COST Action FP1004

Final Meeting

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Cross-laminated timber : modelling of connections using self-tapping screws

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Development of a new SIP based on CLT

Composition

- CLT panels with a thickness of 57mm

(3 plies of wood, made by KLH)

- Semi-rigid insulation : wood wool

- Self-tapping screws for the connections

(WR-T reinforcement screws by SFS and Rothoblass)

Development of a new SIP based on CLT

Aim

- Greener product :
  - lower embodied energy
  - recyclable
  - Insulation is no longer glued to timber

- Diminution of the wood consumption thanks to the I-beam behavior

- Higher level of prefabrication (insulation is included, water protection and cladding could be added in factory)

Development of a new SIP based on CLT

Mechanical behaviour

• Like for a structural insulated panel

• **Insulation** rigidity is **neglected** and replaced by self-tapping screws (STS)

•STS counteract any shear displacement and avoid load bearing problems

•STS can be screwed with different screwing angles

•Different screw features and patterns have been tested in laboratory (number of screws per m², screwing angles, directions, diameters,…)

Development of a new SIP based on CLT

Mechanical behaviour

•The number of screws has to be minimized for financial and technical reasons (thermic, rapidity of production,…)

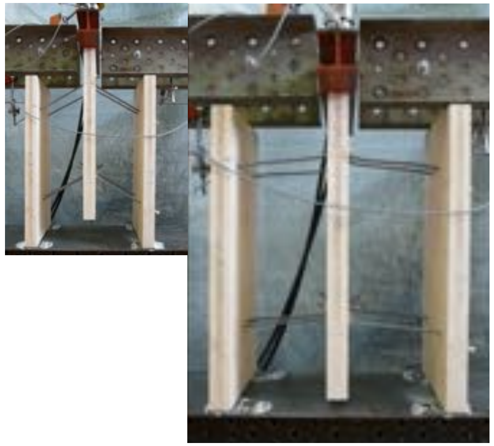
•Finite element models have been developed for each configuration

•Calibrations have been done thanks to experimental results

→Objective : develop design rules for this kind of connections

Finite element modelling of connections

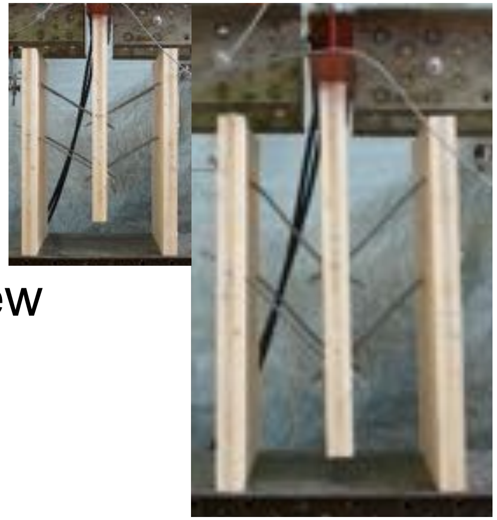
Compression and shear of the screws



2 failure modes :

- ductile failure with a plastic hinge at the interface
- buckling of the screw

Tension and shear of the screws



2 failure modes :

- ductile failure with a plastic hinge at the interface
- brittle failure of timber due to the pull-out of the screw

Modelling method (Abaqus)

Second-order models are used to represent the ductile failures and the buckling.

The model for the screw is elastic – perfectly plastic

The timber is modeled thanks to the Hill criterion

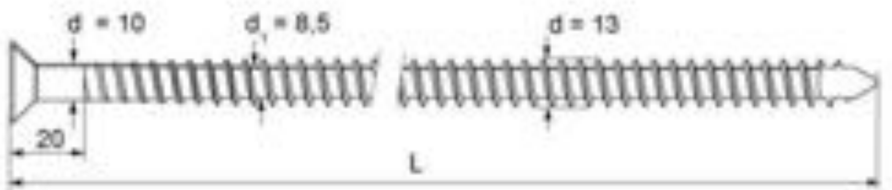
The brittle failure at the interface between the wood and the screw is introduced by means of a cohesive surface (like a 3D springs system).

