SIMPLIFIED METHOD FOR TEMPERATURE DISTRIBUTION IN SLIM FLOOR BEAMS

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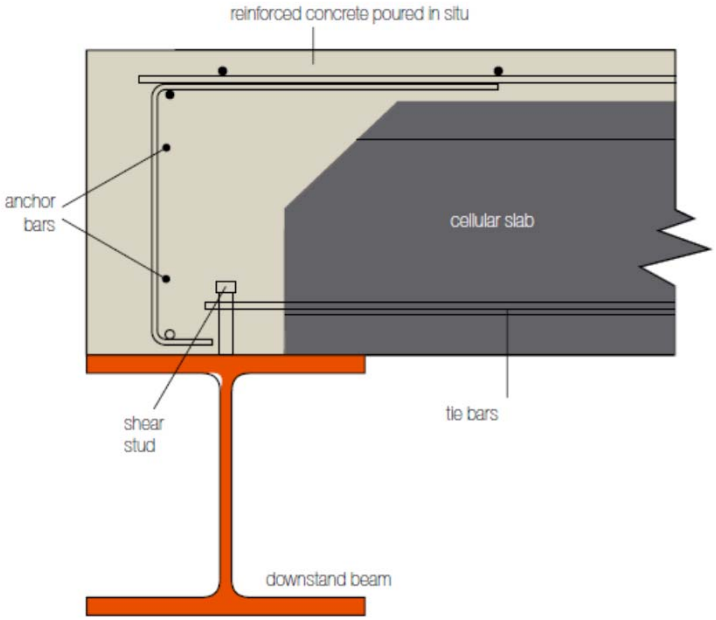
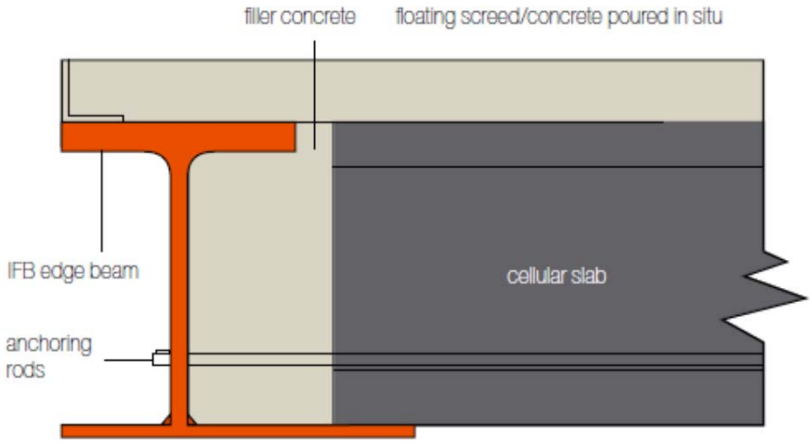




