

# HARDWOOD-BASED COMPOSITES WITH FLEXIBLE POLYURETHANE ADHESIVE JOINTS



**JUNE 15-20,  
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**FORT COLLINS,  
COLORADO**

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InnoRenew CoE

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# • WHY HARDWOOD-BASED COMPOSITES ?

Mld PLN

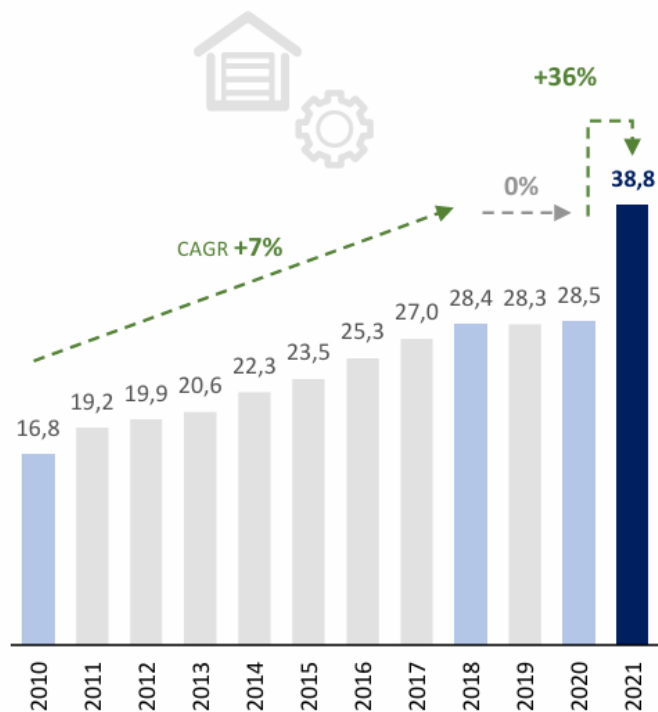


Figure 1: Value of sold production of the wood industry, 2010-2021 Poland [1]

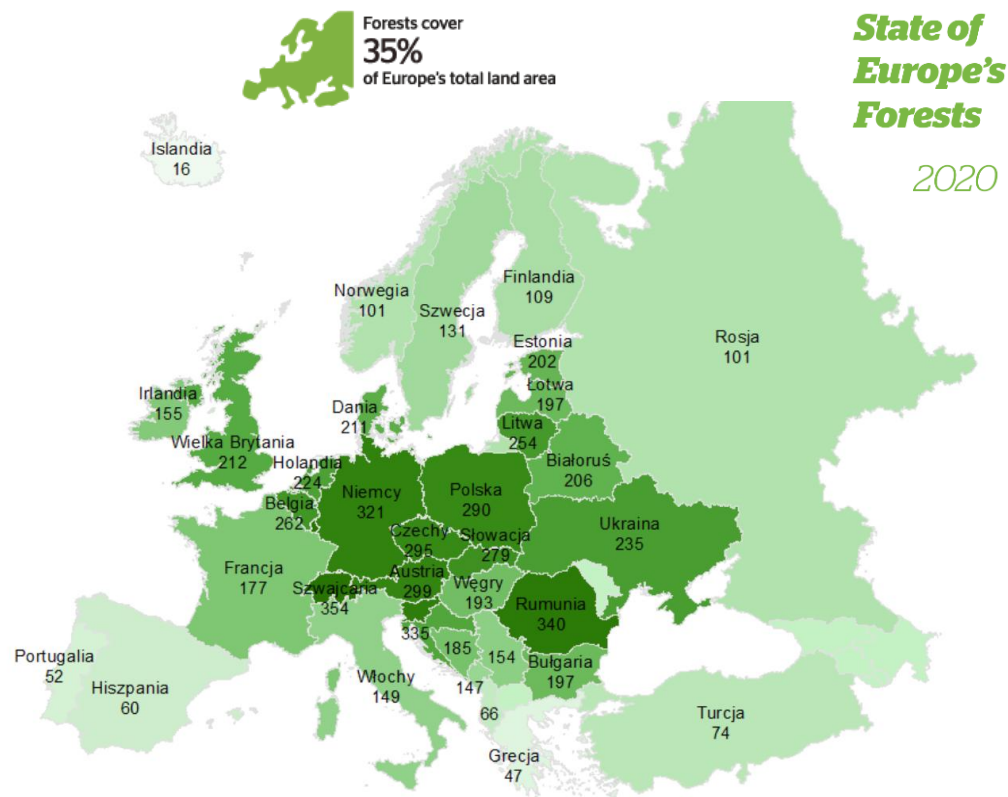


Figure 2: Average amount of forest m³/h [2]

In Europe, almost 50% of forests are covered with hardwood species.

