LOCAFI+

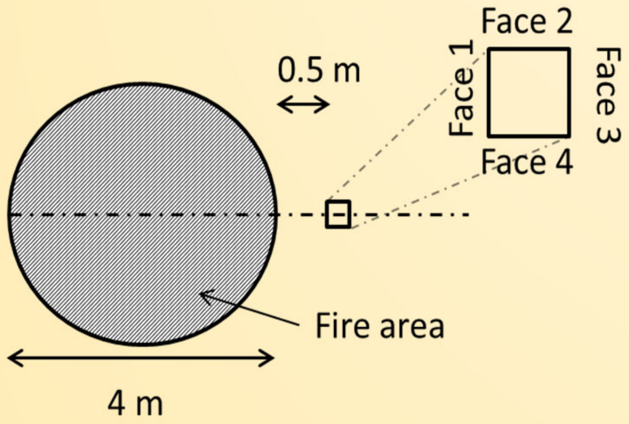
Temperature assessment of a vertical member subjected to LOCAlised FIre
Dissemination

Grant Agreement n° 754072

7. Worked examples

7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire



Column section : HEB 300

Diameter of the fire source : 4m

Distance between the fire and the column : 0.5m

Rate of heat release density : 1000 kW.m^{-2}

Conic flame

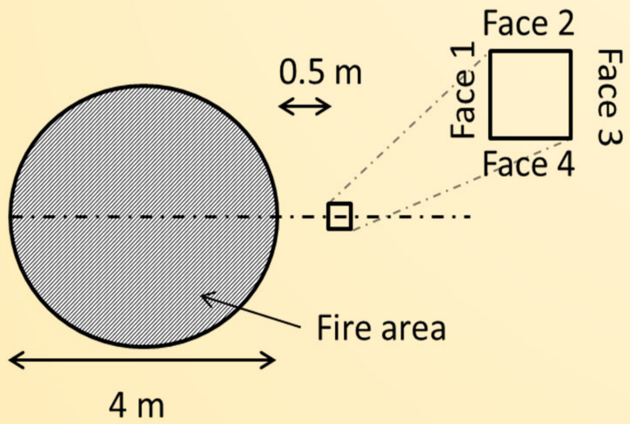
Column situated outside the fire and the smoke layer

No ceiling

Calculation is made for z = 1.0m

7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire



$D = 4\ m$

$Q = RHR * \frac{\pi}{4} * D^2 = 12566371\ W$

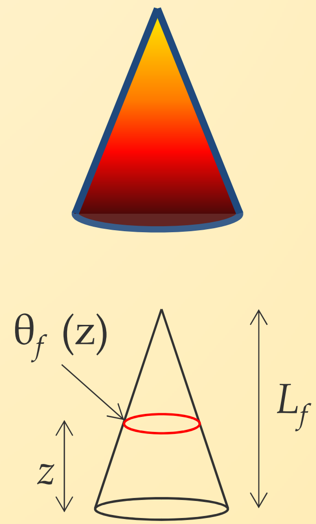
$L_f = -1.02\ D + 0.0148\ Q^{0.4} = 6.15$ m

$z_0 = -1.02\ D + 0.00524\ Q^{0.4} =$ -0.48 m

Flame temperature

$$\theta_f(z) = \min\left(900; 20 + 0.25\left(0.8Q(t)\right)^{2/3}(z - z_0)^{-5/3}\right)$$

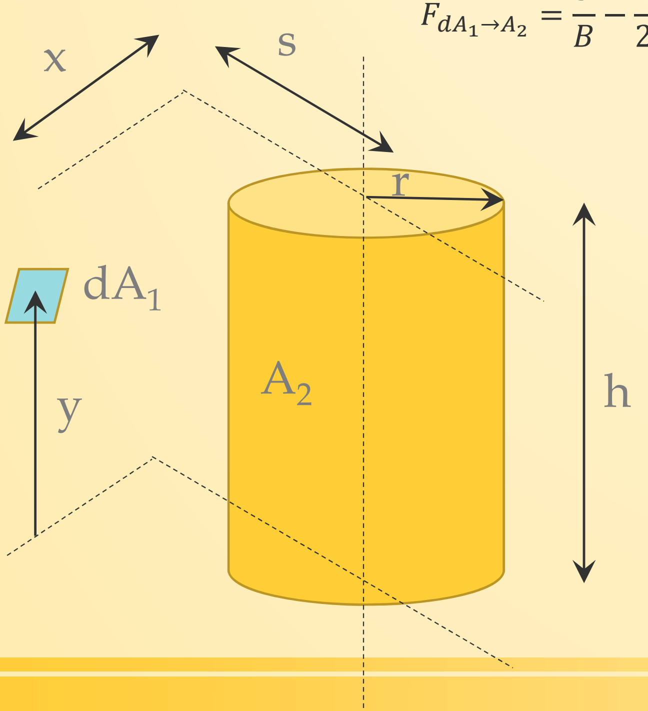
z (m)	T (°C)
0	900
0.5	900
1	900
1.5	900
2	900
2.5	900
3	900
3.5	900
4	900
4.5	827.9
5	708.4
5.5	614.8
6	540.0
6.5	479.3
7	429.1
7.5	387.2



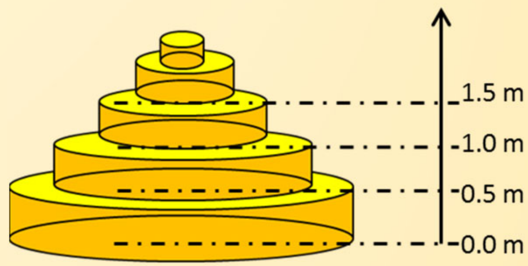
7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire

<u>Face 1</u>



$$F_{dA_1 \to A_2} = \frac{S}{B} - \frac{S}{2B\pi} \left\{ \begin{array}{l} cos^{-1}\left(\frac{Y^2 - B + 1}{A - 1}\right) + cos^{-1}\left(\frac{C - B + 1}{C + B - 1}\right) \\ -Y\left[\frac{A + 1}{\sqrt{(A - 1)^2 + 4Y^2}} cos^{-1}\left(\frac{Y^2 - B + 1}{\sqrt{B}(A - 1)}\right)\right] \\ -\sqrt{C}\frac{C + B + 1}{\sqrt{(C + B - 1)^2 + 4C}} cos^{-1}\left(\frac{C - B + 1}{\sqrt{B}(C + B - 1)}\right) \\ +H cos^{-1}\left(\frac{1}{\sqrt{B}}\right) \end{array} \right\}$$



$$S = s/r$$
$$X = x/r$$
$$H = h/r$$
$$A = X^2 + Y^2 + S^2$$
$$B = S^2 + X^2$$
$$C = (H - Y)^2$$

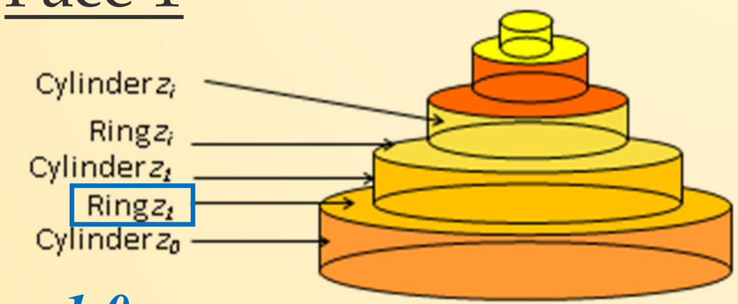
$$F_i = F_{dA_1 \to A_2}\left(s = s_f, x = x_f, r = r_i, h = |z_i - z_f|\right)$$
$$F_{i+1} = F_{dA_1 \to A_2}\left(s = s_f, x = x_f, r = r_i, h = |z_{i+1} - z_f|\right)$$

$$\left| \begin{array}{l} if\ z_i \geq z_f\ then\ F = F_{i+1} - F_i \\ else\ F = F_i - F_{i+1} \end{array} \right.$$

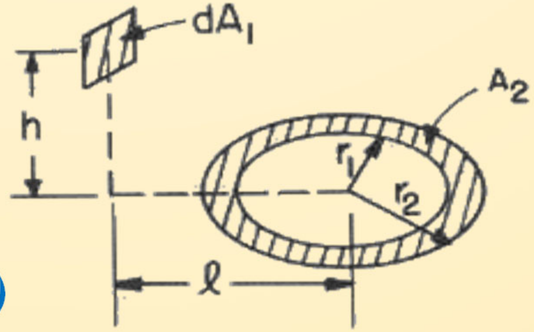
7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire

<u>Face 1</u>



$$F_{dA_1 \rightarrow A_2} = \frac{H}{2}\left(\frac{H^2 + R_2^2 + 1}{\sqrt{(H^2 + R_2^2 + 1)^2 - 4R_2^2}} - \frac{H^2 + R_1^2 + 1}{\sqrt{(H^2 + R_1^2 + 1)^2 - 4R_1^2}}\right)$$



$H = h/l = (1 - 0.5)/2.5 = 0.2$

$R_2 = r_2/l = 2/2.5 = 0.8$

$R_1 = r_1/l = 1.84/2.5 = 0.73$

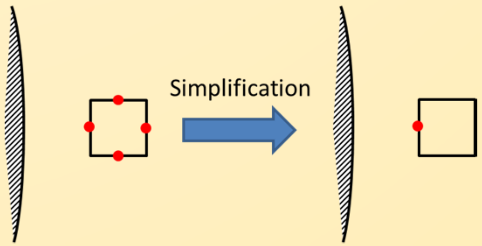
$z_f = 1.0m$

→ Only one ring to consider ($z_i = 0.5m$)

External radius $r_2 = 2.0m$

Internal radius $r_1 = (6.15-0.5)/6.15*2.0m = 1.84m$

Simplification : $l = 2.5m$



7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire

Face 1

Input data				
HRR	Dfire	Q	Q	hf
kW/m²	m	W	MW	m
1000	4	12566370.6	12.57	6.15

Constant	
σ	Tabs
5.67E-08	273.15

Section coordinate		
sf	xf	zf
m	m	m
2.5	0	1

Intermediate variables	
z_{virt}	l
-0.46	2.5

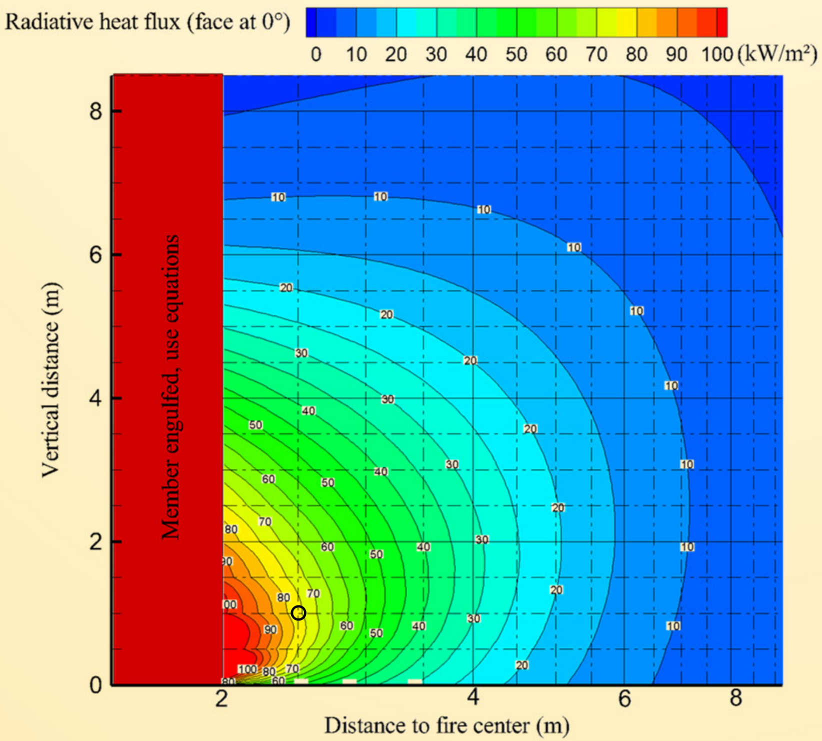
						Cylinder									Ring		
zi	Tf	ri	$F_{cylinder\_zi}$	F_{ring_zi}	$Flux_{face1}$	Fi	Fi+1	S	X	A	Hi	Hi+1	|zi-zf|	|zi+1-zf|	H	Ri	Ri+1
m	°C	m	-	-	kW/m²	-	-	-	-	-	-	-	m	m	-	-	-
0	900	2.00	0.0726	0	7.79	0.3705	0.2979	1.25	0	1.56	0.50	0.25	1.00	0.50	0	0.00	0.00
0.5	900	1.84	0.2374	0.0555	31.45	0.2374	0.0000	1.36	0	1.85	0.27	0.00	0.50	0.00	0.20	0.80	0.73
1	900	1.67	0.1893	0	20.33	0.0000	0.1893	1.49	0	2.23	0.00	0.30	0.00	0.50	0	0.73	0.67
1.5	900	1.51	0.0823	0	8.84	0.1514	0.2337	1.65	0	2.73	0.33	0.66	0.50	1.00	0	0.67	0.60
2	900	1.35	0.0361	0	3.88	0.1953	0.2315	1.85	0	3.43	0.74	1.11	1.00	1.50	0	0.60	0.54
2.5	900	1.19	0.0177	0	1.91	0.1958	0.2136	2.11	0	4.43	1.26	1.68	1.50	2.00	0	0.54	0.47
3	900	1.02	0.0095	0	1.02	0.1797	0.1893	2.44	0	5.95	1.95	2.44	2.00	2.50	0	0.47	0.41
3.5	900	0.86	0.0054	0	0.58	0.1564	0.1618	2.90	0	8.41	2.90	3.48	2.50	3.00	0	0.41	0.34
4	900	0.70	0.0031	0	0.34	0.1296	0.1328	3.57	0	12.77	4.29	5.00	3.00	3.50	0	0.34	0.28
4.5	828	0.54	0.0018	0	0.15	0.1009	0.1027	4.66	0	21.68	6.52	7.45	3.50	4.00	0	0.28	0.21
5	708	0.37	0.0010	0	0.05	0.0711	0.0720	6.68	0	44.58	10.68	12.02	4.00	4.50	0	0.21	0.15
5.5	615	0.21	0.0004	0	0.02	0.0405	0.0409	11.80	0	139.24	21.24	23.60	4.50	5.00	0	0.15	0.08
6	540	0.05	0.0001	0	0.00	0.0095	0.0096	50.71	0	2571.11	101.41	111.55	5.00	5.50	0	0.08	0.02
6.5	479	0	0	0	0	0	0	0	0	0	0	0	5.50	6.00	0	0.02	0
7	429	0	0	0	0	0	0	0	0	0	0	0	6.00	6.50	0	0	0
7.5	387	0	0	0	0	0	0	0	0	0	0	0	6.50	1.00	0	0	0

Incident heat flux on face 1	76.36	kW/m²
Absorbed heat flux on face 1	53.45	kW/m²

7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire

Face 1

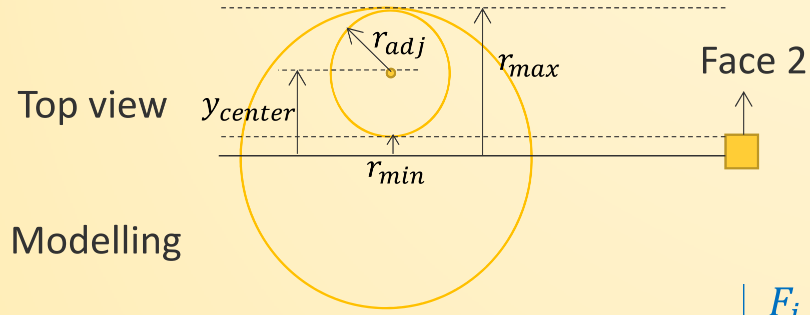


$$\text{Absorbed flux} = \varepsilon * \varphi_{tot}$$
$$= 0.7*77 \text{ kW/m2}$$
$$= 53.9 \text{ kW/m2}$$

7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire

Face 2



$F_i = F_{dA_1 \rightarrow A_2}(s = y_{center} - x_f, x = s_f, r = r_{adjusted}, h = |z_i - z_f|)$

