On-going R&D Projects in COST Member Countries

(Nov. 2011)

Countries S-Z

Slovenia

University of Ljubljana

Department of Wood Science & Technology

Faculty of Civil Engineering

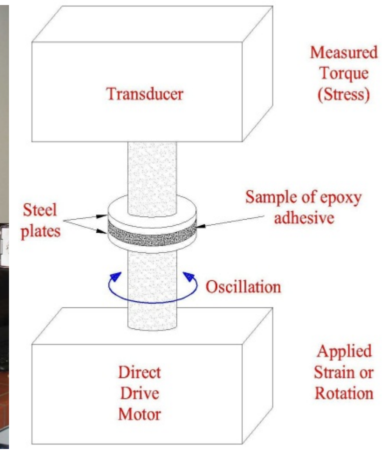
ZAG

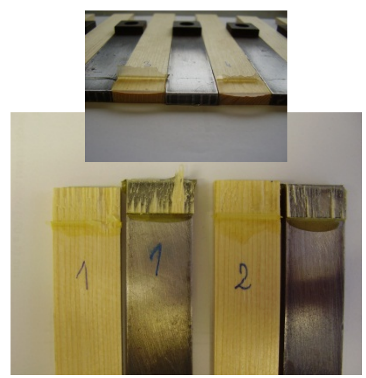
Slovenian National Building and Civil Engineering Institute, Ljubljana

University of Ljubljana
Dep. of Wood Science & Technology

Adhesion between wood and steel – Glued-in rods for connections

- Rheological properties of adhesives
- ARES G2 stress control rheometer
- Oscillatory test, parallel plates
- 5 temperatures: 30, 40, 50, 60, 80 °C
- 3 epoxy adhesives
- Gel and vitrification time
- Shear strength of lap-joints
- Glued-in rods – shear strength:
- anchoring length
- diameter of rod





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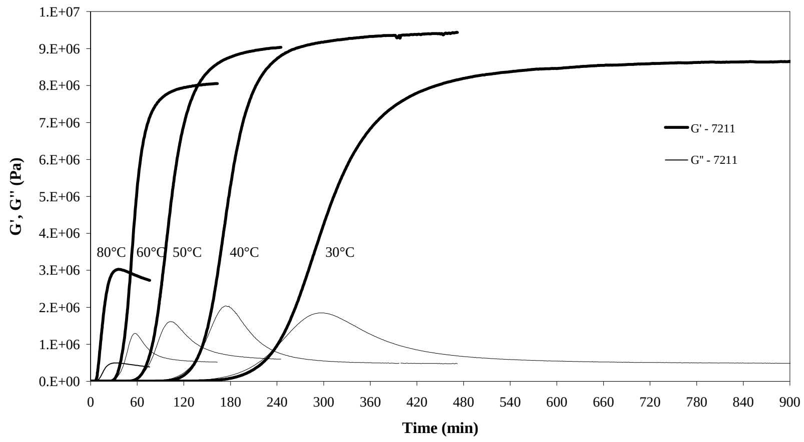
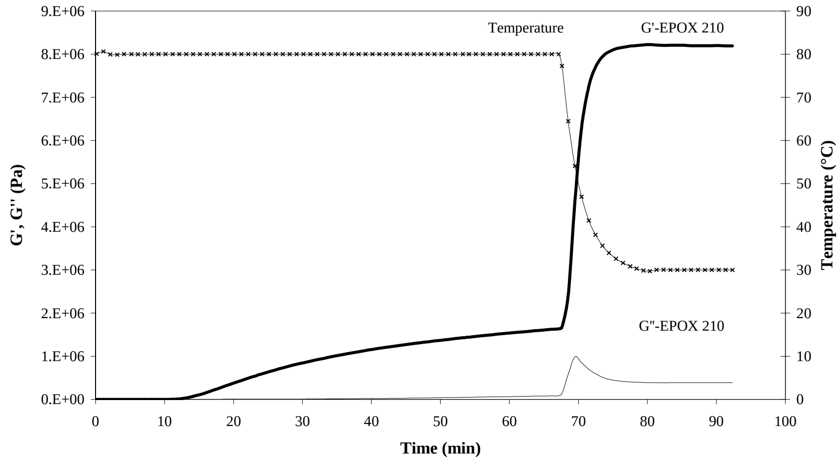
Adhesion between wood and steel - Glued-in rods for connections

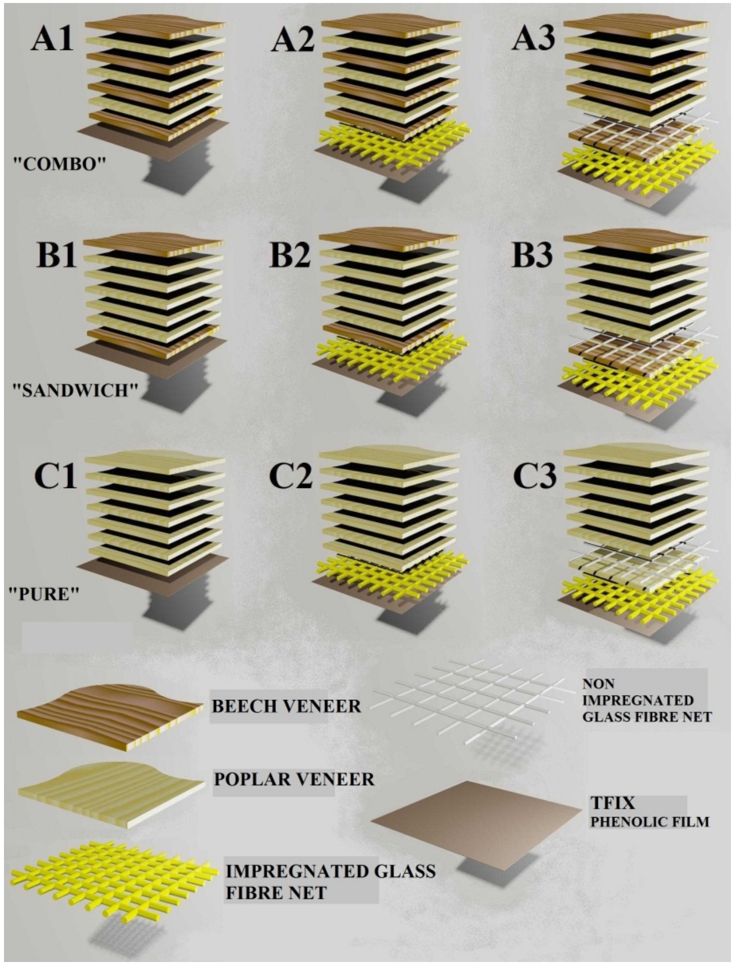
- Significant differences in curing behavior among adhesives
- Increasing the curing temperature accelerated the curing process
- The storage modulus G' and the loss modulus G" changed with the temperature





Enhancement of bending strength of plywood by adding synthetic fibres

- To enhance bending properties of plywood
- Different combinations of plywood (Beech/poplar veneer, glass fibres, Tfix)
- 7-layer plywood
- MUF adhesive
- Bending test (MOR, MOE)
- Density



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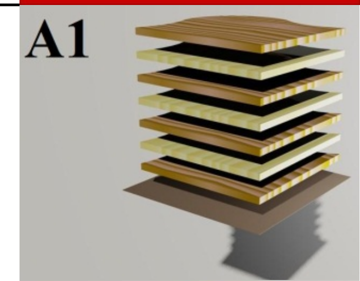
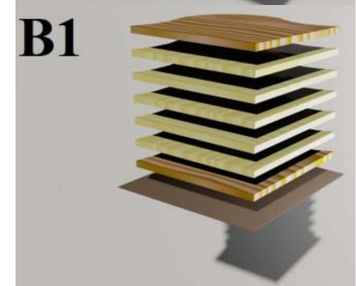
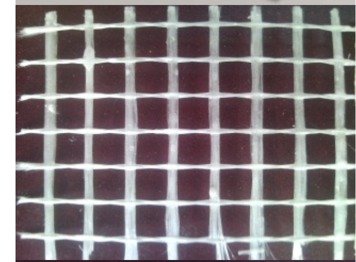
Enhancement of bending strength of plywood by adding synthetic fibres

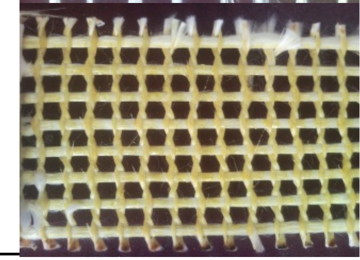
Results

- The combination with the highest bending strength „combo“ → due to the higher share of beech veneer
- The combination with the best strength / density ratio „sandwich“ → due to the low density of poplar veneer
- Non-impregnated glass-fibre nets on the outer layers reduce the bending strength → poor adhesion
- Melamine resin-impregnated nets on the outer layers improve bending strength → sufficient adhesion









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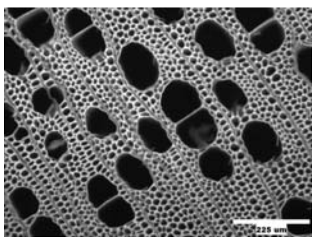
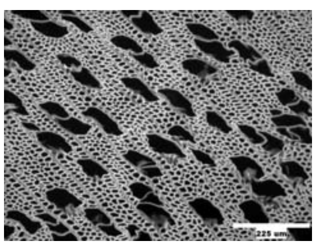
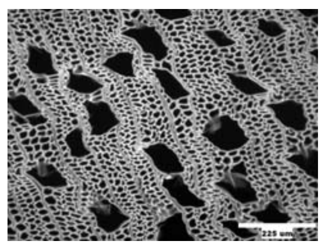
Viscoelastic thermal compression (VTC) of wood

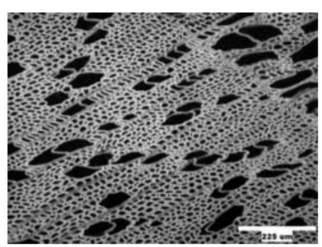
- Mechanical properties of **densified wood**
- VTC wood for new laminated composites

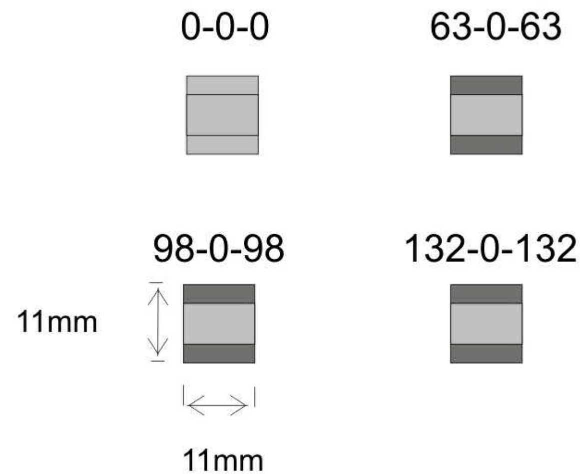
- 0 %
- 63 %
- 98 %
- 132 %

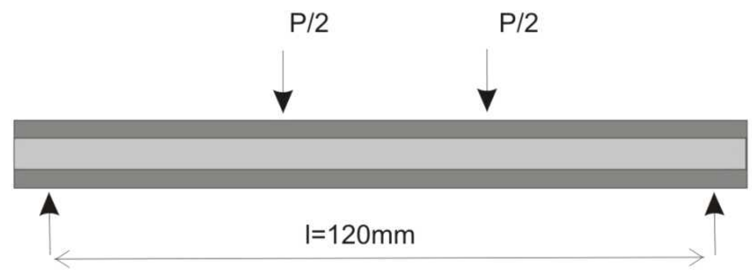




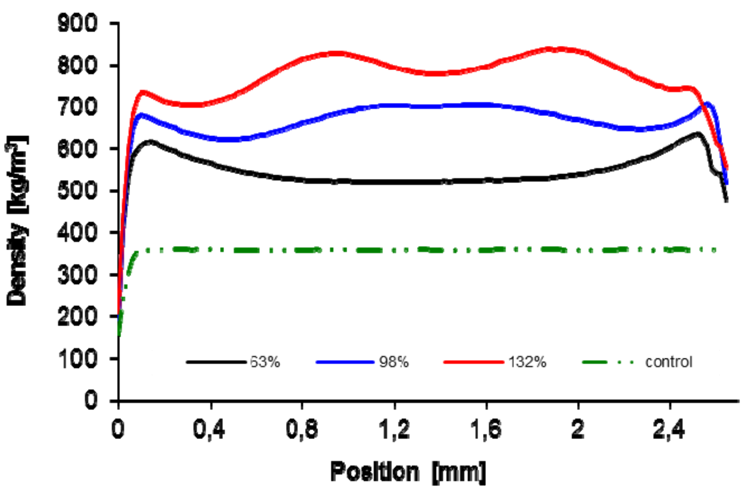


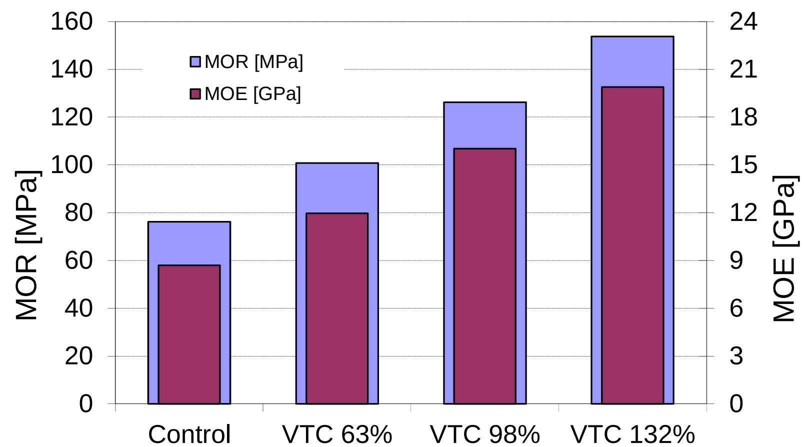


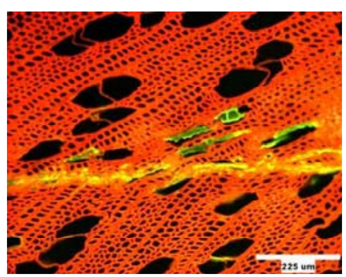




Viscoelastic thermal compression (VTC) of wood



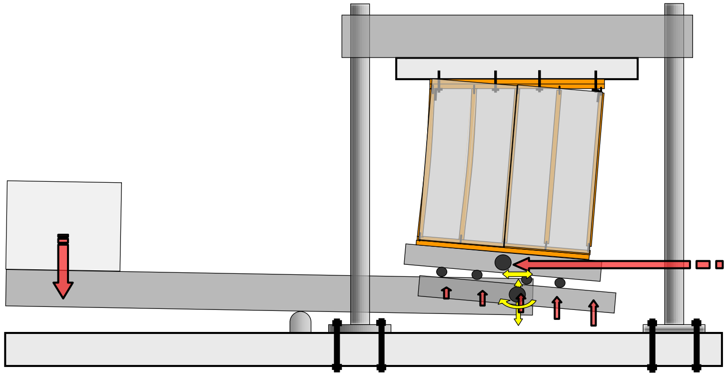




Composite	MOE [GPa]	MOR [MPa]
0-0-0	8.2	64.0
63-0-63	10.3	80.8
98-0-98	11.8	82.8
132-0-132	12.1	87.0