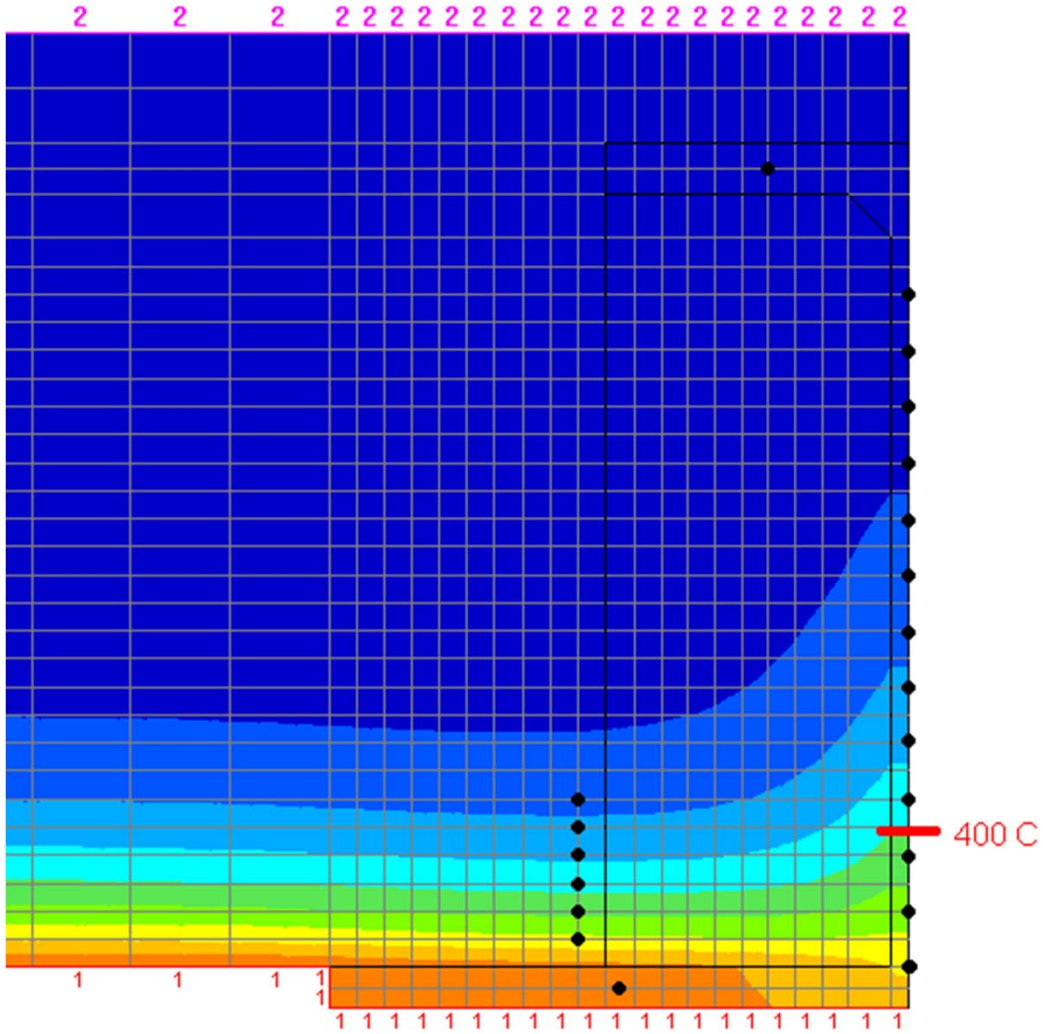
“Classic”

- temperature in the steel beam easy to calculate

Slim Floor

- due to the presence of the concrete, a proper temperature distribution in the steel beam may be calculated by numerical anlysis

A parametric study based on numerical simulations using SAFIR was done, in order to propose simple formulas for the calculation of the temperatures in various points in the cross-section of Slim Floor beams.