$F_{i+1} = F_{dA_1 \rightarrow A_2}(s = y_{center} - x_f, x = s_f, r = r_{adjusted}, h = |z_{i+1} - z_f|)$

z = 0

$\boldsymbol{r_{min} = max(-r_i, x_f) = 0}$

$\boldsymbol{r_{max} = r_i = 2.0\ \mathrm{m}}$

$\boldsymbol{y_{center} = \frac{r_{min}+r_{max}}{2} = 1.0\ \mathrm{m}}$

$\boldsymbol{r_{adjusted} = \frac{r_{max}-r_{min}}{2} = 1.0\ \mathrm{m}}$

7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire

Face 2

zi	Tf	ri	$F_{cylinder\_zi}$	F_{ring_zi}	$Flux_{face2}$	Ring: H	Ring: Ri	Ring: Ri+1
m	°C	m	-	-	kW/m²	-	-	-
0	900	2.00	0.0175	0	1.88	0	0.00	0.00
0.5	900	1.84	0.0193	0.0060	2.71	0.20	0.40	0.37
1	900	1.67	0.0160	0	1.72	0	0.37	0.33
1.5	900	1.51	0.0103	0	1.10	0	0.33	0.30
2	900	1.35	0.0056	0	0.60	0	0.30	0.27
2.5	900	1.19	0.0028	0	0.30	0	0.27	0.24
3	900	1.02	0.0014	0	0.15	0	0.24	0.20
3.5	900	0.86	0.0006	0	0.07	0	0.20	0.17
4	900	0.70	0.0003	0	0.03	0	0.17	0.14
4.5	828	0.54	0.0001	0	0.01	0	0.14	0.11
5	708	0.37	0.0000	0	0.00	0	0.11	0.07
5.5	615	0.21	0.0000	0	0.00	0	0.07	0.04
6	540	0.05	0.0000	0	0.00	0	0.04	0.01
6.5	479	0	0	0	0	0	0.01	0.00
7	429	0	0	0	0	0	0	0
7.5	387	0	0	0	0	0	0	0
		Incident heat flux on face 2			8.57	kW/m²		
		Absorbed heat flux by face 2			6.00	kW/m²		

Input data				
HRR	Dfire	Q	Q	hf
kW/m²	m	W	MW	m
1000	4	12566370.6	12.57	6.15

Section coordinate		
sf	xf	zf
m	m	m
2.5	0	1

Constant	
σ	Tabs
5.67E-08	273.15

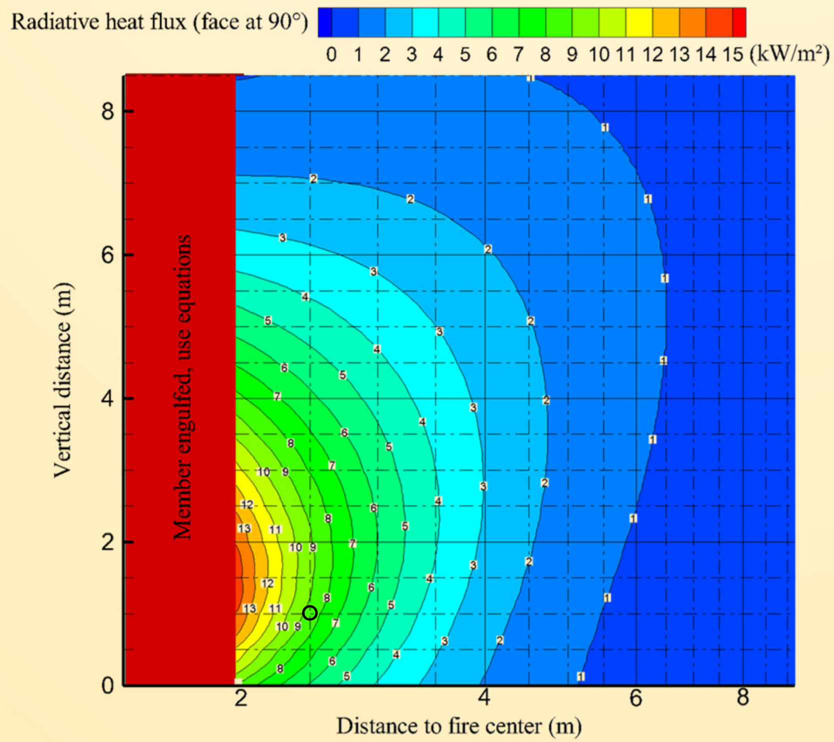
Intermediate variables	
z_{virt}	l
-0.46	2.5

Modified cylinder / ring: rmin	rmax	$ri_{\_adjusted}$	y_{center}	Cylinder: Fi	Fi+1	s	S	X	A	Hi	Hi+1	$\lvert z_i - z_f \rvert$	$\lvert z_{i+1} - z_f \rvert$
m	m	m	m	-	-	-	-	-	-	-	-	m	m
0	2.00	1.00	1.00	0.0403	0.0229	1.00	1.00	2.50	7.25	1.00	0.50	1.00	0.50
0	1.84	0.92	0.92	0.0193	0.0000	0.92	1.00	2.72	8.40	0.54	0.00	0.50	0.00
0	1.67	0.84	0.84	0.0000	0.0160	0.84	1.00	2.99	9.91	0.00	0.60	0.00	0.50
0	1.51	0.76	0.76	0.0130	0.0233	0.76	1.00	3.31	11.93	0.66	1.32	0.50	1.00
0	1.35	0.67	0.67	0.0185	0.0241	0.67	1.00	3.70	14.72	1.48	2.22	1.00	1.50
0	1.19	0.59	0.59	0.0187	0.0215	0.59	1.00	4.21	18.74	2.53	3.37	1.50	2.00
0	1.02	0.51	0.51	0.0161	0.0174	0.51	1.00	4.88	24.81	3.90	4.88	2.00	2.50
0	0.86	0.43	0.43	0.0124	0.0130	0.43	1.00	5.80	34.64	5.80	6.96	2.50	3.00
0	0.70	0.35	0.35	0.0086	0.0089	0.35	1.00	7.15	52.09	8.58	10.01	3.00	3.50
0	0.54	0.27	0.27	0.0053	0.0054	0.27	1.00	9.31	87.70	13.04	14.90	3.50	4.00
0	0.37	0.19	0.19	0.0026	0.0027	0.19	1.00	13.35	179.33	21.37	24.04	4.00	4.50
0	0.21	0.11	0.11	0.0009	0.0009	0.11	1.00	23.60	557.97	42.48	47.20	4.50	5.00
0	0.05	0.02	0.02	0.0000	0.0000	0.02	1.00	101.41	10285.43	202.82	223.11	5.00	5.50
0	0	0	0	0	0	0	0	0	0	0	0	5.50	6.00
0	0	0	0	0	0	0	0	0	0	0	0	6.00	6.50
0	0	0	0	0	0	0	0	0	0	0	0	6.50	1.00

7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire

Face 2



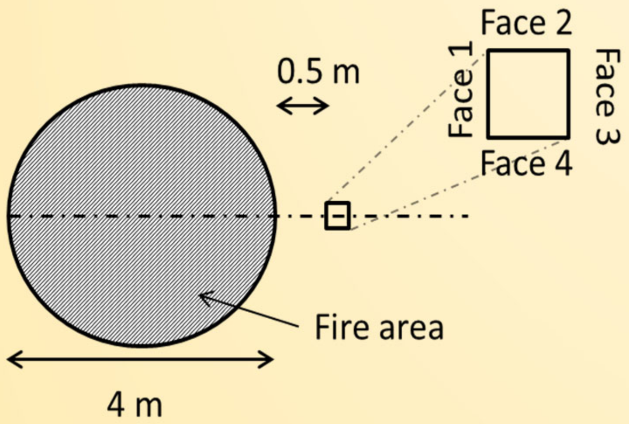
Absorbed flux $= \varepsilon * \varphi_{tot}$

$= 0.7*8.7$ kW/m2

$= 6.1$ kW/m2

7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire



Heat flux absorbed by each face (assuming $\varepsilon = 0.7$)

Face 1 : 53.45 kW/m²

Face 2 : 6.00 kW/m²

Face 3 : 0.00 kW/m²

Face 4 : 6.00 kW/m²

→ Mean heat flux = 16.36 kW/m²

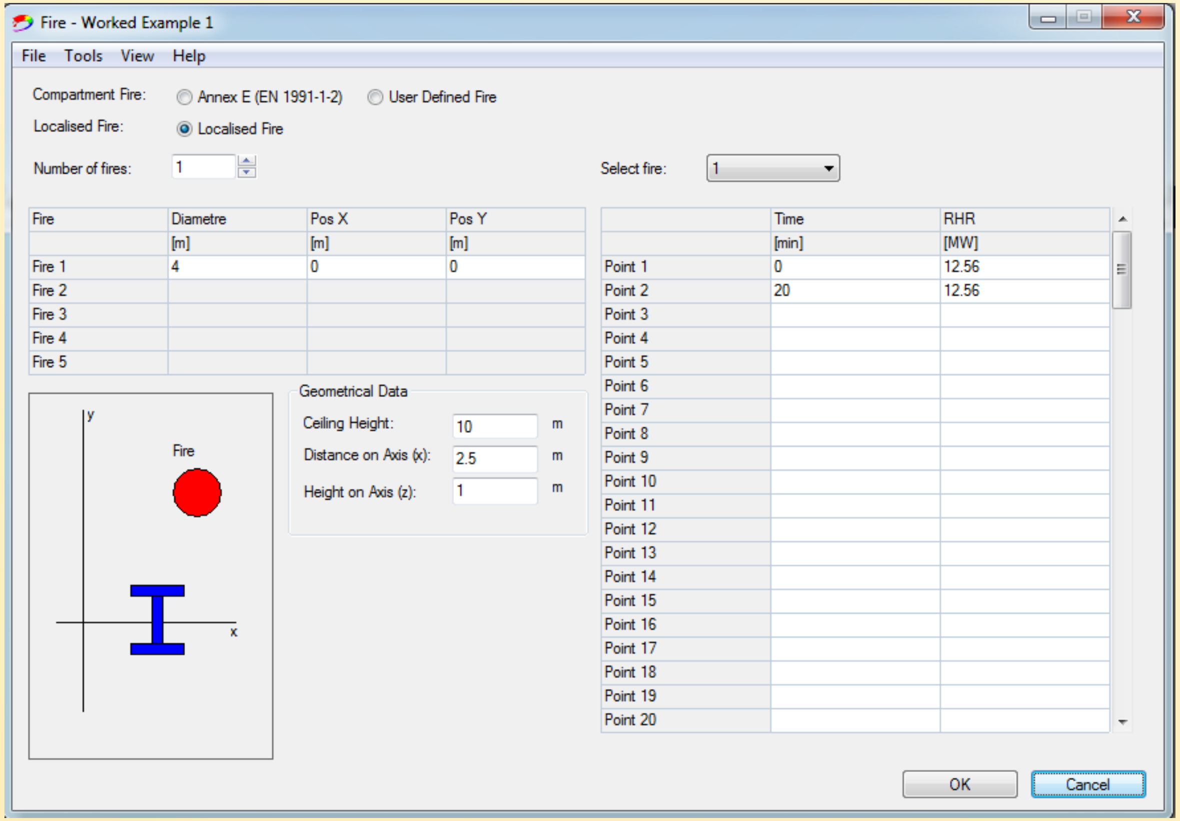
$$0 = \underbrace{h(\theta - 20)}_{\text{Emitted net convective flux}} + \underbrace{\sigma\varepsilon[(\theta + 273)^4 - (20 + 273)^4]}_{\text{Emitted radiative flux}} - \underbrace{\varepsilon * \varphi_{tot}}_{\text{Absorbed flux}}$$

$$h = 35\, W.m^{-2}.K^{-1};\ \sigma = 5.67 * 10^{-8}\, W.m^{-2}.K^{-4}$$

θ (°C)	Emitted flux W/m²
20	0
30	392.03
40	788.42
50	1189.49
…	…
280	12519.26
290	13145.11
300	13786.06
310	14442.65
320	15115.43
330	15804.96
340	16511.80
350	17236.55
360	17979.78

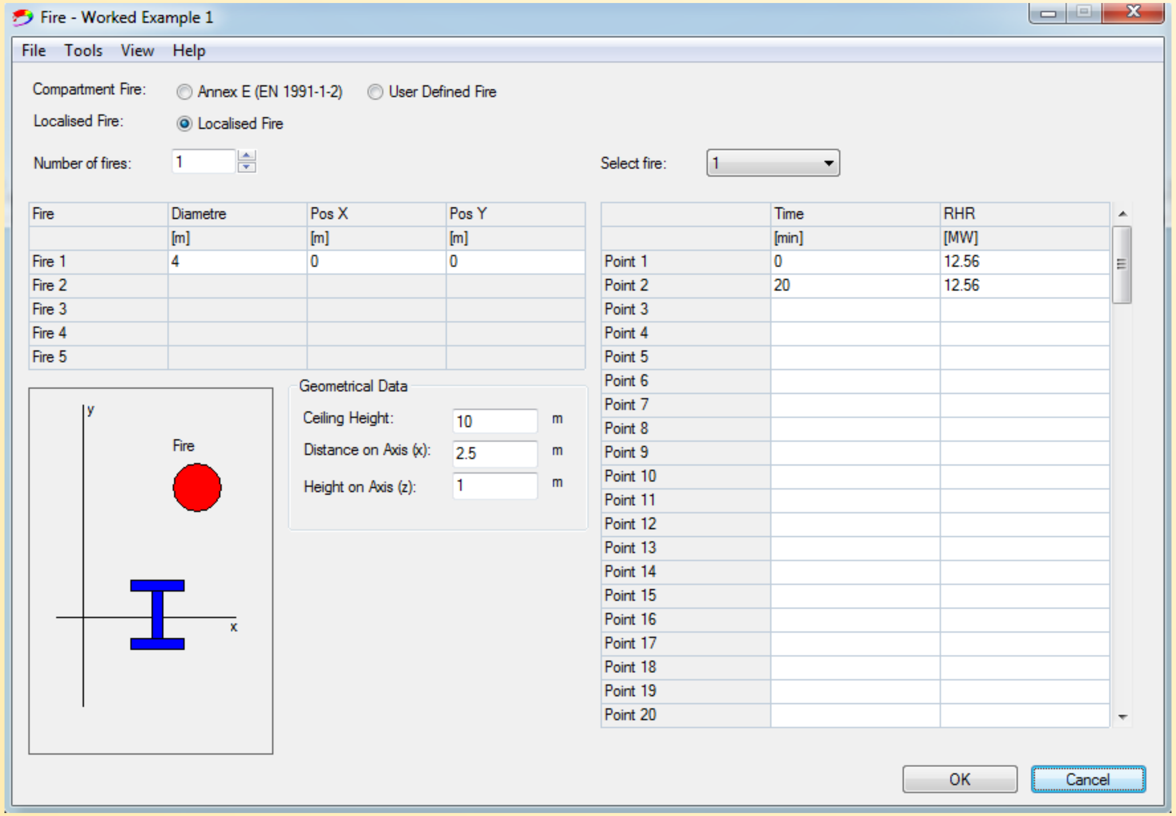
7. Worked examples

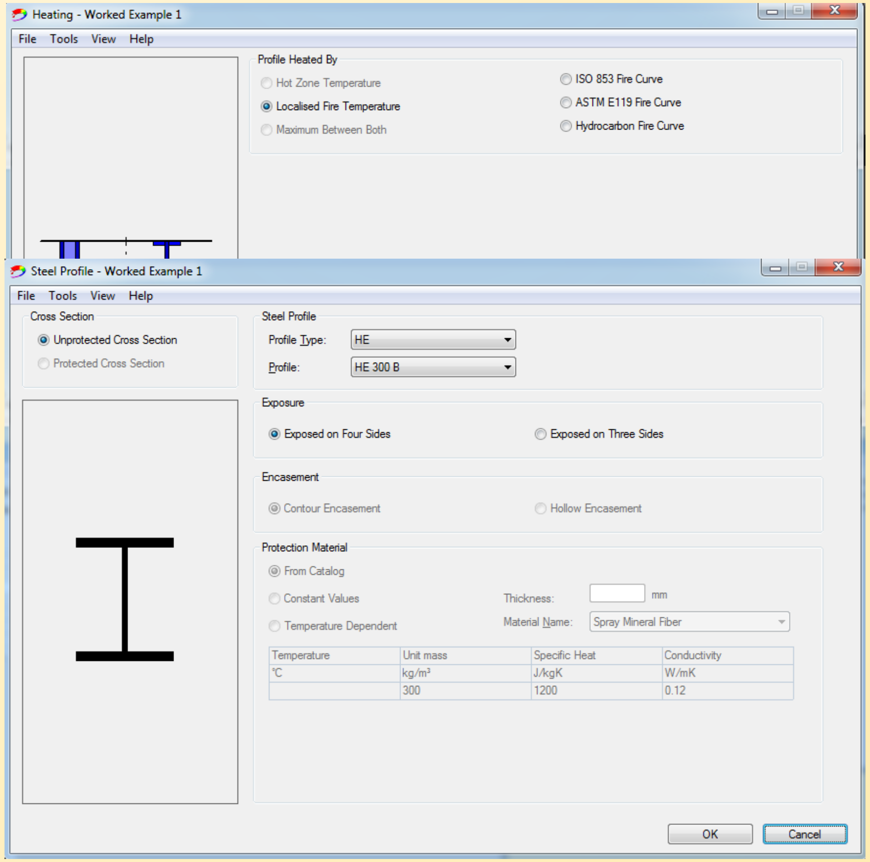
7.1. Example 1 : Radiation fluxes under localised fire