Seismic resistance of composite structural systems timber-structural glass with optimal energy dissipation

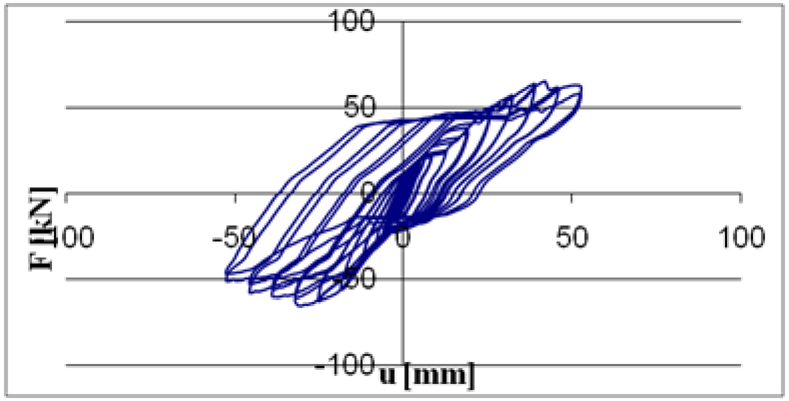
- Wood framed glass panels are easy-to-fix structural elements for different layouts of low rising buildings or to be used as infill elements in high rising frame systems
- Research needs: EC for glass structures (from cyclic to shaking table testing of panels and their assemblies)



Universities of Ljubljana & Zagreb
Faculty of Civil Engineering

Seismic resistance of composite structural systems timber-structural glass with optimal energy dissipation

- **On-going research:** vertical load-bearing capacity of 2-ply glass sheet, cyclic shear test of wood-framed double 2-ply glass sheet panel
- **Future research:** Shaking testing of full scale models, development of computational model of panel, parametric study of various systems



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Assessment and rehabilitation of historic timber structures

Roof and floor structures of Minorite monastery in Maribor

- The origins date in 13th century, majority renovated in 18th century
- Roof and floor structures have been assessed, some structures were in bad condition (e.g. supports of roof beams and hollow timber floors).

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Assessment and rehabilitation of historic timber structures

- Deterioration of massive timber floors was not so expressed - in some areas only surface was affected (mainly by the brown rot).
- The inadequate load bearing capacity of floor was improved by adding concrete slab, connected by steel dowels.



Further work

- Investigation in combined timber-concrete floors will continue
- Effect of creep and influence of changing moisture have to be studied.

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Strengthening curved glued laminated elements failed in tension perpendicular to grain

Roof beams failed in use and during in-situ loading test

- 15 pitched and curved roof beams in a stable failed under snow load
- The roof beam of the same design was tested with the dead load, brittle failure occurred at load equal 1.16 x design load.

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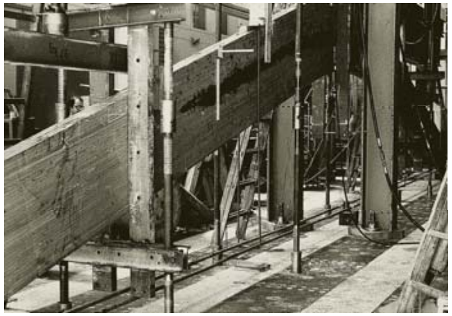
Strengthening curved glued laminated elements failed in tension perpendicular to grain

- Strengthening by adding a steel rod into tensile zone (changing a simple supported beam into an arch) and tying the central curved part with the outer clamps perpendicular to grains.
- Tensile rod increases capacity to 4.2x and clamps 3.0x design load.



Further work

New types of strengthening (glued in rods) are going to be investigated.

Spain

USC and CIS-Madeira, Galicia

USC-PEMADE, Galicia

Platform of Structural Timber Engineering

CETEMAS, Asturias & Media Madera, S.L.

UPM Madrid

Research Group of Timber Construction

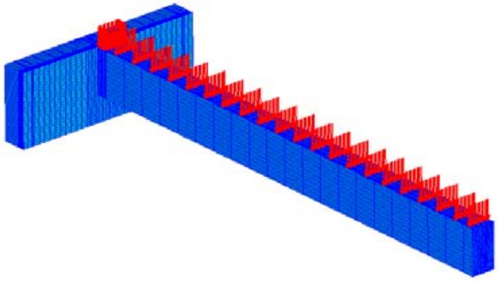
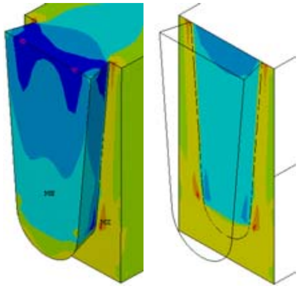
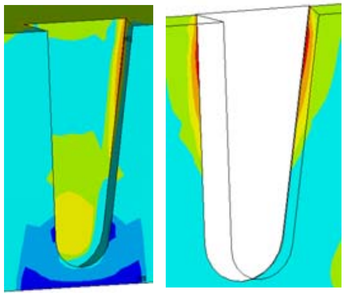
UNAV, Navarra & Cornel University, USA

University of Salamanca

USC and CIS-Madeira, Galicia & UPM, Madrid

Dimensioning dovetail joints between structural beams

- Calculating dovetail joints in wood structures by numerical model and experimental validation.
- By the introducing the Tsai-Wu quadratic failure criterion, they have discussed load-carrying capacities as a function of geometry based on the failure detected including the material entering plasticity.

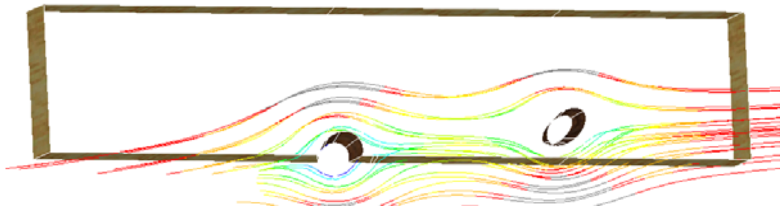





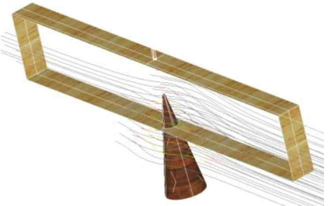
USC-PEMADE, Galicia

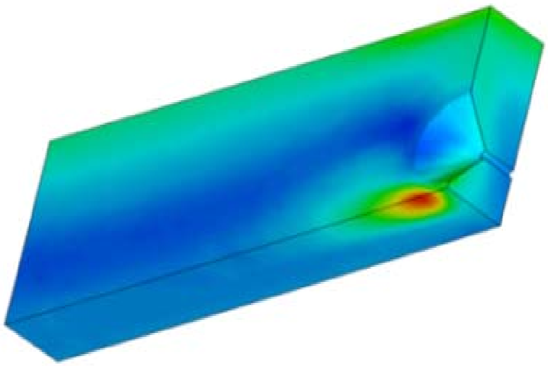
Platform of Structural Timber Engineering

A wood material model to simulate the effect of all kind of knots

- FE model to understand and predict the behavior of structural members under the influence of all kind of knots considering wood as a transverse isotropic material with anisotropic plasticity.
- Knots generated as elliptical oblique and truncated cones, which produce the deviation of grain around them.
- Fibre deviation predicted from knots shape by 3D flow-grain analogy







USC-PEMADE, Galicia

Platform of Structural Timber Engineering

FE validation and stiffness analysis of timber in bending through low cost photogrammetry

Objective:

Analysis and finite element validation of bending tests by low-cost photogrammetric equipment of app. 2,000 €.

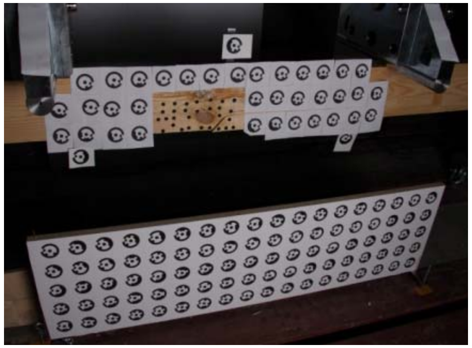
- Equipment composed by 3 non-professional cameras of 10 MP and the software Photomodeler Scanner
- Accuracy of 1:6200 did not allow contrasting strains, but displacements could be evaluated.

USC-PEMADE, Galicia

Platform of Structural Timber Engineering

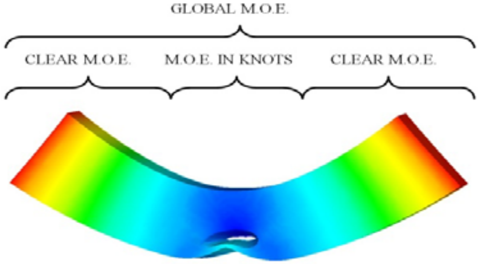
FE validation and stiffness analysis of timber in bending through low cost photogrammetry

High distortion of the deflection curve and stiffness heterogeneity due to the presence of knots and other non-homogeneities.



Proposal: Calculation of

- a clear MOE regarded to free-defect zones,
- a MOE in zone with presence of knots respect to the distorted areas
- and a global MOE which encompasses both.



USC-PEMADE, Galicia
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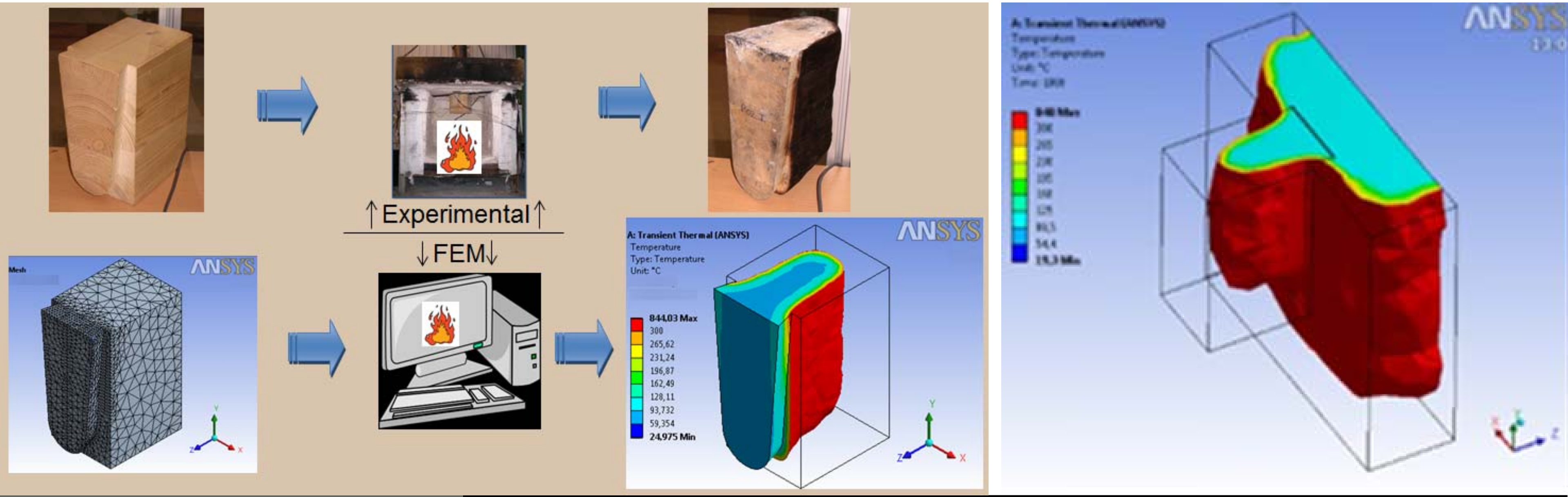
Analysis of timber carpenter joints in a fire event using FEM

Objective:

To model the behavior of a carpenter joint in a fire event considering its charring rate, its geometrical changes and its bearing capacity.

