PROTECTED AND UNPROTECTED W-W-W CONNECTION AT ELEVATED TEMPERATURES

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FIRE SAFETY 2017, International Conference on Research and Advanced Technology in Fire Safety, Santander 20th-21st October 2017

1- INTRODUCTION

The wood, as a structural material, continues to grow far beyond traditional applications. Connections are often considered as the critical point of timber structures because their resistance and durability mainly depend on the joining design in structural elements. For imposed thermal loads, it remains important to improve the knowledge of the connection behaviour under fire.

Objectives:

- To present an approach for Wood-Wood-Wood (W-W-W) connections designed in double shear at ambient and high temperatures, using dowelled connectors.
- W-W-W connection will be considered unprotected at ambient temperature, and protected for high temperature.
- W-W-W connection will be conducted according Eurocodes and using a report guide (Ruben F P Silva, 2009).

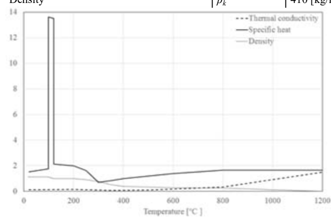
Keywords: W-W-W connection, dowel, extra thickness, insulation, thermal analysis.

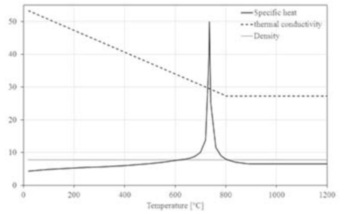
2- MATERIAL PROPERTIES

Mechanical and thermal properties of an orthotropic yellow birch wood GL28h (Glue Laminated Timber, GLULAM or GL) and an isotropic hot-rolled low carbon steel S275:

Strength Class	GL28h Designation	Value
Bending strength	$f_{m,k}$	28 [MPa]
Tension parallel to the fibers	$f_{t,0,k}$	19,5 [MPa]
Modulus of elasticity parallel to the fibers	$E_{0,mean}$	12600[MPa]
Shear modulus	G_{mean}	780 [MPa]
Density	ρ_k	410 [kg/m³]

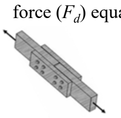
Steel grade	S275 Designation	Value
Characteristic value of strength, max load	$f_{u,k}$	400 [MPa]
Yield strength	f_y	275 [MPa]
Ultimate tensile strength	f_u	430 [MPa]
Modulus of elasticity	E	210 [GPa]
Poisson's ratio	υ	0,3
Density	ρ_s	7850 [kg/m³]





3- W-W-W CONNECTION UNDER ROOM TEMPERATURE

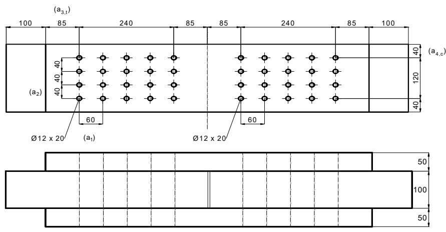
Since the connections are made basically to resist the mechanical loads, an initial model of 4 plates of GL28h joined by ϕ12[mm] steel dowels is calculated according EC5. Calculations determine cross-section size, number of bolts, spacing between fasteners, assuming an applied force (F_d) equal to 100[kN].



$$F_{v,R,d} = \frac{k_{mod} \times F_{v,R,k}}{\gamma_M} = \frac{0,9 \times 7731,81}{1,25} = 5566,90\ [N]$$

	Cross-section of wood
Designation	$A_s\ [mm^2]$
References EC5	Cap 6.1.2; equation (6.1)
Equation used	$\sigma_{t,0,d} = \frac{F_d}{A_s} \le f_{t,0,d} = \frac{k_{mod} \times f_{t,0,k}}{\gamma_M}$
Calculation results	7122,507 N
Considered results	7122,507 N

Number of dowels	Minimum spacing, mm			
Nº (in symmetry for the other side)	a_1	a_2	$a_{3,t}$	$a_{4,c}$
Cap 8.2.2; equation (8.7)	Cap 8.6; table (8.5)			
$N^{o} = \frac{F_d}{F_{v,R,d}}$				
≈18	60	36	84	36
20	60	40	85	40



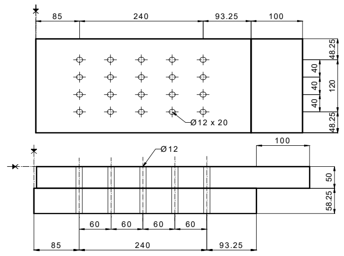
Front and top view: (dimensions in millimeters [mm])

4- W-W-W CONNECTION UNDER HIGH TEMPERATURE

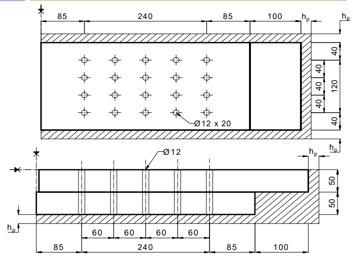
EC5 is used to determine an extra thickness for the unprotected connection, and panel thickness for protected connection.

