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FIRE BEHAVIOUR OF STEEL COLUMNS

FIRE IN BUILDINGS

CONSEQUENCES:

- **Material damages**
- **Human injuries and lost of lives**

STATISTICAL INFORMATION:
Cumulative fire damages are beiger then damages made by earthquakes

FIRE SAFETY OBJECTIVES

1. **Protection of human lives**
2. **Protection of neighboring buildings**
3. **Protection of material goods in the building**
4. **Avoiding non tolerant ecologic damaged**

FIRE IN BUILDINGS

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STRUCTURAL FIRE SAFETY REQUIREMENTS

1. **To provide bearing capacity in fire condition for required time**
2. **To prevent fire spread on neighboring buildings**
3. **To provide condition for people evacuation**
4. **To provide condition for fire extinguishing**

FIRE INFLUENCE ON STEEL STRUCTURES

RAPID HEATING

HIGH TEMPERATURES

MATERIAL DEGRADATION

- Decrease of yield stress

- Decrease of strength limit

- Decrease of modulus of elasticity

- Significant changes in s-e relation

This material degradation cause significant increase of structural deformations which lead to:

Stability problems / Lost of load bearing capacity

TECHNICAL REGULATION CRITERION

$t_{f,r}$ – TIME OF FIRE RESISTANCE

$t_{r,f}$ – REQUIRED TIME OF FIRE RESISTANCE

$$t_{f,r} \geq t_{r,f}$$

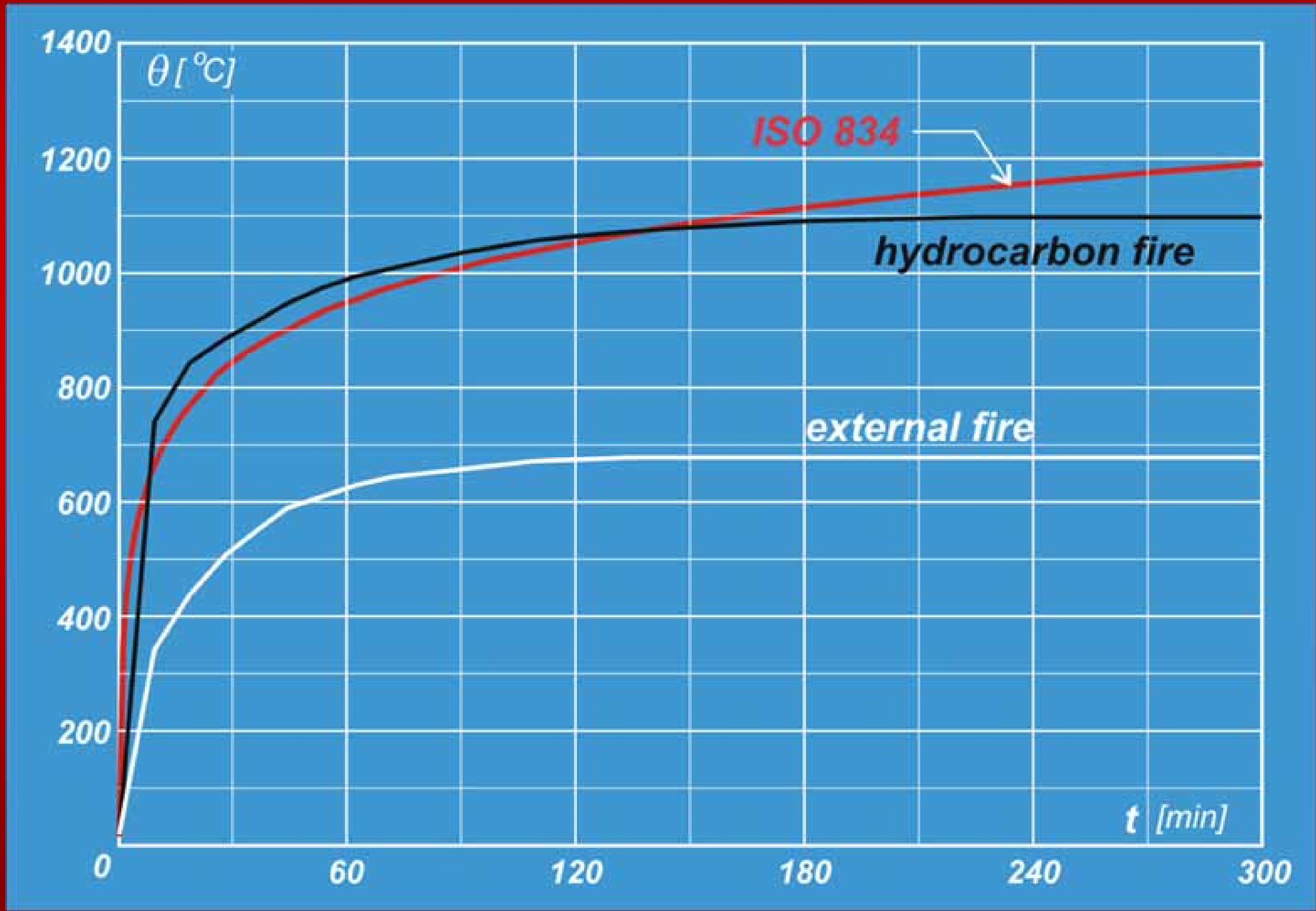
1/ STANDARD TEST – experimental procedure

2/ ANALYTICAL ALTERNATIVE OF STANDARD TEST

- **Eurocode 0: Basis of Design**
- **Eurocode 1: Actions on Structures**
  Part 1-2: Actions on Structures Exposed to Fire
- **Eurocode 3: Design of Steel Structures**
  Part 1-2: Structural Fire Design