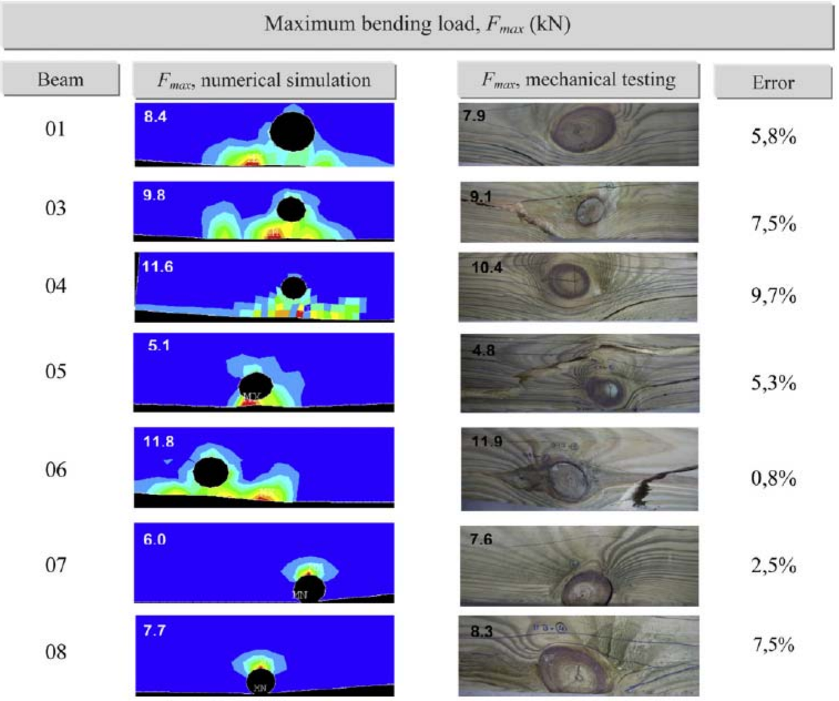


USC, Galicia & CETEMAS, Asturias

Strength loss in timber beams of scots pine due to circular knots

Objectives:

- Development of a tool to simulate the elastoplastic behavior of timber beams in a bending test
- Predict the fracture load of beams according to the size and position of knots and local deviation of grain
- Analysis of the MOR influence for different sizes and positions of knots throughout of the height of the beam



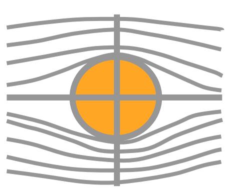
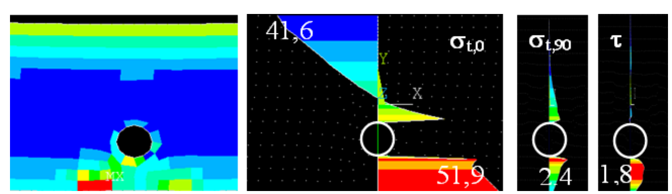
Maximum bending load, F_{max} (kN)			
Beam	F_{max}, numerical simulation	F_{max}, mechanical testing	Error
01	8.4	7.9	5,8%
03	9.8	9.1	7,5%
04	11.6	10.4	9,7%
05	5.1	4.8	5,3%
06	11.8	11.9	0,8%
07	6.0	7.6	2,5%
08	7.7	8.3	7,5%

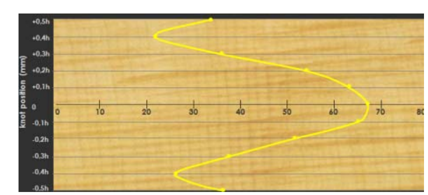
USC, Galicia & CETEMAS, Asturias

Strength loss in timber beams of scots pine due to circular knots

Objectives:

- Influence of knots on the stress distribution
- Analysis of the influence of normal and shear stresses in the quadratic rupture criterion.

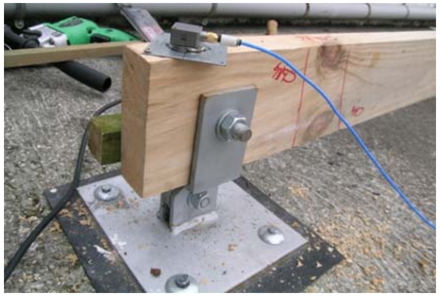






CETEMAS, Asturias & Media Madera, S.L.

Behavior of timber footbridges by static and dynamic load testing

- Evaluation of the frequencies of vibration of timber footbridges using dynamic tests (IMC Devices equipment and LMS TestLab software)
- Analysis of the influence of different design configurations on their respective natural frequencies of vibration, assessing the risk of resonance due to transition of pedestrians according to the normative.
- Study supports influence on natural frequency of timber beams

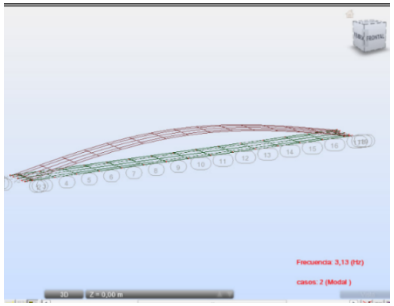


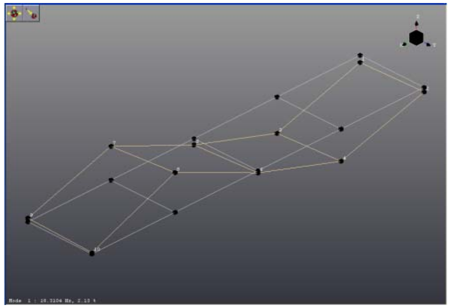
CETEMAS, Asturias & Media Madera, S.L.

Behavior of timber footbridges by static and dynamic load testing

On-going work:

- Prediction of stiffness and strength of timber footbridges comparing static and dynamic load tests
- Analysis of the theoretical, numerical and experimental frequencies of vibration

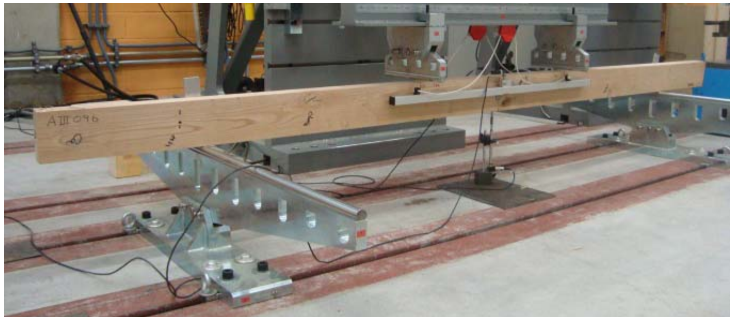




CETEMAS, Asturias & PEMADE, Galicia

Physical and mechanical properties of Chestnut timber from Spain

- Determination of physical properties:
  Density at different MC, water vapor adsorption, dimension stability, water vapor permeability and impregnability.
- Determination of the mechanical properties:
  Bending strength, longitudinal modulus of elasticity, density and transversal modulus of elasticity.



CETEMAS, Asturias & PEMADE, Galicia

Physical and mechanical properties of Chestnut timber from Spain

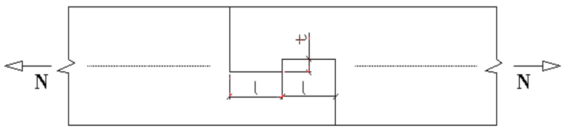
Visual classification and determination of the dynamic MOE using NDT and correlation with static MOE and MOR.

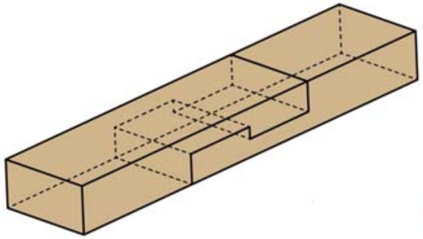
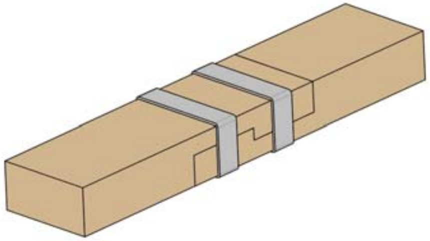
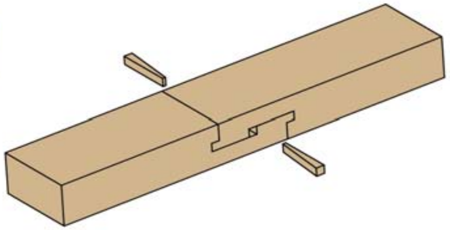


UPM Madrid
Research Group of Timber Construction

Stress analysis in halved and tabled joint by FEM

- To determine the stress distribution in the joint carpenter of halved and tabled joint with the finite element method
- Comparison with values from the therory of Strength of Materials.
- The stress concentration areas where analyzed and the influence of mesh refinement was studied on the results



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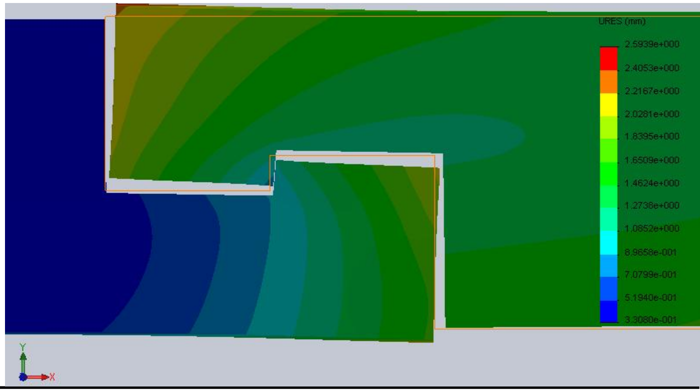
Stress analysis in halved and tabled joint by FEM

- The results show central symmetry of the isobar lines distribution, centre of symmetry corresponds to the geometric centre of the joint.
- In areas where stress concentrations occurs, the same values increase considerably with the refinement of the mesh.
- Comparison of normal stress levels obtained by FEM and classical theory show small differences, except at points of stress concentration

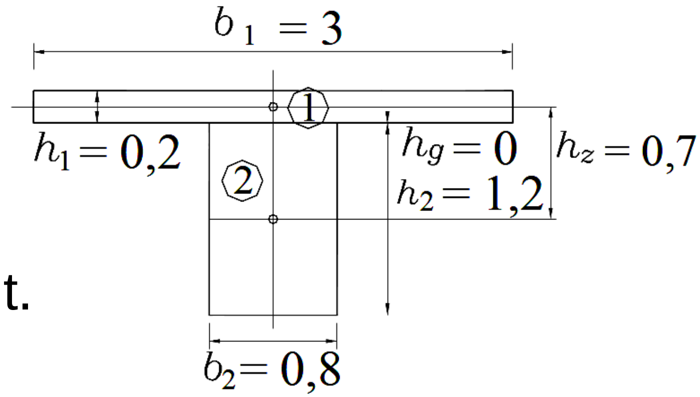


Timber composite beams with a discrete connection system

Objective:

To obtain the flexibility matrix of the whole beam, for a general case with a gap and arbitrary position of the connectors.

- Results compared with the Newmark's differential equation and with FE method
- Changes in temperature and moisture contents can be easily addressed, even though without any transversal gradient.
- The use of the flexibility matrix has the interest of using an analytical tool



section type without gap (measurements in meters)

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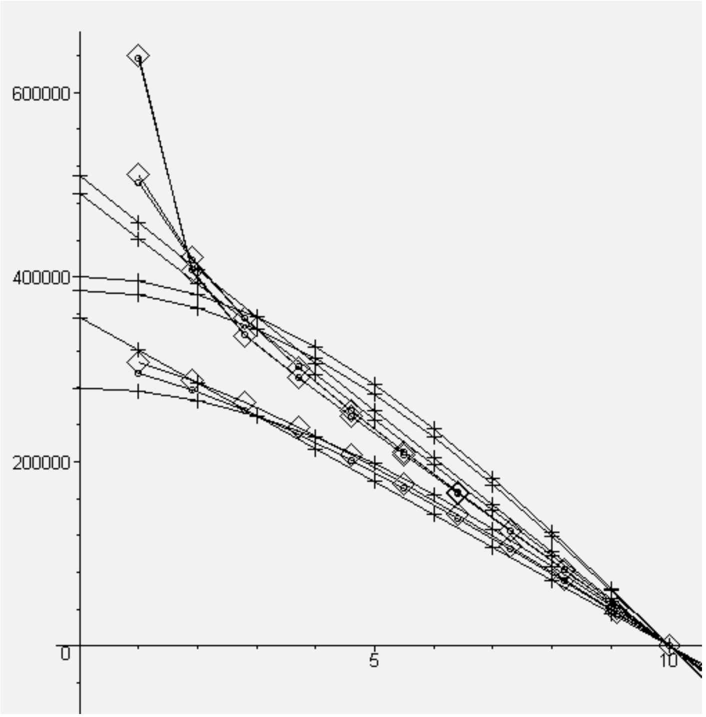
Timber composite beams with a discrete connection system

- The proposed FEM model is very precise and simple to use for practical cases.
- The location of the first connector notably affects the shear force distribution.
- For any practical cases, as e.g. in refurbishment, the use of the Gamma model (EC-5) is not safe.



