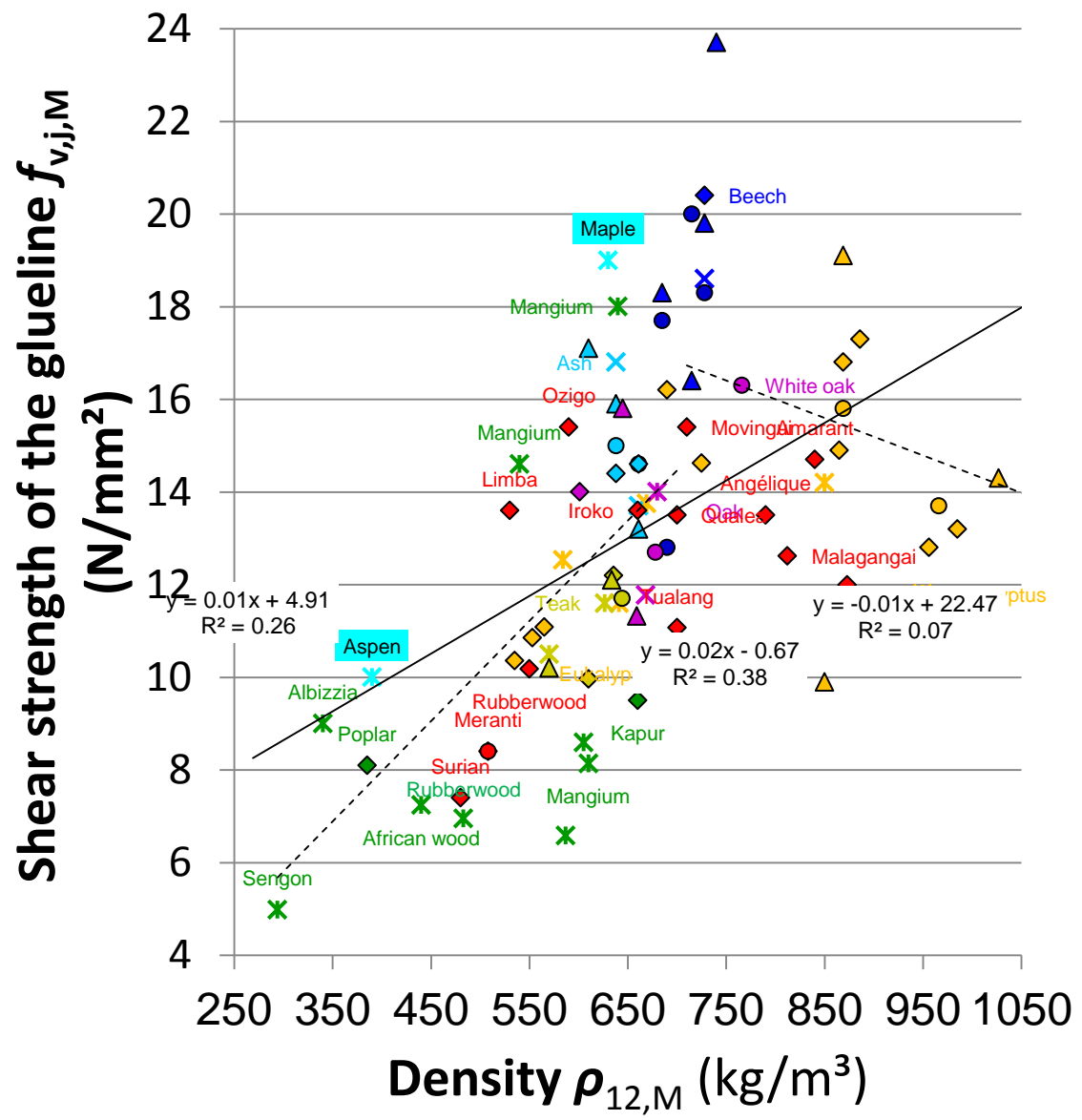




WP3

Adhesives for structural hardwood bonding



- Ash (Jiang et al. 2014, Knorz et al. 2013, Luedtke et al. 2015)
- Beech (Aicher/Ohnesorge 2009, Aicher/Reinhardt 2007, Jiang et al. 2014, Luedtke et al. 2015, Schmidt et al. 2009)
- Oak (Frihart et al. 2015, Luedtke et al. 2015, MPA xxxx)
- Eukalyptus (Altmüller 2007, Belleville et al. 2015, Belfas et al. 1993, Castro/Paganini 2003, Lopéz-Suevos/Richter 2009, Perkitny et al. 1975)
- Teak (Altmüller 2007, Belleville et al. 2015)
- Plantation hardwoods (Alamsyah et al. 2007/2008, Castro/Paganini 2003, Herawati et al. 2010, Komariah et al. 2015, Nadir/Nagarajan 2014)
- Tropical hardwoods (Bedel/Gautier 1972, Bourreau et al. 2013, MPA 2015-1/2/3, Tan et al. 1991)
- Other European / North American hardwoods (Frihart et al. 2015)
- MUF
- ◇ PRF
- △ PU
- × EPI

650 block shear tests with hardwood glulam beams for 4 european hardwood species:

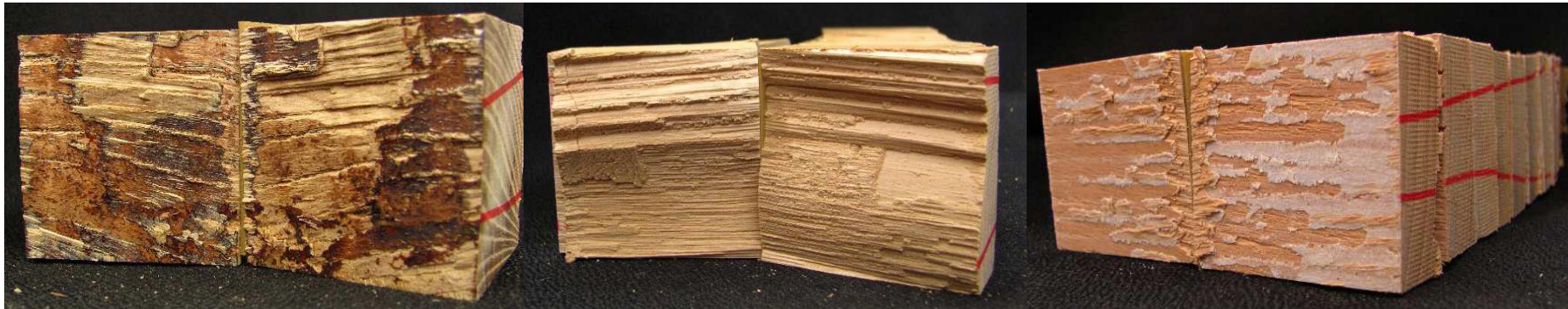
- **beech, ash, oak, chestnut**

and 4 tropical hardwood species:

- **keruing, meranti, malagangai, teak**

Next step:

Analyze the data and define a clear (general?) requirement for glue line integrity of hardwood glulams





Duration of load (DOL) tension shear tests with **oak and chestnut** and two different adhesives

Actual state:

- Suitable boards/materials received, now in conditioning
- Test set-up modified (special feature: serial testing of multiple specimens possible without influence of single specimen failure on other intact specimens)

Milestone	Status
16: Adhesives	Extensive block shear tests with glulam made from different hardwood species completed. DOL tests concerning the durability of gluelines in progress.
17: Finger-jointing	Analysis of all summarized finger joint data (see WP 2) in progress.

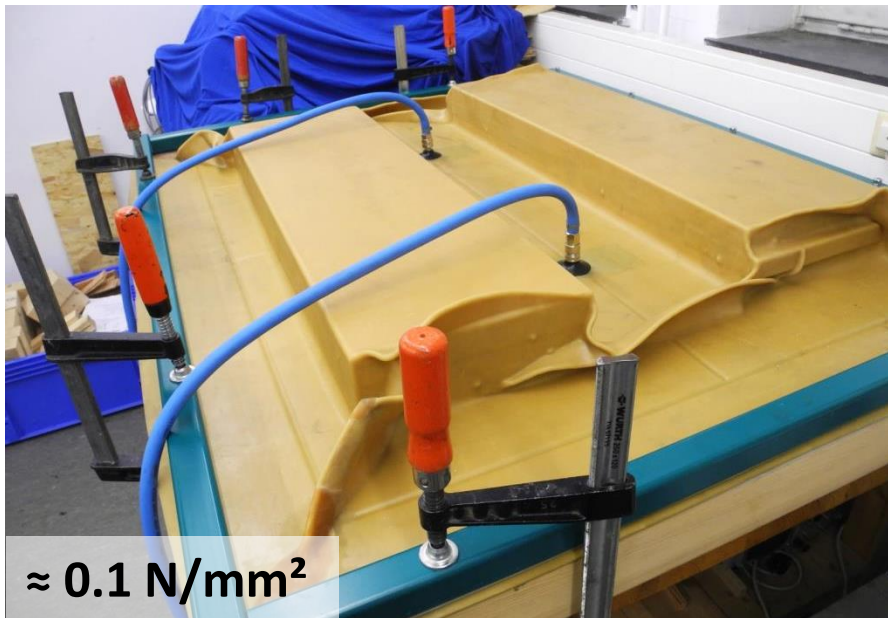
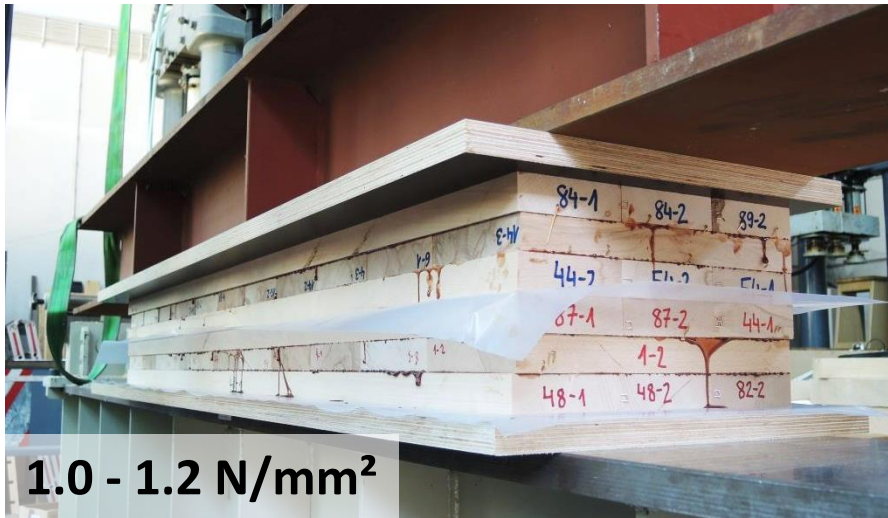


