Integrated Fire Engineering and Response
COST action network number TU0904 in domain Transport and Urban Development

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WP6 - Thought for Eurocodes Upgrade

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Proposal for EN1994-1-2

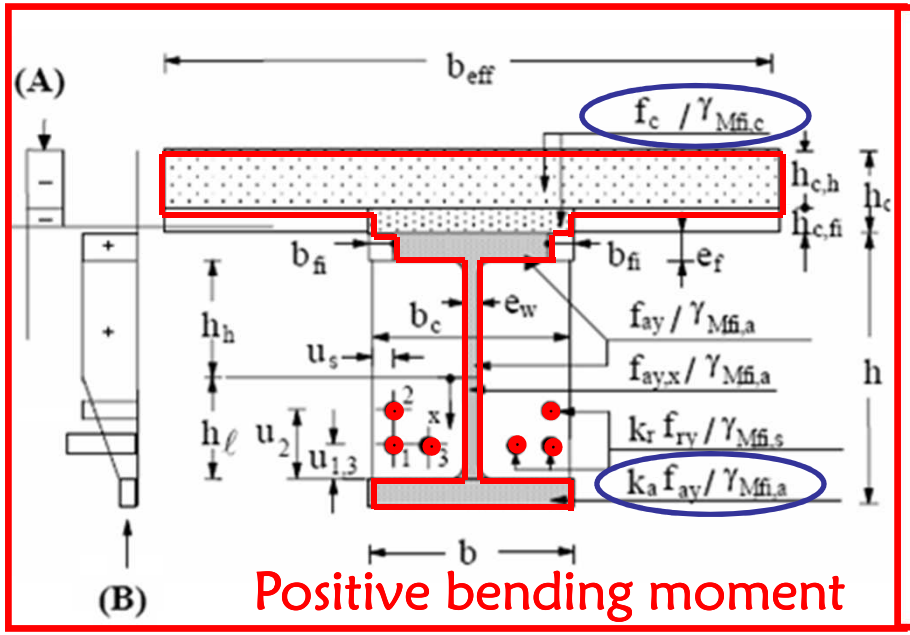
Improvements and updating of Annex F

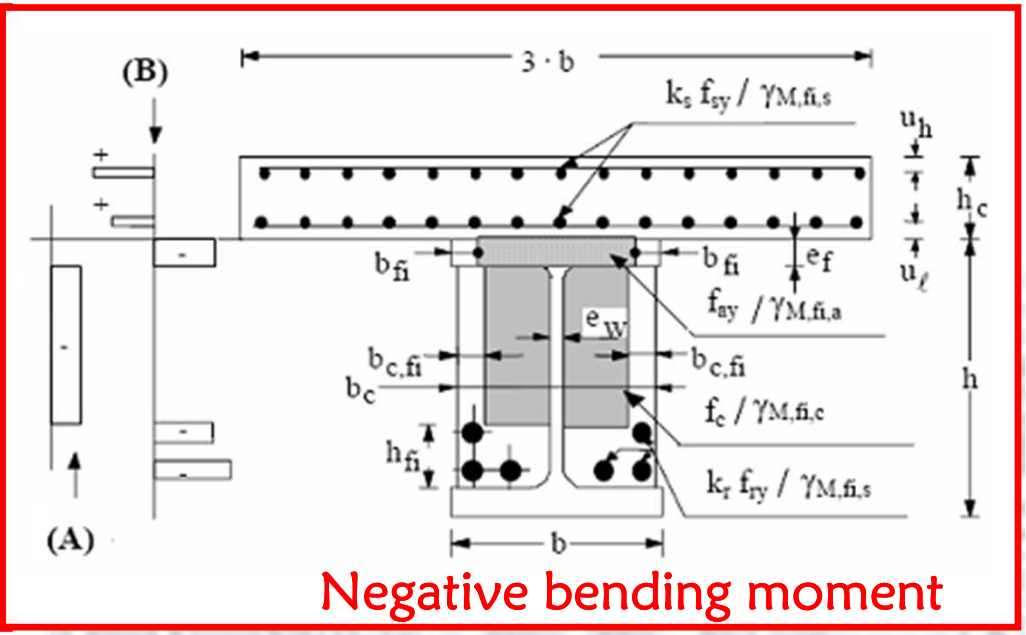
(simplified method for partially encased composite beams)