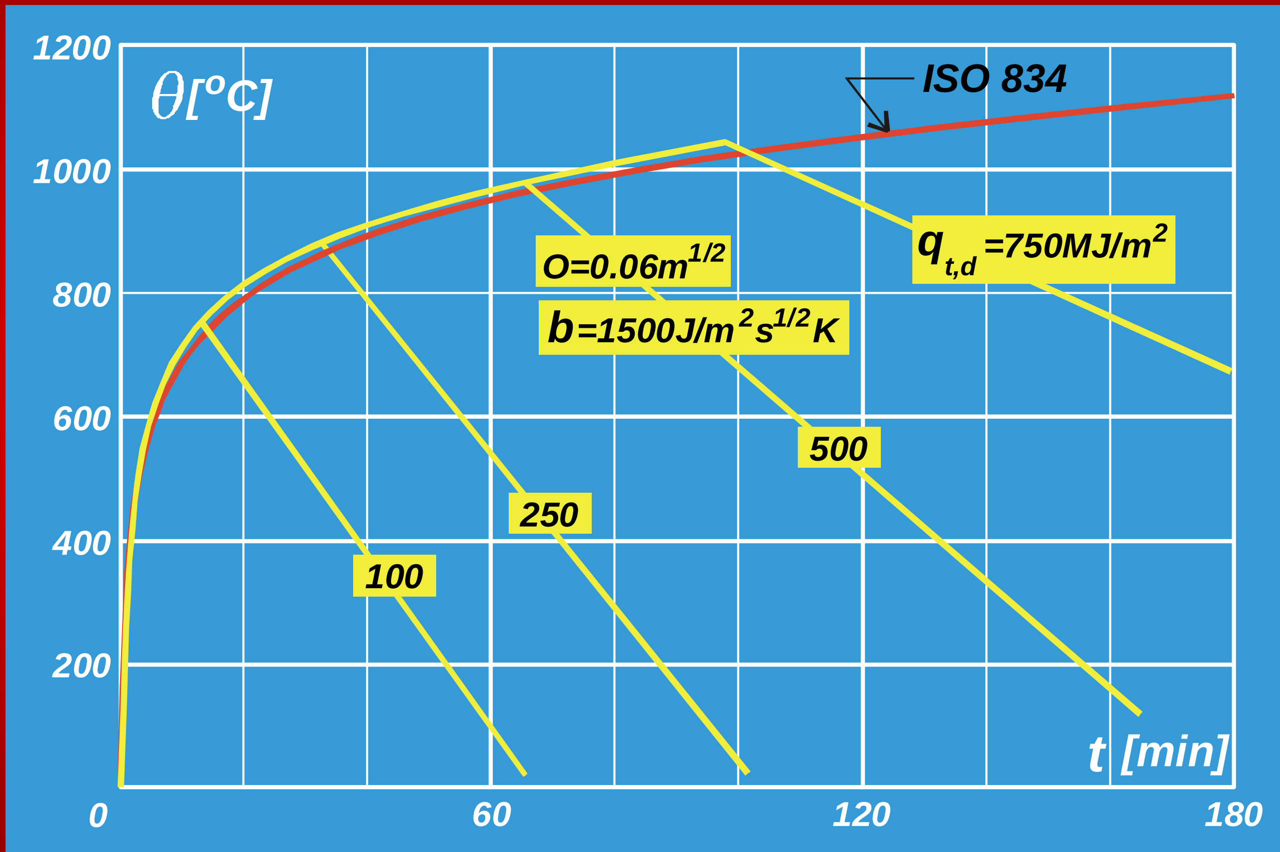
THERMAL ACTION

EC1: Part 1.2: Actions on Structures Exposed to Fire



PARAMETRIC TEMPERATURE-TIME CURVES
EC1: Part 1-2

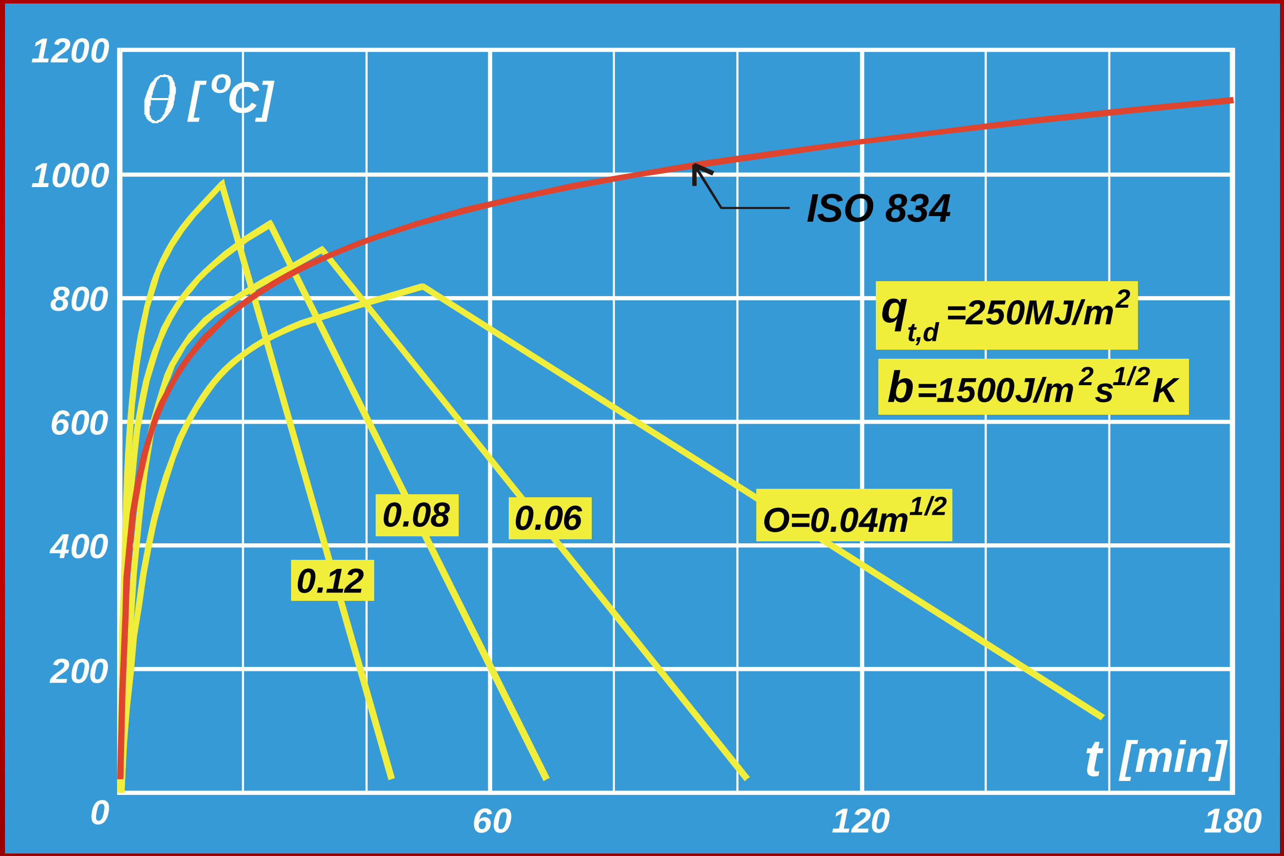
FIRE LOAD DENSITY



$$q_{fi,t,k} = \frac{Q_{fi,k}}{A_t} = \frac{\sum M_{k,i} \cdot H_{u,i} \cdot m_i \cdot \psi_i}{A_t}$$

