Damage of the Cell Wall During Extrusion and Injection Molding of Wood/HDPE Composites

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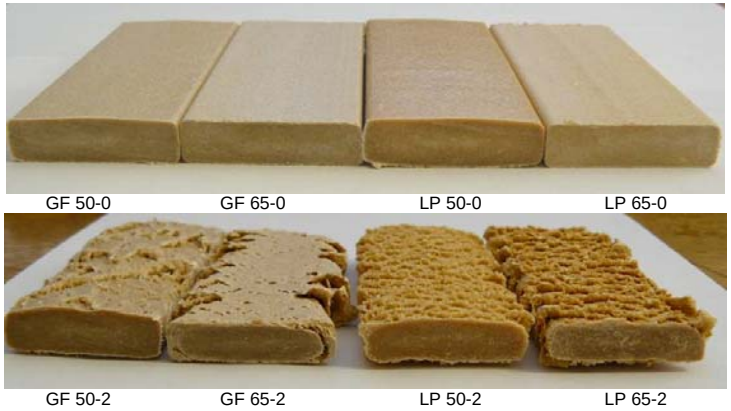
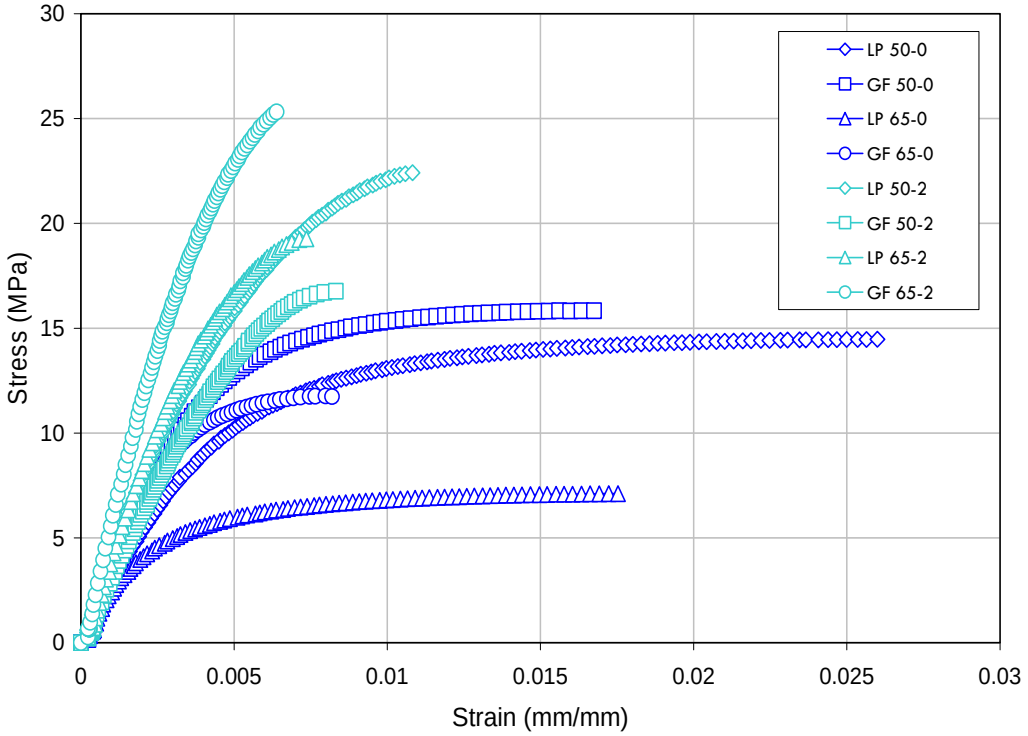
Wood Plastic Composites, WPC

Why…?



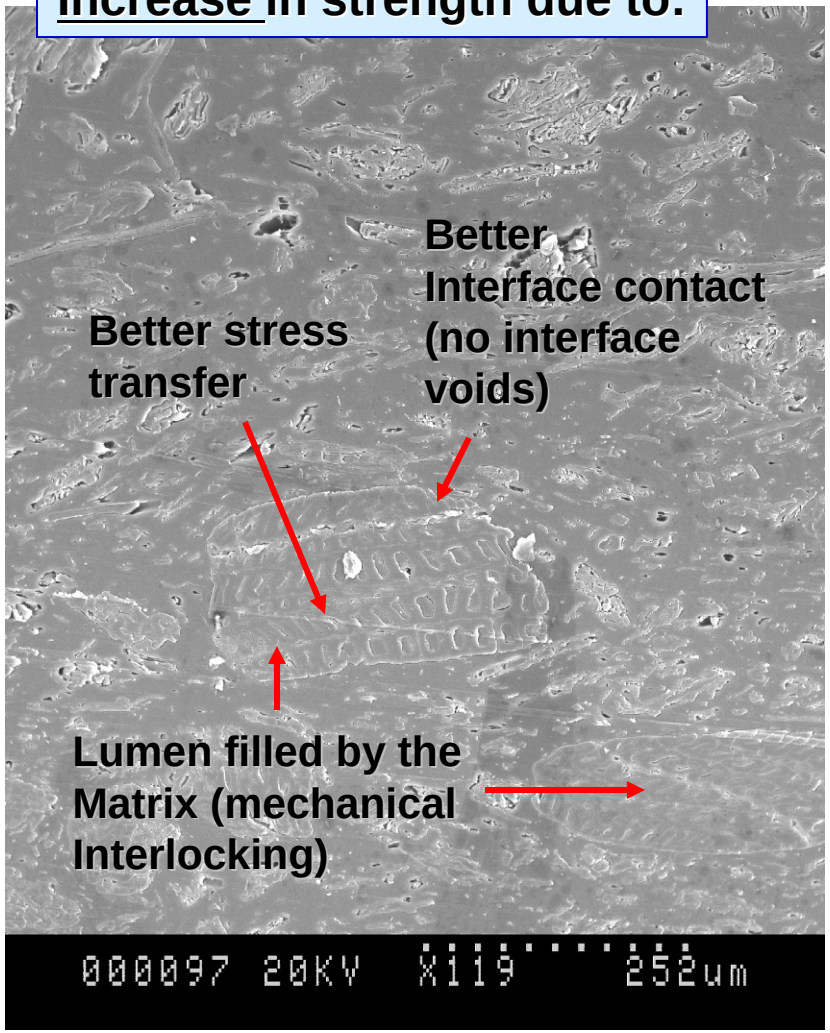


OBJECTIVE

Establish **quantitative correlations** between **mechanical properties**, **microstructure** and **phase properties** on WPCs produced with different wood species

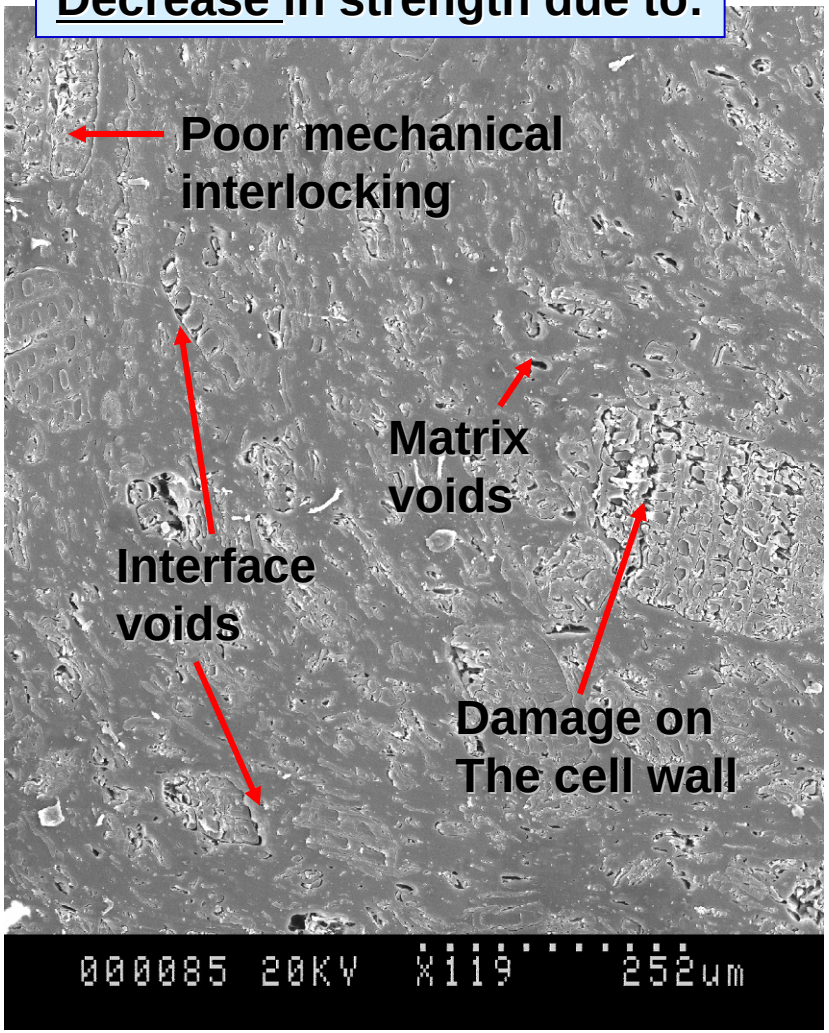
The hypothesis…

Increase in strength due to:



Grand fir, Outerwood

Decrease in strength due to:



