THE DEVELOPMENT OF BIO-BASED ADHESIVES ENABLES A HIGH ADDED VALUE OF RESIDUAL MATERIALS FROM THE WOOD AND PAPER INDUSTRY

14th INTERNATIONAL SCIENTIFIC CONFERENCE **WOODEMA**

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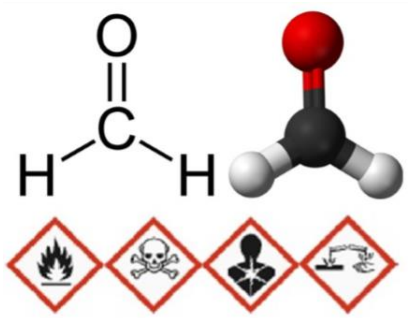
INTRODUCTION

- The wood and paper industry produces large quantities of residual materials and by-products
  - most of them are burned to produce energy
- These materials are:
  - **bark and wood residues** from the wood industry and
  - **technical lignins** from the paper industry
- Wood biomass

WOOD ADHESIVES

- The demand and **consumption of wood panels** is increasing:
  - 400 million m^3 / year worldwide (FAO, 2020)
- Wood panels requires about **24 million tons of adhesives**
- **90 % are synthetic** adhesives
- The most commonly used among them contain **formaldehyde**
- This methanol derivative is problematic due to **environmental and health concerns**
- Alternative => **bio-based adhesives**



TANNIN AND LIGNIN ADHESIVES

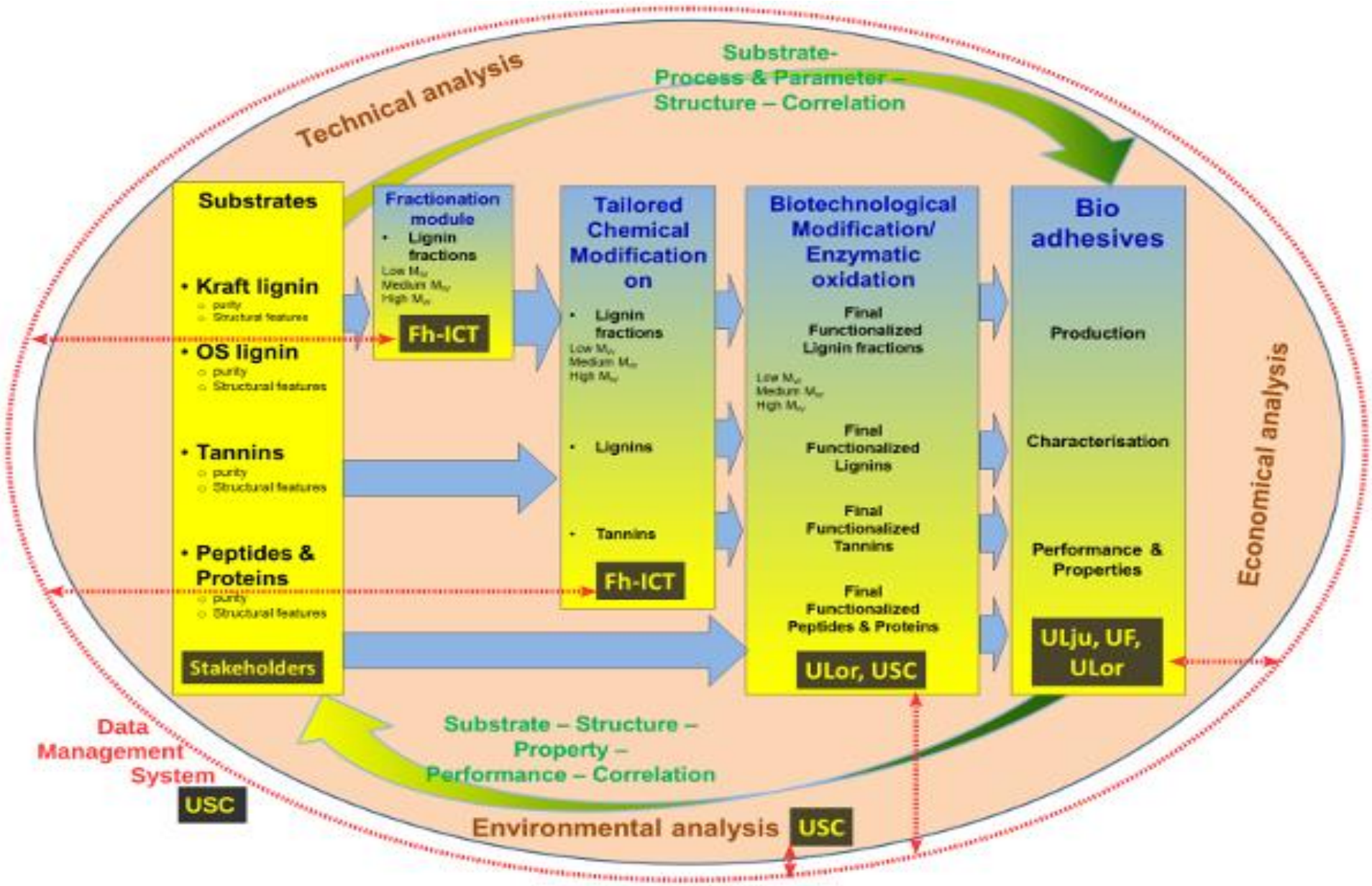
1950 — Replacing up to ⅓ phenol or resorcinol in FF and RF adhesives with lignin / tannin