PARAMETRIC TEMPERATURE-TIME CURVES
EC1: Part 1-2

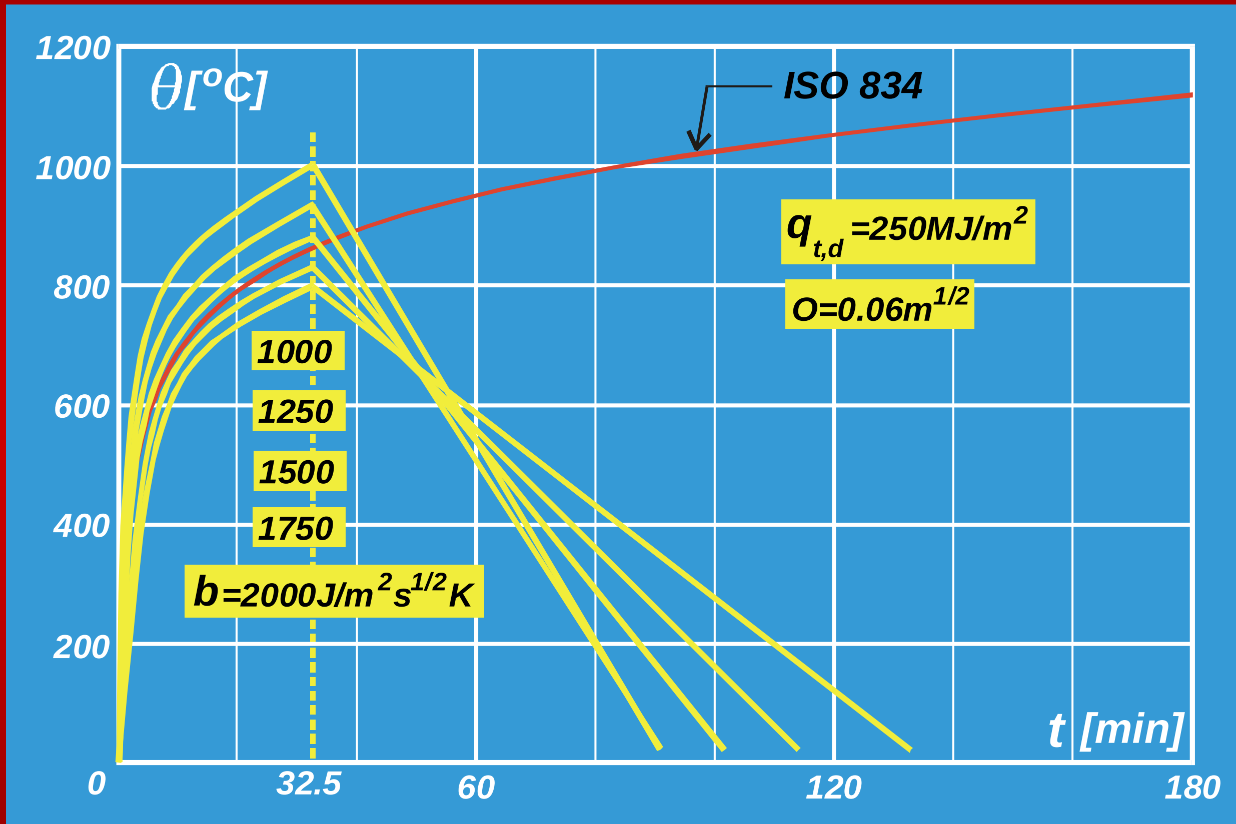
OPENING FACTOR



$$O = A_v \cdot \sqrt{h_v} \; / \; A_t$$

PARAMETRIC TEMPERATURE-TIME CURVES
EC1: Part 1-2

THERMAL PROP. OF SURROUNDING STRUCTURE

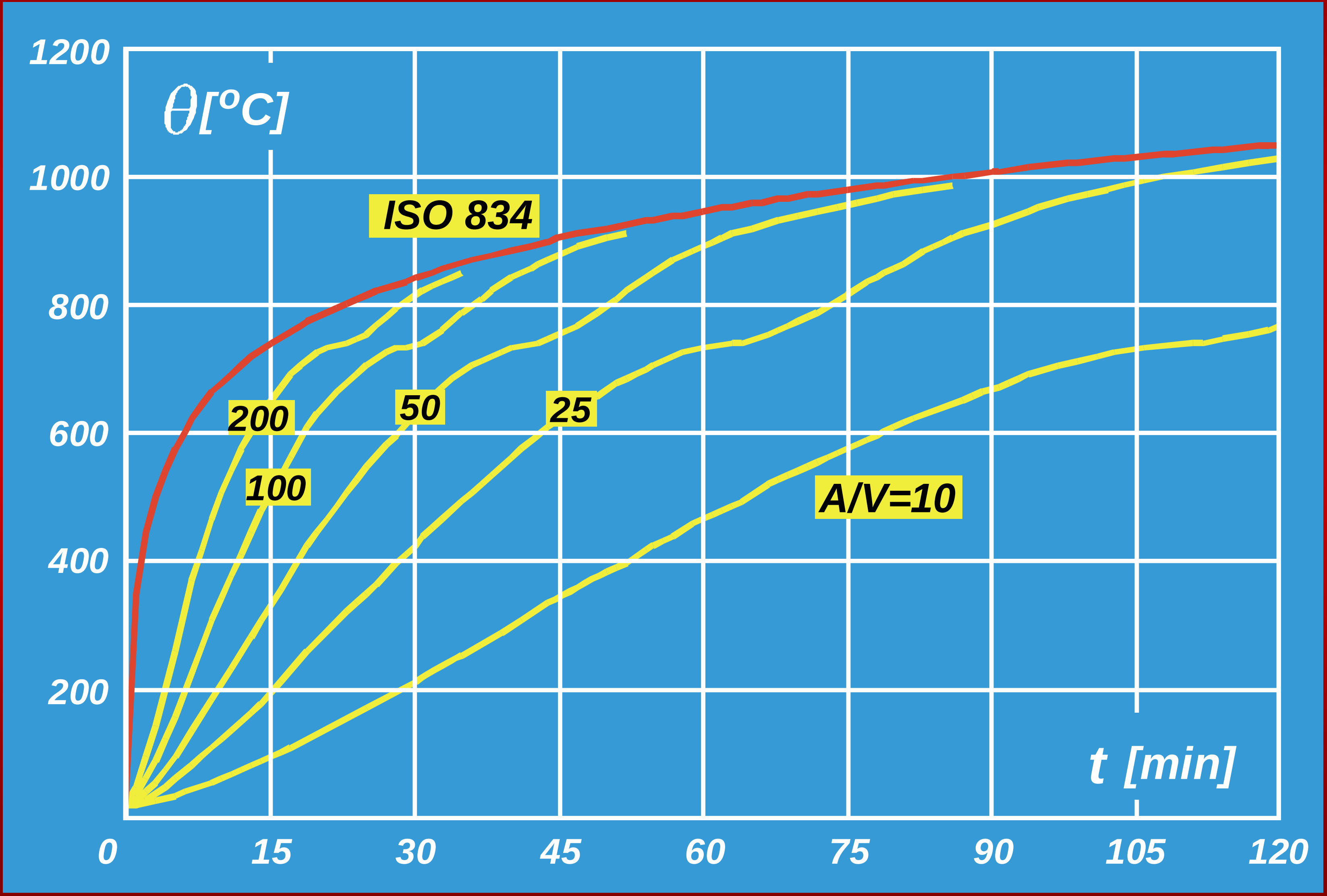


$$b = \sqrt{\rho \cdot c \cdot \lambda}$$

$$b = \sqrt{(\Sigma s_i \cdot c_i \cdot \lambda_i)} \, / \, \sqrt{(\Sigma s_i \cdot c_i \cdot \lambda_i / b_i^2)}$$

