Bio-based foams and wood-based composites

Prof. dr. Milan Šernek
University of Ljubljana, Biotechnical Faculty
Department of Wood Science and Technology

Innovations & potential new technologies - the uncharted possibilities of utilizing the European LKWS in the bio-based products

May 9, 2023

Co-funded by the Erasmus+ Programme of the European Union

EDU2
WOOD+ Project

This event has been funded with support from the European Union.
2020-1-CZ01-KA203-078483.

Outline of the presentation

1. **Tannin-based foams from the bark of coniferous species**
2. **Laminated wood-based composites from LKWS**

WoodWisdom-Net

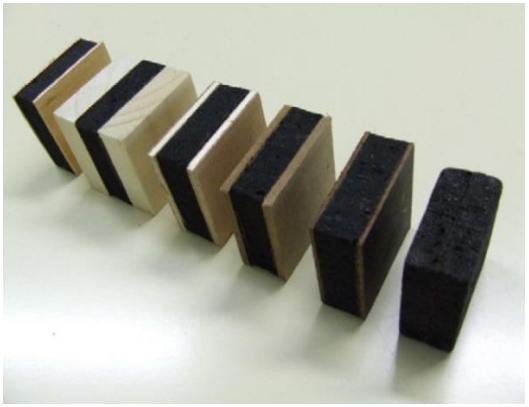
REPUBLIC OF SLOVENIA
MINISTRY OF HIGHER EDUCATION, SCIENCE AND TECHNOLOGY

BIOFOAMBARK
Bark Valorization into Insulating Foams and Bioenergy

Tannin-based foams from the bark of coniferous species

Prof. dr. Milan Šernek
&
Dr. Matjaž Čop
University of Ljubljana, Slovenia

The scope of the project



From hardwood tannin
to softwood tannin !

The objectives of the study

1. To formulate and develop **new bio-based foams** from **softwood tannin**.
2. To **characterize the curing kinetics** of tannin-based foams as influenced by the individual components in the composition.
3. To determine the influence of the individual components on the **physical and mechanical properties** of tannin-based foams.

Materials

Tannin-based foams are networked structures that are obtained by polycondensation of furfuryl alcohol and tannins

Three different types of tannins:

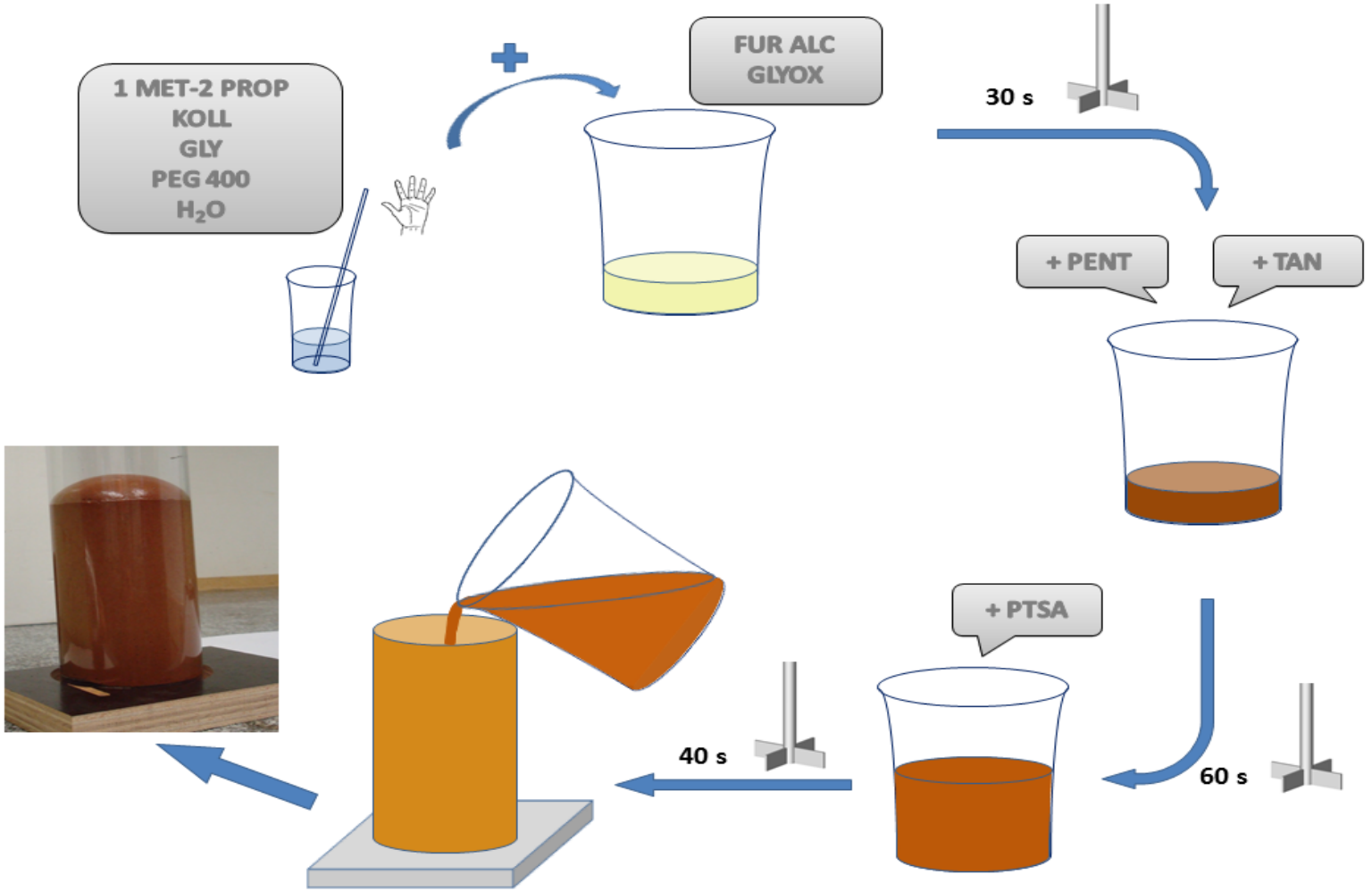
- Maritime pine (Pinus pinaster)
  1. **Pine tannin (PT) (92-94 %)**
- Norway spruce (Picea abies L.)
  2. **Non-purified spruce tannin (NPST) (58 %)**
  3. **Purified (hot water) spruce tannin (PST) (79 %)**

Additives

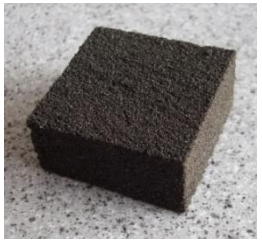
Other reagents:

- Para-toluene sulphonic acid (PTSA), **catalyst**
- Pentane (PENT), **blowing agent**
- Glyoxal (GLYOX), **strengthener/cross-linker**
- 1-methoxy-2-propanol (1-MET-2-PROP), **solvent**
- Water, **solvent**
- Kolliphor ELP (KOLL), **surfactant**
- Glycerol (GLY), **plasticizer**
- Polyethylene glycol (PEG), **plasticizer**

Preparation of the foams



Experimental



TANNIN BASED FOAMS - RESEARCH METHODS

PROPERTIES

MORPHOLOGICAL
- Scanning electron microscopy (SEM)

PHYSICAL/MECHANICAL
- Density
- Compressive strength

RESISTANCE

ABIOTIC DECAY
- Fire

BIOTIC DECAY
- Fungi

CURING

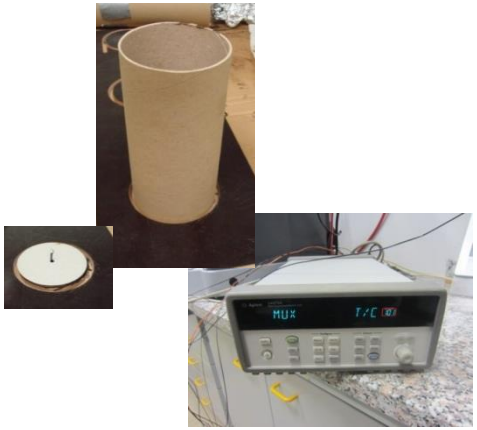
MECHANICAL ASPECT
- Rheometry

ELECTRICAL ASPECT
- Dielectric analysis

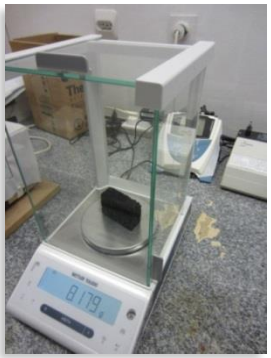
CHEMICAL ASPECT
- Differential scanning calorimetry (DSC)