1990 — Use of VOC-free hardeners (hexamine, glyoxal, furfuryl alcohol,…)

Modification of lignin

Tannins from European conifers

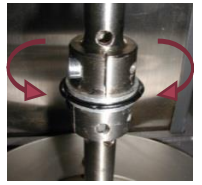
2019 — The most commercially interesting tannin-hexamine


Technical analysis
Substrate-
Process & Parameter –
Structure – Correlation
Substrates
• Kraft lignin
○ purity
○ Structural features
• OS lignin
○ purity
○ Structural features
• Tannins
○ purity
○ Structural features
• Peptides & Proteins
○ purity
○ Structural features
Stakeholders
Fractionation module
• Lignin fractions
Low Mw
Medium Mw
High Mw
Fh-ICT
Tailored Chemical Modification on
• Lignin fractions
Low Mw
Medium Mw
High Mw
• Lignins
• Tannins
Fh-ICT
Biotechnological Modification/ Enzymatic oxidation
Final Functionalized Lignin fractions
Low Mw
Medium Mw
High Mw
Final Functionalized Lignins
Final Functionalized Tannins
Final Functionalized Peptides & Proteins
ULor, USC
Bio adhesives
Production
Characterisation
Performance & Properties
ULju, UF, ULor
Economical analysis
Data Management System
USC
Substrate – Structure – Property – Performance – Correlation
Environmental analysis
USC

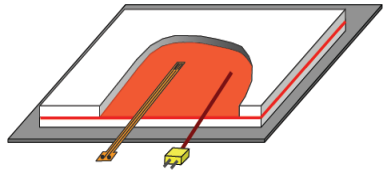
CURING CHARACTERIZATION

- **DSC:**
  - HP DSC1 (isothermal or dynamic conditions)
  - Heat flow => degree of cure

- **DMA:**
  - oscillatory tests (rheometer ARES G2)
  - G‘, G‘‘ => gel / vitrification time