Lodgepole pine, Outerwood

Outline

Wood Characterization

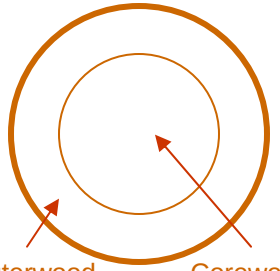
IM-Composites

Macroscale

Microscale

Wood species properties variability

Inside the log



Among species

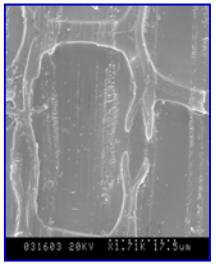
Grand fir

Douglas fir

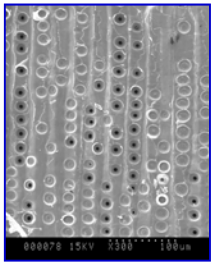
Lodgepole pine

Wood anatomical features

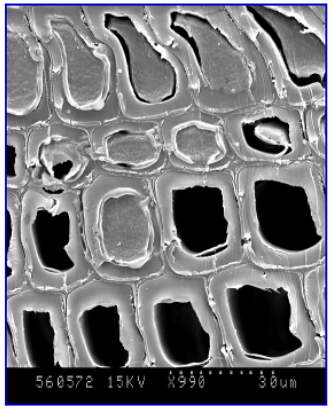
Cross Section



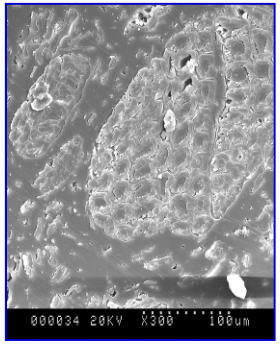
Longitudinal Section



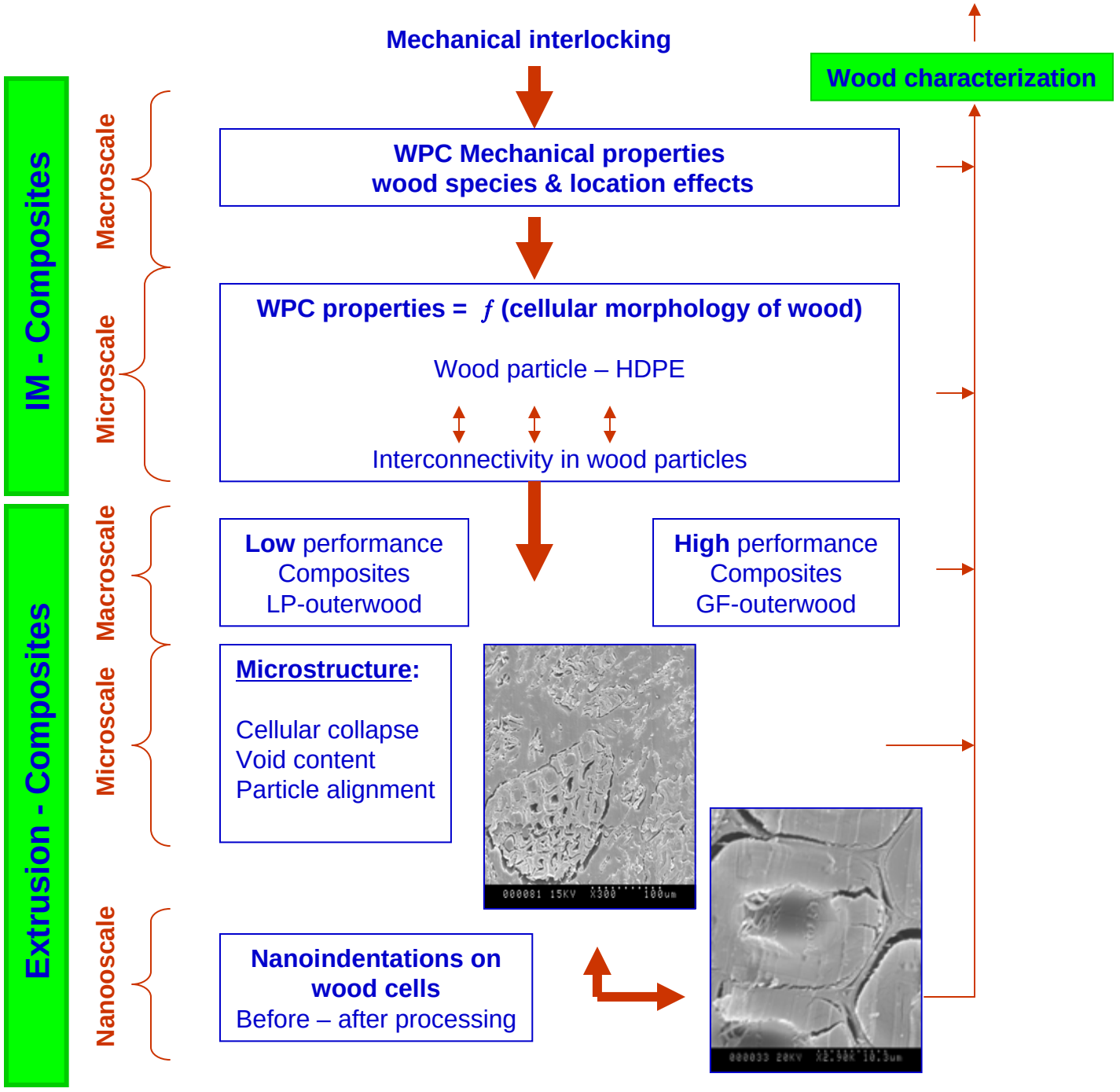
Physical interaction wood/HDPE



HDPE - Solid wood



Injection Molding WPC

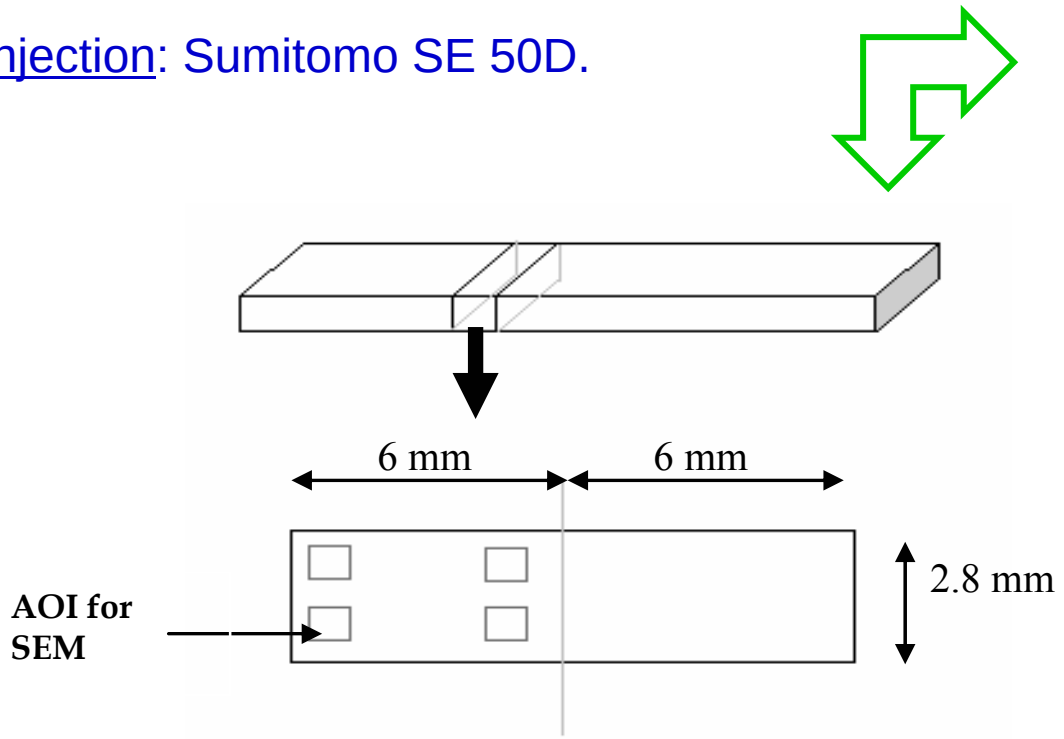

Mechanical interlocking
Wood characterization
IM - Composites
Extrusion - Composites
Macroscale
Microscale
Macroscale
Microscale
Nanoscale
WPC Mechanical properties
wood species & location effects
WPC properties = ƒ (cellular morphology of wood)
Wood particle – HDPE
Interconnectivity in wood particles
Low performance
Composites
LP-outerwood
High performance
Composites
GF-outerwood
Microstructure:
Cellular collapse
Void content
Particle alignment
Nanoindentations on
wood cells
Before – after processing

METHODS

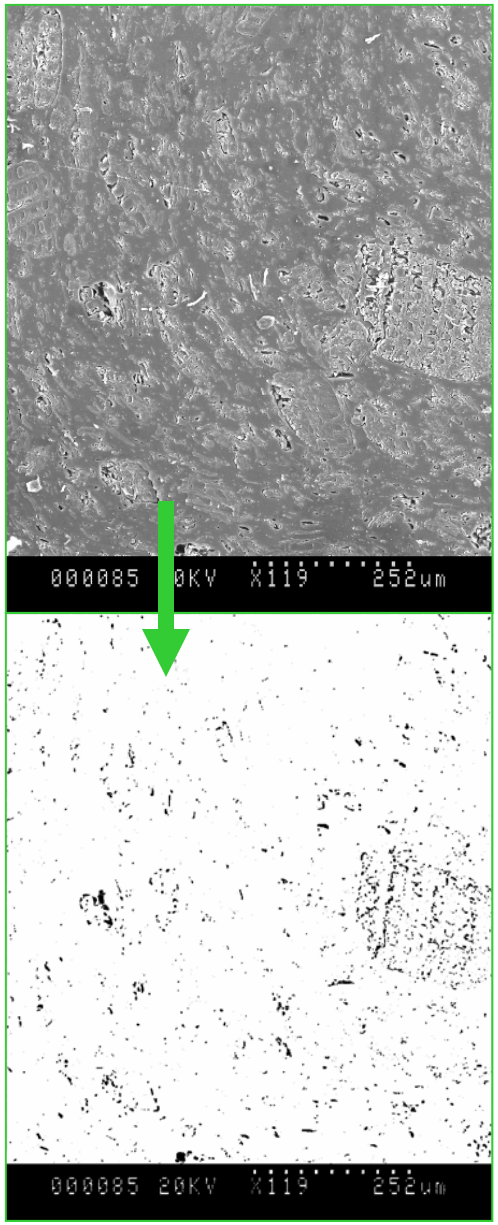
IM composites
HDPE –wood physical interaction

Extrusion: Leistritz 18 mm twin screw Extruder

Injection: Sumitomo SE 50D.

