Co-funded by the Erasmus+ Programme of the European Union

Knowledge FOr Resilient soCiEty

2ND INTERNATIONAL SYMPOSIUM K-FORCE 2019

Tirana, September 9, 2019

RC BEAM EXPOSED TO DIFFERENT FIRE MODELS

Riste Volchev [1] *Teaching Assistant, Ss. Cyril and Methodius University in Skopje, Republic of Macedonia, volcev@gf.ukim.edu.mk*

Meri Cvetkovska [5] *Full Professor, Ss. Cyril and Methodius University in Skopje, Republic of Macedonia, cvetkovska@gf.ukim.edu.mk*

INTRODUCTION

- *Fire safety of structures is one important component of an overall fire safety design strategy;*

- *The role of fire safety of structures is to ensure that elements of a structure, within a built environment, are capable of preventing or delaying fire spread and structural failure, so that the fire safety objectives, such as safety of life, conservation of property, continuity of operations, preservation of heritage and protection of the environment, are not compromised;*

- *Most designs for the fire safety of structures have been based on prescriptive requirements set by building regulations, building codes and associated standards.*

Co-funded by the
Erasmus+ Programme
of the European Union

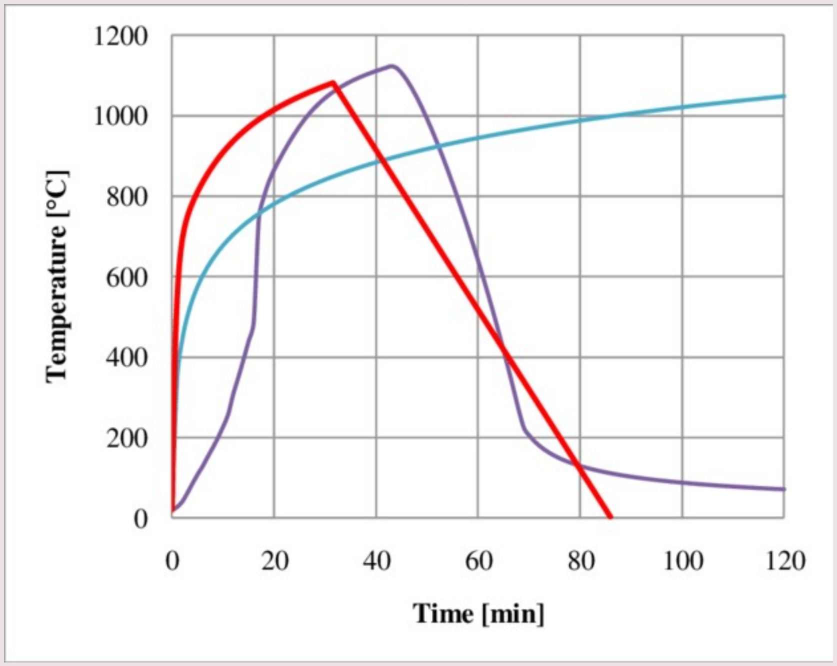
FIRE MODELS ACCORDING TO EUROCODE 1

A structural fire design analysis should take into account the following steps as relevant:

- *selection of the relevant design fire scenarios*
- *determination of the corresponding design fires*
- *calculation of temperature distribution in the cross section of structural elements*
- *calculation of the mechanical behaviour of the structure exposed to fire*

Co-funded by the Erasmus+ Programme of the European Union

FIRE MODELS ACCORDING TO EUROCODE 1



- The simplest way of presenting the standard fire exposure is by using nominal fire curves. Nominal fire curves are monotonically increasing functions over time. The cooling phase is not taken into account.

