



decivil universidade de aveiro
departamento de engenharia civil

**EN 1993-1-2: STAINLESS STEEL MEMBERS
SUBJECTED TO COMBINED BENDING AND AXIAL
COMPRESSION IN CASE OF FIRE**

**Nuno Lopes; Paulo Vila Real
LABEST - Universidade de Aveiro**



EN1993-1-2 fire resistance formulae



Same formulae developed for carbon steel columns

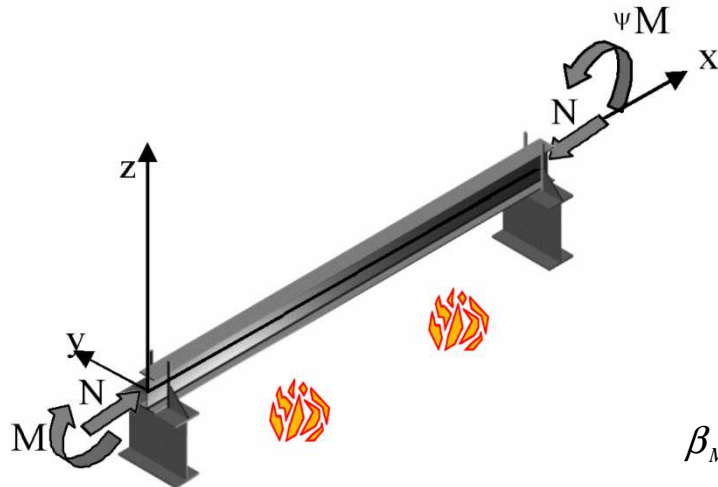
$$\frac{N_{fi,Ed}}{\chi_{\min,fi} A \frac{k_{y,\theta} f_y}{\gamma_{M,fi}}} + K_{y,fi} \frac{M_{y,fi,Ed}}{W_{pl,y} \frac{k_{y,\theta} f_y}{\gamma_{M,fi}}} + K_{z,fi} \frac{M_{z,fi,Ed}}{W_{pl,z} \frac{k_{y,\theta} f_y}{\gamma_{M,fi}}} \leq 1$$

$$\frac{N_{fi,Ed}}{\chi_{z,fi} A \frac{k_{y,\theta} f_y}{\gamma_{M,fi}}} + K_{LT,fi} \frac{M_{y,fi,Ed}}{\chi_{LT} W_{pl,y} \frac{k_{y,\theta} f_y}{\gamma_{M,fi}}} + K_{z,fi} \frac{M_{z,fi,Ed}}{W_{pl,z} \frac{k_{y,\theta} f_y}{\gamma_{M,fi}}} \leq 1$$

$$K_{LT,fi} = 1 - \frac{\mu_{LT,\theta} N_{fi,Ed}}{\chi_{z,fi} A k_{y,\theta} \frac{f_y}{\gamma_{M,fi}}} \quad \text{with } K_{LT,fi} \leq 1$$

$$K_{y,fi} = 1 - \frac{\mu_{y,\theta} N_{fi,Ed}}{\chi_{y,fi} A k_{y,\theta} \frac{f_y}{\gamma_{M,fi}}} \quad \text{with } K_{y,fi} \leq 3$$

$$K_{z,fi} = 1 - \frac{\mu_{z,\theta} N_{fi,Ed}}{\chi_{z,fi} A k_{y,\theta} \frac{f_y}{\gamma_{M,fi}}} \quad \text{with } K_{z,fi} \leq 3$$



$$\beta_{M,i} = 1.8 - 0.7\psi_i$$

$$\mu_{LT,\theta} = 0.15 \bar{\lambda}_{z,\theta} \beta_{M,LT} - 0.15 \leq 0.9$$

$$\mu_{y,\theta} = (2\beta_{M,y} - 5) \bar{\lambda}_{y,\theta} + 0.44\beta_{M,y} + 0.29 \leq 0.8 \quad \text{with } \bar{\lambda}_{y,20^\circ C} \leq 1.1$$

$$\mu_{z,\theta} = (1.2\beta_{M,z} - 3) \bar{\lambda}_{z,\theta} + 0.71\beta_{M,z} - 0.29 \leq 0.8$$