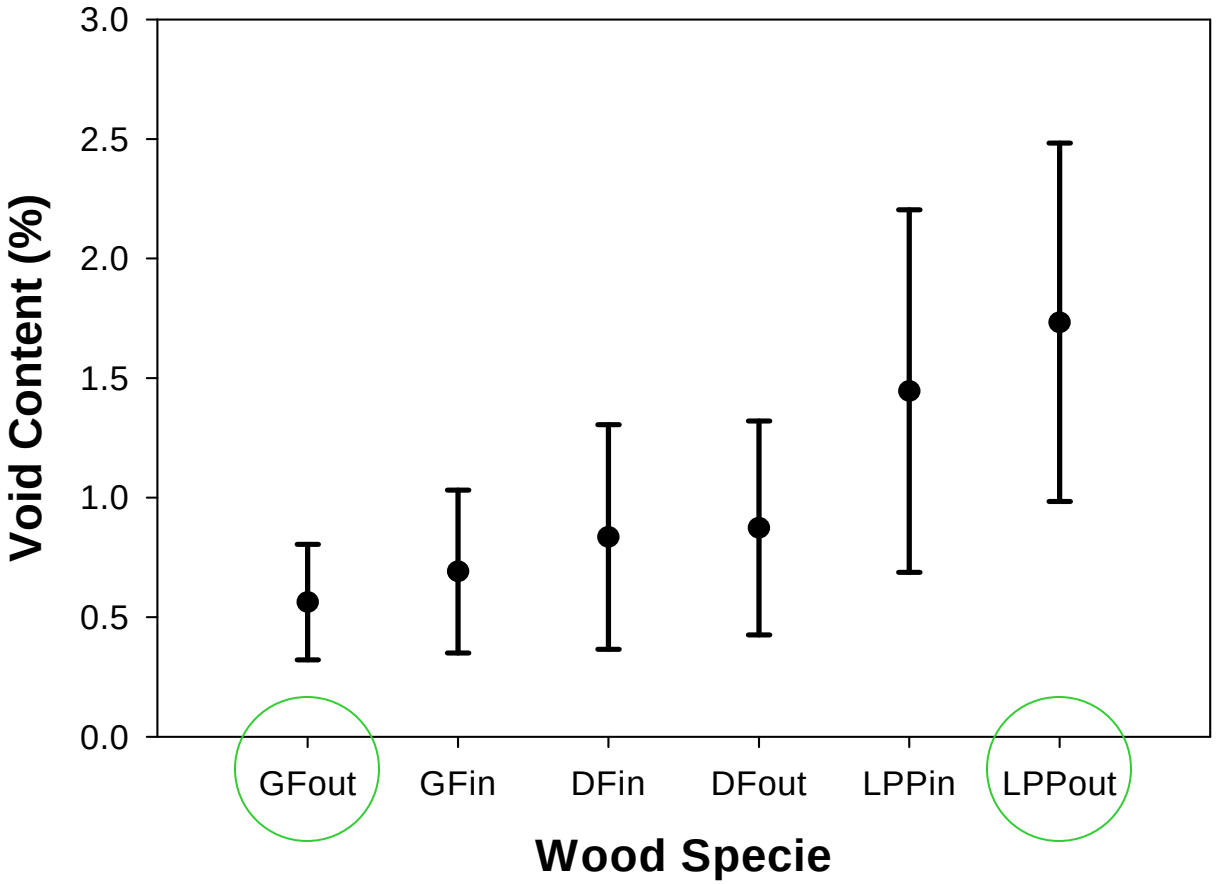


AOI = 770 x 880 μm^2
Image treatment: Pruning filter, threshold = 53

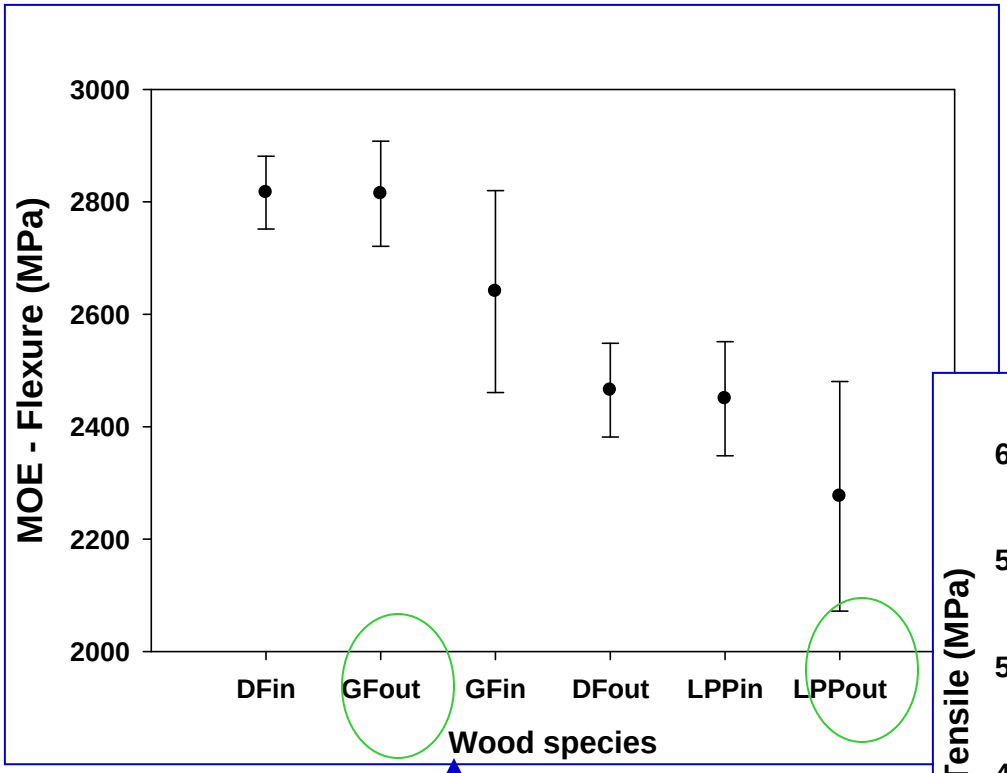


RESULTS

IM - WPC's microstructure

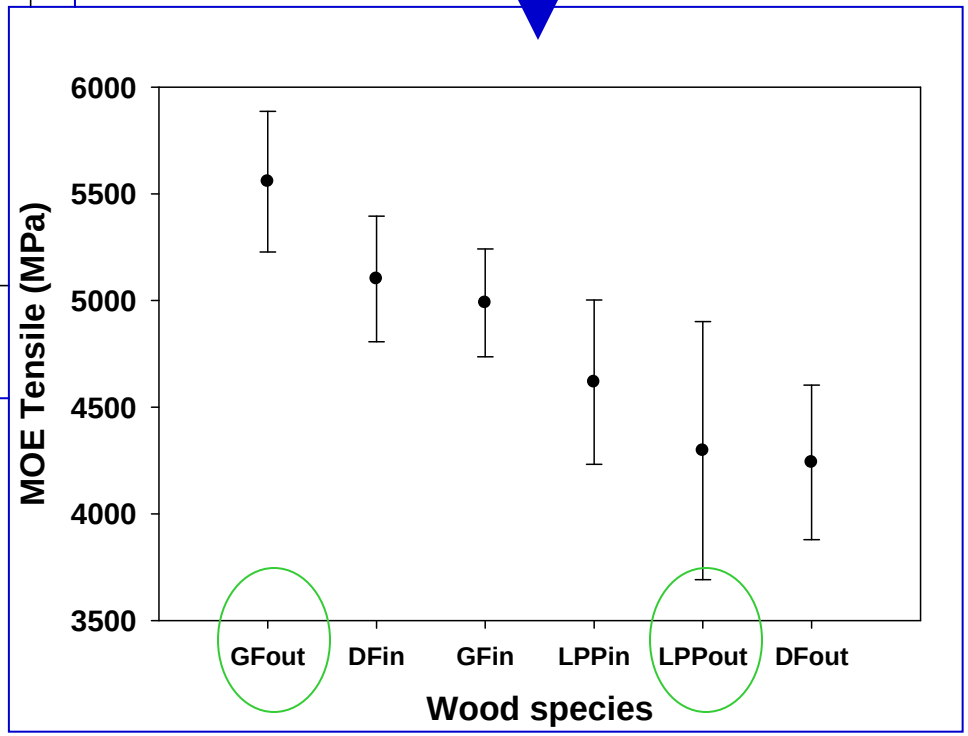


IM – WPCs
Mechanical Properties



Bending

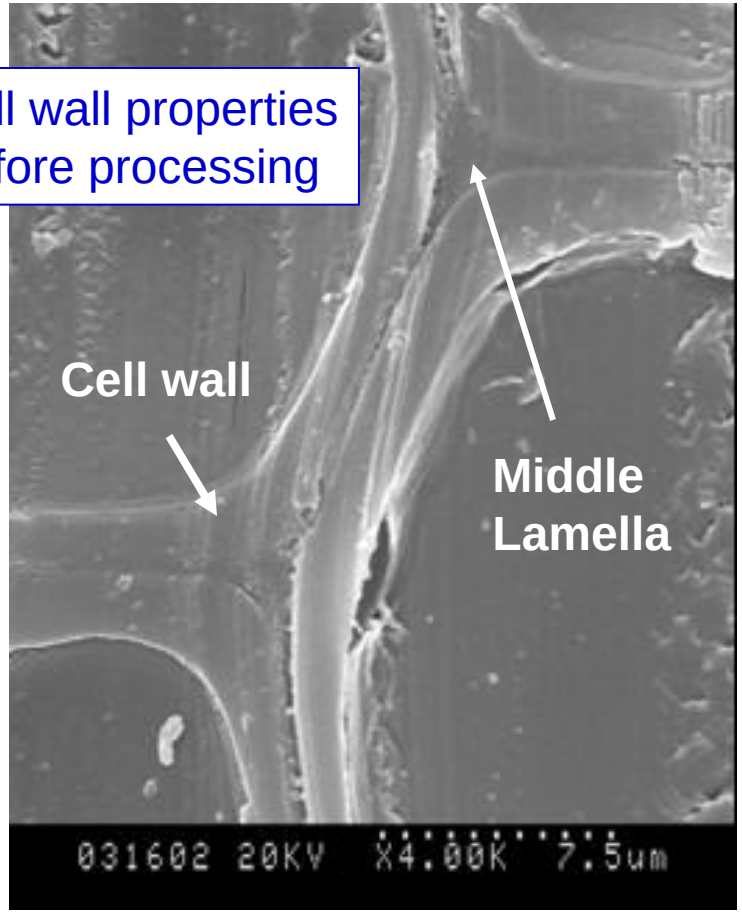
Tensile



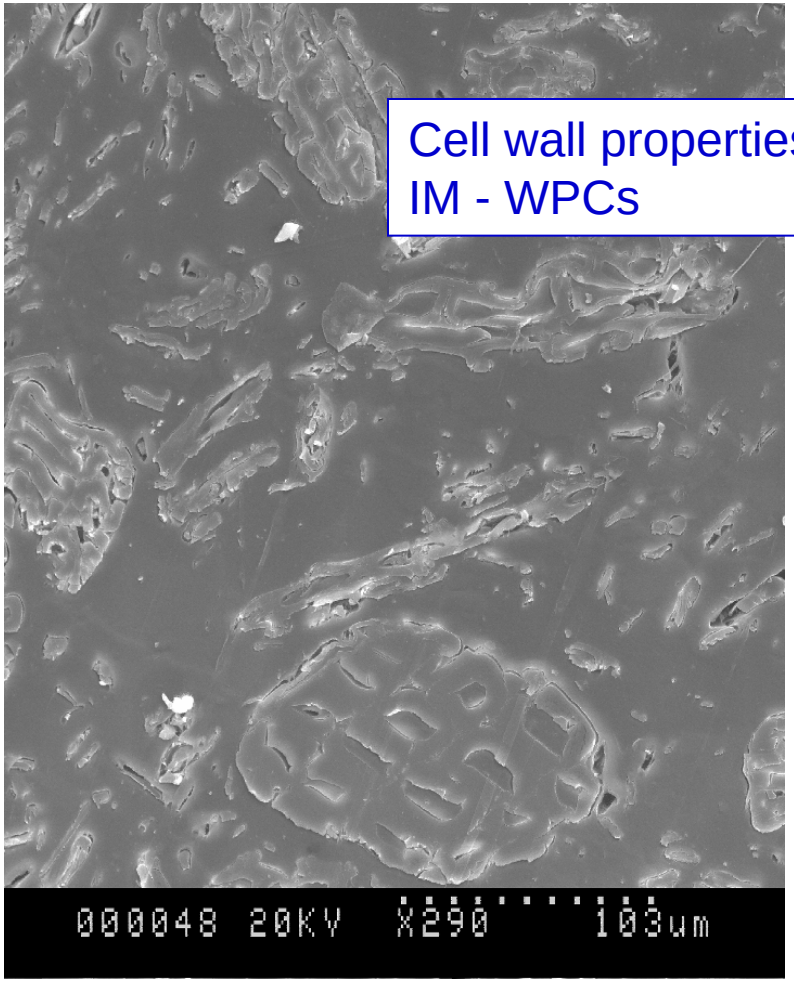
METHODS

IM - WPCs,
Damage of the cell wall

$$E_1 = D^f E_1^{\,f} V^f + E^m (1 - V^f)$$

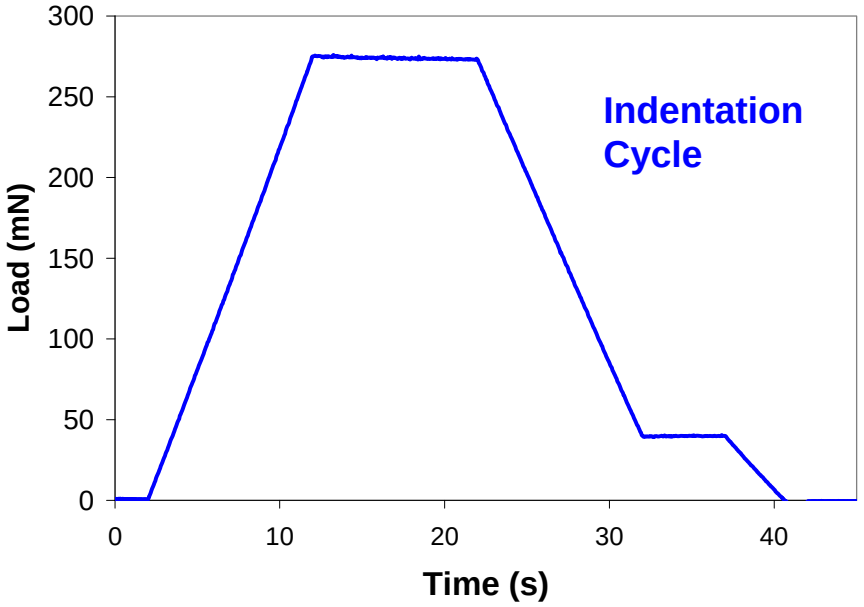


Only two species…



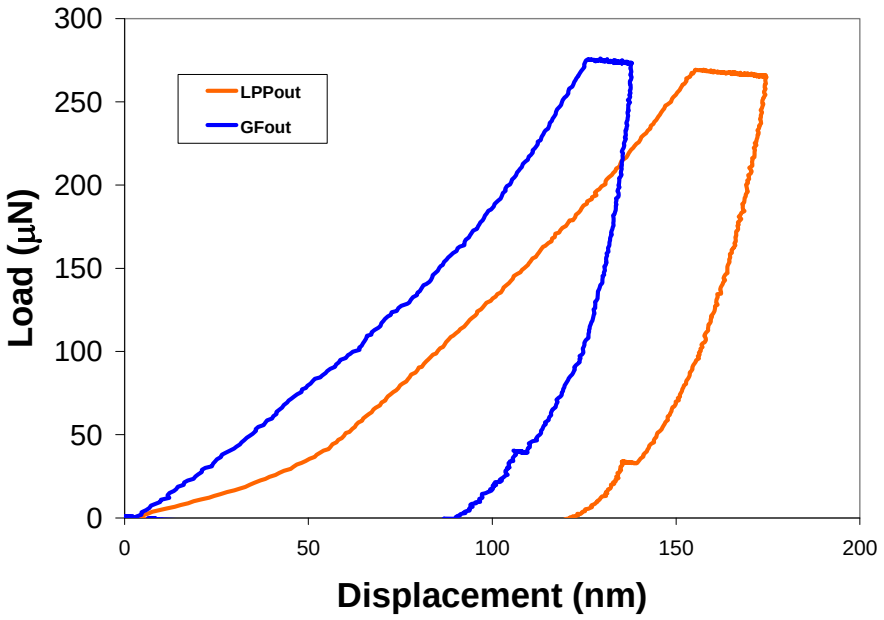
Nanoindentation test

$$E_r = \left[\frac{1-\nu_s^{\,2}}{E_s} + \frac{1-\nu_i^{\,2}}{E_i} \right]^{-1}$$



