Current Achievements of the VETROLIGNUM Project

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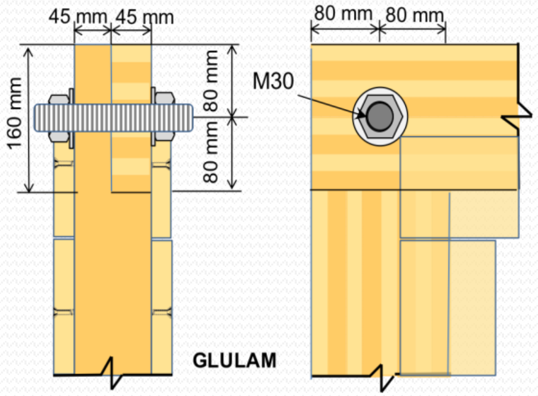
Racking testing of optimized CLT-laminated glass hybrid panel

Roko Žarnić, University of Ljubljana

Optimization of hybrid panel

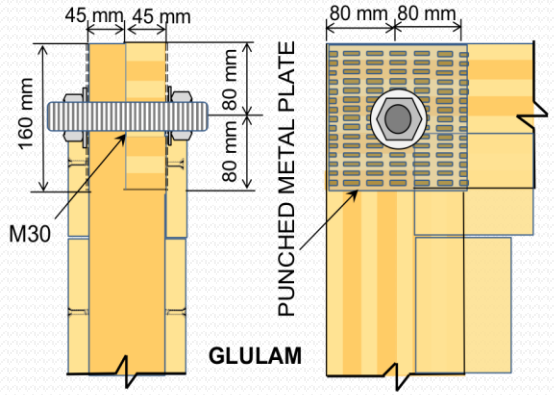
- Choosing the optimal joint configuration
- Examination of influence of glazing thickness
- Examination of influence of vertical load

Optimization of the timber frame joint



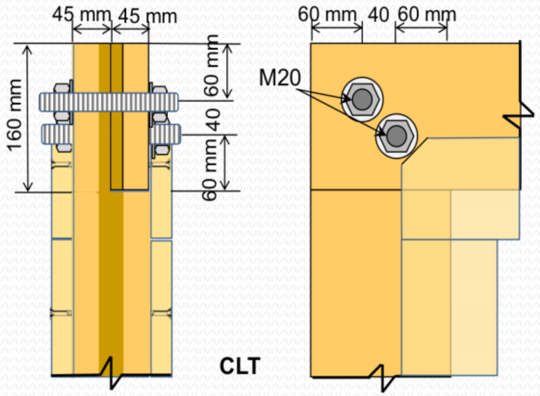
Joint type No.1

Joint Type No.1



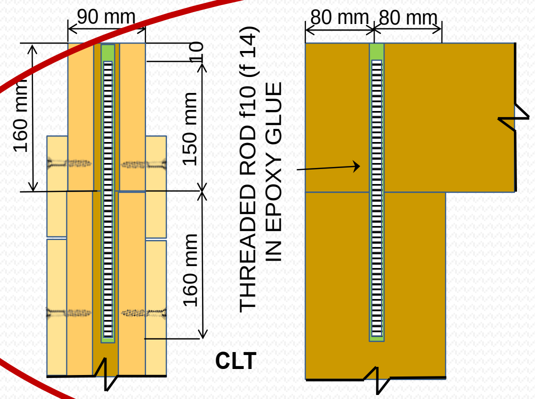
Joint type No.2

Joint Type No.2



Joint type No.3

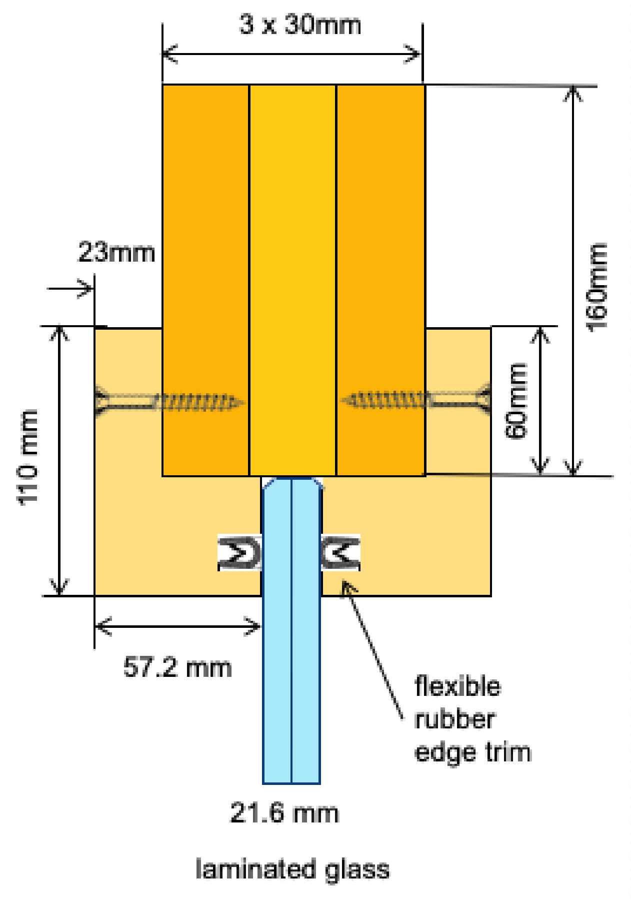
Joint Type No.3

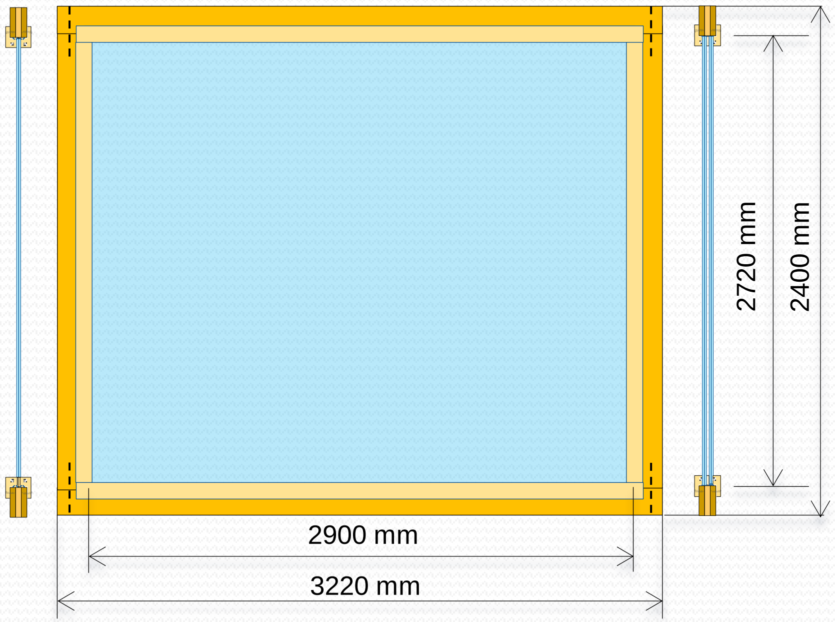


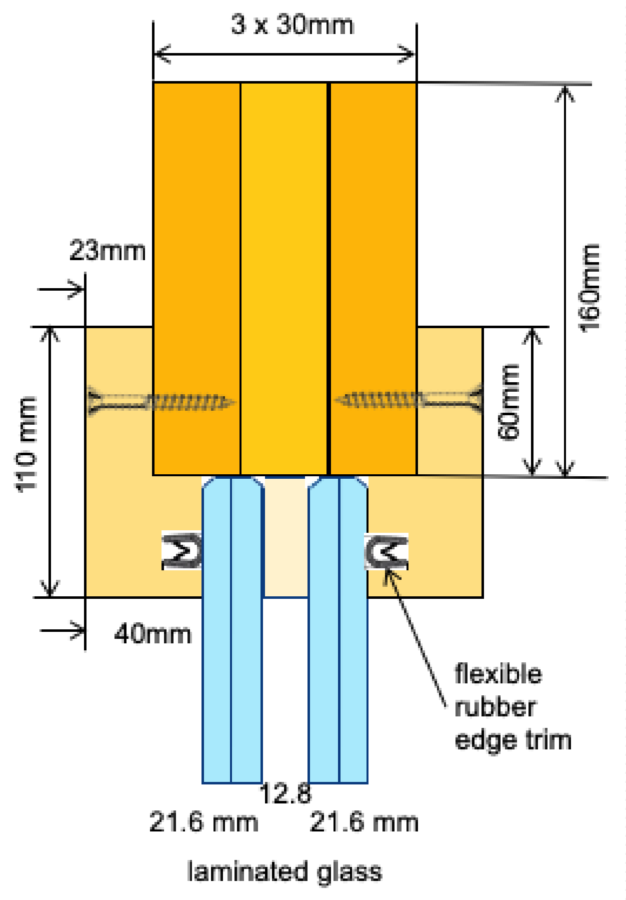
Joint type No.4

Joint Type No.4

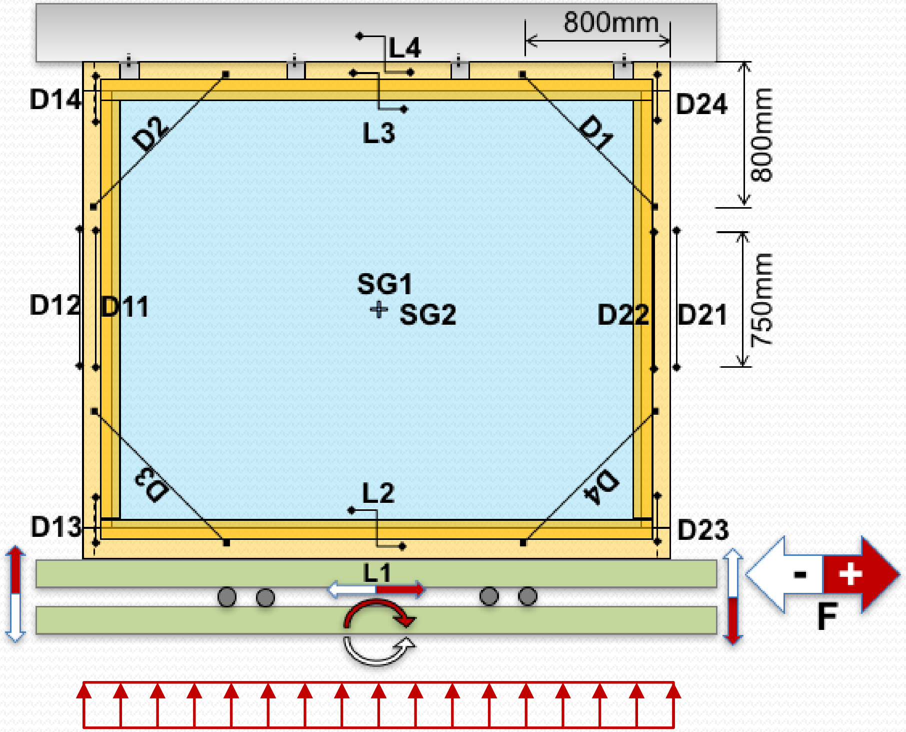
Examination of influence of glazing thickness