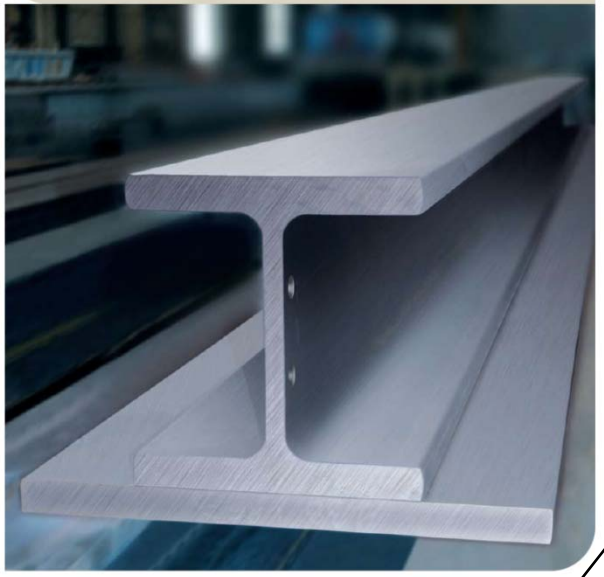


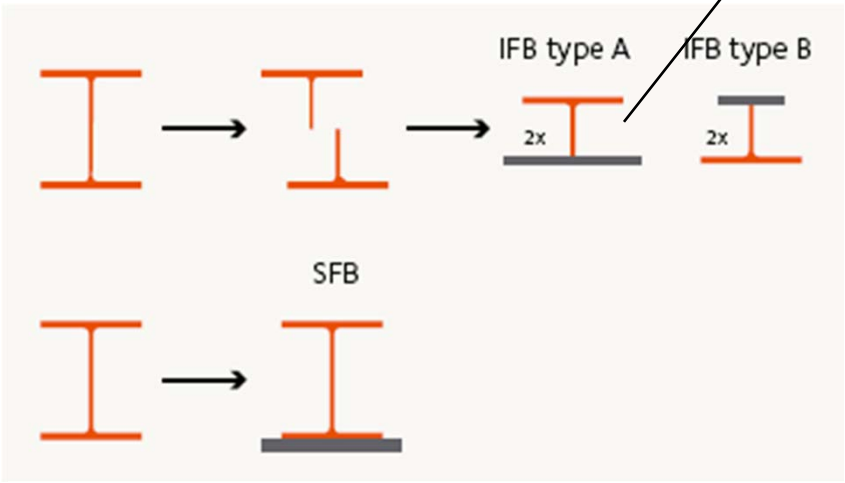
Long Carbon Europe
Sections and Merchant Bars