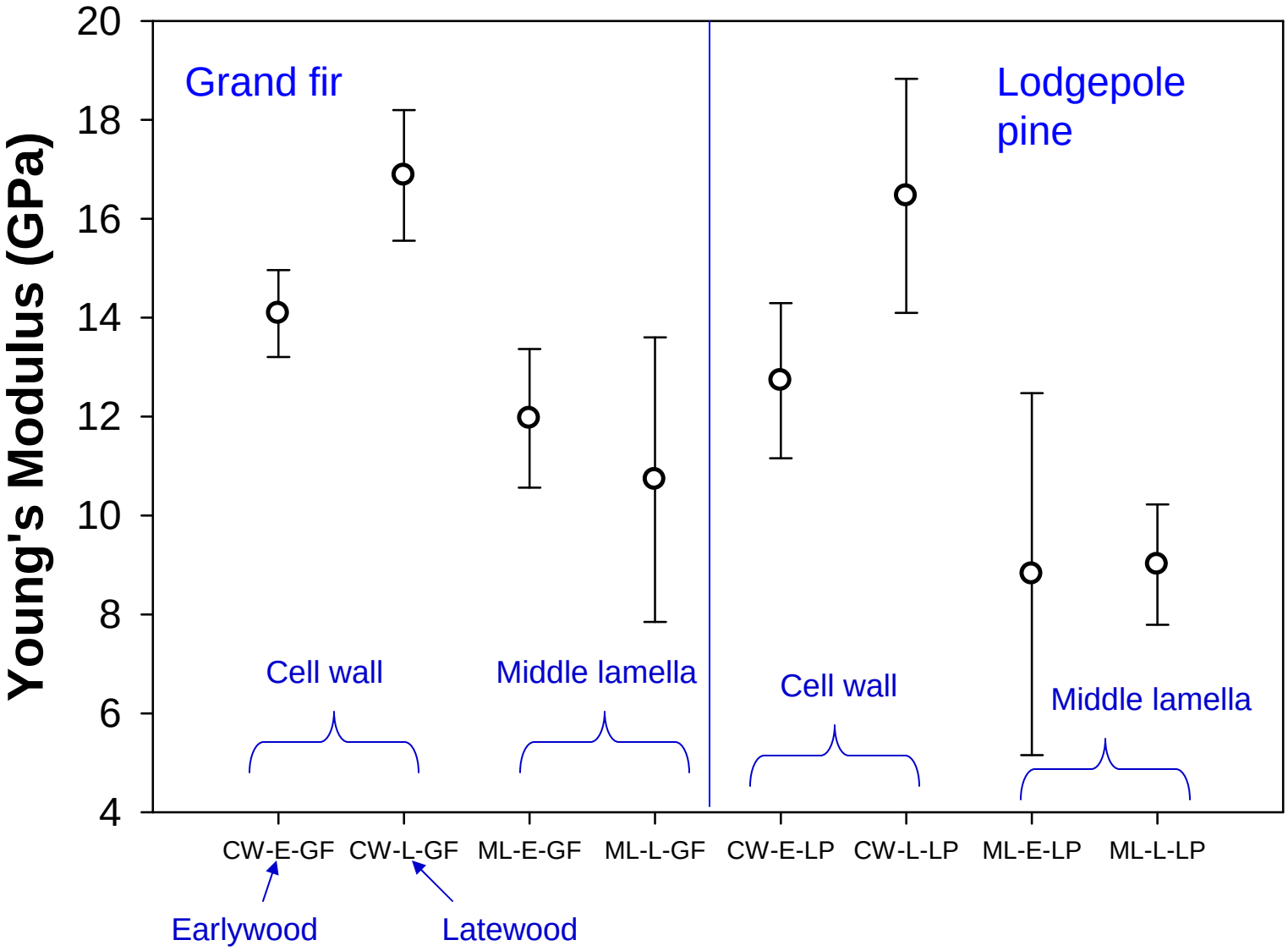
$$E_r = \frac{\sqrt{\pi}}{2} \frac{S}{\sqrt{A}}$$