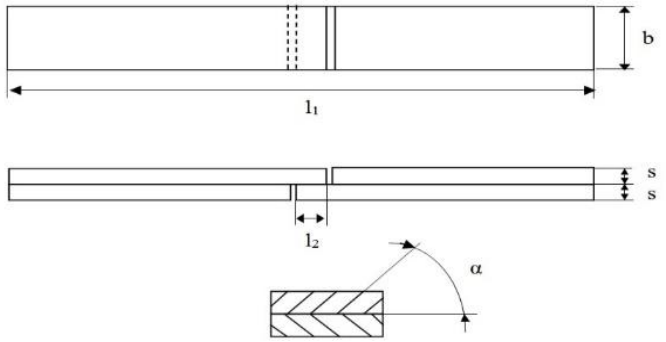


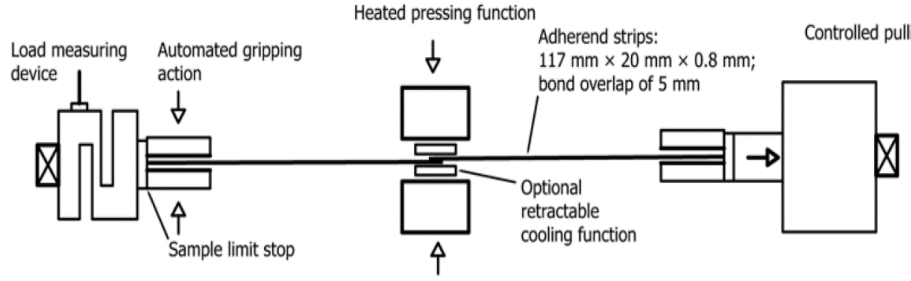
- **DEA:**
  - LCR meter and IDEX sensor
  - electrical conductivity => degree of cure



STRENGTH AND DURABILITY TESTING

- **Testing machine - Zwick:**
  - EN standard – shear test
  - Exposure to different conditions
- **ABES:**
  - Bond strength development
  - Optimisation of pressing parameters

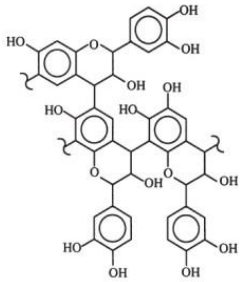




OBJECTIVES

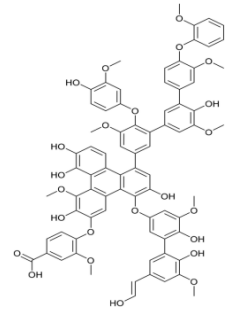
- To study the feasibility of replacing formaldehyde in wood adhesives by natural components derived from wood:
  - **Tannins**
  - **Lignin**
- To examine the potential of residual wood biomass to result in higher added value

MATERIALS

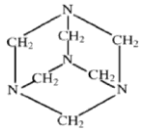


Tannin

Lignin



Hexamine



Water

ADHESIVE FORMULATIONS

Adhesive Name	Tannin : Lignin : Hexamine Dry Weight Ratio	pH Value
UF	-	6.4
T100R	100 : 0 : 6	6.5
T0-L100	0 : 100 : 6	11.6
T20-L80	20 : 80 : 6	11.7
T40-L60	40 : 60 : 6	11.3
T60-L40	60 : 40 : 6	11.4
T80-L20	80 : 20 : 6	11.4
T100-L0	100 : 0 : 6	11.0

BONDING

- Beech lamellas (EN 205)
  - 5 mm
  - 10 %
  - 200 g/m^2
- Hot press:
  - 150 °C
  - 15 bars
  - 10 min

TESTING

- Pre-treatment:
  - Dry (20/65)