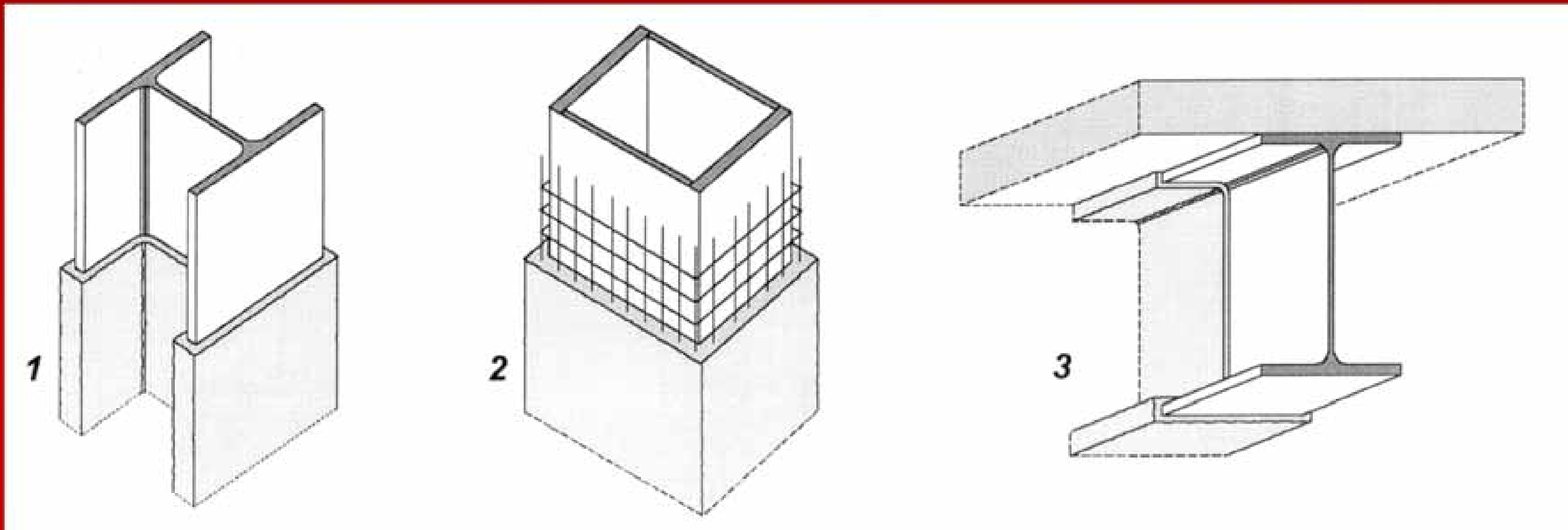
HEAT TRANSFER

UNPROTECTED STEEL



HEAT TRANSFER

MATERIALS FOR FIRE PROTECTION

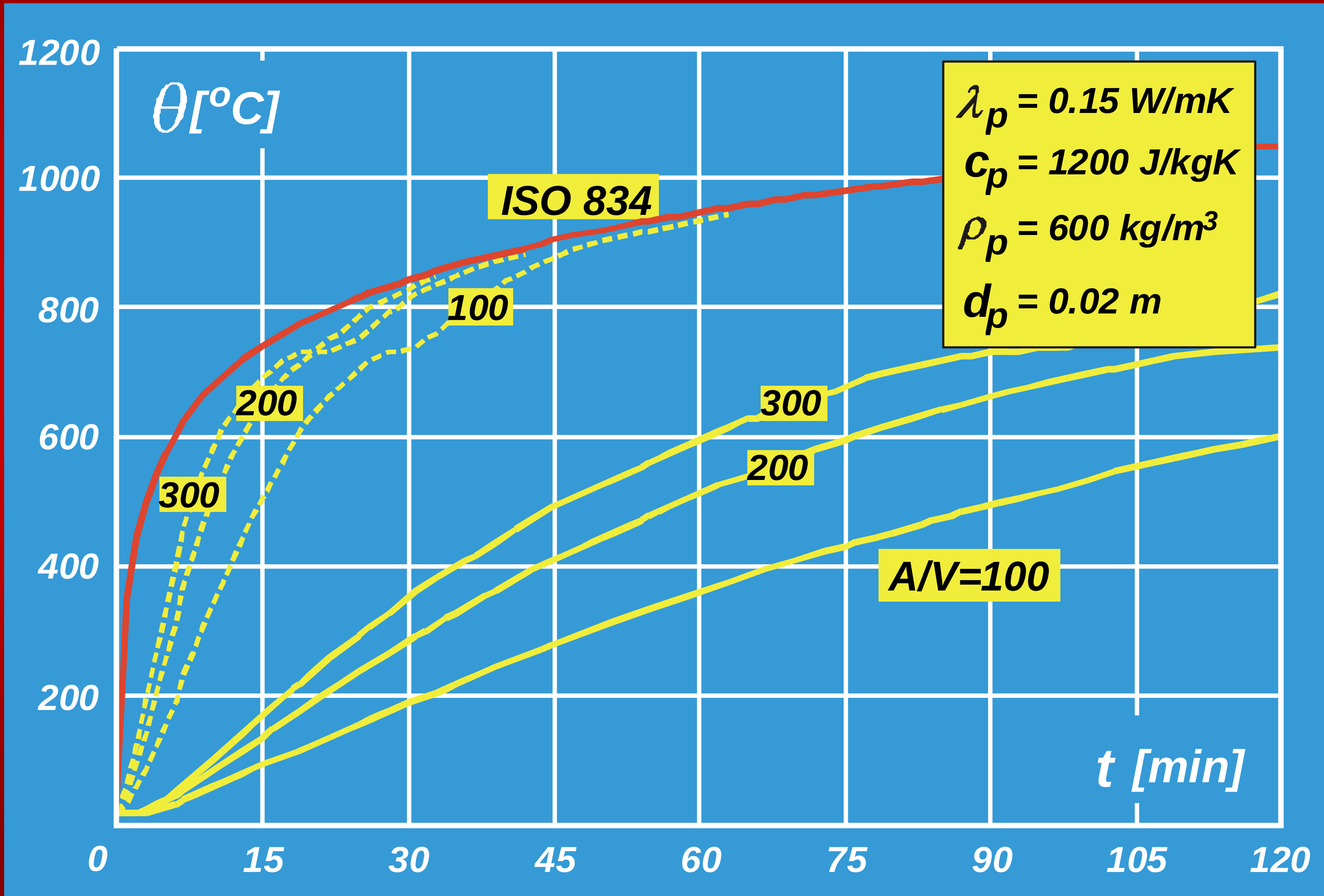


SPRAYS
BOARDS
COMPRESSED FIBRE BOARDS

EXSPANDED VERMICULITE
MINERAL FIBRE
GYPSUM
PERLITE

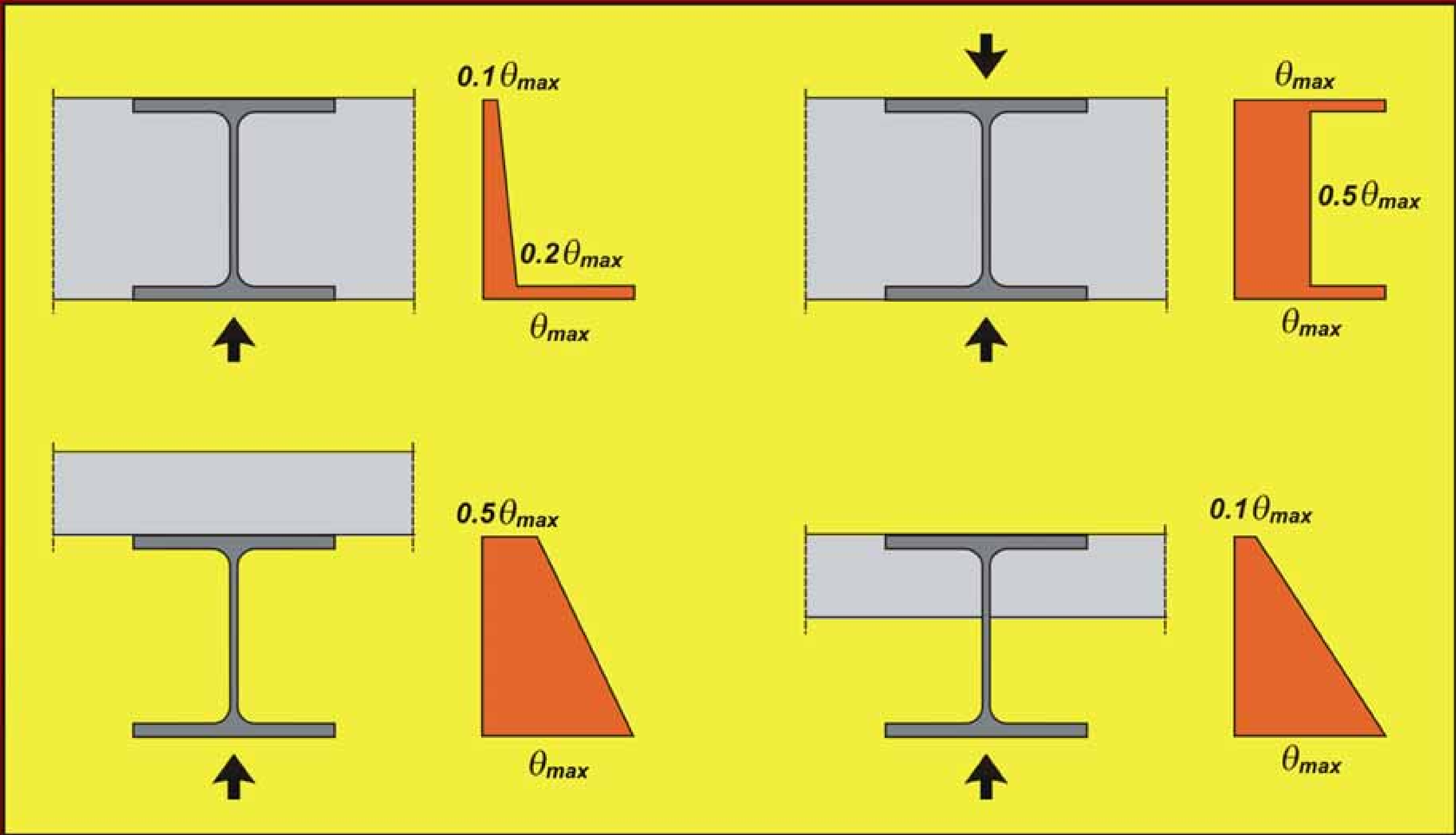
HEAT TRANSFER

PROTECTED STEEL



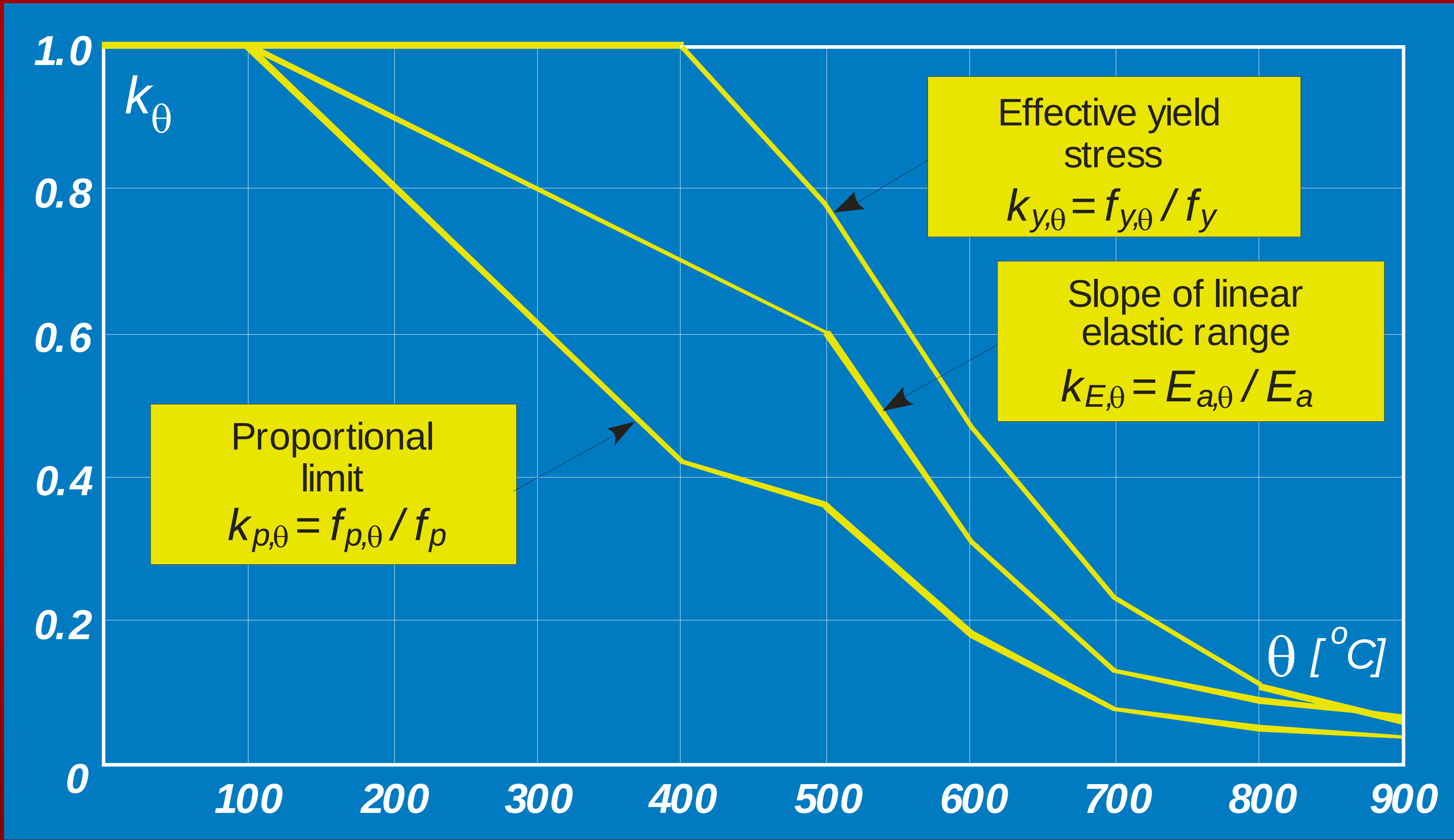
HEAT TRANSFER

NON-UNIFORM HEATING OF COLUMNS



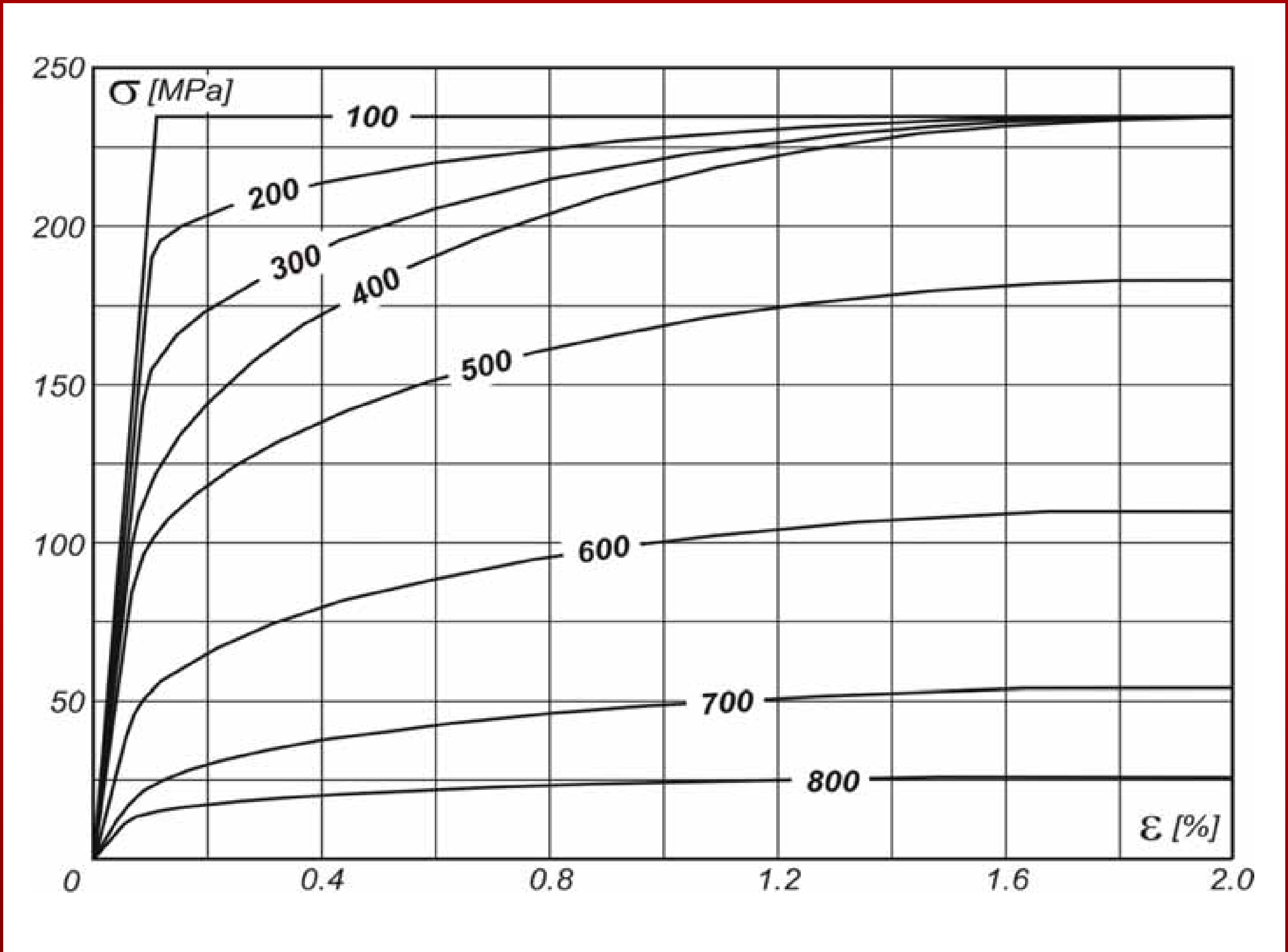
MECHANICAL PROPERTIES: EC3, Part 1.2

REDUCTION FACTORS



MECHANICAL PROPERTIES: EC3, Part 1.2

Shape of σ – ε diagram at elevated temperatures



FIRE BEHAVIOUR OF STEEL COLUMNS

BUCKLING RESISTANCE OF COMPRESSED ELEMENT (EC3: Part 1-2)

The design buckling resistance *N*b,fi,t,Rd at time *t* of a compression member with a Class 1, Class 2 or Class 3 cross-section with a uniform temperature θ a should be determined from:

$$N_{b,fi,t,Rd} = \chi_{fi} A \, k_{y,\theta} f_y / \gamma_{M,fi}$$

$$\chi_{fi} = \frac{1}{\varphi_\theta + \sqrt{\varphi_\theta^{\,2} - \bar{\lambda}_\theta^{\,2}}}$$