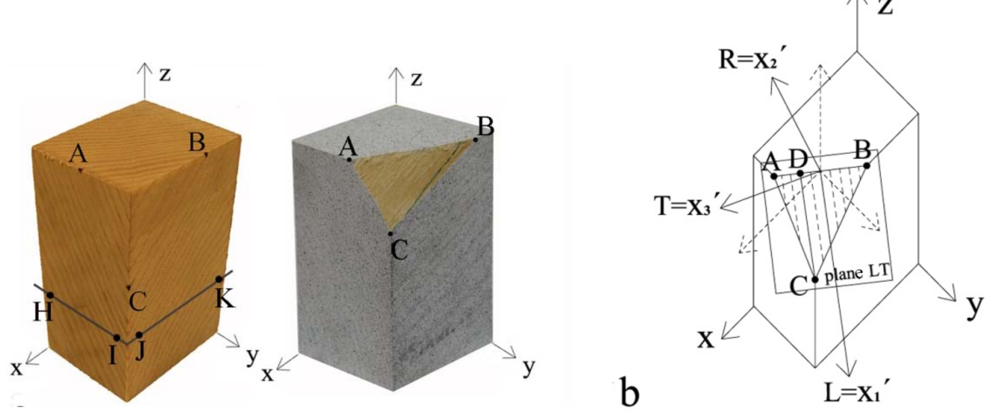
UPM Madrid & GOM, Germany

Characterization of clear wood by a single test

Objectives:

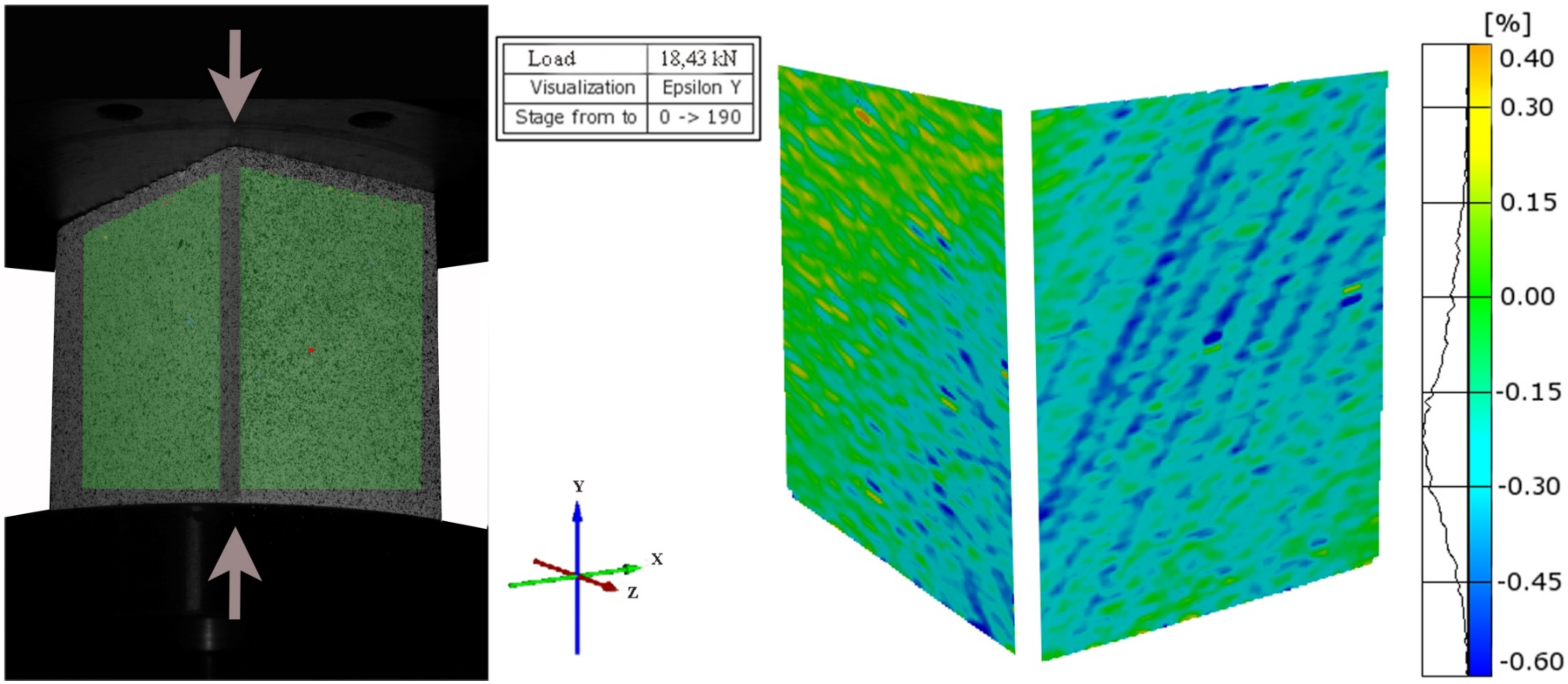
Use of 3D digital measurements to obtain the whole compliance matrix

- Experimental results with a 5Mg pixels 3D equipment (ARAMIS 3D)
- Standard methods need many specimens to obtain data. The new procedures is more robust as all data come from the same specimen.



UPM Madrid & GOM, Germany

Characterization of clear wood by a single test

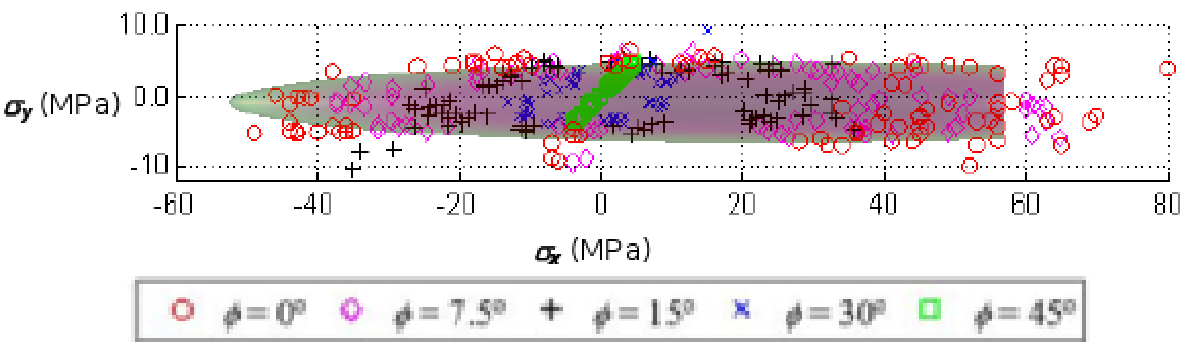


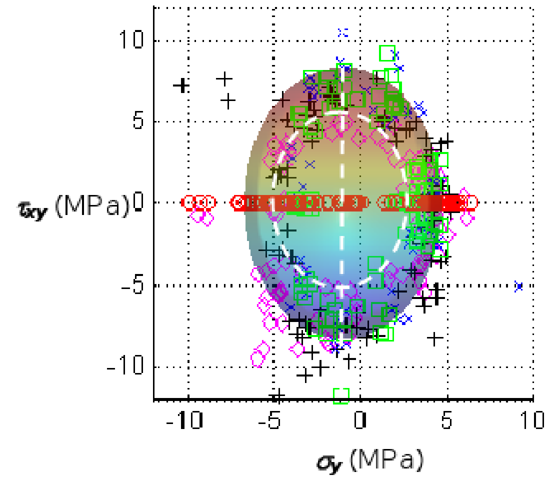
UNAV, Navarra & Cornel University, USA

Failure criteria for wood

- A previous work reviewed different failure criteria proposed for wood under multiaxial loading.
- None of the analyzed criteria obtains adequate predictions for all the loading conditions and failure modes.

Objective: A new failure criterion





UNAV, Navarra & Cornel University, USA

Failure criteria for wood

Objective: A new failure criterion

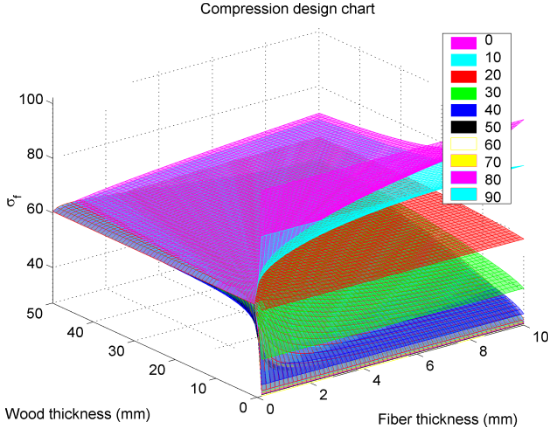
- Considering fiber fracture
- Truncated ellipsoid
- Without using a larger number of fitting parameters than previous models, it provides a better fitting to the experimental results.

New work is under development, with additional collaboration from Prof. Cuntze (Germany).

UNAV, Navarra & TU Dresden, Germany

Analytical and numerical models for fiber reinforced wood

- Analytical and numerical models for fiber reinforced wood to study the structural performance of a novel structural wooden tube.
- Parametric study on the performance of wood reinforced tubes submitted to axial compression with experimental verification.
- Developed models based on the Classical Laminate Theory in combination with Tsai-Wu failure criteria



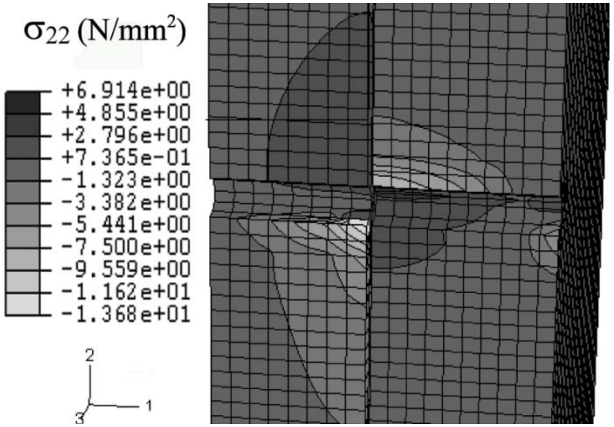
University of Salamanca

Connections with metal dowel-type fasteners in double shear

- To study the design stresses in connections with metal dowel-type fasteners in double shear.
- Results obtained using the rules included in EC 5 will be compared with those arising from the finite element method.

On-going:

Investigation of interaction between stresses and other variables such as geometry, section and material

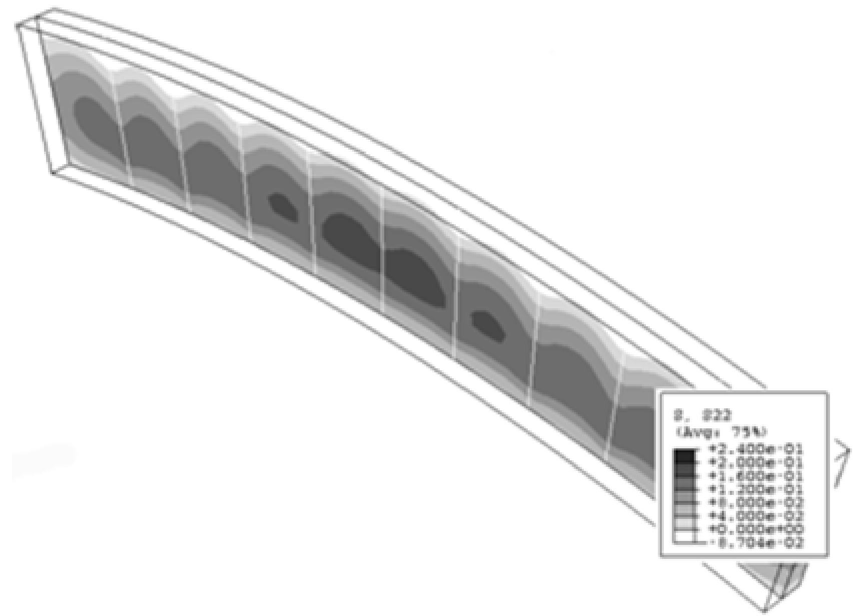


University of Salamanca

Reduction of perpendicular to the grain stresses in the apex zone of curved beams using glued-in rods

- FEM-study of the reduction, using glued in rods, of the perpendicular to the grain stresses in the apex zone of curved glulam beams.

- Practical approach, by conducting a numerical simulation of the stress behavior in the apex zone with the presence of glued-in rods
- Assembly optimization



Sweden

Chalmers University of Technology, Göteborg

Civil and Environmental Engineering, Steel & Timber Structures

Lund University

Department of Structural Engineering

Linnaeus University, Växjö

School of Technology, Building Department

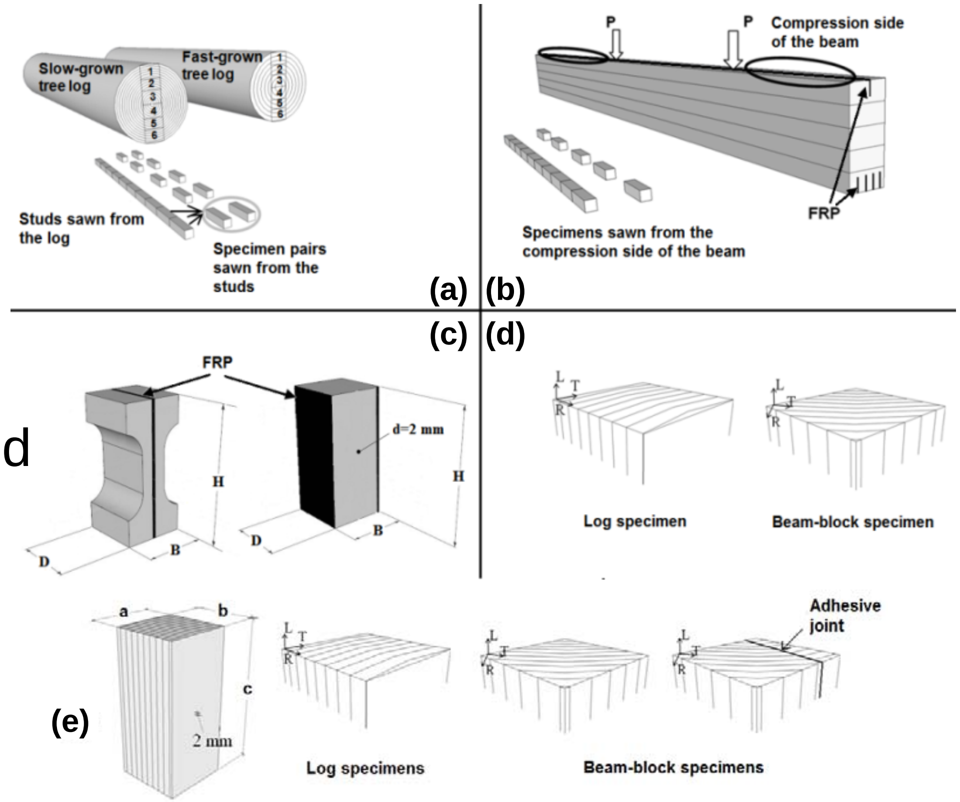
Compression failure mechanism of wood reinforced with FRP

Aims of the investigation :

a) Determine experimentally the stress-strain relationship of CFRP-reinforced wood spec. under uniaxial compression

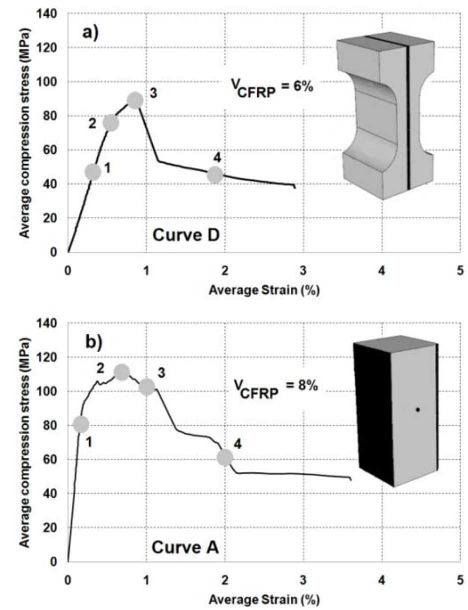
b) Mechanism of compression failure in CFRP-reinforced wood

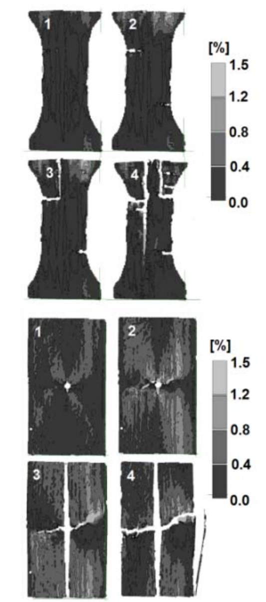
c) Determine experimentally a material model for CFRP-reinforced wood under compression.