WP5

Cross laminated hybrid timber

- 1. Laboratory and industrial production**
- 2. Rolling shear properties**
- 3. Structural design implications**
- 4. Glue line integrity and gluability tests**

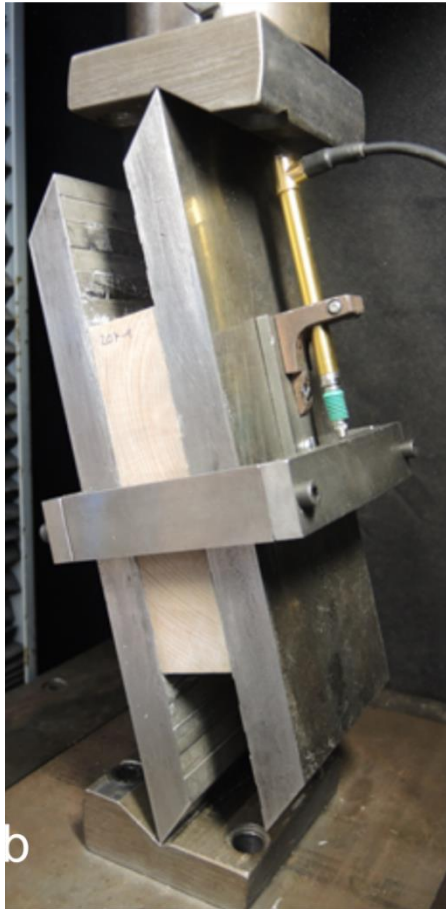
	Laboratory production	Industrial production
Structure	3-layered homogenous (beech-beech-beech) hybrid (spruce-beech-spruce)	3-layered + 5-layered hybrid (spruce-beech-spruce-beech-spruce)
Dimensions	0.28-0.3 m x 1.1-1.2 m	2.2 m x 6.5 m
No. of specimens	4 x homogenous 2 + 8 = 10 x hybrid	2 + 1 = 3 x hybrid
Adhesives	PRF (Prefere 4040 + Hardener 5835) PUR + Primer (Purbond HB S139 + PR 3105) MUF (Kauramin 683 + Hardener 688)	PUR + Primer (Purbond HB S139 + PR 3105)
Pressing	Hydraulic (1.2 N/mm ²) Vacuum (0.1 N/mm ²)	Hydraulic (1.0 N/mm ²)



Hydraulic and vacuum pressing of beech CLT at the laboratory and industrial production

Industrial production of hybrid beech CLT is feasible!

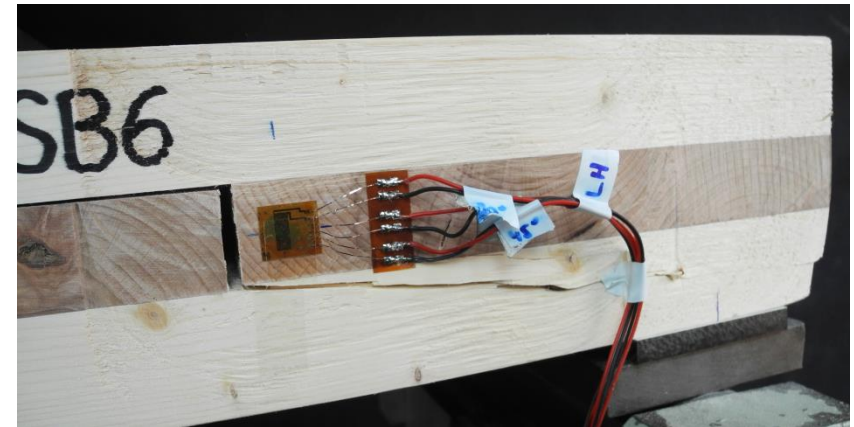
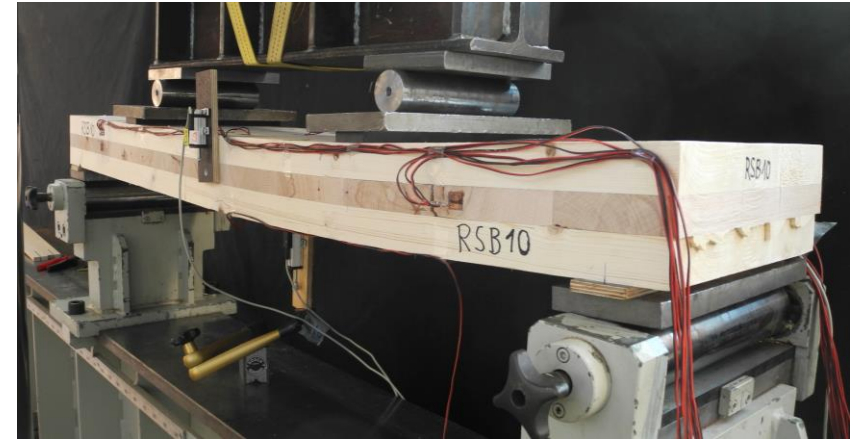
- Adjustments for hybrid beech CLT:
 - shorter beech board lengths (< 1.5 m)
 - primer application for PUR
 - high cramping pressure (1.0 – 1.2 N/mm²)