ArcelorMittal

Slim Floor

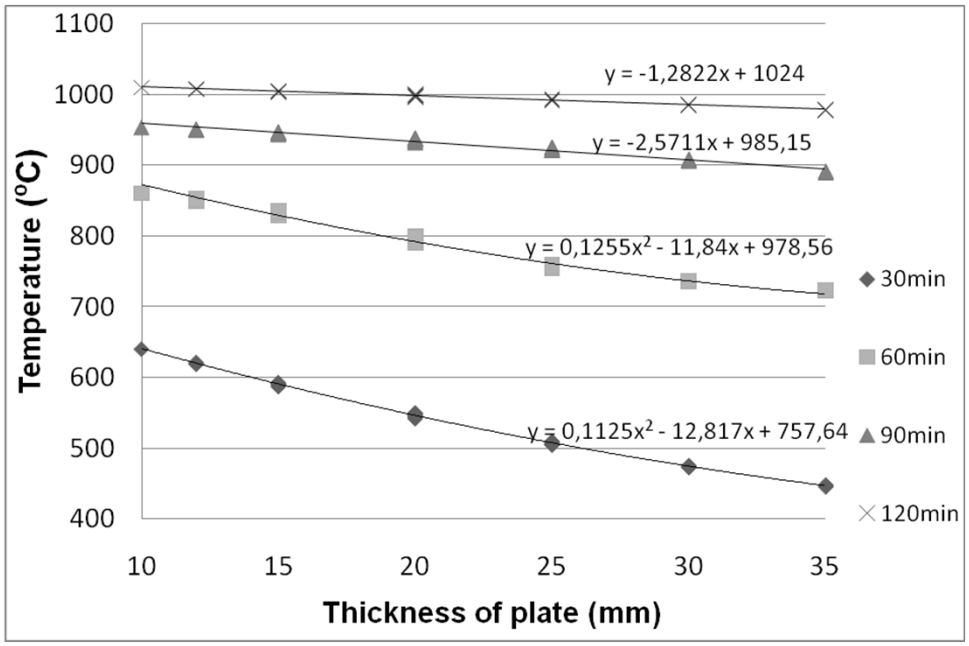
An innovative concept for floors

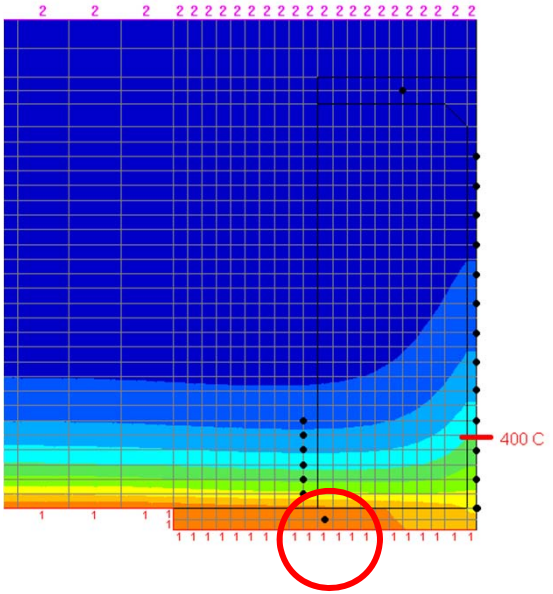




	Section	Plate B x t	Type	G kg/m	H mm	h mm	b mm	t_w mm	t_f mm	r mm	A cm^2	I_y cm^4	W_y cm^3	y_1 cm	y_2 cm
½	IPE 400	380 x 10	A	63,0	200,0	400,0	180,0	8,6	13,5	21,0	80,3	6558	543	8,9	12,1
½	IPE O 400	390 x 12	A	74,6	202,0	404,0	182,0	9,7	15,5	21,0	95,0	7893	627	8,8	12,6
½	IPE 450	390 x 12	A	75,5	225,0	450,0	190,0	9,4	14,6	21,0	96,2	9857	707	9,8	13,9
½	IPE O 450	400 x 12	A	84,0	228,0	456,0	192,0	11,0	17,6	21,0	107,0	11230	834	10,5	13,5
½	IPE 500	400 x 12	A	83,2	250,0	500,0	200,0	10,2	16,0	21,0	106,0	13332	897	11,3	14,9
½	IPE O 500	410 x 15	A	102,1	253,0	506,0	202,0	12,0	19,0	21,0	130,0	16702	1072	11,2	15,6
½	IPE 550	410 x 15	A	100,9	275,0	550,0	210,0	11,1	17,2	24,0	128,5	19499	1143	11,9	17,1
½	IPE O 550	420 x 15	A	110,7	278,0	556,0	212,0	12,7	20,2	24,0	141,0	21826	1317	12,7	16,6
½	IPE 600	420 x 15	A	110,7	300,0	600,0	220,0	12,0	19,0	24,0	141,0	25375	1419	13,6	17,9
½	IPE O 600	430 x 15	A	128,0	305,0	610,0	224,0	15,0	24,0	24,0	163,0	29831	1749	14,9	17,1
½	IPE O 600	430 x 20	A	144,8	305,0	610,0	224,0	15,0	24,0	24,0	184,5	34207	1817	13,7	18,8
½	HE 220 M	430 x 15	A	109,3	120,0	240,0	226,0	15,5	26,0	18,0	139,2	4209	581	6,2	7,3
½	HE 240 M	450 x 20	A	149,0	135,0	270,0	248,0	18,0	32,0	21,0	189,8	7323	872	7,1	8,4
½	HE 260 B	460 x 12	A	89,8	130,0	260,0	260,0	10,0	17,5	24,0	114,4	4252	553	6,5	7,7
½	HE 260 M	470 x 20	A	160,0	145,0	290,0	268,0	18,0	32,5	24,0	203,8	9088	1036	7,7	8,8
½	HE 280 M	500 x 20	A	172,8	155,0	310,0	288,0	18,5	33,0	24,0	220,1	11219	1217	8,3	9,2
½	HE 280 M	500 x 25	A	192,4	155,0	310,0	288,0	18,5	33,0	24,0	245,1	12854	1274	7,9	10,1
½	HE 300 B	500 x 15	A	117,4	150,0	300,0	300,0	11,0	19,0	27,0	149,6	7483	820	7,4	9,1
½	HE 300 M	500 x 25	A	217,1	170,0	340,0	310,0	21,0	39,0	27,0	276,6	17045	1672	9,3	10,2
½	HE 320 B	500 x 15	A	122,2	160,0	320,0	300,0	11,5	20,5	27,0	155,7	8806	931	8,0	9,5
½	HE 320 M	500 x 25	A	220,6	179,5	359,0	309,0	21,0	40,0	27,0	281,0	19209	1809	9,8	10,6
½	HE 320 M	500 x 30	A	240,2	179,5	359,0	309,0	21,0	40,0	27,0	306,0	21544	1883	9,5	11,4
½	HE 340 B	500 x 15	A	126,0	170,0	340,0	300,0	12,0	21,5	27,0	160,5	10173	1033	8,7	9,8