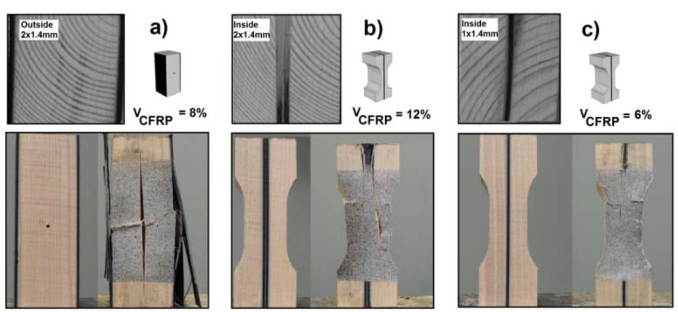


Compression failure mechanism of wood reinforced with FRP

- A large increase in the Young's modulus, peak stress and steady-state stress was observed for most specimens if compared to unreinforced specimens.
- The kinkband was usually initiated in the vicinity of the radius due to stress concentrations

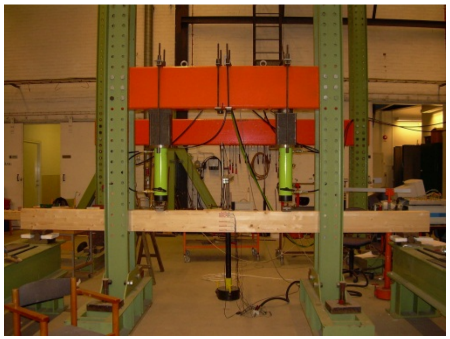


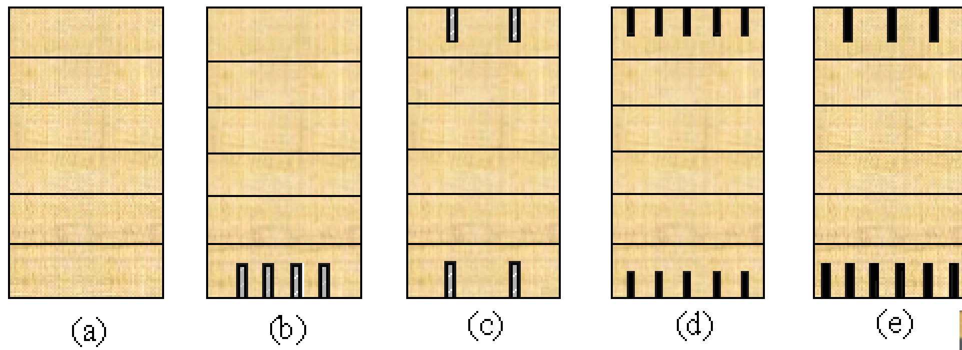




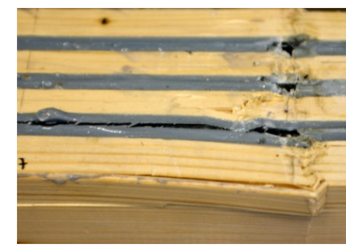
- The mechanism of compression failure was studied using a digital image correlation system (ARAMIS)

Strengthening glulam beams with FRP composites



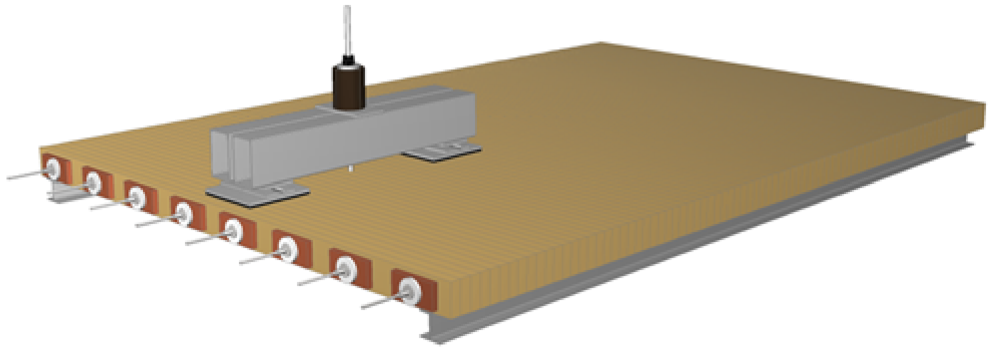


Steel
CFRP
Adhesives



- Much higher stiffness and higher moment capacity
- For same moment capacity, about 30% of glulam can be saved using only 1% FRP of the glulam cross-section area
- Prediction based on experimentally obtained material models do not fully agree with experimental results
- CFRP reinforcement in the compression side of the beam can be accounted for in the developed analytical model based on experiments

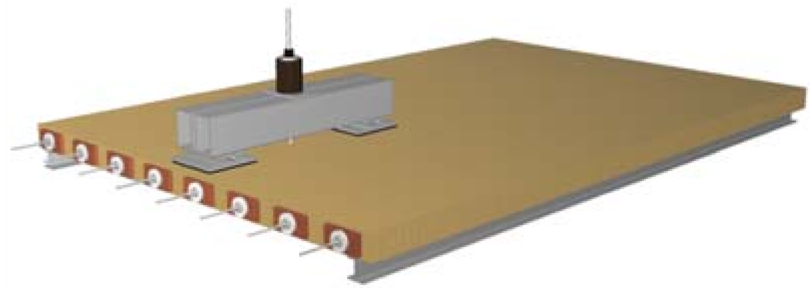
Enhanced understanding of timber bridges subjected to eccentric failure loads



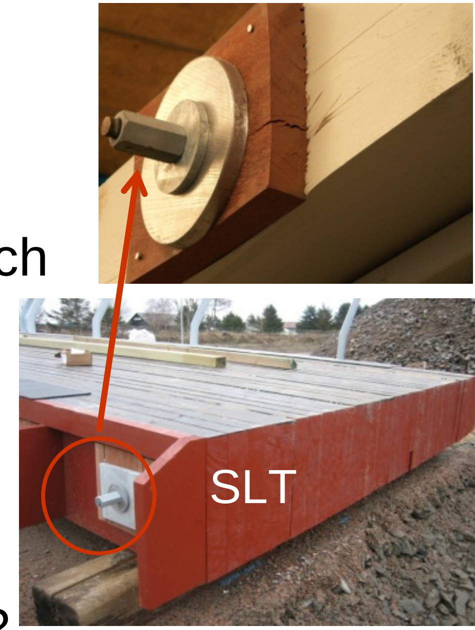
- The objective for the project is to investigate factors influencing the ultimate limit capacity of stress-laminated-timber (SLT) decks.
- Full-scale test of SLT decks has been performed.

Enhanced understanding of timber bridges subjected to eccentric failure loads

- Non-linear deflection behavior was observed for loads corresponding to loads in the serviceability limit state.
- Failure loads were obtained at load levels higher then anticipated.



Enhanced pre-stressed area using self-tapping screws



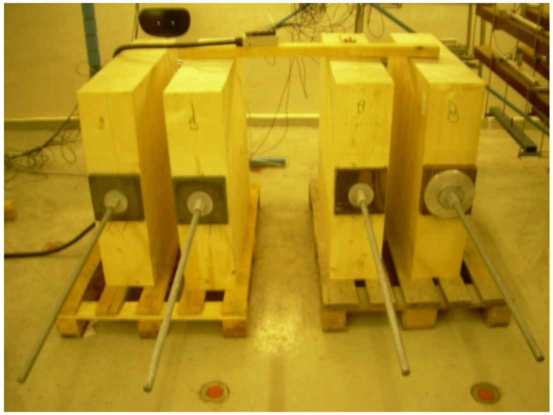
- The pre-tension of the bars introduces compressive stresses in the transverse direction of the deck.
- Problem: loss of tension in the pre-stressed bars, which leads to a reduction in the structural efficiency.

Objectives:

- Are full-threaded self-tapping screws good alternative as a strengthening systems under pre-stressing bars?
- Prove that failure modes in compression perpendicular to the grain will not lead to a reduction in the performance of the structure due to the loss of pre-stress in SLT

Enhanced pre-stressed area using self-tapping screws

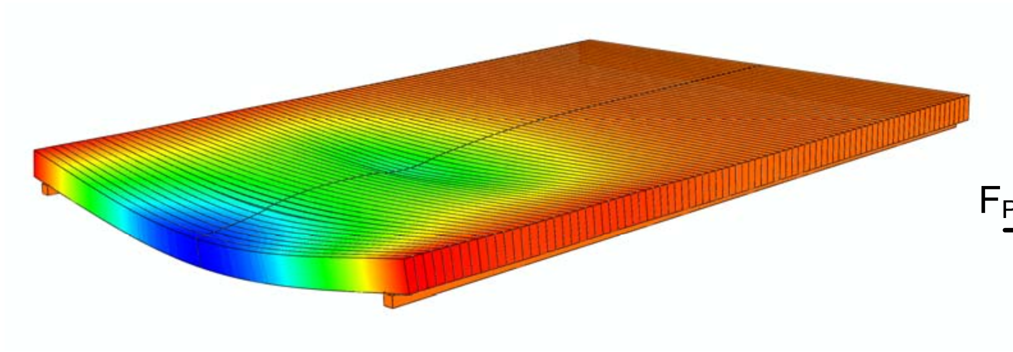
- The reinforcement of compression perpendicular to the grain by means of full-threaded self-tapping screws increases the capacity of the anchorage system by 50 to 85%
- The reinforcement with full-threaded self-tapping screws considerably enhances the performance of the anchorage systems in varying relative humidity

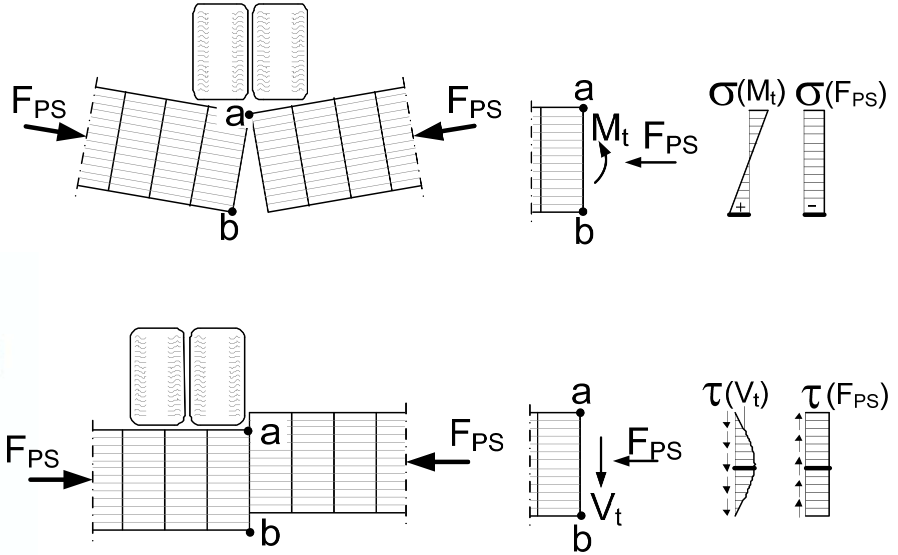


Non-linear FE modelling of stress-laminated-timber decks

Objective: Develop methods and procedure for numerical modelling of interlaminar slip and transversal gaps in stress-laminated-timber decks.

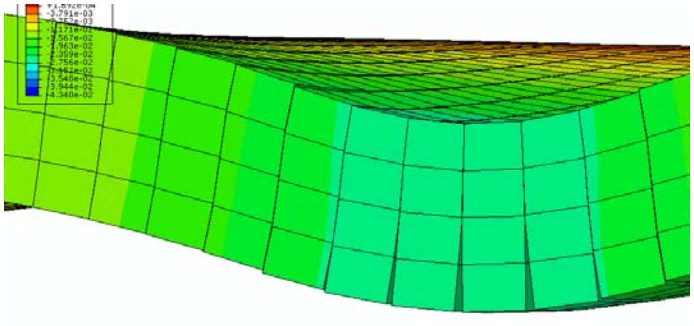
FE models used for simulation of gaps and slip influence in between laminations

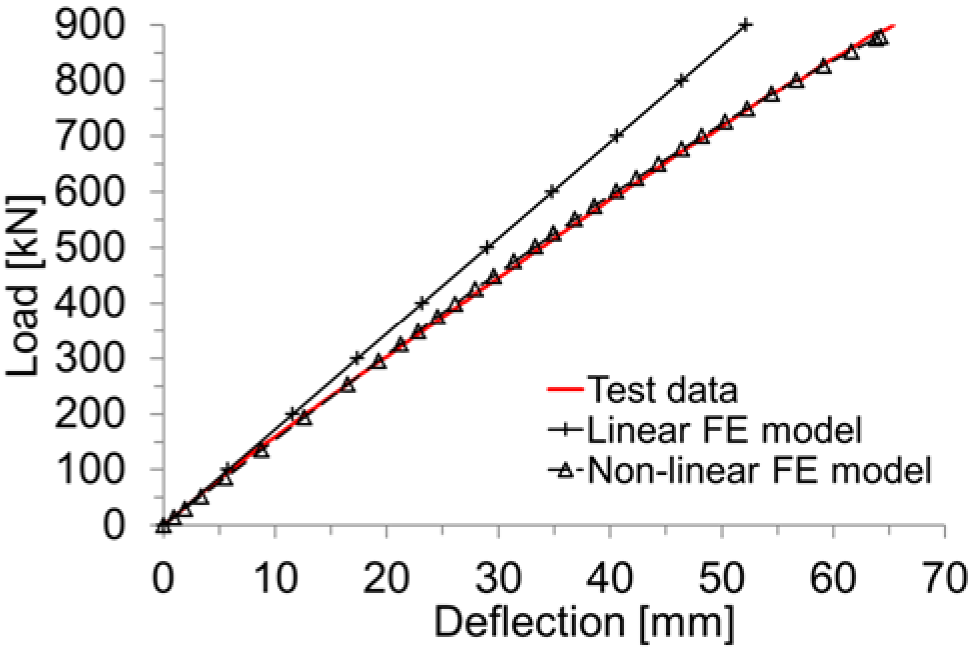




Non-linear FE modelling of stress-laminated-timber decks

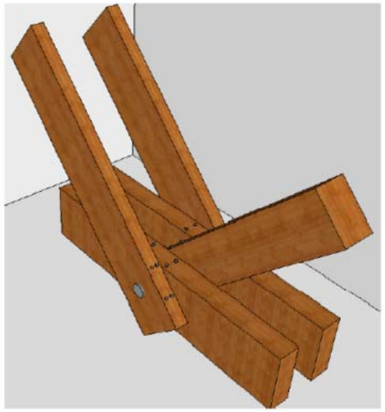
Non-linear behavior of deflection is mainly due vertical and horizontal interlaminar slip in between laminations.