ANNEX F - Simplified Model for composite partially encased beams

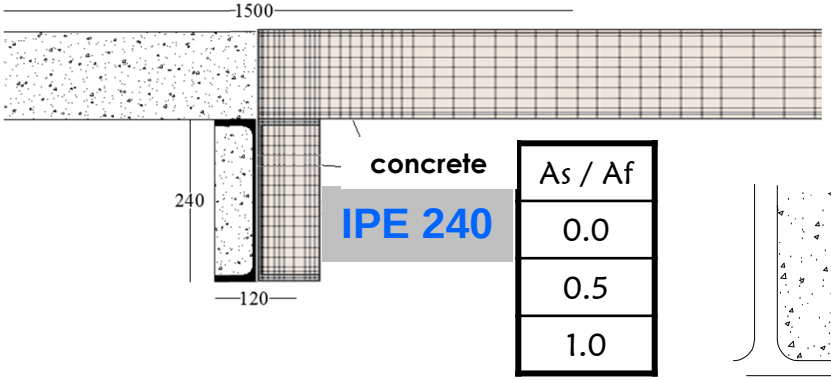
Temperature Effect

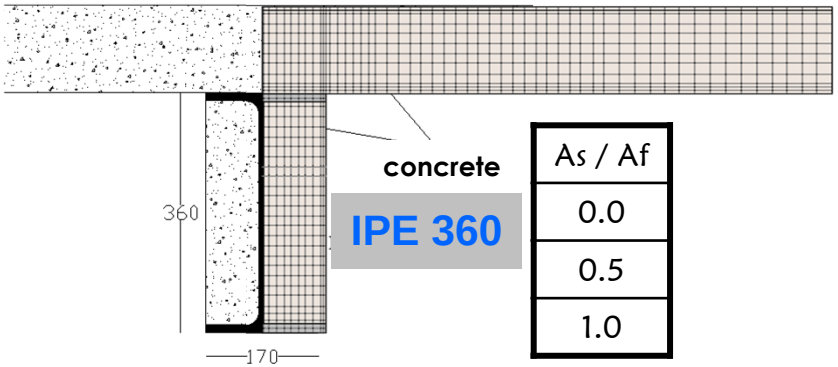
- reduction of beam dimensions
- reduction of mechanical properties of materials