Examination of influence of vertical load

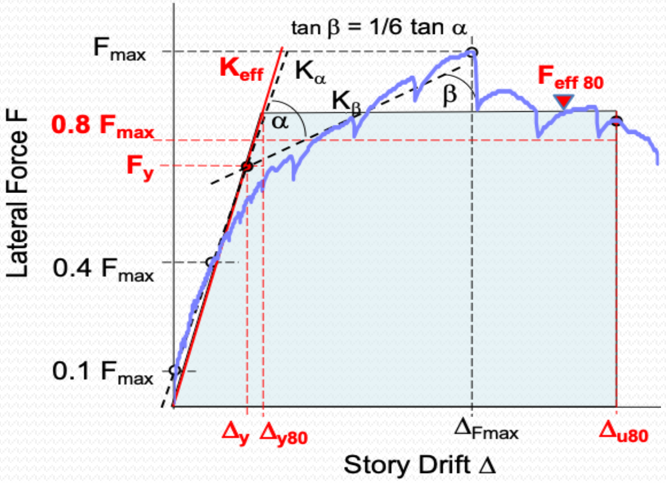


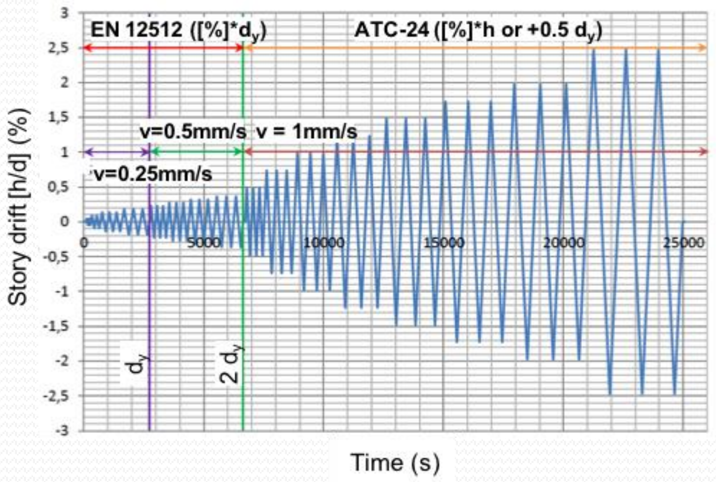
Case 1: 25 kN/m’ single & double glazing

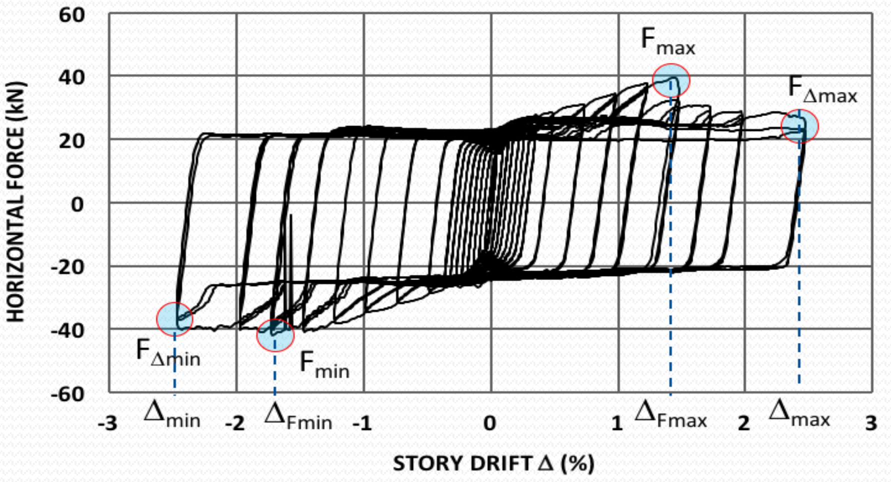
Case 2: 0.25 kN/m’ double glazing own weight

Case 3: 0.15 kN/m’ single glazing own weight

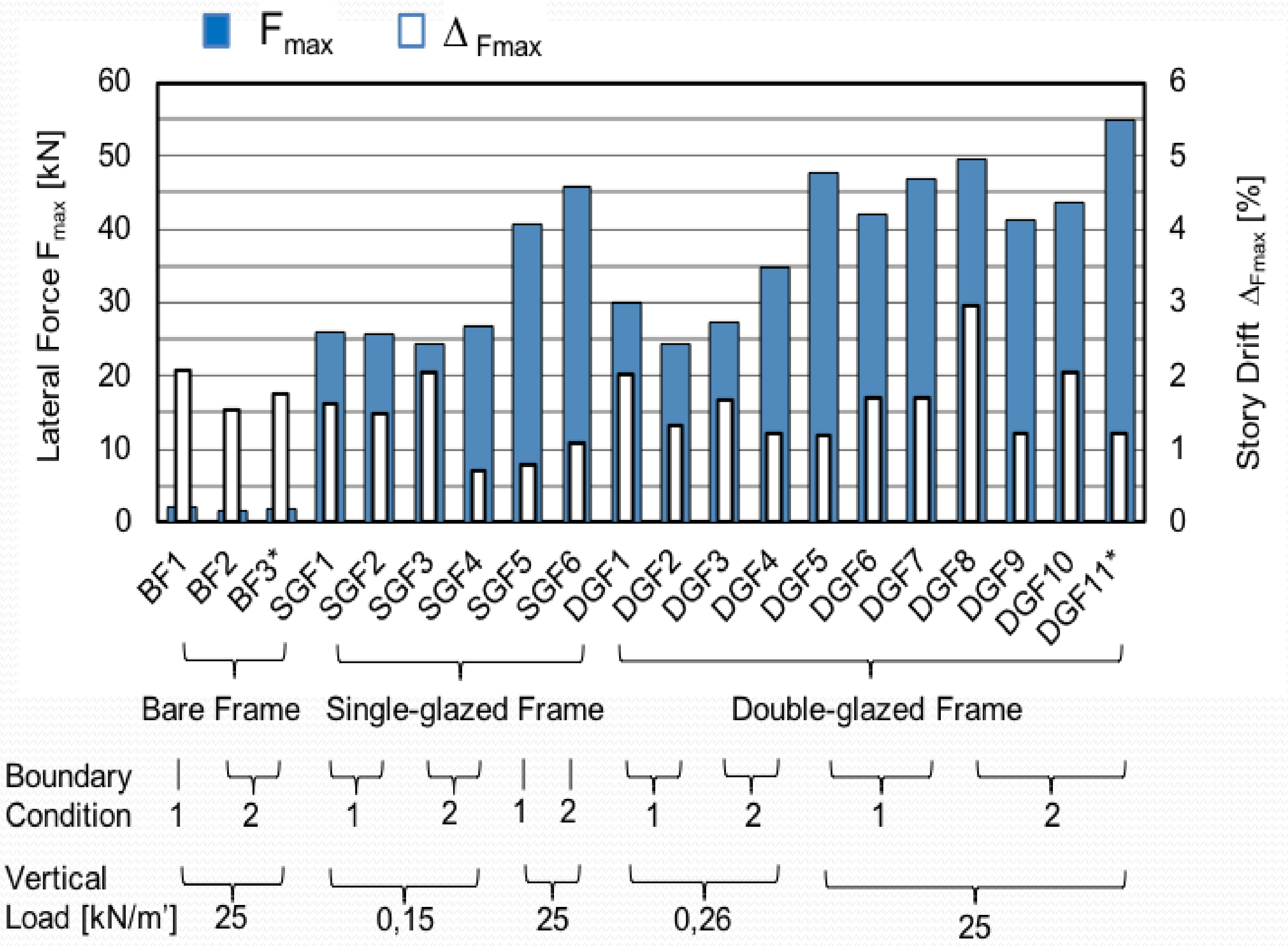
Racking testing of hybrid panels







Lateral load bearing capacity



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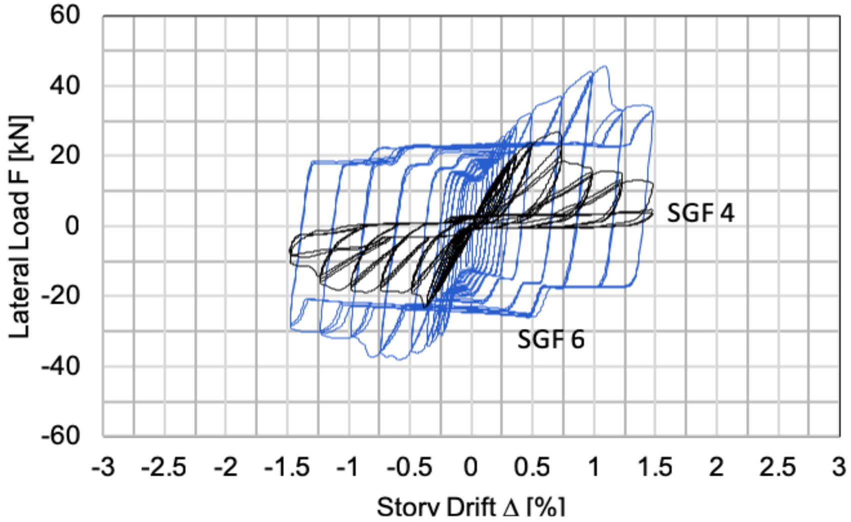
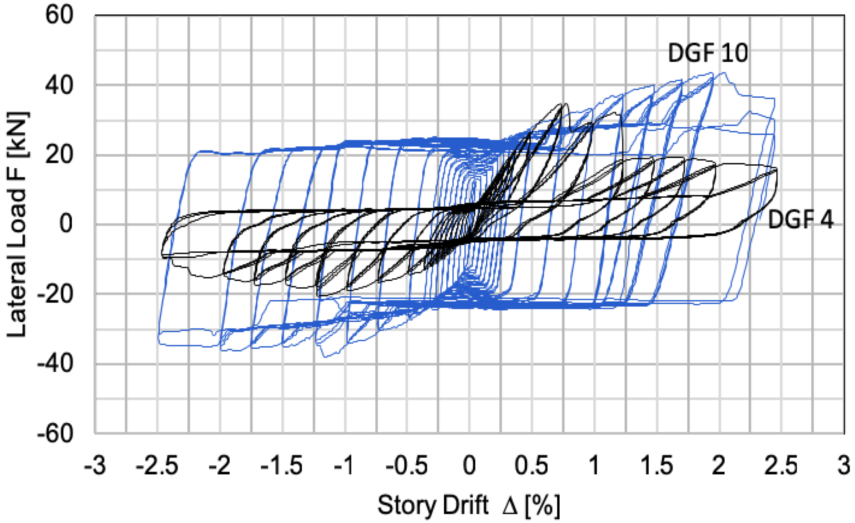
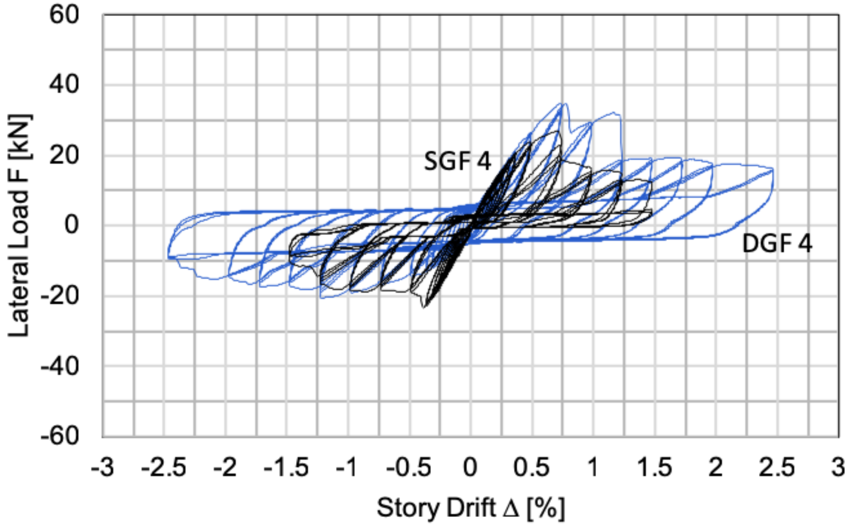
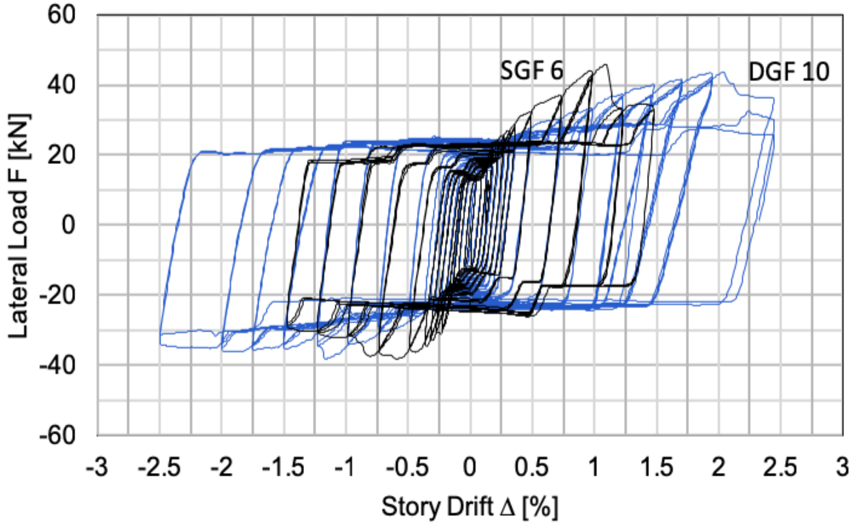
PROTOTIPE OF MULTIPURPOSE TIMBER - STRUCTURAL GLASS COMPOSITE PANEL