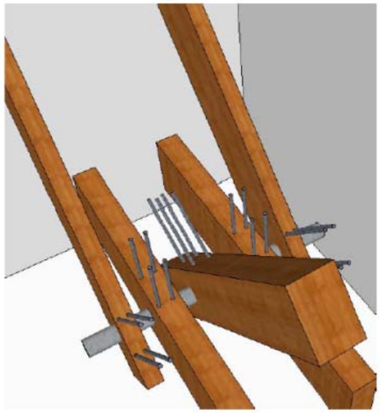




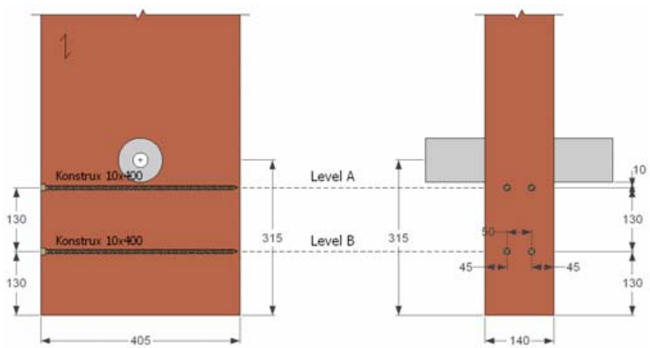
Strengthened single dowel connections

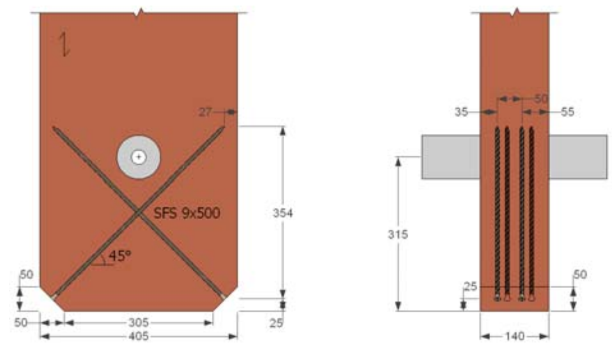
- Objectives: Check the feasibility of a reinforced single-large-dowel connection
- Aim of the research:
  - Investigate behavior of the novel node
  - Focus on splitting
  - Evaluate suitable reinforcements
- How?
  - Full-scale test series

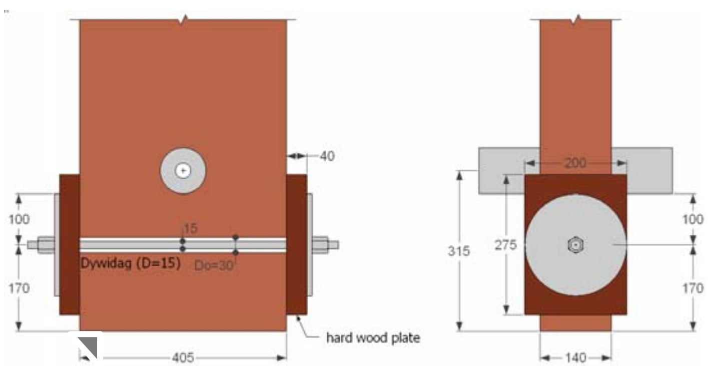




Strengthened single dowel connections







Method A&B → + 70 ÷ 80%
Method C → + 130%

- Reinforcing screws impede splitting and can significantly enhance the bearing capacity
- Lateral prestressing is suitable to prevent splitting and enhancing bearing capacity

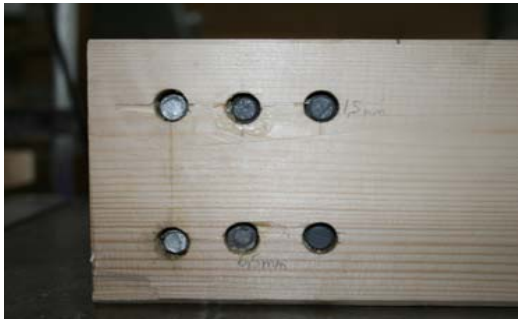
Compression perpendicular to the grain

Aim of the research:

- Check the compression strength perpendicular to the grain in real beams
- Check the influence of support length
- Investigate the behavior of different strengthening method:
  - Nail plates
  - Glued-in rods
  - Glued-in birch rods

Birch rods d=19

Steel rods d=12



Compression perpendicular to the grain

Main conclusions

- Compression perpendicular to grain strength decrease with increasing support length
- Nail plates increase compression perpendicular to grain strength significantly (they are normally disregarded during design)
- Both steel rods and birch rods increase compression perpendicular to grain strength significantly
- Birch rods allows for a more accurate manufacture. More “user friendly”

Timber-concrete composite floors with fibre reinforced prefabricated slab

Aim of the research:

Test of innovative shear connectors for prefabricated floor elements

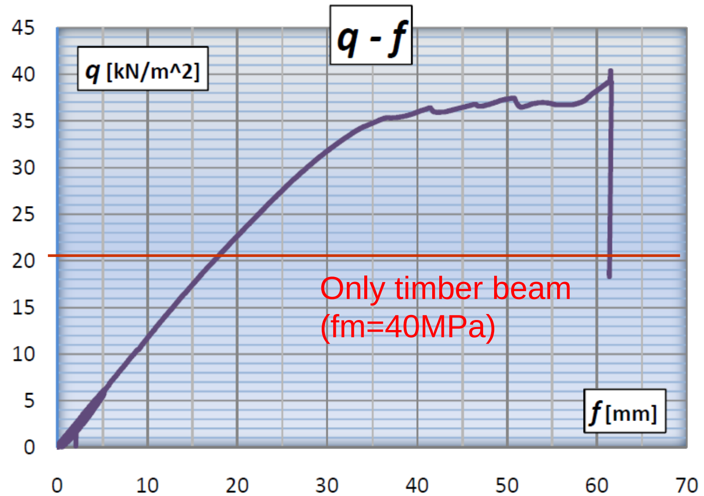
Formwork with installed wooden shear anchors-keys

Formwork with installed steel tubes for insertion of screws

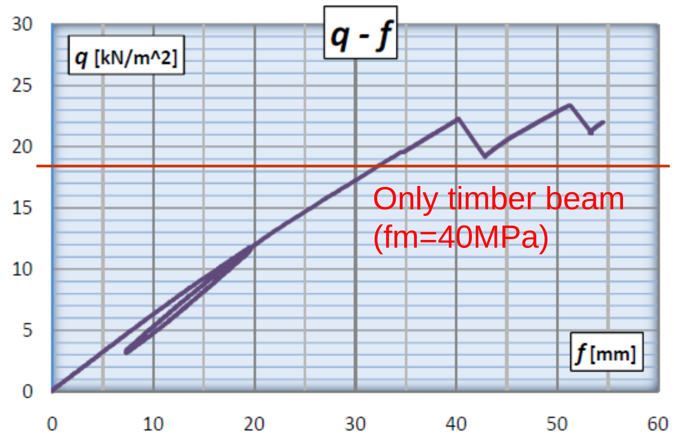
Timber-concrete composite floors with fibre reinforced prefabricated slab

- Suitable for prefabrication and reinforcing existing timber floors
- Considerable increase in strength and especially in stiffness

Composite floor, 1,6 m x 6 m
-2 beams 90x360, c/c=800
-Wooden shear connectors



Composite floor, 1,6 m x 8 m
-2 beams 90x450, c/c=800
- screws in steel tubes



Split beams with large hole (d/h = 0,5)

Aim of the research:

- Influence of large holes placed at mid-span and close to the support
- Influence of reinforcment by means of self-tapping screws

Reinforced

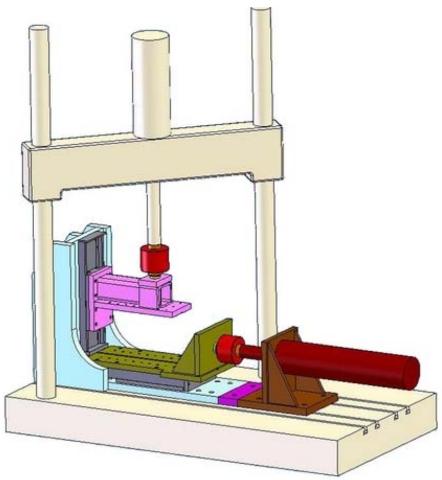
Unreinforced

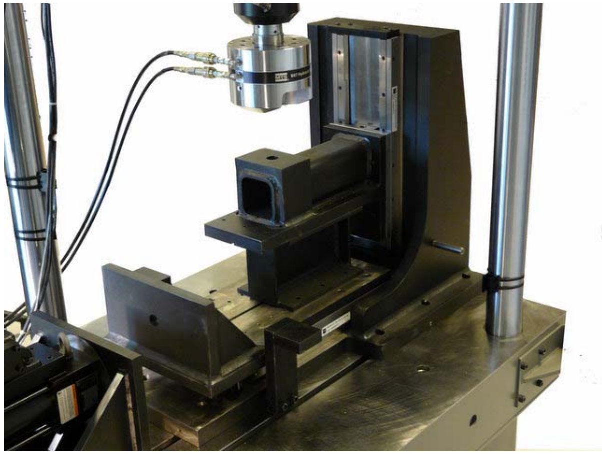
MechWood II

- Finding and using material properties relevant for simulation of the complex behavior in wood.
- The Linneaus University takes part in this project lead by TU Vienna.
- Linneaus University will work particularly with the following topics:
    - Fracture mechanics computations
    - Experimental tests of glulam and CLT in medium/large scale
    - Use of DIC-techniques in testing/calibration of computations
    - Influence of knots/deviations in grain direction on strength

Timber joint fasteners in mixed mode loading

- Objective: to find coupling effects in timber joints in order to be able to simulate the joints in a more detailed manner.
- The coupling properties will be investigated experimentally (biaxial testing) and simulated in FE- software.

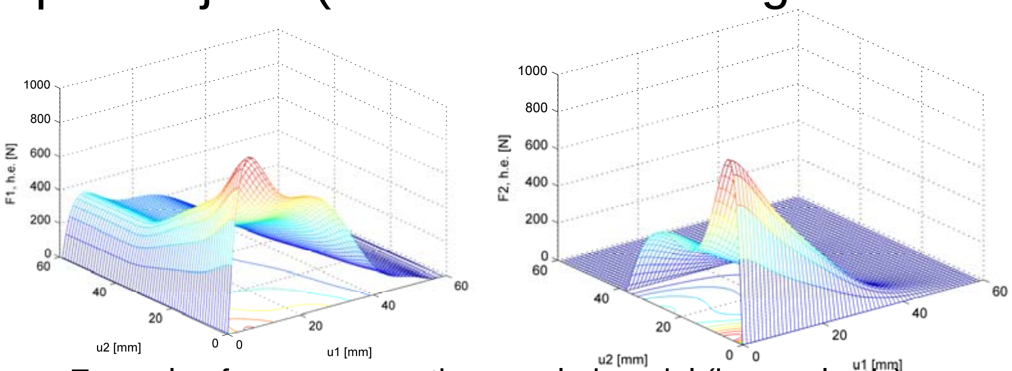




Timber joint fasteners in mixed mode loading

- Introductory simulations based on assumptions on different coupling behavior have already been performed, see figure below.
- All elastic models (they are correct only under certain conditions)

Next steps: experimental tests to be base for a numerical model of a specific joint (start with sheathing-to-framing joint for a shear wall)



$$\mathbf{K}^{\tan} = \frac{\partial(F1, F2)}{\partial(u1, u2)} = \begin{bmatrix} \frac{\partial F1}{\partial u1} & \frac{\partial F1}{\partial u2} \\ \frac{\partial F2}{\partial u1} & \frac{\partial F2}{\partial u2} \end{bmatrix}$$

$$\frac{\partial F1}{\partial u2} = \frac{\partial F2}{\partial u1}$$

Example of one conservative coupled model (hyper elastic)

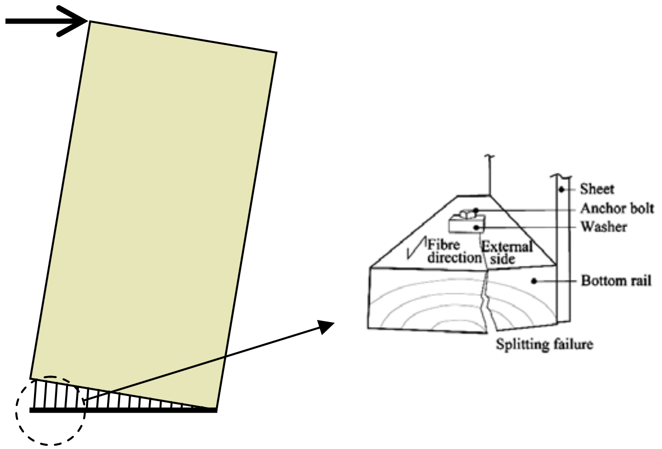
Linnaeus University, Växjö

School of Technology, Building Dept.