Foam properties

- Temperature during foam formation



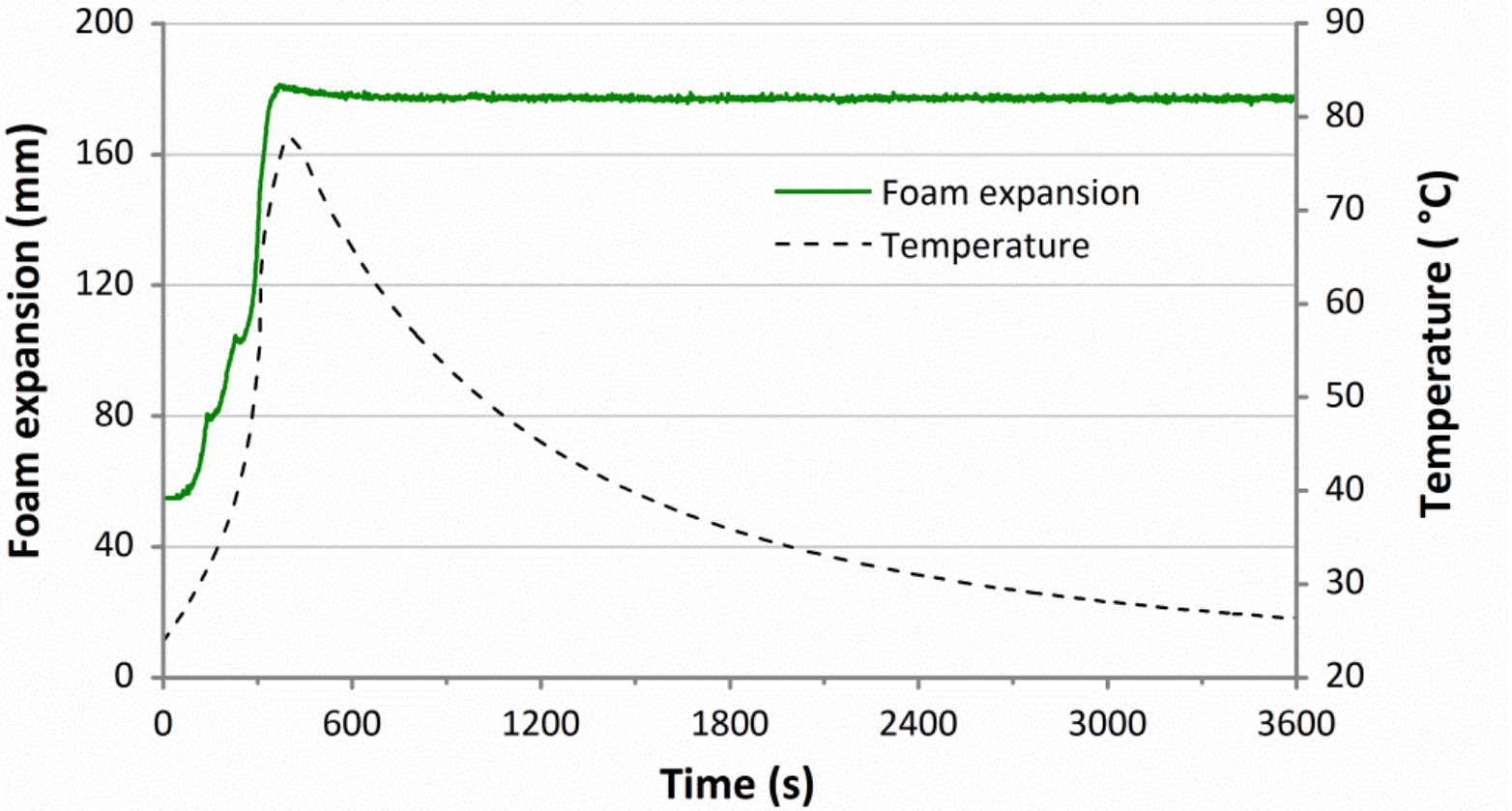
- Density of foam



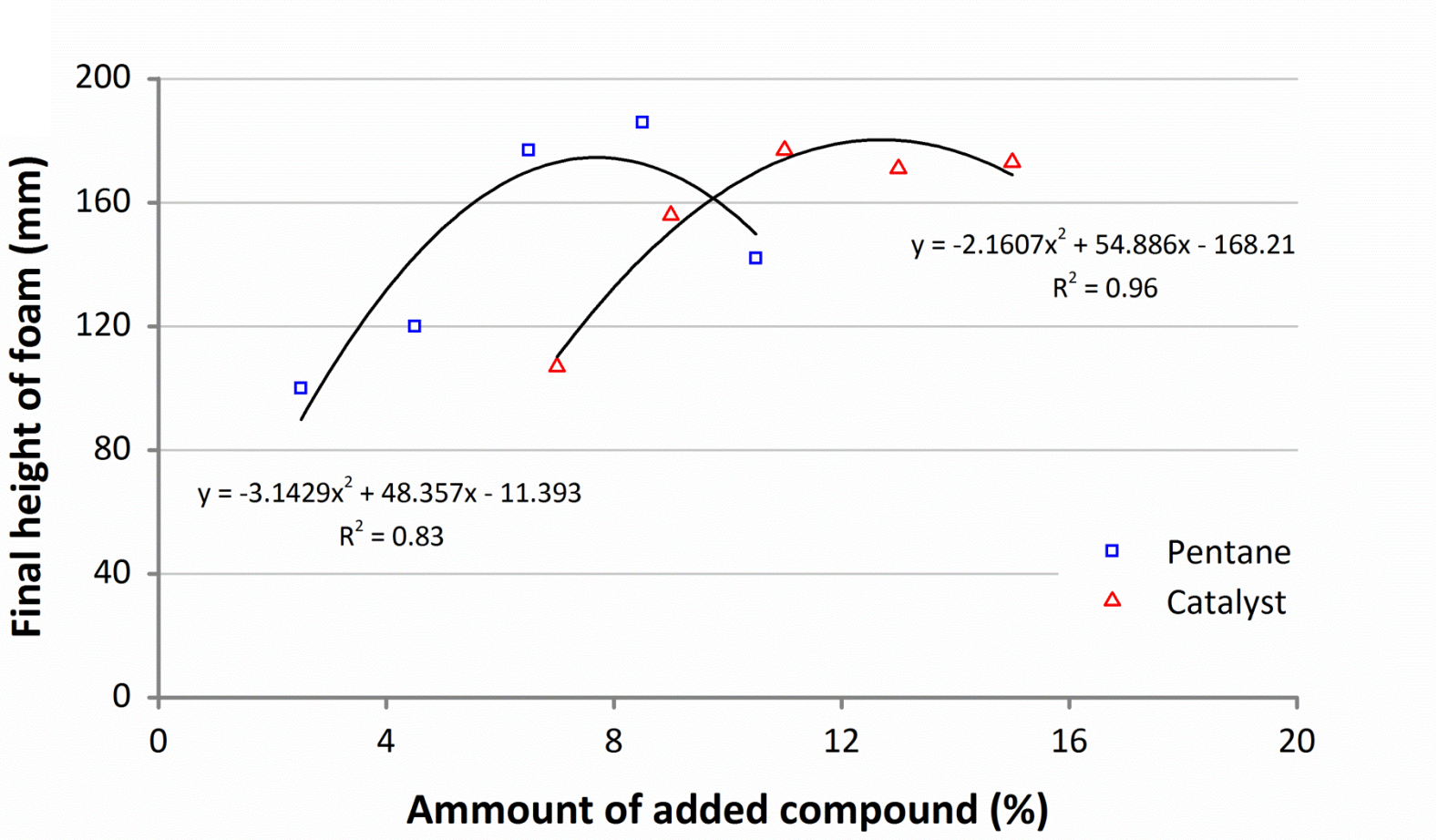
- Morphology (SEM)