½	HE 340 M	500 x 25	A	222,1	188,5	377,0	309,0	21,0	40,0	27,0	282,9	21299	1925	10,3	11,1
½	HE 340 M	500 x 30	A	241,7	188,5	377,0	309,0	21,0	40,0	27,0	307,9	23849	2001	9,9	11,9
½	HE 360 B	500 x 15	A	129,8	180,0	360,0	300,0	12,5	22,5	27,0	165,3	11661	1140	9,3	10,2
½	HE 360 M	500 x 25	A	223,3	197,5	395,0	308,0	21,0	40,0	27,0	284,4	23467	2036	10,7	11,5
½	HE 360 M	500 x 30	A	242,9	197,5	395,0	308,0	21,0	40,0	27,0	309,4	26234	2113	10,3	12,4
½	HE 400 B	500 x 20	A	156,1	200,0	400,0	300,0	13,5	24,0	27,0	198,9	17420	1407	9,6	12,4
½	HE 400 M	500 x 25	A	226,0	216,0	432,0	307,0	21,0	40,0	27,0	287,9	28311	2271	11,6	12,5
½	HE 400 M	500 x 30	A	245,6	216,0	432,0	307,0	21,0	40,0	27,0	312,9	31559	2352	11,2	13,4
½	HE 450 B	500 x 20	A	164,1	225,0	450,0	300,0	14,0	26,0	27,0	209,0	22963	1707	11,0	13,5
½	HE 450 M	500 x 25	A	229,8	239,0	478,0	307,0	21,0	40,0	27,0	292,7	35066	2575	12,8	13,6
½	HE 450 M	500 x 30	A	249,4	239,0	478,0	307,0	21,0	40,0	27,0	317,7	38978	2661	12,3	14,6
½	HE 500 A	500 x 20	A	156,0	245,0	490,0	300,0	12,0	23,0	27,0	198,8	25945	1721	11,4	15,1
½	HE 500 B	500 x 20	A	172,2	250,0	500,0	300,0	14,5	28,0	27,0	219,3	29448	2034	12,5	14,5
½	HE 500 M	500 x 25	A	233,3	262,0	524,0	306,0	21,0	40,0	27,0	297,2	42530	2876	13,9	14,8
½	HE 500 M	500 x 30	A	252,9	262,0	524,0	306,0	21,0	40,0	27,0	322,2	47155	2968	13,3	15,9
½	HE 550 A	500 x 20	A	161,6	270,0	540,0	300,0	12,5	24,0	27,0	205,9	32357	1990	12,7	16,3
½	HE 550 B	500 x 20	A	178,2	275,0	550,0	300,0	15,0	29,0	27,0	227,1	36480	2334	13,9	15,6
½	HE 550 B	500 x 25	A	197,9	275,0	550,0	300,0	15,0	29,0	27,0	252,1	40972	2406	13,0	17,0
½	HE 550 M	500 x 25	A	237,2	286,0	572,0	306,0	21,0	40,0	27,0	302,2	51214	3203	15,1	16,0
½	HE 550 M	500 x 30	A	256,9	286,0	572,0	306,0	21,0	40,0	27,0	327,2	56660	3301	14,4	17,2
½	HE 550 M	500 x 35	A	276,5	286,0	572,0	306,0	21,0	40,0	27,0	352,2	61669	3387	13,9	18,2
½	HE 600 A	500 x 20	A	167,4	295,0	590,0	300,0	13,0	25,0	27,0	213,3	39636	2275	14,1	17,4
½	HE 600 B	500 x 20	A	184,5	300,0	600,0	300,0	15,5	30,0	27,0	235,0	44424	2652	15,2	16,8
½	HE 600 B	500 x 25	A	204,1	300,0	600,0	300,0	15,5	30,0	27,0	260,0	49851	2733	14,3	18,2