Hysteretic response of hybrid panels







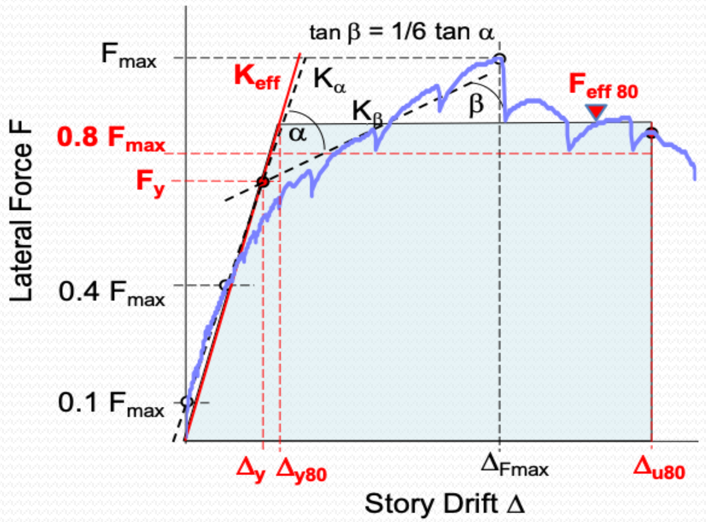


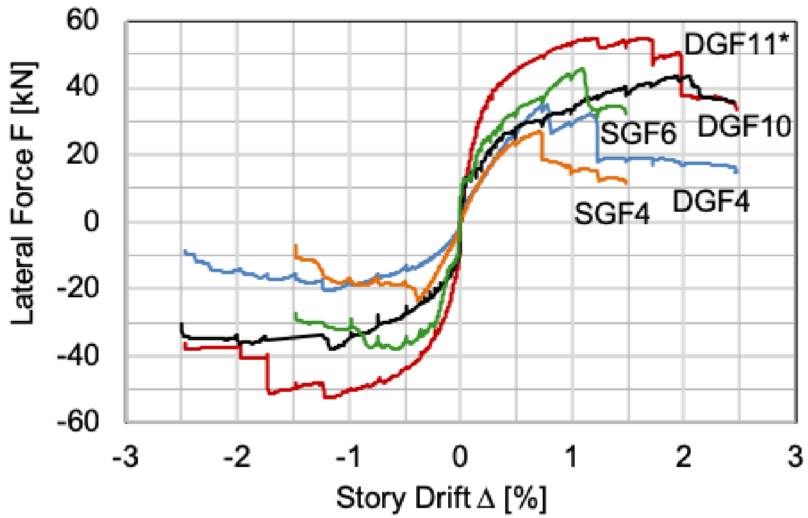
Parameters of hysteretic response

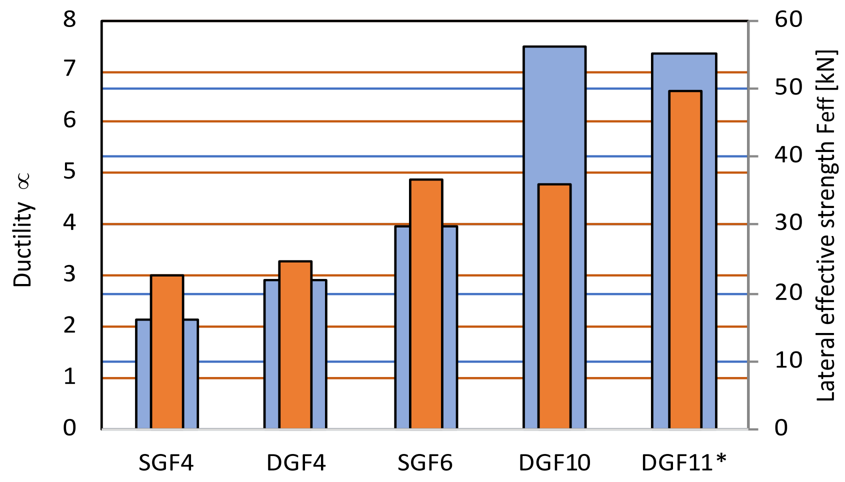
- Ductility of the tested structural element;
- Drop of strength due to three subsequent repetitions of lateral load;
- Cycle-to-cycle stiffness degradation;
- Energy dissipation due to glass-to-wood friction and plastic deformation of joint rods.

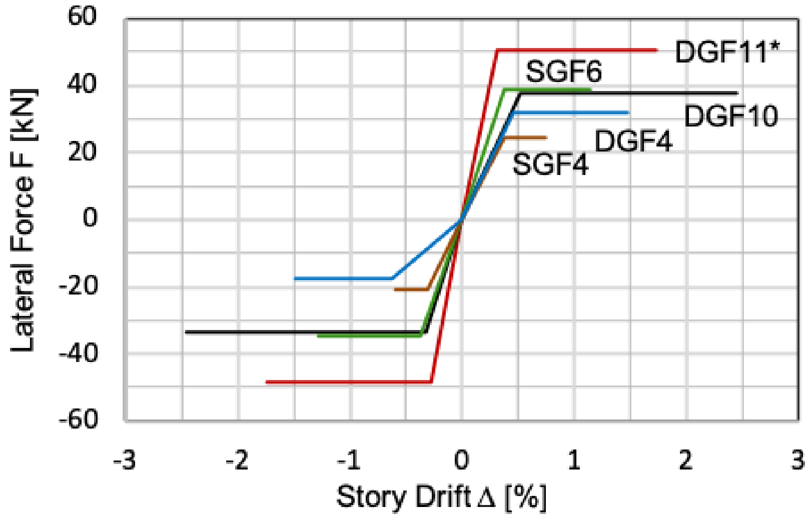
Ductility of hybrid panels

$$\mu = \frac{\Delta_{u80}}{\Delta_{y80}}$$









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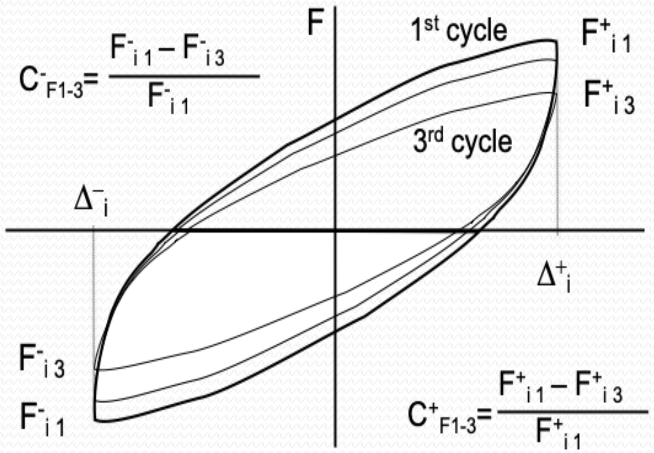
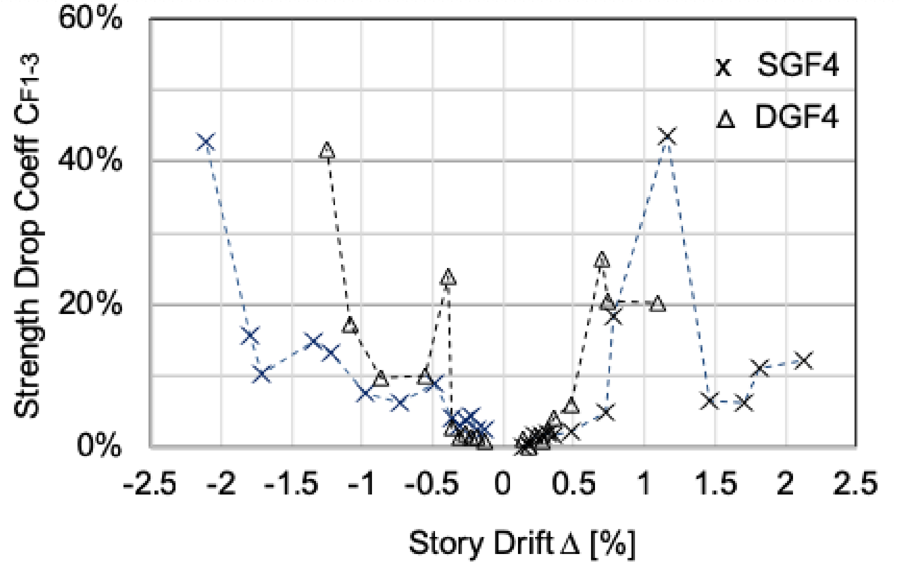
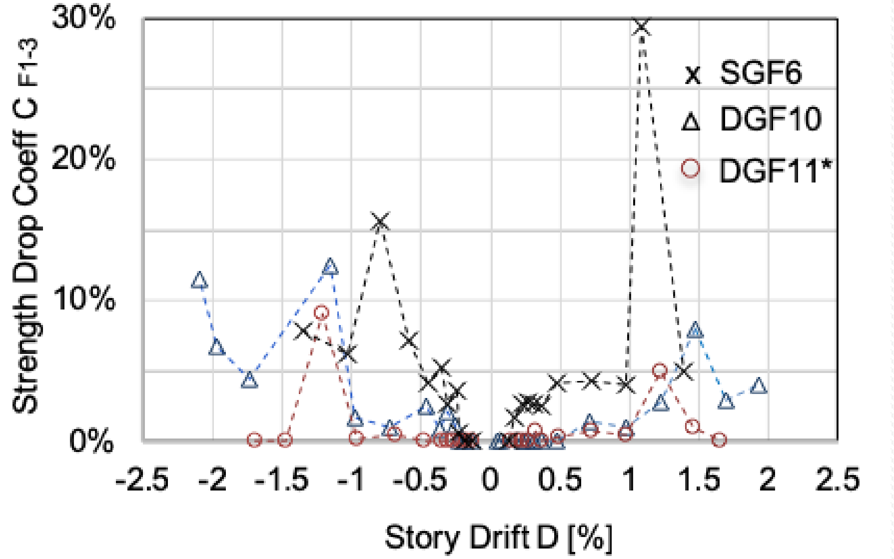
Drop of strength of hybrid panels