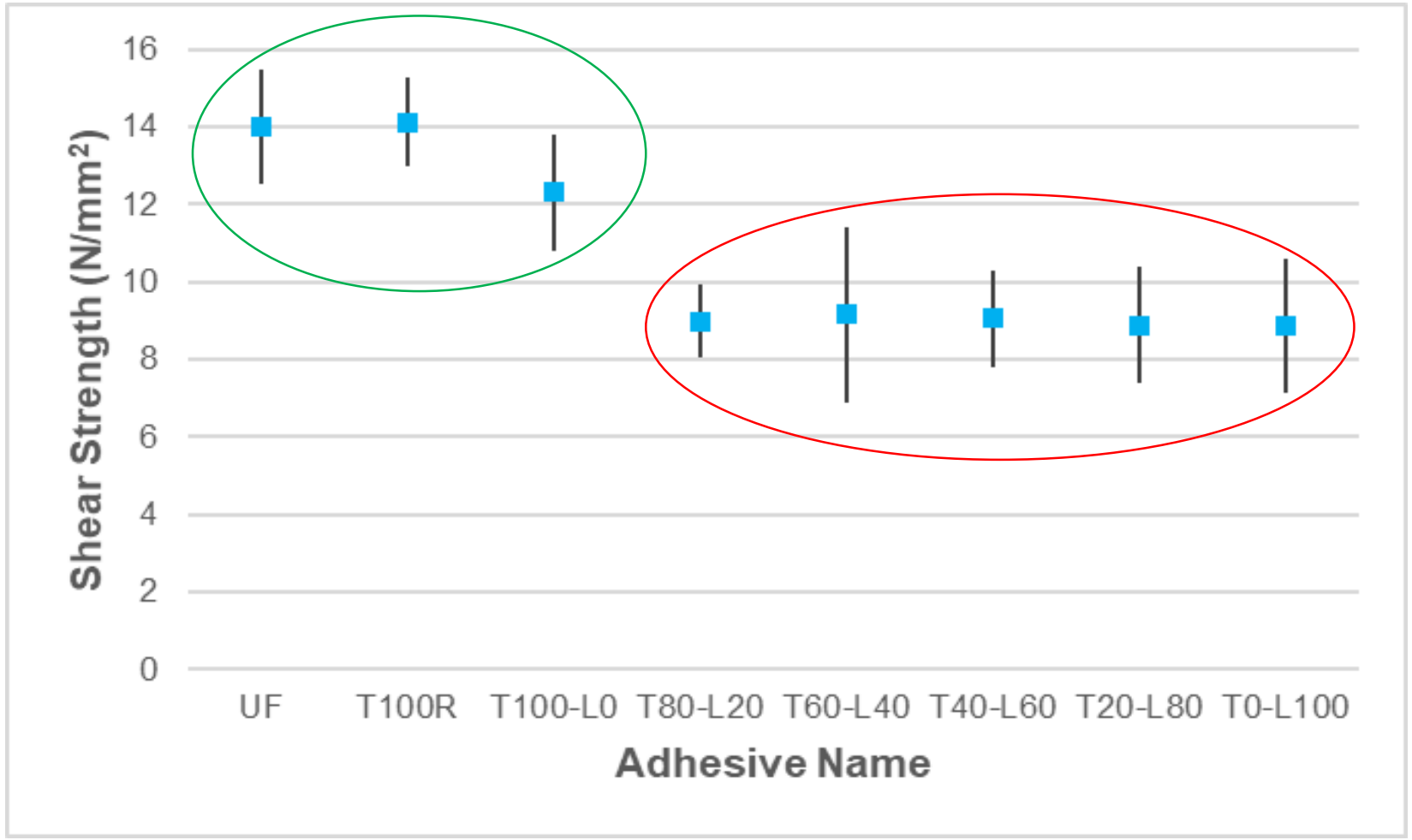
- Shear strength test of lap joints

- % of wood failure

REQUIREMENTS

Conditioning sequences		Adhesive strength in N/mm² **Durability classes**			
Sequence number	Duration and condition	**C1**	**C2**	**C3**	**C4**
1	7 days in standard atmosphere 20 °C / 65 % RH	≥10	≥10	≥10	≥10
2	7 days in standard atmosphere 1 day in water at 20±5 °C		≥7	≥7	≥7
3	7 days in standard atmosphere 3 h in water at 67±2 °C 2 h in water at 20±5 °C			≥4	
4	7 days in standard atmosphere 3 h in boiling water 2 h in water at 20±5 °C				≥4