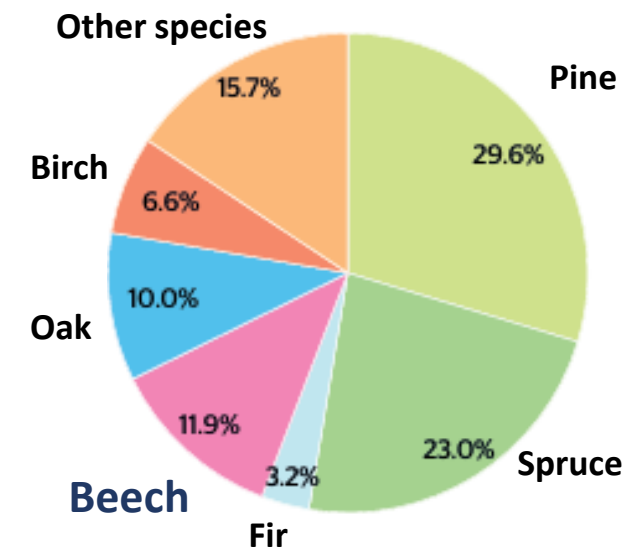
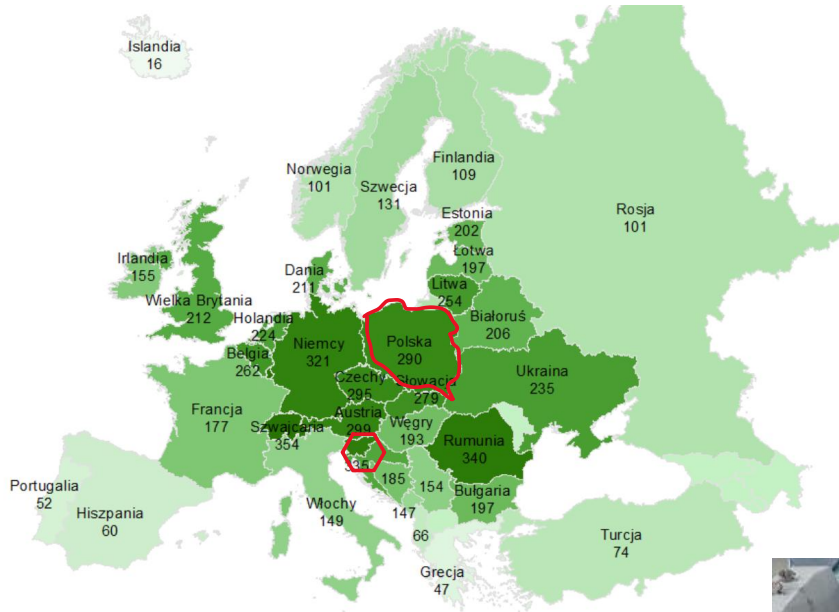


Figure 3: Europe's growing stock by main tree species, 2020 [2]

[1] GUS, Analizy Pekao

[2] [https://foresteurope.org/wp-content/uploads/2016/08/SoEF\\_2020.pdf](https://foresteurope.org/wp-content/uploads/2016/08/SoEF_2020.pdf)

## • WHY HARDWOOD-BASED COMPOSITES ?



Two countries: Poland and Slovenia

Four research institutes:

- Slovenian National Building and Civil Engineering Institute
- InnoRenew CoE
- AGH University of Science and Technology
- Cracow University of Technology



ZAVOD ZA  
GRADNENIŠTVO  
SLOVENIJE

SLOVENIAN  
NATIONAL BUILDING  
AND CIVIL ENGINEERING  
INSTITUTE



Cracow University  
of Technology

**Beech wood** – based composites with flexible polyurethane adhesive joints.



**DIAgnostics and Mechanical tests Of aged adhesive layers used in joiNts of wooDen structureS**



**N** NARODOWE CENTRUM NAUKI

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Figure 4: Hardwood-Based Composites with flexible polyurethane adhesive joints

## THE DIAMONDS PROJECT



- Characterize and study flexible types of adhesives (FPUR).
- Explore the use of flexible adhesives in beech composites over time.
- Understand and describe adhesive, wood-adhesive joints durability.
- Expand testing of commercial PUR.
- **Adhesives:** join objectives, transfer loads, use in composites, engineered wood products...
- **1C PUR:** easy to use: cure at room temperature - no need for expensive heating presses, highest adaptability of PUR chemistry, formaldehyde-free...
- **FPUR** - a wide range of flexibility, repairing masonry buildings reinforcements in seismic areas.