½	HE 600 M	500 x 30	A	260,5	310,0	620,0	305,0	21,0	40,0	27,0	331,9	66995	3629	15,5	18,5
½	HE 600 M	500 x 35	A	280,1	310,0	620,0	305,0	21,0	40,0	27,0	356,9	72792	3720	14,9	19,6
½	HE 650 A	500 x 20	A	173,3	320,0	640,0	300,0	13,5	26,0	27,0	220,8	47826	2577	15,4	18,6
½	HE 650 B	500 x 25	A	210,5	325,0	650,0	300,0	16,0	31,0	27,0	268,2	59792	3076	15,6	19,4
½	HE 650 M	500 x 25	A	244,8	334,0	668,0	305,0	21,0	40,0	27,0	311,9	71098	3860	17,5	18,4
½	HE 650 M	500 x 30	A	264,4	334,0	668,0	305,0	21,0	40,0	27,0	336,9	78375	3971	16,7	19,7
½	HE 650 M	500 x 35	A	284,1	334,0	668,0	305,0	21,0	40,0	27,0	361,9	85035	4068	16,0	20,9
½	HE 280 A	80 x 40	B	63,3	162,0	270,0	280,0	8,0	13,0	24,0	80,7	4004	396	7,4	10,1
½	HE 300 A	100 x 30	B	67,7	161,0	290,0	300,0	8,5	14,0	27,0	86,3	4375	417	7,0	10,5
½	HP 360 x 109	170 x 20	B	81,2	180,3	346,4	371,0	12,8	12,9	15,2	103,5	6739	606	8,2	11,1
½	HP 360 x 109	170 x 30	B	94,6	190,3	346,4	371,0	12,8	12,9	15,2	120,5	8716	832	9,8	10,5
½	HP 360 x 133	170 x 20	B	93,0	180,3	352,0	373,8	15,6	15,7	15,2	118,5	7527	634	7,7	11,9
½	HP 360 x 133	170 x 30	B	106,4	190,3	352,0	373,8	15,6	15,7	15,2	135,5	9795	866	9,3	11,3
½	HP 360 x 152	170 x 30	B	116,2	190,3	356,4	376,0	17,8	17,9	15,2	148,0	10585	895	9,0	11,8
½	HP 360 x 152	170 x 40	B	129,5	200,3	356,4	376,0	17,8	17,9	15,2	165,0	12909	1117	10,3	11,6
½	HP 400 x 122	190 x 20	B	91,1	180,0	348,0	390,0	14,0	14,0	15,0	116,0	7597	678	8,2	11,2
½	HP 400 x 122	190 x 30	B	106,0	190,0	348,0	390,0	14,0	14,0	15,0	135,0	9837	932	9,8	10,6
½	HP 400 x 140	190 x 30	B	115,0	190,0	352,0	392,0	16,0	16,0	15,0	146,5	10658	960	9,5	11,1
½	HP 400 x 140	190 x 40	B	129,9	200,0	352,0	392,0	16,0	16,0	15,0	165,5	12931	1194	10,8	10,8
½	HP 400 x 158	190 x 30	B	123,6	190,0	356,0	394,0	18,0	18,0	15,0	157,5	11435	983	9,2	11,6
½	HP 400 x 158	190 x 40	B	138,6	200,0	356,0	394,0	18,0	18,0	15,0	176,5	13926	1230	10,5	11,3
½	HP 400 x 176	190 x 30	B	132,7	190,0	360,0	396,0	20,0	20,0	15,0	169,0	12179	1009	8,9	12,1
½	HP 400 x 176	190 x 40	B	147,6	200,0	360,0	396,0	20,0	20,0	15,0	188,0	14874	1261	10,2	11,8
½	HP 400 x 194	190 x 30	B	142,1	190,0	364,0	398,0	22,0	22,0	15,0	181,0	12899	1037	8,8	12,4
½	HP 400 x 194	190 x 40	B	157,0	200,0	364,0	398,0	22,0	22,0	15,0	200,0	15786	1293	10,0	12,2