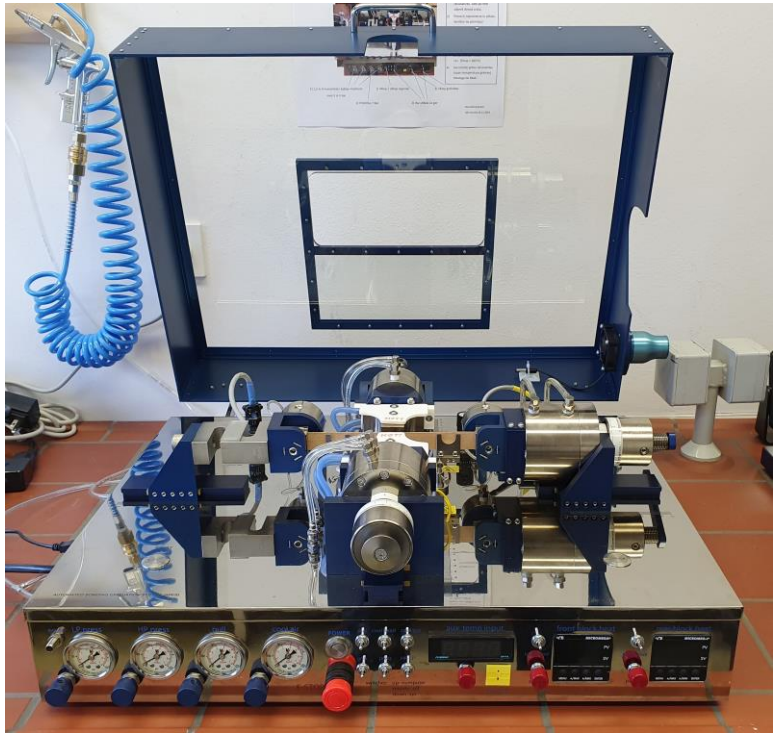
SHEAR STRENGTH RESULTS



CONCLUSIONS

- Two **tannin adhesives** and one commercial **UF adhesive passed** the threshold value for **C1** (10 N/mm^2)
- All the **specimens bonded with** the adhesive mixture containing **lignin did not achieve** requirement for **C1**
- With further **optimization** of the mixtures and pressing at higher temperatures, **tannin-lignin adhesives have a potential** for further development and application
- Utilization of tannin and lignin in **bio-based adhesives has a great potential** to result in **higher added value to residual wood biomass**