- Compression strength

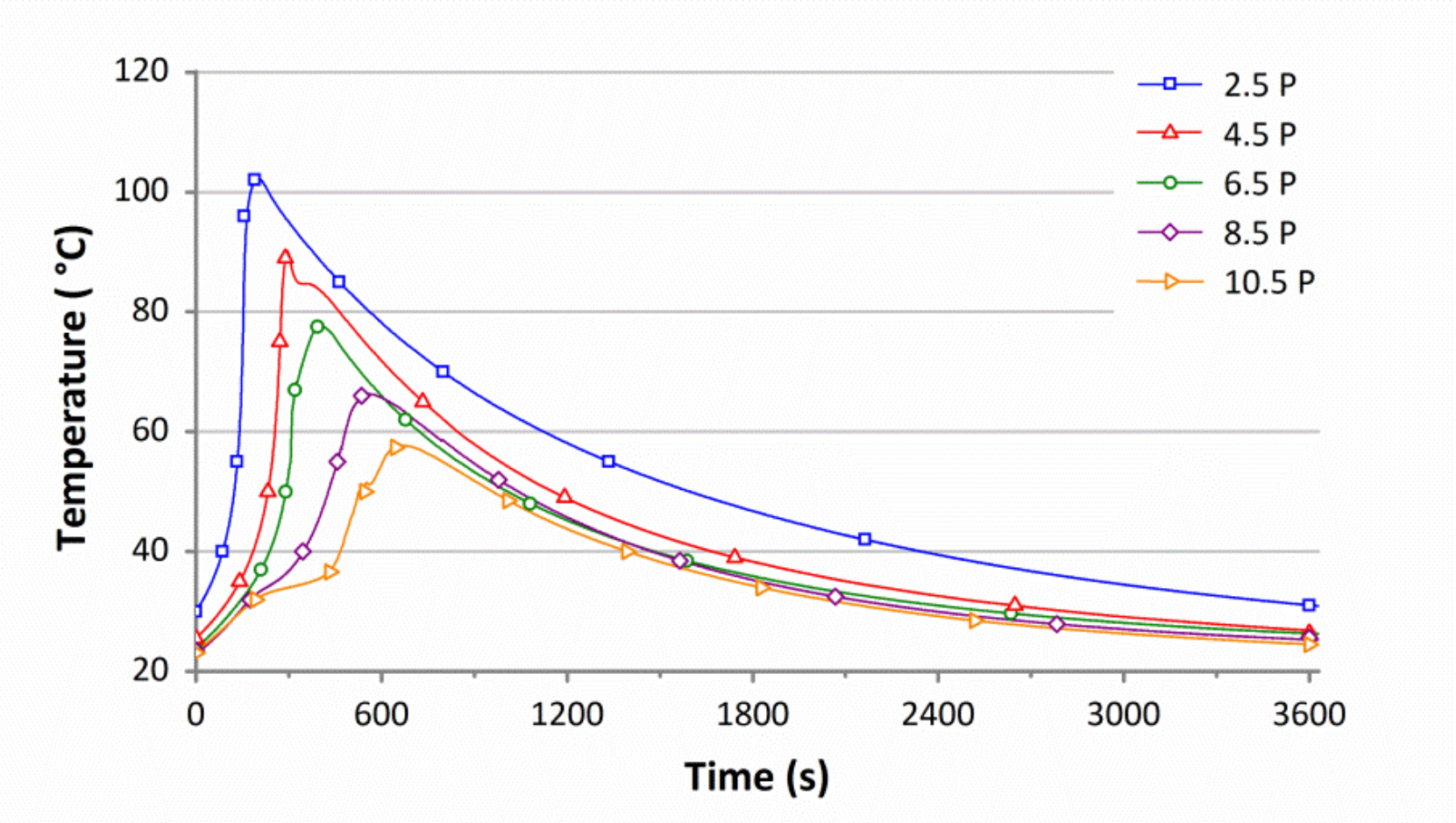
Temperature and foam expansion



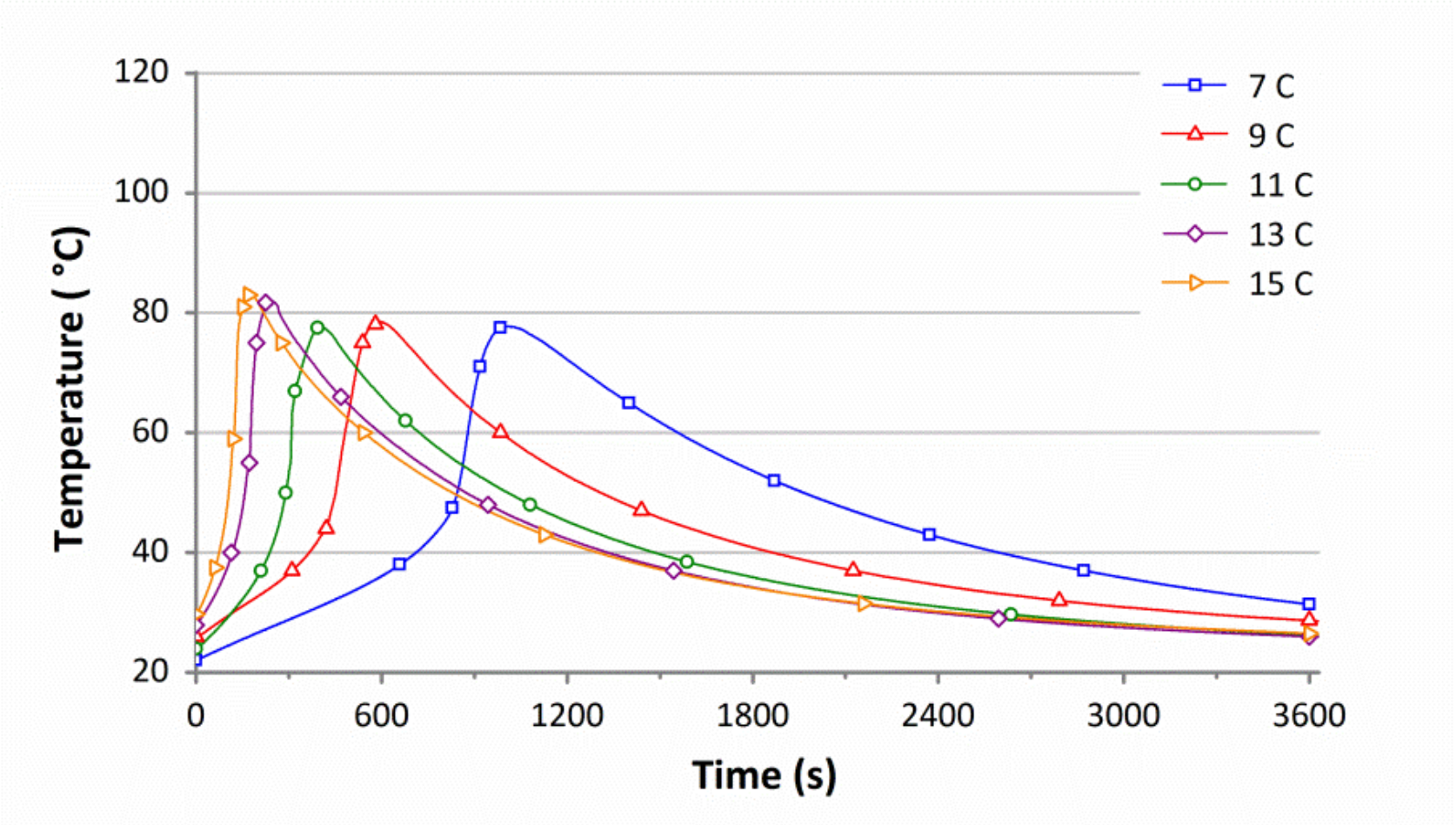
Foam expansion



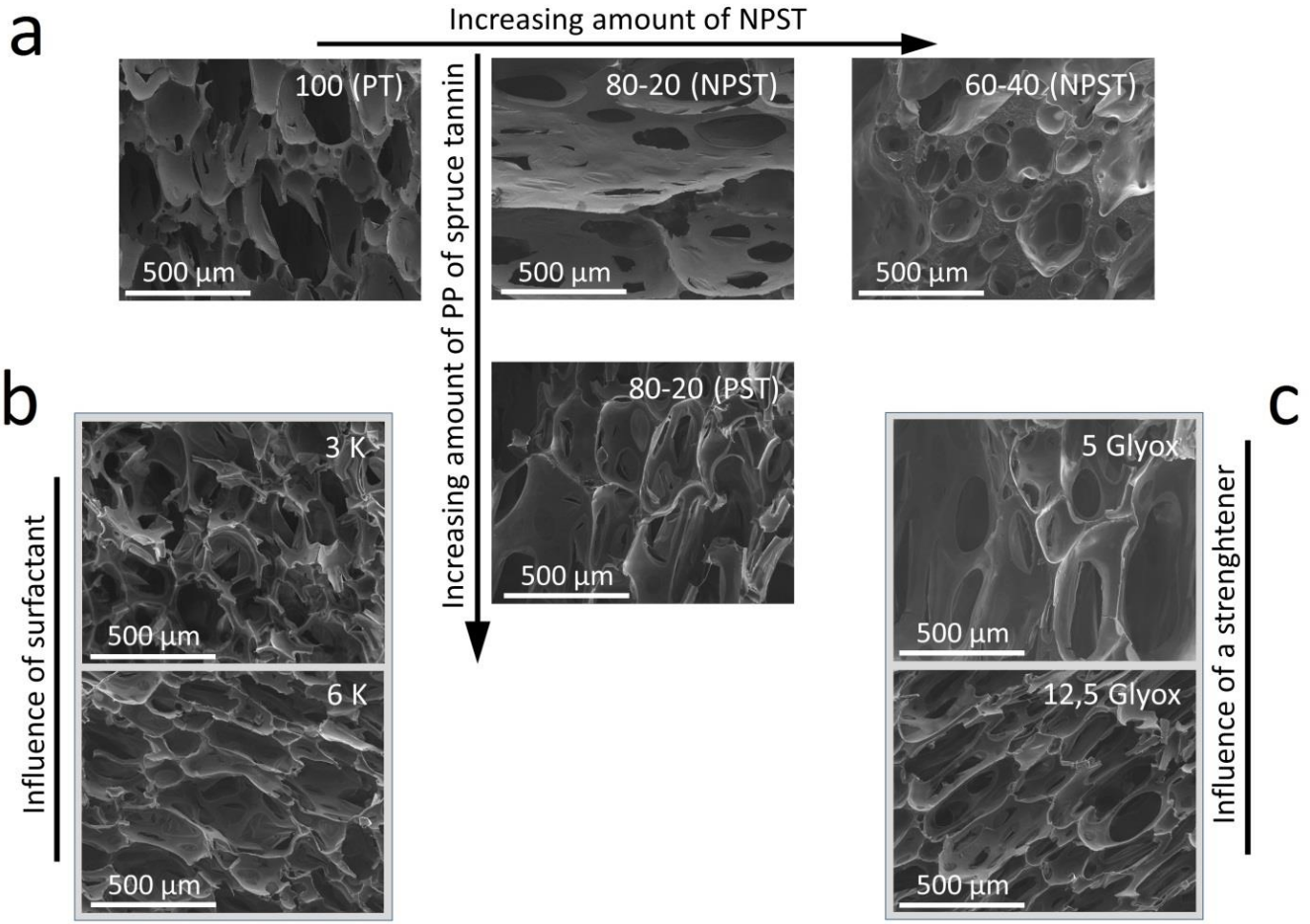
Temperature during foaming- pentane



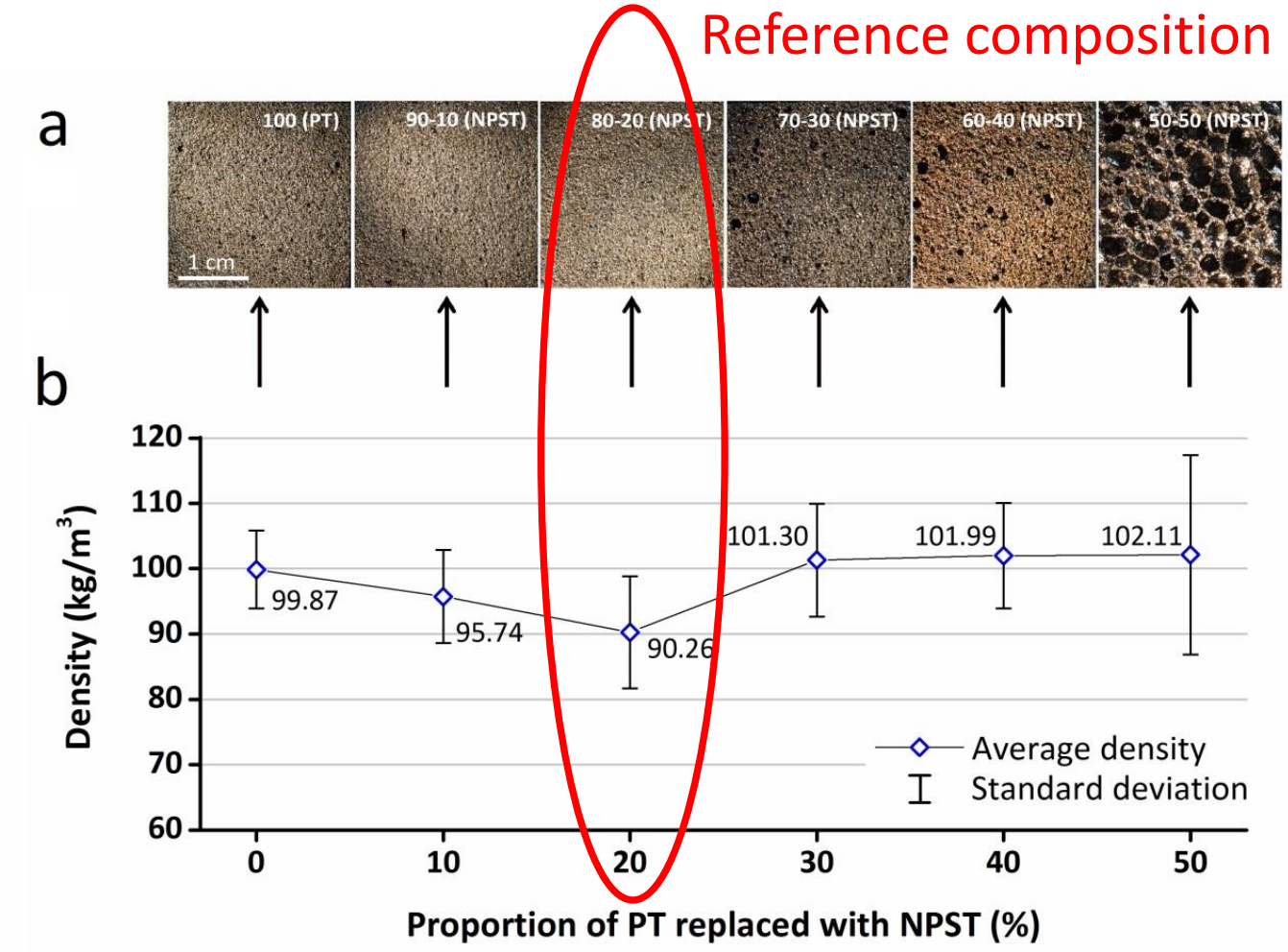
