

Supplementary Information

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Effective Cross-Section of a Timber Beam Exposed to Natural Fires

Sabina Huč^{a,b,*}, Tomaž Hozjan^a, Robert Pečenko^a

^a Faculty of Civil and Geodetic Engineering, University of Ljubljana, Jamova 2, Ljubljana, Slovenia

^b Faculty of Chemistry and Chemical Technology, University of Ljubljana, Večna pot 113, Ljubljana, Slovenia

* Corresponding author. *Email address:* sabina.huc@fgg.uni-lj.si

Table S1 Input parameters in the fire model: conductivity of the enclosure λ , width of the openings l_w and design fire load density $q_{f,d}$, and output parameters of each fire scenario (No.) which represent a natural fire curve: maximum gas temperature $T_{g,max}$ reached at time $t_{g,max}$, time of the cooling phase end $t_{g,end}$ and linear cooling rate $v_{cool,lin}$

No.	λ [W m ⁻¹ K ⁻¹]	$l_w/2$ [m]	$q_{f,d}$ [MJ m ⁻²]	$T_{g,max}$ [°C]	$t_{g,max}$ [min]	$t_{g,end}$ [min]	$v_{cool,lin}$ [°C min ⁻¹]
1	2.2500	16.94	900	591	56	92	14.0
2	3.0625	15.24	800	623	51	83	16.0
3	1.0000	16.94	900	613	56	92	14.6
4	2.2500	16.94	1200	599	70	118	10.7
5	0.2500	16.94	900	639	56	92	15.4
6	3.0625	11.01	500	740	38	57	29.8
7	2.2500	16.94	1250	600	72	122	10.2
8	2.2500	16.94	1300	602	75	127	10.1
9	0.5625	15.24	800	680	51	83	18.0
10	1.0000	16.94	1200	618	70	118	11.2
11	4.0000	13.55	900	670	56	92	15.4
12	1.0000	16.94	1250	619	72	122	10.7
13	1.0000	16.94	1300	620	75	127	10.5
14	4.0000	5.08	300	844	30	44	38.2
15	0.2500	16.94	1200	640	70	118	11.8
16	3.0625	9.31	500	816	38	57	31.8
17	1.5625	13.55	900	714	56	92	16.7
18	0.5625	15.24	1100	685	65	109	13.4
19	4.0000	13.55	1200	684	70	118	11.9
20	2.2500	10.16	600	822	42	66	27.0
21	2.2500	3.39	300	855	36	57	23.4
22	2.2500	10.16	650	828	45	70	25.7
23	1.5625	13.55	1200	725	70	118	12.9
24	1.5625	5.08	300	987	30	44	40.2
25	1.0000	10.16	600	889	42	66	29.8
26	0.5625	11.85	800	834	51	83	21.7
27	2.2500	3.39	350	884	40	65	21.0
28	4.0000	7.62	600	901	42	66	27.4
29	1.0000	10.16	650	894	44	70	27.2
30	0.5625	9.31	500	980	38	57	39.2
31	2.2500	10.16	900	856	56	92	19.2
32	2.2500	3.39	400	909	45	73	19.7
33	2.2500	10.16	950	860	59	96	18.6
34	0.2500	10.16	600	972	42	66	33.0
35	2.2500	10.16	1000	865	61	101	17.8
36	1.0000	3.39	300	1001	37	58	27.7
37	1.0000	10.16	900	914	56	92	21.0
38	4.0000	5.08	600	962	47	76	22.6
39	1.5625	7.62	600	1028	42	66	32.0
40	1.0000	10.16	950	916	58	96	19.8
41	1.0000	3.39	350	1033	41	66	25.1
42	4.0000	7.62	900	960	56	92	20.0
43	1.0000	3.39	400	1058	45	74	22.7
44	1.5625	5.08	600	1120	48	77	27.0