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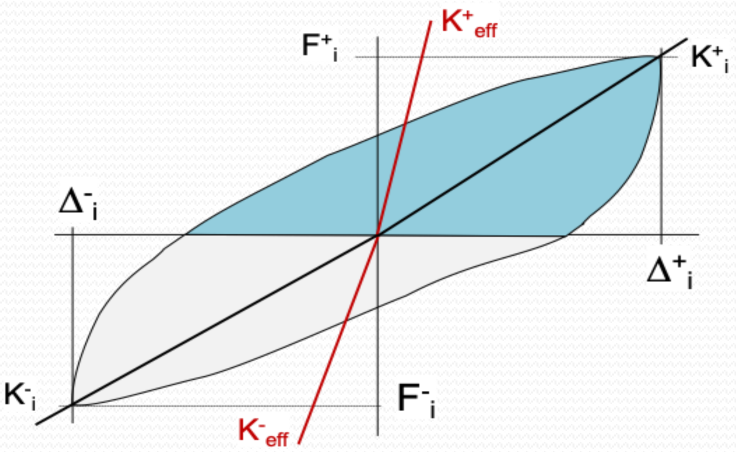
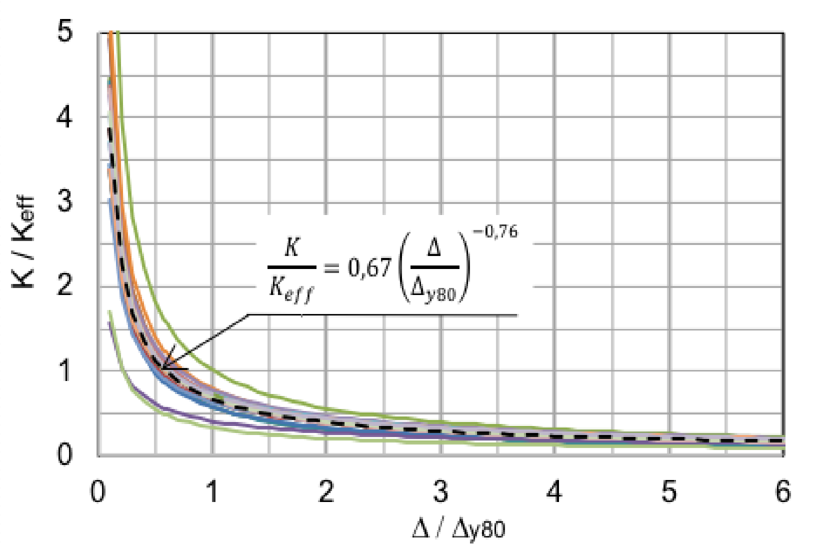
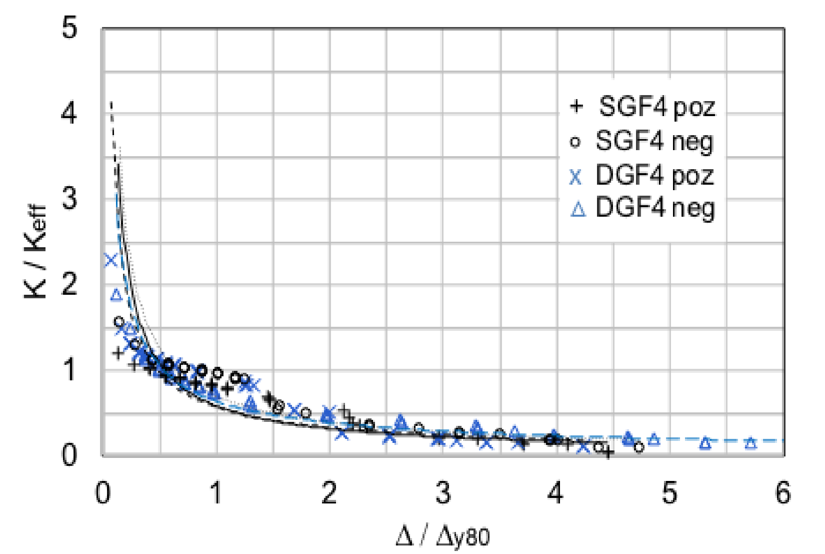
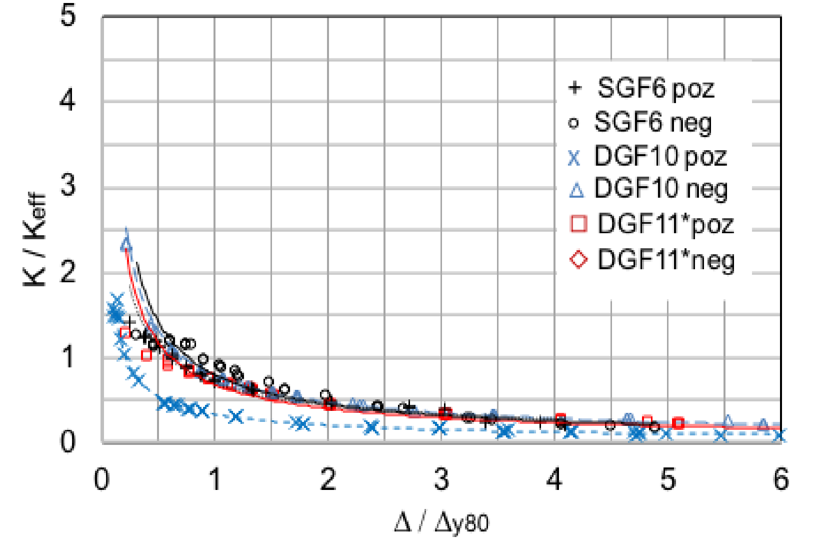
Cycle-to-cycle stiffness degradation









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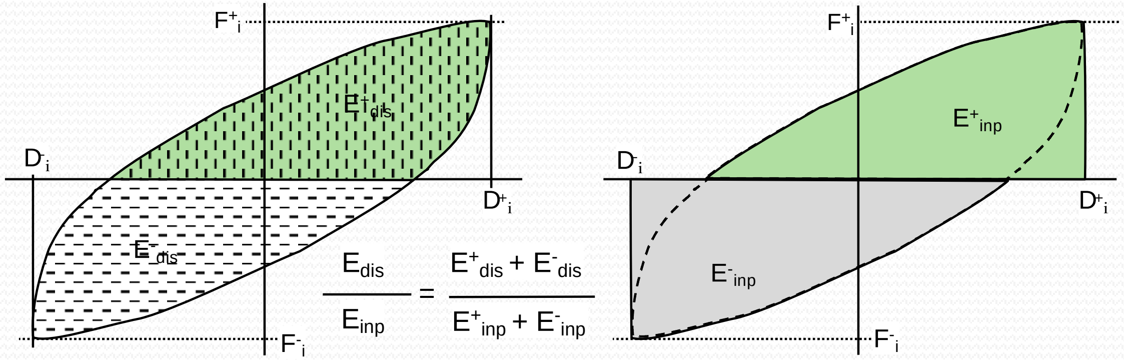
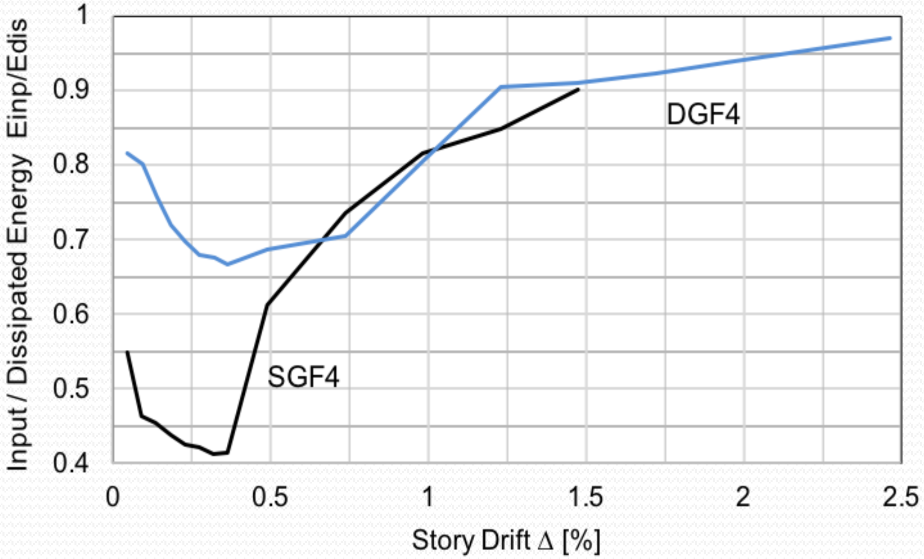
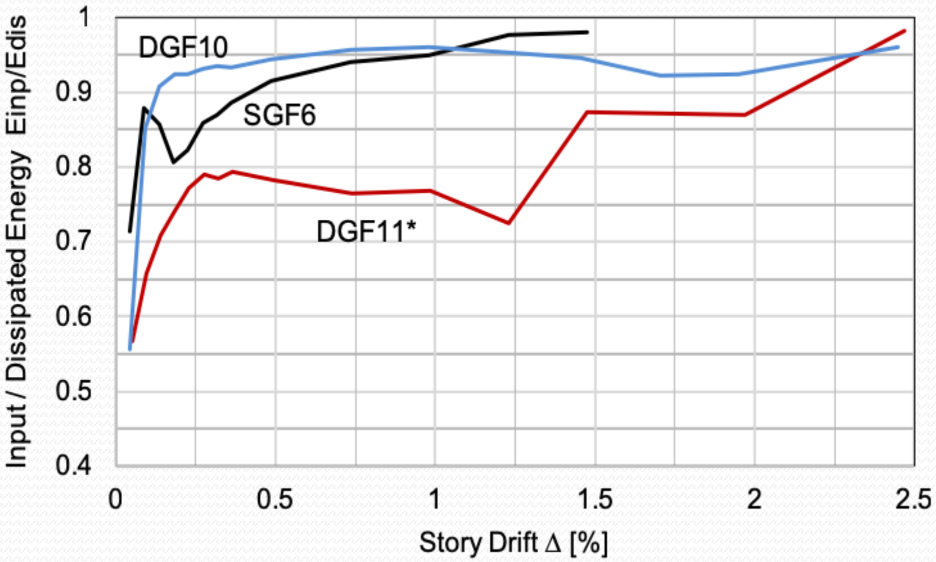
Energy dissipation due to glass-to-wood friction and plastic deformation of joint rods



$$\frac{E_{dis}}{E_{inp}} = \frac{E^{+}_{dis} + E^{-}_{dis}}{E^{+}_{inp} + E^{-}_{inp}}$$