Temperature during foaming-catalyst



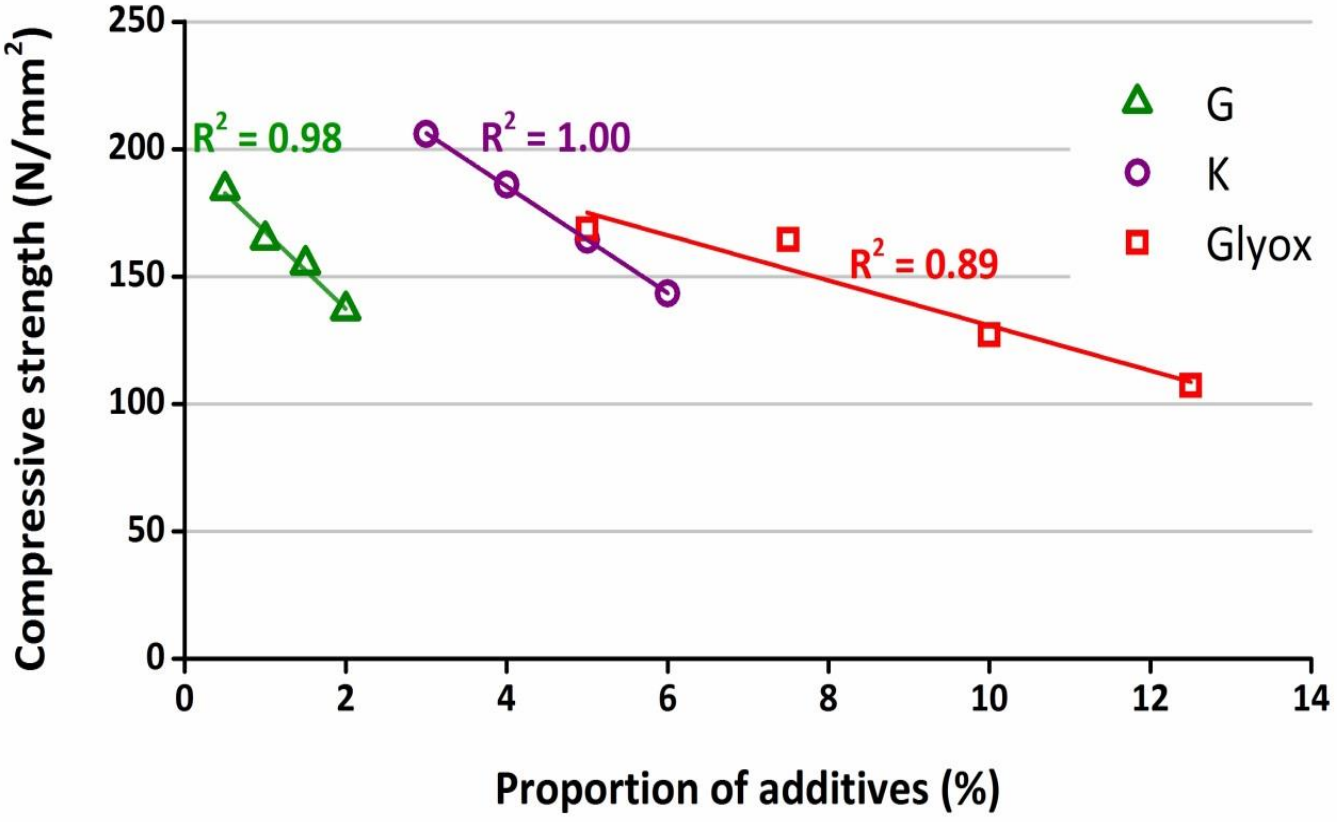
Morphology


a
Increasing amount of NPST
100 (PT)
80-20 (NPST)
60-40 (NPST)
500 µm
Increasing amount of PP of spruce tannin
80-20 (PST)
b
Influence of surfactant
3 K
6 K
c
Influence of a strenghtener
5 Glyox
12,5 Glyox