7. Worked examples

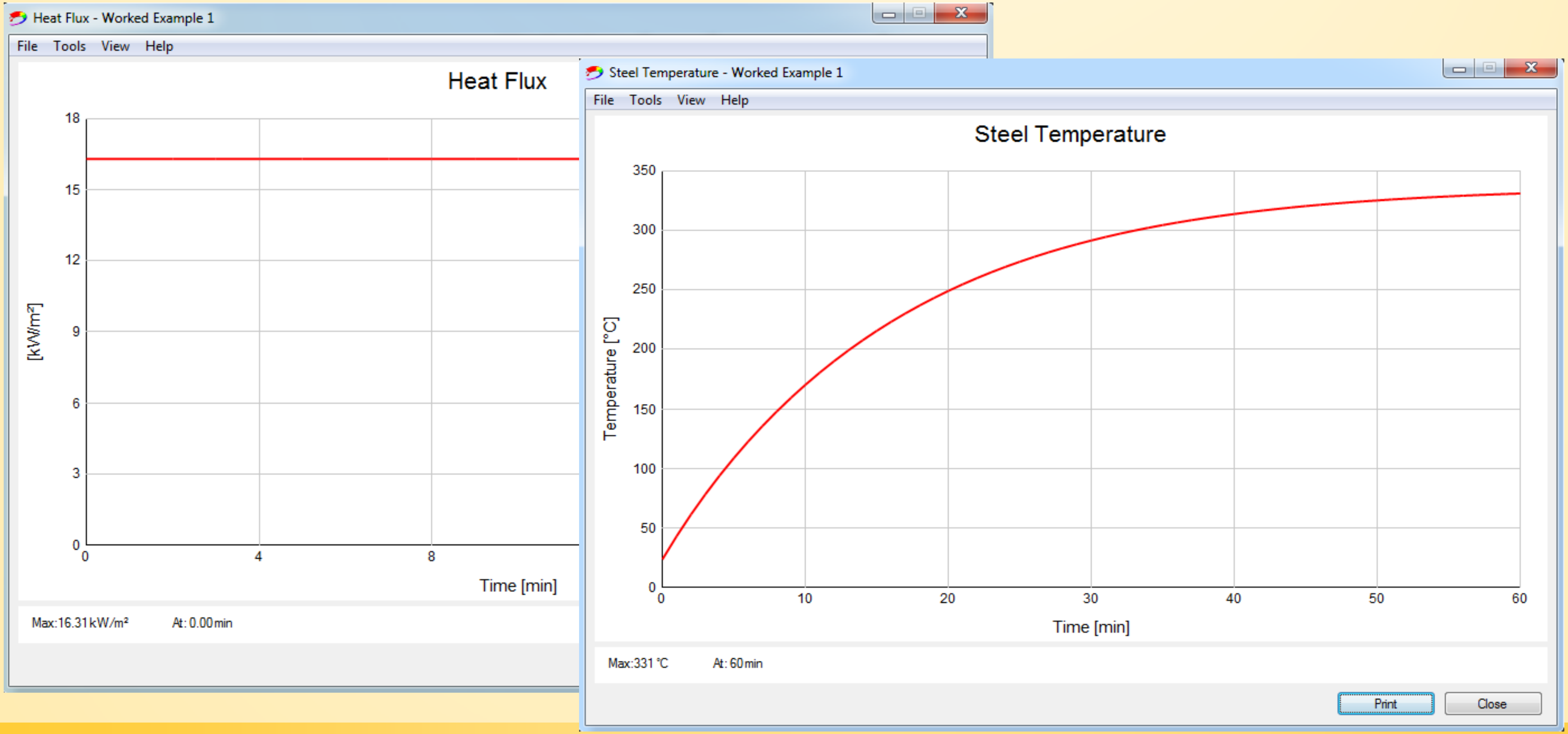
7.1. Example 1 : Radiation fluxes under localised fire





7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire

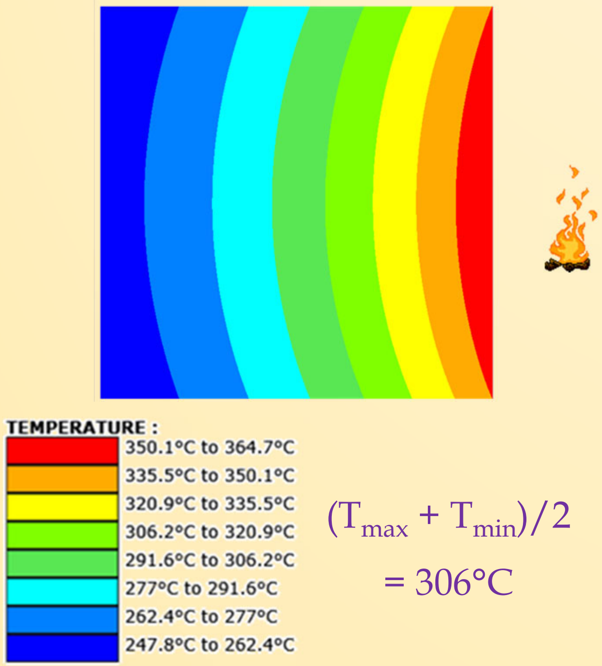


7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire

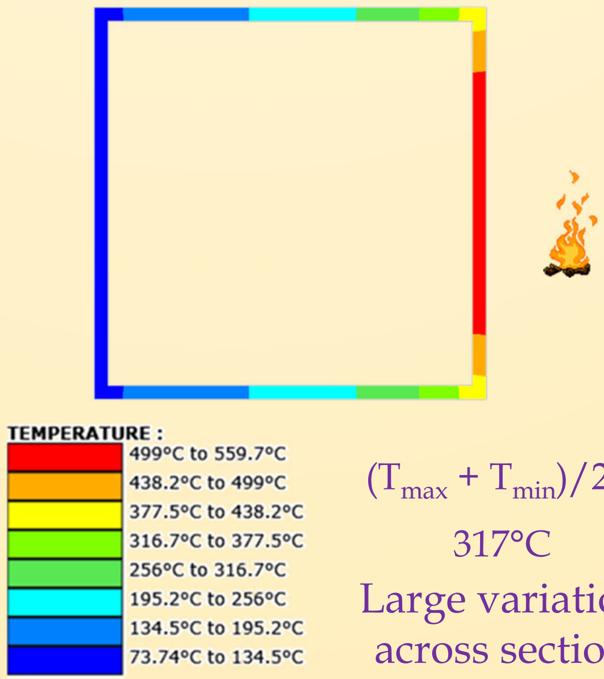
Distribution of temperature at equilibrium (LOCAFI)

<u>Square 300x300</u>



$(T_{max} + T_{min})/2$ = 306°C

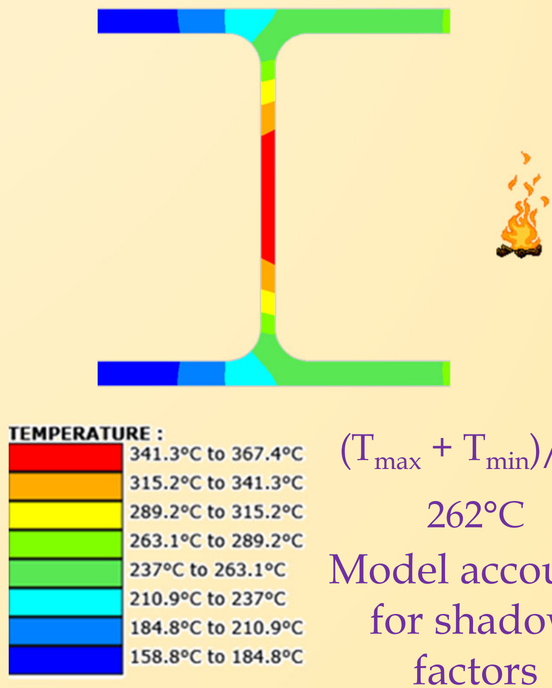
<u>Tube 300x300x10</u>



$(T_{max} + T_{min})/2 =$ 317°C

Large variation across section

<u>HEB 300</u>

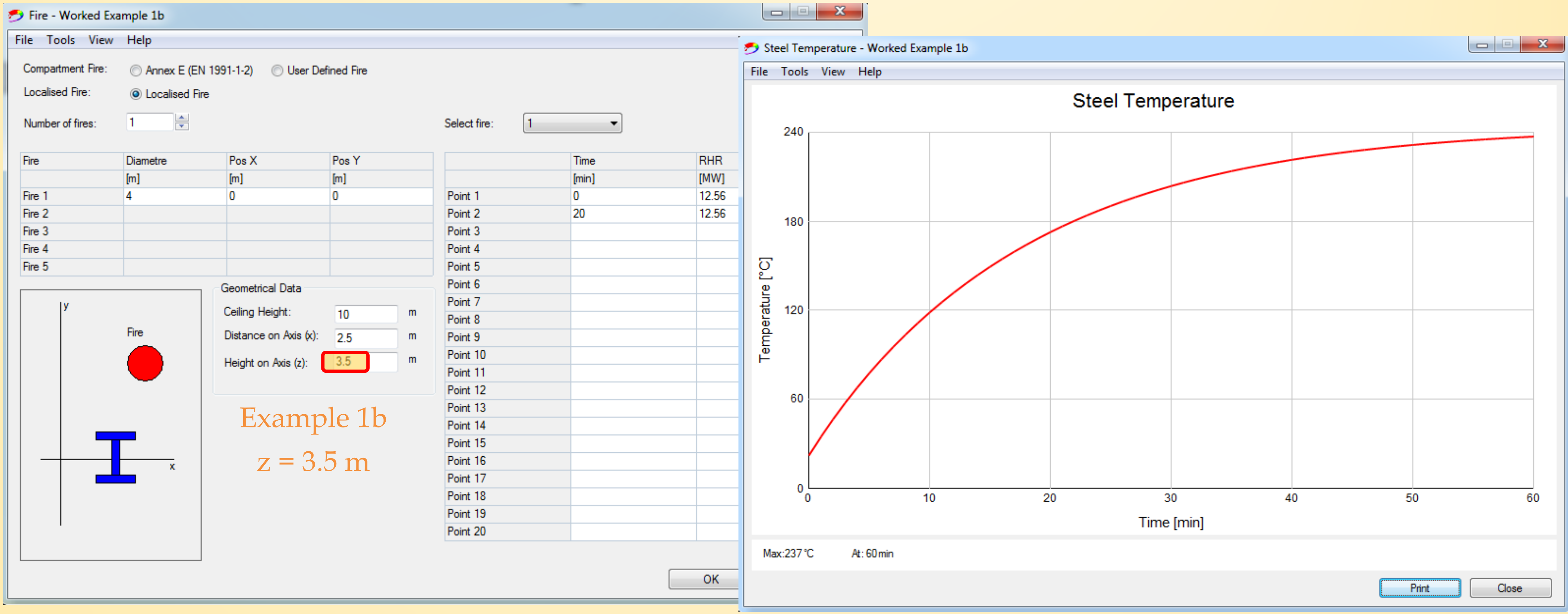


$(T_{max} + T_{min})/2 =$ 262°C

Model accounts for shadow factors

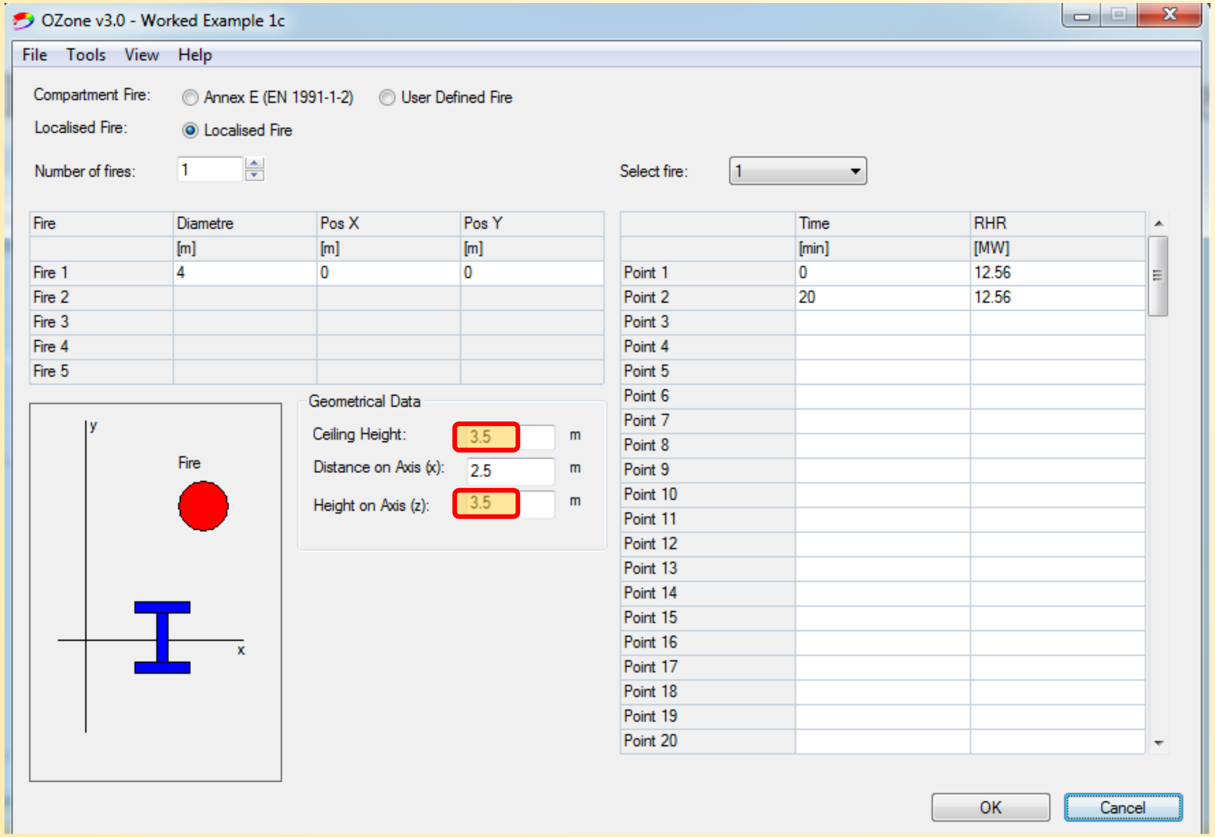
7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire



7. Worked examples

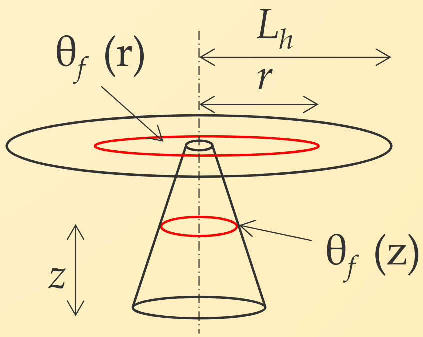
7.1. Example 1 : Radiation fluxes under localised fire



Example 1c

$z = 3.5$ m

$z_{ceiling} = 3.5$ m



$$L_h = H\left(2.9Q_H^{0.33} - 1\right) = \mathbf{4.54\ m}$$

7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire

HASEMI (EN 1991-1-2 – Annex C)

$$Q_D^* = \frac{Q}{1.11*10^6*D^{2.5}} = 0.3536$$

$$z' = 2.4*D*\left(Q_D^{*\,2/5} - Q_D^{*\,2/3}\right) = 1.535$$

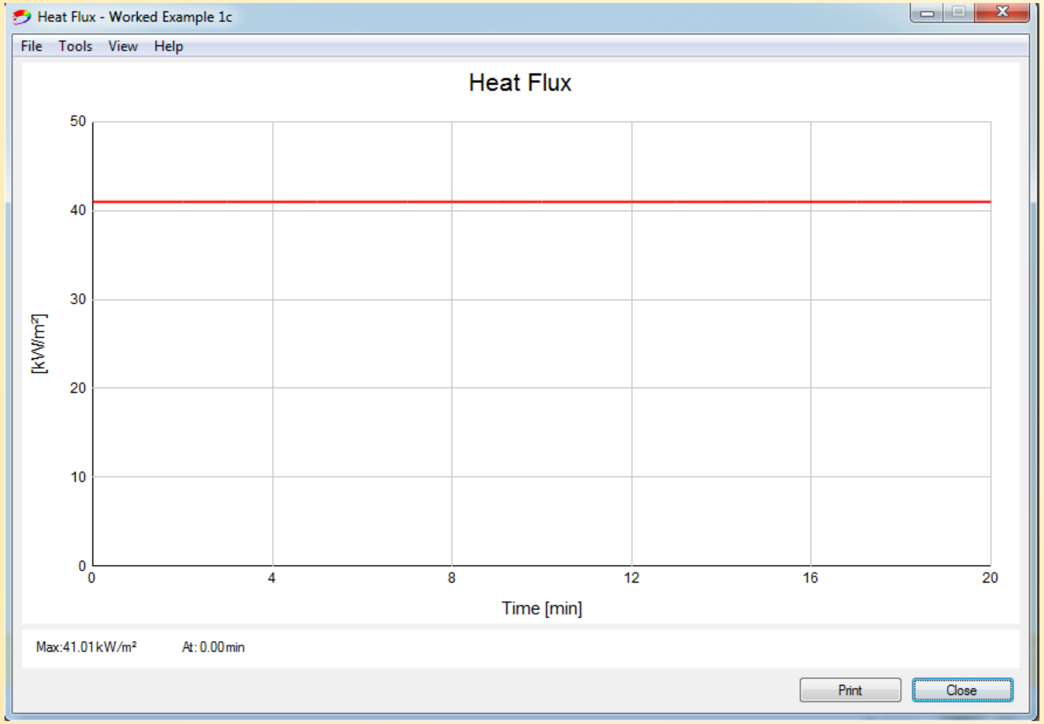
$$y = \frac{r + H + z'}{L_h + H + z'} = 0.787$$

