

Innovative Timber Composites: Improving wood with other materials

17 October 2013 – Nicosia, Cyprus



Comparison of different techniques for the strengthening of glulam members

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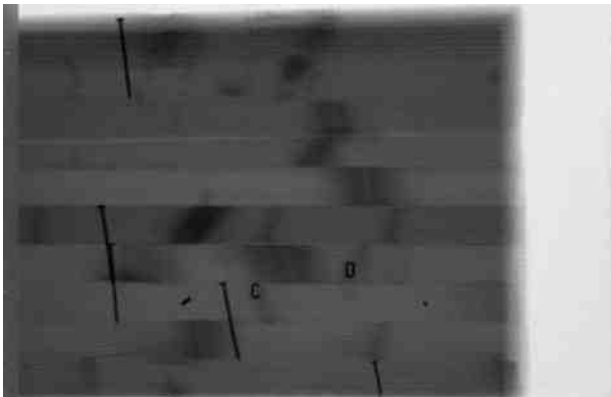
EMPA Structural Engineering Research Laboratory

Duebendorf, Switzerland

AP-Holz Project



Practically oriented Assessment and Strengthening of Glulam Elements



■ Projectparameters

- Duration 10/2010 bis 03/2013
- Budget 1.1 Mio. CHF, of which 550 kCHF by FOEN
- In total 12 project partners

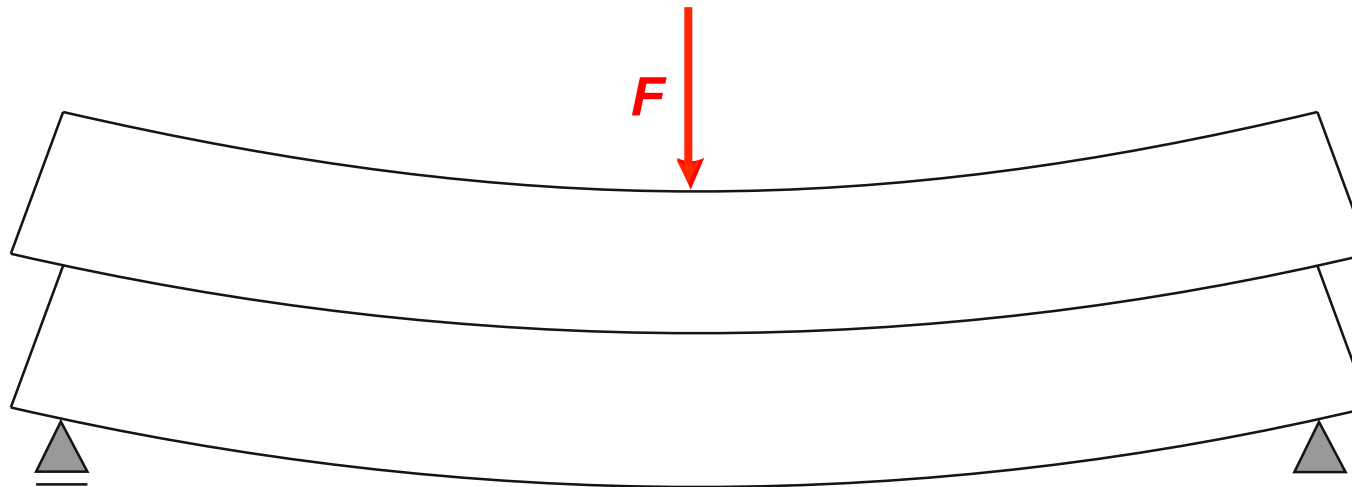
Test Setup for provoking Shear Failures



- Short span 3-point bending tests

Strengthening Techniques:

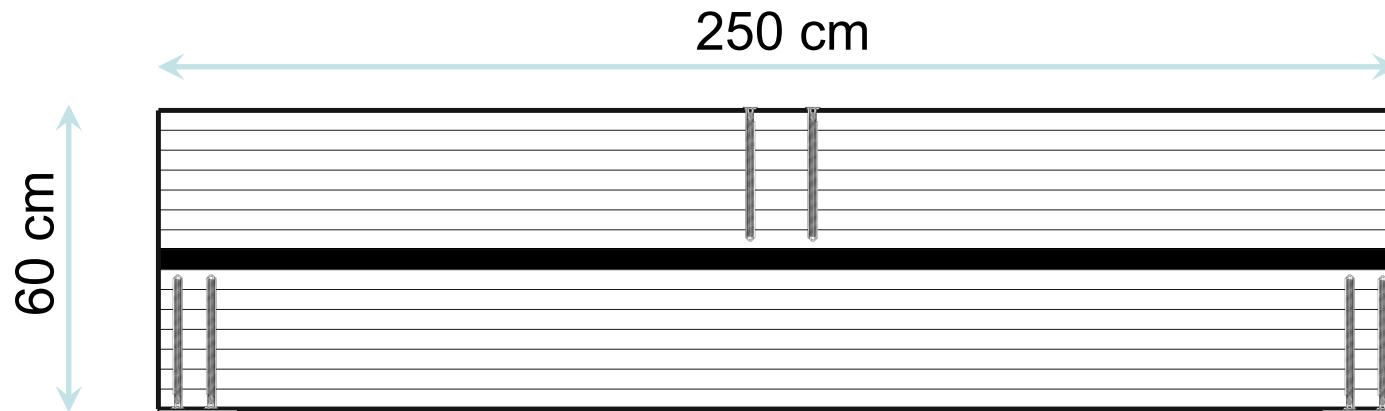
- Glued-in rods
- CFRP sheets
- Clamps
- Self tapping screws
- Refilling of glue line
- CLT / LVL