Figure 5: Diamonds project team - working meeting in Izola

**PUFJ** – PolyUrethane Flexible Joints  
innovative solution for high loads and high deformations



2016 - FlexAndRobust Systems company is a spin – off company set by scientists from Cracow University of Technology

- ➔ repairing masonry buildings
- ➔ reinforcement of structural elements
- ➔ structure security systems for earthquake areas



# INNOVATIVE FLEXIBLE BONDING SOLUTION PUFJ

## New flexible polyurethane adhesive:

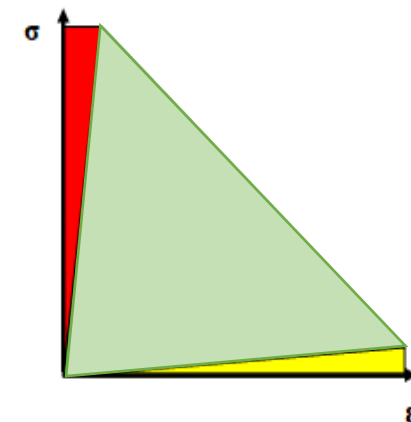
- blocks the transfer of moisture and thermally insulates from the ground
- enables quick assembly and direct connection of elements made of various materials
- ensures tightness of connections along their entire length
- ensures stability of deformation properties under cyclic loads

JOINTS IN STRUCTURAL ELEMENTS  
MADE OF BRITTLE MATERIALS

STIFF JOINTS

POLYMER FLEXIBLE JOINTS

SEALANTS

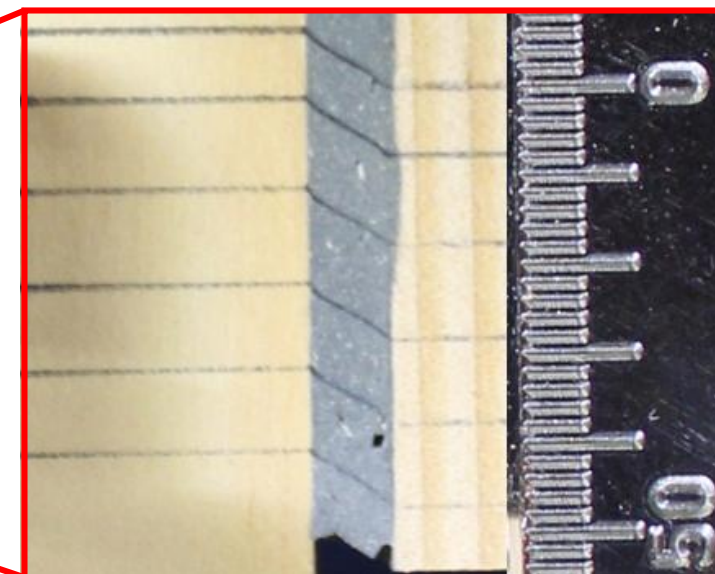
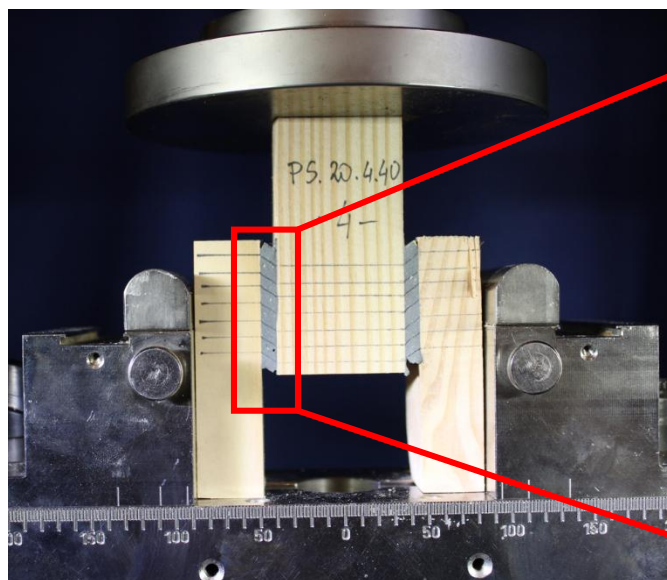


## PolyUrethane Flexible Joints

transfer high loads  
and high deformations  
simultaneously

| Material samples | Thermal conductivity coefficient $\lambda$ [W/(mK)] |
|------------------|---|
| Wood             | 0,1157  |
| PM polymer       | 0,1013  |