New proposal



$$\mu_{LT,\theta} = (-0.14\beta_{M,LT} + 0.11)\bar{\lambda}_{z,\theta} + 0.50\beta_{M,LT} - 0.09$$

if $\bar{\lambda}_{z,\theta} \leq 0.4$ then $\mu_{LT,\theta} \leq 1.0$ else $\mu_{LT,\theta} \leq 0.8$

$$K_{LT,fi} = 1 - \frac{\mu_{LT,\theta} N_{fi,Ed}}{\chi_{z,fi} A k_{y,\theta} \frac{f_y}{\gamma_{M,fi}}}$$

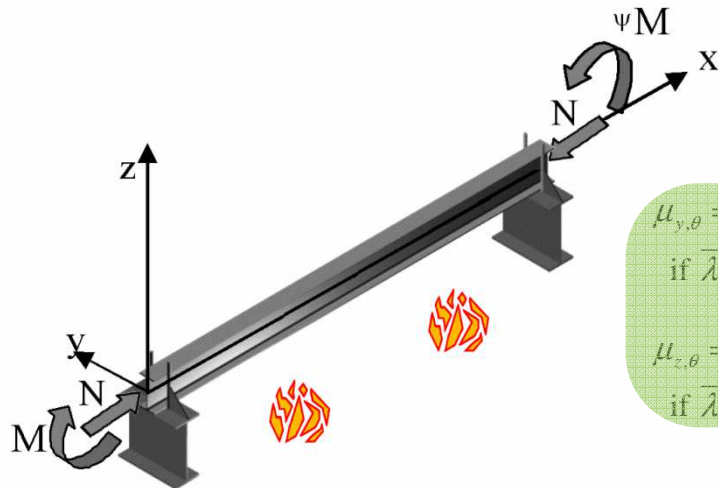
with $K_{LT,fi} \leq 1$ and $K_{LT,fi} \geq \mu_{LT,\theta} - 0.5$

$$K_{y,fi} = 1 - \frac{\mu_{y,\theta} N_{fi,Ed}}{\chi_{y,fi} A k_{y,\theta} \frac{f_y}{\gamma_{M,fi}}}$$

with $K_{y,fi} \leq 0.8\bar{\lambda}_{y,\theta} + 0.9$ and $K_{y,fi} \geq \mu_{y,\theta} - 0.5$

$$K_{z,fi} = 1 - \frac{\mu_{z,\theta} N_{fi,Ed}}{\chi_{z,fi} A k_{y,\theta} \frac{f_y}{\gamma_{M,fi}}}$$

with $K_{z,fi} \leq 0.8\bar{\lambda}_{z,\theta} + 0.9$ and $K_{z,fi} \geq \mu_{z,\theta} - 0.7$



1.4301 and 1.4003

$$\mu_{y,\theta} = (1.27\beta_{M,y} - 2.63)\bar{\lambda}_{y,\theta} + 0.66\beta_{M,y} - 0.49$$

if $\bar{\lambda}_{y,\theta} \leq 0.4$ then $\mu_{y,\theta} \leq 1.0$ else $\mu_{y,\theta} \leq 0.8$

$$\mu_{z,\theta} = (1.53\beta_{M,z} - 3.20)\bar{\lambda}_{z,\theta} + 0.41\beta_{M,z} + 0.24$$

if $\bar{\lambda}_{z,\theta} \leq 0.3$ then $\mu_{z,\theta} \leq 1.0$ else $\mu_{z,\theta} \leq 0.9$

$$\mu_{y,\theta} = (4.33\beta_{M,y} - 8.56)\bar{\lambda}_{y,\theta} + 0.33\beta_{M,y} + 0.11$$

if $\bar{\lambda}_{y,\theta} \leq 0.4$ then $\mu_{y,\theta} \leq 1.0$ else $\mu_{y,\theta} \leq 0.7$

$$\mu_{z,\theta} = (3.03\beta_{M,z} - 6.33)\bar{\lambda}_{z,\theta} + 1.93\beta_{M,z} - 2.45$$