Test Specimens



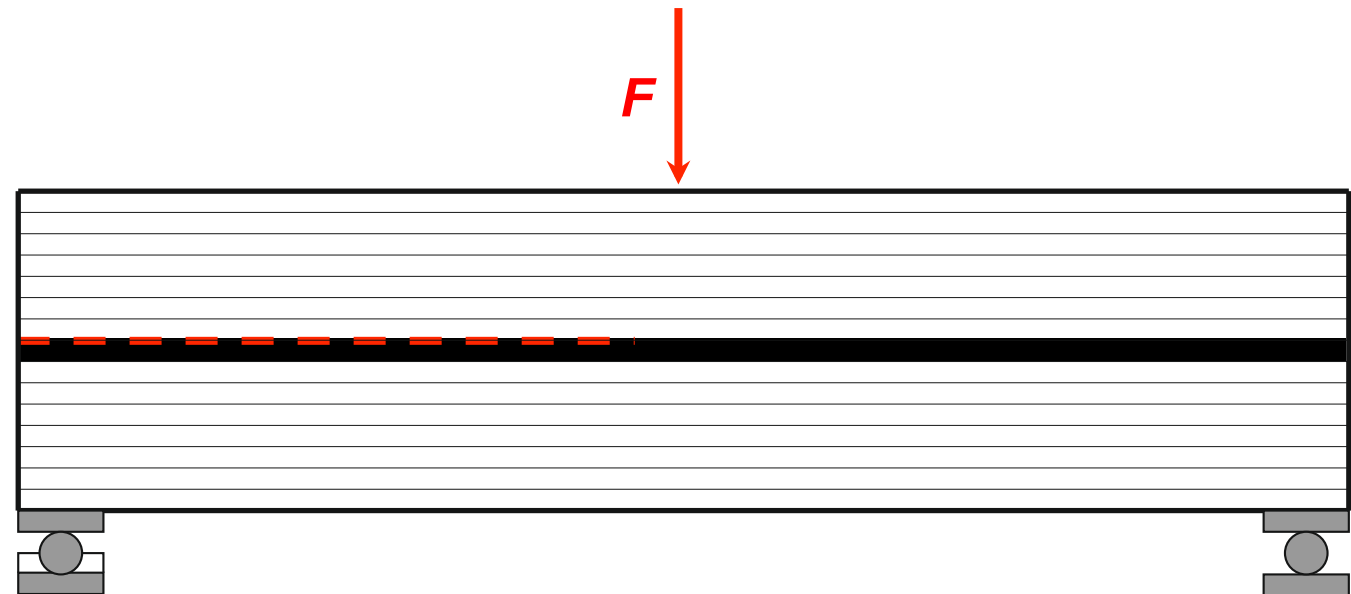
- 4 x 2 Beams, Glulam GI 24 (h), Norway Spruce, with Edge-lamellas from Ash
- Center-lamella misglued
- Reinforcement with selftapping screws at supports and loading point