author's archive



# PUFJ (POLYURETHANE FLEXIBLE JOINTS)

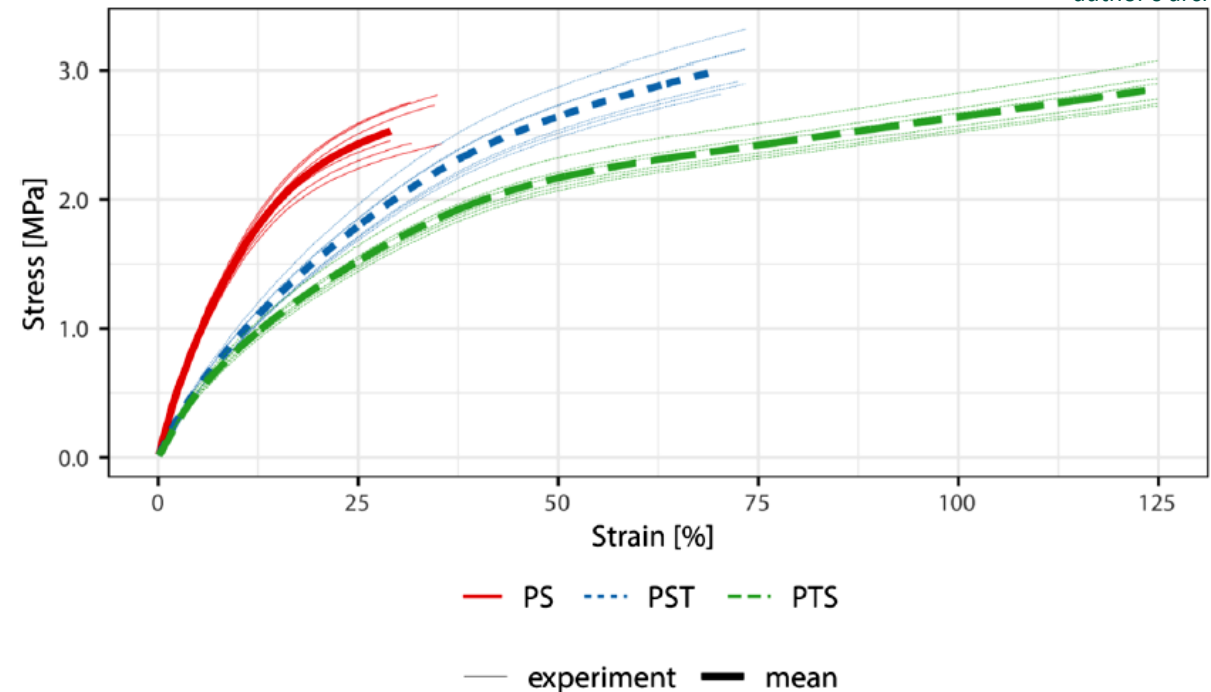
7 flexible polyurethane adhesives of various visco-elasto-plastic properties:

- Young modulus 1-700 MPa,
- ultimate elongation 10-600%
- tensile strength 1-25 MPa



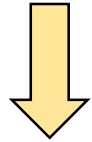
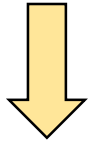
author's archive

| Adhesive types | Young modulus $E_R$ [MPa] | Ultimate elongation $\epsilon_{max}$ [%] | Tensile strength $R_R$ [MPa] | Shore'a A hardness [°] |
|----------------|---------------------------|--|------------------------------|------------------------|
| PT             | 700                       | 10                                       | 25                           | 98                     |
| PSTF           | 20                        | 35                                       | 4,3                          | 85                     |
| PS             | 20                        | 30                                       | 2,6                          | 80                     |
| PST            | 15                        | 65                                       | 3,0                          | 75                     |
| PTS            | 12                        | 120                                      | 2,9                          | 70                     |
| PM             | 4                         | 110                                      | 1,4                          | 55                     |
| PBM            | 1                         | 600                                      | 0,7                          | 35                     |



# PUFJ (POLYURETHANE FLEXIBLE JOINTS)

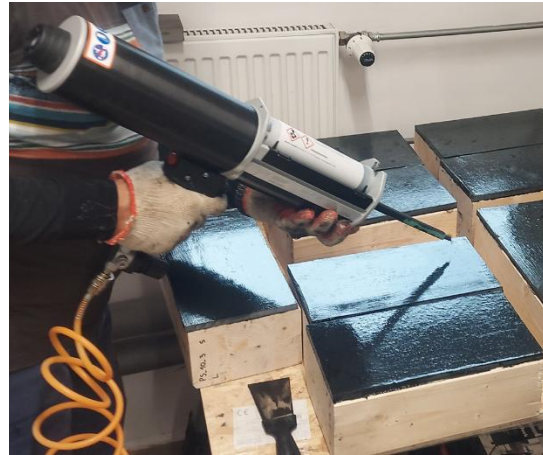
APPLICATION METHODS



INJECTION

PREFABRICATION

Thickness from 1 to 30mm



## FACTORS OF AGEING

- The main factors that influence a high bondline performance throughout the service life of glued products includes:
  - environmental conditions:** temperature, moisture
  - material:** adherent-adhesive interaction
  - type of loading – creep.**



Figure 6: Natural weathering test site – Poland/Cracow



Figure 7: Natural weathering test site – Slovenia/Izola

## TESTS: LAP SHEAR JOINT

NW period:

- 4 M (May-Sep)
- 8 M (Dec 2025)
- 12 M (May 2025)
- A1 Reference
- FPUR: PS, PTS, PST