Response



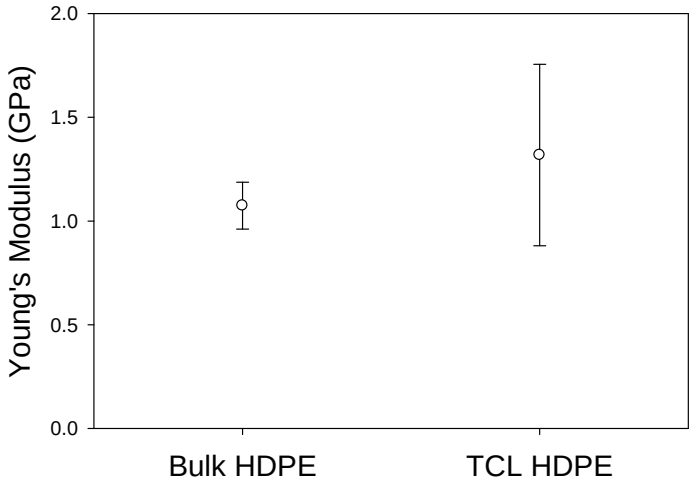
RESULTS

Wood species nanoproperties

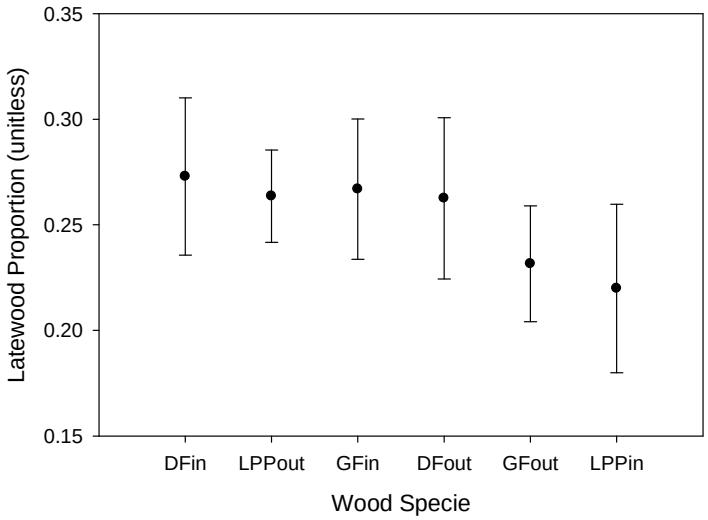


IM - WPCs and Wood properties

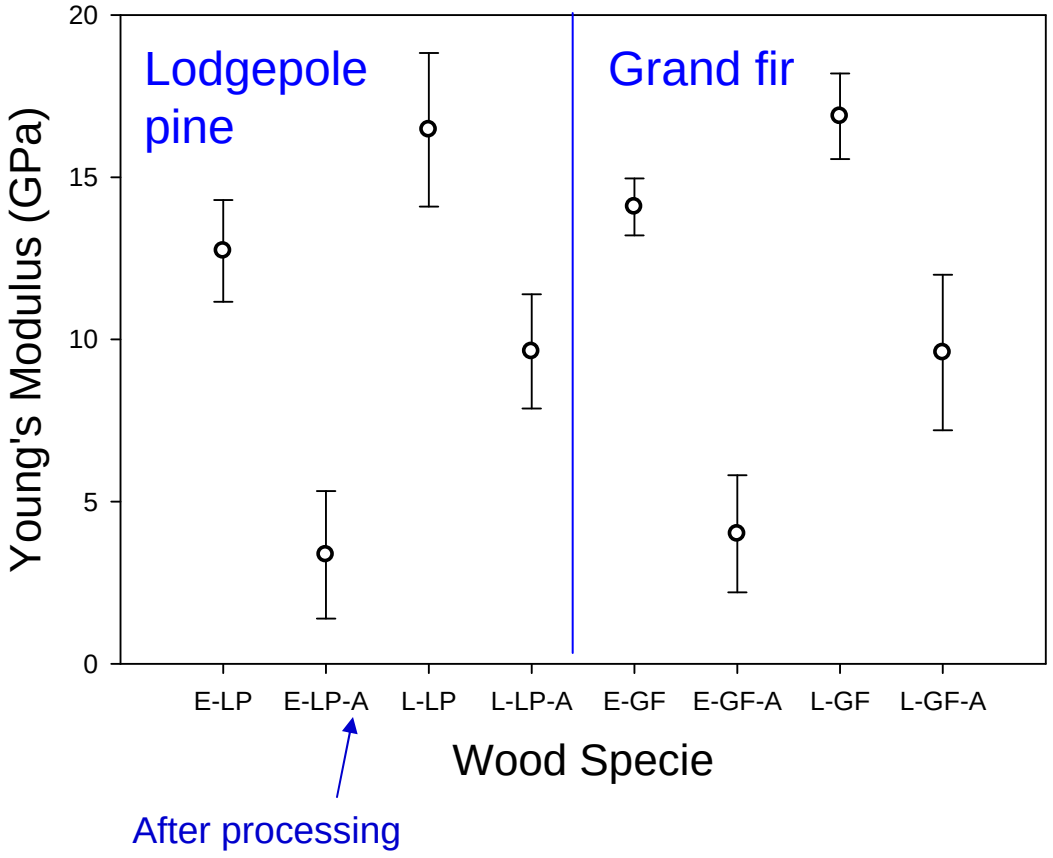
Thermoplastic phase



Latewood proportion



Modulus reduction after processing

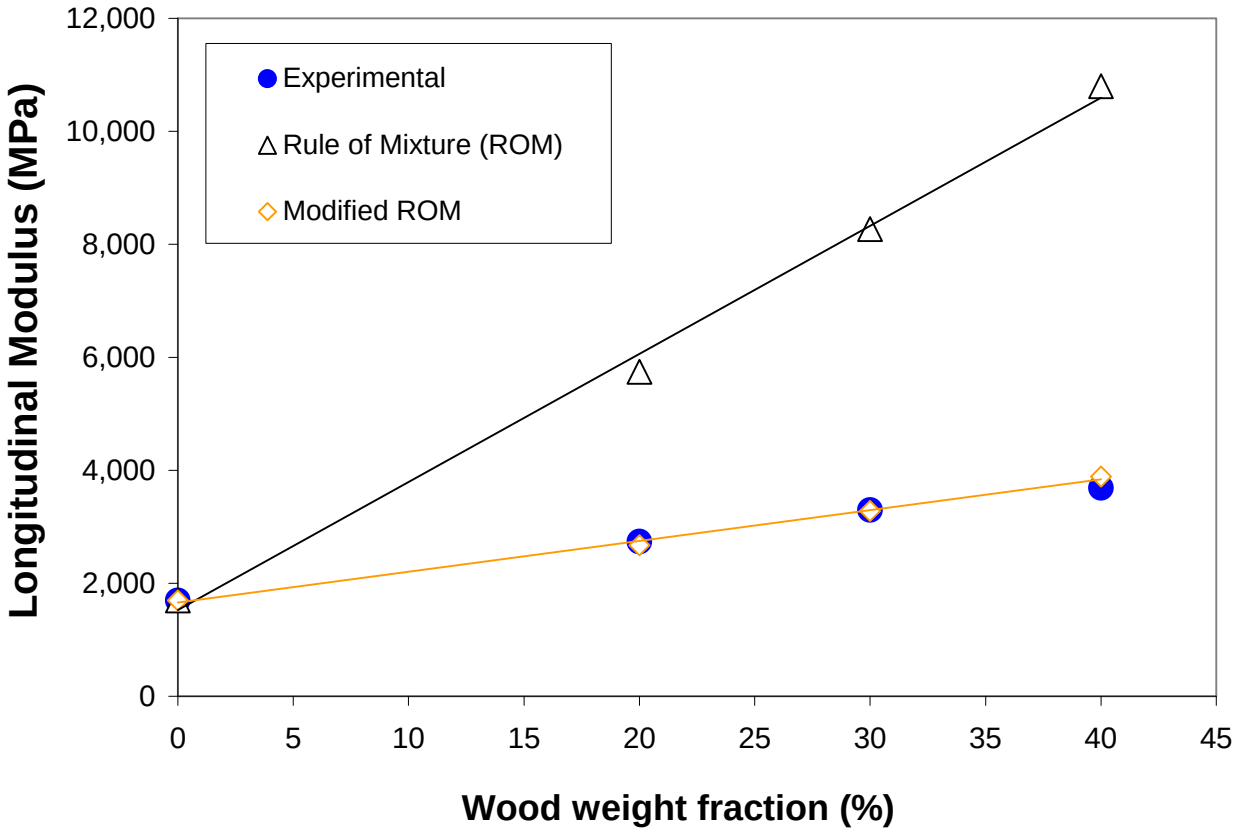


IM - WPCs properties prediction

$$E_1 = D^f E_1^f V^f + E^m (1 - V^f)$$

$$E_D = \frac{E_b - E_a}{E_b}$$

$$D^f = D_E + D_L = E_w (1 - E_{DE}) + L_w (1 - E_{DL})$$



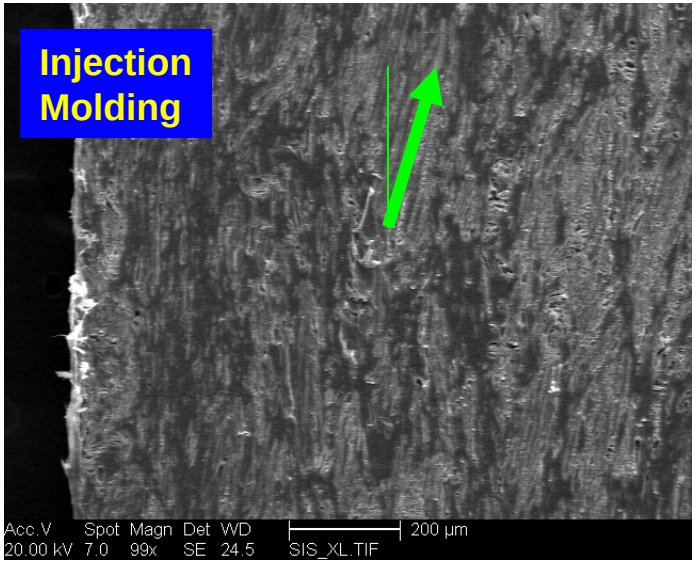
METHODS

Extrusion of WPCs

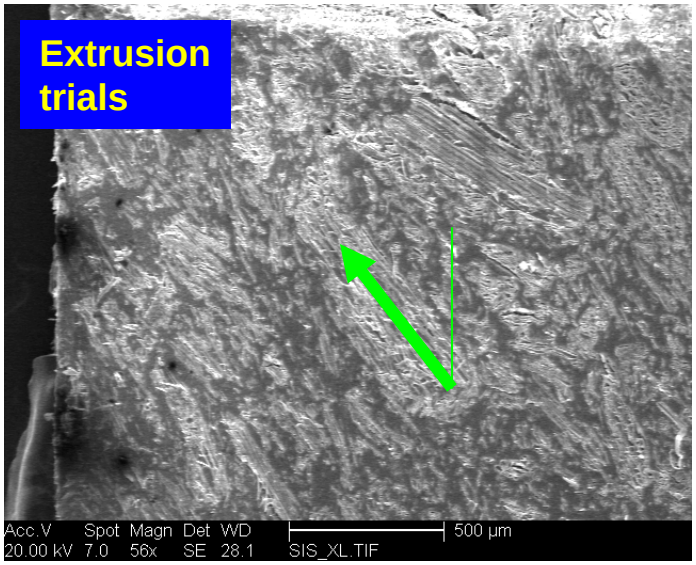