Short span 3-point bending tests



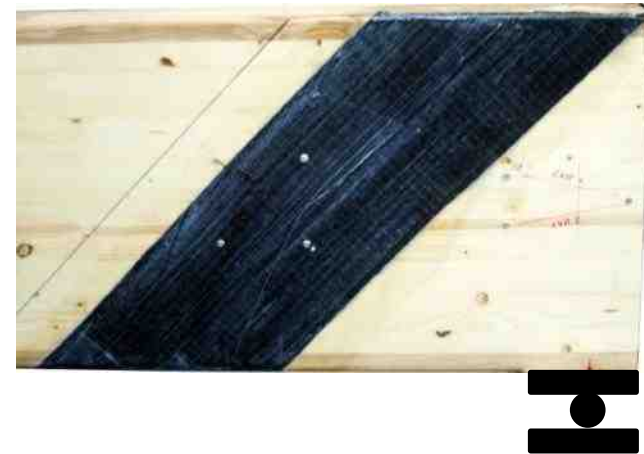
Test Cycles



Reinforcement Techniques



- 1 x SFS WT 13 x 800
- 2 x SFS WT 13 x 800
- 4 x SFS WT 13 x 800



- 1 x SikaWrap®-230 C/45
- 2 x SikaWrap®-230 C/45

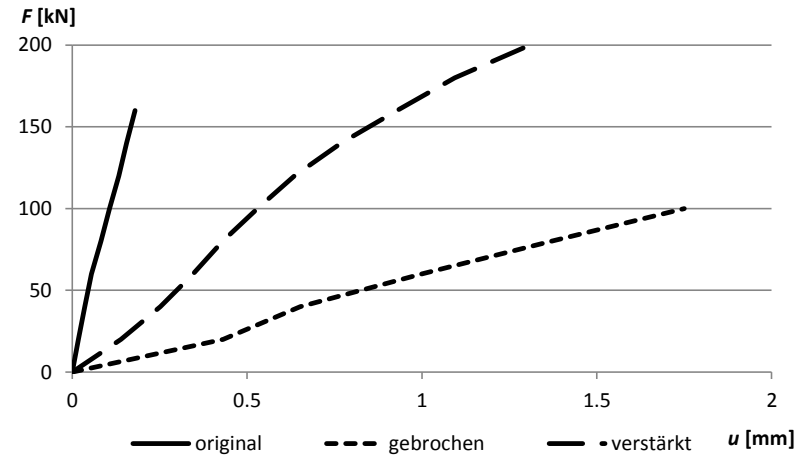
Test Results Strength



| Beam | Reinforcement | Failure Mode | F_{max} | τ^* | σ_c | σ_c^* |
|------|---------------|-------------------|-----------|-------------------|-------------------|-------------------|
| No. | | | kN | N/mm ² | N/mm ² | N/mm ² |
| 1a | none | shear | 160 | 1.43 | 10.8 | 3.57 |
| | 1 x 1 CFRP | shear | 218 | 1.95 | 14.7 | 4.87 |
| | 2 x 1 CFRP | compression perp. | 303 | 2.71 | 20.5 | 6.76 |
| 1b | none | shear | 240 | 2.14 | 16.2 | 5.36 |
| | 1 x 2 CFRP | shear | 251 | 2.24 | 20.0 | 5.60 |
| | 2 x 2 CFRP | compression perp. | 436 | 3.89 | 29.5 | 9.73 |
| 2a | none | (delaminated) | 0 | 0 | 0 | 0 |
| | 1 x 4 SFS 13 | shear | 220 | 1.96 | 14.9 | 4.91 |
| | 2 x 4 SFS 13 | compression perp. | 361 | 3.22 | 24.4 | 8.06 |
| 2b | none | shear | 180 | 1.61 | 12.2 | 4.02 |
| | 1 x 4 SFS 13 | shear | 244 | 2.18 | 16.5 | 5.45 |
| | 2 x 4 SFS 13 | compression perp. | 290 | 2.59 | 19.6 | 6.47 |
| 3a | none | shear | 200 | 1.79 | 13.5 | 4.46 |
| | 1 x 2 SFS 13 | shear | 240 | 2.14 | 16.2 | 5.36 |
| | 2 x 2 SFS 13 | bending | 372 | 3.32 | 25.1 | 8.30 |
| 3b | none | shear | 235 | 2.10 | 15.9 | 5.25 |
| | 1 x 2 SFS 13 | shear | 329 | 2.94 | 22.2 | 7.34 |
| | 2 x 2 SFS 13 | shear | 398 | 3.55 | 26.9 | 8.88 |
| 4a | none | shear | 208 | 1.86 | 14.1 | 4.64 |
| | 1 x 1 SFS 13 | shear | 290 | 2.59 | 19.6 | 6.47 |
| | 2 x 1 SFS 13 | shear | 376 | 3.36 | 25.4 | 8.39 |
| 4b | none | shear | 196 | 1.75 | 13.2 | 4.38 |
| | 1 x 1 SFS 13 | shear | 245 | 2.19 | 16.6 | 5.47 |
| | 2 x 1 SFS 13 | bending | 360 | 3.21 | 24.3 | 8.04 |

Test Results

Stiffness



Lamella Deformation Modulus V/u in kN/mm

| Beam | Reinforcement | original | failed | reinforced | Factor | Mean |
|------|---------------|----------|--------|------------|--------|------|
| 1a | 1 x CFRP | 406 | 95 | 223 | 2.35 | 2.35 |
| 1b | 2 x CFRP | 426 | 28 | 108 | 3.86 | 3.86 |
| 2a | 4 x SFS | -- | 24 | 59 | 2.49 | 2.72 |
| 2b | | 550 | 29 | 86 | 2.95 | |
| 3a | 2 x SFS | 244 | 26 | 55 | 2.10 | 2.24 |
| 3b | | 492 | 25 | 60 | 2.38 | |
| 4a | 1 x SFS | 253 | 22 | 40 | 1.80 | 1.68 |
| 4b | | 334 | 30 | 47 | 1.57 | |

Conclusions



- Missglued glulam beams were tested upon shear failure, then reinforced and tested again
- Reinforcements tested so far (SFS self-tapping screws and Sika CFRP mesh) showed high strength
- Stiffness after failure and reinforcement clearly inferior to initial stiffness
- Effective shear strength of the reinforcements could not be determined due to different failure modes.
- **Next steps:** different strengthening techniques and different test methods (14° compression-shear test)