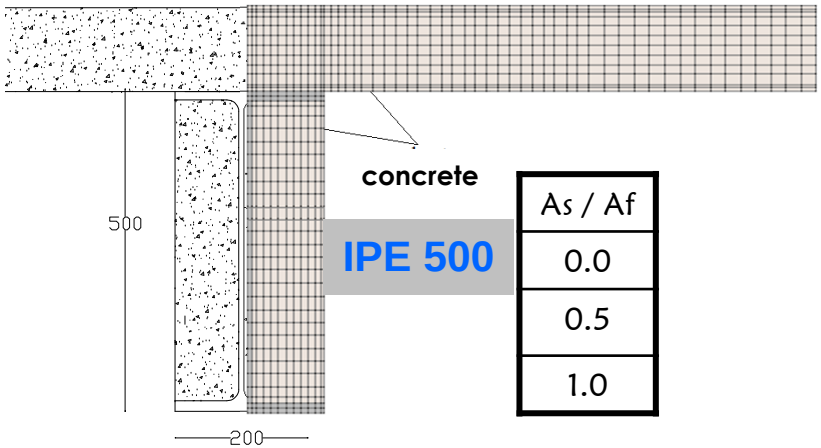




Comparison between accurate and simplified methods





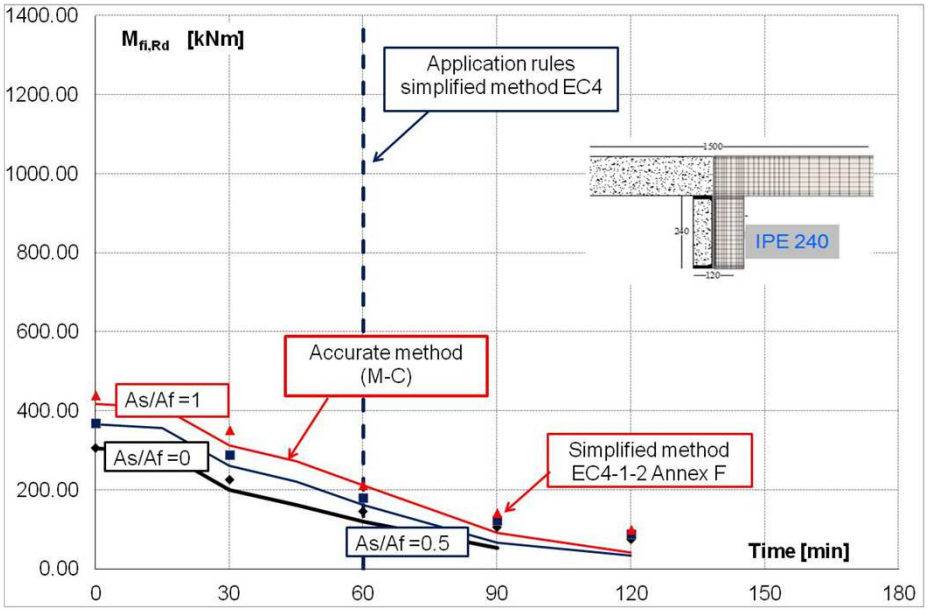


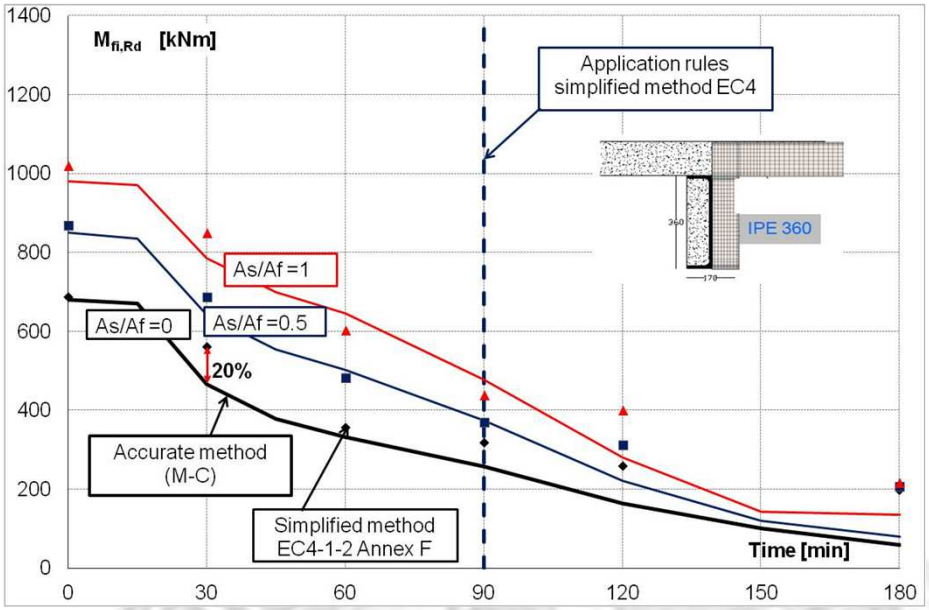
Parametric Analysis

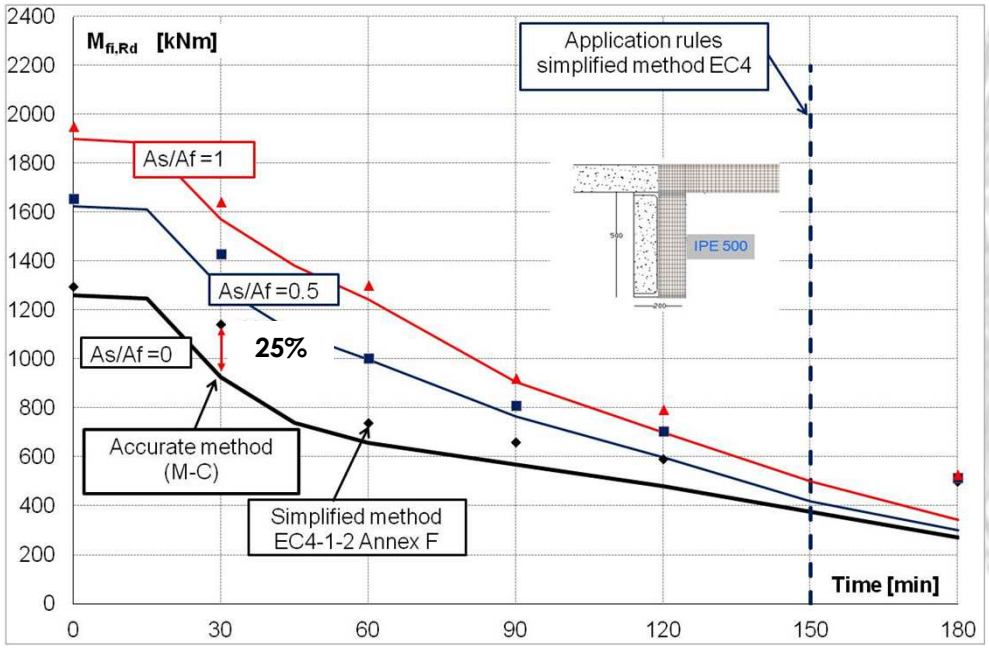
HE240B – IPE240 – A_s/A_f=0			
u_{x1}		u_{x2}	
u_{y1}		u_{y2}	
HE240B – IPE240 – A_s/A_f=0.5			
u_{x1}	45	u_{x2}	45
u_{y1}	100	u_{y2}	130
HE240B – IPE240 – A_s/A_f=1			
u_{x1}	45	u_{x2}	45
u_{y1}	100	u_{y2}	130
HE300B – IPE300 – A_s/A_f=0			
u_{x1}		u_{x2}	
u_{y1}		u_{y2}	
HE300B – IPE300 – A_s/A_f=0.5			
u_{x1}	45	u_{x2}	45
u_{y1}	100	u_{y2}	130
HE300B – IPE300 – A_s/A_f=1			
u_{x1}	45	u_{x2}	45
u_{y1}	100	u_{y2}	130
HE360B – IPE360 – A_s/A_f=0			
u_{x1}		u_{x2}	
u_{y1}		u_{y2}	
HE360B – IPE360 – A_s/A_f=0.5			
u_{x1}	45	u_{x2}	45
u_{y1}	100	u_{y2}	130
HE360B – IPE360 – A_s/A_f=1			
u_{x1}	45	u_{x2}	45
u_{y1}	100	u_{y2}	150