Density – replacement of PT with NPST

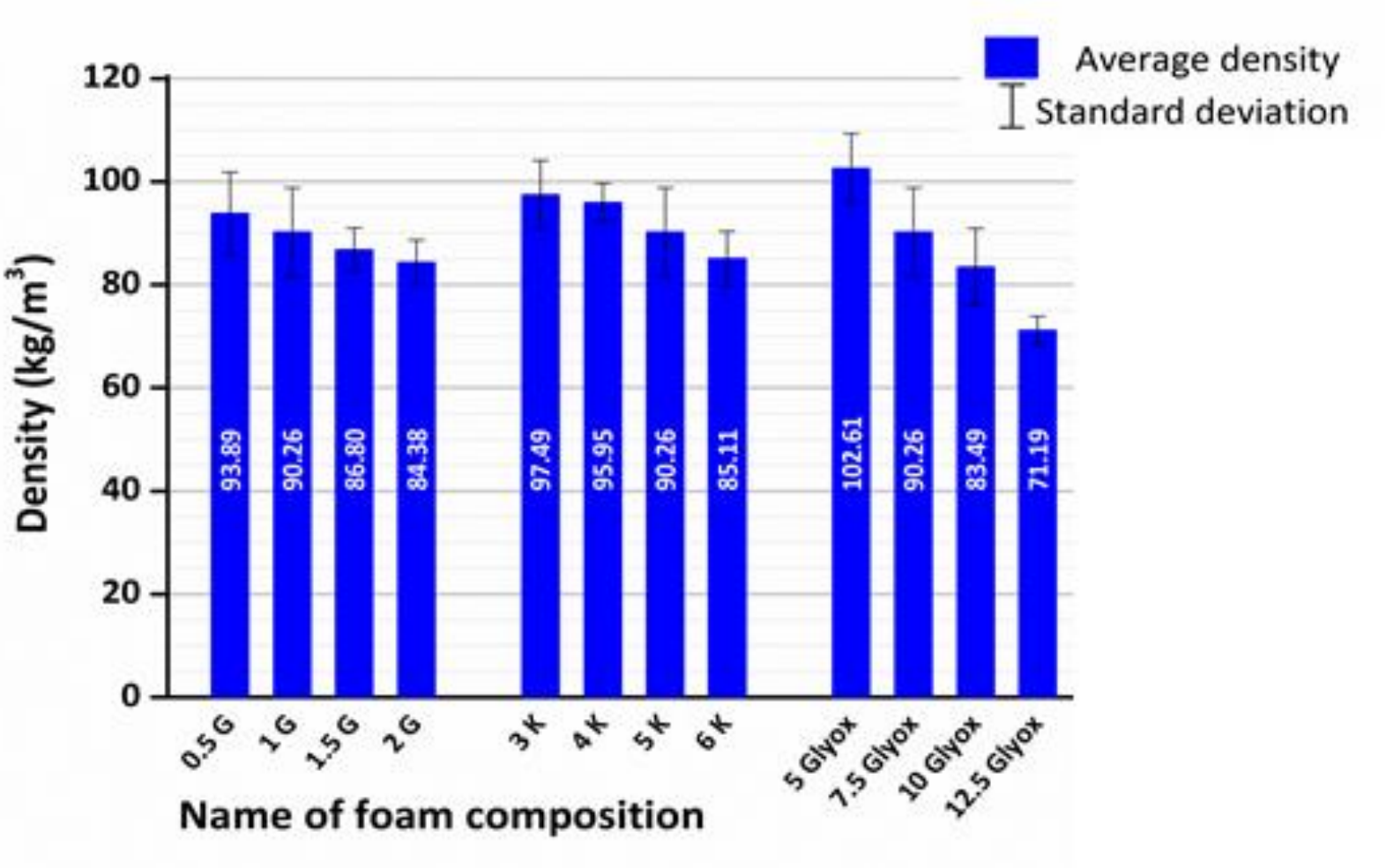


Compression strength



Glycerol, plasticizer
Kolliphor, surfactant
Glyoxal, strengthener

Density of foams



Curing characterization methods

- **DSC**
  (DSC HP-1)

$$\alpha(t)_{DSC} = \frac{\Delta H(t)}{\Delta H_T}$$

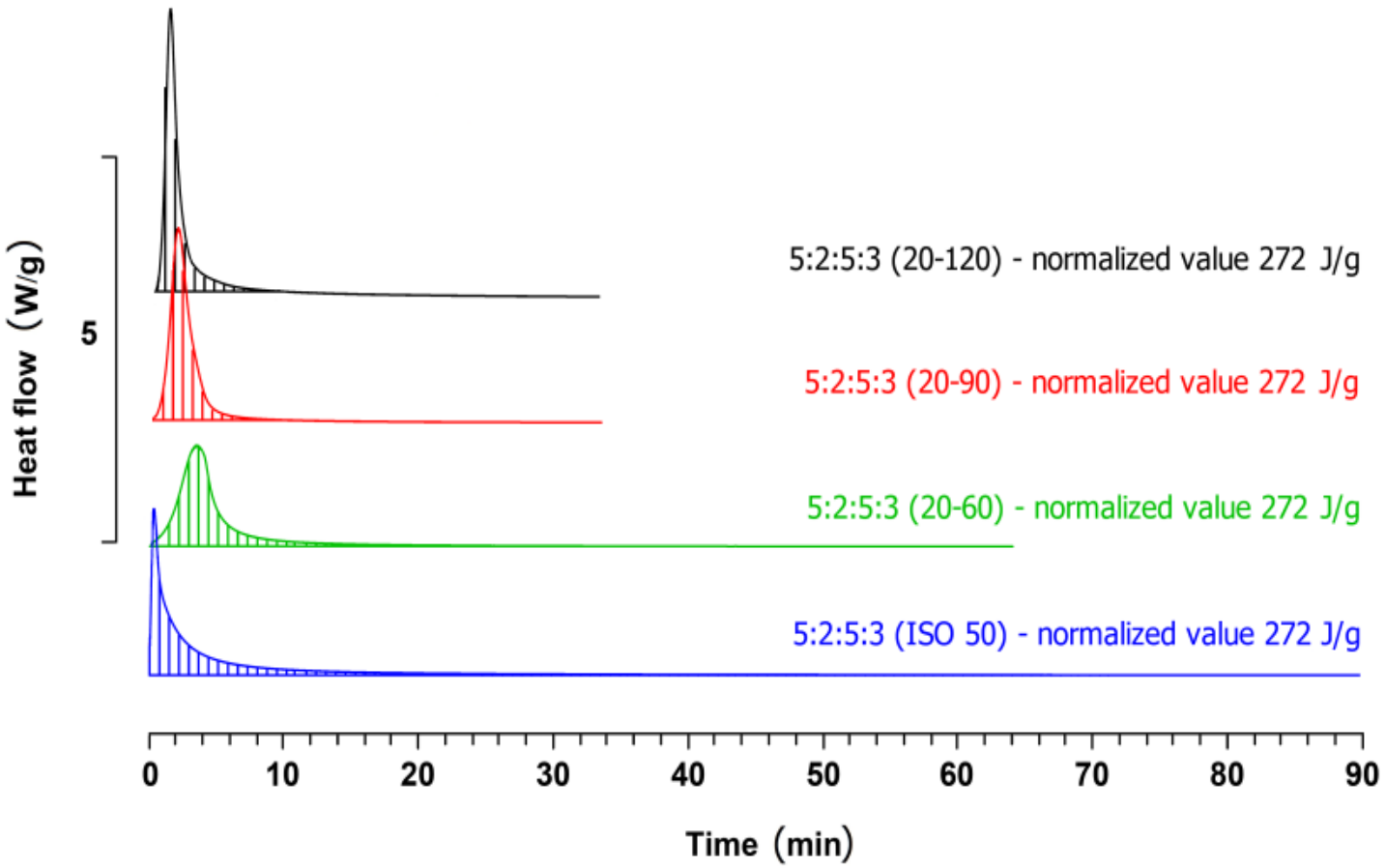
- **DEA + temp. + height**
  (IDEX sensor + thermocouple + US sensor)