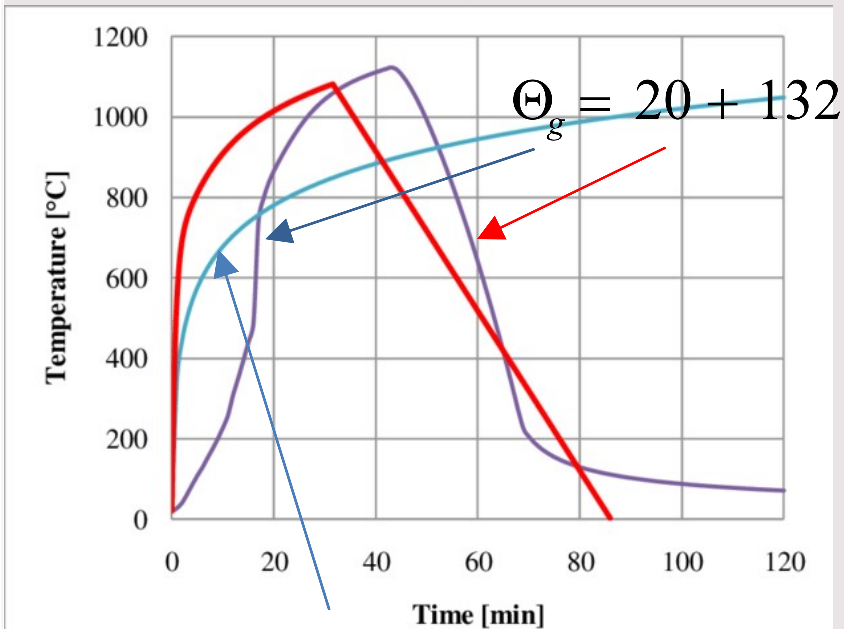
- Parametric fire curves also consist of time temperature relationships, but these relationships contain some parameters deemed to represent particular aspects of reality.

Co-funded by the
Erasmus+ Programme
of the European Union

FIRE MODELS ACCORDING TO EUROCODE 1

Parametric fire curve

$$\Theta_g = 20 + 1325\left(1 - 0.324e^{-0.2\,t^*} - 0.204e^{-1.7\,t^*} - 0.72\,e^{-19\,t^*}\right)$$



ISO 834 fire model (nominal fire curve)

- *floor area of the fire compartment*
- *total area of enclosure*
- *window heights and position*
- *total area of vertical openings*
- *total area of horizontal openings*
- *fire load density $q_{f,d}$ per m^2*
- *Fuel or ventilation controlled fire*

Co-funded by the
Erasmus+ Programme
of the European Union

HEAT TRANSFER

Thermal stresses appear in every structure that experiences a temperature gradient from some equilibrium state, if it is not free to expand in all directions, or if the temperature field is not uniform. The temperature distribution can be calculated once the Theory of Heat Transfer is used. The governing differential equation of heat transfer in conduction is:

$$\frac{\partial}{\partial x}\left(\lambda_x \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(\lambda_y \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(\lambda_z \frac{\partial T}{\partial z}\right) = \rho c \frac{\partial T}{\partial t}$$

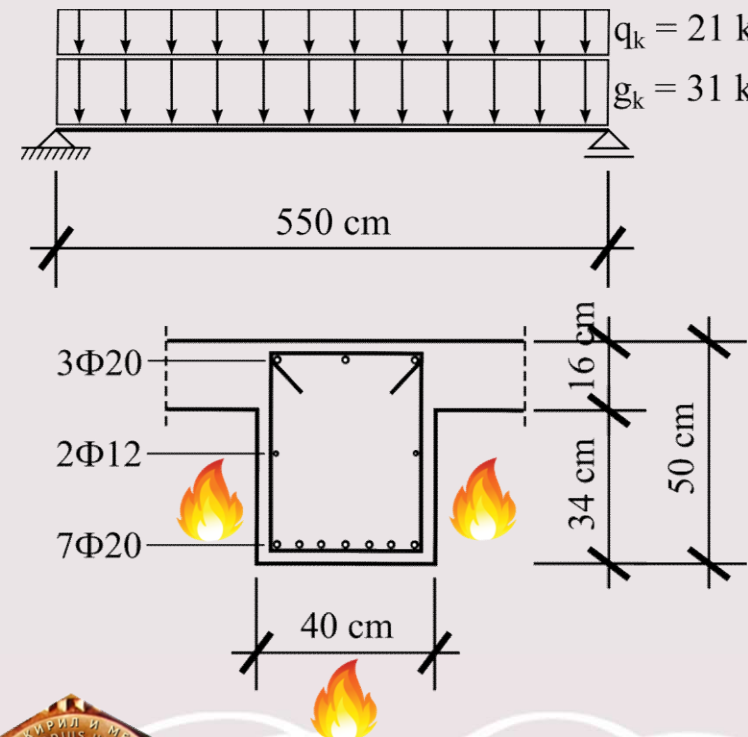
Where: $\lambda_{x,y,z}$ *is a thermal conductivity;*

ρ *is a density of the material;*

c is a specific heat.