Adapted model

$$E_1 = D^f E_1^f V^f + E_1^m (1 - V^f)$$

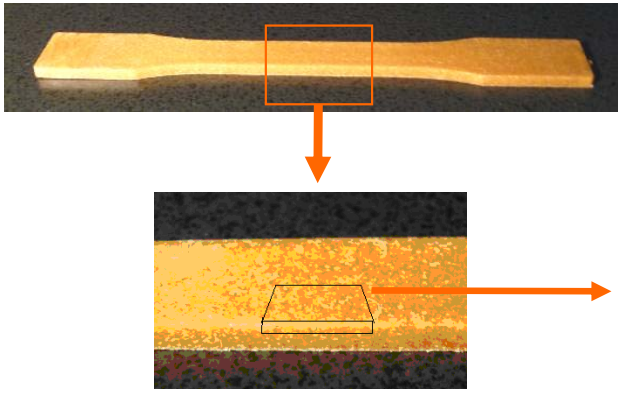
$$\boxed{D^f = D_\theta^f D_D^f}$$

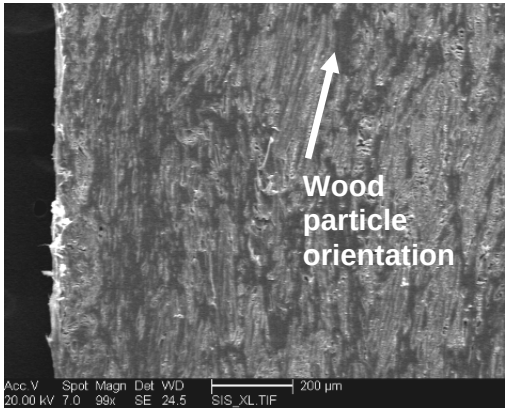


1-Direction

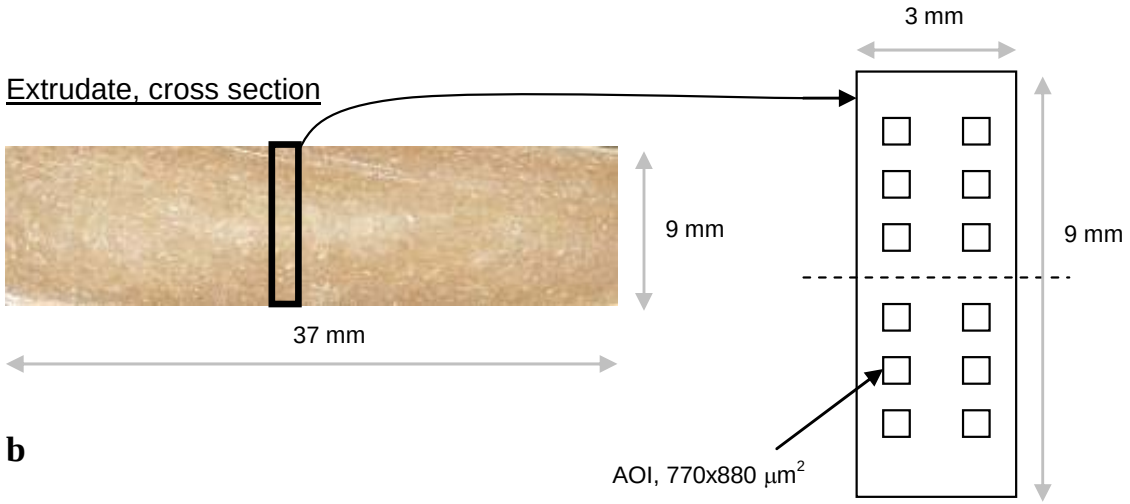


Microstructure characterization



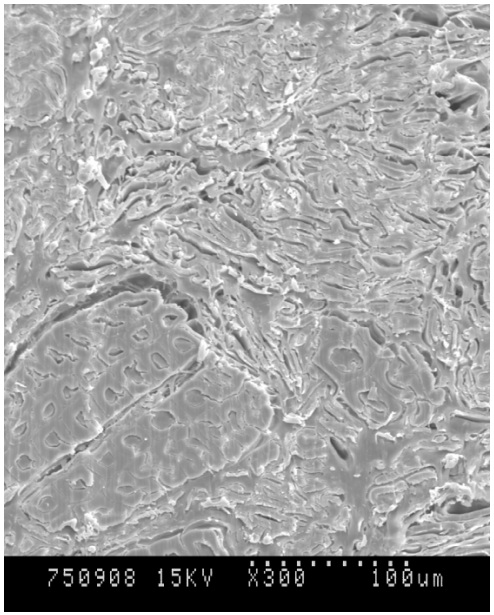


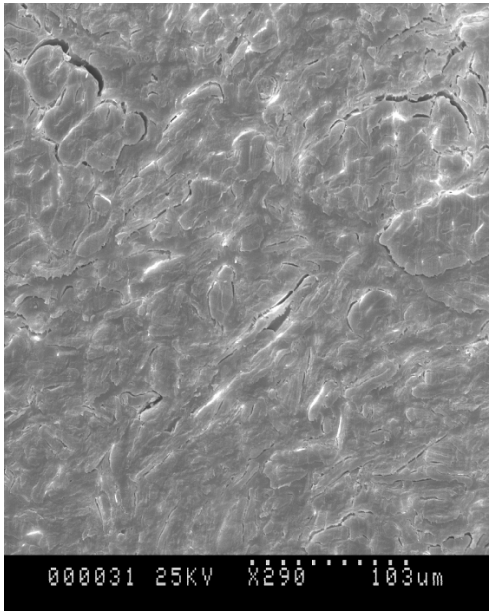
a



b

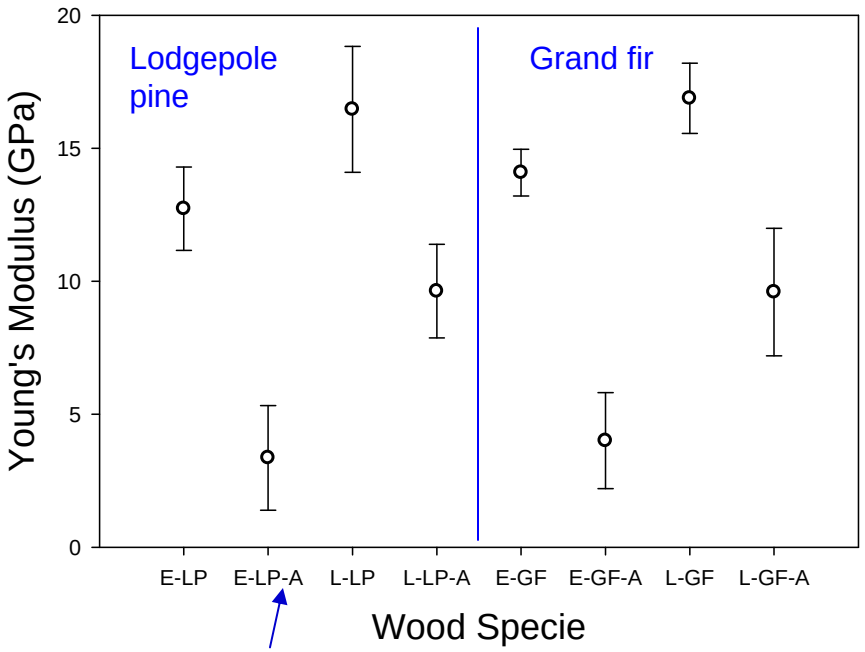
LP65-0





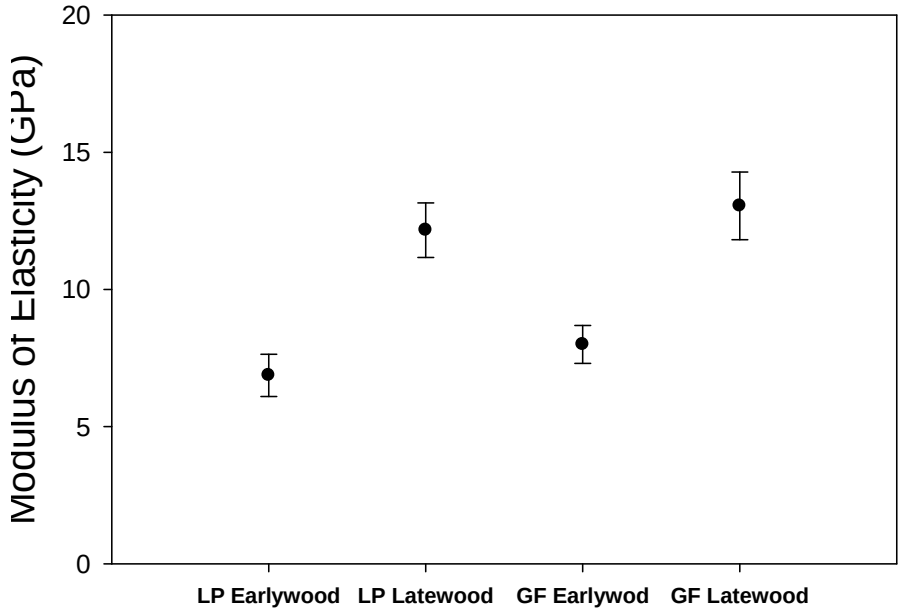
GF65-2

Modulus reduction after IM

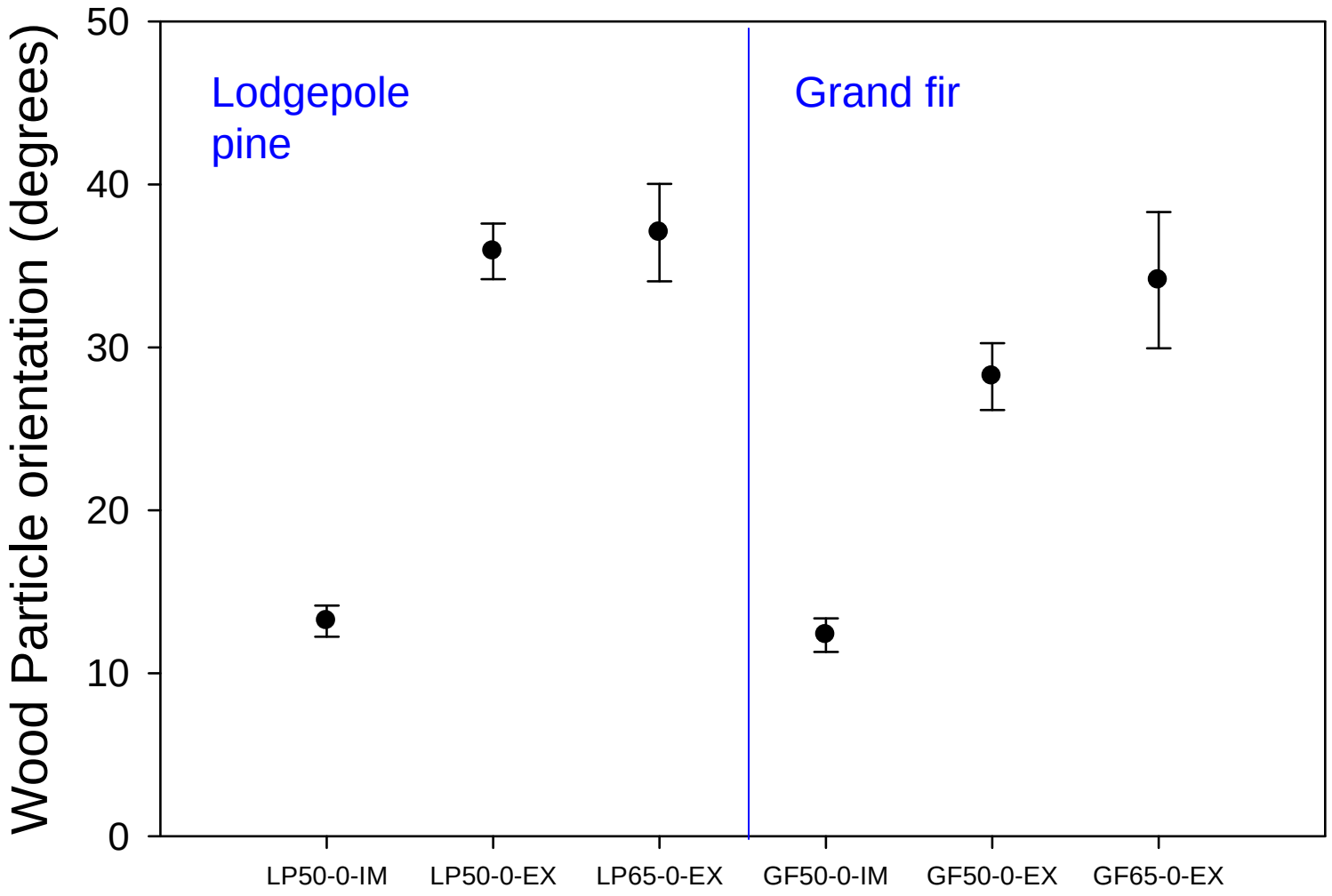


After processing

Cell wall properties After Extrusion