$$\alpha(t)_{DEA} = \frac{G_{max} - G_{(t)}}{G_{max} - G_{min}}$$

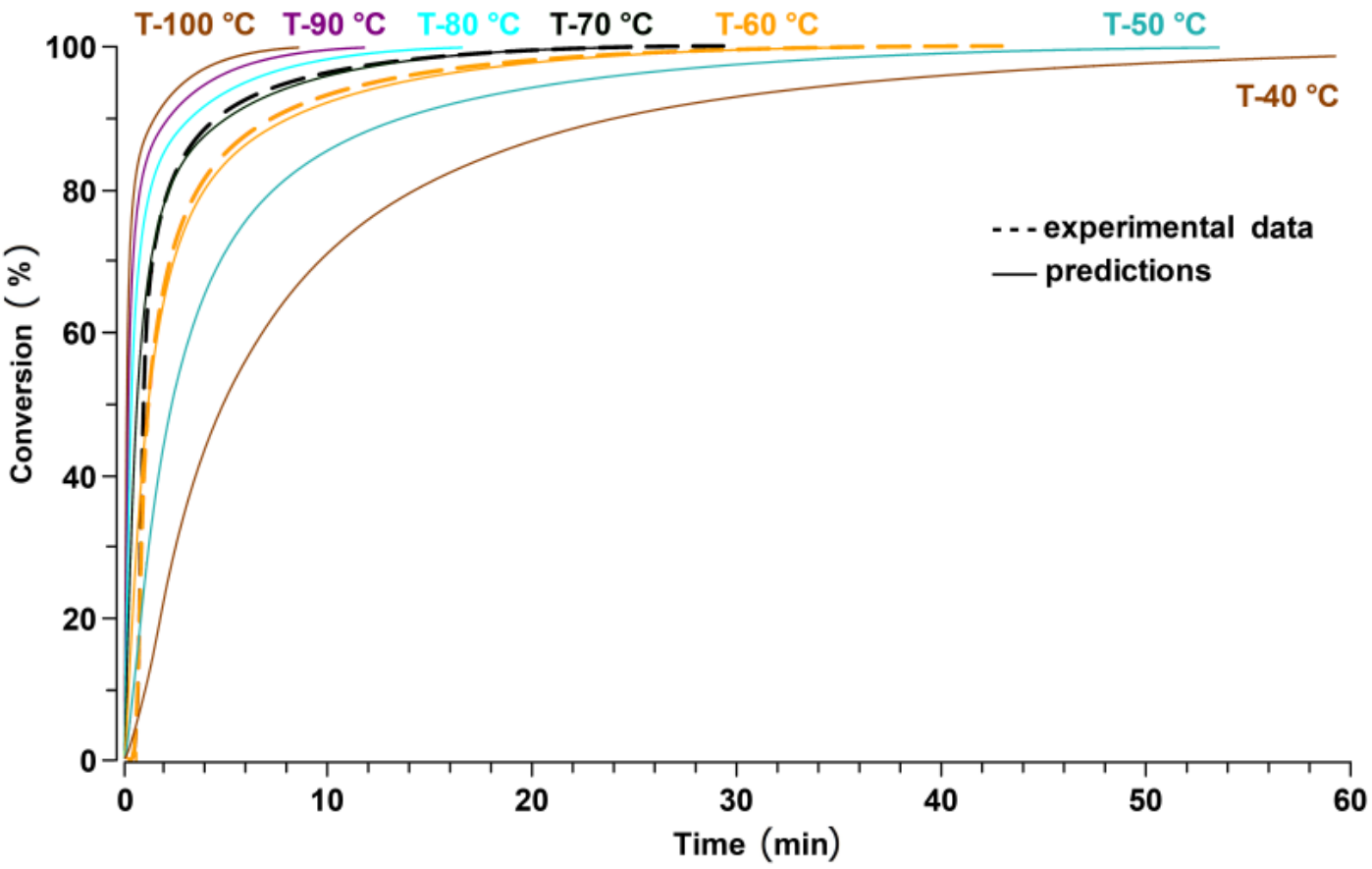
- **RHEOMETRY**
  (Ares G2, wooden discs)