Temperature in the bottom flange

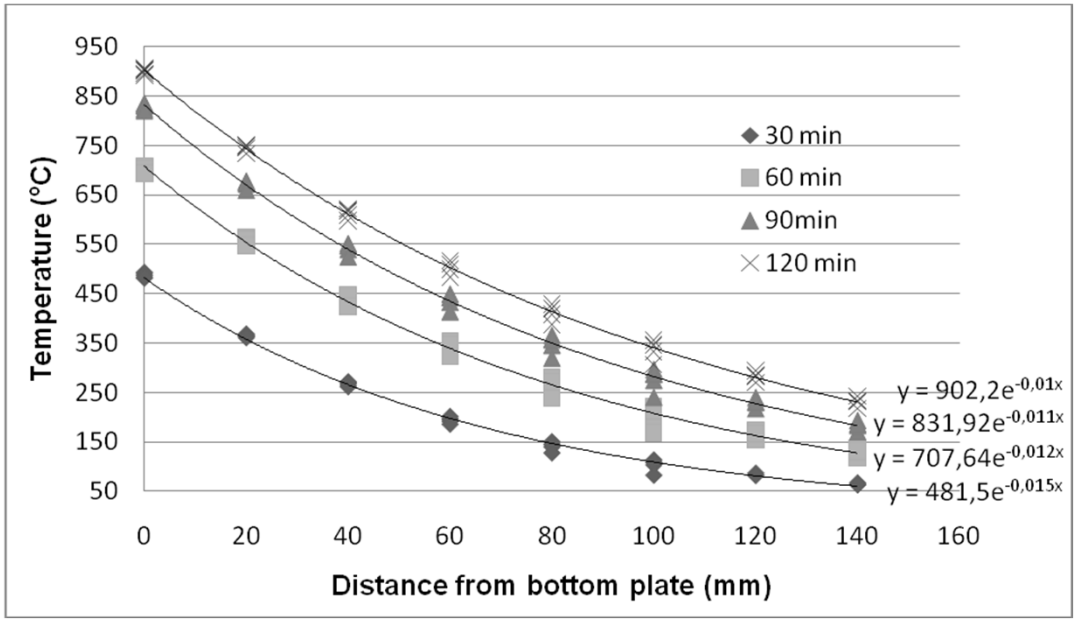


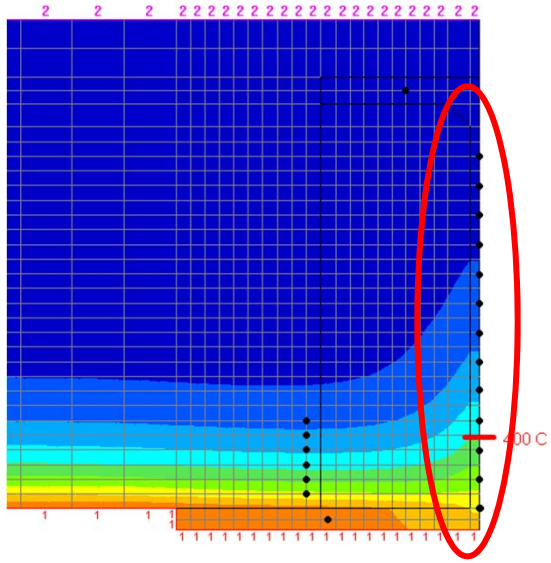


$$T_i = A_i t_{pl}^2 + B_i t_{pl} + C_i$$

Time [min]	A_i	B_i	C_i
30	0.113	-12.50	760
60	0.130	-11.80	980
90	-	-2.60	990
120	-	-1.25	1025