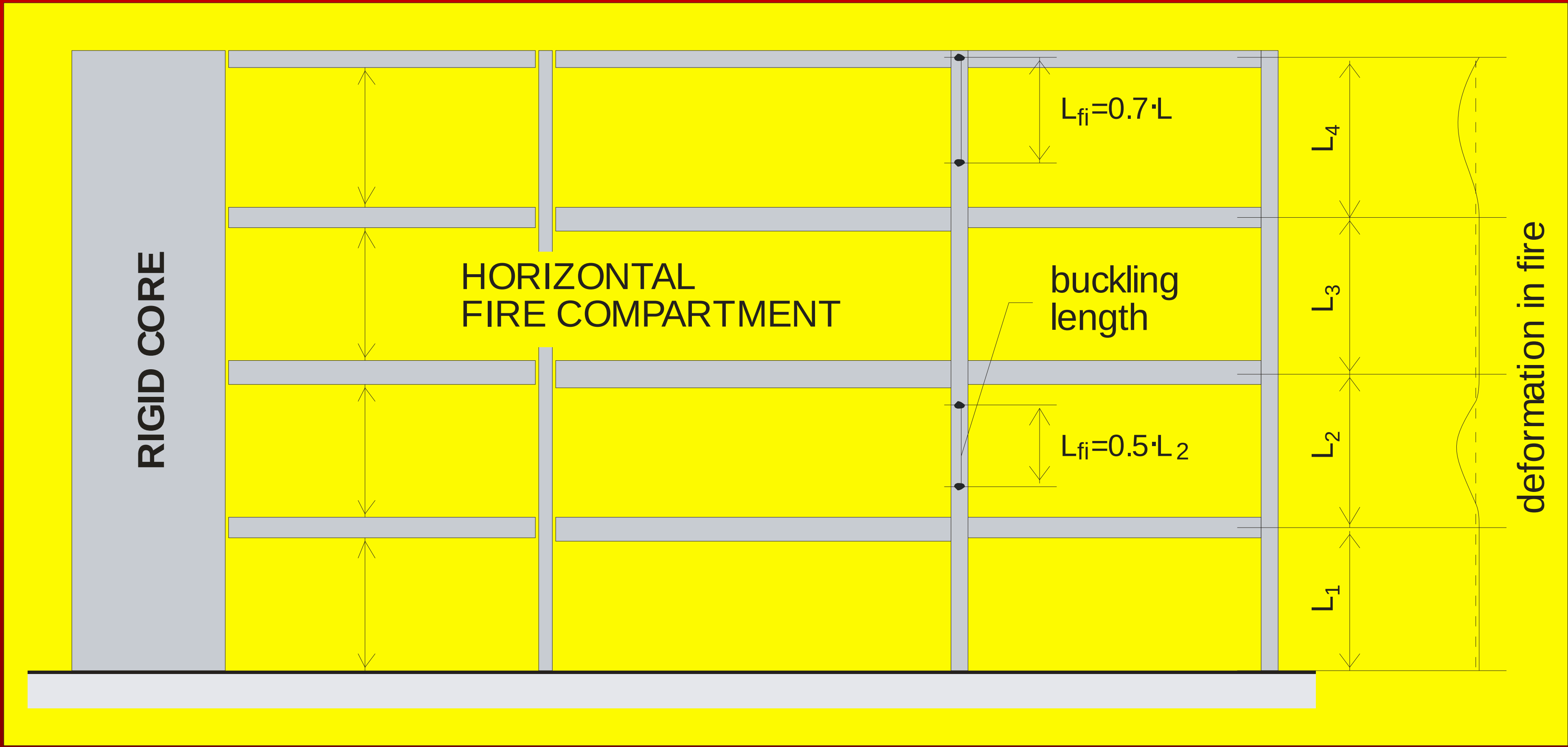
$$\varphi_\theta = \frac{1}{2}[1 + \alpha \bar{\lambda}_\theta + \bar{\lambda}_\theta^{\,2}]$$

$$\alpha = 0,65\sqrt{235 / f_y} \qquad \bar{\lambda}_\theta = \bar{\lambda}\,[k_{y,\theta} / k_{E,\theta}]^{0,5}$$