Table S2 Input parameters in the hygro-thermal model and the mechanical model

Material parameter	Symbol and value	Unit
Hygro-thermal model		
Universal gas constant	$R = 8.3144$	$\text{J mol}^{-1} \text{K}^{-1}$
Gas constant for water vapor	$R_v = 461.5$	$\text{J kg}^{-1} \text{K}^{-1}$
Gas constant for air	$R_a = 287$	$\text{J kg}^{-1} \text{K}^{-1}$
Diffusion coefficient tangential dir.	$D_0 = 7 \cdot 10^{-6}$	$\text{m}^2 \text{s}^{-1}$
Specific permeability of dry wood	$K = 5 \cdot 10^{-16}$	m^2
Relative permeability of gas	$K_g = 1$	-
Direction dependent reduction factor	$\zeta = 0.03$	-
Specific heat of water	$C_w = 4200$	$\text{J kg}^{-1} \text{K}^{-1}$
Specific heat of water vapor	$C_v = 1800$	$\text{J kg}^{-1} \text{K}^{-1}$
Specific heat of air	$C_a = 1000$	$\text{J kg}^{-1} \text{K}^{-1}$
Heat of sorption	$\Delta H_s = 2500$	kJ kg^{-1}
Initial dry density of timber	$\rho_0 = 420$	kg m^{-3}
Porosity of timber	$\varepsilon_g = 0.67$	-
Energy required to break a hydrogen bond	$E_b = 38.5 - 29 c_b / \rho_0$	J mol^{-1}
Initial bound water concentration	$c_{b0} = 81.6$	kg m^{-3}
Initial water vapor concentration in lumens	$\rho_{v,0} = 9$	g m^{-3}
Initial gas pressure	$P_{g,0} = 100$	kPa
Initial temperature	$T_0 = 20$	$^{\circ}\text{C}$
Surface emissivity	$\varepsilon_m = 0.8$	-
Surface emissivity of fire	$\varepsilon_f = 1$	-
Coefficient of heat transfer	$\alpha_c = 35$	$\text{W m}^{-2} \text{K}^{-1}$
Mass transfer coefficient	$\beta = 20 \cdot 10^{-8}$	s m^{-1}
Thermal conductivity of timber and char layer	k , according to EN 1995-1-2	$\text{W m}^{-1} \text{K}^{-1}$
Specific heat of timber and char layer	C , according to EN 1995-1-2	$\text{J kg}^{-1} \text{K}^{-1}$
Density of timber and char layer	ρ , according to EN 1995-1-2	kg m^{-3}
Sorption parameters	$C_1 = 2.7 \cdot 10^{-4}$, $C_{21} = 2.74 \cdot 10^{-5}$, $C_{22} = 19$, $C_3 = 60$, $C_4 = 10^{-7}$	-
	$b_{10}^d = 16.3$, $b_{11}^d = -0.01367$, $b_{20}^d = 2.13$,	-
	$b_{22}^d = 0.0535$	-
Mechanical model		
Characteristic bending strength of timber	$f_{m,k} = 35$	MPa
The first load level	$F_1 = 56.0$	kN
Load increment	$\Delta F = 0.0056$	kN
Shear modulus	$G = 81$	MPa
Shear section	$A_s = 320$	cm^2
Modulus of elasticity at room temperature	$E_{t,T0} = E_{c,T0} = 13350$	MPa
Hardening modulus	$E_{c,p,T0} = E_{t,p,T0} = 500$	MPa
Characteristic tension strength at room temperature	$f_{t,T0} = 22.5$	MPa
Characteristic compression strength at room temperature	$f_{c,T0} = 25$	MPa
Strains in the bilinear material model	$D_{t,T0} = 0.0016$, $D_{c,T0} = 0.0019$, $D_{t,p} = 0.018$,	-
	$D_{c,p} = 0.035$	-
Coefficient of thermal expansion	$\alpha_T = 5 \cdot 10^{-6}$	K^{-1}

Table S3 Output parameters of the hygro-thermal and the mechanical models in each fire scenario (No.): the mechanical resistance under fire conditions $M_{Rd,fi}$ obtained at the time t_{end} , the time of the charring thickness end value $t_{dch,end}$, the charring thickness d_{ch} , the zero-strength layer thickness d_0 , and the effective thickness d_{ef}