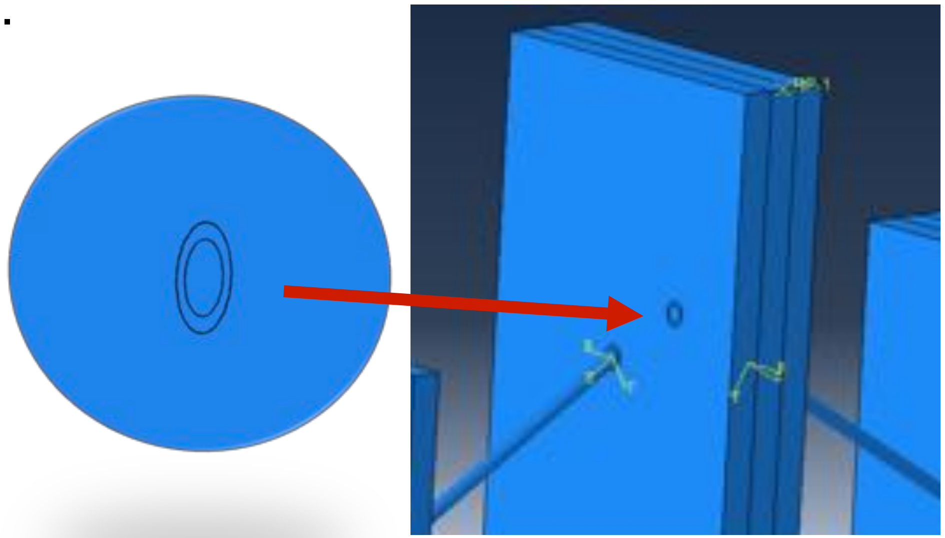
In our case, only the springs parallel to the screw axe have been used to prevent unrealistic tension stresses when the screw embeds the wood.

Finite element modelling of connections

Modelling method (Abaqus)

- The brittle failure is always positioned at a diameter of 13mm or higher (outer diameter of the screw)
- Screws are modelled with a smooth shank of approximately 9mm to respect the rigidities (EA and EI)
- A fictitious material, perfectly elastic and relatively soft, is used to fill the gap between the different diameters.





Modelling method

- The fictitious material has a radial E modulus that is relatively low. It minimizes the stress concentrations, which has an important impact on the Hill criterion and helps to converge . Other mechanical properties are similar to the wood

- The Hill criterion uses the mean values for spruce to allow an easier correlation with the experimental tests. It is not possible to differentiate the tension and compression properties. The smallest value is chosen for each case (longitunal strength, transverse strength,…)

Finite element modelling of connections

Modelling method

Hill criterion			
$F_{c,0,mean} = F_{t,0,mean}$	$45MPa$	$\tau_{12} = \tau_{13}$	$7MPa$
$F_{t,90,mean} = F_{c,90,mean}$	$3MPa$	τ_{23} (rolling shear)	$3.5MPa$
Soft material			
Radial E modulus	$50MPa$	Tang. and long. E mod	$370MPa$
G modulus	$600MPa$	Poisson coefficients	0
Cohesive surface			
Long. rigidity	$40N/mm^3$	Tang. and rad. rigidities	$0N/mm^3$
Shear stress limit	$5MPa$	Damage evolution	linear ($0N$ after $4mm$)

Finite element modelling of connections

Models

- Different models have been developed to consider the different loading conditions

  - Pull-out tests : characterization of the withdrawal capacity
    - Brittle failure → cohesive surface

    2 models : one for a comparison with the ETA (load capacity), one based on the experimental results of R. Jockwer (stiffness and post-failure behavior)

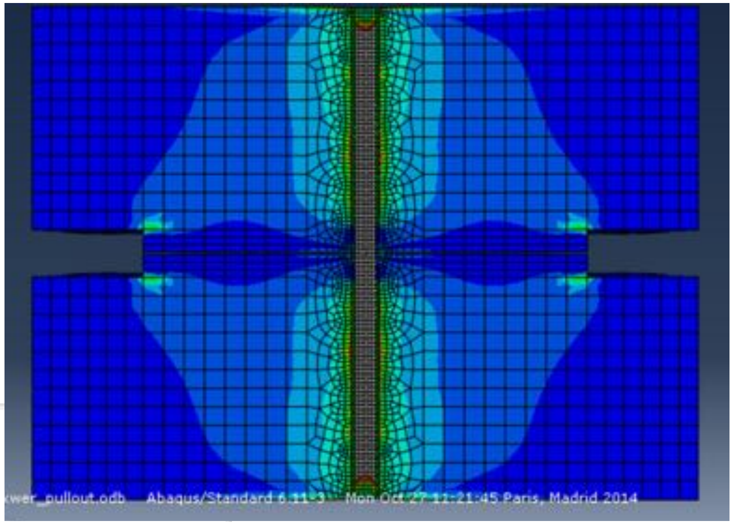
  - Triumphal arches: characterization of the shear capacity
    - Ductile failure (bending of the screw and embedment of the wood) → Hill criterion and plasticity of the screw