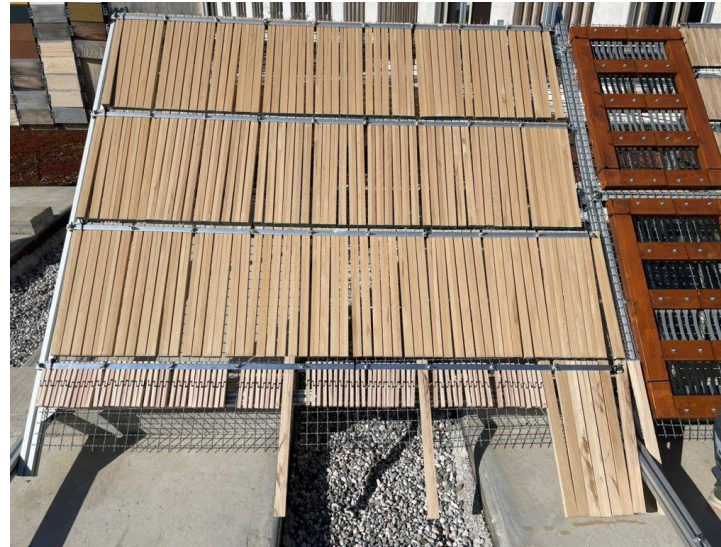


Figure 7: Test stand Izola - start

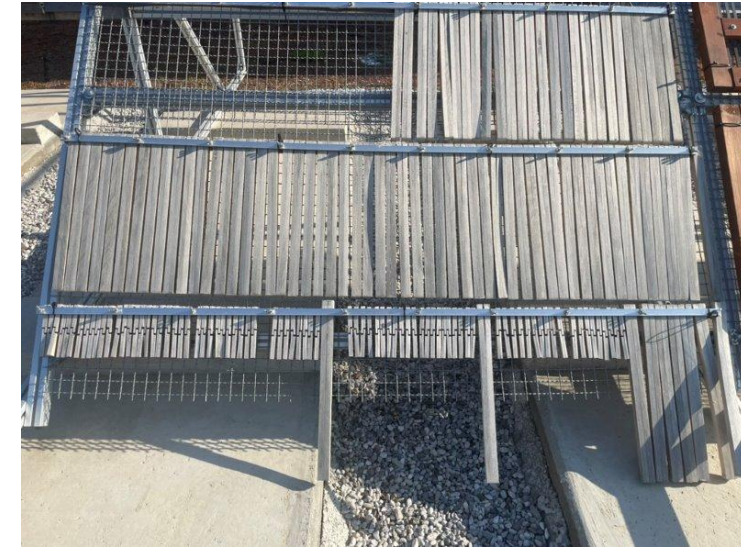


Figure 8: Test stand -after 4M



Figure 9: Test stand Cracow - start

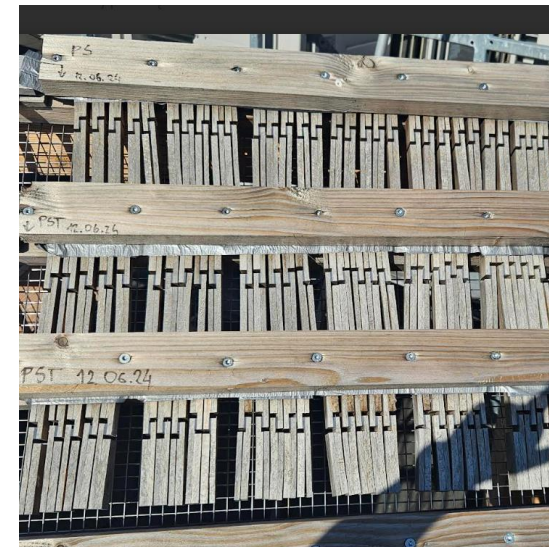


Figure 10: Test stand -after 4M