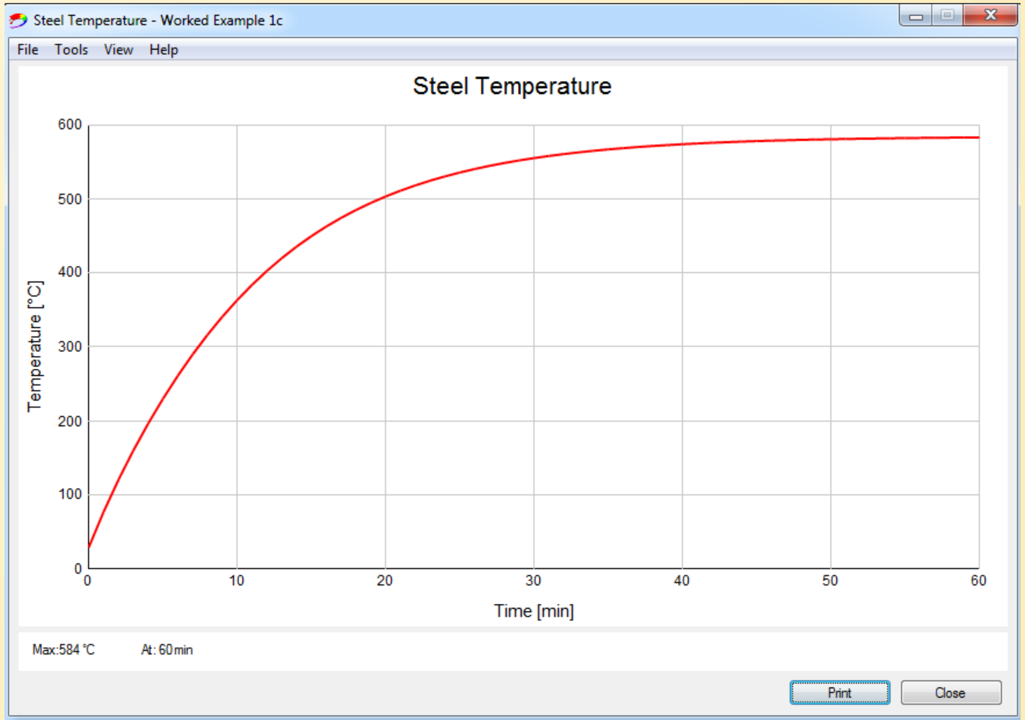
$$0.3 < y < 1 \rightarrow \dot{h} = 136300 - 121000\,y$$

$$\rightarrow \dot{h} = 41073\ W/m^2$$

7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire



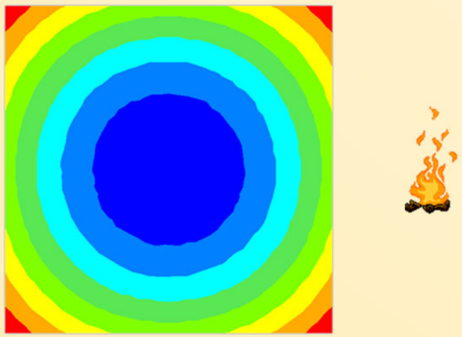


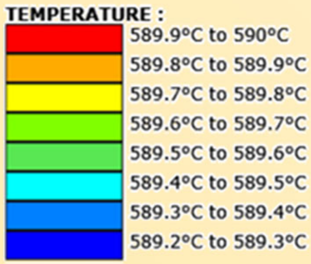
7. Worked examples

7.1. Example 1 : Radiation fluxes under localised fire

Distribution of temperature at equilibrium (HASEMI)

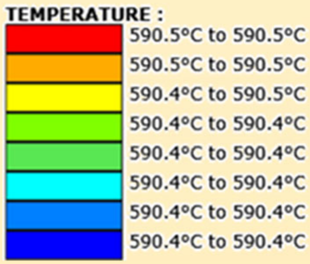
<u>Square 300x300</u>





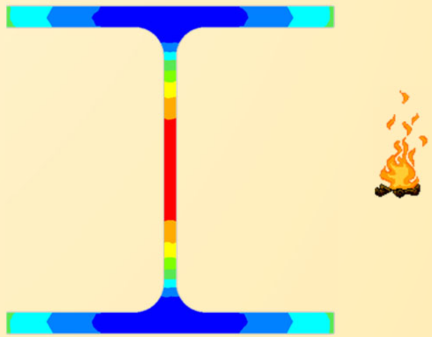
T_{aver} = 589°C

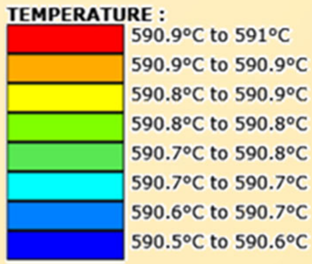
<u>Tube 300x300x10</u>



T_{aver} = 590°C

<u>HEB 300</u>

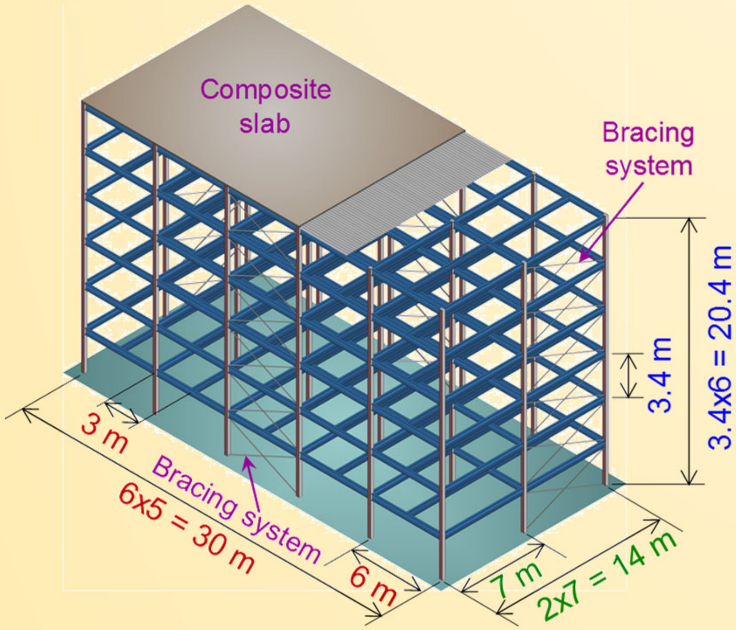




T_{aver} = 591°C

7. Worked examples

7.2. Example 2 : Column of an office building



Fire source situated at a distance of 0.5 m from the column

Ceiling level : 3.5 m

Fire source : 500 kg of paper (17.5 MJ/kg) on a 2.5m² area

$RHR_{max} = 1000\ kW/m^2$

7. Worked examples

7.2. Example 2 : Column of an office building

Development of the fire according to EN 1991-1-2 Annex E

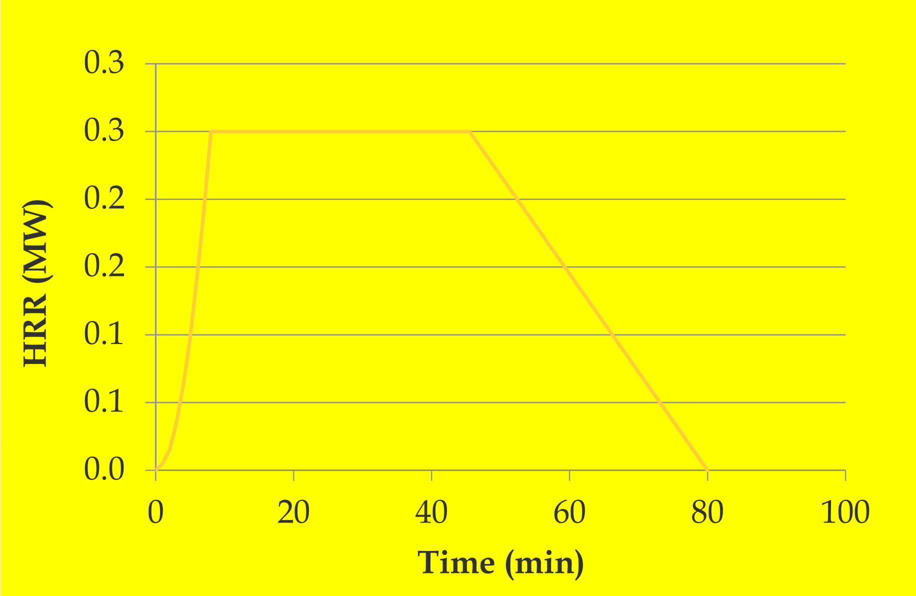
- ***Growing phase : $Q(t) = 10^6*(t/t_\alpha)^2$***

- ***Speed of development : Medium***

→ RHR = 1 MW after t_α = 300 sec

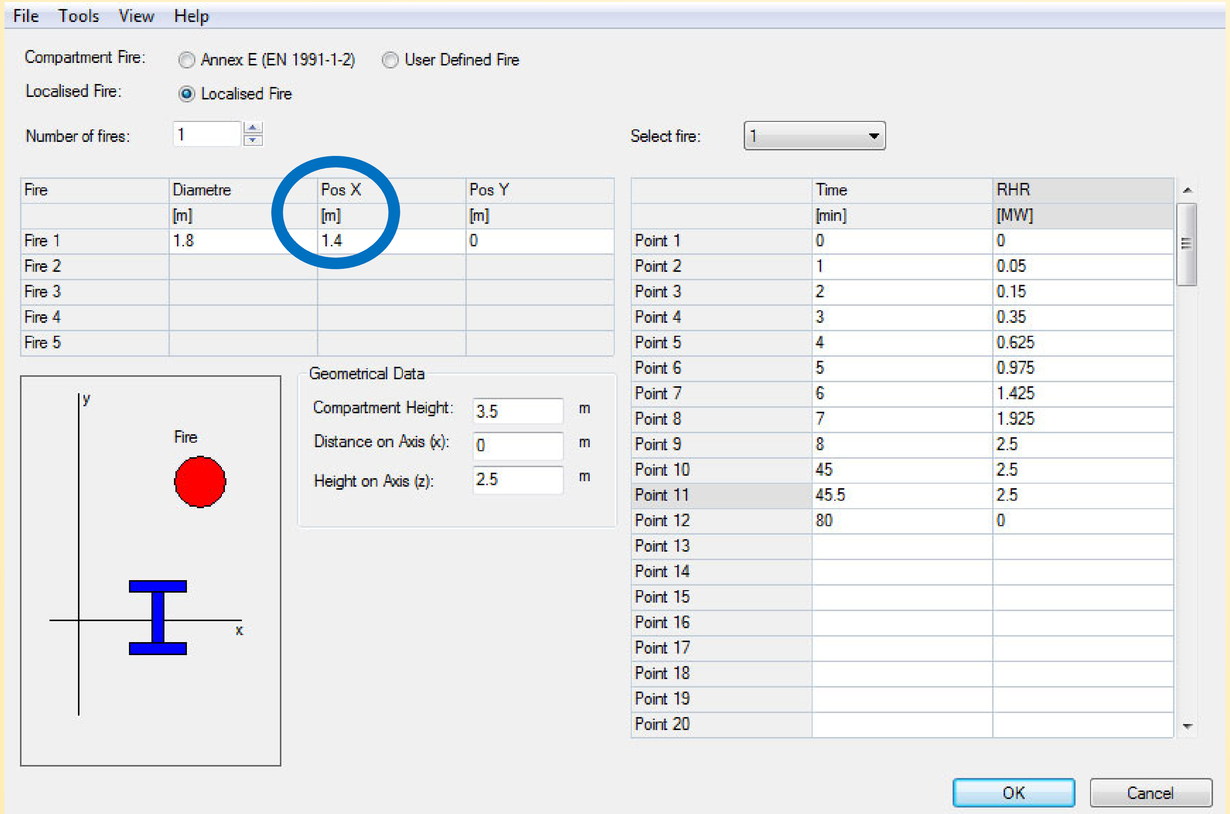
- ***RHR_{max} = 2.5m2 * 1000kW/m^2 = 2.5 MW***

- ***Decay phase starts after 70% of the fuel has burnt***



7. Worked examples

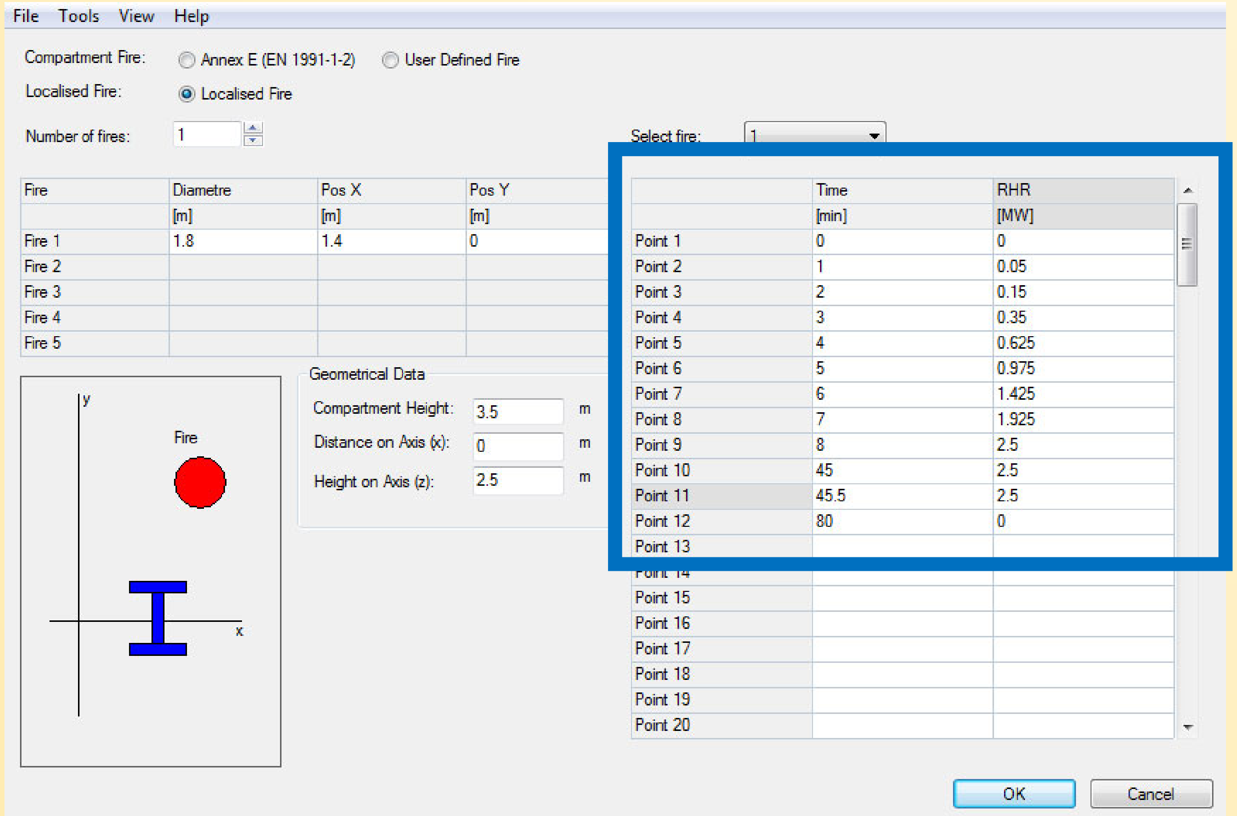
7.2. Example 2 : Column of an office building