Temperature in the web of the steel profile





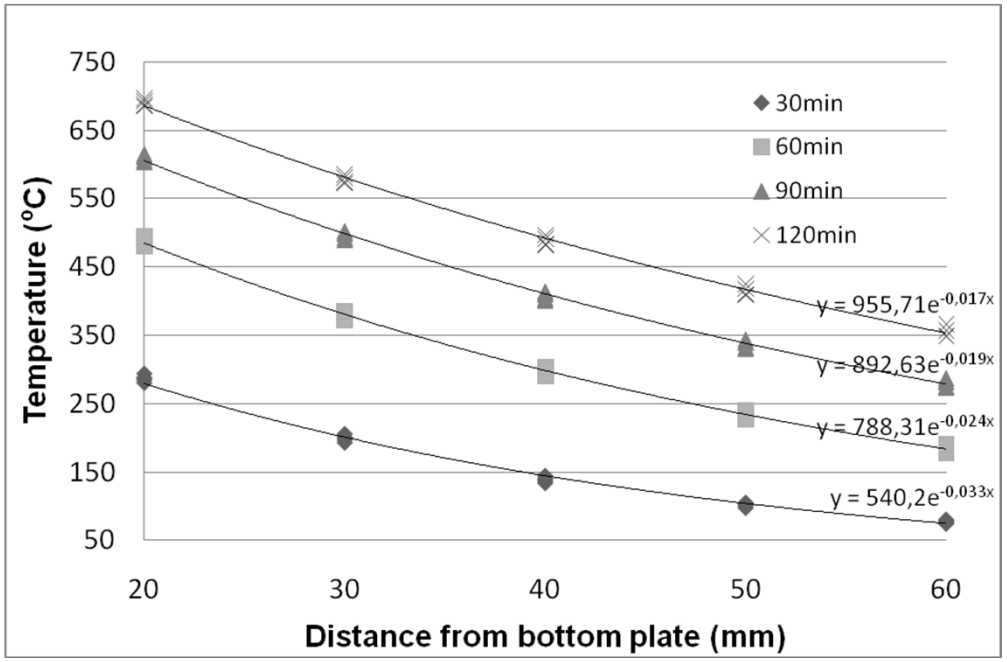
$$T_w = k_1 \, e^{k_2 \, z}$$

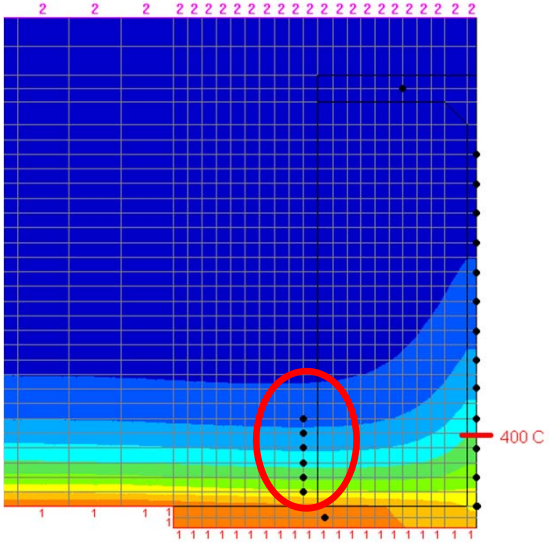
$$k_1 = A_w \ln\left(t_{pl}\right) + B_w$$

$$k_2 = C_w \ln\left(t_{pl}\right) + D_w$$

Time [min]	A_w	B_w	C_w	D_w
30	-140.70	832.42	0.0317	-0.230
60	-103.80	968.60	0.0232	-0.182
90	-108.60	1146.70	0.0198	-0.154
120	-70.44	1124.40	0.0158	-0.134

Temperature in the rebars





$$T_c = k_3 \, e^{k_4 \, z}$$

$$k_3 = A_c \ln\left(t_{pl}\right) + B_c$$

$$k_4 = C_c \ln\left(t_{pl}\right) + D_c$$

Time [min]	A_c	B_c	C_c	D_c
30	-6.90	612.67	0.0009	-0.342
60	-4.06	834.64	-0.0005	-0.240
90	-2.71	970.63	-0.0005	-0.181
120	-1.37	1043.80	-0.0005	-0.150

Conclusions

- The temperature distribution on the cross-sections of the composite Slim Floor beams subjected to ISO fire was investigated using numerical methods and some simple formulas have been developed for determining the values of temperatures in various points, by means of a parametric study.

- Using these formulas, the load bearing capacity of the beams may be calculated, by means of a simple analytical approach, by considering each part of the cross-section that contributes to the load bearing capacity with the corresponding reduced resistance, function of the temperature.

Thank you for your attention !

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