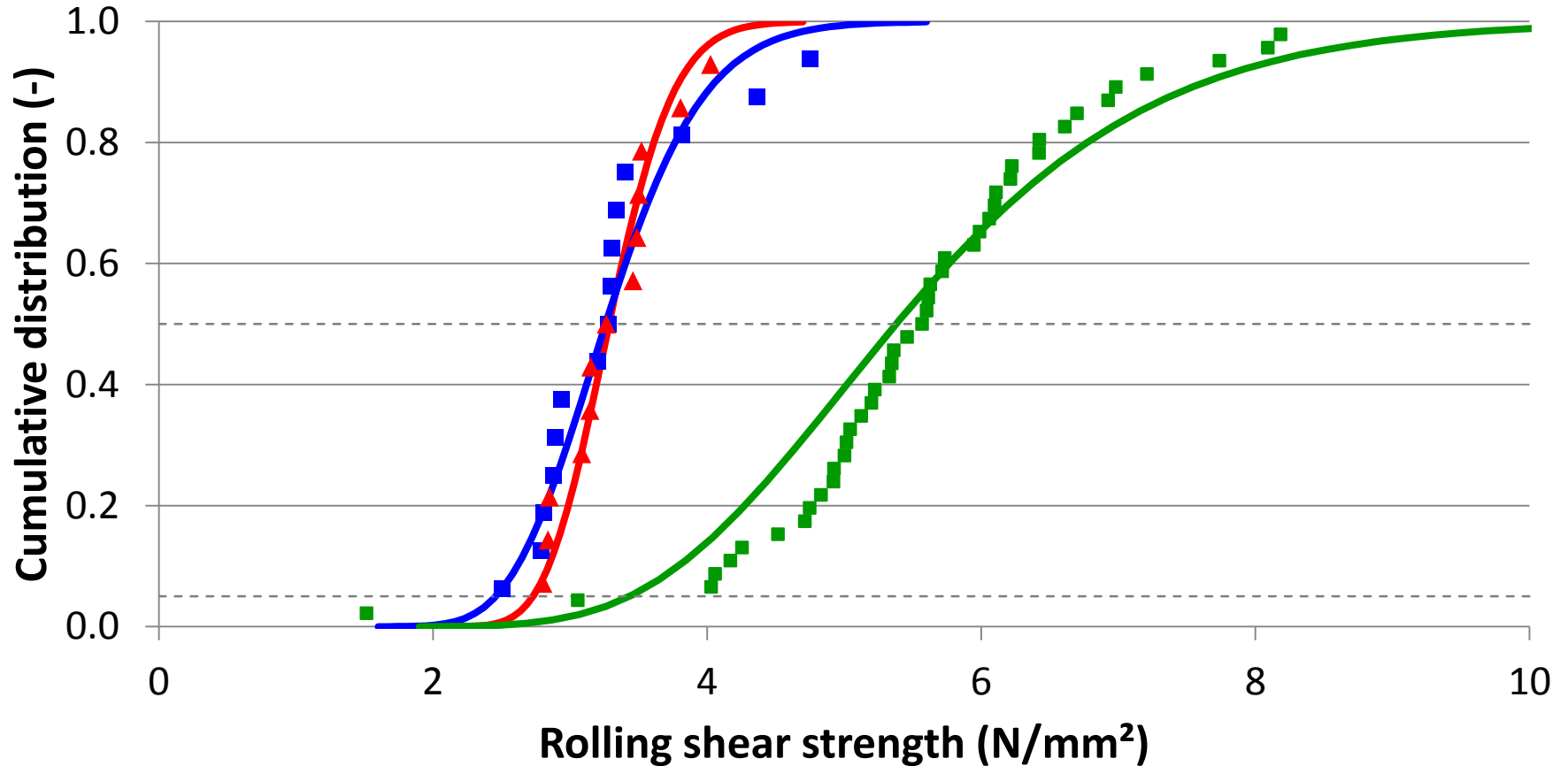
Compression shear tests with single beech board slabs



