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Integrated Fire Engineering and Response

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Section factor A/V in columns with asymmetric heating

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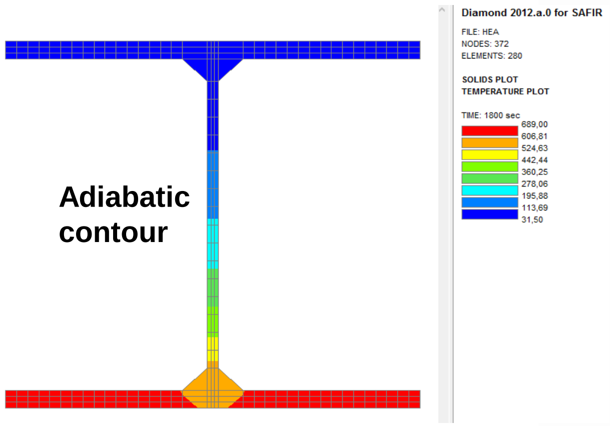
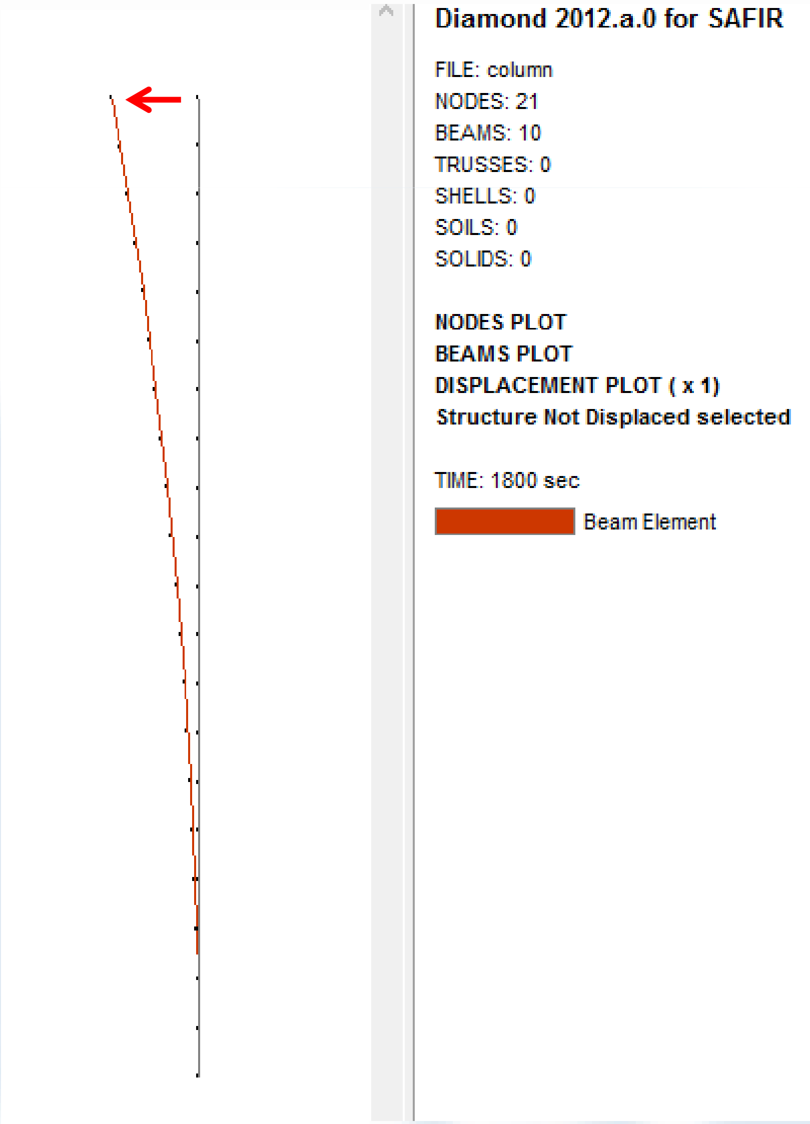
PROBLEMS CAUSED BY THERMAL GRADIENT

Non-uniform heating produces thermal gradients through the cross-section and these thermal gradients cause displacements out of axis of column (known as bowing effect).