HE400B – IPE400 – A_s/A_f=0			
u_{x1}		u_{x2}	
u_{y1}		u_{y2}	
HE400B – IPE400 – A_s/A_f=0.5			
u_{x1}	60	u_{x2}	60
u_{y1}	120	u_{y2}	150
HE400B – IPE400 – A_s/A_f=1			
u_{x1}	60	u_{x2}	60
u_{y1}	120	u_{y2}	170
HE500B – IPE500 – A_s/A_f=0			
u_{x1}		u_{x2}	
u_{y1}		u_{y2}	
HE500B – IPE500 – A_s/A_f=0.5			
u_{x1}	40	u_{x2}	40
u_{y1}	80	u_{y2}	130
HE500B – IPE500 – A_s/A_f=1			
u_{x1}	40	u_{x2}	40
u_{y1}	80	u_{y2}	130
HE600B – IPE600 – A_s/A_f=0			
u_{x1}		u_{x2}	
u_{y1}		u_{y2}	
HE600B – IPE600 – A_s/A_f=0.5			
u_{x1}	60	u_{x2}	60
u_{y1}	120	u_{y2}	150
HE600B – IPE600 – A_s/A_f=1			
u_{x1}	60	u_{x2}	60
u_{y1}	120	u_{y2}	170

Comparisons - Resistant Bending Moment in fire situation

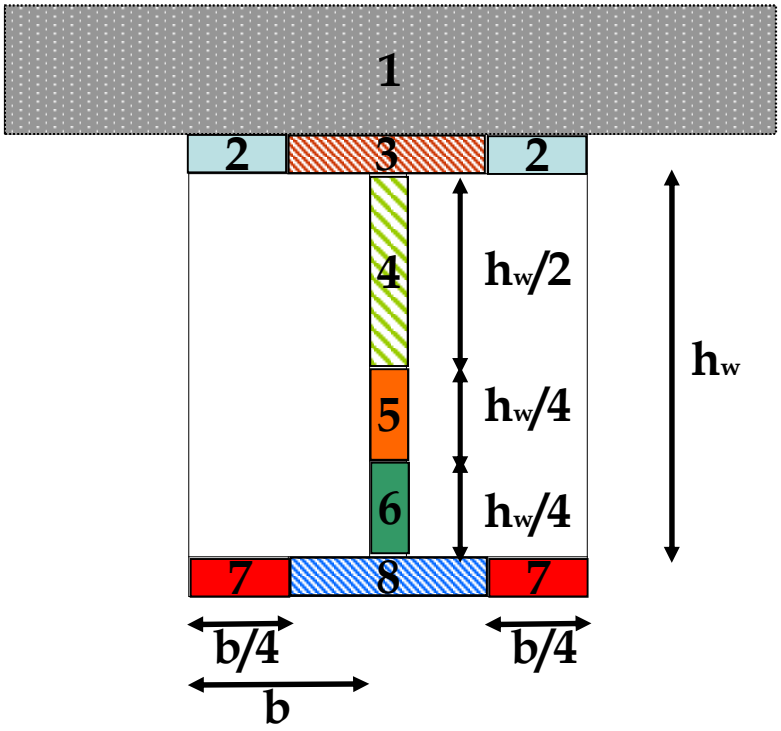


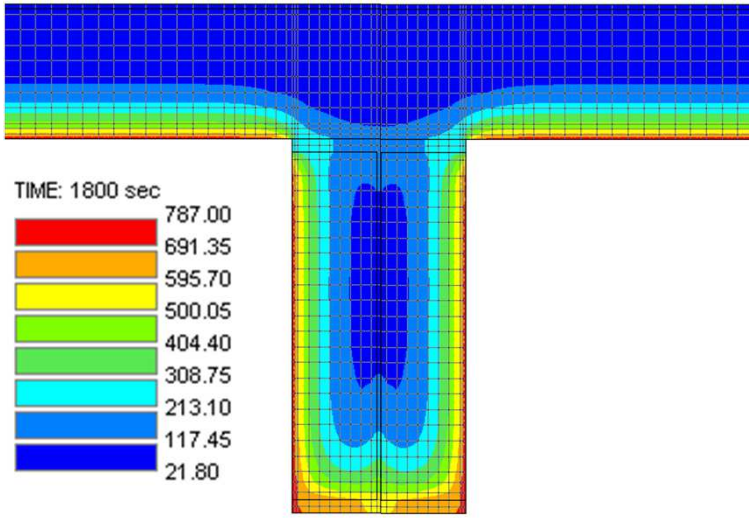




- The simplified method of Annex F is unsafe in several cases compared to plastic analysis, also suggested by EC4 as accurate method.
- The scattering increases outside the application range of the simplified method.