$$\alpha(t)_{REO} = 1 - \frac{G'_{max} - G'(t)}{G'_{max} - G'_{min}}$$

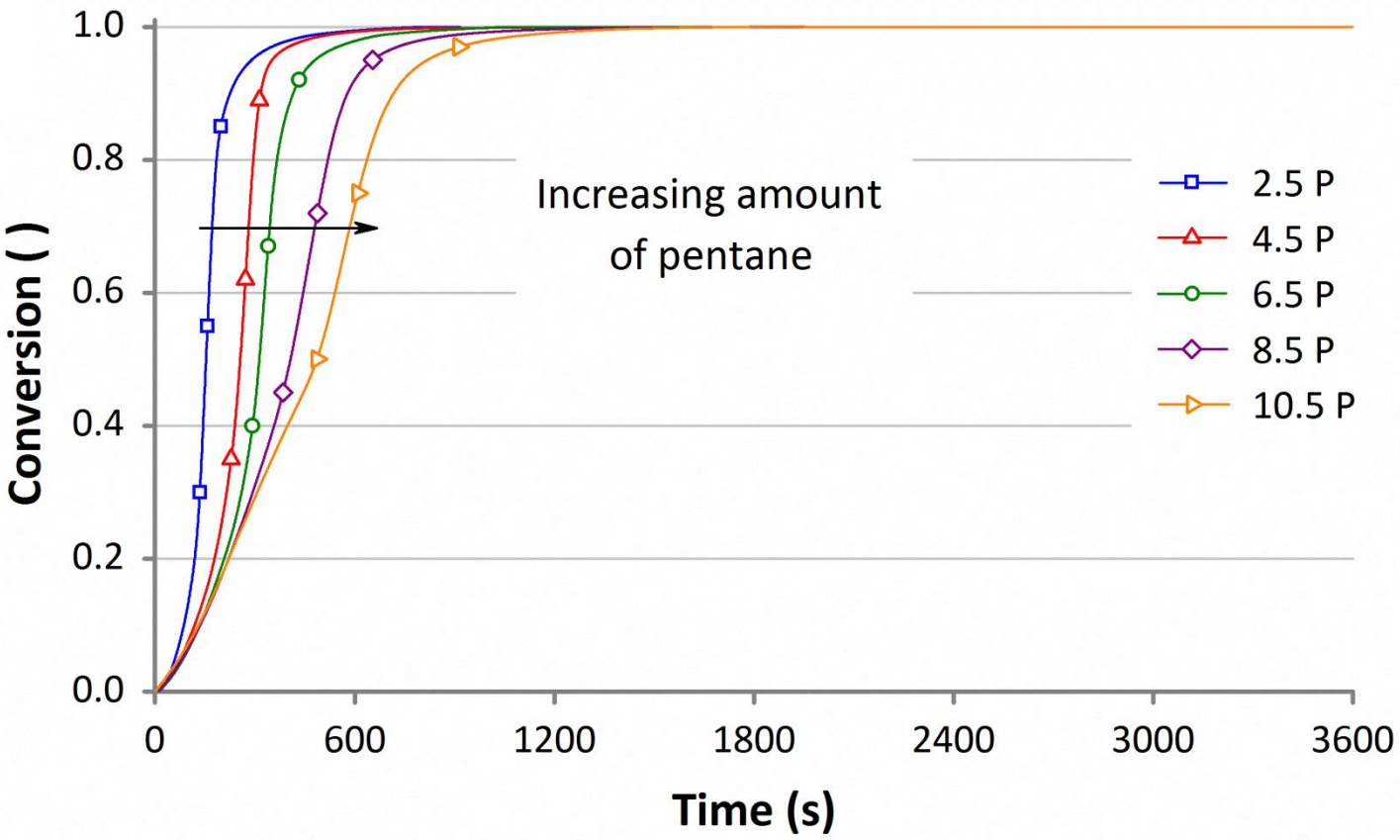
DSC thermograms



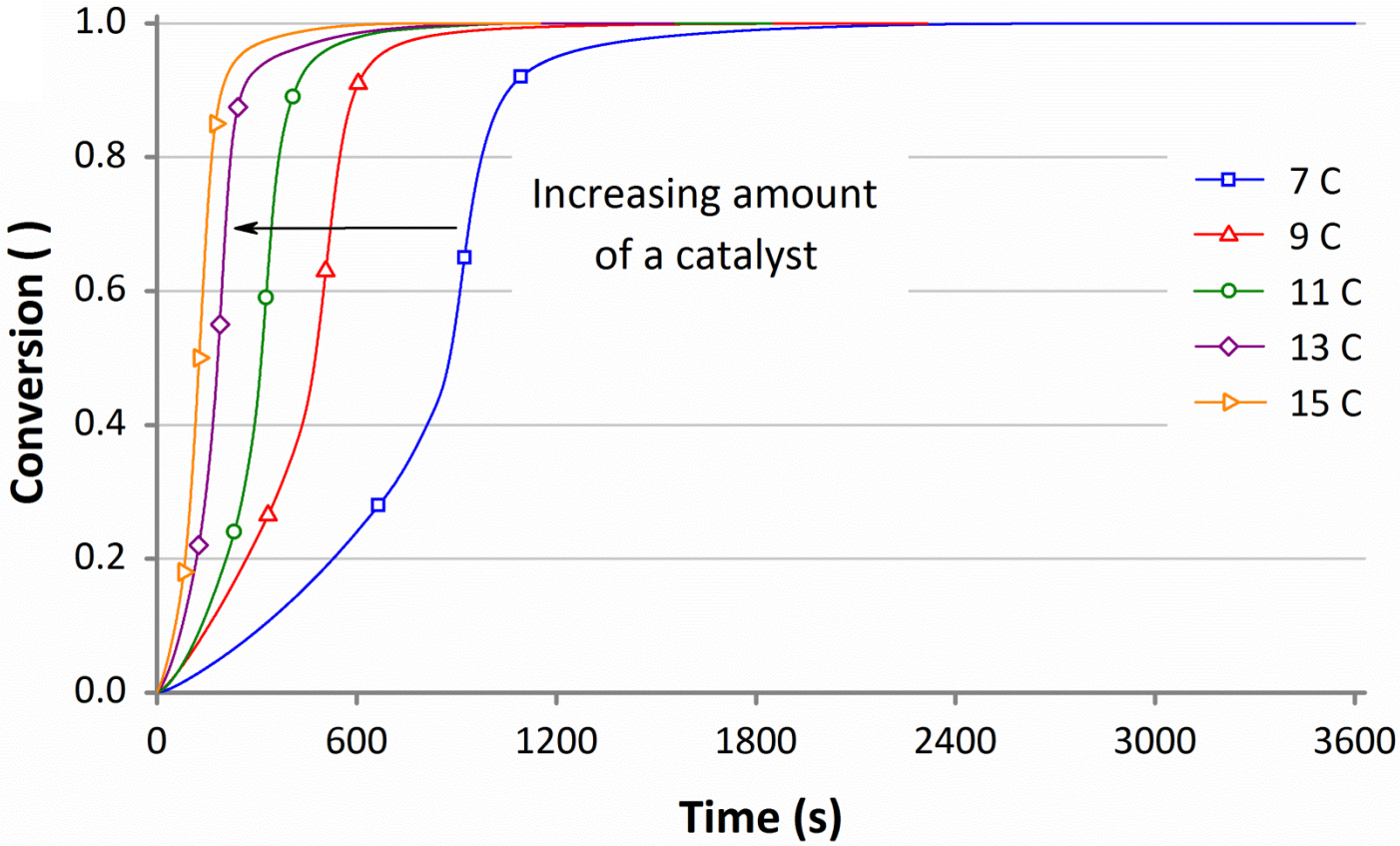
Prediction of conversion by AMFK



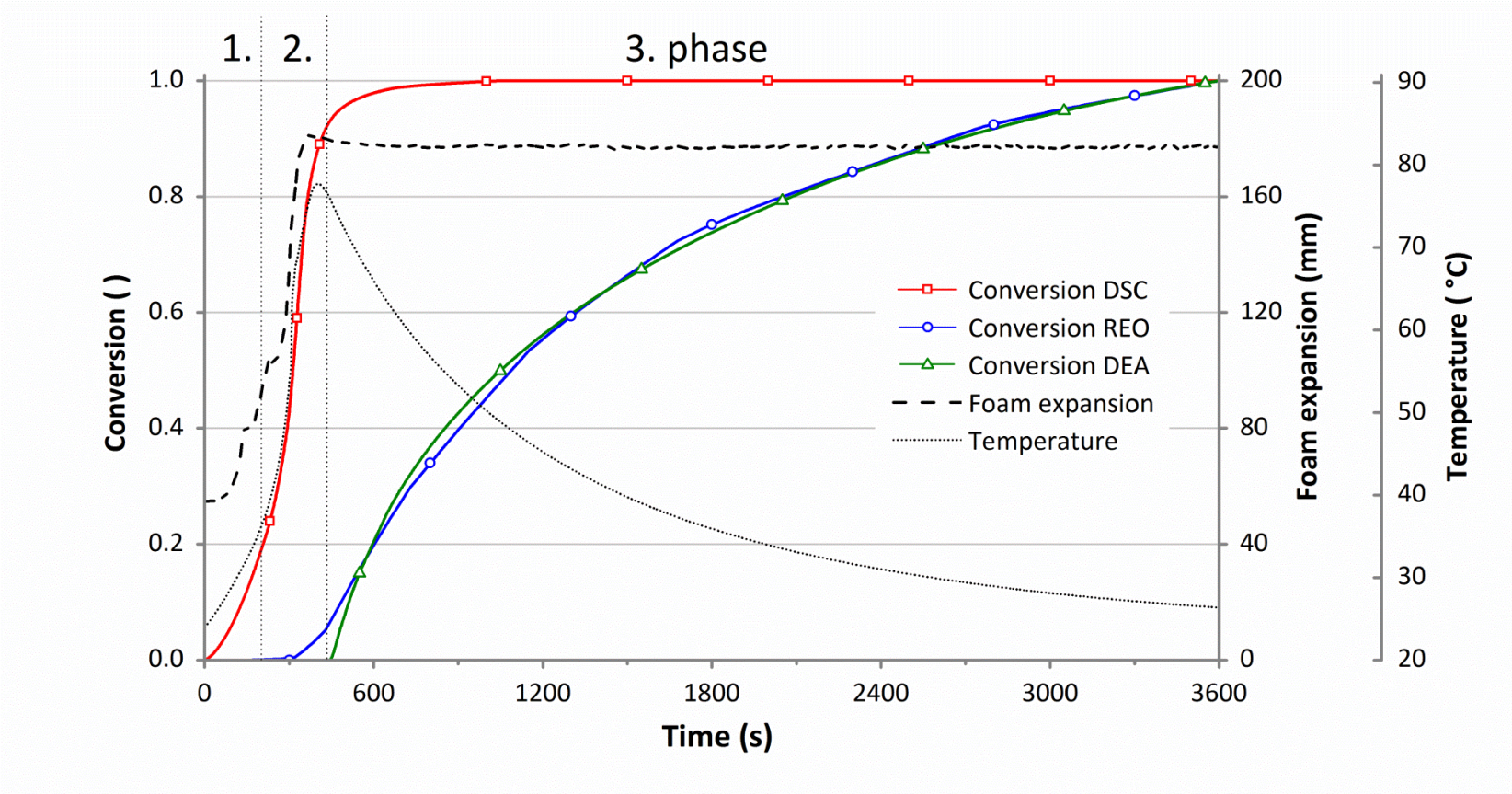
Curing conversions from DSC data – pentane, P



Curing conversions from DSC data – catalyst, C

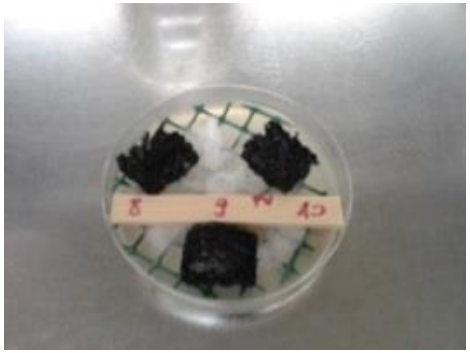


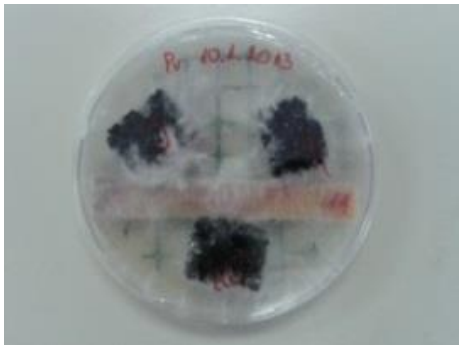
Comparison of conversions



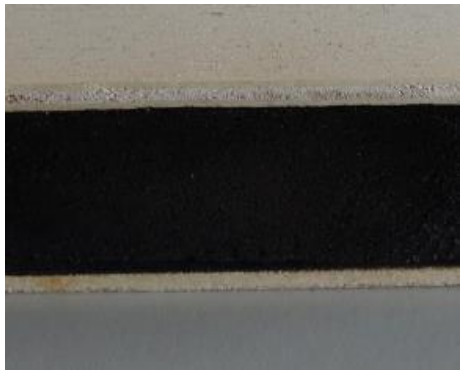
Other studies

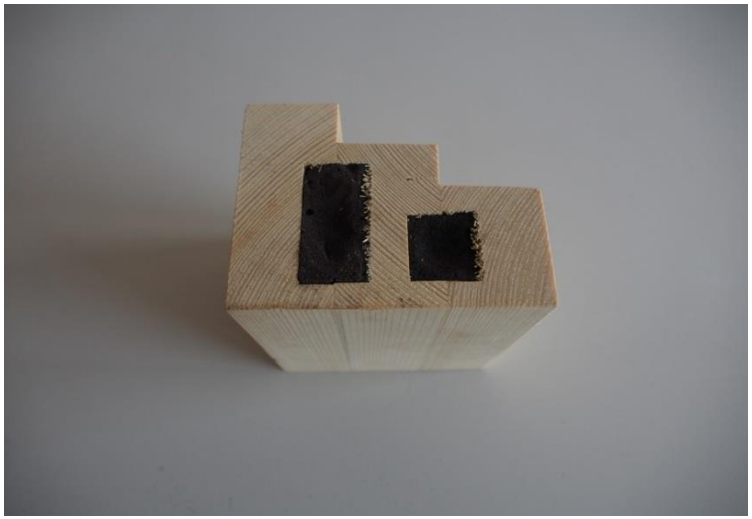
- Thermal conductivity
- Resistance against fire
- Resistance against fungi