Compression shear tests with hybrid beech CLT stripes



Bending shear tests with hybrid beech CLT beams

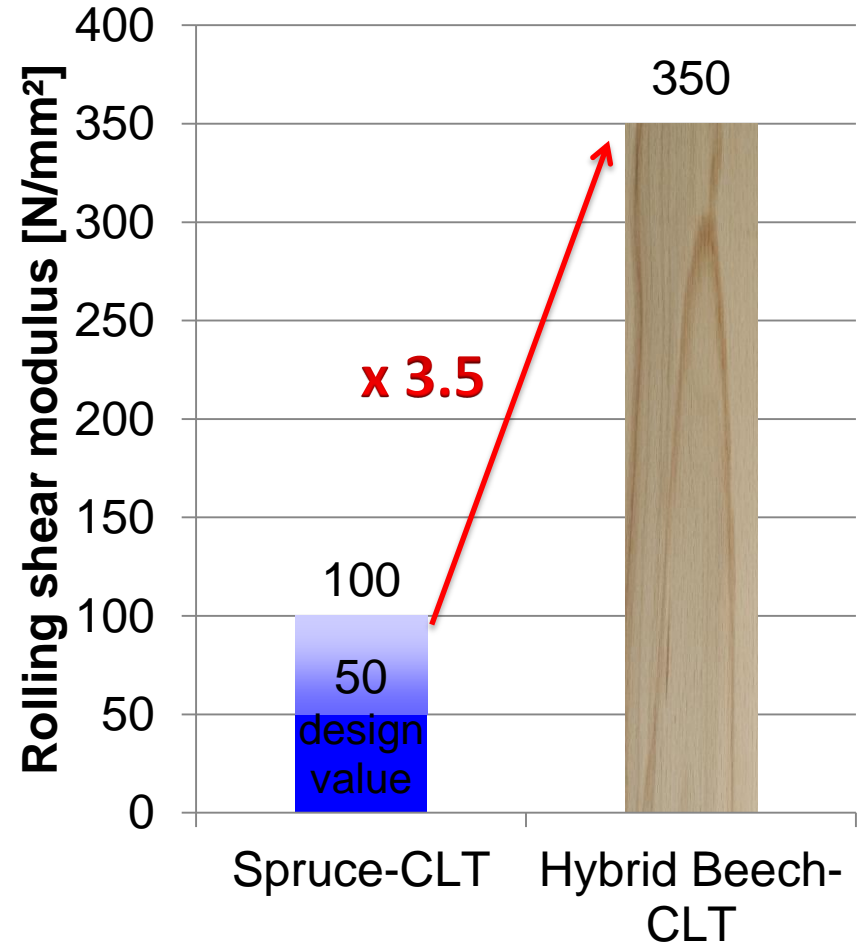
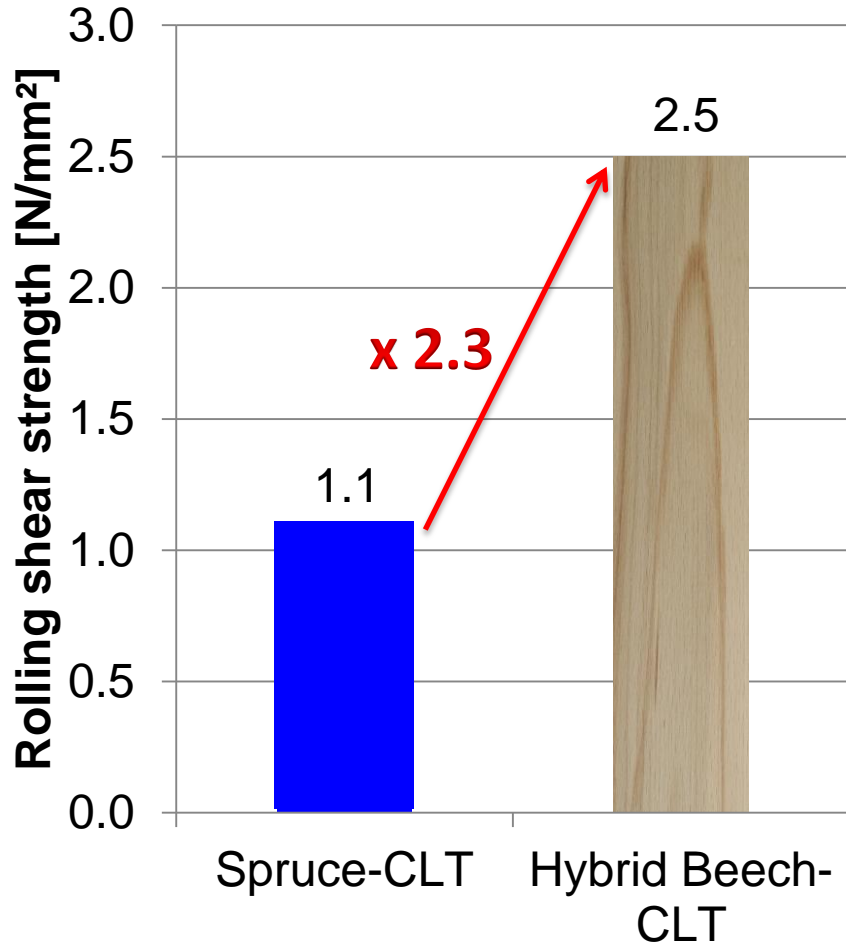