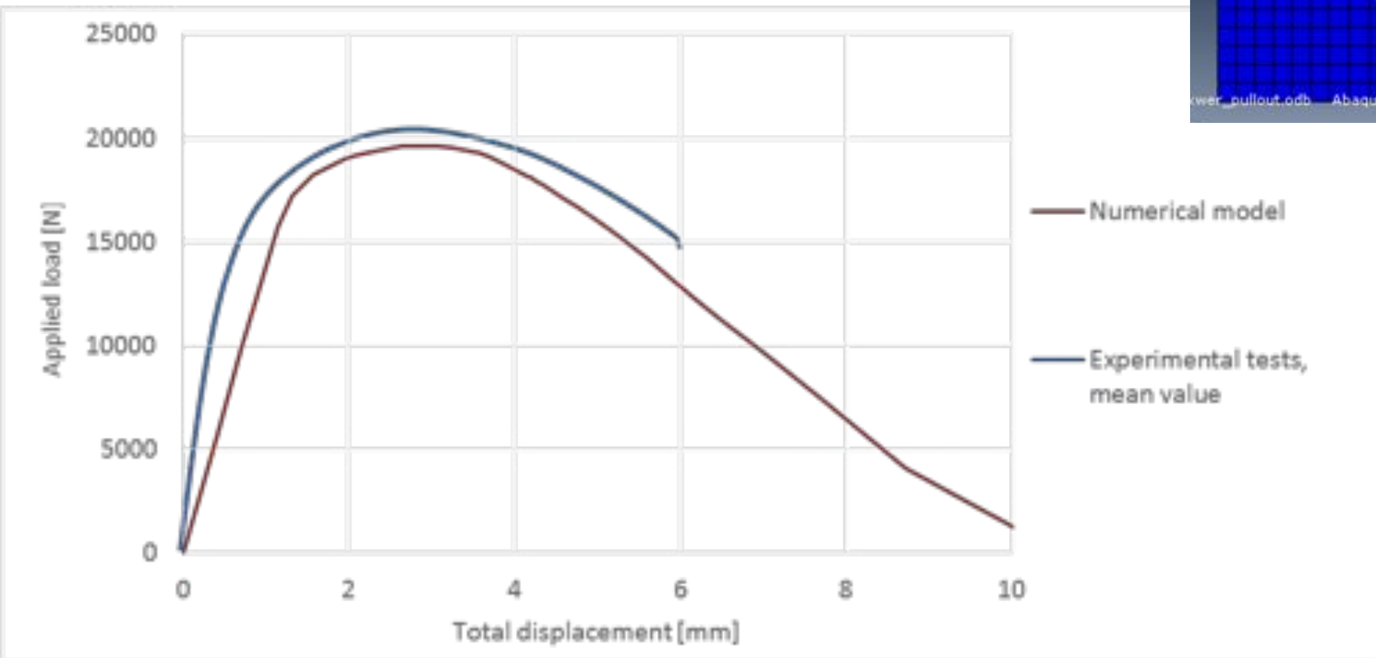
Finite element modelling of connections

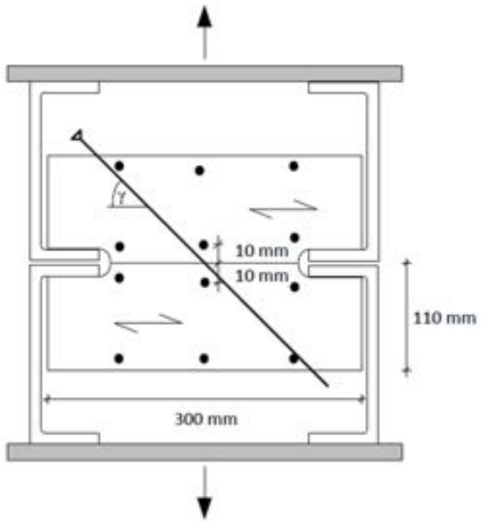
Models

- R. Jockwer

R. Jockwer et Al., Fully threaded self-tapping screws subjected
to combined axial and lateral loading with dierent load to grain angles,
Materials and Joints in Timber Structures, Vol. 9, RILEM 2014, pp.265-272.