ONGOING WORK

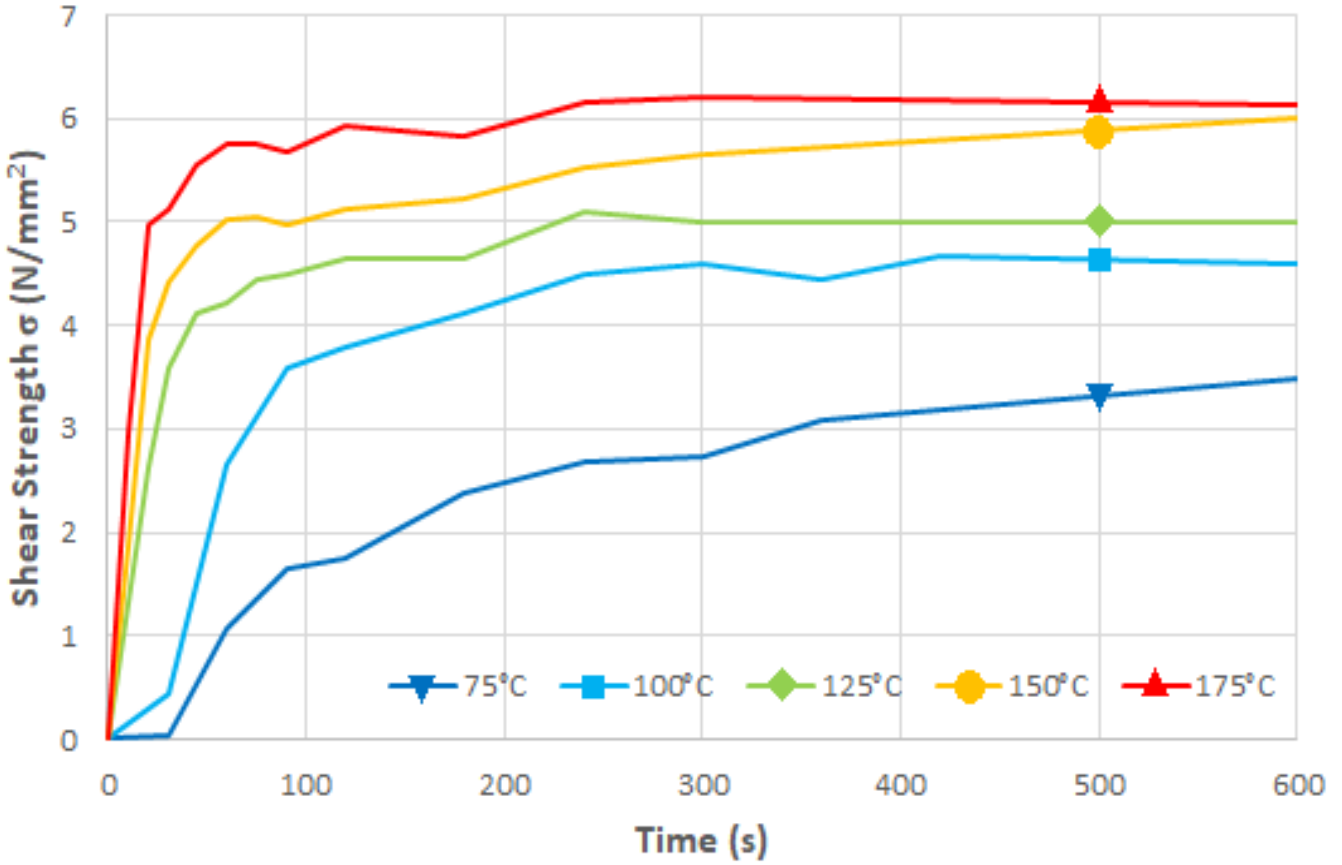


ABES

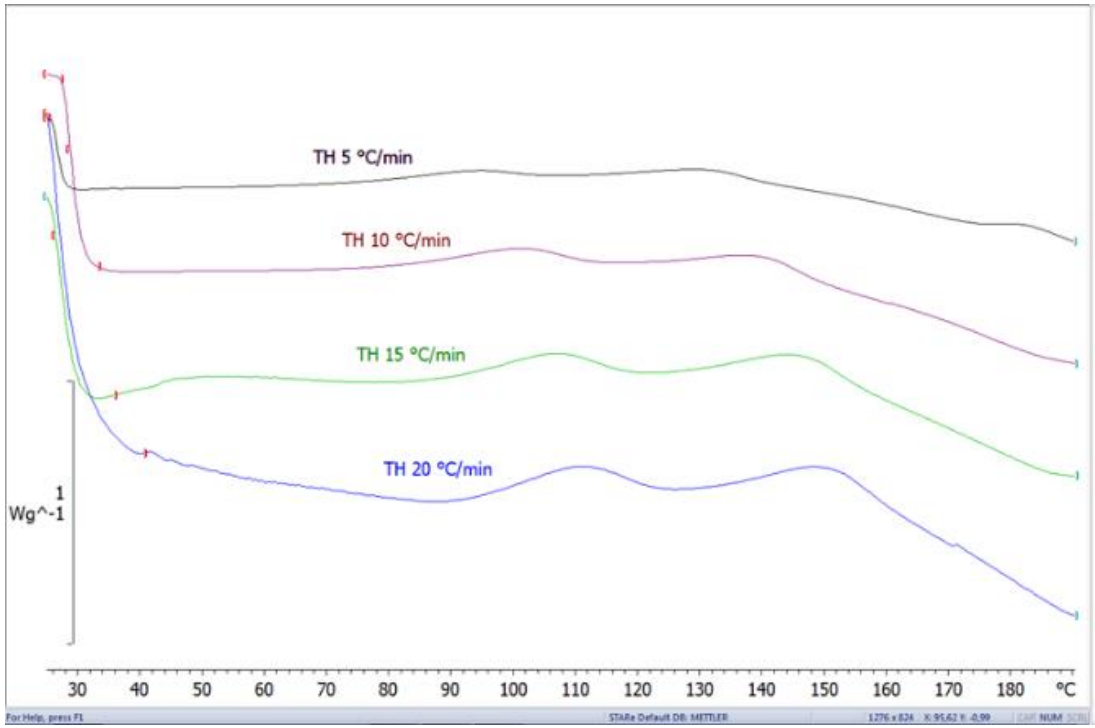
DSC

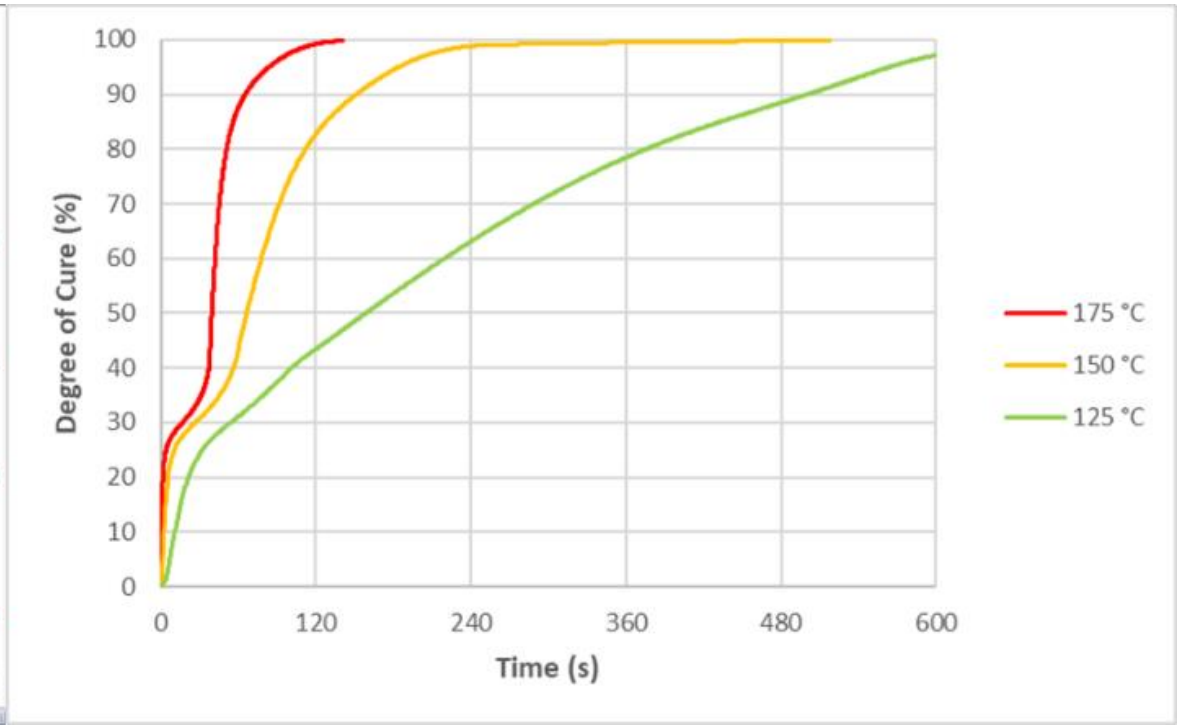
Correlation

ABES

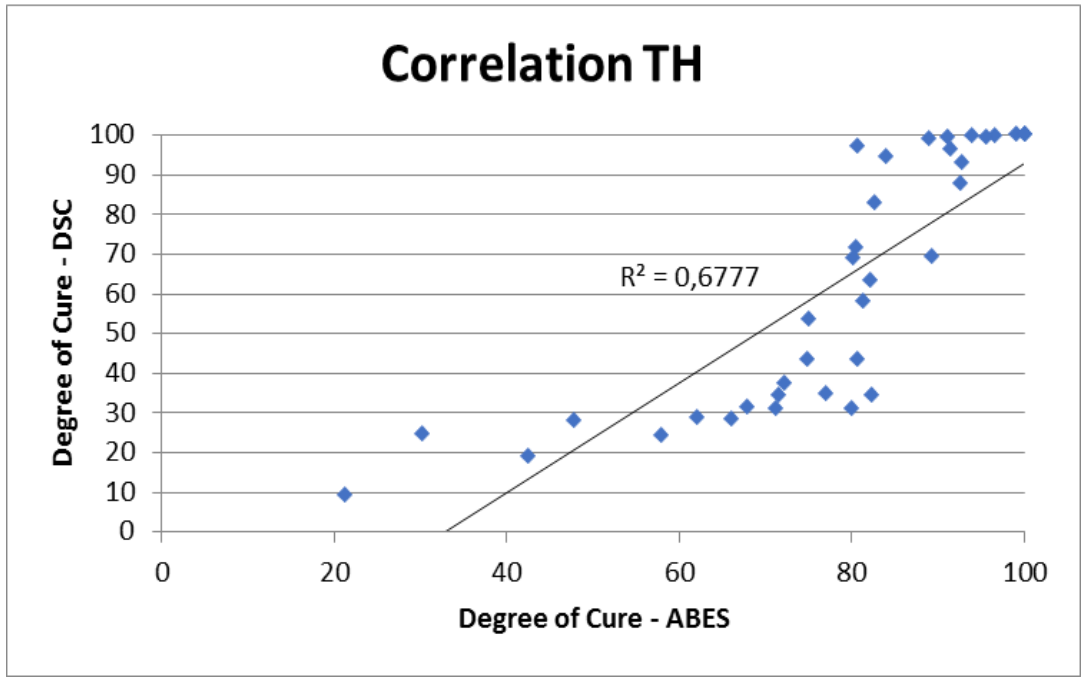

Shear Strength σ (N/mm²)