Co-funded by the
Erasmus+ Programme
of the European Union

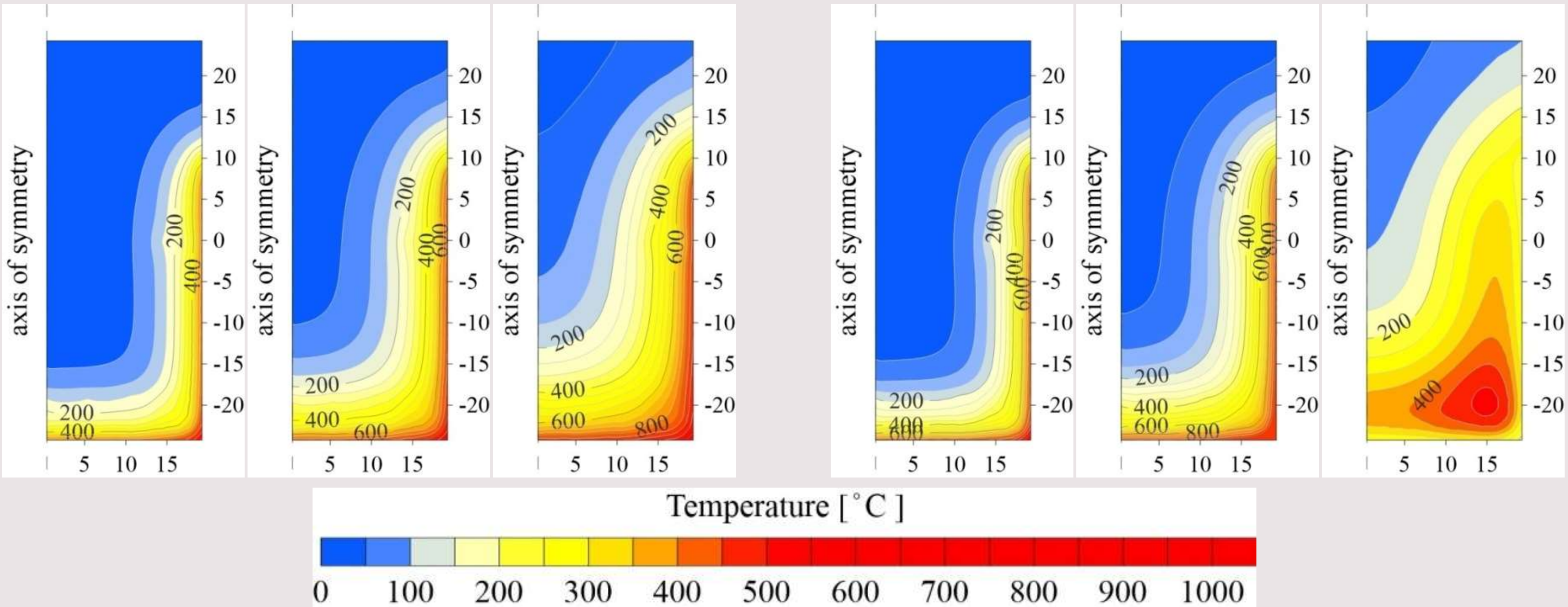
RC BEAM EXPOSED TO DIFFERENT FIRE MODELS



The floor area of the fire compartment A_f is 440.64 m^2 and the total area of enclosure A_t is 1124.3 m^2. The weighted average of window heights on all walls h_v is 1.6 m and the total area of vertical openings on all walls is 61.44 m^2. Design fire load density $q_{f,d}$ related to the floor area is 900 MJ/m^2. The fire is ventilation controlled.

