Short description of the laboratory		
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Main topics	Example of activities	Number of scientists
• **Biomechanics of trees**	Wind stability of trees Growth stresses modelling	**3**
• **Damage mechanics**	Damage accumulation Design of timber components Duration of load experiments Crack propagation in glued joints Non destructive testing of components	**5**
• **Design of composites**	Modelling of glulam beams Creep and stability of structural panels Local reinforcement in composite beams Processes: densification, forming…	**4**

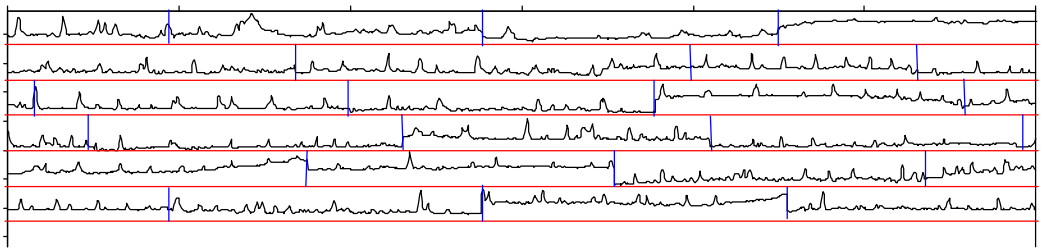
Main equipments : testing machines, climate rooms, bending creep rigs for structural size specimens, vacuum drying kiln, hot press, peeling machine, workstations

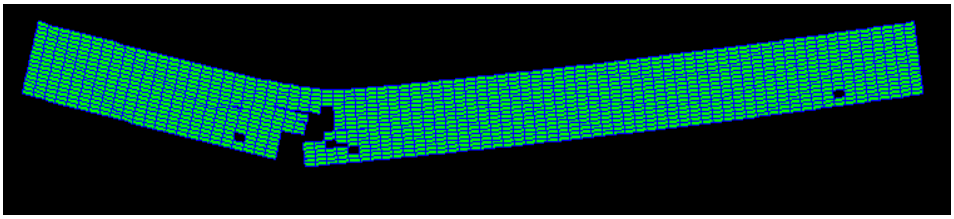
Activities related to the field of COST Action E24

Numerical models for glulam (P. Castéra, B. Lasserre, P. Morlier)

Reliability of glulam in bending

In this work, a probabilistic model of glulam strength in bending is proposed. The main input of the model are the statistical distribution of finger joints tension strength, the strength of glue lines under tangential and normal forces, and the local wood properties within laminations, described using the stochastic field theory. All data have been gathered from experiments or non destructive evaluation (densitometric profiles). The model, which has been implemented in a FE code, is based on a weakest link approach, but accounts for stress redistribution after failure in one element (progressive failure).



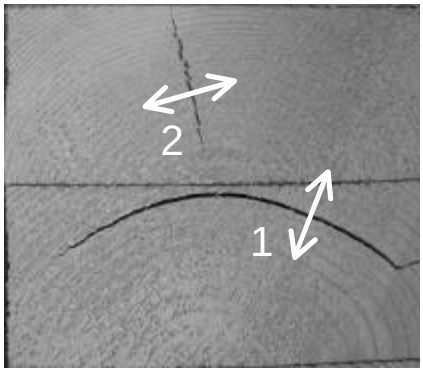


This work was used as a method for studying size effects as well as laminating effects in glulam. It could however be improved regarding the mechanical behaviour of glued joints, and co-operation in the field of COST Action E24 could be an opportunity for improving models.

Long term mechanical behaviour of glued joints in glulam

In timber engineering, glulam beams frequently exhibit incipient cracks, which represent a potential risk for the structure integrity. These beams, even sheltered from direct contact with rain or sun ray, are submitted to temperature and relative humidity variations which influence the mechanical behaviour. A 3D numerical model has been implemented in a FE code, which simulates moisture transfer and damage accumulation in glued laminated beams

The cutting up mode (lamella orientation, pith off-centring) seems to be a parameter influencing the development of these cracks; as a matter of fact, stresses and strains are developing differently as a function of ring orientation in the cross section. Besides bonded joints produce stress concentration which can lead to the failure of the gluing interface.
Specimens of glulam composed of four lamellas are numerically submitted to variations of the climatic environment; the mechanical state is analysed by the way of a criterion based on average values of stresses or strain energy densities according to the Weibull's theory. Comparisons are finally performed between different configurations corresponding to several combinations of lamellas orientation.

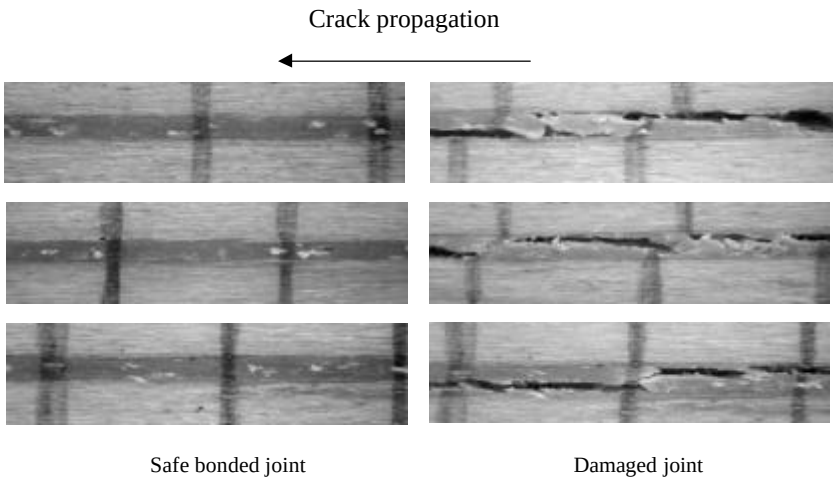


Damage and fracture of wood adhesive joints under shear and opening loading (F. Simon, G. Valentin)