Time (s)
0
1
2
3
4
5
6
7
0
100
200
300
400
500
600
75°C
100°C
125°C
150°C
175°C

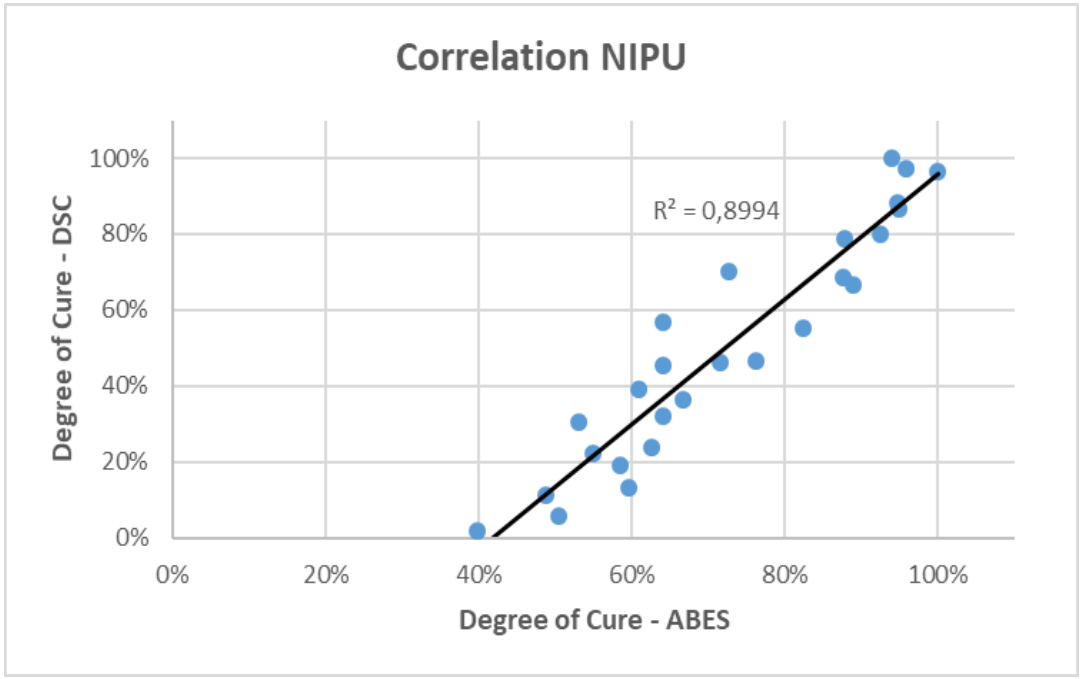
DSC


TH 5 °C/min
TH 10 °C/min
TH 15 °C/min
TH 20 °C/min
1
Wg^-1
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 °C


Degree of Cure (%)
0 10 20 30 40 50 60 70 80 90 100
0 120 240 360 480 600
Time (s)
175 °C
150 °C
125 °C

CORRELATIONS





THANK YOU

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http://www.woodema.org/