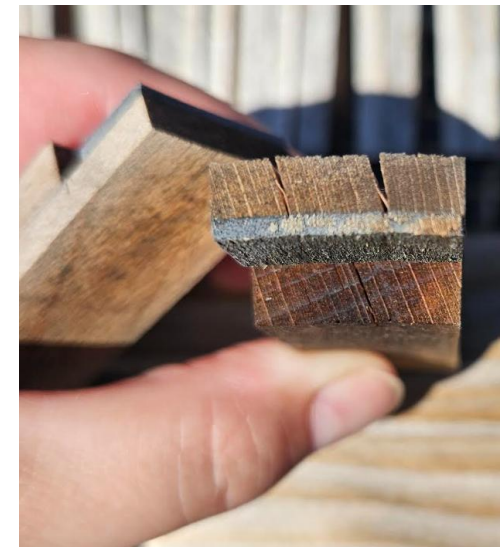


Figure 11: Sample destruction

## LAP SHEAR TESTS: REF, NW 4M

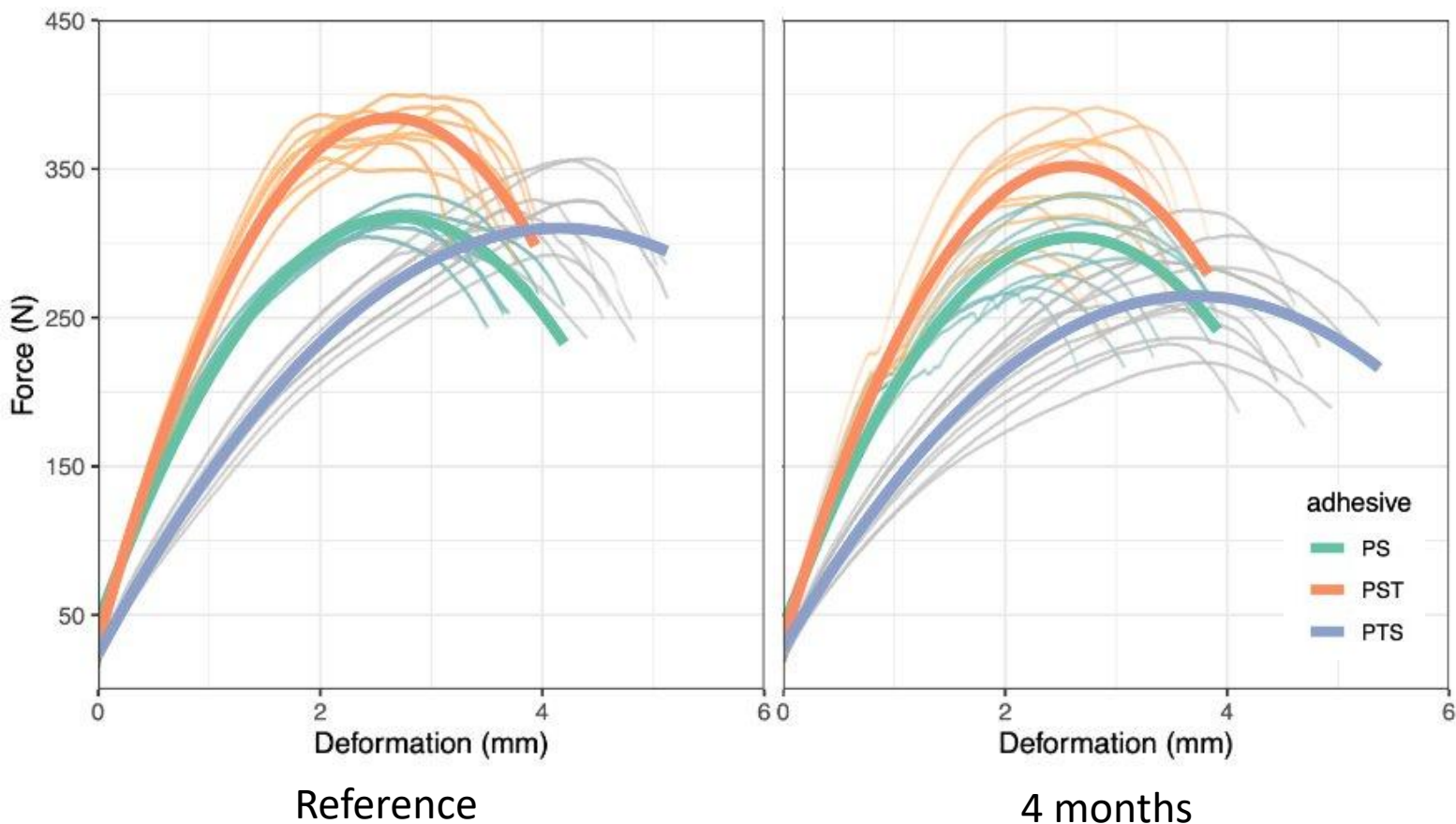
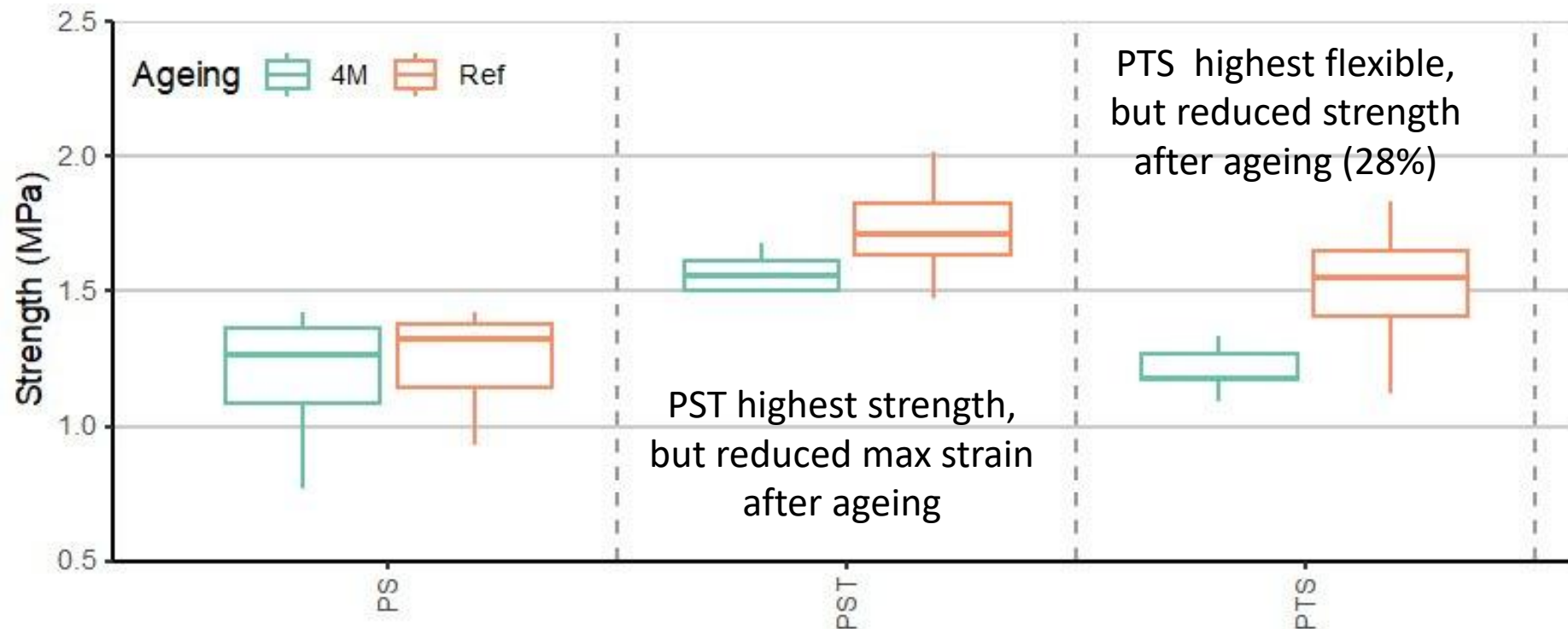
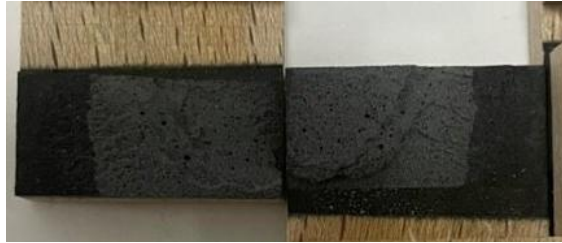
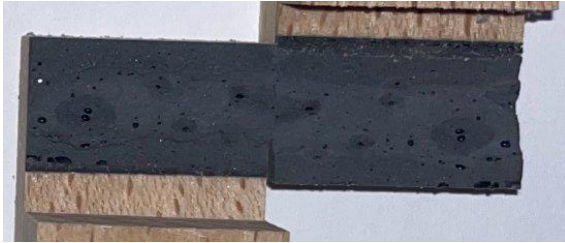