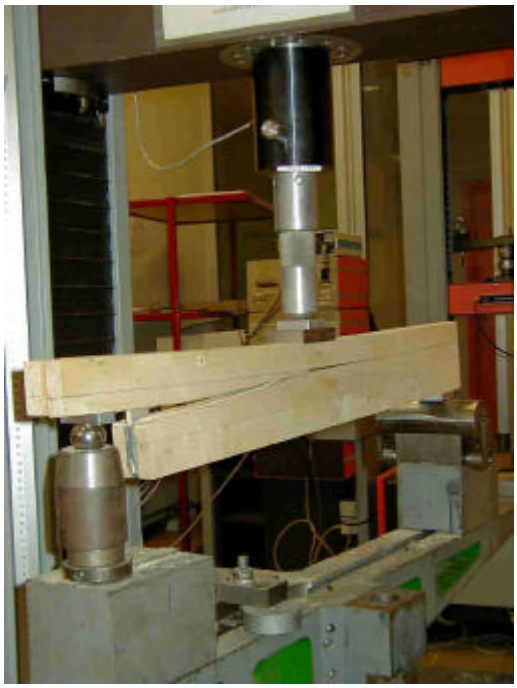
Applying simple crack analysis methods to the failure of adhesive bonds is difficult because of a large damage area appearing ahead of the crack tip before fracture. This damage area influences the overall behaviour of the bonded structure whatever the load applied. This project deals with the analysis of damage and fracture of wood bonded joints for various bond thicknesses.

One specimen type especially designed to provide stable crack propagation in the joint for Mode I and Mode II loading is tested: the modified Tapered End Notched specimen in Flexure. Two adhesives are chosen: a polyurethane (PU) resin displaying a semi-brittle behaviour and a resorcinol-phenol-formaldehyde (RPF) resin currently used in wood industry. Substrates are made of spruce wood. The specimens are submitted to an increasing loading at constant cross head displacement and load-deflection curves are recorded. These curves enable to evaluate the critical strain energy release rate and the fracture energy, including damage and non linear phenomena during the cohesive crack initiation (voids and cavities growing, fibrils bridging, microcracking). Tests results show various crack propagation patterns (cohesive cracking, crack deviated into wood, wavy crack propagation) which have a great effect on the evaluation of fracture energy.

Fractographic observations are also made in order to correlate fracture surface morphology to the variation of energy calculated for all combinations of adhesive-substrate-bond thickness and each loading mode. Numerical calculations have been made with a finite element code assuming that the bond line displays a softening behaviour. Results show a good agreement with the experimental measures for both modes of loading.



Local reinforcement of timber with composites (J.L. Coureau, E. Cuvillier, P. Morlier)



This study aims at upgrading the structural behaviour of timber elements by local reinforcement using composite materials, such as Pultruded Glass Fibre (PGF) or glass fibre fabrics with structural adhesive like resorcine or epoxy. Reinforcement is realised in areas where high stress concentration effects occur (geometric singularities) and which usually undergo perpendicular to grain stresses. Such stresses are considered to be critical for the performance of the member.

Experimental investigations trough bending tests on original and reinforced beams have been undertaken. The comparison of the ultimate load reveals that the relative increase of the strength can reach 100 and 200%. The combination of glass-fibre and adhesives acts as a crack stopper in the failure mechanism, which produce some ductility in the specimens. An empirical formulation of the reinforced beam strength is proposed according to the geometry of the notched beams and reinforcement and the choice of the glue. Three point bending tests performed on full size specimens show the good agreement with the estimations.

In order to validate the empirical formulation, finite element simulations are realised. The main interest is to model with simple considerations about ultimate characteristics of wood and adhesive, the simultaneous crack propagation in timber and the damage of the glued interface.

Selected references

Photoelastic investigations on damage process zone in a cracked adhesive joint under shear loading.
F.SIMON, S.MOREL, G.VALENTIN
Mechanical behaviour of adhesive joints, Analysis, Testing and Design EUROMECH 358 Nevers, Proceedings: ed. Pluralis, pp341-350,1997

Prediction range for a simple damage accumulation model as affected by uncertainty of estimators
P. GALIMARD, M. LEBATTEUX, P. CASTERA et B. LASSERRE
Proceedings of the IUFRO S5.02 Timber Engineering Conference, Copenhagen, 18-20 June **1997**.

Duration of Load behaviour of end-notched beams.
P. J. GUSTAFSSON, P. HOFFMEYER, G. VALENTIN
Holz als Roh und Werkstoff, Vol 56, pp 307-317, 1998

Lifetime of wood joints. Fracture mechanics and damage modelling.
M.CHAPLAIN*, G.VALENTIN, E.FOURNELY
Proceedings Pacific Timber Eng. Conf. Rotorua (NZ), 1999

Probabilistic damage models for wood based panels
P. CASTERA and F. BOS
Proc. ICASP 8 Conference on Application of Statistics and Probablity – Civil engineering reliability and risk analysis, Ed. Melchers & Stewart **2000** Balkema : 273-278.

Local reinforcement of structural element by composite materials
J. L. COUREAU, H. NIANDOU, P. MORLIER
First RILEM Symposium on Timber Engineering,
pp 235 -244, Stockholm, 1999