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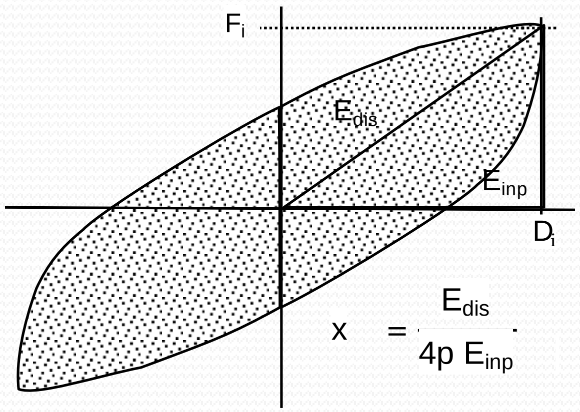
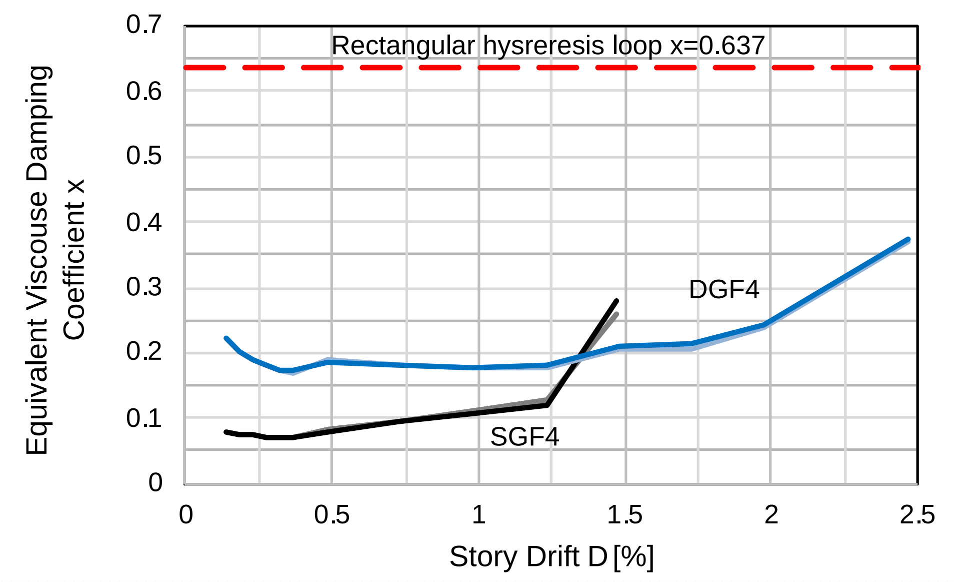
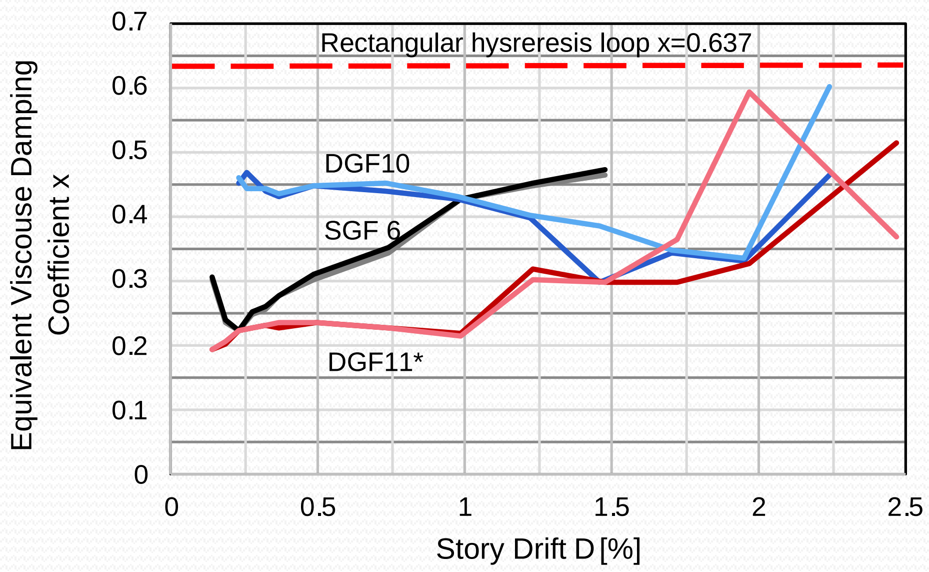
Energy dissipation due to glass-to-wood friction and plastic deformation of joint rods







Conclusions

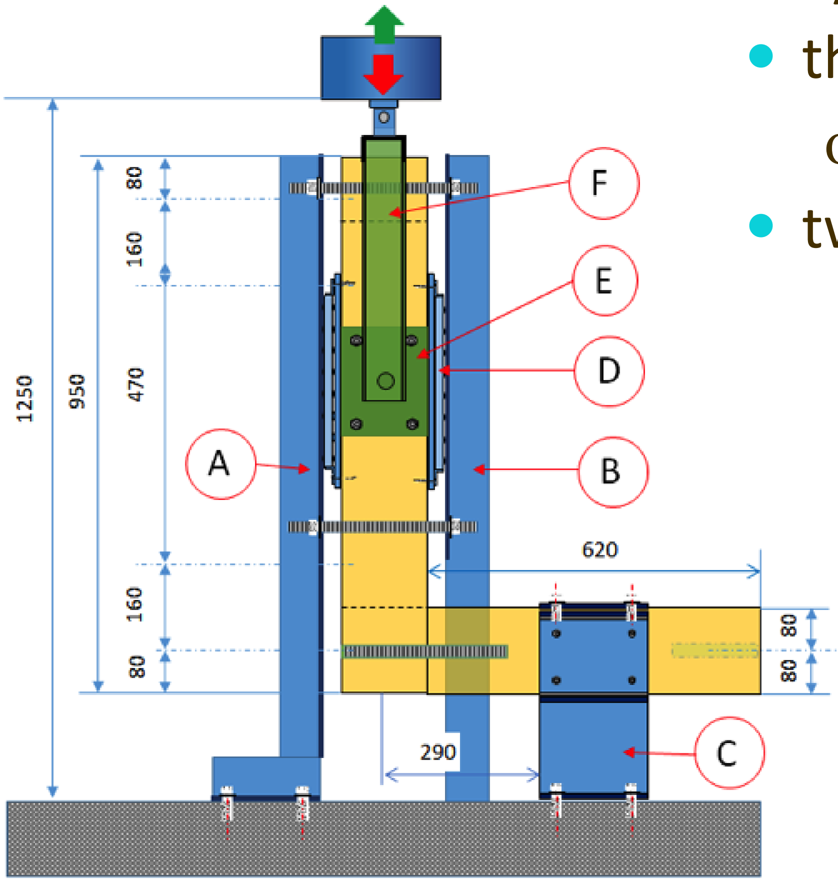
- The advantage of the glued-in-rod timber joint is in its ductility and energy dissipation due to plastic deformations of steel
- The glazing thickness does not much influence the lateral strength of hybrid panel
- The thickness of rod has a direct influence on lateral strength of panel and its ductility
- Intensity of vertical load increase ductility of entire panel due to glass-to-wood friction
- Cycle-to-cycle drop of lateral strength is approx. twice in case of low vertical load
- Cycle-to-cycle stiffness degradation is not influenced by glass thickness or intensity of vertical load
- Vertical load highly influence the amount of dissipated hysteretic energy due to glass-to-wood friction

Cycling testing of glued-in rod CLT joints

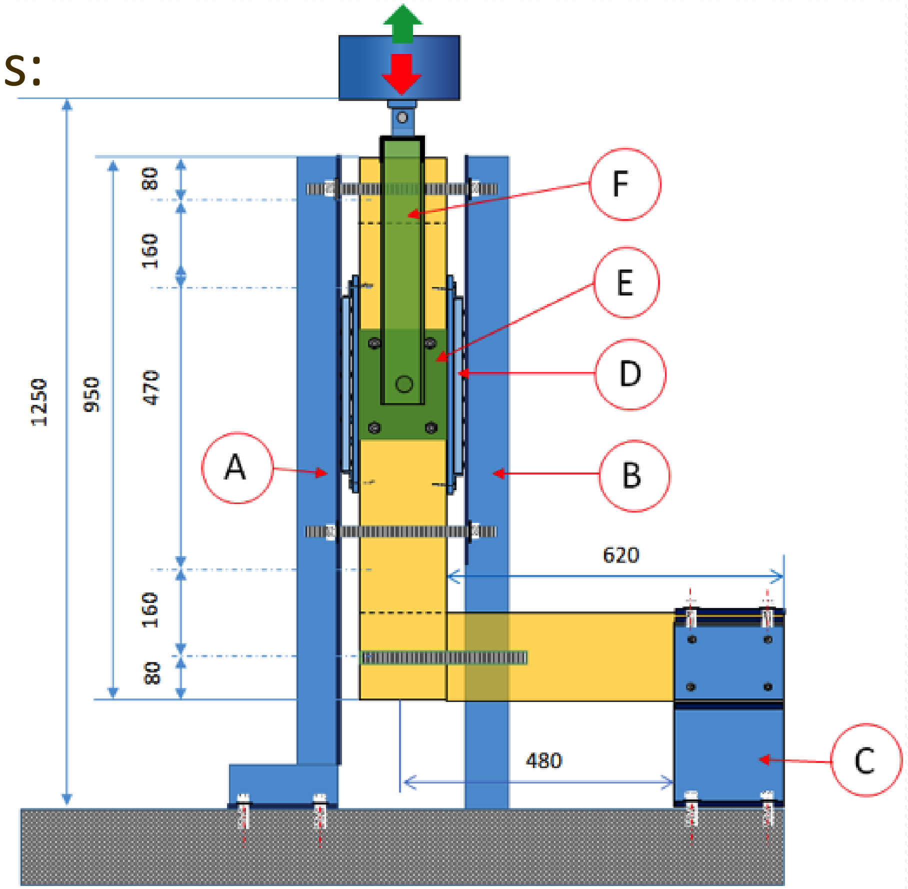
Jure Barbalić, University of Zagreb

Test set-up

- system is rotated for 90°
- three diameters of glued-in rods:
  $\phi 10$, $\phi 14$, $\phi 20$
- two positions of stud support