Modeling of fracture in the bottom rail in shear walls

Objective: to find closed form expressions for the critical load in an eccentrically loaded bottom rail in partially anchored shear walls.

- In a plastic design philosophy any brittle failure is devastating.
- Failure may occur in eccentrically loaded partially anchored shear walls



Modeling of fracture in the bottom rail in shear walls

- In the current project the topic is addressed by suggesting a closed form expression for the critical load in the rail.
- The expressions are verified by models based on fracture mechanics and on experimental tests.
- Good agreement has be found for a certain case and the next step involves including any loading case including sheathing on both sides.

Switzerland

Bern University of Applied Sciences, Biel

Architecture, Wood and Civil Engineering

EMPA, Dübendorf

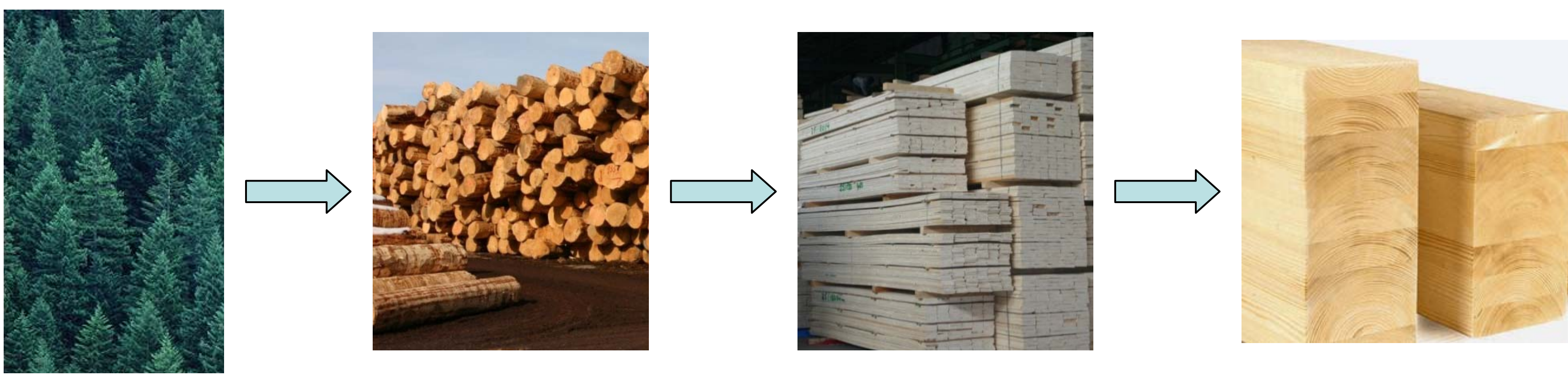
Structural Engineering Research Laboratory

ETH Zürich

Institute of Structural Engineering

Development of an integral production chain for high quality products

- Adjustment and optimization within the production chain
- Increasing of the speed of the grading
- Better accuracy of the grading by reducing the criteria used



Development of an integral production chain for high quality products

→ Reduction of the production cost
→ Optimization of the utilization of the raw material
→ Ensure of the mechanical properties

Further on-going work

- Tension tests of graded lamellas
- Production of specific glulam beams and finger-jointed lamellas
- Testing of the glulam beams and finger-jointed lamellas

EMPA Dübendorf
Structural Engineering Research Laboratory

High strength glued-laminated timber made from hardwood: Implementation as standardized construction product into market

- State of the art – research, products, objects, standards, approvals
- Identification of knowledge and data gaps
- Set-up of a project series to fulfill requirements for market implementation


EMPA


N'H Lungern


BAFU

EMPA Dübendorf
Structural Engineering Research Laboratory

Glued-laminated timber made from hardwood: Implementation as standardized construction product into market

Aim

- Utilization of the big quantities of hardwood (esp. beech) in Swiss forests
- Provision of high strength hardwood GLT structural elements
- Guaranteed properties and quality on base of standardized requirements

On-going work

- Running project application with a national research fund
- Co-ordination with other national projects for the utilization of Swiss hardwoods in structures
- Set-up of an intensive R&D program

Influence of local material properties on the bearing capacity of glued-laminated timber

- Probabilistic description of the scatter of material properties (within member and between member variability)
- More reliable prediction of the material properties of glulam beams
- More reliable grading methods for glulam lamellas

Further on-going work, next steps etc.

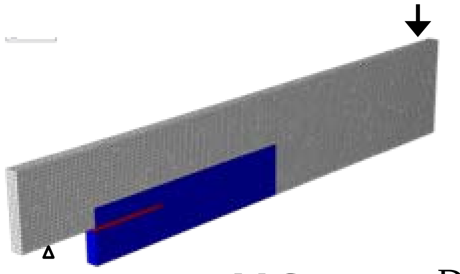
- Experimental analysis on glulam beams with well known local material properties (based on the results of non-destructive tension tests)
- Development of a stochastic FEM to predict the material properties of glulam beams (based on the results of the experimental analysis)

Structural behavior of glulam beams with notches at the support or with holes

- Determining geometrical limitations for unreinforced notches and holes
- Impact of varying material properties on the load carrying capacity
- Defining adequate reinforcements for restoring load carrying capacity
- Taking boundary conditions of practical applications into account
  - Dimensions
  - Strength classes
  - Varying moisture contents
  - Availability and variability of material property values in codes and standards

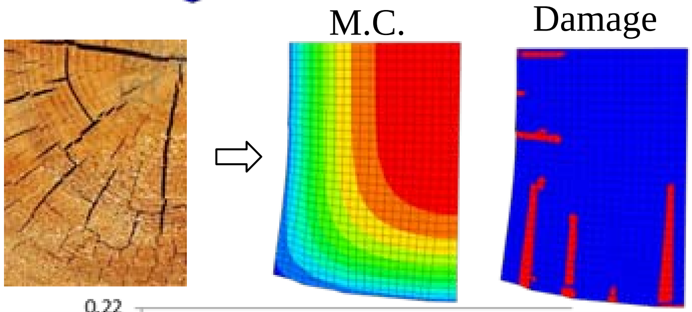
ETH Zürich, Institute of Structural Engineering
EMPA Dübendorf, Wood Laboratory

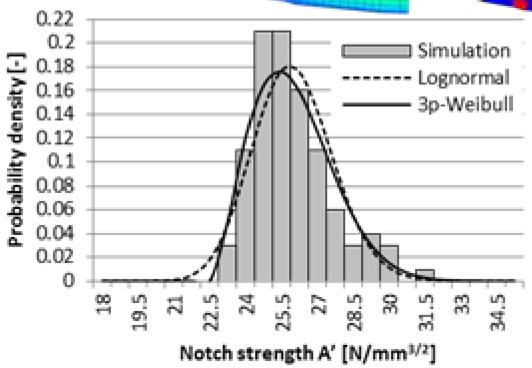
Structural behavior of glulam beams with notches at the support or with holes



On-going work

- Adjusting damage model in FE for crack propagation
- Combining damage model with shrinking and swelling
- Analysis of FE-Models with stochastic variations in material properties
- Analytical model for optimizing the use of reinforcement in notched beams





United Kingdom

University of Bath

Department of Architecture and Civil Engineering

Edinburgh Napier University

Forest Products Research Institute

Edinburgh Napier University

Institute for Sustainable Construction

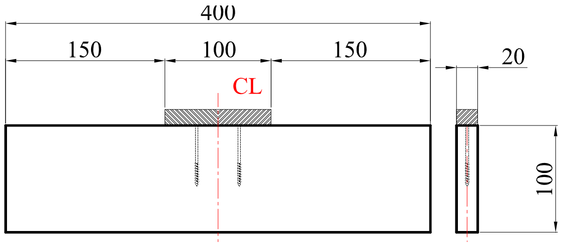
Rotafix, Swansea

University of Bath

Dep. of Architecture and Civil Engineering

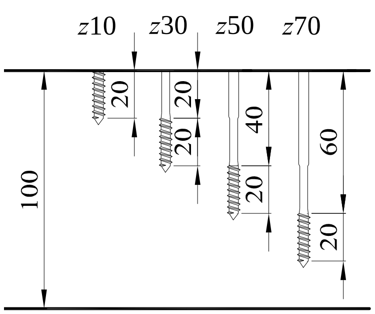
Compression strength of perpendicular to the grain of screw-reinforced wood

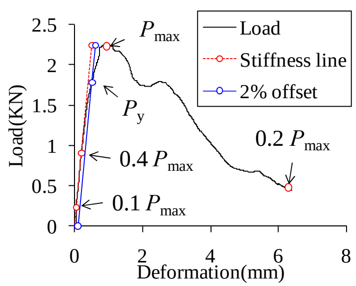
- Explore how effective the screws are to reinforce the mechanical properties of wood perpendicular to the grain
- Propose a model to estimate the strength perpendicular to the grain after the wood is reinforced by screws.



Experiments, considering

1. locations of the screws,
2. number and length of the screws,
3. shapes of loadings,
4. area compression imposed



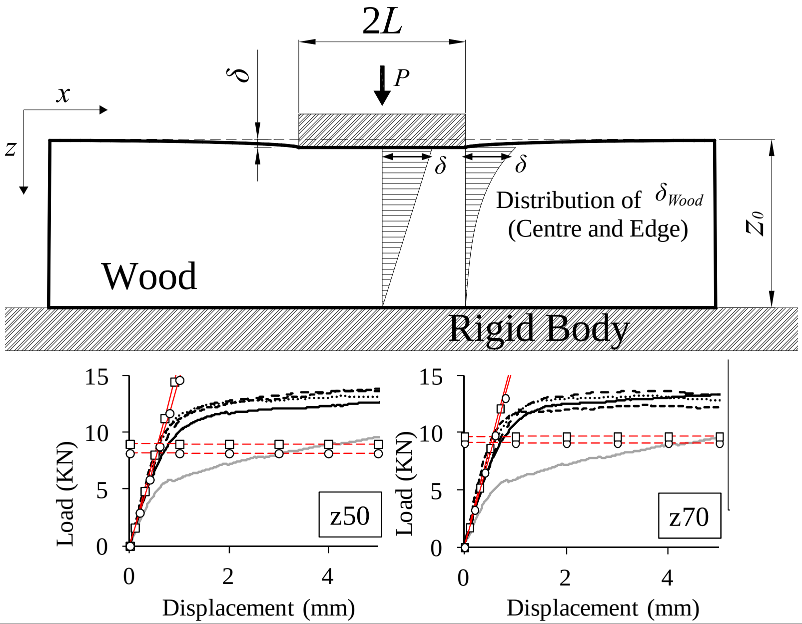


University of Bath

Dep. of Architecture and Civil Engineering

Compression strength of perpendicular to the grain of screw-reinforced wood

- Analytical: distribution of internal displacement along the screw
- Propose a model to estimate the initial stiffness and yield strength of the wood reinforced with the screws.



On-going work:

- Employ non-metallic strategy to enhance mech. properties of timber
- Effect of different reinforcement strategies under dynamic loadings

Thin structural toppings for the upgrade of existing timber floors

- Objectives:

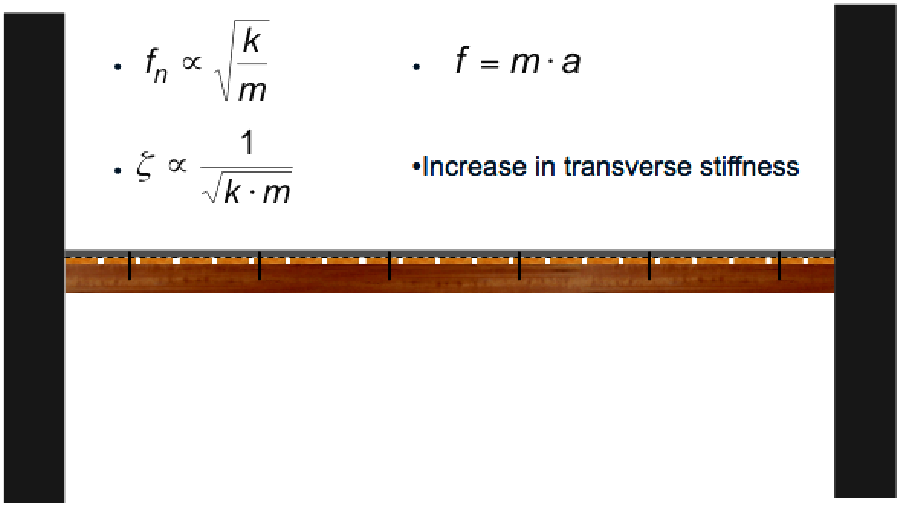
  Understand the opportunities for improved vibration response of thin-topping floors under dynamic load

- Experiments:

  Push-out static and cyclic tests with thin toppings (20 mm)

  - Various shear connectors
  - Various toppings

Consequences of upgrade

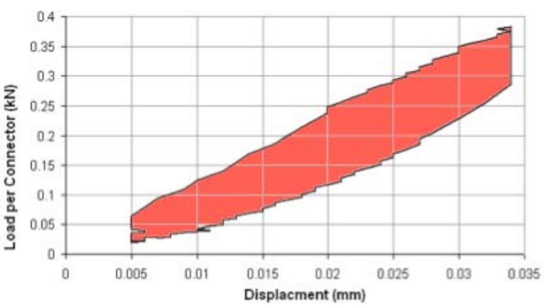


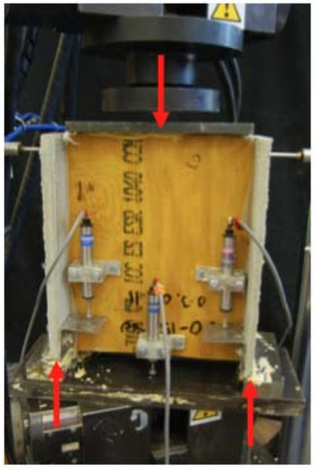
Thin structural toppings for the upgrade of existing timber floors

Initial results:

- Proof of effective energy dissipation demonstrated
- Proof of effectiveness of 20 mm topping demonstrated

Damping

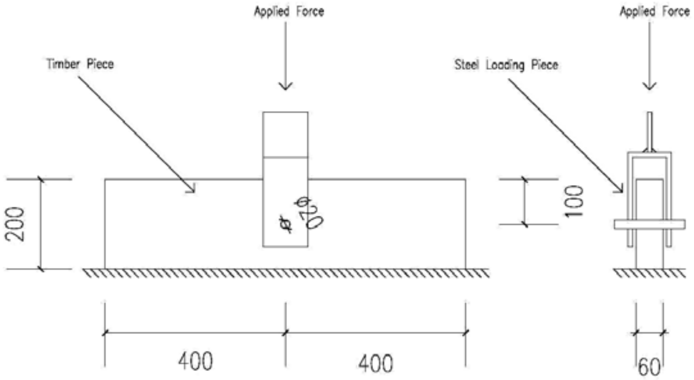




Further on-going work, next steps etc.