Extrusion vs. IM
Wood particles orientation

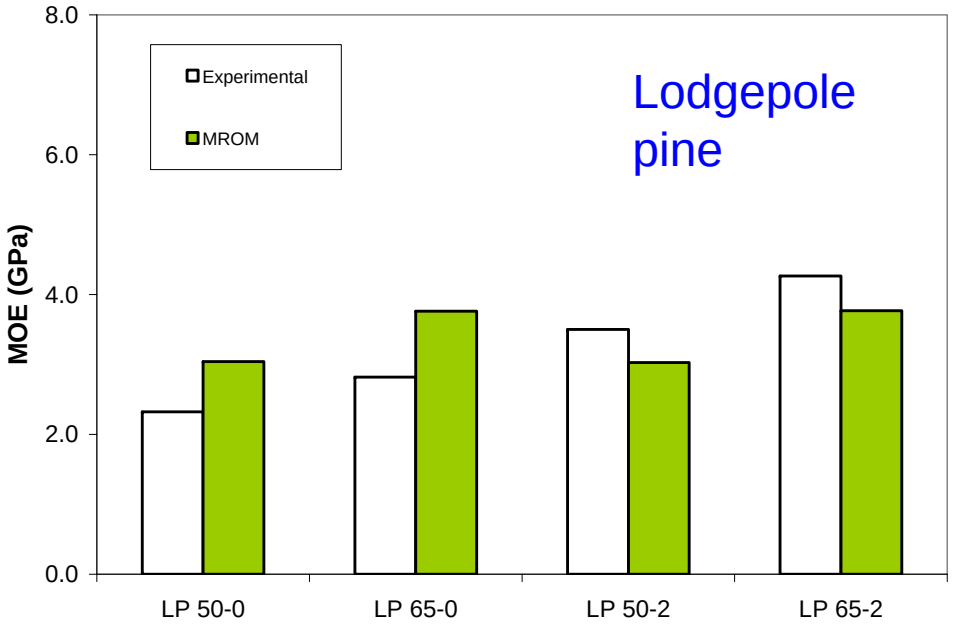


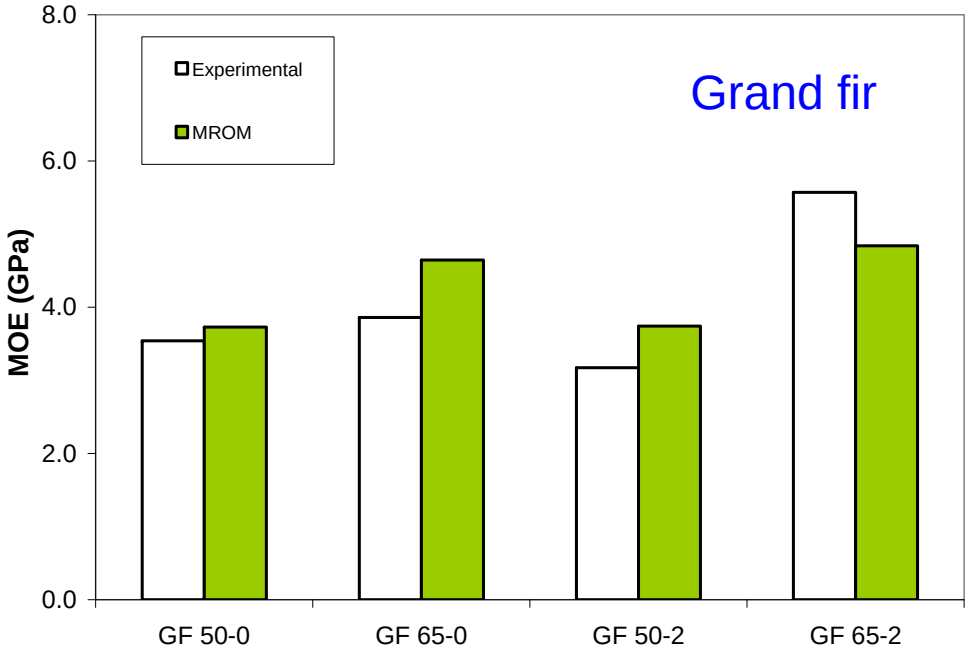
Extrusion trials
Properties prediction

$$E_1 = D^f E_1^{\,f} V^f + E_1^{\,m}(1 - V^f)$$

New ideas…

$$E_1 = D^f E_1^{\,f} V^f + D^m E_1^{\,m} V^m + E_1^{\,TCL} V^{TCL}$$





CONCLUSIONS

- **Anatomical features ~ The phase morphology and mechanical properties of WPC.**
- **A poor interpenetration of HDPE ~ Free buckling of cell walls during extrusion.**
- **Wood particle alignment and wood particle degradation may affect final properties of WPCs made in different processes.**