setup C



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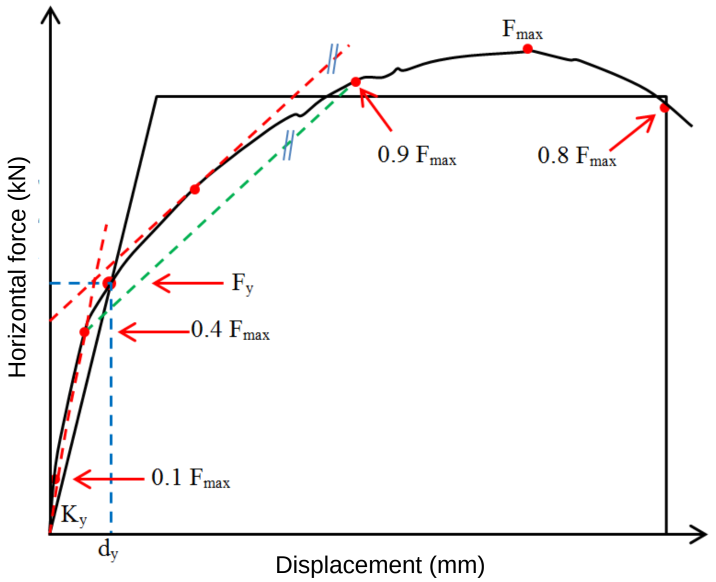
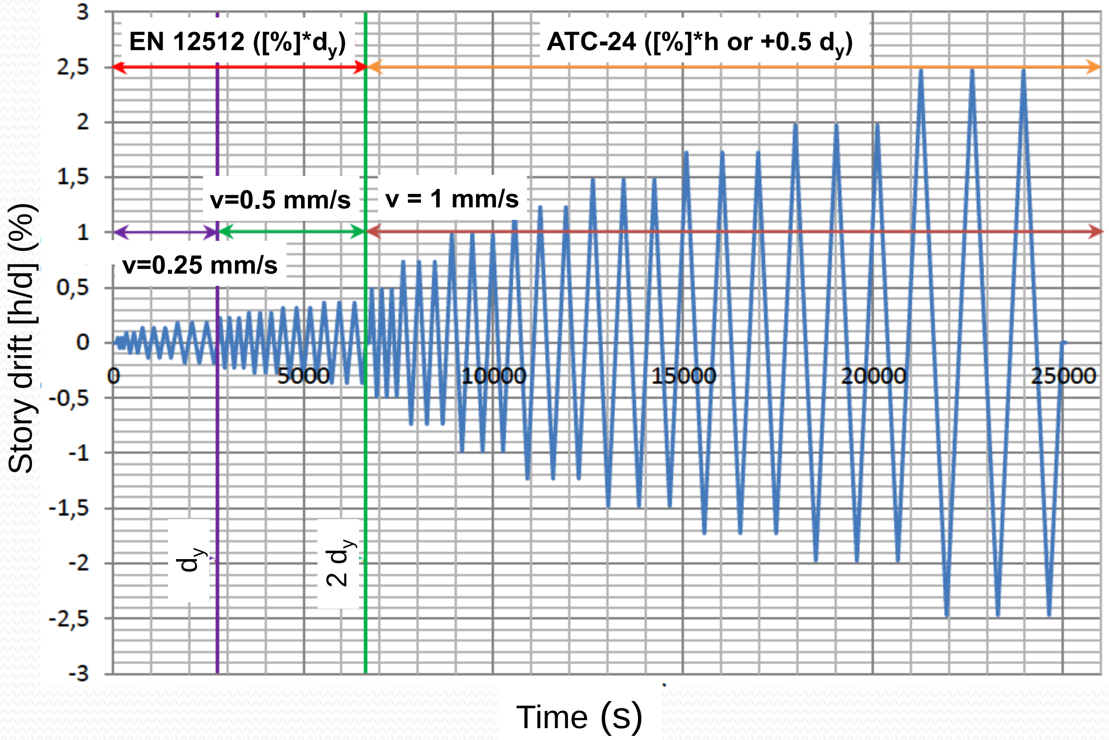
Test protocol

- The cyclic horizontal load protocol is composed of three sets of rules:
  - definition of a yielding point (the Yasumura and Kawai (1997) procedure for timber shear wall)
  - cyclic protocol EN 12512:2001 (1997) in the range of low displacement amplitudes (up to 2dy)
  - cyclic protocol ATC-24 [24] in the range of high displacement amplitudes (over 2dy)



- specimens of each type of joints were loaded by monotonous lateral loads until reaching a 20% drop of load bearing capacity to obtain the load-deformation curve which was used to determine the displacement at a yielding point (dy)



- the range of low amplitudes is divided into parts concerning the actuator velocity of 0.25 mm/s up to displacement amplitude equal to dy and velocity of 0.5 mm/s up to a displacement amplitude of 2dy
- after reaching the limit of 2dy the speed of actuator increased to 1 mm/s
- three cycles of loading were performed for each selected amplitude
- testing ended when the complete failure of joints was achieved

Test results

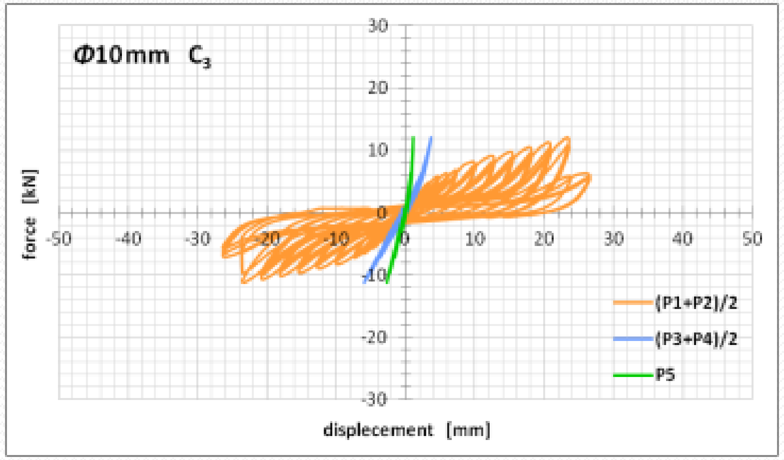
- fracture of joint with M10 rod starts when the rod is bent in both timber members where final failure happened due to tensile failure of rod (regardless of the boundary condition)
- fracture of joint with M14 and M20 rod starts when the rod is bent, forming a plastic hinge inside the column, where final failure happened due to overflow of wood compressive strength (regardless of the boundary condition)
- fracture of joint with M20 rod starts when the rod is bent, forming a plastic hinge inside the column or girder (depending of of the boundary condition), where final failure happened by ejection of central lamella (of column in CL sample or girder in C sample)

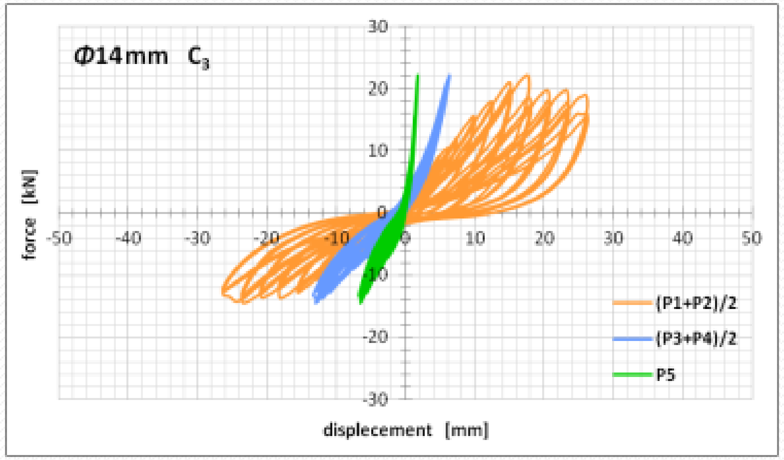
Test results

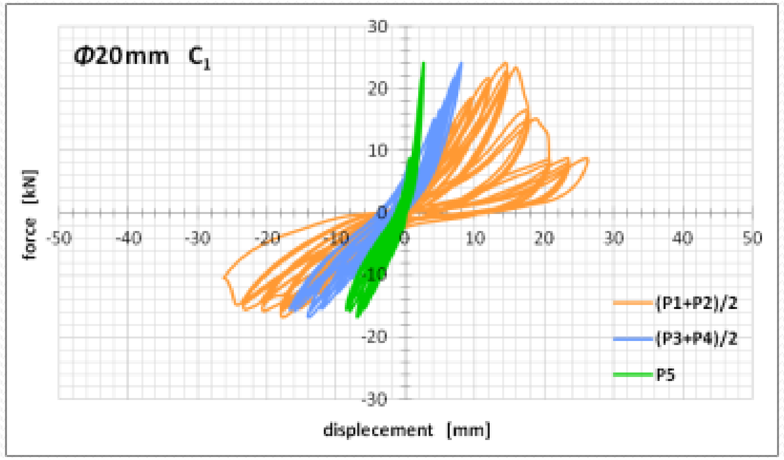
- bearing capacity of the joint made with glued-in rod M14 is higher by 30% compared to the joint made with M10 rod as well as 10% lower in relation to the joint made with M20 rod
- the best ratio of ductility and bearing capacity is shown in hysteresis curve of joint with M14 rod
- it can be concluded that joint with M14 glued-in rod in corner of timber frame is optimal in regular application

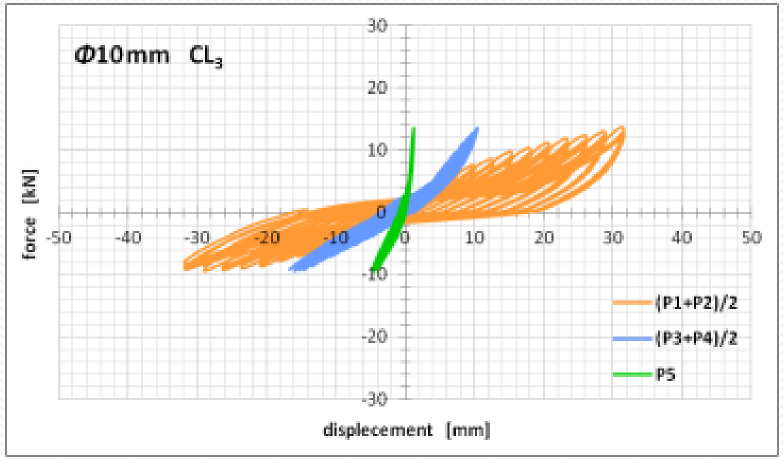
SPECIM.	Fmean [kN]	σ_F	CoV_F	d [mm]	σ_d	CoV_d
Ø 20 C	-19,109	1,683	0,088	-20,871	4,103	0,197
	24,189	3,198	0,132	15,754	4,103	0,260
Ø 20 CL	-17,868	2,211	0,124	-37,387	5,209	0,139
	23,244	2,404	0,103	37,530	4,918	0,131
Ø 14 C	-14,625	1,692	0,116	-22,406	3,514	0,157
	18,236	5,036	0,276	20,542	3,514	0,171
Ø 14 CL	-15,265	1,278	0,084	-33,865	2,803	0,083
	22,488	1,149	0,051	33,443	3,527	0,105
Ø 20 C	-19,109	1,683	0,088	-20,871	4,103	0,197
	24,189	3,198	0,132	15,754	4,103	0,260
Ø 20 CL	-17,868	2,211	0,124	-37,387	5,209	0,139
	23,244	2,404	0,103	37,530	4,918	0,131