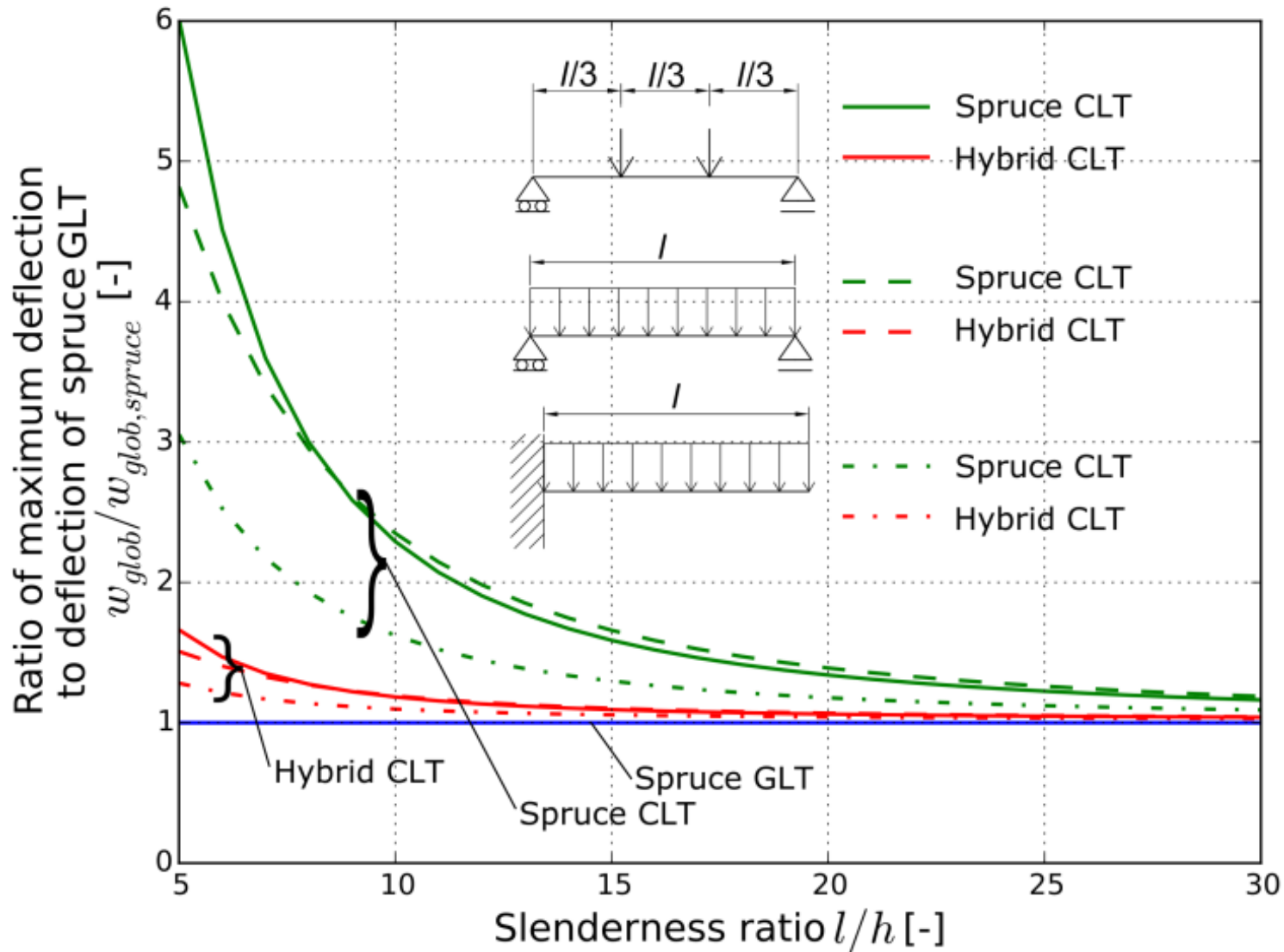
**Compression
shear tests with
single beech
board slabs**

**Compression shear
tests with hybrid
beech CLT stripes**

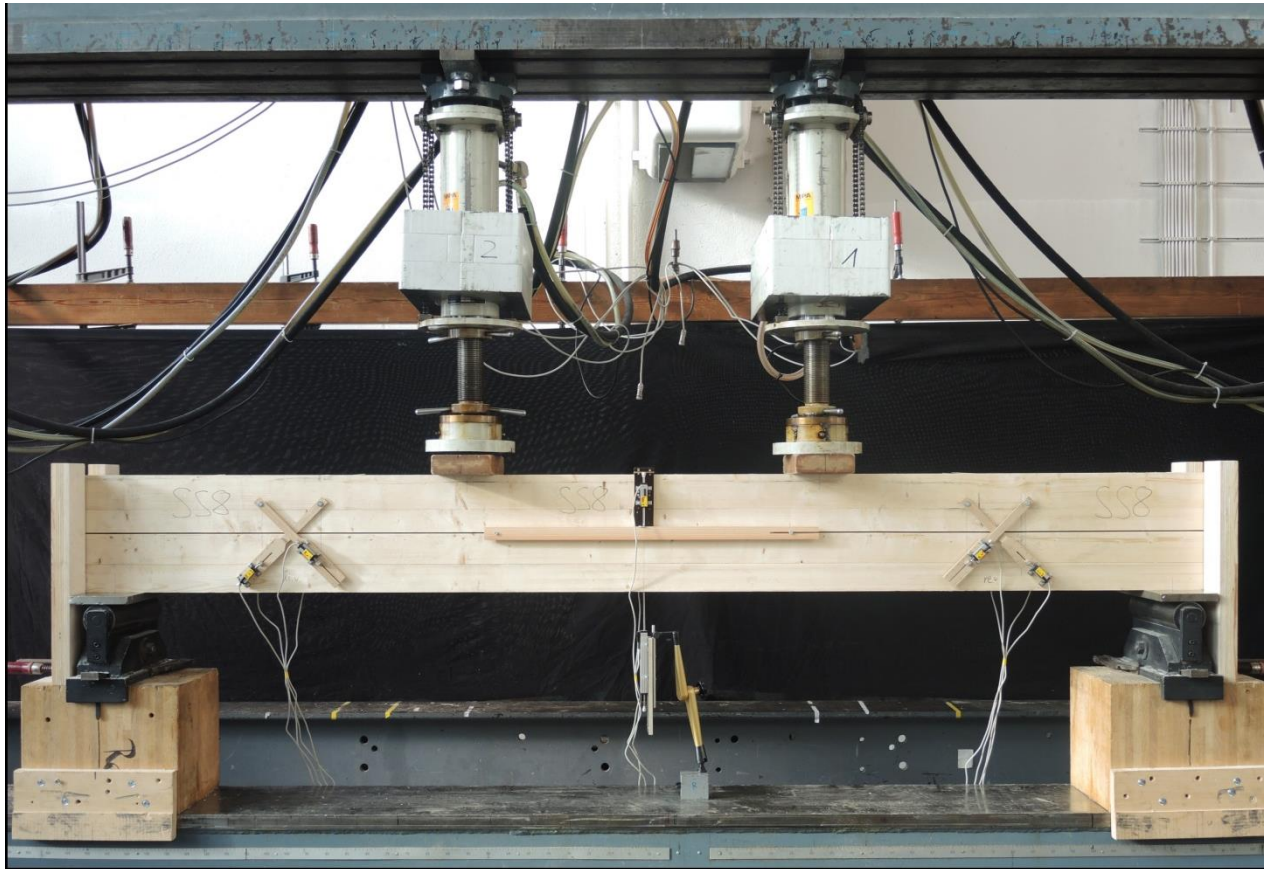
**Bending shear tests
with hybrid beech CLT beams**