FIRE BEHAVIOUR OF STEEL COLUMNS

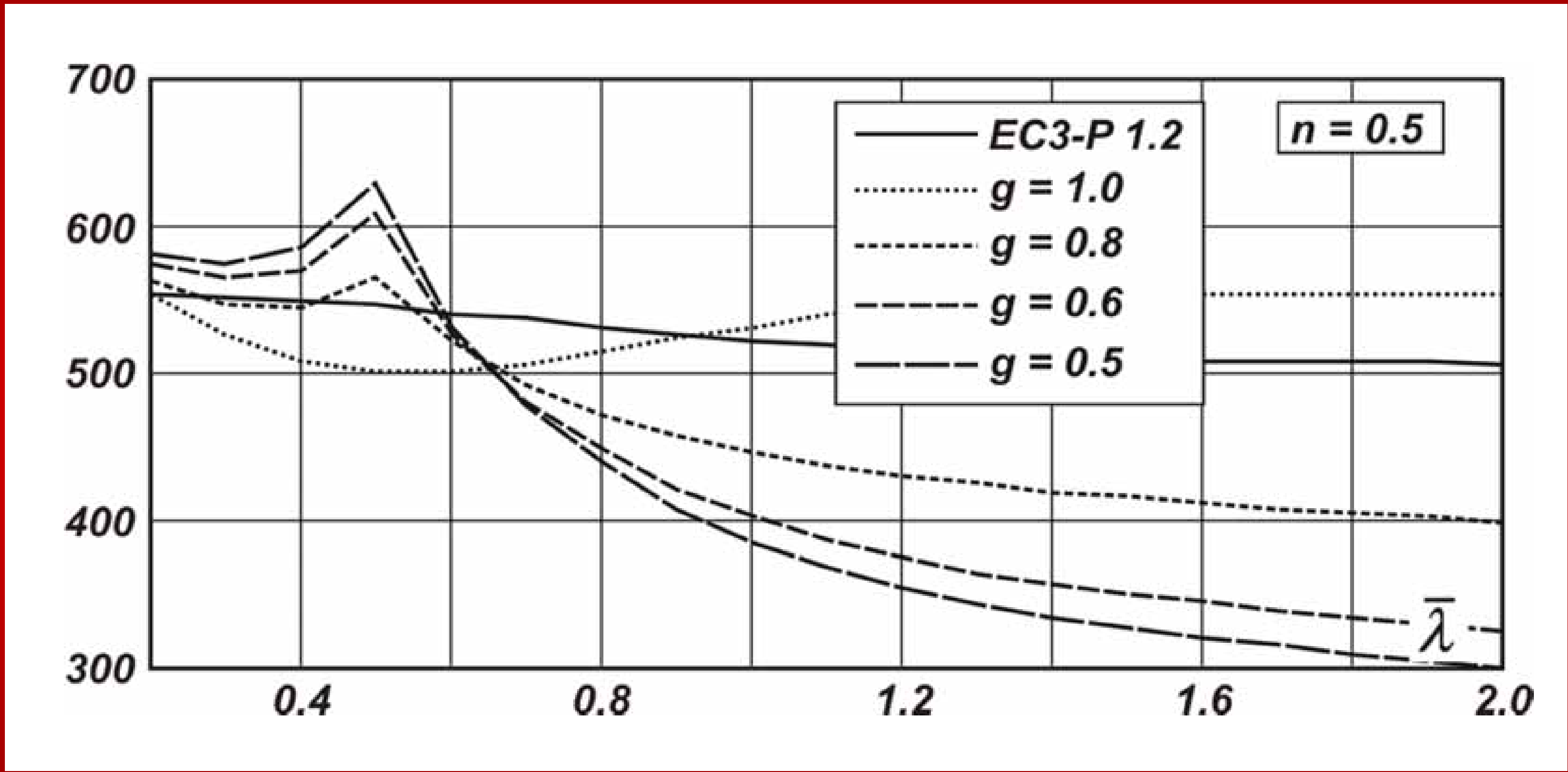
COMPRESSED ELEMENTS – BUCKLING LENGTH

1/ MULTI STORY BRACED FRAMES
2/ HORIZONTAL FIRE COMPARTMENTISATION



FIRE BEHAVIOUR OF STEEL COLUMNS

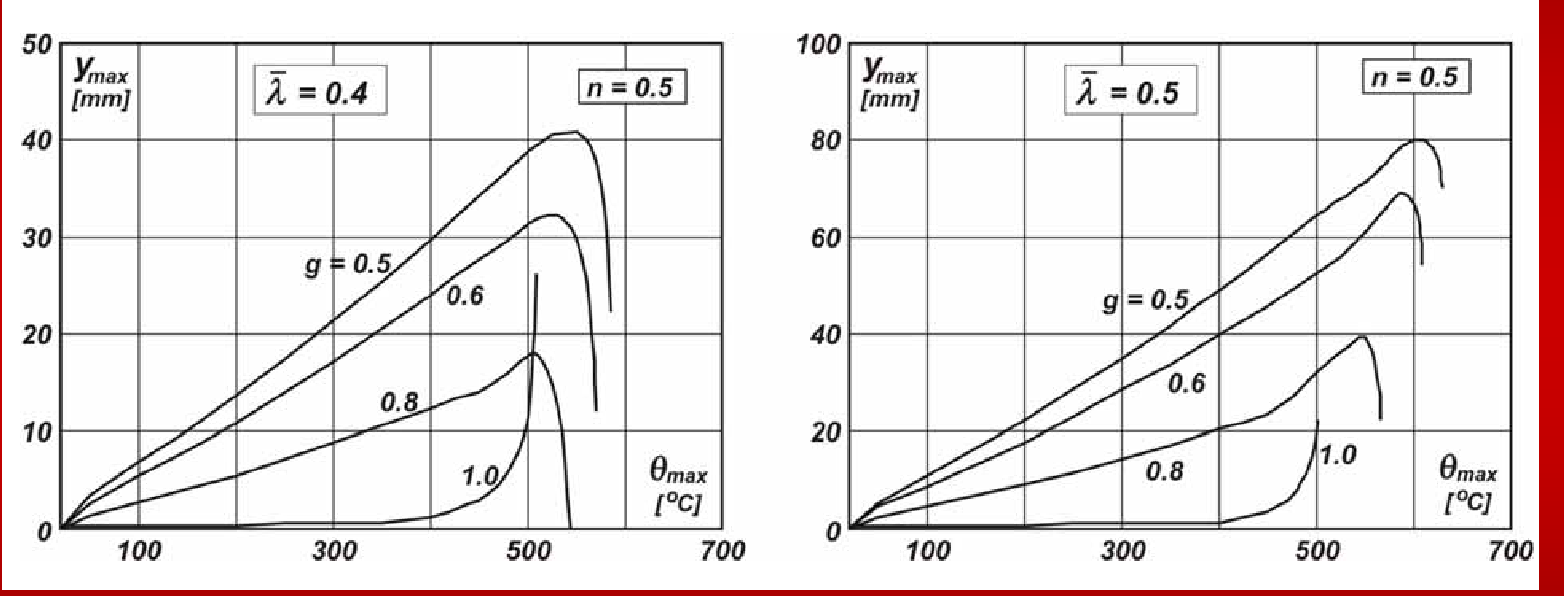
NON-UNIFORM HEATING IN THE CROSS-SECTION



HEB300, S235, STRONG AXES

FIRE BEHAVIOUR OF STEEL COLUMNS

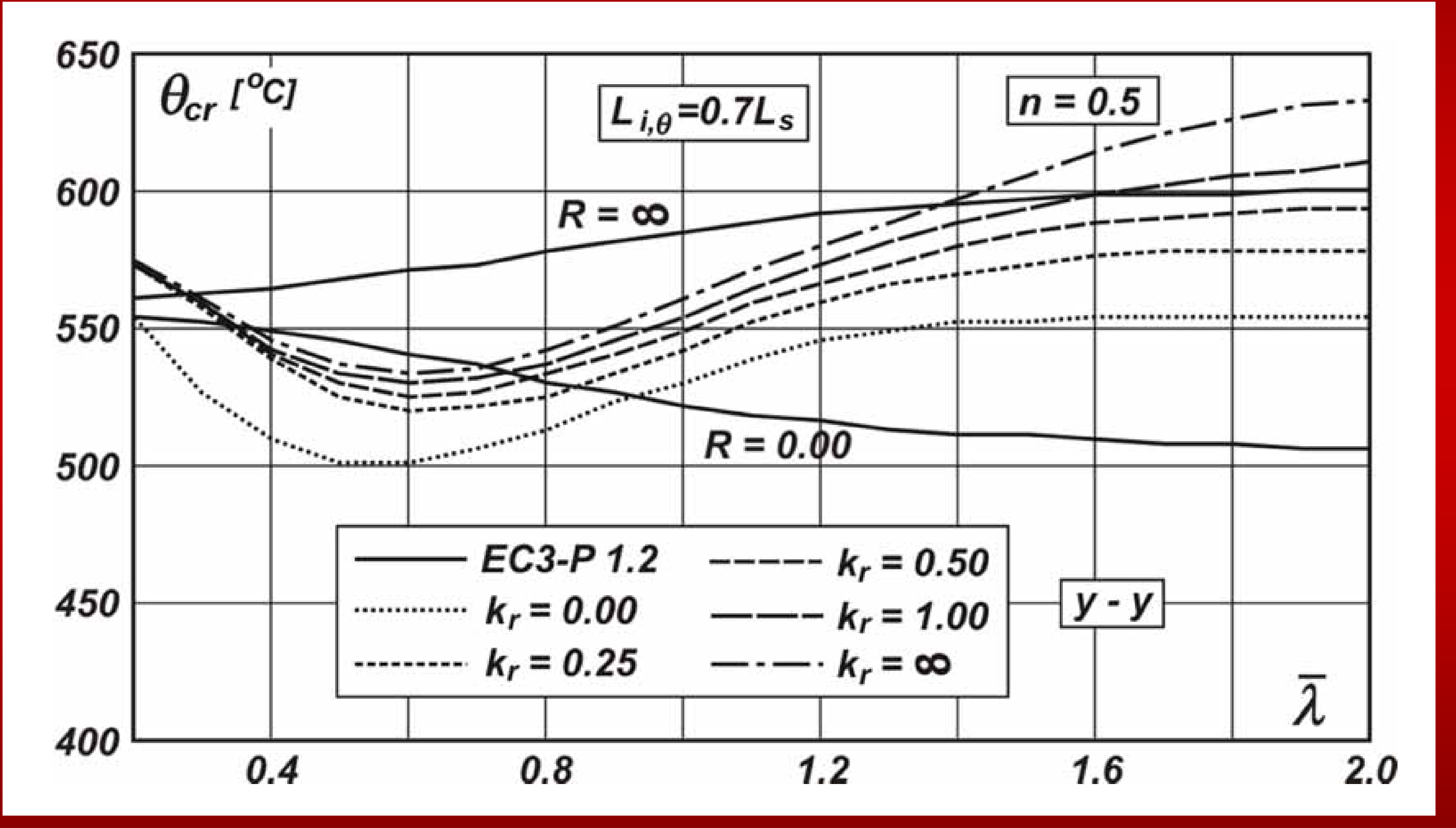
NON-UNIFORM HEATING IN THE CROSS-SECTION