HEA 300



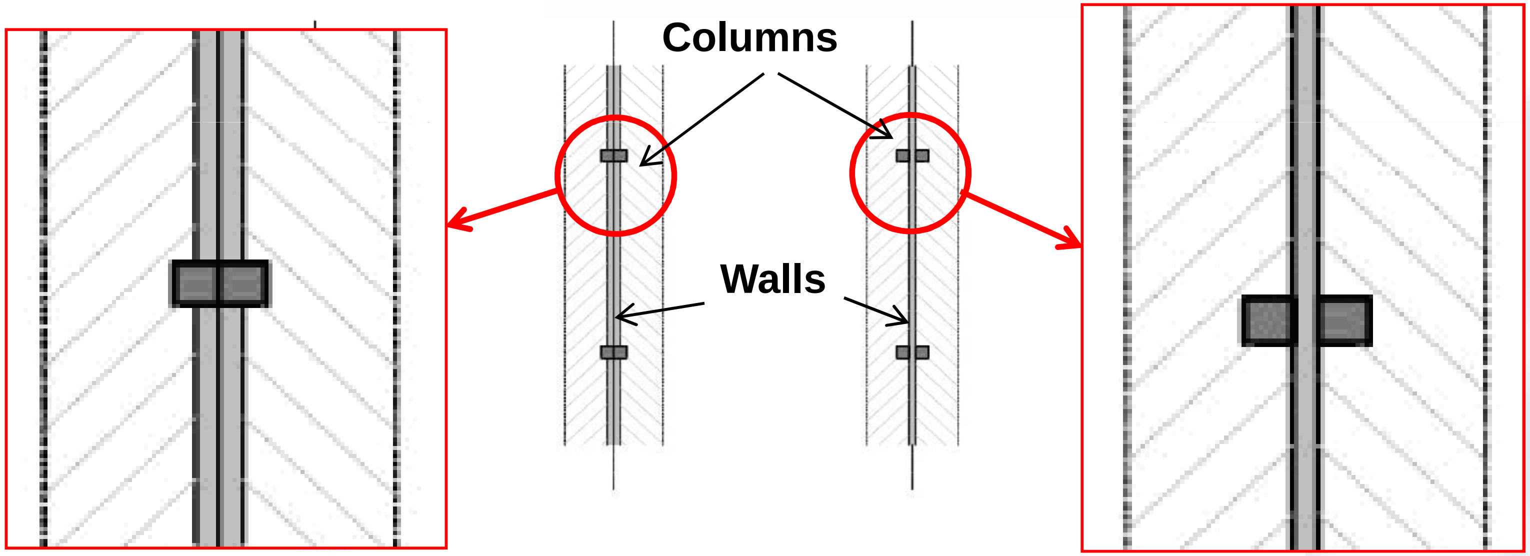
ISO 834 **30 min**

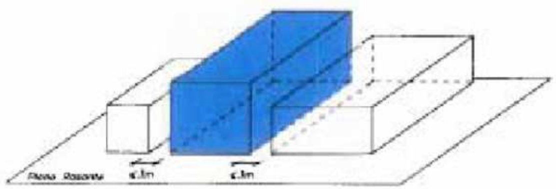


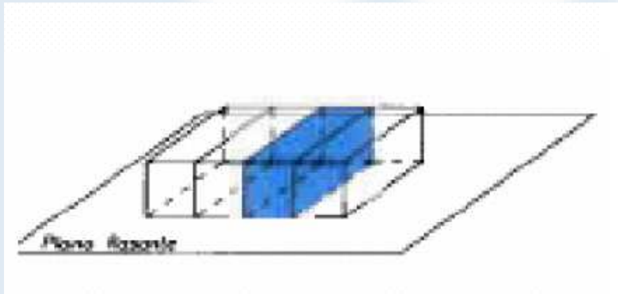
In cases where there is a strong asymmetric distribution of temperature, this bowing can produce DISTORTION OR BREAKAGE OF THE WALL and the loss of its integrity (E criterion).

BREAKEAGE OF WALL

PLAN VIEW



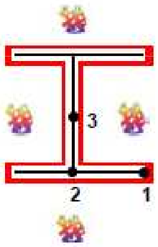


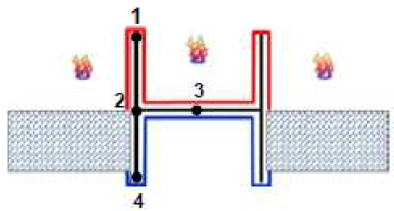


In Catalonia there are prescriptive rules which recommends using double columns in some situations. For example in walls which separate different buildings. This measure can help to prevent damages caused by bowing effect.