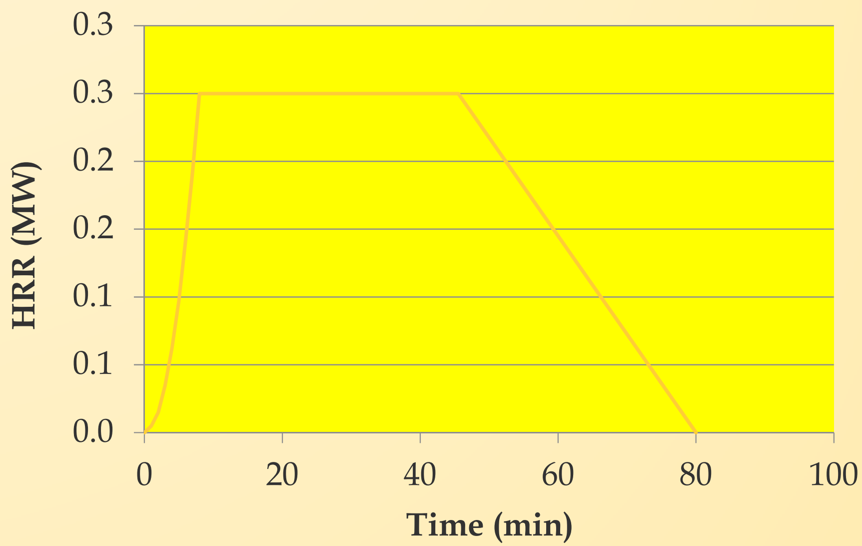


Pos x : 0.5m + 1.8m/2 = 1.4m

7. Worked examples

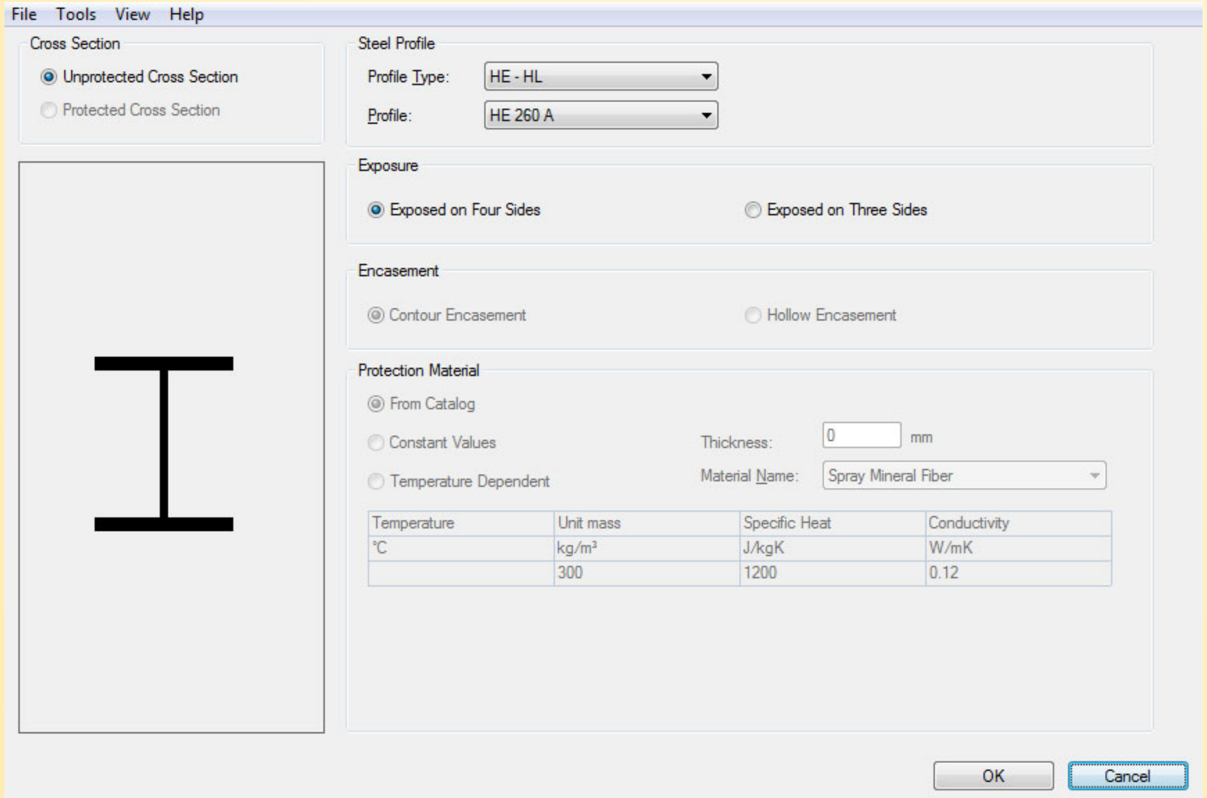
7.2. Example 2 : Column of an office building





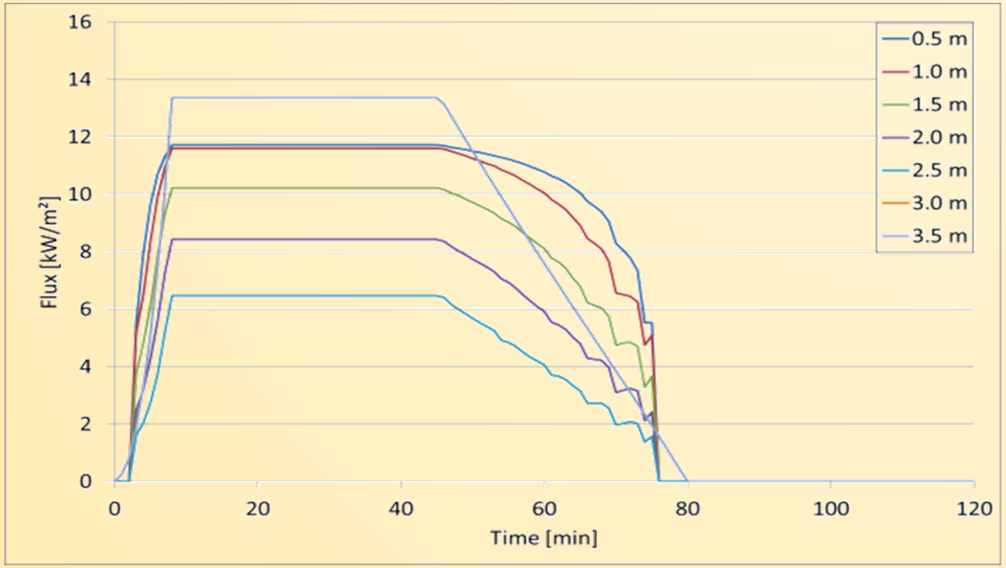
7. Worked examples

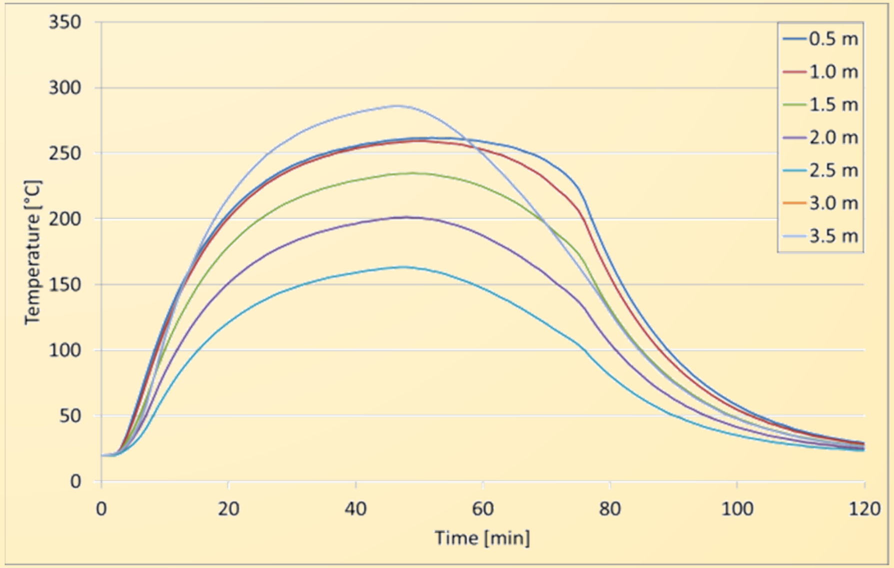
7.2. Example 2 : Column of an office building



7. Worked examples

7.2. Example 2 : Column of an office building

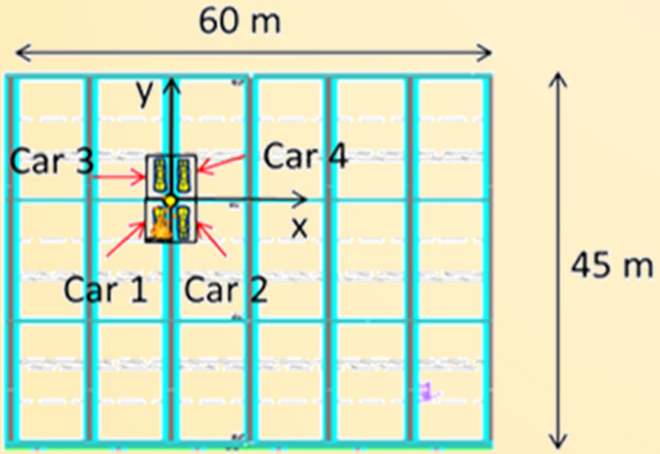


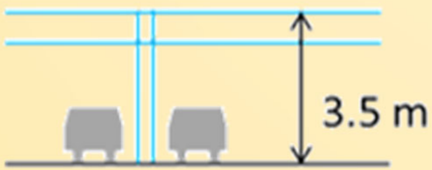


- Maximum absorbed radiative heat flux in the hot smoke layer
- Hot smoke layer (z = 3.5m) : temperature reaches 290°C
- Outside smoke layer (z = 0.5m and z = 1m) : ~250°C

7. Worked examples

7.3. Example 3 : Column of a car park





HEA 300 column

Ceiling level : 3.5 m

*Dimensions of the parking slot : 2.5m*5m*

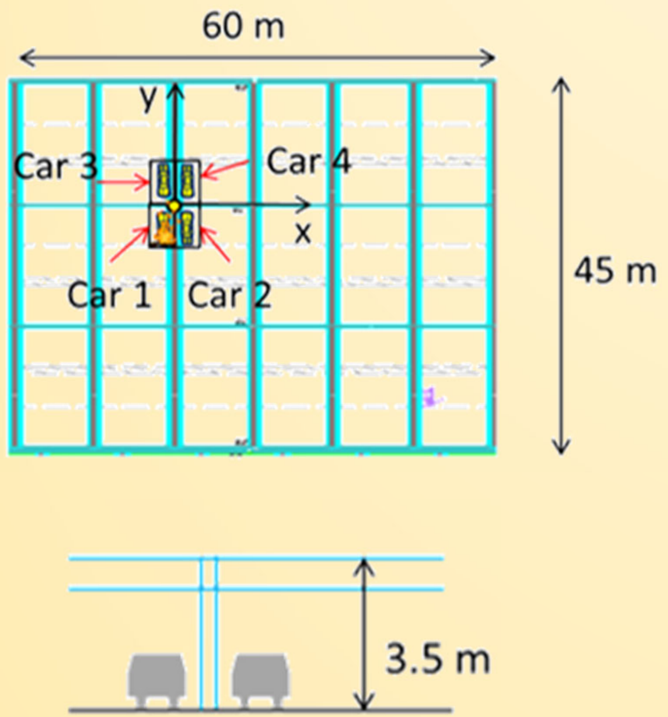
→ Equivalent diameter of the fire : 4 m

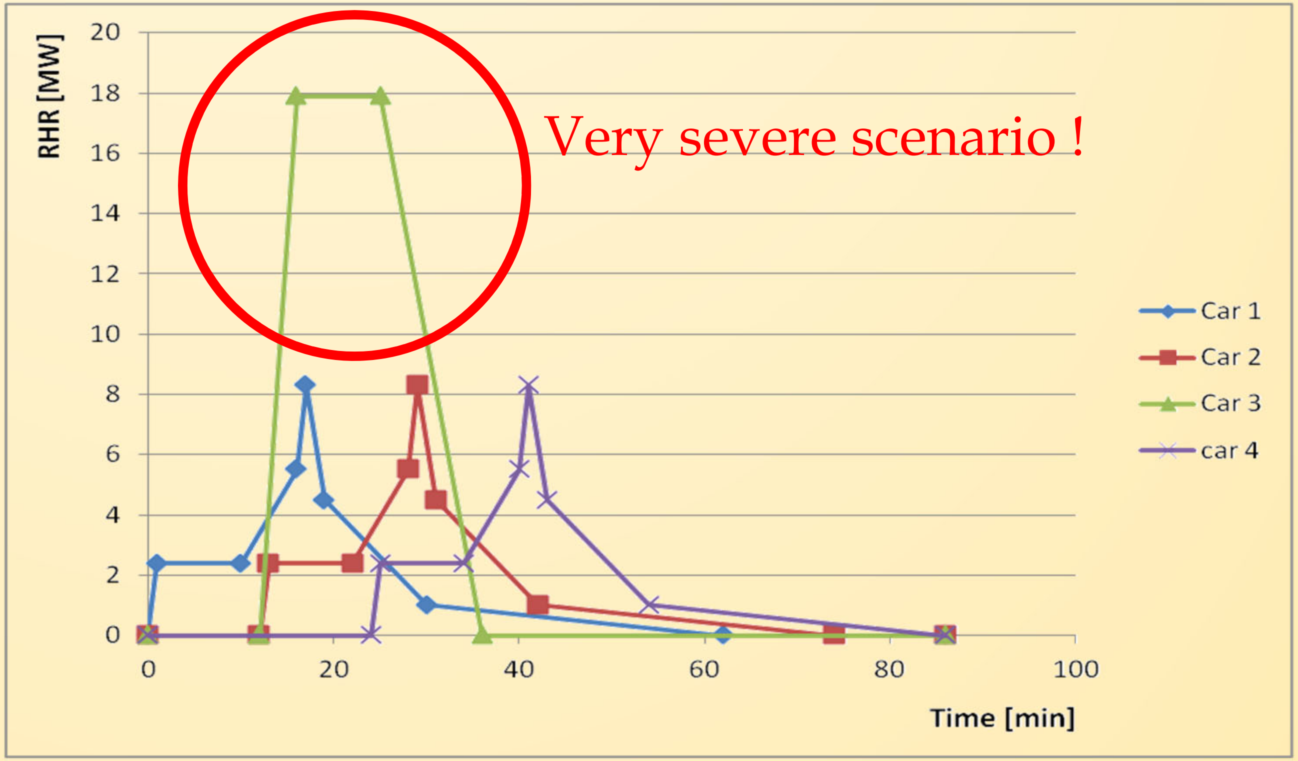
Fire scenario : 3 cars + 1 van (risk analysis – highly severe assumption)