👉 **Rolling shear properties of Hybrid Beech-CLT by factor 2.5 – 3.5 higher compared to classic Spruce-CLT**

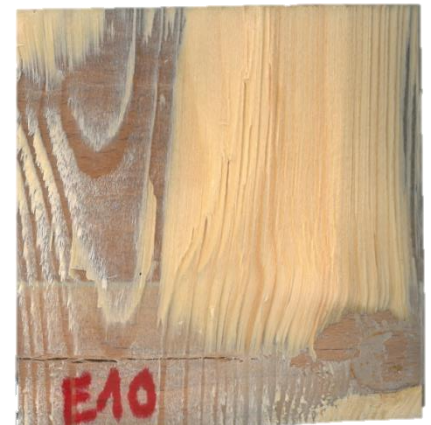
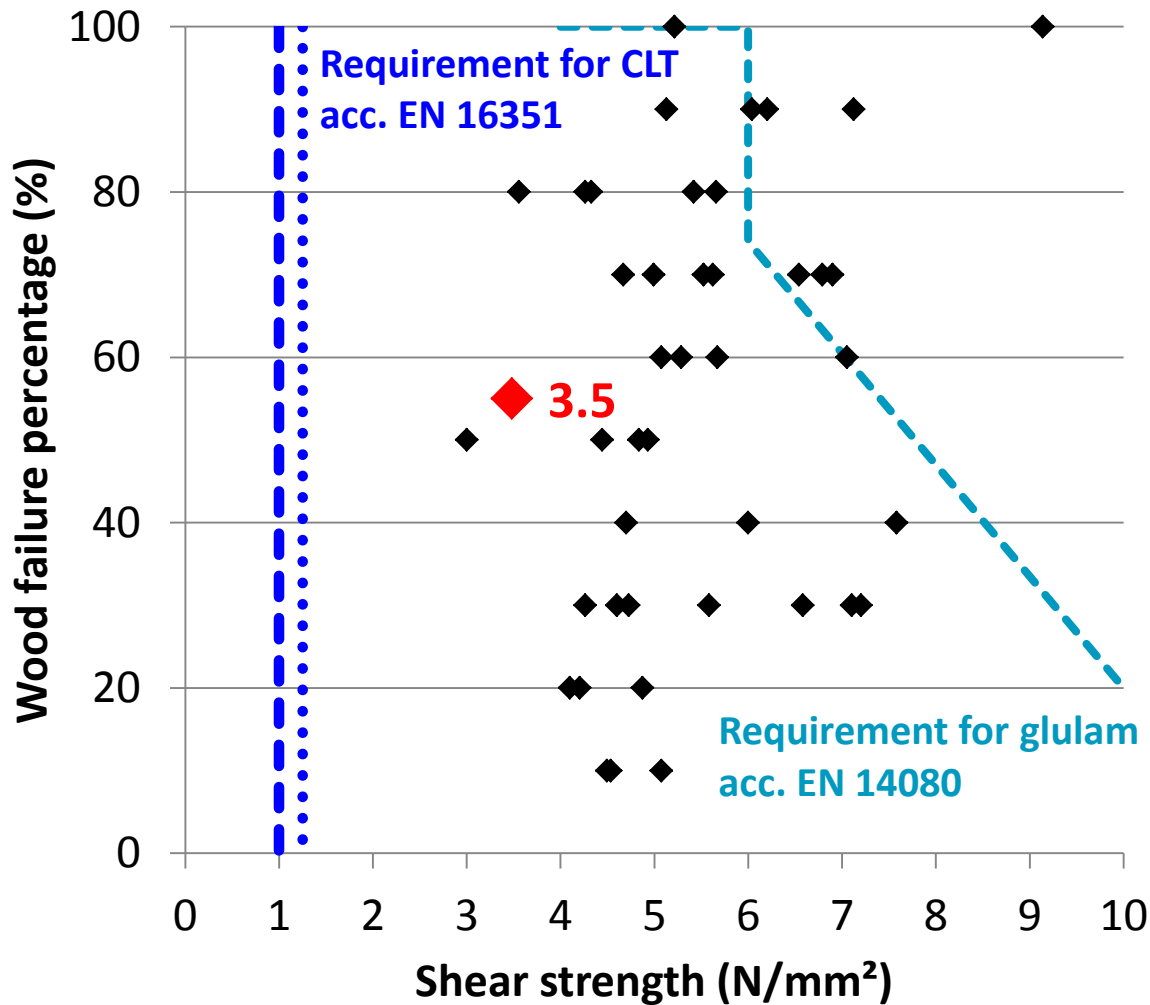




- 👉 **Deflection of hybrid beech CLT is considerably reduced compared to classic spruce CLT.**
- Assumption of a homogenous cross-section (neglecting the shear-lag) is a good approximation →
- 👉 **great simplification of the engineering-wise calculations**



Block shear tests and delamination of the industrially produced specimens – requirements acc. EN 16351 fulfilled