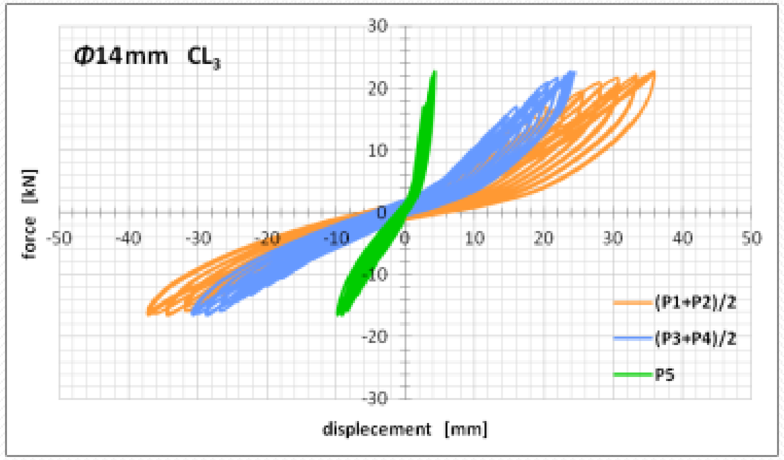
Test results

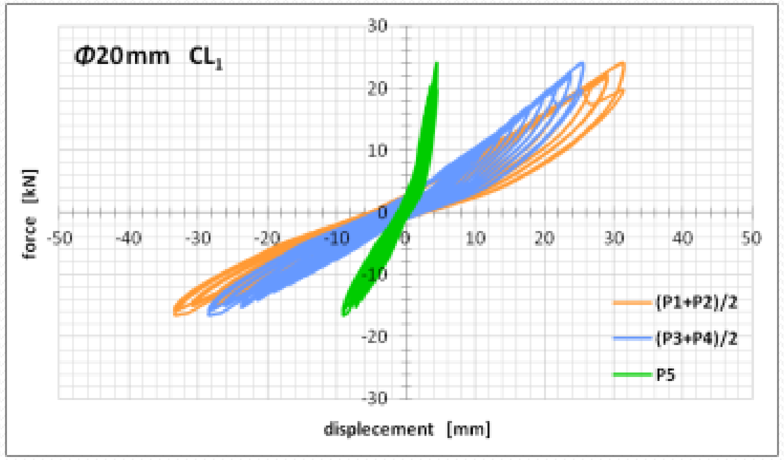






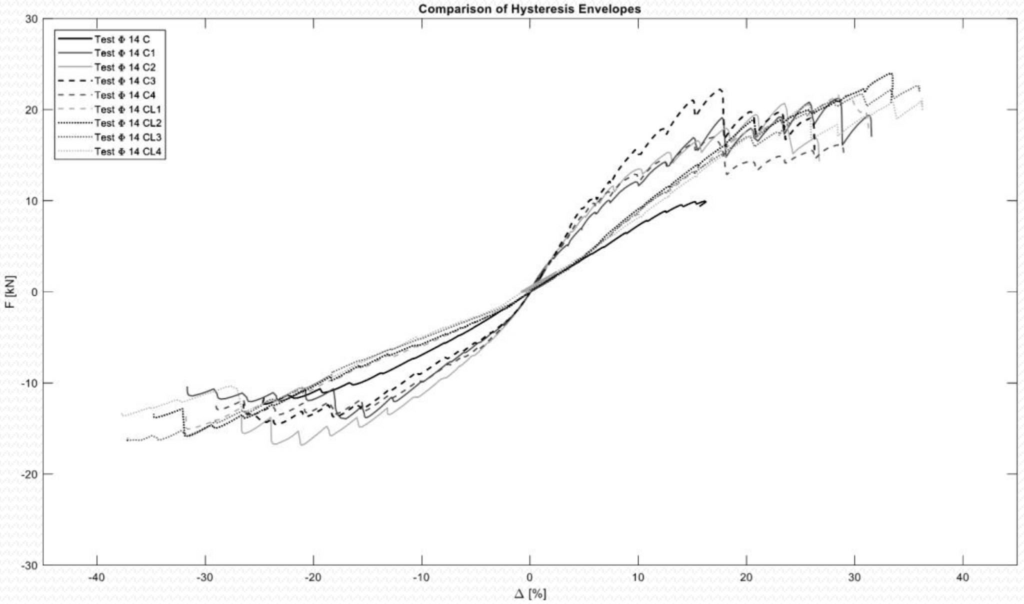


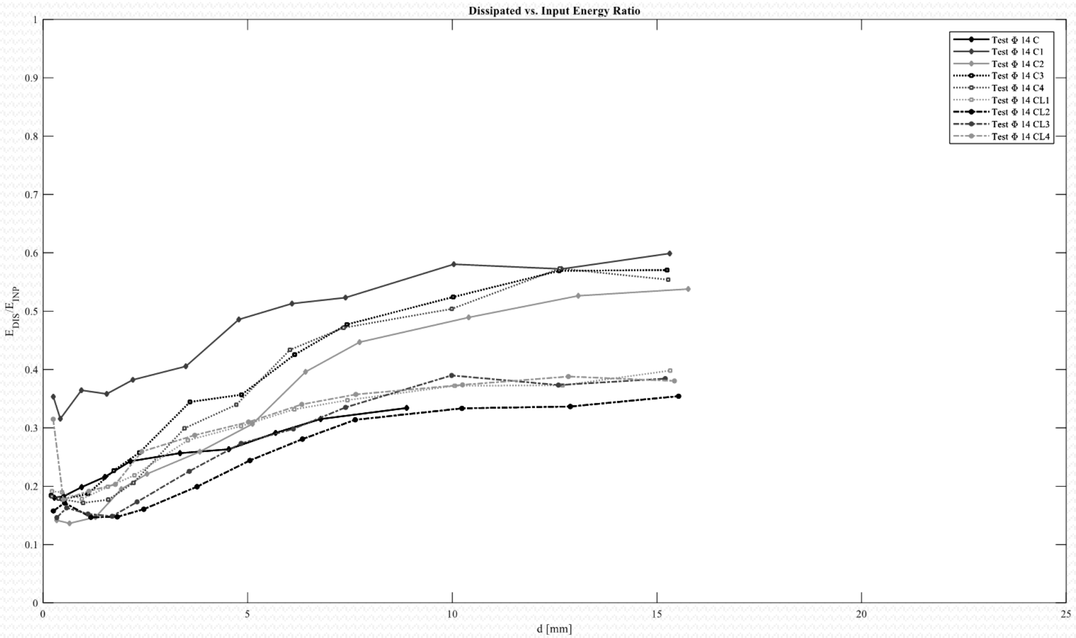




Lesson learned from test results

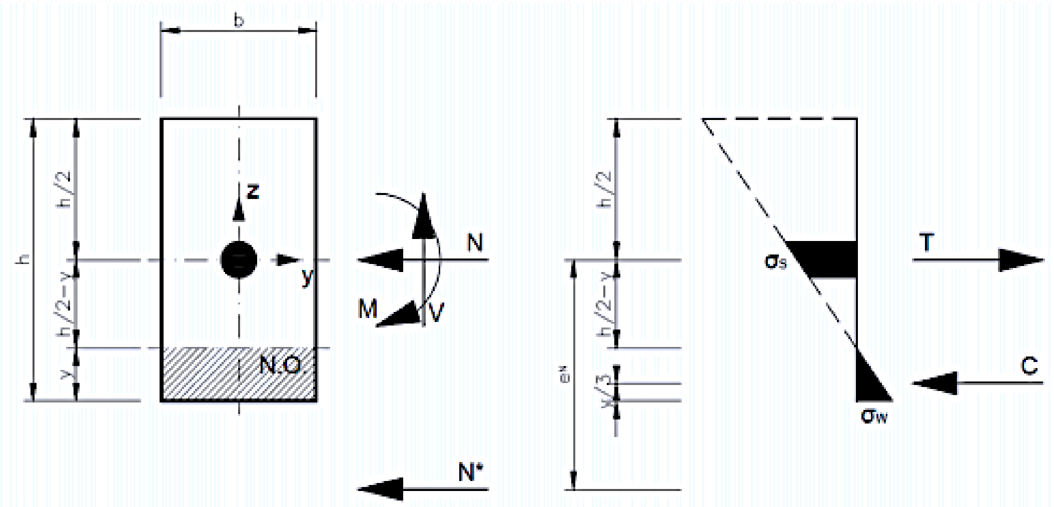
- test gave a better insight in behaviour of the single glued-in-rod joint under shear and bending load, as well as better insight in influence of flexural and shear stiffness of frame on the joint failure mechanism

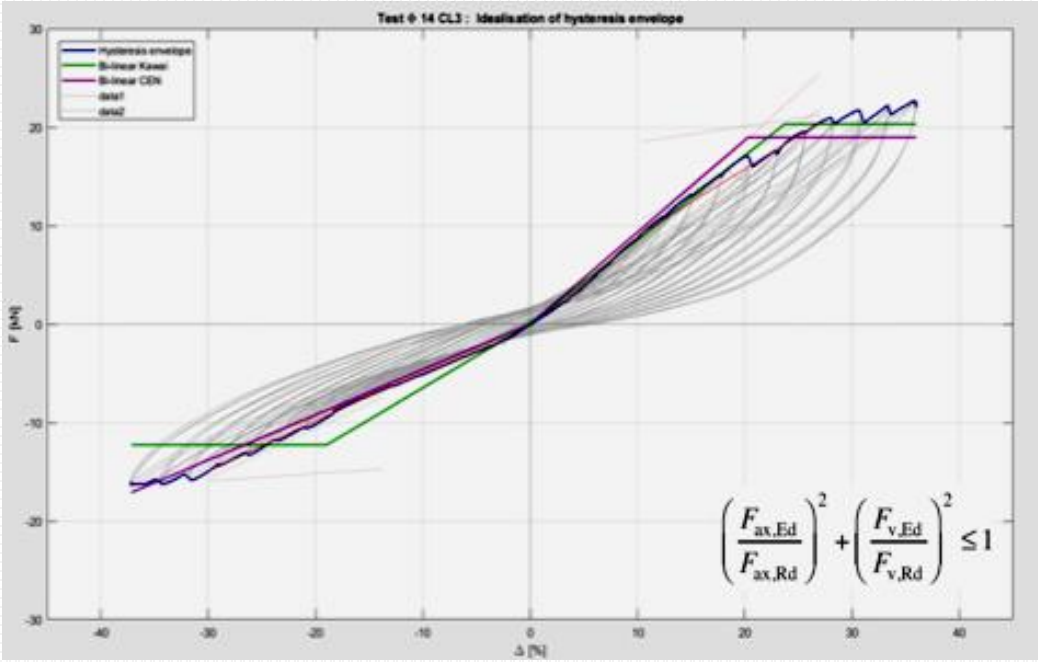




Equivlent viscous damping coefficient ξ

- an analytical expression will be derived from two aspects :
  - static – to determine the total bearing capacity of joint
  - dynamic – to determine the hysteresis behavior of joint with known material stiffness