Figure 12: View of samples: before and after natural weathering

## LAP SHEAR TESTS: REF, NW 4M



# LAP SHEAR TESTING: FAILURES IN ADHESIVES

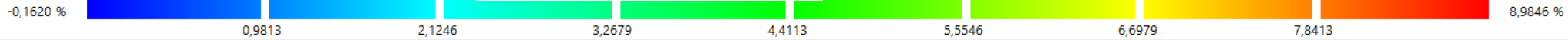
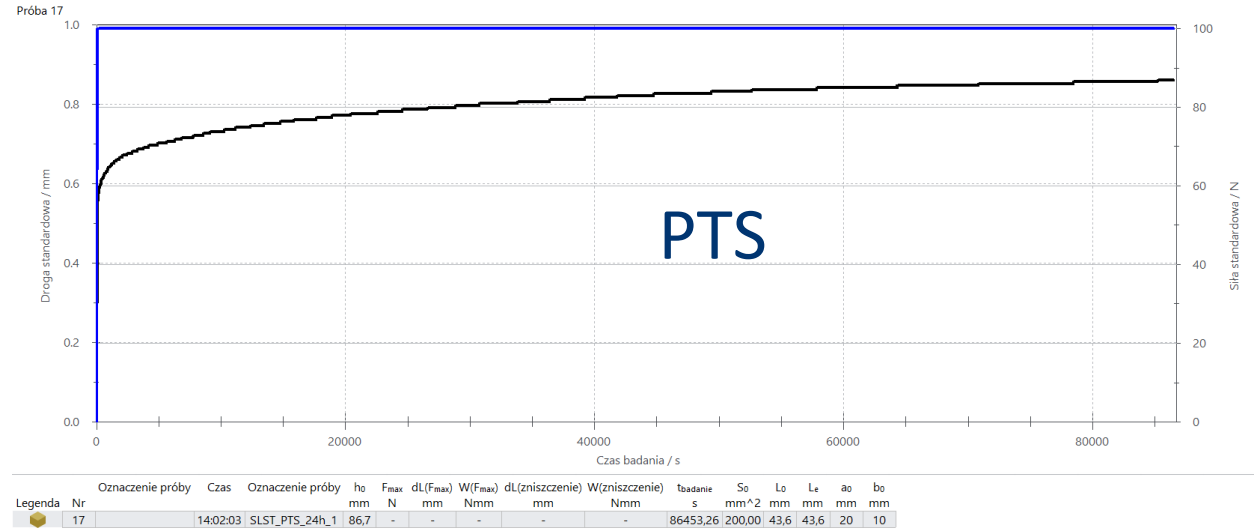
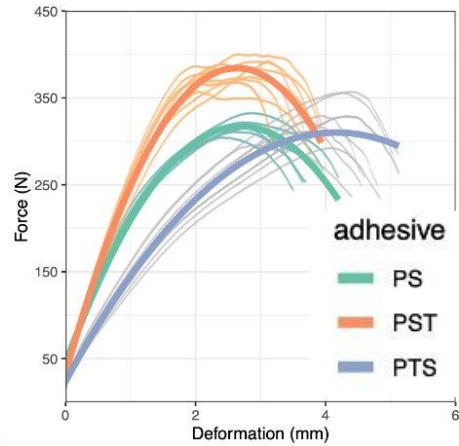
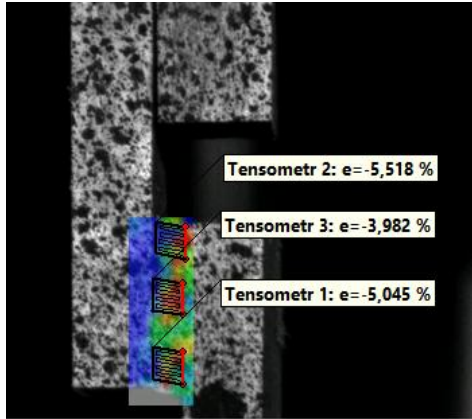


