## 2.20 Steel beam under edge moments (short version)

Tsalikis Ch., Greece

Aristotle University of Thessaloniki
Department of Civil Engineering
Institute of Metal Structures

# STEEL BEAM UNDER EDGE MOMENTS

- Determination of the K1 – increasing factors of the stress-strain relationship for steel double-T cross sections subjected to non-uniform temperature distribution
- Decomposition of arbitrary stress fields

Chris T. Tsalikis – DIC, Phd Student
Efthimios K. Koltsakis – Ass. Professor
Charalampos C. Baniotopoulos – Professor

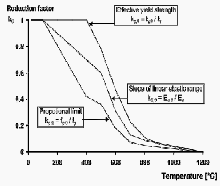




### [ Introduction ]

- EC3. Part 1.2 proposes reduction factors for the mechanical properties of carbon steel.

$$K_i = f(\theta)$$




- When a member is under thermal gradient, the mechanical properties of the material are not straightforward.





### [Scope]

- Calculation of the equivalent $K_{\Delta\theta}$ factors for double-T cross-sections
- Reference temperature = maximum temperature of the thermal field

$$K_{\Delta\vartheta} = \frac{K_{\max\vartheta}}{K_1}$$

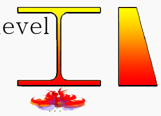
- $K_1$ : Increasing factor is derived as K(max constant temperature) over K(linear temperature across the cross-section)

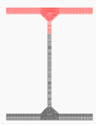




### [Implementation – $K_{1,y\vartheta}$ factor]

- Plastic analysis at a cross – section level
- Planarity of the cross-section
- Linear field of temperatures
- As $\Delta\theta$ rises, so does the distance of the plastic neutral axis from the mid-height









### [Implementation – $K_{1,y\vartheta}$ factor]

- Several solutions performed for three commonly used types of steel cross-sections
- The plastic modulus was calculated for three slopes of thermal gradients.

$$W_{pl,\Delta\vartheta} = \sum_{i=1}^{n} A_i z_i k_{y,\vartheta,i}$$

- The $K_{1,y\theta}$ was derived taking into account the plastic modulus of the cross-section under the maximum temperature of the thermal field

$$W_{pl,\Delta\vartheta} = k_{y,\Delta\vartheta} \times W_{pl,20} = k_{y,\Delta\vartheta} \times \frac{W_{pl,\vartheta\max}}{K_{y,\vartheta\max}} \Rightarrow$$

$$W_{pl,\Delta\vartheta} = \frac{W_{pl,\vartheta\max}}{K_{1y,\vartheta}} \Rightarrow K_{1y,\vartheta} = \frac{W_{pl,\vartheta\max}}{W_{pl,\Delta\vartheta}}$$





### [Implementation – $K_{1,E\vartheta}$ factor]

- Simply-supported beams under edge moments were analysed elastically
- Deflection curve using Euler-Bernoulli beam equation for constant temperature (the highest of the thermal field)

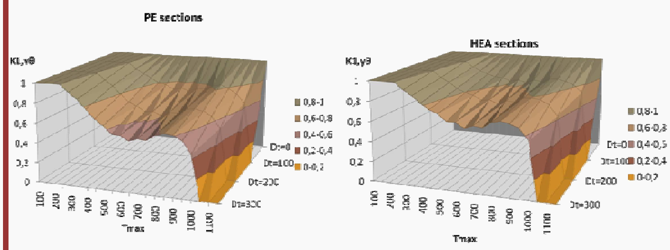
$$M = -EI\frac{d^2w}{dx^2}$$

- Calculation of the equivalent $K_{E,\Delta\theta}$ for the same deflection curve and loading conditions
- Determination of $K_1$ for various slopes of thermal gradients

$$K_1 = \frac{K_{E,\max\vartheta}}{K_{E,\Delta\vartheta}}$$

## [Results – $K_{1,y\vartheta}$ factor]

- EC3 proposes $K_{1,y\theta}$ = 0.7 for unprotected steel beam under thermal gradient
- Analysis showed that a realistic factor is 0,85 for $\Delta\theta$ >100$^0$C.
- $A_{fl}$ / $A_{tot}$ increase → $K_{1,y\theta}$ decrease