Energy efficiency mock-up long term measuring campaign

Nikola Perković, University of Zagreb

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VETROLIGNUM

PROTOTIPE OF MULTIPURPOSE TIMBER - STRUCTURAL GLASS COMPOSITE PANEL

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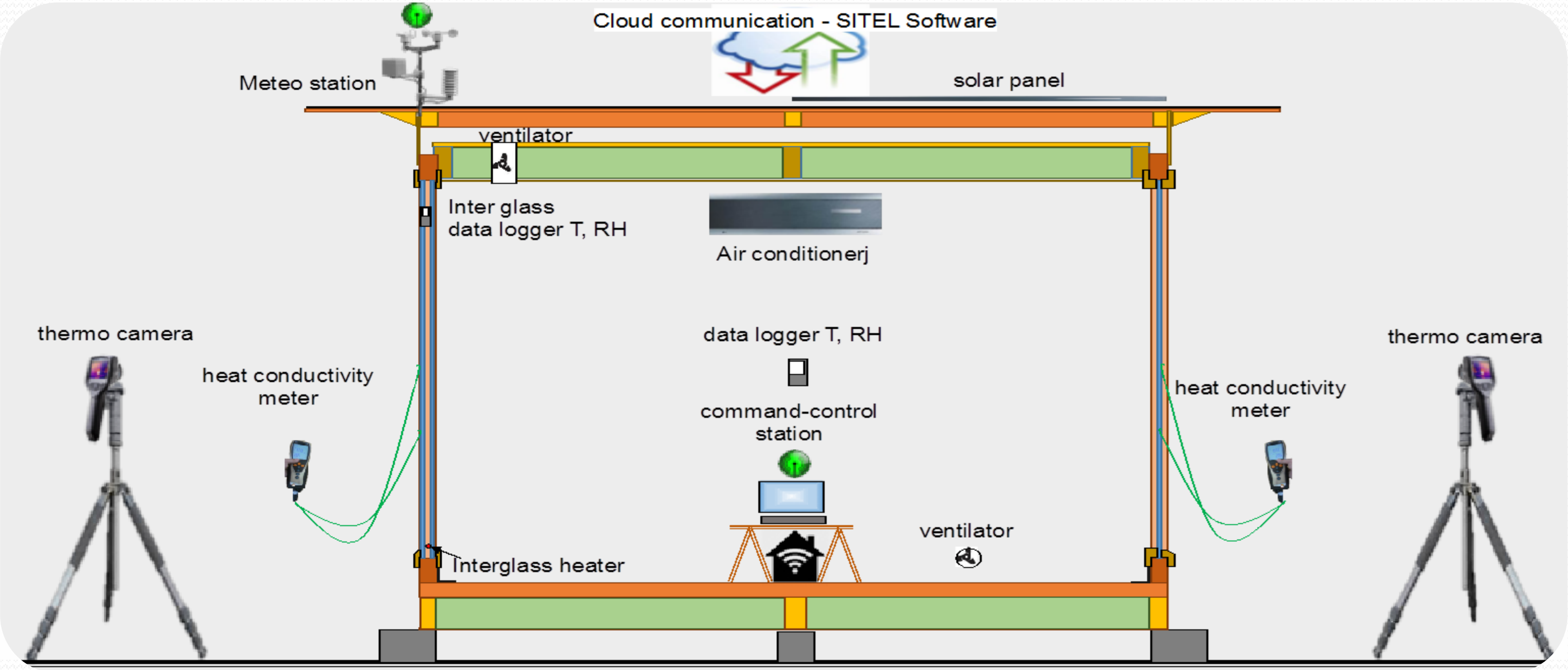
PROTOTIPE OF MULTIPURPOSE TIMBER - STRUCTURAL GLASS COMPOSITE PANEL

Preliminary testing

- Two-year program and test of VETROLIGNUM basic mechanical - physical properties and the impact on the energy balance of the facility in which they are built. Tests will enable the continuation of panel development in the direction of energy performance optimization and alignment with the required national and European standards.
- Experimental and analytical testing of thermal properties is intended to contribute to achieving the level of technological readiness and development of high - level prototypes with the demonstration of composite wood - bearing glass.
- The „Live - Lab" will enable energy efficiency measurements in two annual cycles (2018-2019 and 2019-2020) throughout all four seasons.
- After obtaining data and physical properties of the walls, a numerical simulation will be made, which will serve as a constant comparison of the measured and calculated parameters.

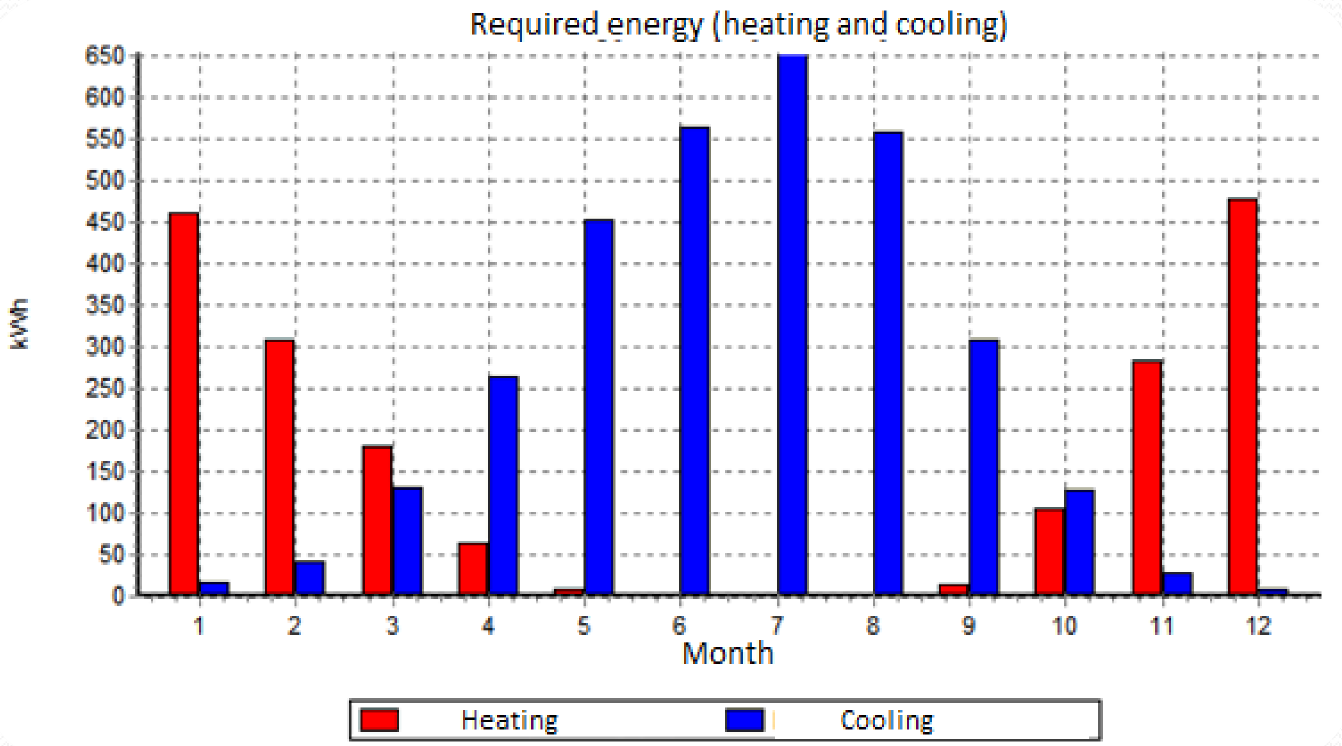
Measurement scheme



The test results obtained according to the presented program will enable us to develop the thermal characteristics of the VETROLIGNUM panel and to obtain the parameters for building design in accordance with the applicable Technical Regulations.

The preliminary phase of the test involves measuring the relative humidity and temperature in the space between the two glass panes. With this we want to gain insight into the behavior of the system before it comes to a realistic state, all with the aim of gradually following improvements and optimizing energy efficiency.

Numerical modelling



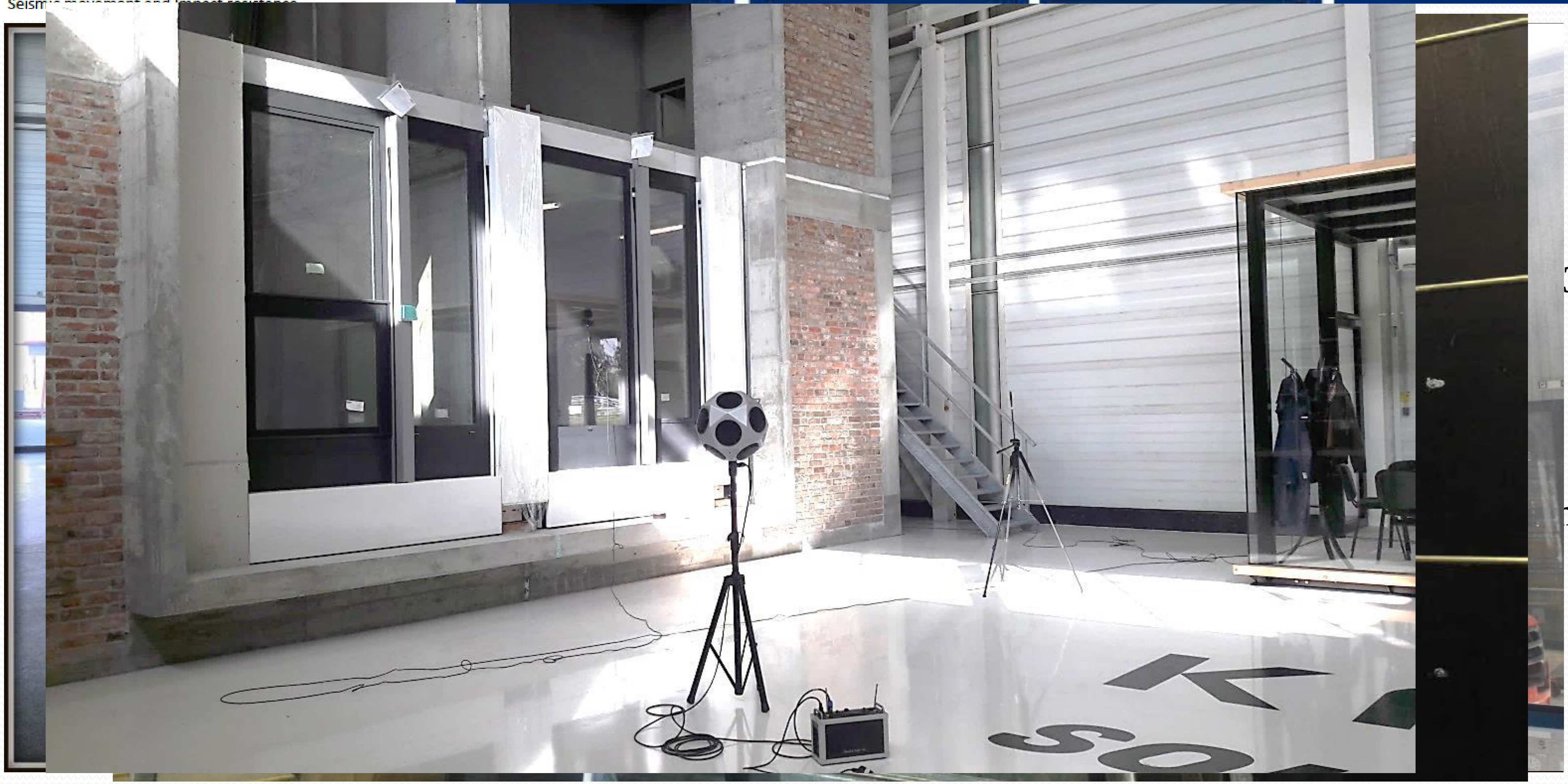
KFK

KFK Tehnika d.o.o.

Facade Test Facility

A

Air permeability, Resistance to wind load, Watertightness (static and Dynamic), Seism



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ms – Test method

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PROTOTYPE OF MULTIPURPOSE TIMBER - STRUCTURAL GLASS COMPOSITE PANEL

Thank you for attention!