UNCONSERVATIVE ESTIMATION OF LOAD CAPACITY

Another problem is that the assumption of uniform temperature distribution could lead to obtain unsafe results in terms of column capacity, specially in very slender columns that are loaded with more than 50% of their ambient load capacity.





Failure temperatures (T_F) and failure time (t_F) for W12 × 58 column with uniform temperature distribution.

W12x58		$0.9\,P_n^{20}$	$0.8\,P_n^{20}$	$0.7\,P_n^{20}$	$0.6\,P_n^{20}$	$0.5\,P_n^{20}$	$0.4\,P_n^{20}$	$0.2\,P_n^{20}$
λy	P_n^{20} (kN)	Failure temperature (°C) and time of failure (minutes)						
10	3740	265 (41)	440 (73)	492 (84)	531 (94)	567 (104)	607 (116)	703 (148)
30	3520	185 (29)	298 (46)	441 (73)	505 (88)	545 (98)	585 (109)	686 (145)
40	3230	182 (28)	267 (41)	385 (61)	478 (81)	530 (94)	572 (105)	679 (142)
50	2930	182 (28)	261 (40)	347 (54)	444 (75)	517 (90)	561 (103)	670 (139)
60	2670	171 (27)	241 (37)	324 (50)	413 (66)	506 (88)	551 (99)	660 (134)
80	2160	167 (26)	234 (36)	300 (47)	374 (59)	472 (80)	538 (96)	650 (131)
100	1690	167 (26)	239 (37)	298 (47)	363 (58)	461 (77)	537 (96)	647 (129)
150	859	207 (32)	288 (44)	353 (56)	420 (68)	522 (92)	564 (103)	674 (140)

Shaded cells mark the cases where designing for all around heating would be unconservative if columns were heated so that there was a thermal gradient along the flanges.

AGARWAL, A.; CHOE, L.; VARMA, A.H. "Fire design of steel columns: Effects of thermal gradients". Journal of Constructional Steel Research, ELSEVIER, ISSN: 0143-974X. Volume 93, Pages 107–118, 2014

ADVICES FOR APPLICATION OF GENERAL FORMULAS 4.25 AND 4.27 OF EN 1993-1-2

So, it could be convenient give some advices for the application of general formulas 4.25 and 4.27 in the cases of columns with asymmetric heating from tables 4.2 and 4.3.

4.25 (Unprotected Steel)

$$\Delta\theta_{a,t} = k_{sh} \frac{A_m/V}{c_a \rho_a} \dot{h}_{net} \Delta t$$

4.27 (Protected Steel)

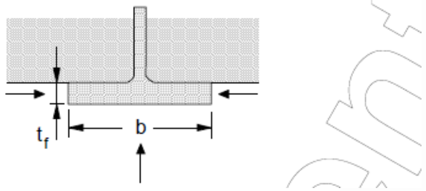
$$\Delta\theta_{a,t} = \frac{\lambda_p A_p/V}{d_p c_a \rho_a} \frac{(\theta_{g,t} - \theta_{a,t})}{(1 + \phi/3)} \Delta t - (e^{\phi/10} - 1)\Delta\theta_{g,t}$$

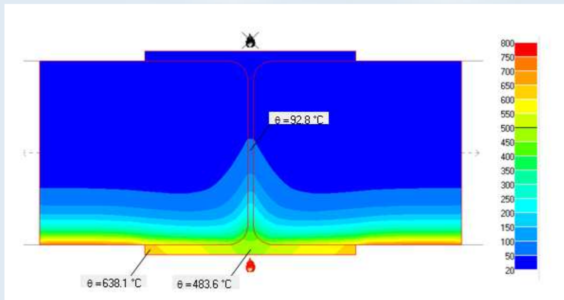
For instance, the addition of a new clause or note to warning in the case of columns or beam-columns when calculating the section factor with asymmetry, like both cases shown below.