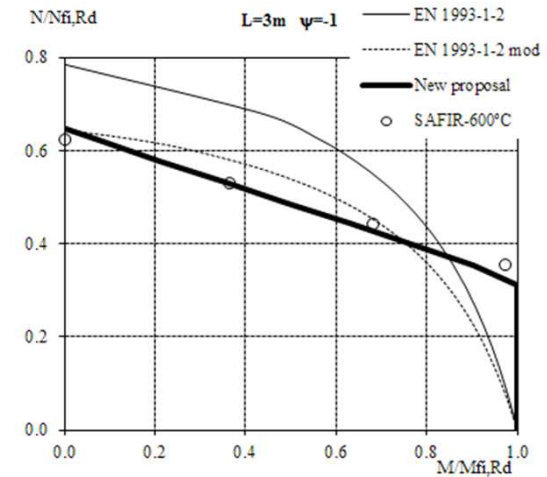
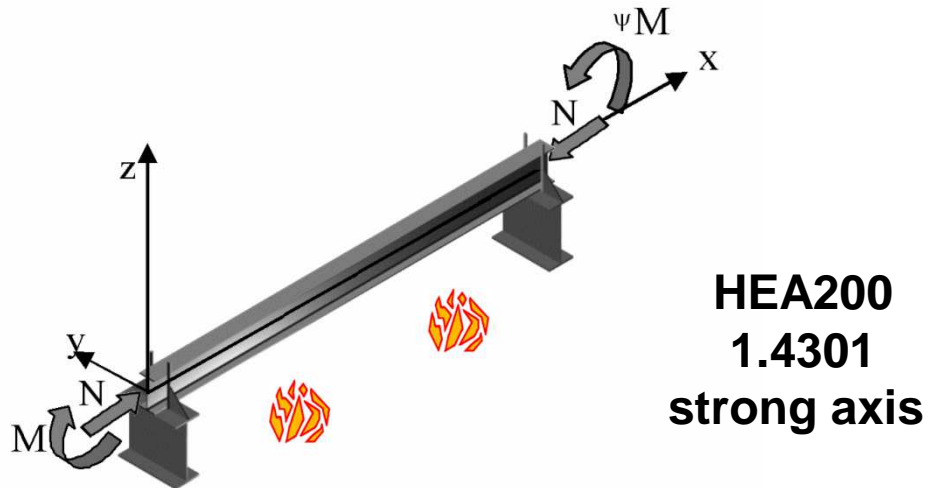
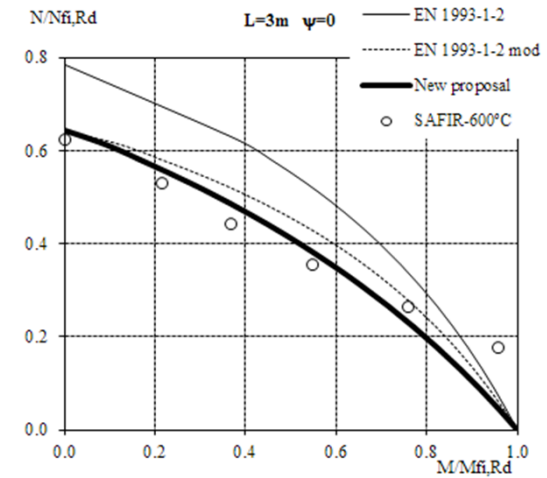
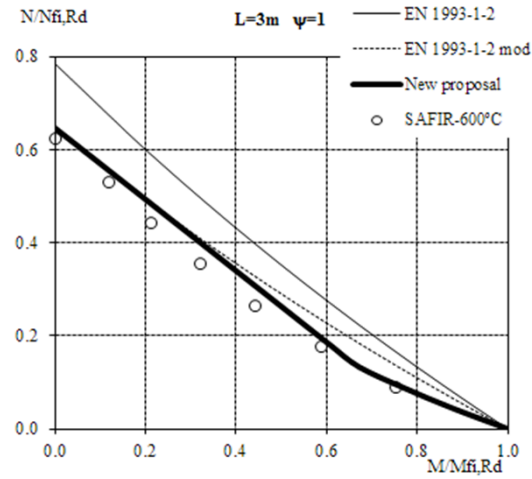
if $\bar{\lambda}_{z,\theta} \leq 0.3$ then $\mu_{z,\theta} \leq 1.0$ else $\mu_{z,\theta} \leq 0.7$