Co-funded by the Erasmus+ Programme of the European Union

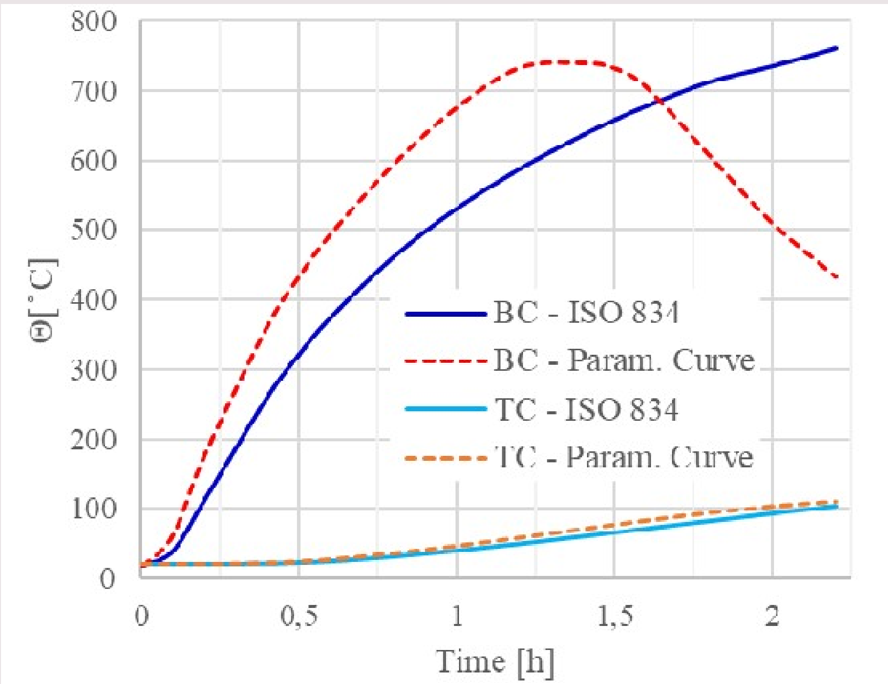
RESULTS AND DISCUSSIONS



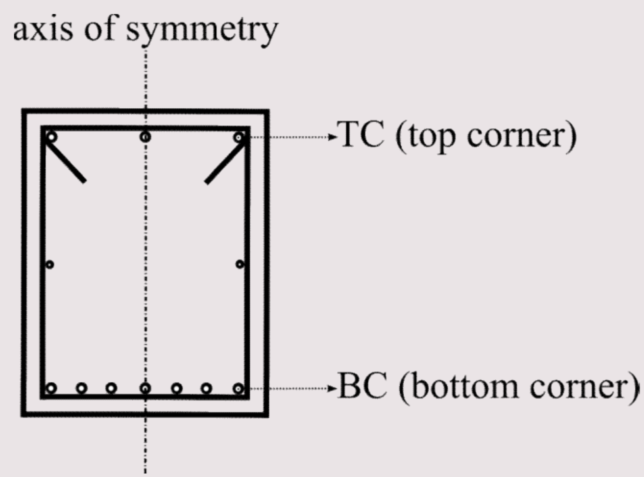
Temperature profiles of RC beam exposed to ISO 834 fire curve and Parametric fire curve after 30,60 and 120 minutes