LATERAL DEFLECTION

FIRE BEHAVIOUR OF STEEL COLUMNS

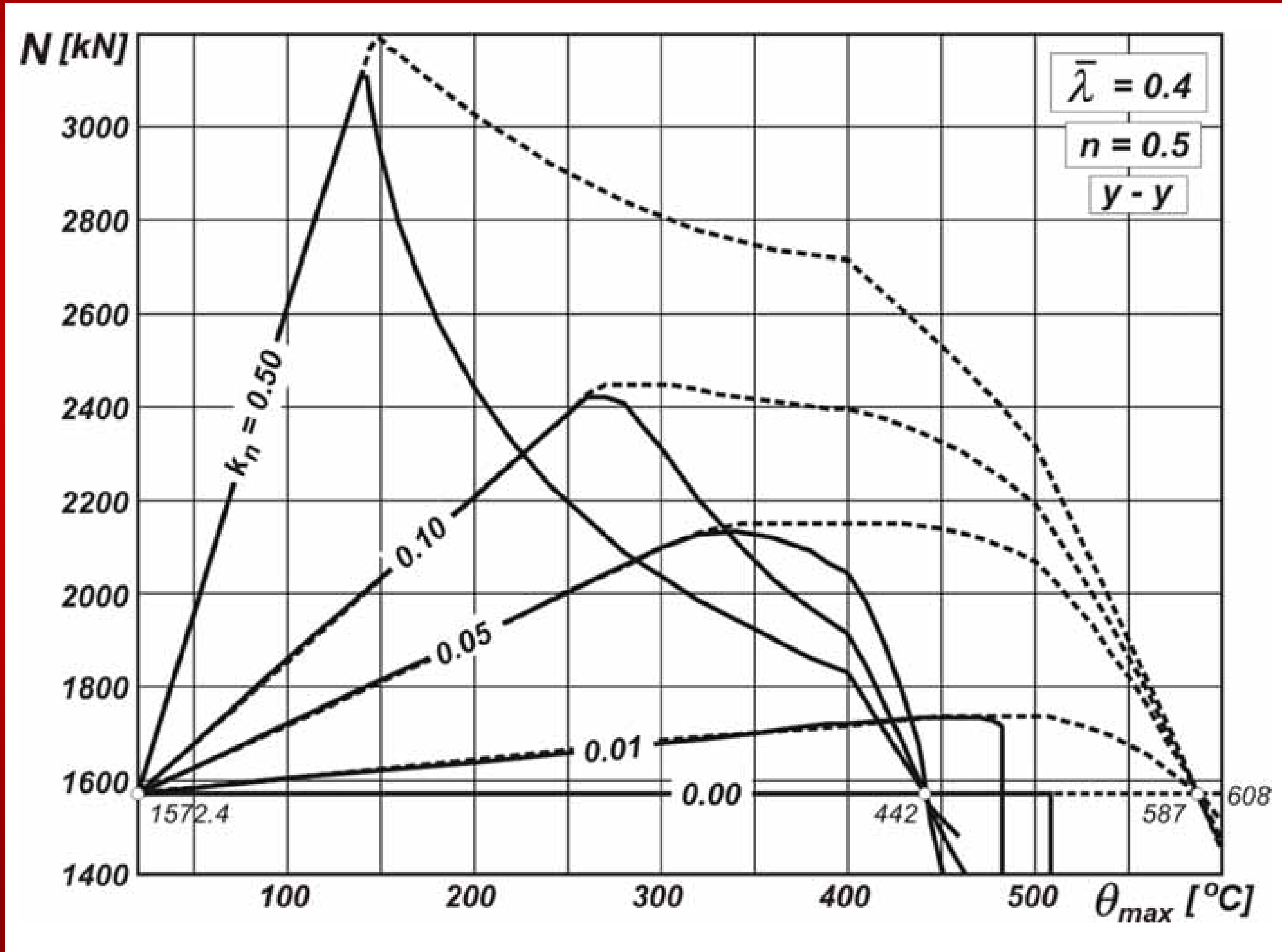
INFLUENCE OF ROTATIONAL RESTRAINTS



HEB300, S235, STRONG AXES

FIRE BEHAVIOUR OF STEEL COLUMNS

INFLUENCE OF AXIAL RESTRAINTS



HEB300, S235, STRONG AXES

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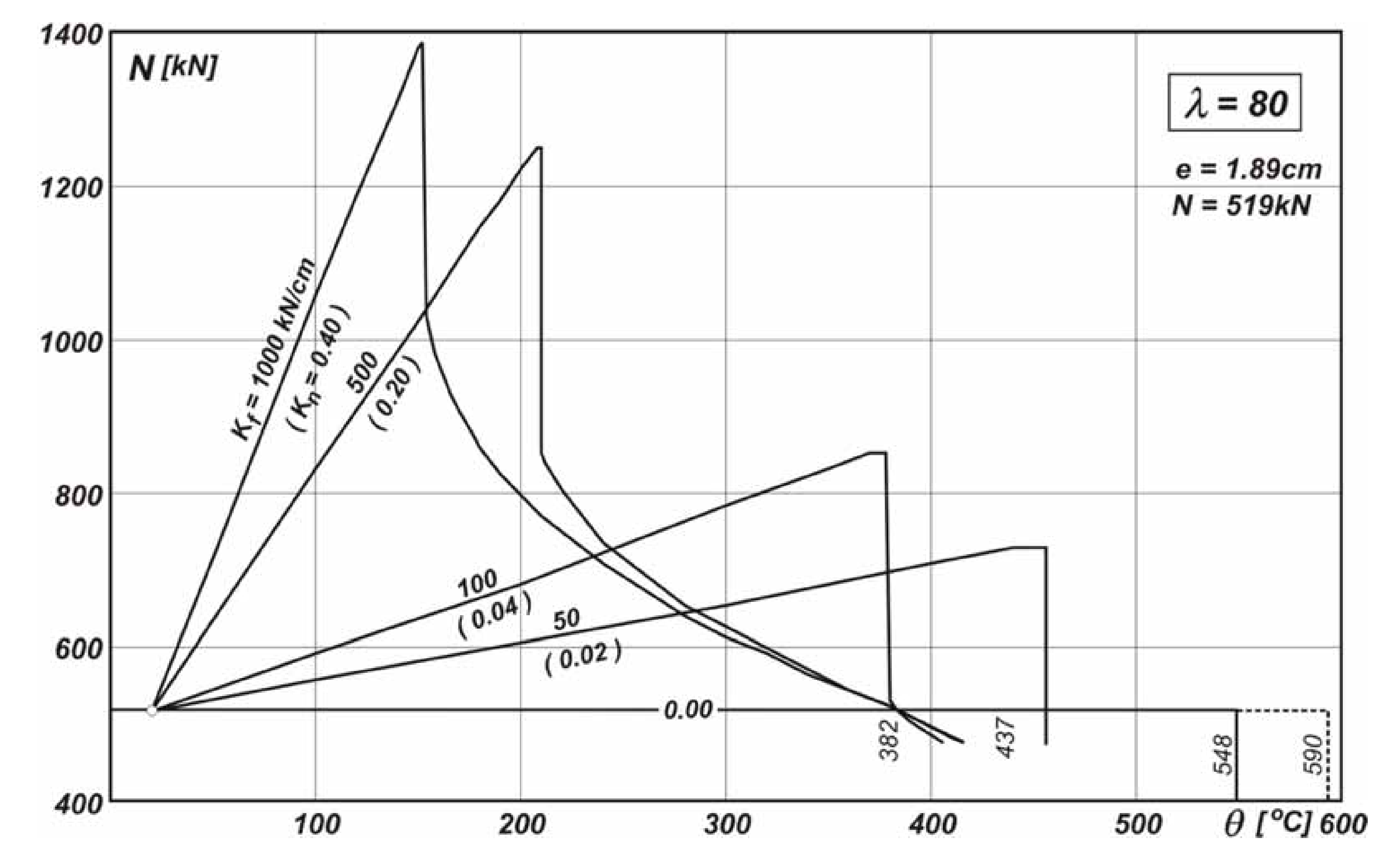
INFLUENCE OF AXIAL RESTRAINTS



Eccentrically compressed column (HEB220)

CONCLUSIONS

STRUCTURAL FIRE BEHAVIOR AND FIRE RESISTANCE IS A PART OF STRUCTURAL DESIGN

Assessment of the fire compartment parameters is a necessary condition to define adequate measures and concept of fire safety.

The temperature distribution and the rate of heating depend on structural parameters. These parameters should be defined in the structural design and they are base for calculation of necessity, type and amount of thermal protection.

Rotational restraints at columns have beneficial effect expressed by decrease of buckling length for room temperatures, especially for columns exposed to fire, where the increase of critical temperature is in range of 100-200°C.

Axial restraint of fire exposed columns has detrimental effect on the stability and the critical member temperature.
This effect can be neglected only for columns with low slenderness ratios. Increase of the slenderness ratio leads to decrease in the column critical temperature (50-300°C).

THANKS FOR YOUR ATTENTION