Thanks…

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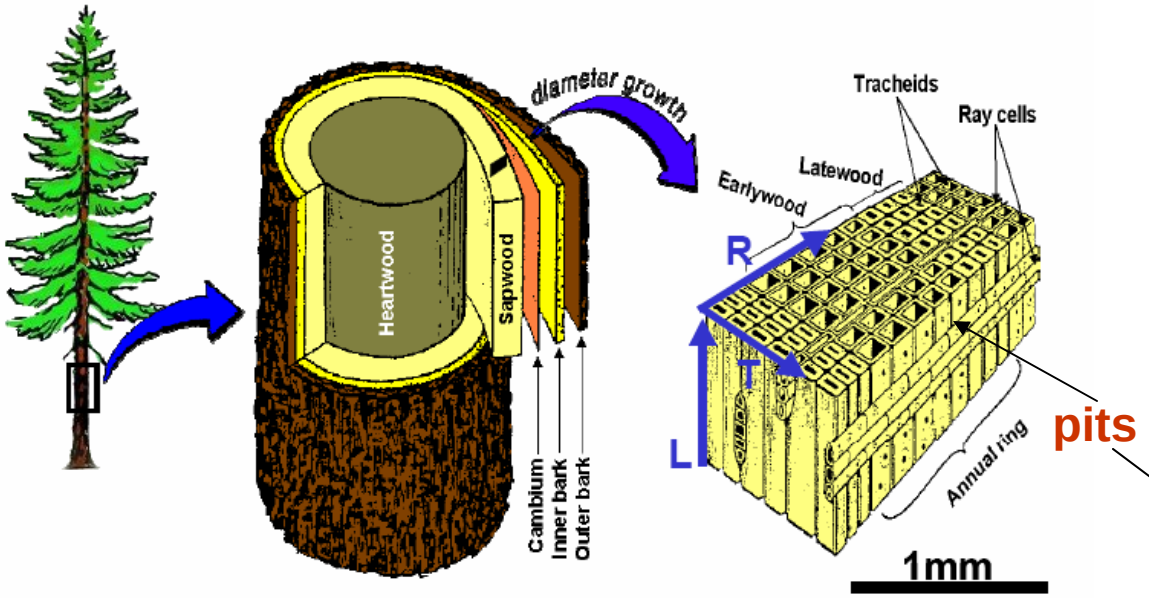
Background:
Wood structure

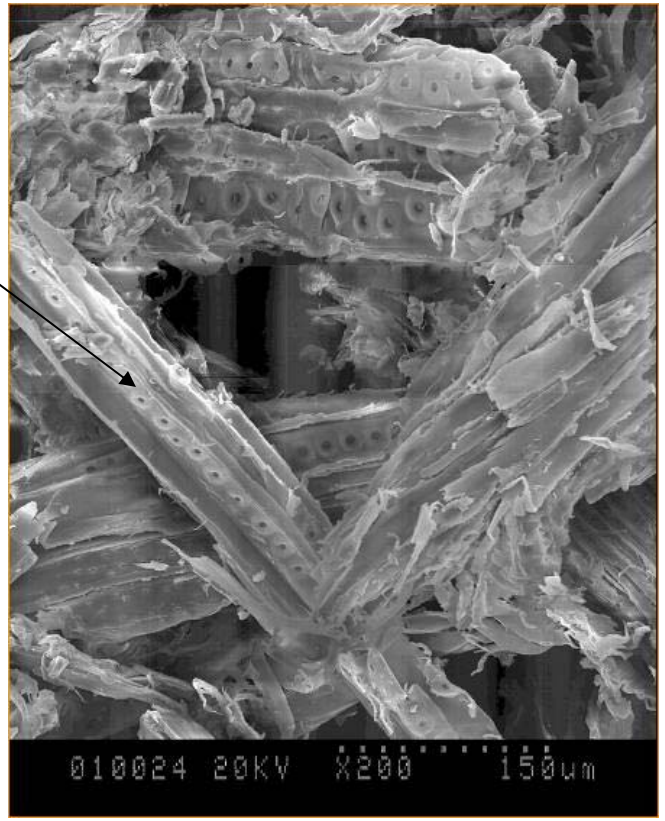


De Magistris, 2005

Pit's function…

Fluid Mobility

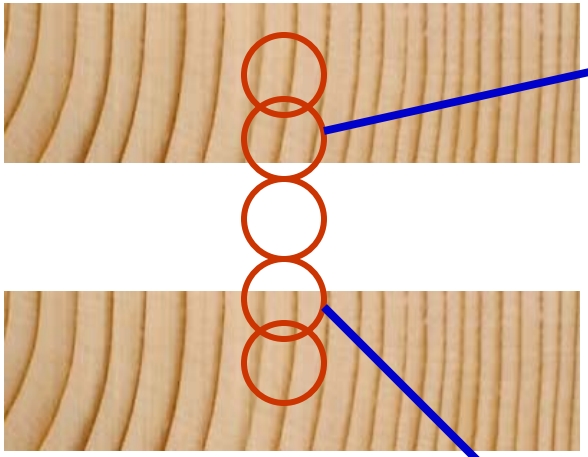
Pine:
Wood flour 60 mesh



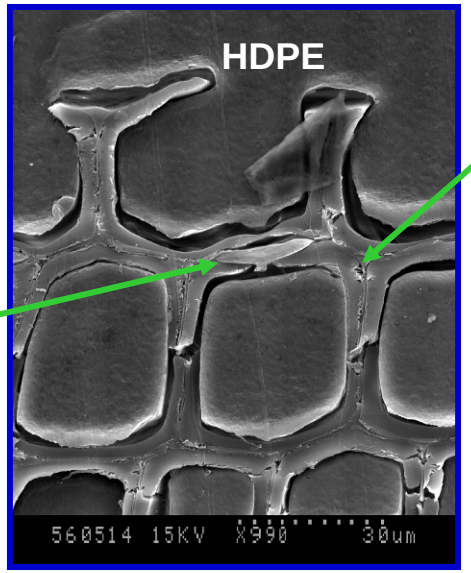
Gacitua-Wolcott, 2005

Mechanisms of Adhesion in WPC

Bond as a system…

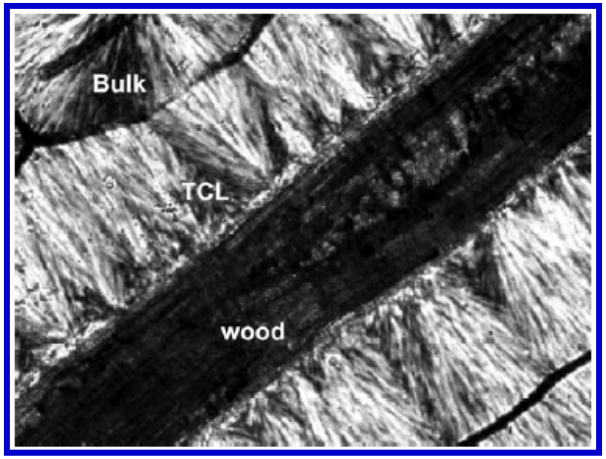


Mechanical Interlocking



Gacitua W., Wolcott M., 2005

Chemical Adhesion



Source: Harper D., Wolcott M., 2004