Co-funded by the Erasmus+ Programme of the European Union

RESULTS AND DISCUSSIONS



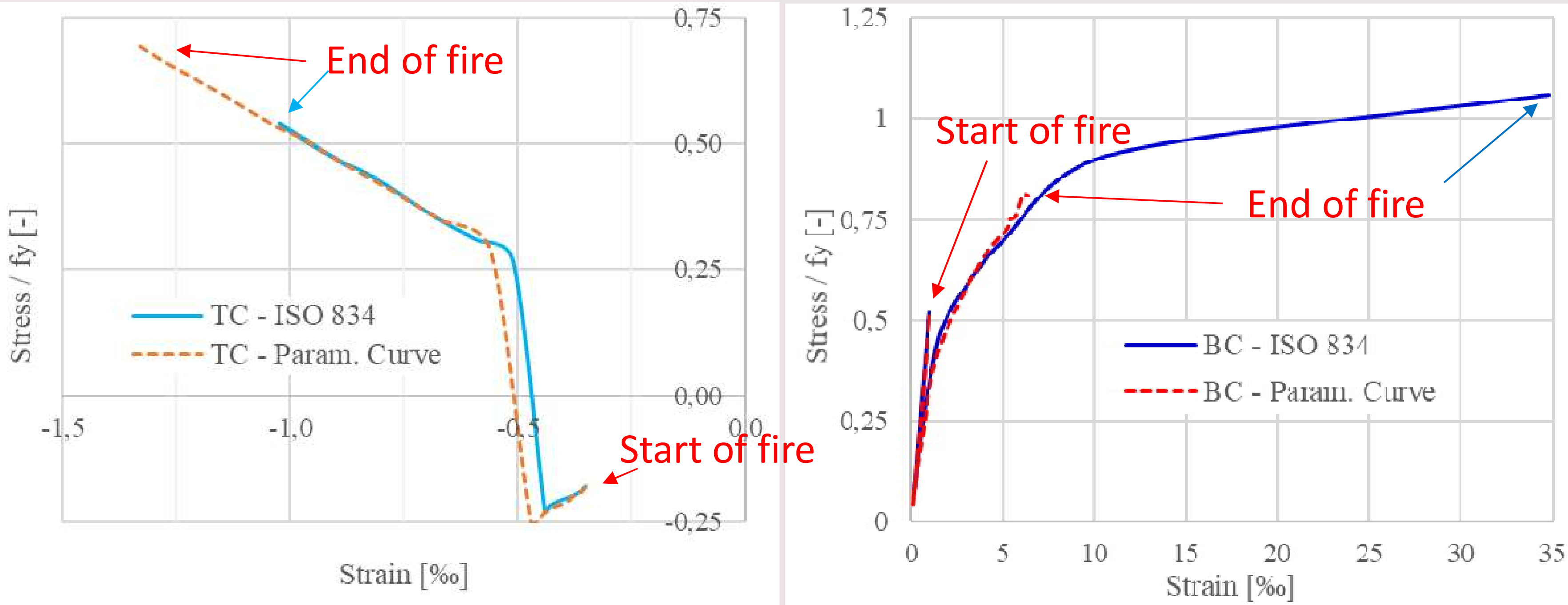
Temperature - time histories



Temperature in the bottom corner bar is considerably higher in comparison with the top corner bar.