I-section flange exposed to fire on three sides:

$A_m/V = (b + 2t_f)/(bt_f)$

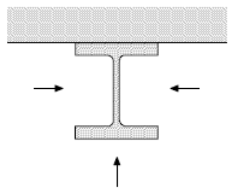
If $t \ll b$: $A_m/V \approx 1/t_f$

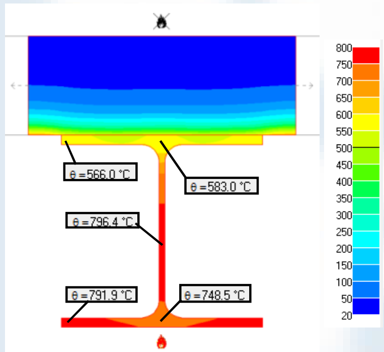




Open section exposed to fire on three sides:

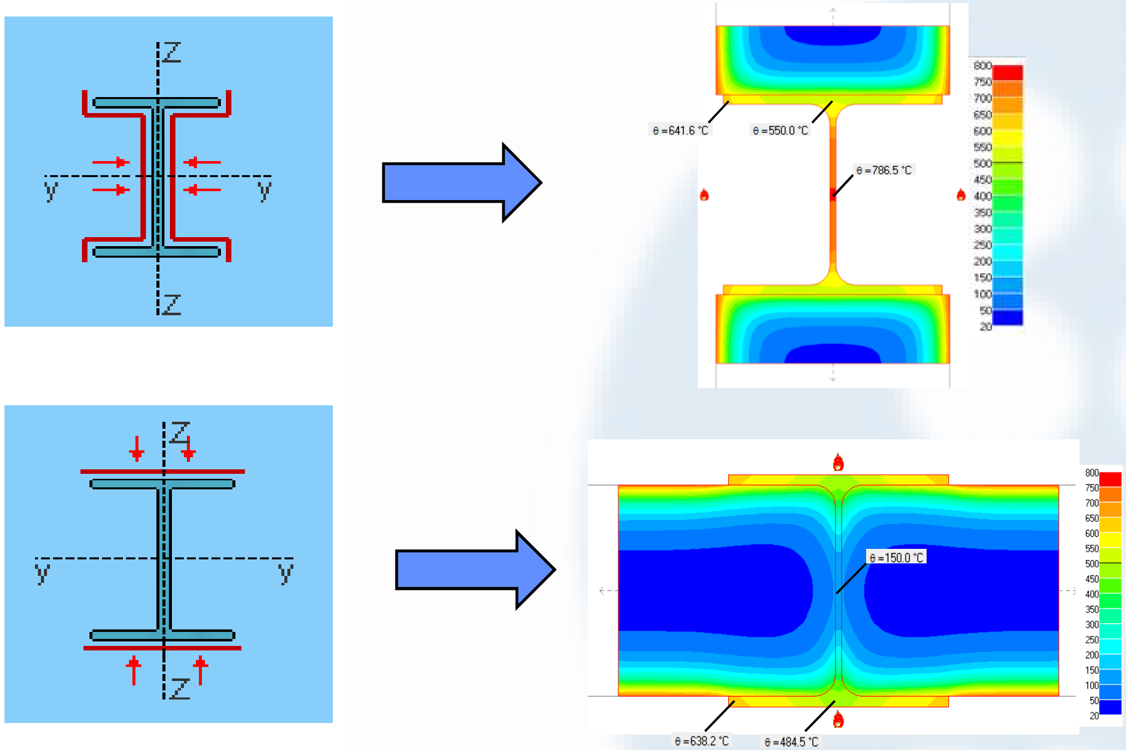
$$\frac{A_m}{V} = \frac{\text{surface exposed to fire}}{\text{cross- section area}}$$





MECHANICAL AND THERMAL DOUBLE SYMMETRY

Otherwise, it may be possible to incorporate new cases of columns or beam-columns with mechanical and thermal double symmetry in tables 4.2 and 4.3. In these cases there are no thermal gradients.



REFERENCES

AGARWAL, A.; CHOE, L.; VARMA, A.H. "Fire design of steel columns: Effects of thermal gradients". Journal of Constructional Steel Research, ELSEVIER, ISSN: 0143-974X. Volume 93, Pages 107–118, 2014

CORREIA, A.; RODRIGUES, J.P.C; VALDIR, V.P.; LAÍM, L. "Section factor and steel columns embedded in walls". Proceedings of the Nordic Steel Construction Conference 2009. NSCC2009- Malmö (Sweden), Luleå University of Technology and Swedish Institute of Steel Construction. Pages 172-179, 2009

RENAUD, C. "Guide de vérification des entrepôts en structure métallique en situation d'incendie". Centre Technique Industriel de la Construction Métallique. CTICM, Référence: SRI – 05/78f – CR/NB, n° Affaire: CA 030166, 2006

Thanks for your attention

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