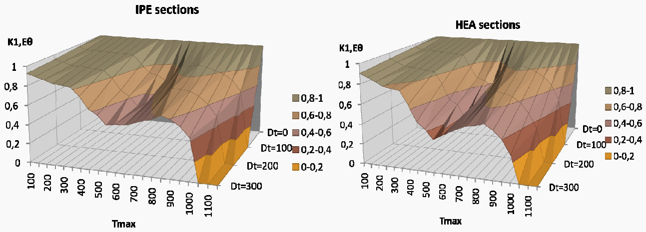







## [Results – $K_{1,E\vartheta}$ factor]

- Finite element analysis incorporates any deviation from the planarity of the cross section.
- Analysis showed that a safety factor is 0,90 for $\Delta\theta$ >100$^0$C








## [ In a few words… ]

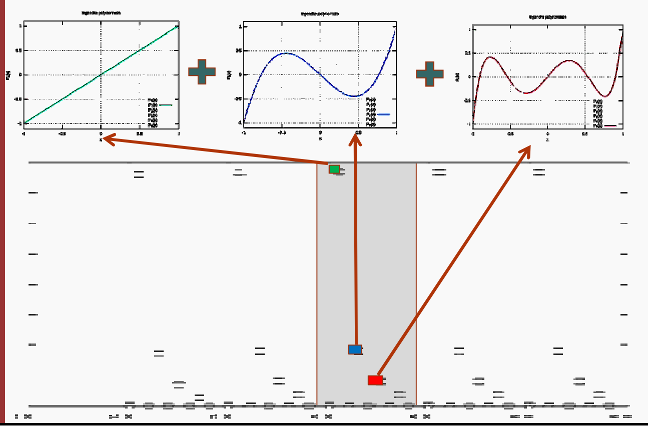
- Aim: Accurate description of the direct stress field
- How? : Decomposition of the stress field into basic polynomials
- Adapt legendre polynomials to the geometry of the cross–section, to satisfy orthogonality.
- Following an iterative procedure, obtain the weight of each polynomial.

$$\sigma_{tot} = w_1 \times \sigma_1 + w_2 \times \sigma_2 + \ldots + w_n \times \sigma_n$$





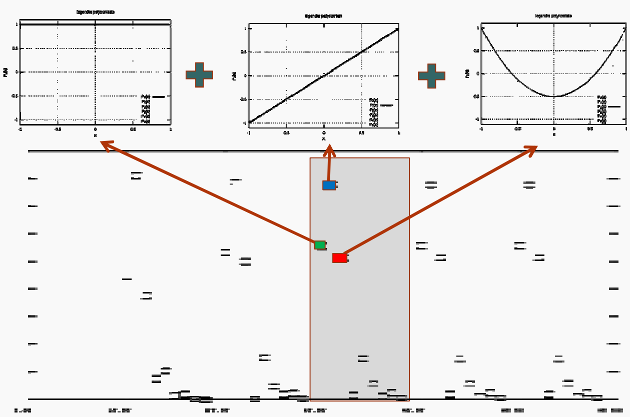
- Steel beam / IPE section / Tconstant = 600$^0$ C / Edge Moments
- Grey area represents the integrals of the (weight x basic functions)







- Steel beam / IPE section / Thermal Gradient / Edge Moments
- Wrong position of the N.A. → Laguerre Polynomials







## [ Conclusions ]

- Accurate description of the stress field across the cross–section in a simplified way.
- Sort out the stresses that produce axial force, bending moment and possible higher order moments.

## [ Future investigation… ]

- Energetic assessment of the above method
- Application of associated legendre polynomials in order to incorporate the movement of the neutral axis in case of thermal gradient.

*…thank you*