Co-funded by the
Erasmus+ Programme
of the European Union

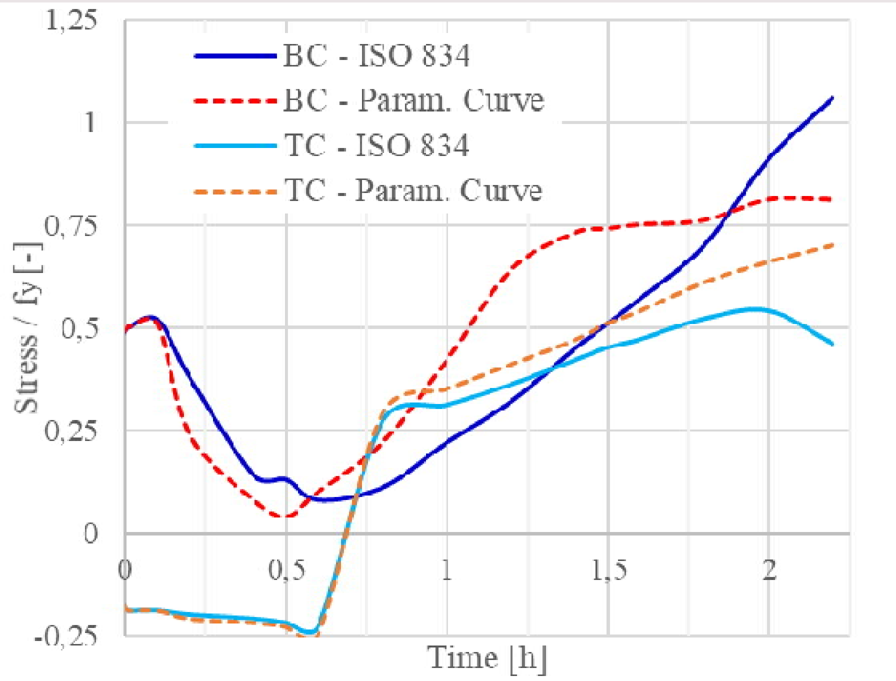
RESULTS AND DISCUSSIONS



Stress - strain diagrams a) top bar, b) bottom bar

Co-funded by the
Erasmus+ Programme
of the European Union

RESULTS AND DISCUSSIONS

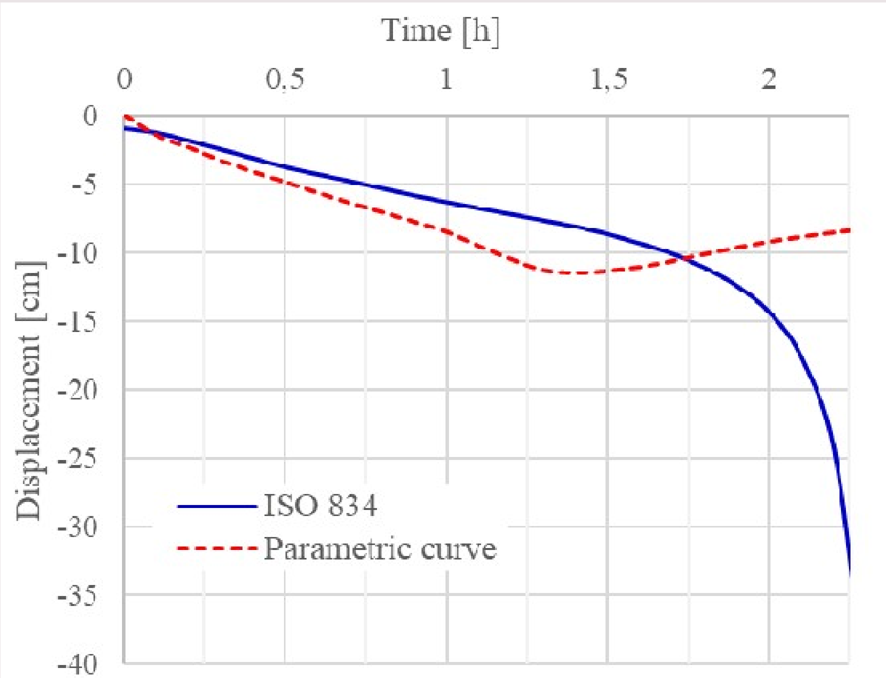


Stress - time histories

At the beginning of fire action, due to the large temperature differences between the bottom and the top zone of the cross section, the stresses decrease in the tensioned steel bars, which has favorable impact on the behavior of the RC beam at that moment. The top corner bar after approximately 40 minutes of fire action changes the stresses from compression to tension.

Co-funded by the
Erasmus+ Programme
of the European Union

RESULTS AND DISCUSSIONS



The vertical displacements of the beam exposed to the parametric fire curve decrease during the cooling phase, while in case of ISO 834 fire curve vertical displacements increase during the whole period of fire action.

Co-funded by the
Erasmus+ Programme
of the European Union

CONCLUSIONS

- *Despite the strict fire resistance requirements prescribed by the codes, according to the recommendations given in Eurocodes the fire resistance of structures may be proved either by applying a Standard fire curve, in which case the structure has to survive during the prescribed time, or by applying a parametric fire curve, in which case the structure has to survive during entire period of fire action.*

- *The results obtained by usage of the parametric fire curve are more realistic, as the cooling phase is of a great importance for the behavior of structural elements.*

- *As a result of the descending branch the vertical displacements of the mid-span are much lower in comparison with action of nominal curves.*

- *During the heating phase the temperatures of the cross section in case of ISO 834 standard curve are lower, but there is no cooling phase*

- *Due to the fire exposure of the RC beam only from the bottom side of the element, the temperature differences between the bottom and the top part of the cross section are considerably high and this effect results with redistribution of stresses.*

Co-funded by the
Erasmus+ Programme
of the European Union

REFERENCES

[1] CEN – European Committee for Standardization 2004. Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire. Brussels: CEN.

[2] Dzolev, Igor et al. 2015. Thermal Analysis of Concrete Members Subjected to Fire According to EN 1991-1-2 & EN 1992-1-2. Proceeding of the 13th International Scientific Conference iNDiS 2015: 708 – 715

[3] ISO International Standards and National Law 2019. Fire safety engineering — Performance of structures in fire — Part 1: General. Available at: .

[4] Rao, S. Singiresu 2004. The Finite Element Method in Engineering (fourth edition). Elsevier Science & Technology Books.

Co-funded by the
Erasmus+ Programme
of the European Union

Co-funded by the
Erasmus+ Programme
of the European Union

Thank you
for your attention

Meri Cvetkovska, Full Profesor, Ss. Cyril and Methodius University in Skopje,
Republic of Macedonia, cvetkovska@gf.ukim.edu.mk

Knowledge **FO**r **R**esilient so**C**i**E**ty