Ignition time between two consecutive cars : 12 minutes

7. Worked examples

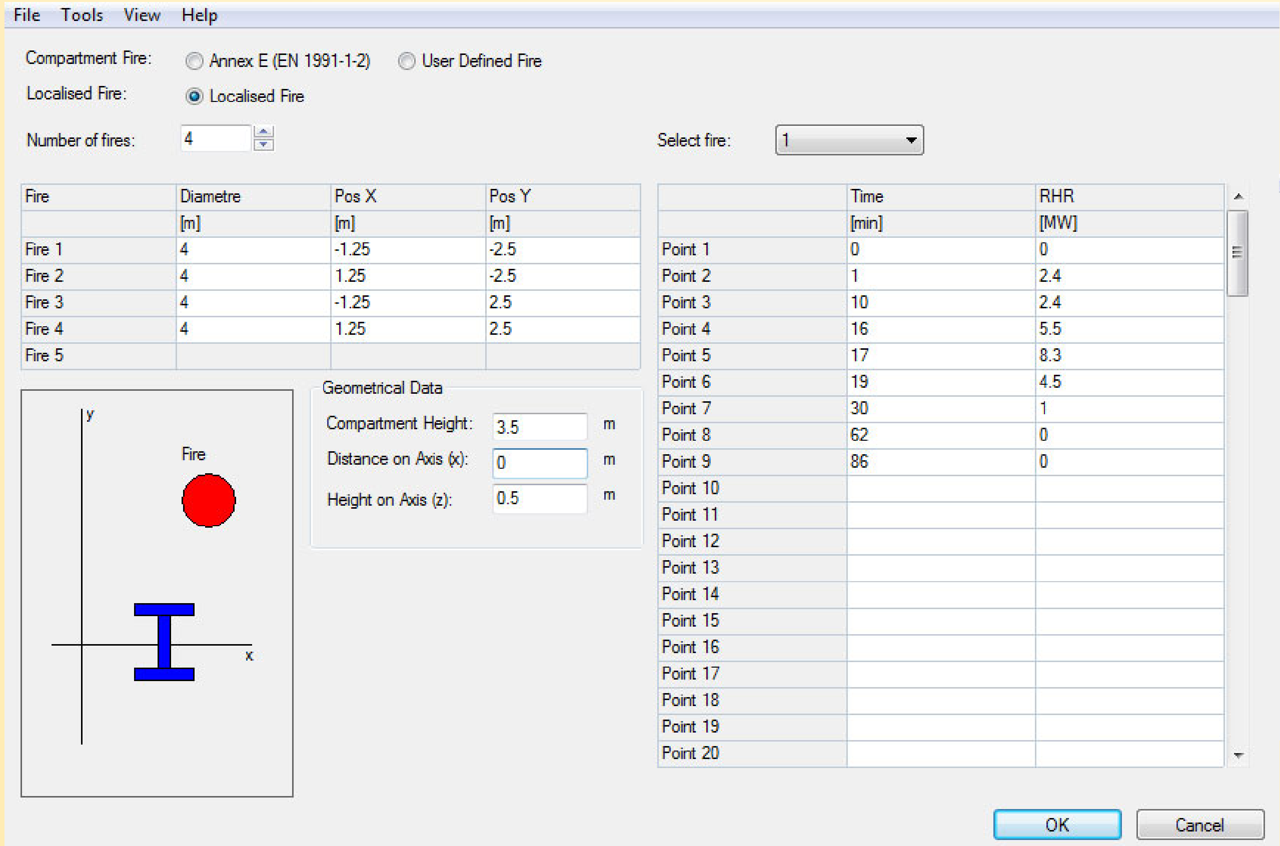
7.3. Example 3 : Column of a car park

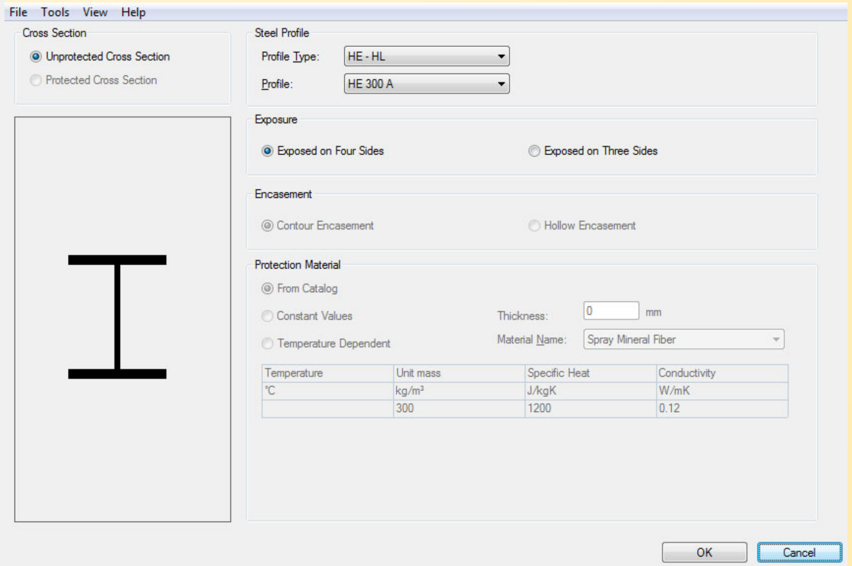




7. Worked examples

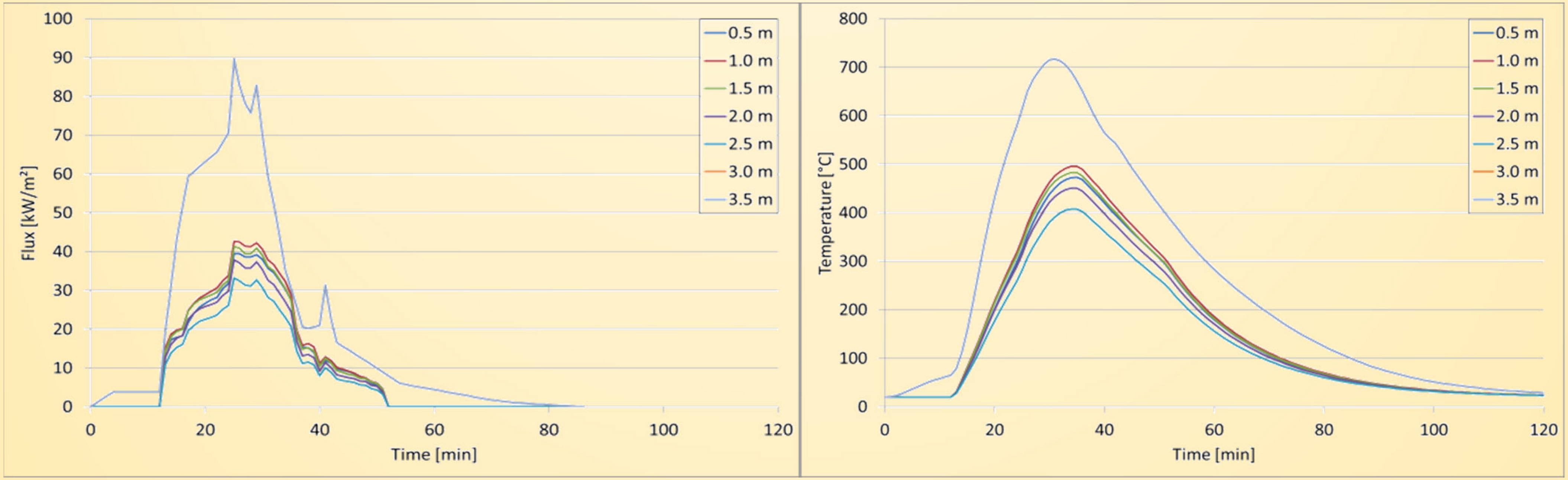
7.3. Example 3 : Column of a car park





7. Worked examples

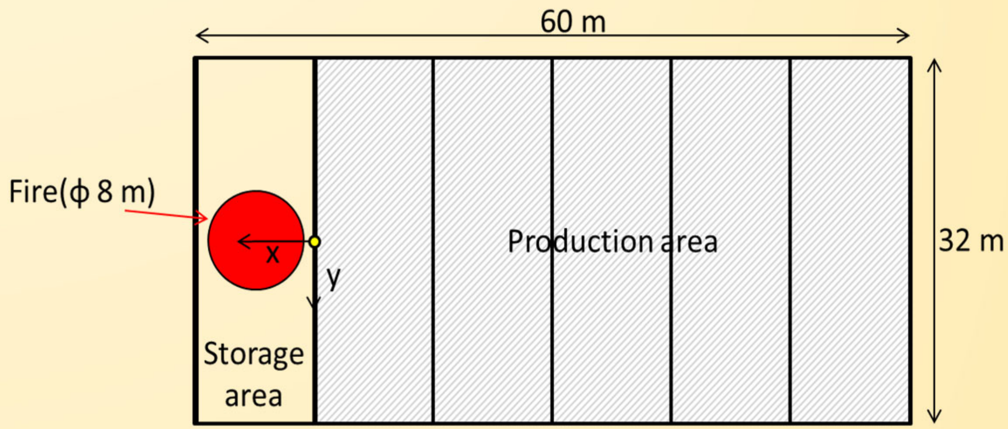
7.3. Example 3 : Column of a car park



- Outside hot smoke layer (z = 1 m) : t_{max} = 500°C
- In hot smoke layer (z = 3.5 m) : t_{max} = 718°C

7. Worked examples

7.4. Example 4 : Truss of an industrial building



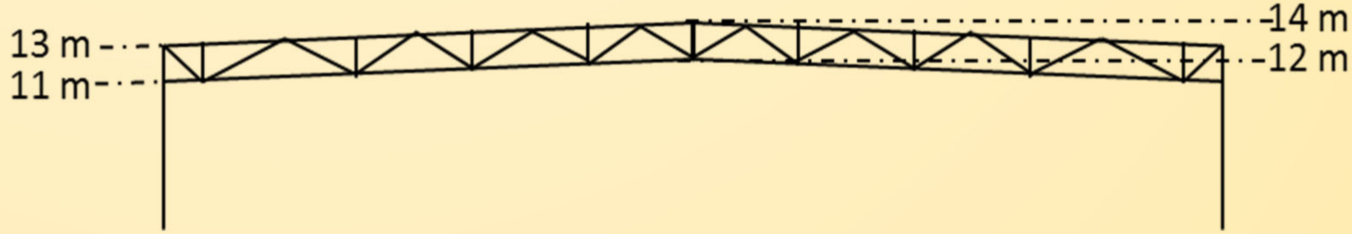
Description of the structure :

Truss flanges section : HEA 220

*Truss diagonals section : 2 L60*60*6*

Distance between 2 steel frames : 10 m

Apex height : 14 m



7. Worked examples

7.4. Example 4 : Truss of an industrial building

<u>Fire scenario</u> **:**

Fire area : 50 m^2 (center of storage area)

→ Equivalent diameter : 8 m

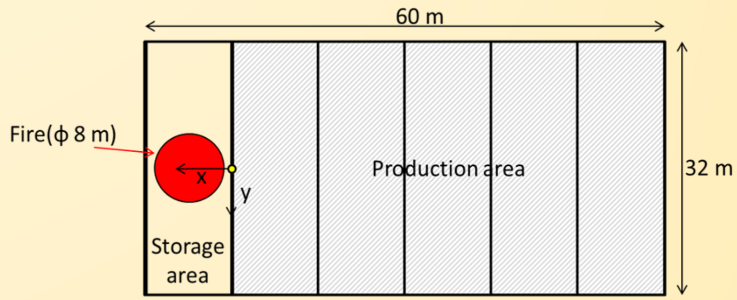
Speed of development : Medium

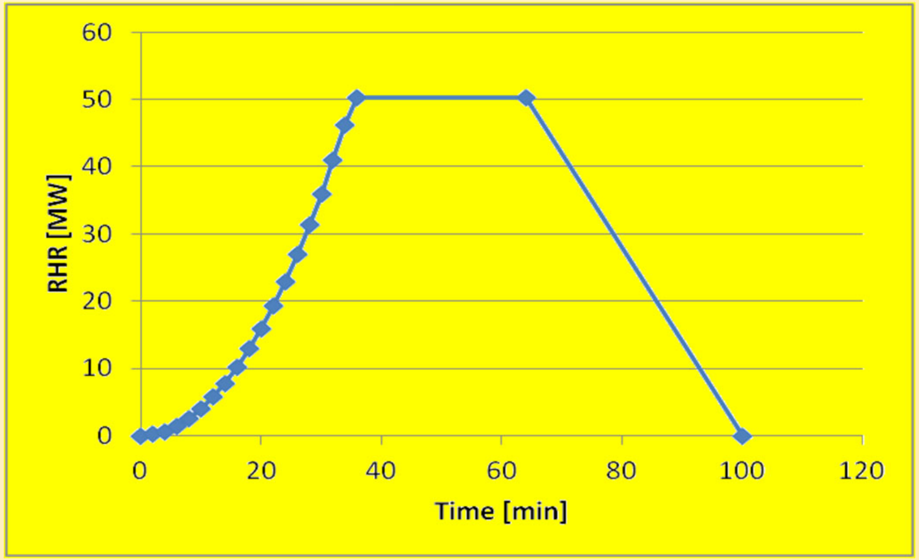
→ RHR = 1 MW after t_α = 300 sec

RHR_{max} = 1000 kW/m^2*50m^2 = 50 MW

Fire Load : 10 To (cellulosic)

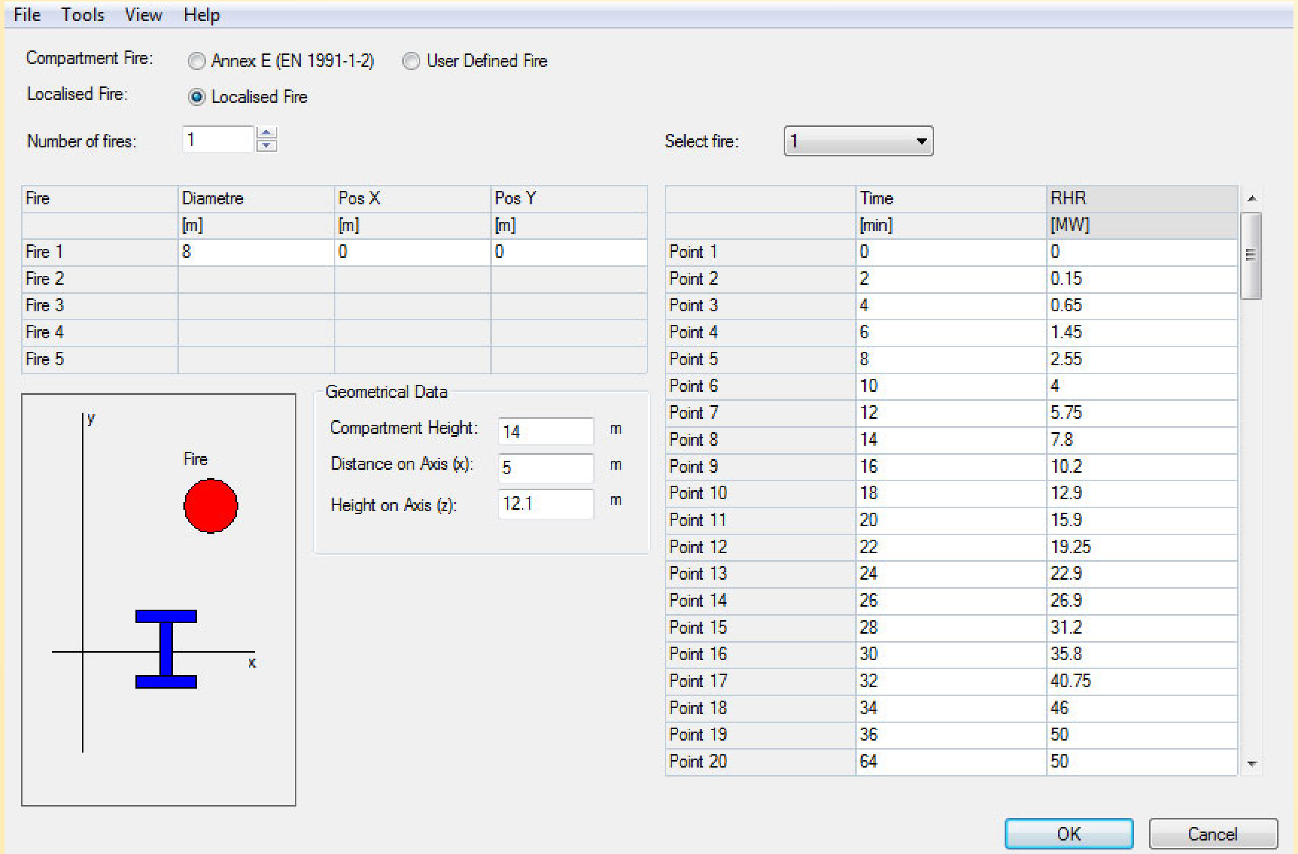
→ Q = 17.5 MJ/kg*10000 kg = 175000 MJ





7. Worked examples

7.4. Example 4 : Truss of an industrial building



File Tools View Help

Compartment Fire: Annex E (EN 1991-1-2) User Defined Fire

Localised Fire: Localised Fire

Number of fires: 1

Select fire: 1

Fire	Diametre	Pos X	Pos Y
	[m]	[m]	[m]
Fire 1	8	0	0
Fire 2			
Fire 3			
Fire 4			
Fire 5			

	Time	RHR
	[min]	[MW]
Point 1	0	0
Point 2	2	0.15
Point 3	4	0.65
Point 4	6	1.45
Point 5	8	2.55
Point 6	10	4
Point 7	12	5.75
Point 8	14	7.8
Point 9	16	10.2
Point 10	18	12.9
Point 11	20	15.9
Point 12	22	19.25
Point 13	24	22.9
Point 14	26	26.9
Point 15	28	31.2
Point 16	30	35.8
Point 17	32	40.75
Point 18	34	46
Point 19	36	50
Point 20	64	50