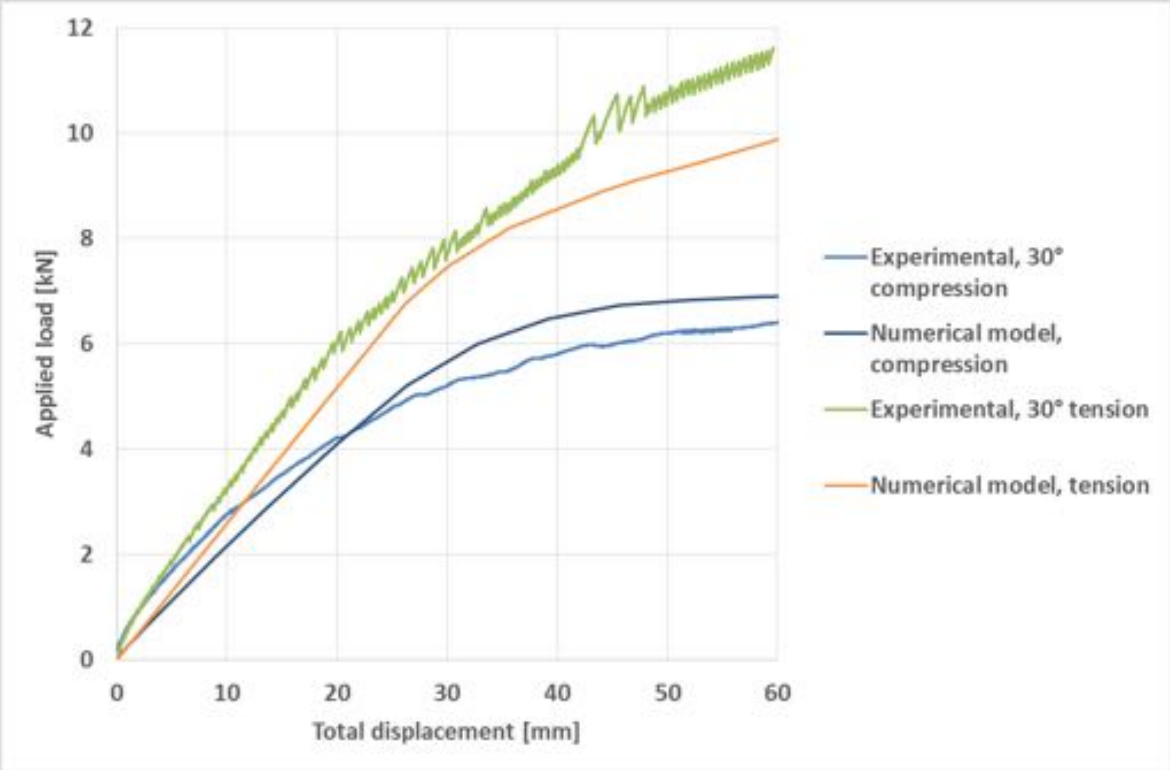


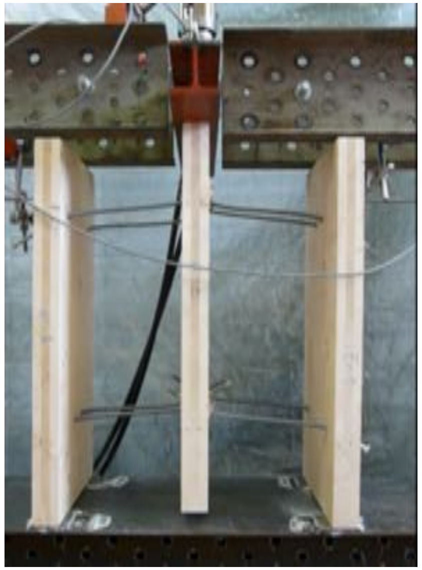


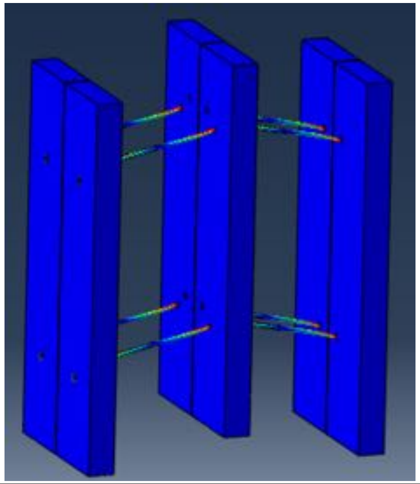
Finite element modelling of connections

Models

Triumphal arches







Calibration

The main part concerned the "soft material"

2 conclusions can be drawn:

- The longitudinal Emod of the soft material largely influences the rigidity for pull-out tests. There is no impact on triumphal arches perpendicularly screwed
- The radial Emod largely influences the stiffness of the connection for thriumphal arches perpendicularly screwed. There is no impact on pull-out tests

→ It is easy to calibrate the model. Any model for screws at different angles could be valid

Conclusion

- A new method to model this kind of connections has been developed
- The model is based on a fictitious material and the use of a cohesive surface
- The technique seems efficient, robust and easy to implement
- One set of parameters is sufficient for all the configurations (pull-out, arches, different angles,…)
- Deviations between experimental tests and numerical models are generally smaller than 10%, which is promising given the few number of experimental tests made for the moment (standard deviation not known).

Thank you for your attention !