PS

PST

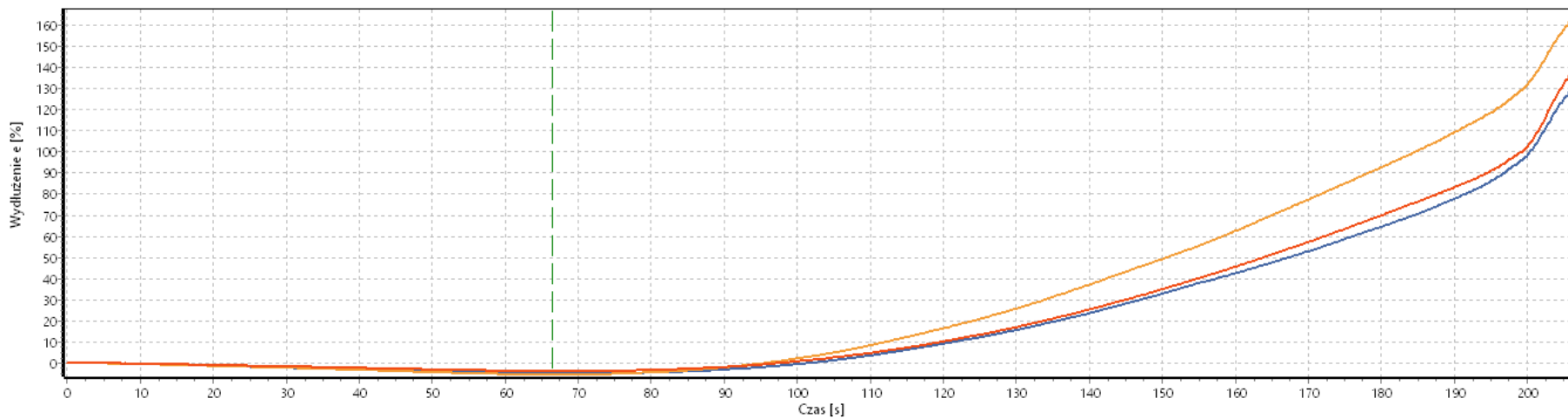
PTS

# LAP SHEAR TESTS: REF



Tensometr

Wydłużenie e



Tensometr 1  
Tensometr 2  
Tensometr 3



## CONCLUSION

- **PS** hardest adhesive retain strength and elongation after aging but reduces strength when used in connection with wood, despite this, we obtained the highest stability of results.
- **PST** has highest strength (among used in LS) good extension to failure. It loses both properties during ageing. No damage was observed in the joint after the first period of natural weathering
- **PTS** has the greatest elongation to failure both before and after ageing. The adhesive loses strength by about 28% with ageing. Reduced flexibility does not adapt to the aggressive shrinking-swelling of beech wood under natural weathering.
- In the creep test, the highest initial strain increase was observed for the **PTS** polyurethane.



## THANK YOU FOR YOUR TIME !

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**DI**Agnostics and **M**echanical tests **O**f aged adhesive layers  
used in **joiN**ts of **wooD**en structure**S**



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