Geometrical Data

Compartment Height: 14 m

Distance on Axis (x): 5 m

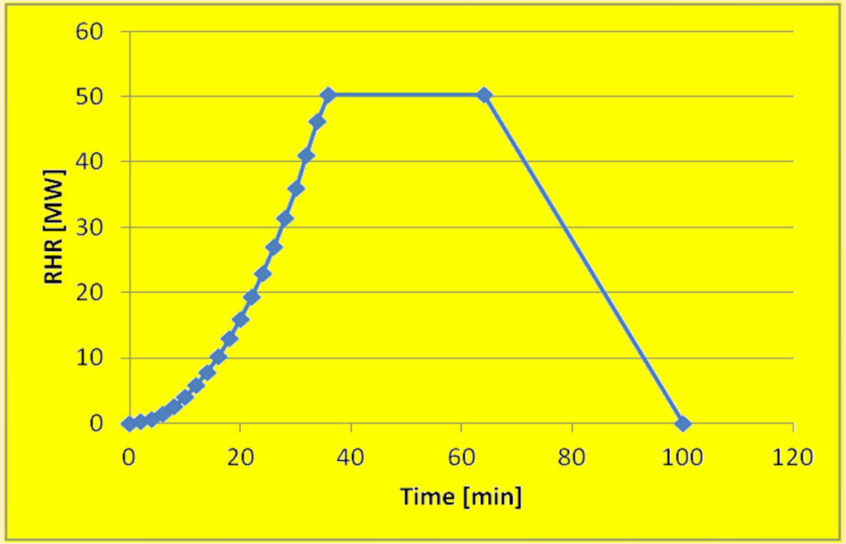
Height on Axis (z): 12.1 m

y

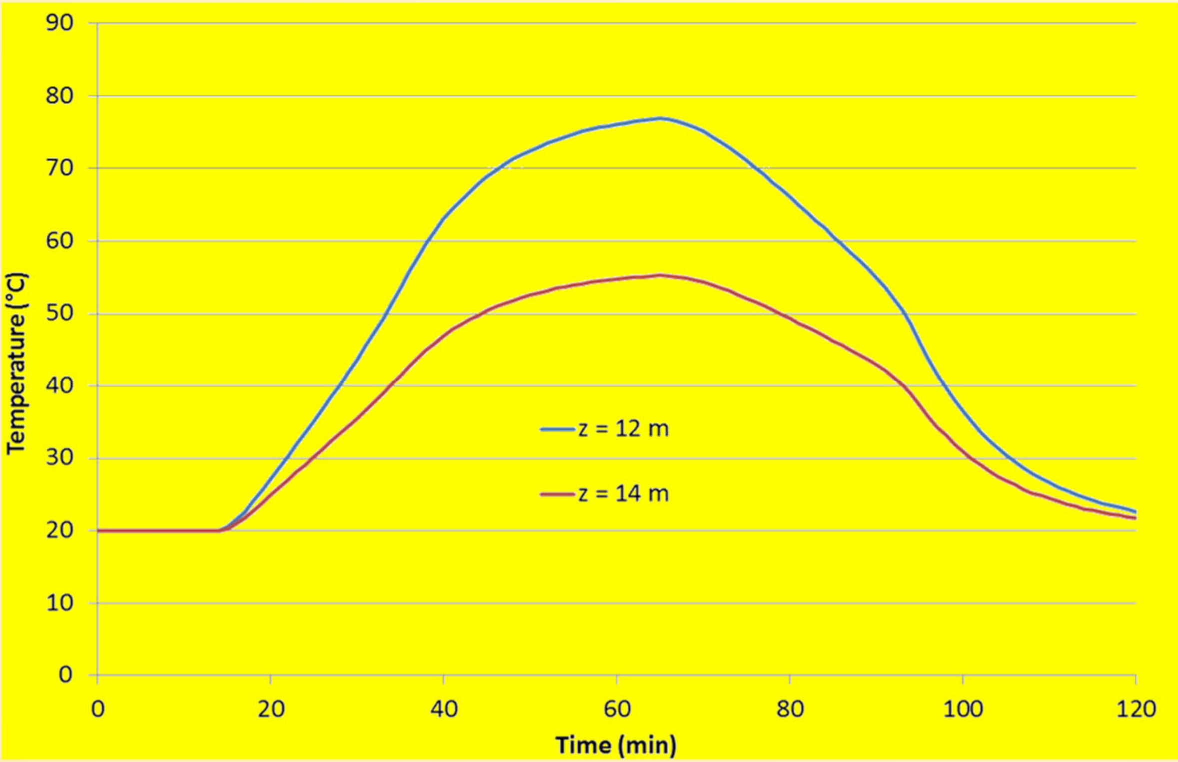
Fire

x

OK Cancel



7.4. Example 4 : Truss of an industrial building



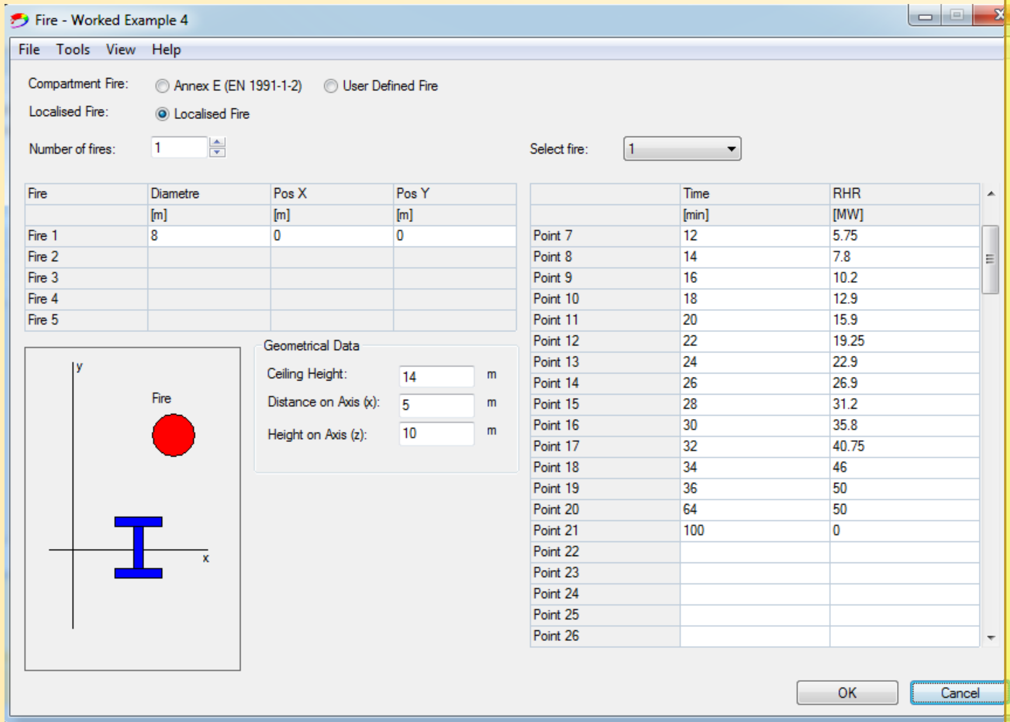
Flame height = 9.7m

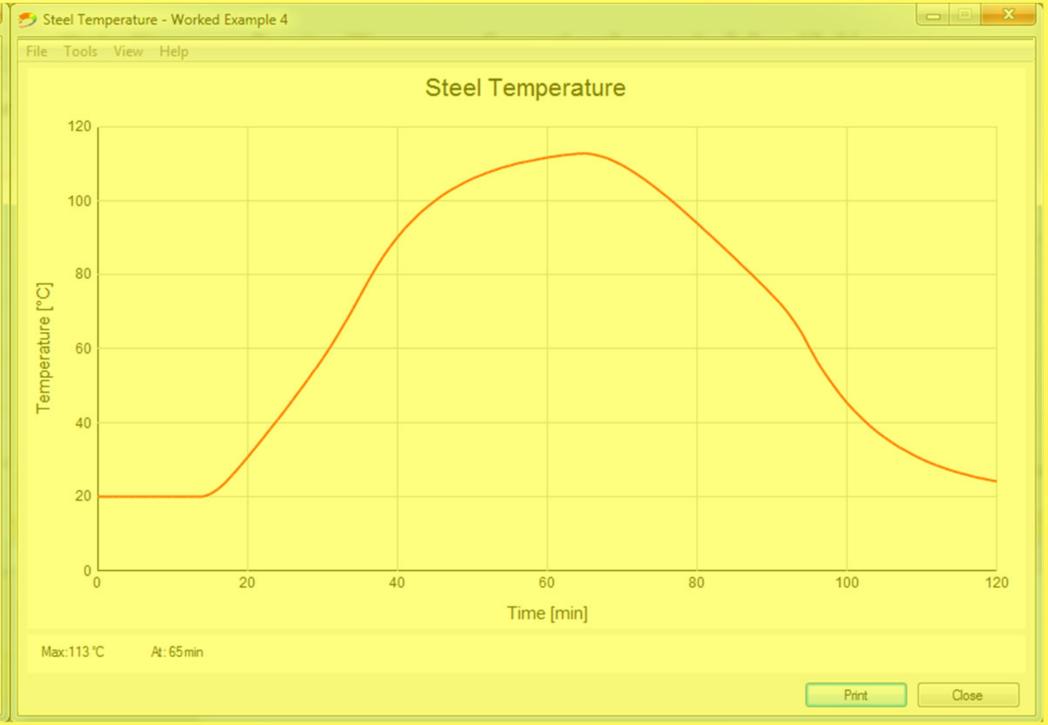
→ Truss members are situated above the solid flame

Max. temperature of trusses = 210°C

7. Worked examples

7.4. Example 4 : Truss of an industrial building

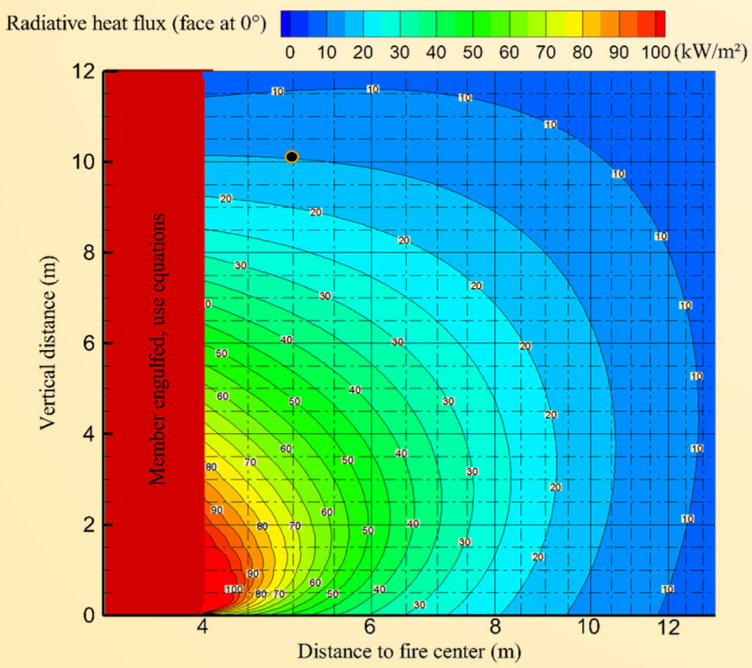




7. Worked examples

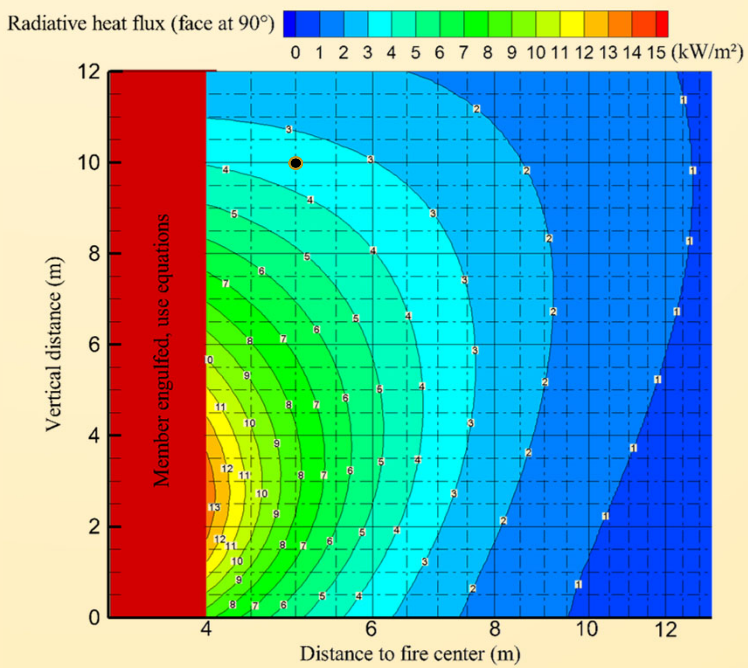
7.4. Example 4 : Truss of an industrial building

<u>Face 1</u>



$\varepsilon * \varphi_{tot} = 0.7*15 \text{ kW/m}^2 = 10.5 \text{ kW/m}^2$

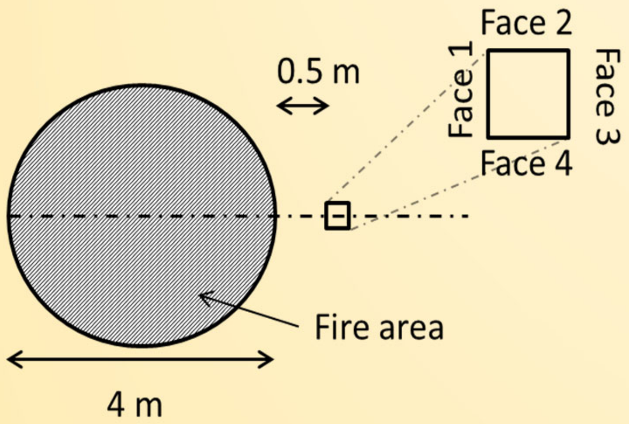
<u>Face 2</u>



$\varepsilon * \varphi_{tot} = 0.7*3.5 \text{ kW/m}^2 = 2.45 \text{ kW/m}^2$

7. Worked examples

7.4. Example 4 : Truss of an industrial building



Heat flux received by each face (assuming ε = 0.7)

Face 1 : 10.5 kW/m²

Face 2 : 2.45 kW/m²

Face 3 : 0.00 kW/m²

Face 4 : 2.45 kW/m²

→ Mean heat flux = 3.85 kW/m²

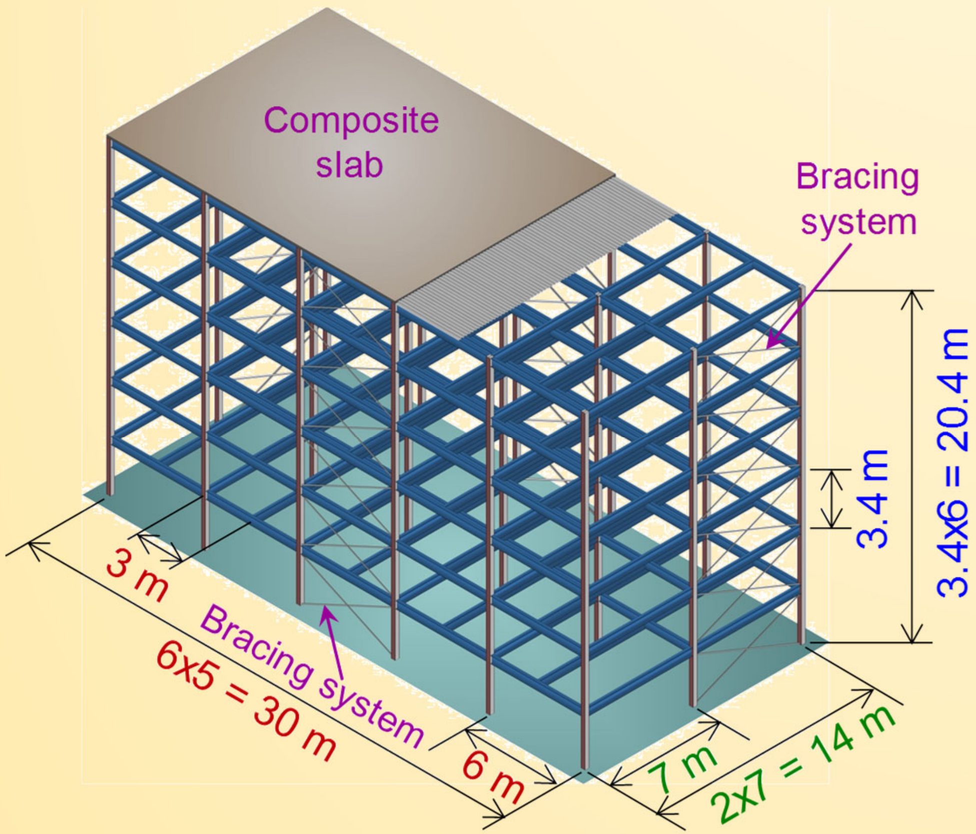
$$0 = \underbrace{h(\theta - 20)}_{\text{Emitted convective flux}} + \underbrace{\sigma\varepsilon[(\theta + 273)^4 - (20 + 273)^4]}_{\text{Emitted radiative flux}} - \underbrace{\varepsilon * \varphi_{tot}}_{\text{Absorbed flux}}$$

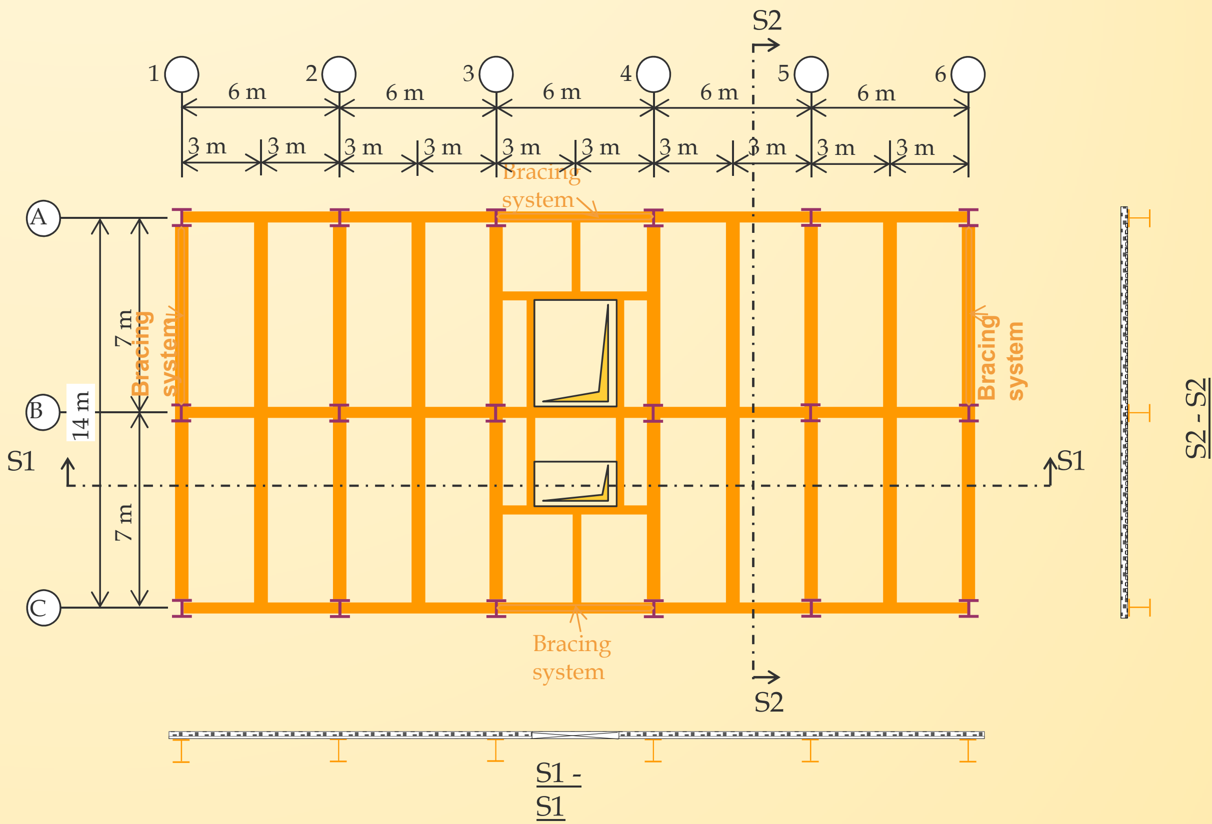
$$h = 35\, W.m^{-2}.K^{-1};\ \sigma = 5.67 * 10^{-8}\, W.m^{-2}.K^{-4}$$