Possible applications





Conclusions

1. Spruce and pine tannins are a promising material for the production of tannin-based foams.
2. Morphology, density and compression strength of tannin-based foams are suitable for application.
3. The cure kinetics of tannin-based foams strongly depends on the purity of tannin and it is affected by the amount and type of additives.
4. The foaming process, which comprises three phases: induction, expansion and strengthening phase, needs to be properly balanced for optimal foam properties.

Laminated wood-based composites from LKWS

Prof. dr. Milan Šernek
University of Ljubljana, Biotechnical Faculty
Department of Wood Science and Technology

Innovations & potential new technologies - the uncharted possibilities of utilizing the European LKWS in the bio-based products

May 9, 2023

Co-funded by the Erasmus+ Programme of the European Union

EDU2
WOOD+ Project

This event has been funded with support from the European Union.
2020-1-CZ01-KA203-078483.

Objective

1. **To make a laminated wood-based composite with the highest strength or stiffness in regard to its specific gravity**

- **Project - APPLAUSE**

Materials

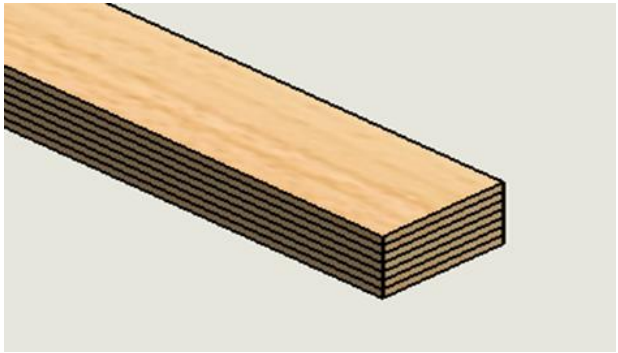
1. **Wood**
   - *Robinia pseudoaccacia* (RP)
   - *Acer negundo* (AN)
   - *Ailanthus altissima* (AA)

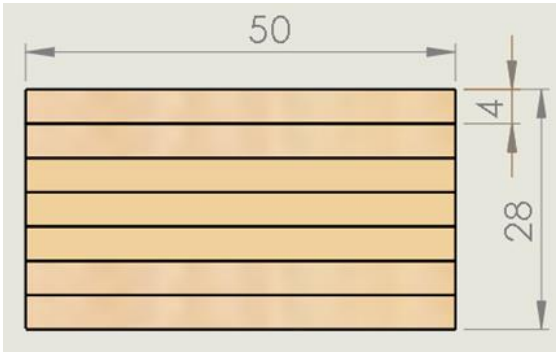
   - *Picea abies* (PA)
   - *Fagus sylvatica* (FS)

2. **Adhesives**
   - Mitopur E45 (PU)

Structure of the composites

- **Laminated composites**
  - Small beams

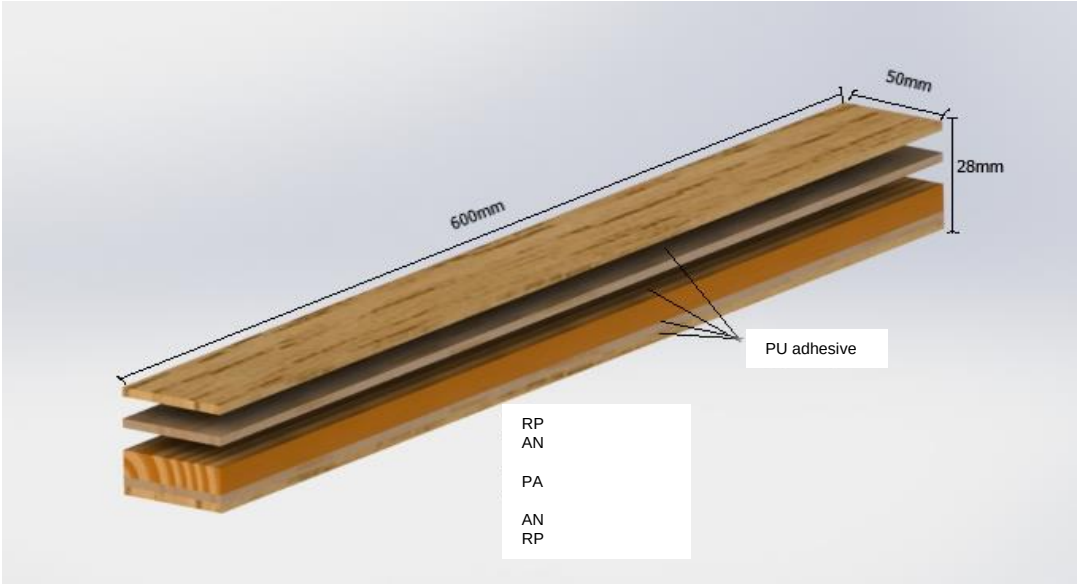




- **Three different structures**

Adhesive bonding

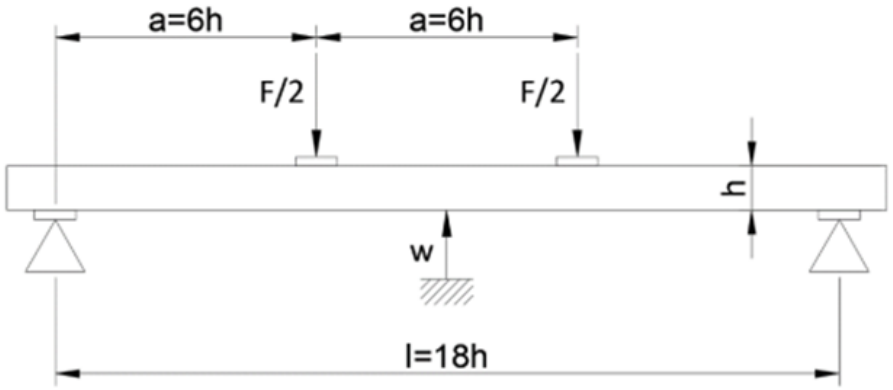
- Pressing parameters
  - 250 g/m^2
  - 20 °C
  - 8 bar
  - 60 min



Bonded samples

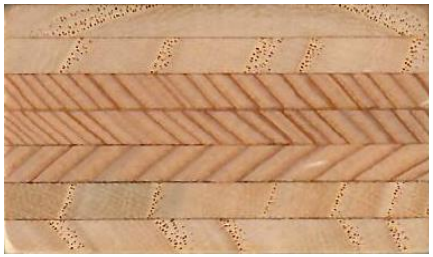
Testing- EN 408:2004

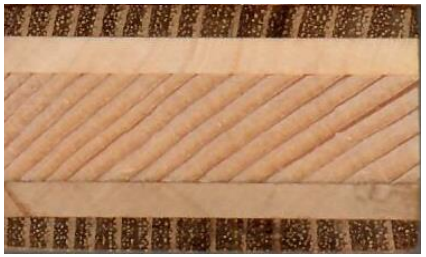
- **Bending strength and modulus of elasticity**
  - 4-point bending test

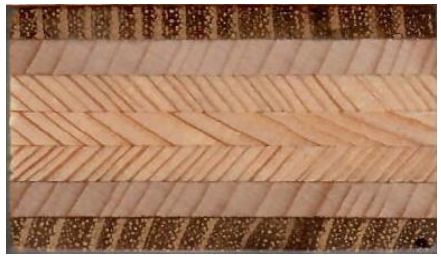


Results

SG	0,55	0,60	0,63
MOR	7,00	12,50	15,00
MOR/SG	12,73	20,83	23,81
MOE	80,00	90,00	100,00
MOE/SG	145,45	150,00	158,73







E_m	7,0 GPa	12,5 GPa	15,0 GPa
f_m	80 MPa	90 MPa	100 MPa
ρ	550 kg/m^3	600 kg/m^3	630 kg/m^3

Conclusions

- Size limitations to make laminated composites from LUWS.
- E_m and f_m of composites are related to density.
- Engineering principles …