1.4462

Lopes, N.; Vila Real, P.; Simões da Silva, L.; Franssen, J.-M. "Numerical analysis of stainless steel beam-columns in case of fire", Fire Safety Journal, Elsevier, volume 50/(35-50), pp 35-50, ISSN 0379-7112, January of 2012.



Validation

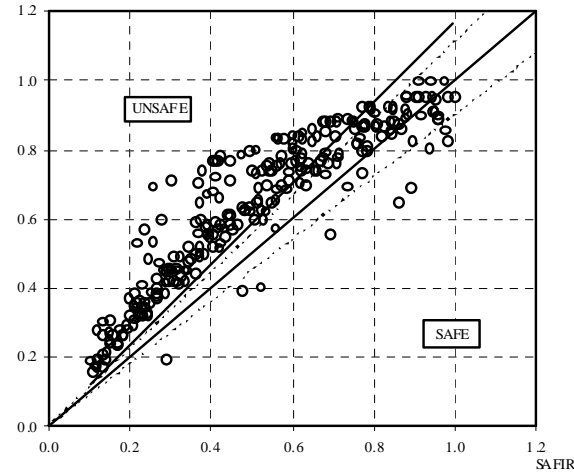




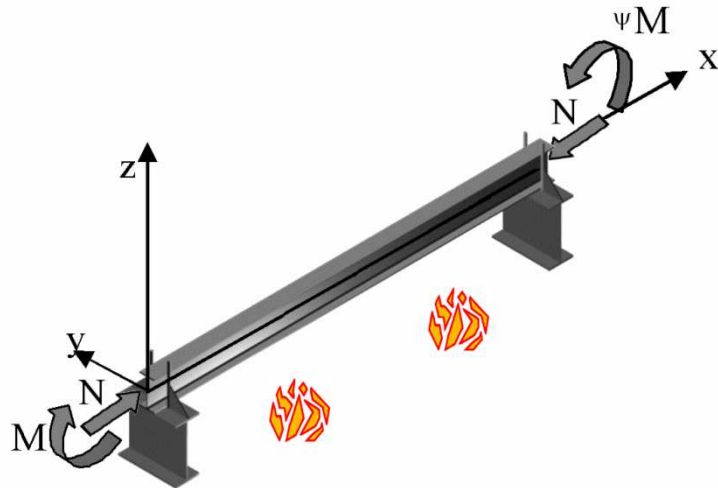
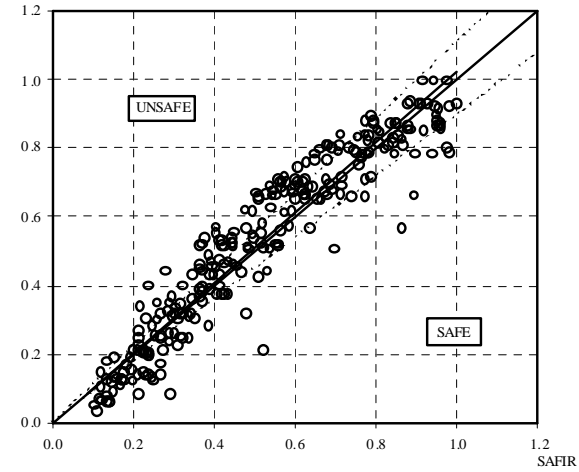
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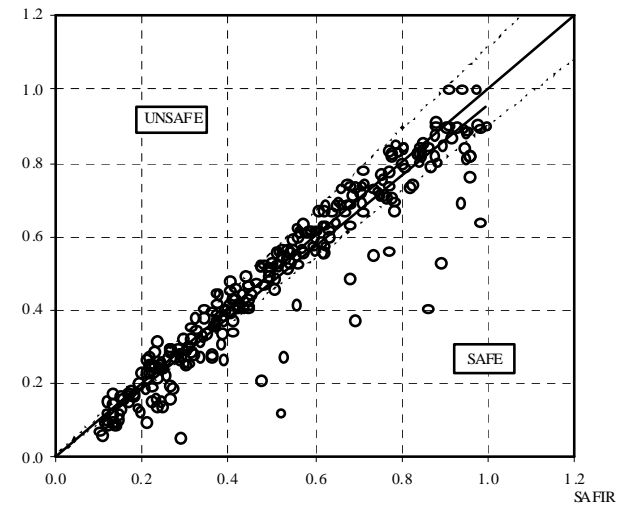
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EN 1993-1-2 mod