No.	$M_{Rd,fi}$ [kN m]	t_{end} [min]	$t_{dch,end}$ [min]	d_{ch} [mm]	d_0 [mm]	d_{ef} [mm]
1	25.8	108.5	79.8	18.2	24.8	43.0
2	26.1	100.7	76.0	19.6	23.0	42.6
3	25.1	99.8	73.5	20.1	23.9	44.0
4	21.7	114.9	78.7	22.3	26.7	49.0
5	24.2	93.1	67.4	22.4	22.8	45.2
6	28.1	71.5	44.6	22.5	17.4	39.9
7	20.9	119.1	81.2	23.0	27.2	50.2
8	20.4	121.9	83.9	23.6	27.4	51.1
9	24.0	95.6	61.9	24.2	21.4	45.6
10	20.8	112.7	77.4	24.2	26.2	50.4
11	22.6	101.9	65.7	24.8	22.8	47.7
12	20.1	121.5	79.9	24.9	26.6	51.5
13	19.5	123.5	106.2	25.6	26.9	52.5
14	26.0	72.4	54.5	25.8	17.0	42.8
15	19.5	114.9	100.2	26.8	25.8	52.6
16	24.1	77.7	49.2	28.1	17.4	45.4
17	20.1	104.5	68.3	29.0	22.6	51.6
18	18.3	116.3	86.2	29.9	24.6	54.5
19	17.1	124.7	86.8	30.8	25.8	56.5
20	21.2	82.0	53.4	31.2	18.5	49.7
21	18.9	103.5	70.7	33.0	20.5	53.4
22	19.2	94.2	69.9	33.4	19.5	52.9
23	14.7	129.0	86.5	35.6	25.2	60.9
24	20.2	73.6	42.2	36.5	14.9	51.4
25	18.4	82.4	59.2	37.1	17.2	54.3
26	16.2	96.6	64.7	38.3	19.8	58.1
27	15.6	119.4	59.2	38.5	20.7	59.1
28	16.8	105.8	56.8	38.9	18.2	57.0
29	16.7	88.5	58.8	39.5	17.7	57.2
30	16.8	75.8	51.0	41.2	15.7	56.9
31	13.0	111.8	91.2	43.3	20.7	64.0
32	11.3	146.8	80.5	44.4	23.2	67.6
33	11.1	137.0	84.3	45.2	22.8	68.0
34	13.7	81.1	56.8	45.3	17.4	62.7
35	10.3	130.5	82.2	46.9	22.6	69.5
36	12.1	107.1	68.9	47.1	18.8	65.9
37	9.7	109.2	77.6	50.7	20.3	71.0
38	9.4	144.2	69.3	50.8	20.8	71.6
39	10.6	98.1	60.5	52.3	16.7	69.0
40	8.5	116.1	82.4	52.8	20.8	73.6
41	7.8	120.2	63.3	55.0	20.4	75.4
42	6.9	126.8	82.9	56.4	21.3	77.7
43	4.8	109.8	76.6	62.8	20.5	83.3
44	2.7	94.4	80.5	72.1	17.8	89.9