Proposed simplified method





Cross section is divided in 10 parts:

- **Concrete slab**

  Isothermal 500 Method(EC2)

- **Top flange of steel section;**

  3 parts

- **Top web of steel section;**
- **Bottom web;**

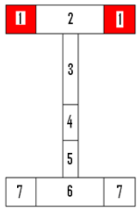
  2 parts

- **Bottom flange;**

  3 parts

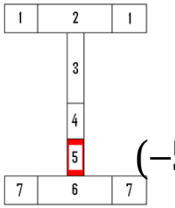
- **Steel reinforcement.**

Temperature-time interpolation curves



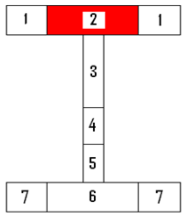
External top flange

$$T = 370 \cdot \ln(t) - (0{,}471 b + 856{,}19)$$



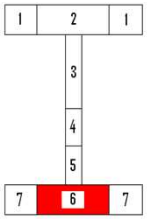
Bottom web

$$T = (-58.553 \cdot h/b + 525.23) \cdot \ln(t) - (14913 \cdot t_f / h + 369.35)$$



Internal top flange

$$T = 370 \cdot \ln(t) - (2{,}768 b + 513{,}5)$$



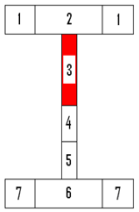
Internal bottom flange

$$T =$$

$$h/b_c \le 1 \qquad T_i(t) = 500 \cdot \ln_{\left(-2.2407\frac{h}{b}+11.611\right)}(t) - \left(\frac{-5b+3200}{t}\right) \ge 400°C$$

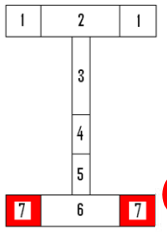
$$h/b_c \ge 1.5 \qquad T_i(t) = (-101.27 \cdot \frac{h}{b} + 653.47) \cdot \ln_{\left(-2.2407\frac{h}{b}+11.611\right)}(t) - \left(\frac{8.8776\,b+1550}{t}\right) \ge 400°C$$

$$1 < h/b_c < 1.5 \qquad T_i(t) = 485 \cdot \ln_{\left(-2.2407\frac{h}{b}+11.611\right)}(t) - \left(\frac{3000 \cdot h/b - 400}{t}\right) \ge 400°C$$



Top web

$$T = 415 \cdot \ln(t) - (3{,}8165(b - t_w) / 2 + 1067{,}2)$$



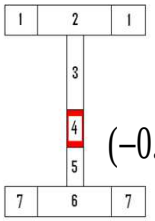
External bottom flange

$$T =$$

$$h/b_c \le 1 \qquad T_i(t) = (-101.27 \cdot \frac{h}{b} + 633.47) \cdot \ln_{(-0.005 \cdot b + 12.2)}(t) - 3000/t \ge 400°C$$

$$h/b_c \ge 1.5 \qquad T_i(t) = (-101.27 \cdot \frac{h}{b} + 633.47) \cdot \ln_{\left(-5.147\frac{h}{b}+18.044\right)}(t) - \left(\frac{16.5 \cdot b + 11.785}{t}\right) \ge 400°C$$

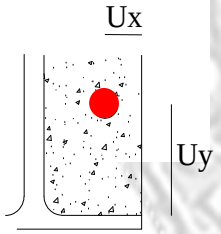
$$1 < h/b_c < 1.5 \qquad T_i(t) = (-101.27 \cdot \frac{h}{b} + 633.47) \cdot \ln_{\left(-45\frac{h}{b}+161\right)}(t) - \left(\frac{-3150\,h/b + 5700}{t}\right) \ge 400°C$$