New proposal



**1.4301 and 1.4003
strong axis**

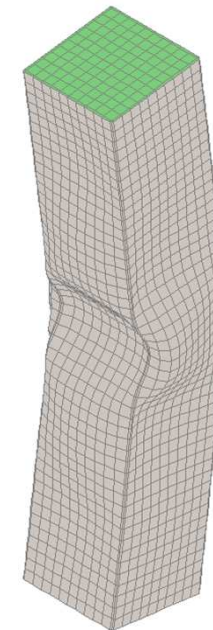
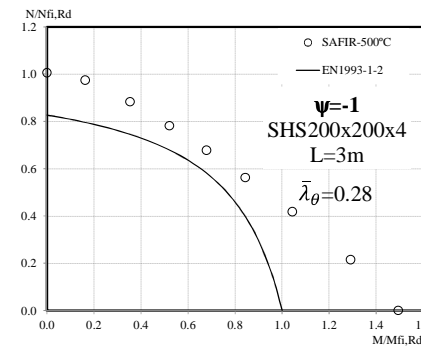
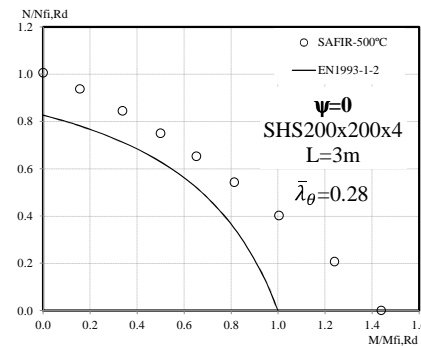
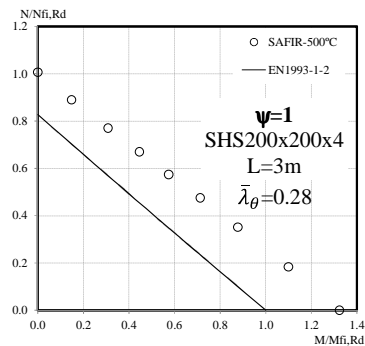


Future developments



Fire resistance of stainless steel structural elements with Class 4 square hollow sections subject to combined bending and axial compression

**SIF'14 - 8th International Conference on Structures In Fire
11-13 June 2014, Tongji University, Shanghai, China**





Integrated Fire Engineering and Response Meeting - 20-21 February 2014 Krakow



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Thank you for your attention

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