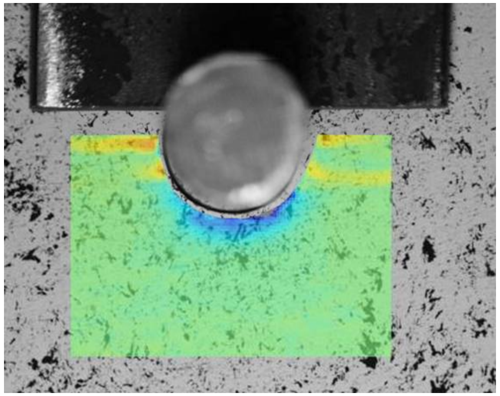
- Slip modulus and energy-slip relationship
- Analytical model to summate energy dissipation along a TCC beam
- Full floor tests for validation and modal response (two-way span etc)

Energy dissipation in dowel-type connectors under small displacement



- Objectives:
  To understand the energy dissipation and hence damping characteristics of dowel-type connectors under cyclic load

- Initial experiments
  Possible mechanisms for energy dissipation:
  - embedment
  - friction and dowel yield



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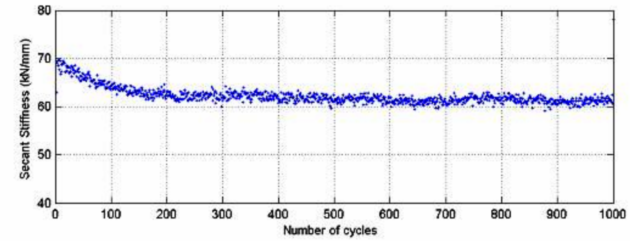
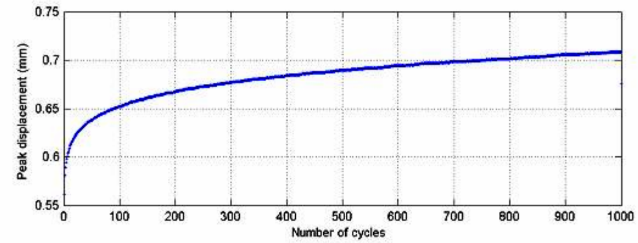
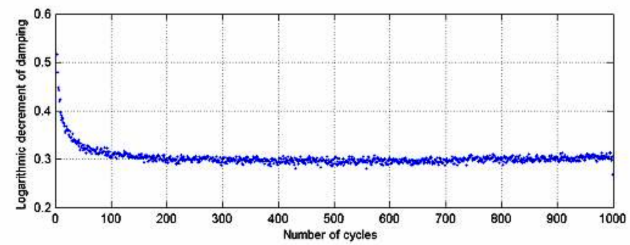
Energy dissipation in dowel-type connectors under small displacement







- Insufficient deformation for dowel yield in the serviceability limit state
- Initial embedment followed by friction, which to continues to provide energy dissipation over many cycles

Further on-going work, next steps

- Isolate friction effects
- Investigate angle to grain effects
- Test dowel groups and apply to full frames

Edinburgh Napier University
Forest Products Research Institute

Strategic integrated research in timber (SIRT)

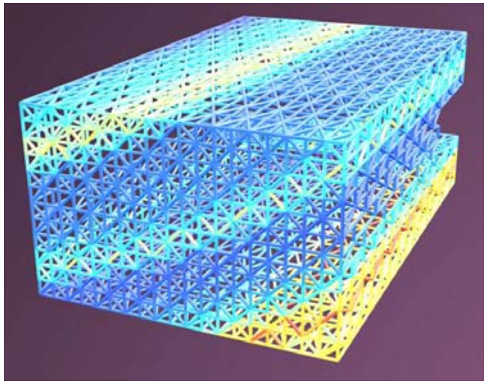
- Understand the nature of the UK forest resource
    - Quality and variation
    - Drivers of quality (growing and processing)
    - Modelling of wood quality (statistical and numerical)
- Improve utilisation of UK-grown timber
    - Improved growing and processing
    - Accessing existing markets (imported timber)
    - New products and uses
- Timber testing and grading rules
- Feeds into projects about timber construction
- Part of a wider ERDF funded project

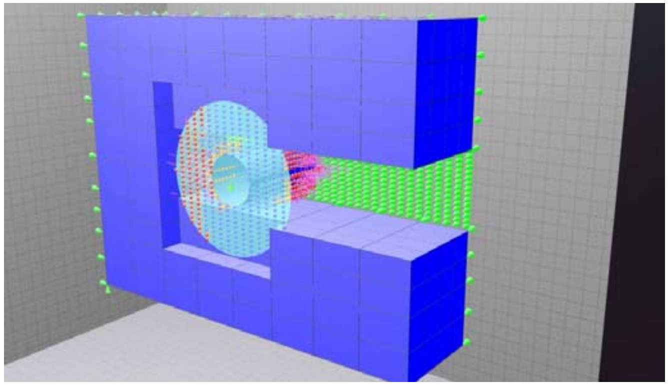
Strategic integrated research in timber (SIRT)

	Region	Forest Research Forestry Commission
km	Forest	
	Stand	
	Tree	
m	Log	
	Sawn timber	Centre for Timber Engineering Edinburgh Napier University
cm	Clear wood	
mm	Growth layer	
	Wood anatomy	Department of Chemistry The University of Glasgow
	Cell	
µm	Cell wall	
	Cell wall layers	
	Microfibril clusters	
nm	Molecular	

3D lattice models for timber connections

- PhD project completed 2009 (Thomas Reichert)
- Extending lattice models to 3D
- To incorporate fracture (and complex stress states, 2nd order behavior)
- Tackling issues of computational efficiency
- Method of inelastic forces





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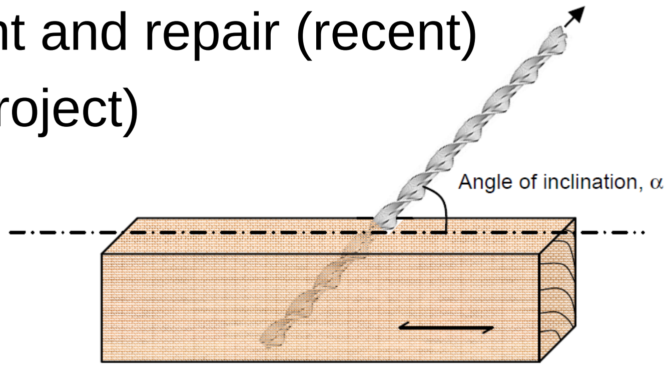
Forest Products Research Institute

Nail and stress laminated timber arch bridges

- Previous work into stress laminated timber arch bridges
- Currently nail laminated timber suspended arch bridges
- For footbridges in rural locations (up to 50 m span so far)
- Supported by the Forestry Commission and a Scottish sawmill

Other projects

- Helical shaped connectors for reinforcement and repair (recent)
- Other fastener development (commercial project)



- Structural Insulated Panels
- Also interested in timber free-form construction.

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Forest Products Research Institute

Modeling dynamic performance

- Large timber trusses (including space trusses)
  - Dynamic
  - Improving numerical simulations (space-time finite element)

- Timber-bamboo composites including modelling of differential thermal and moisture movement.

Dynamic performance of timber roofs and floors

- Timber floors (mainstream timber frame)
  - Dynamic
  - Experimental and numerical simulations
- Timber roofs (trusses)
  - Dynamic
  - Numerical simulations

- Future
  - Composite timber-concrete flooring systems

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Wood chemistry

- Water sorption and desorption
  - Fundamental understanding
  - Influences micromechanical behaviour
  - and duration of loading effects

- Wood modification
  - Changes in mechanical properties → mitigation of e.g. brittleness

- Also interested in adhesive free bonding.

Edinburgh Napier University
Institute for Sustainable Construction

Cross laminated timber from UK timber

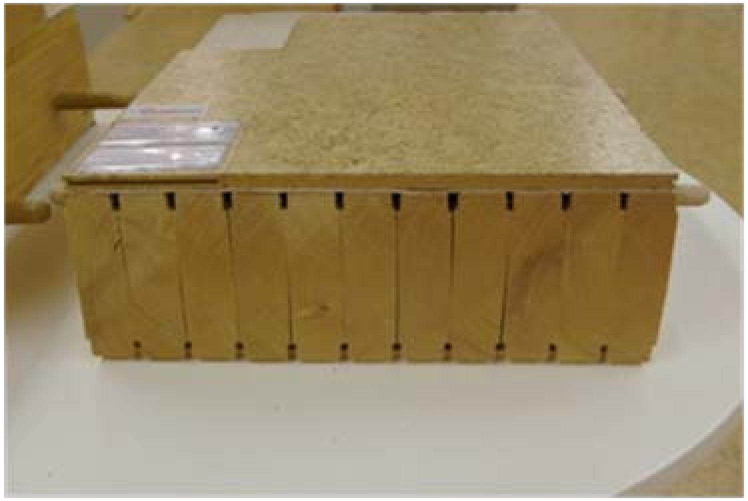
- Also part of the ERDF project
- Sitka spruce (mainly)
  Also Douglas-fir, Scots pine
  larch, Western Hemlock
  & Lawson cyprus
- Fabrication issues
- Performance
  - Testing
  - Modelling
- Economically suitable design/detailing

Glulam from UK timber

- With Norbuild – a small-scale glulam producer
- Sitka spruce and Scots pine
- Dealing with lower grade / variable material / distortion and mc

Stacked plank from UK timber

- With David Blaikie Architects
- Application is off-site modular construction
- Service core for regular timber frame
- Performance
  - Testing
  - Modelling



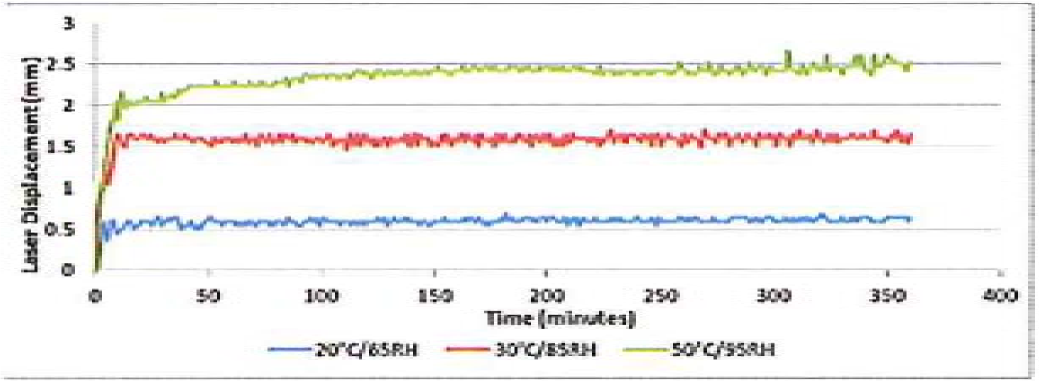
Modified timber

- Commercial projects
  - Structural performance (including creep)
  - Potential for acoustic grading
  - Glulam
- Also
  - Designer support (Tedds software)
  - Product library and proformas

Rotafix, Swansea & Bath University

Creep of a formulated thixotropic adhesive in ‘Bonded in Timber Connections’ as function of temperature and humidity

Objective: Demonstrate that ambient cured systems can withstand high humidity and high temperature



Rotafix, Swansea & Bath University

Creep of a formulated thixotropic adhesive in 'Bonded in Timber Connections' as function of temperature and humidity

Conclusions

- Between T_g and T_g +15°C epoxies behave like classic viscoelastic polymers. Above T_g +15°C they behave like rubbers with no creep
- Epoxy adhesive are a suitable method for structural connections even if operating outside the theoretical T_g limits and temperature range.
- T_g of certain ambient cured epoxy formulations can increase over time. Samples that were 1 year old had a T_g 10°C higher than recently cured samples of the specific adhesive manufactured samples.

Rotafix, Swansea & Bath University

Bonded in rods performance in EWP, LVL, hardwood

Objectives: Prove suitability and compatibility of epoxy adhesives when used in conjunction with EWP, LVL and Hardwood

Establish bond strength performance for EWP, LVL, Hardwood

ADHESIVE	SHEAR STRENGTH (MPa)	
	(TIMBER- ADHESIVE)	(ROD- ADHESIVE)
RSA - LVL	6.40	9.60
RSA - ACCOYA	8.53	12.79
RSA - RADIATA PINE	9.29	13.94
EA - LVL	6.47	9.71
TIMBERSET - LVL	6.11	9.17

Rotafix, Swansea & Bath University

Bonded in rods performance in EWP, LVL, hardwood

Initial Results

- Initial Tests show that epoxy adhesives performance improved in hardwood
- Acetylation process had made the wood brittle

Further work

- Further testing of performance including shear, compression

Rotafix, Swansea & Woodsfield Engineering, Malaysia

Long-term stability of bonded rods joints in MTIB Malaysia

- Objective: Practical testing of creep at elevated temperatures and humidity.
- Measures: Surface temperature, of timber, adhesive and anchor surfaces in joint assembly

Rotafix, Swansea & Woodsfield Engineering, Malaysia

Long-term stability of bonded rods joints in MTIB Malaysia

Conclusions

- Initial measurements complete post installation.
- 3 month results show no difference in the temperature between the joint and the surface ambient temperature, this would suggest no creep has occurred.

Further work

- Monitoring equipment remains in place
- Measurements continue for minimum 36 months following completion of the structure