Central web

$$T =$$

$$(-0.5736 \cdot b + 568.94) \cdot \ln(t) - (-558.44 \cdot b/h + 1942.3)$$

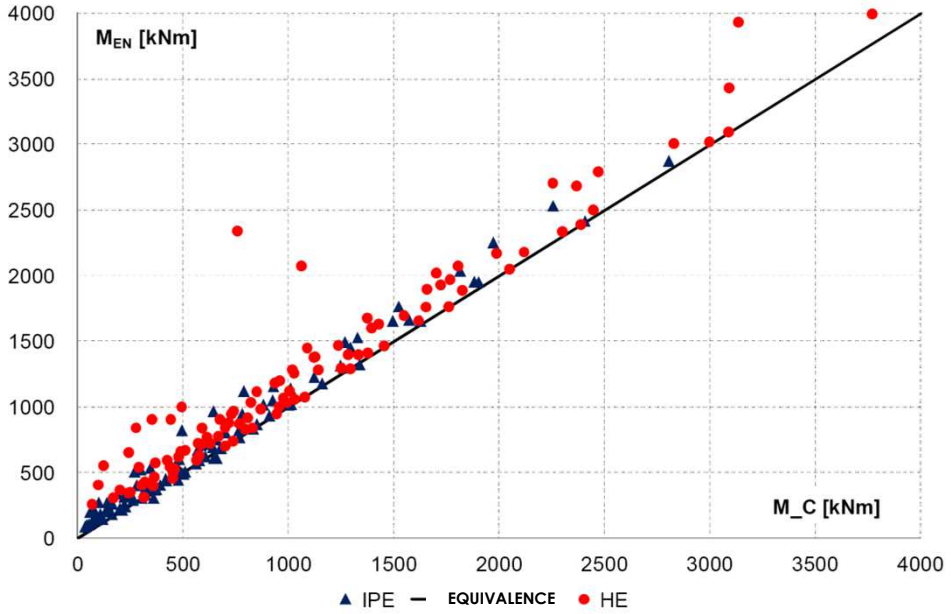


Steel reinforcement

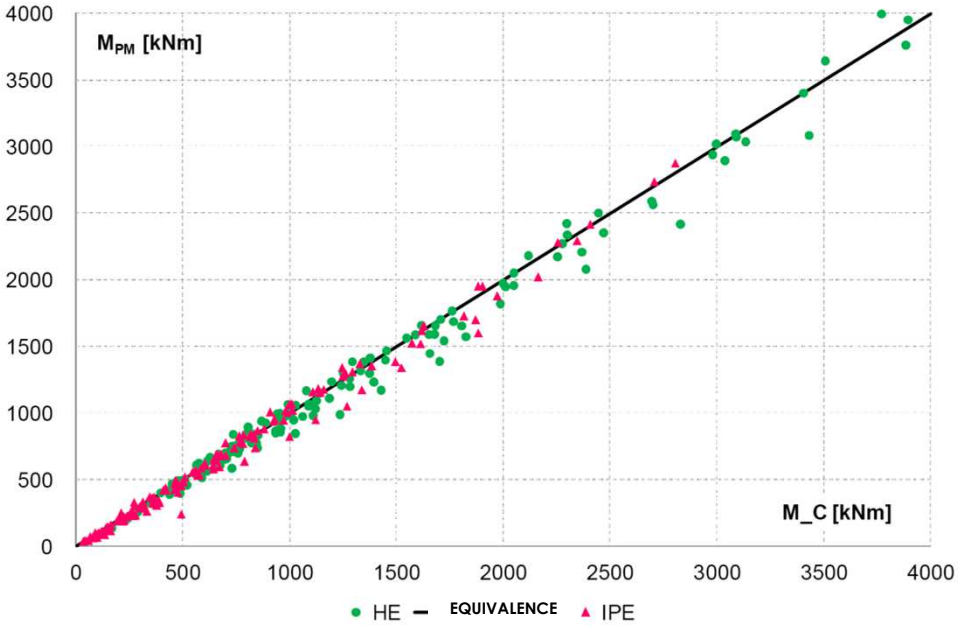
$$T =$$

$$(0.377 \cdot u_d + 353.41) \cdot \ln(t) - \left(49.736 \cdot \frac{1}{1/u_x + 1/u_y + 1/(b - t_w - u_x)}\right)$$