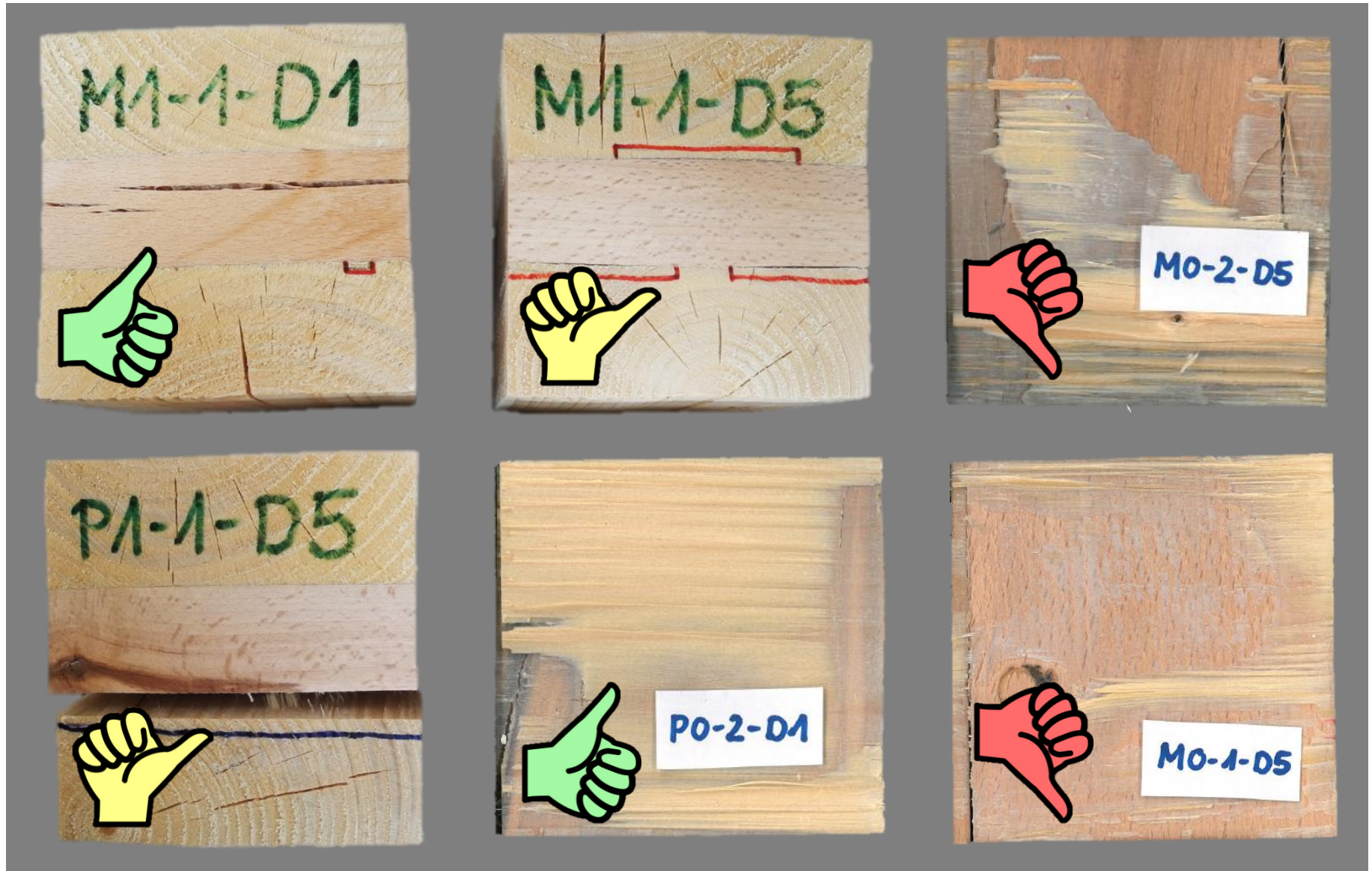
Test matrix		Adhesive type	
		PUR + Primer (Purbond HB S139 + PR 3105)	MUF (Kauramin 683 + Hardener 688)
Press type	Vacuum (0.1 N/mm ²)	2 samples	2 samples
	Hydraulic (1.2 N/mm ²)	2 samples	2 samples

Sample dimensions: 0.28 m x 1.1 m

- 40 delamination tests
- 40 block shear tests
- 28 compression shear tests

Actual state:

- testing nearly finished, first results available



- 👉 **Block shear requirements acc. EN 16351 far exceeded**
 - The required shear strength values are a result of the low rolling shear strength of spruce and must be increased for Hybrid beech CLT.
 - 👉 **Delamination requirements acc. EN 16351 critical**
- ➔ **Further testing necessary**

Milestone	Status
9: CLT build-ups	Testing of 3-layered hybrid structures successfully completed. Industrial production and testing of a 5-layered element: 06-08/2016
11: CLT guideline	Industrial production successfully performed. Guideline in preparation.
15: Publications	<p>Aicher, S., Christian, Z., Hirsch, M. (2016) Rolling shear modulus and strength of beech wood laminations. <i>Holzforschung</i>. Published online De Gruyter 2016-02-24.</p> <p>Submitted 03/2016: Aicher, S., Hirsch, M., Christian, Z., Hybrid cross-laminated timber plates with beech wood cross-layers.</p> <p>Submitted and accepted 05/2016: Aicher, S., Hirsch, M., Christian, Z., Hybrid beech and spruce cross-laminated timber. <i>WCTE 2016</i></p>