Dimension	Initial dimensions	$F_{v,Rk}$ [1]	Exposure time	New dimensions	$F_{v,Rk}$ [2]
[mm]	[mm]	[N]	[min]	[mm]	[N]
Ø12	$t_1 = 50$ lateral $t_2 = 100$ internal	7731,81	30	$t_1 = 58,25$ $t_2 = 100$	8489,26

Dowels Ø12	t_{req}	t_{ch}	h_p
	[min]	[min]	[mm]
Gypsum type A	30	20	12,1
	60	50	22,9
Gypsum type F	30	6	7,1
	60	36	17,9
Wood panelling	30	20	10
	60	50	25



Unprotected model (extra thickness)

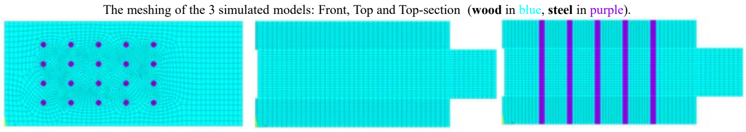


Protected model (protective panel thickness)

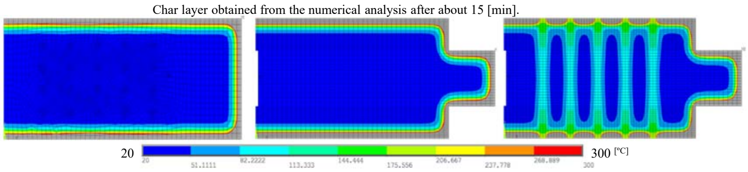
5- THERMAL FEM ANALYSIS OF UNPROTECTED MODELS

One half of all 2D models were produced in FEM program (ANSYS) with a non-linear thermal and transient analysis. The 3 sides of the models will be exposed to standard fire curve ISO834, essential for timber structures to predict the charring rate.

The meshing of the 3 simulated models: Front, Top and Top-section (**wood** in blue, **steel** in purple).



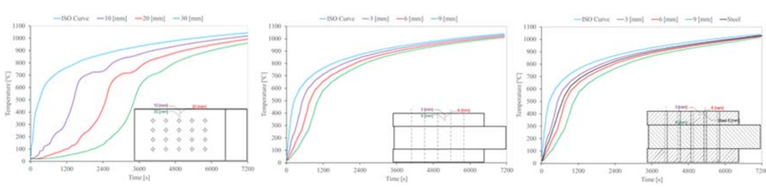
Char layer obtained from the numerical analysis after about 15 [min].



Charring rate from the different models at different nodal positions and time instants.

Model		FRONT						TOP						TOP-SECTION					
Temp.	[ºC]	280			300			280			300			280			300		
Depth (d)	[mm]	10	20	30	10	20	30	2,913	5,83	8,74	2,913	5,83	8,74	2,913	5,825	8,74	2,913	5,825	8,74
Time (t)	[s]	1093,7	2023,7	3013,7	1133,7	2093,7	3073,7	300,3	520,3	740,3	320,3	540,3	760,3	305,2	515,2	745,2	325,2	545,2	775,2
Charring	β	0,59	0,59	0,60	0,53	0,57	0,59	0,58	0,67	0,71	0,55	0,65	0,69	0,57	0,68	0,70	0,54	0,64	0,68
Average	β	0,59			0,56			0,65			0,63			0,65			0,62		

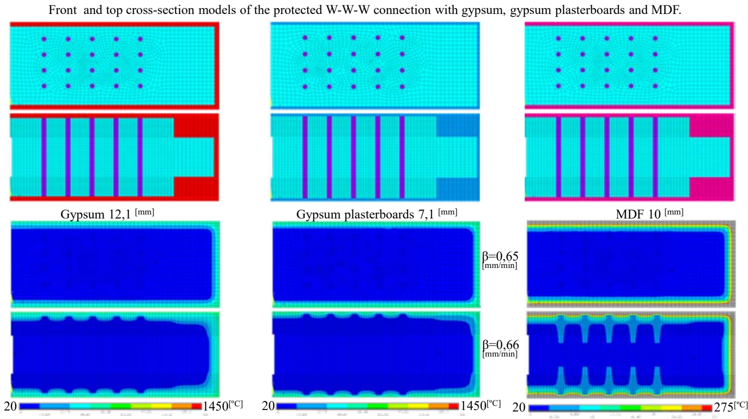
Numerical results of the temperature evolution during 120[min] for the 3 models.

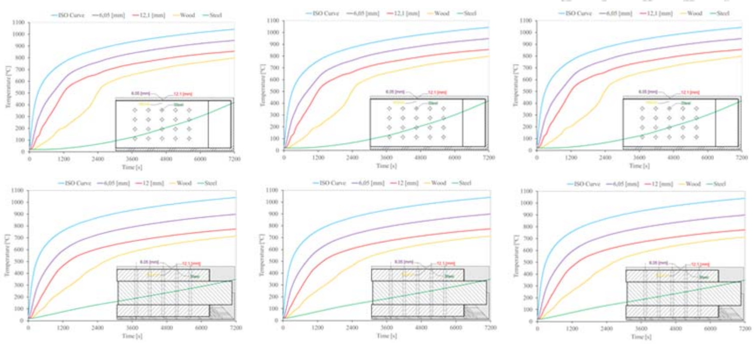


6- THERMAL FEM ANALYSIS OF PROTECTED MODELS

For protected models, 3 different insulation materials were considered (gypsum, gypsum plasterboards and medium density fiberboards MDF), to verify the heat effect produced by fire.

Front and top cross-section models of the protected W-W-W connection with gypsum, gypsum plasterboards and MDF.





7- CONCLUSIONS

- Models insulated with gypsum plasterboard and gypsum are more stable under fire, when compared with the models with an extra thickness of timber or insulated with MDF.
- The numerical analysis of hybrid wood/steel elements allows to understand better the influence of dowels in the heat conduction inside the connections.
- The numerical simulations are very relevant, the models can be used for verification in other type of W-W-W connections subjected to fire action and mechanical loading conditions.
- This knowledge can be taken into account for construction to minimize the failure and increasing the people safety.

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