θ (°C)	Emitted flux W/m²
20	0
30	392.03
40	788.42
50	1189.49
60	1595.53
70	2006.84
80	2423.77
90	2846.62
100	3275.76
110	3711.52
120	4154.27
130	4604.37
140	5062.21
150	5528.18

7. Worked examples

7.5. Example 5 : Buckling resistance of a column

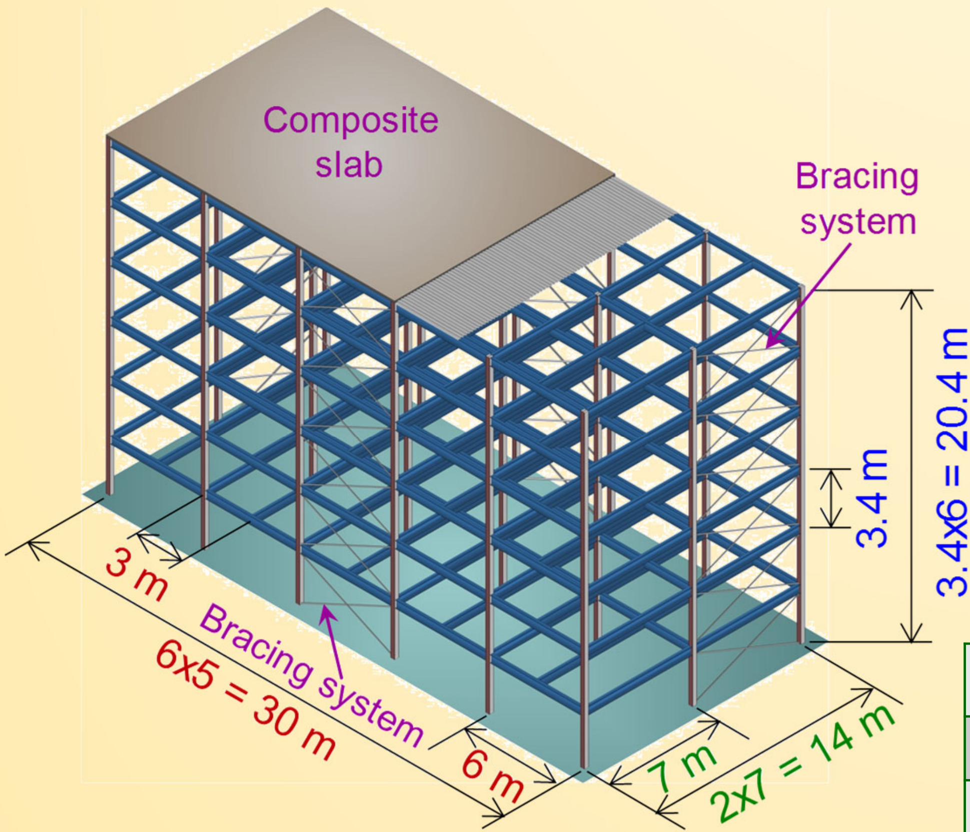




38

7. Worked examples

7.5. Example 5 : Buckling resistance of a column



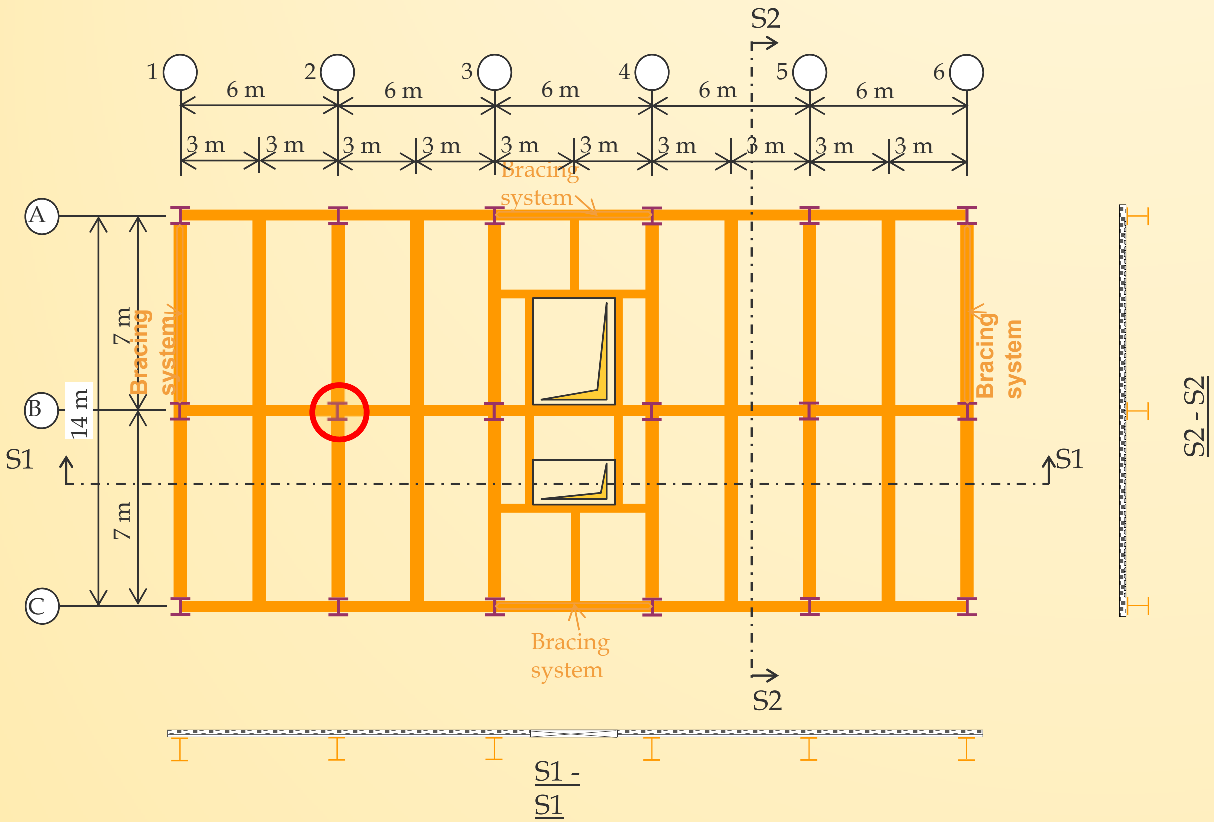
Actions (for all floor levels)

- Self weight G1:
  - ✓ composite slab unit weight: 2.12 kN/m²
  - ✓ steel structural members: according to their sizes
- Permanent load G2:
  - ✓ finishing, services, partitions: 1.50 kN/m²
- Permanent load G3:
  - ✓ Façade cladding load: 2.00 kN/m
- Characteristic values of variable loads and ψ factors

Type	q_k	ψ_1	ψ_2
Live load on floors	4.0 kN/m²	0.7	0.6
Snow on roof	1.7 kN/m²	0.2	0.0

39

7.5. Example 5 : Buckling resistance of a column



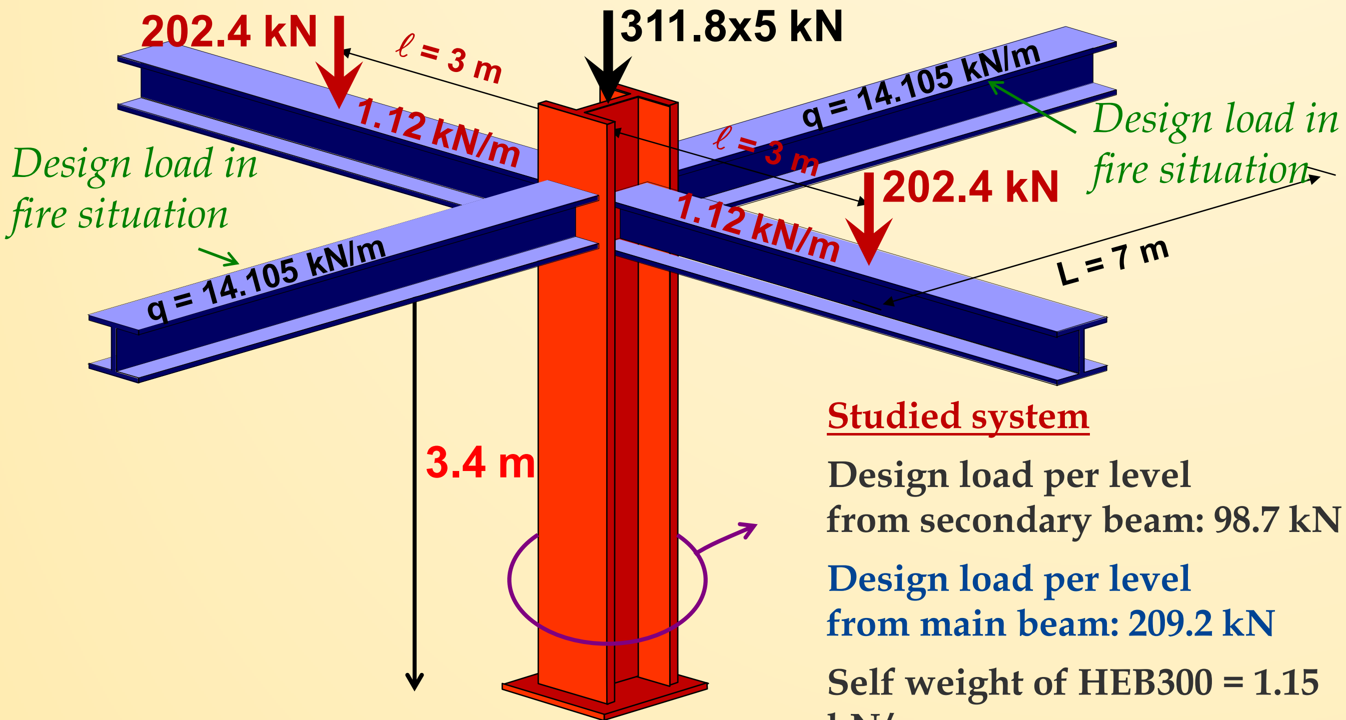
Structural members

- Composite slab:
  - ✓ Total thickness: 12 cm
  - ✓ Steel deck: COFRAPLUS60
  - ✓ Thickness of steel deck: 0.75 mm
  - ✓ Continuous slab over 2 spans
- Common secondary beams:
  - ✓ IPE360 - S275
- Internal main beams:
  - ✓ HEA360 - S275
- Columns for ground level:
  - ✓ Edge columns (ground level): HEA300 - S275
  - ✓ **Central columns (ground level): HEB300 - S275**

40

7. Worked examples

7.5. Example 5 : Buckling resistance of a column



Studied system

Design load per level from secondary beam: 98.7 kN

Design load per level from main beam: 209.2 kN

Self weight of HEB300 = 1.15 kN/m

Step 1: Design mechanical action in fire

- Design load in fire situation

$$E_{fi,d,t} = \sum_{j \geq 1} G_{k,j} + \Psi_{2,1} Q_{k,1} + \sum_{i \geq 2} \Psi_{2,i} Q_{k,i}$$

- Self weight of the column

$$q_{fi,d,t} = 1.15\, kN/m$$

- Total concentrated axial load from steel beams

$$P_{fi,d,t} = \sum \left(G_{k,1} + \psi_{2,1} Q_{k,1} \right)$$
$$= \underbrace{14.105 \times 7}_{\text{secondary beam}} + \underbrace{202.4 + 1.13 \times 6}_{\text{main beam + columns}}$$
$$\approx 307.9\, kN$$

Note : Depending on the country, $\psi_{1,1}$ or $\psi_{2,1}$ should be used.

7.5. Example 5 : Buckling resistance of a column

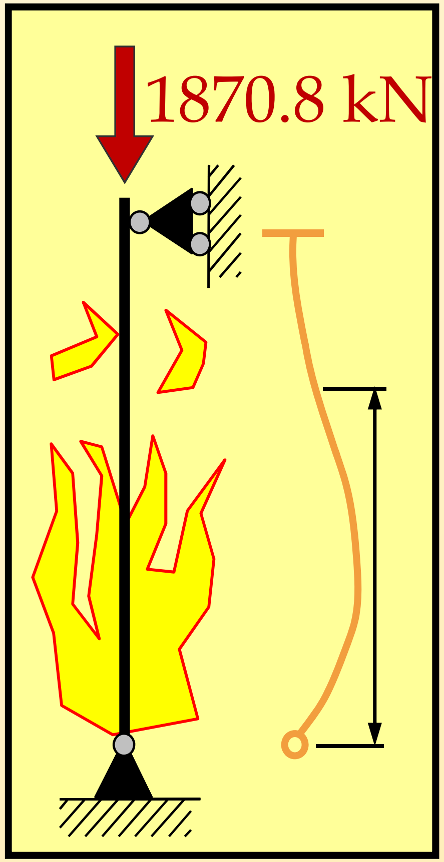
Step 1: Design mechanical action in fire

- Total design loading conditions in fire situation

$$N_{fi,d,t} = (307.9 + 3.9) \times 6 = 1870.8\, kN$$

- Buckling length in fire situation
  - pinned column base

$$L_{fi} = 0.7L = 0.7 \times 3.4 = 2.38\, m$$



7. Worked examples

7.5. Example 5 : Buckling resistance of a column

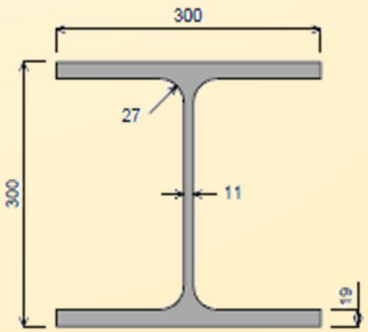
Step 2: Classify member

- Bending member

Relation 4.2 of Eurocode 3 part 1-2

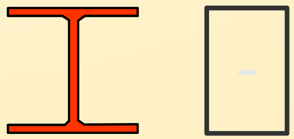
$$\varepsilon = 0.85\sqrt{235/f_y} = 0.786$$

S275



HEB300

Table 5.2 of Eurocode 3 part 1-1



Compression

$c/t_w \leq 33\varepsilon$ → *Web class 1*

$= 18.9$ $= 25.9$

$c/t_f \leq 9\varepsilon$ → *Flange class 1*

6.2 $= 7.07$

Section class 1

43

7.5. Example 5 : Buckling resistance of a column

Step 3: Design resistance at instant 0 (ambient temperature)

Design resistance at instant 0 (ambient temperature) according to Eurocode 3 part 1-2

- Plastic axial resistance

$$N_{pl,fi,0} = A \times f_y / \gamma_{M,fi} = 4099.7 \ \text{kNm}$$

- Non-dimensional slenderness

$$\bar{\lambda}_{fi,0} = \sqrt{\frac{Af_y}{N_{cr}}} = \frac{L_{fi}}{i_z} \frac{1}{93.9\varepsilon} = 0.362$$

HEB300	
A (cm²)	149.08
I_z (cm)	7.58

7. Worked examples

7.5. Example 5 : Buckling resistance of a column

Step 4: Degree of utilisation for tabulated data

$$\mu_0 = \frac{N_{fi,d,t}}{N_{pl,fi,0}} = 0.452$$

Step 5: Critical temperature

linear interpolation of tabulated data $\qquad \bar{\lambda}_{fi,0} = 0.362$

$\bar{\lambda}_{fi,0}$ / μ_0	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
…	…	…	…	…	…	…	…	…	…	…	…
0.40	629	603	578	544	499						
0.42	621	595	569	535	477						
0.44	613	588	561	525	455						
0.46	604	581	553	516	433						
0.48	597	573	545	506	411						
0.50	590	566	536	494	367						
0.52	584	559	528	477							

$$\boxed{\theta_{cr} \approx 560 \ °C}$$