Comparison between methods



Simplified method (EC4) vs Accurate method

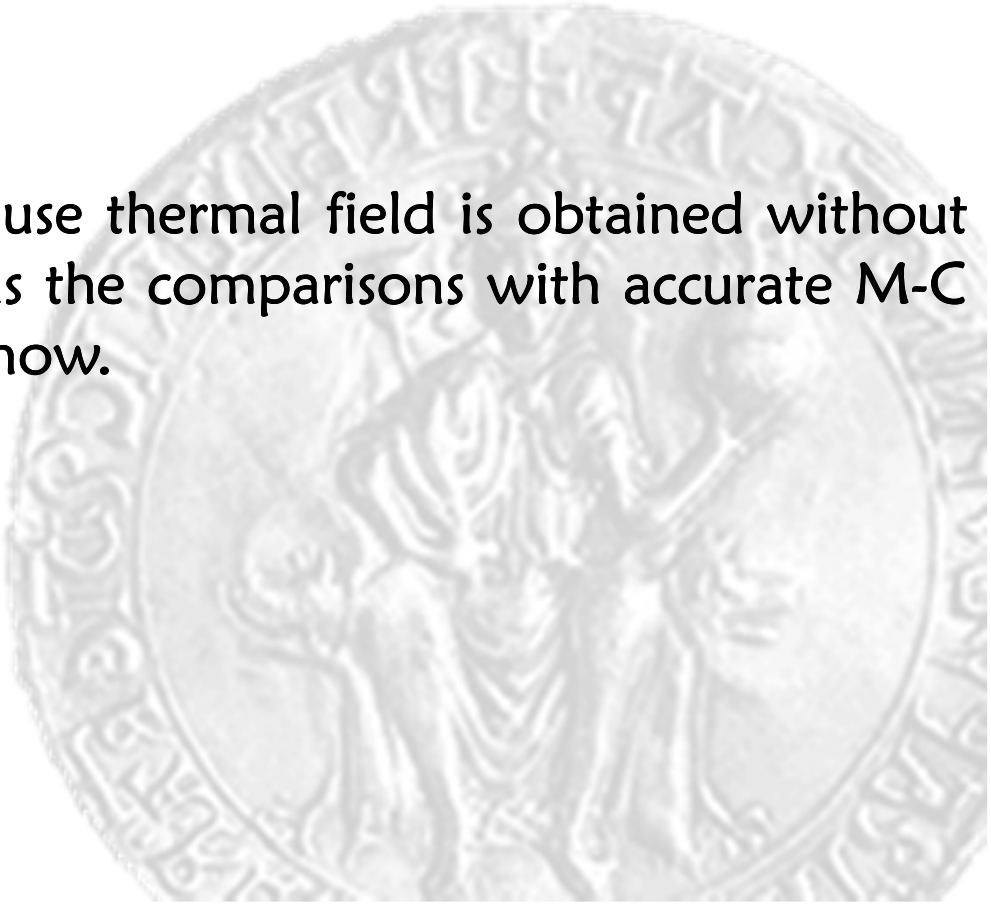


Simplified proposed method vs Accurate method

CONCLUSIONS

- Simplified method (Eurocode 4-1-2 - Annex F) is unsafe in several cases also within its application range. The scattering increases outside the application range.

- Proposed method is simple, because thermal field is obtained without thermal analysis and is reliable, as the comparisons with accurate M-C method and full plastic method show.



Thanks for your attention