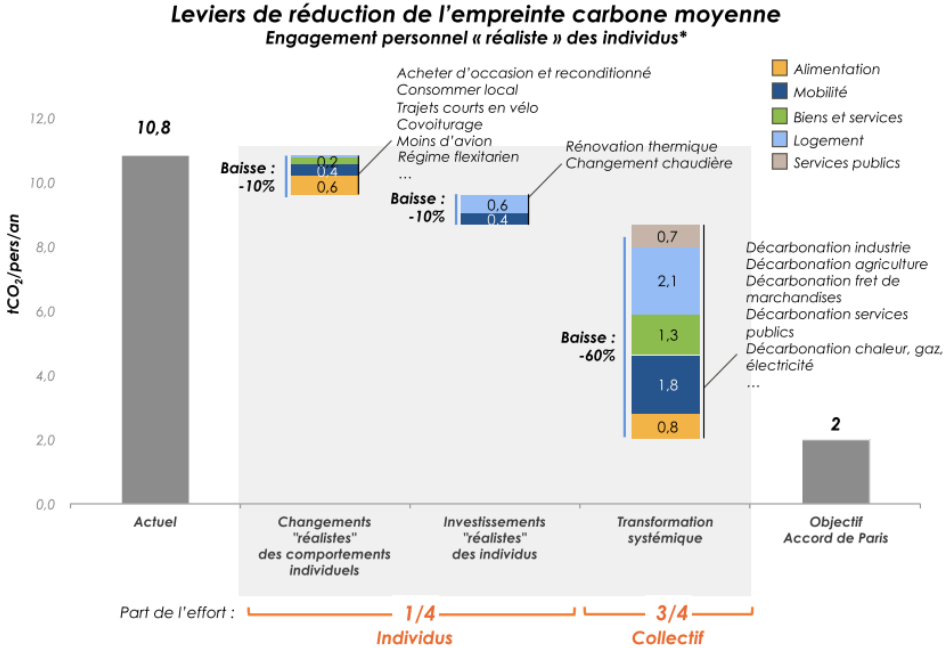
Perspectives



[European Environment Agency 2020]



[Dugast et al 19]

Thermique du bâtiment

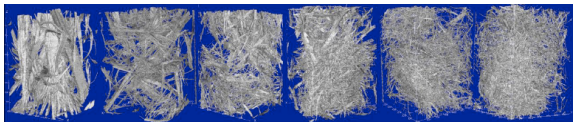
Steico.com

Perspectives sociétales

- Pluridisciplinaire
- Tissu socio-économique

Perspectives académiques

- Multiphysique
- Microstructure / interface



[Vignon 2020]

LABORATOIRE DE THERMIQUE ET ÉNERGIE DE NANTES

Phénomènes de déconsolidation dans les stratifiés composites à matrice thermoplastique

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