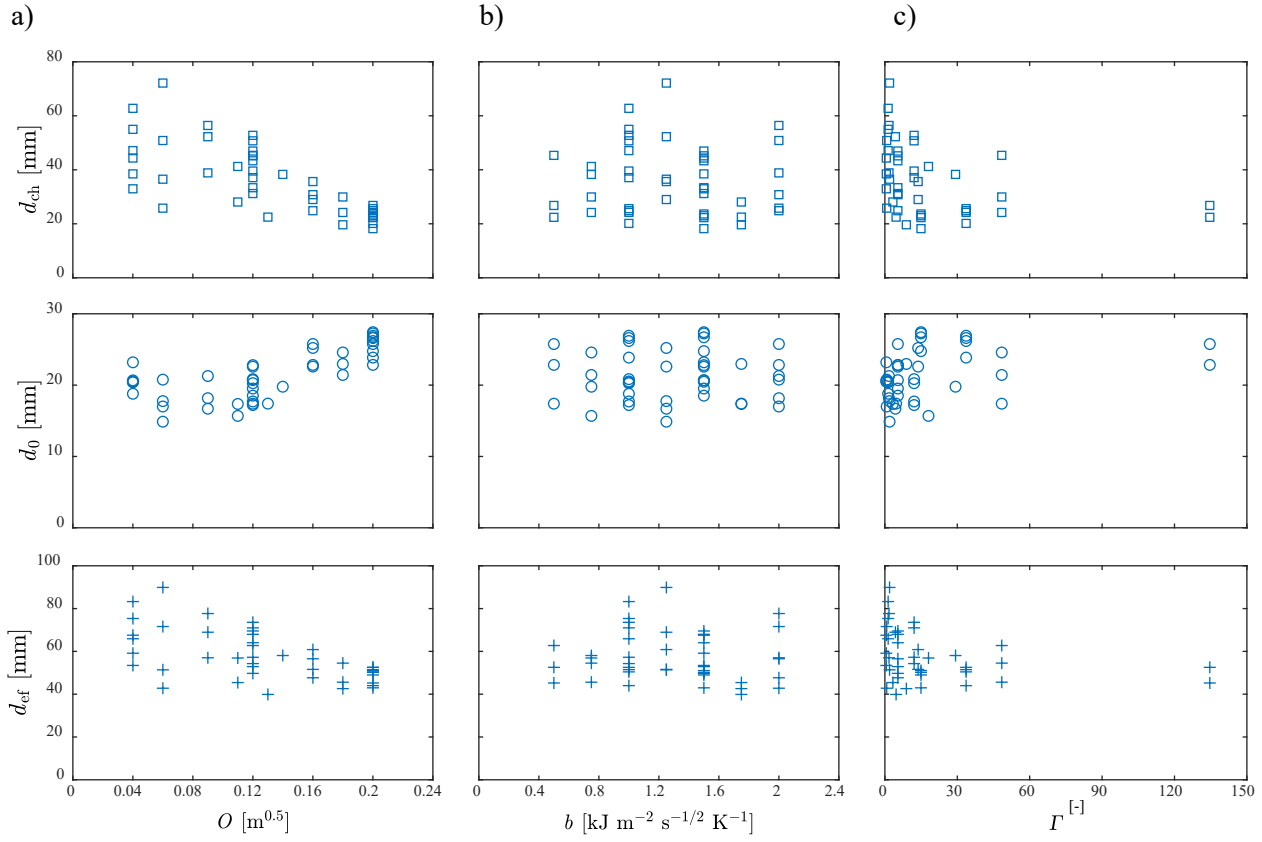


Fig. S1 The charring thickness d_{ch} , the zero-strength layer thickness d_0 and the effective thickness d_{ef} at the time t_{end} plotted against a) the opening factor O , b) the thermal absorptivity for the total enclosure b and c) the dimensionless ratio Γ

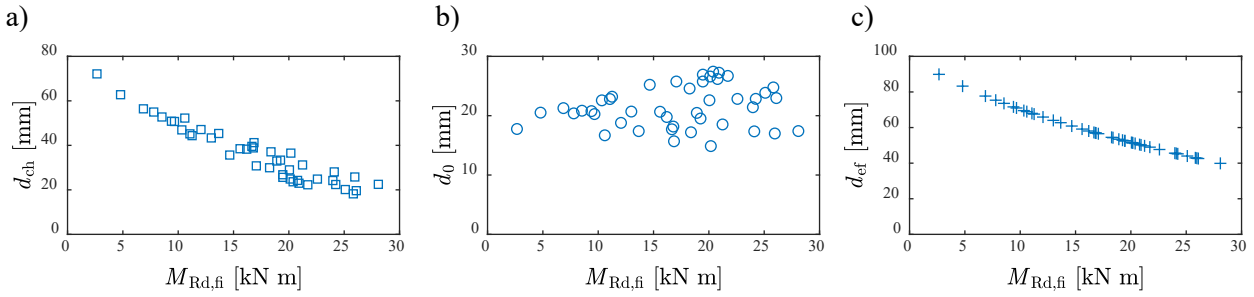


Fig. S2 The charring thickness d_{ch} , the zero-strength layer thickness d_0 and the effective thickness d_{ef} at the time t_{end} in relation to the highest mechanical resistance $M_{Rd,fi}$