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Knowledge FOr Resilient soCiEty

FIRE SAFETY ENGINEERING-FROM THEORY TO PRACTICE

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K-FORCE TEACHING MOBILITY - EPOKA - December 04, 2018

Introduction

DAMAGES COUSED BY EXCEPTIONAL ACTIONS

FIRE

EARTHQUAKE

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Introduction

DAMAGES COUSED BY EXCEPTIONAL ACTIONS

FIRE

EARTHQUAKE

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Introduction

Construction Products Regulation (CPR) 305/2011

Requirements:

No. 1: Mechanical resistance and stability

No. 2 : Safety in case of fire

No. 3 : Hygiene, health and the environment

No. 4 : Safety and accessibility in use

No. 5 : Protection against noise

No. 6 : Energy economy and heat retention

No. 7 : Sustainable use of natural resources

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Introduction

No. 2 : Safety in case of fire

The construction works must be designed and built in such a way that in the event of an outbreak of fire:

(a) the load-bearing capacity of the construction can be assumed for a specific period of time;

(b) the generation and spread of fire and smoke within the construction works are limited;

(c) the spread of fire to nearby construction works is limited;

(d) occupants can leave the construction works or be rescued by other means;

(e) the safety of rescue teams is taken into consideration.

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Introduction

No. 2 : Safety in case of fire

HOW TO ACHIEVE THIS ?

FIRE ENGINEERING

Active fire protection measures (sprinklers, installations etc.)

+

Passive fire protection measures (construction, materials, etc.) → EUROCODES

+

Risk management in case of fire

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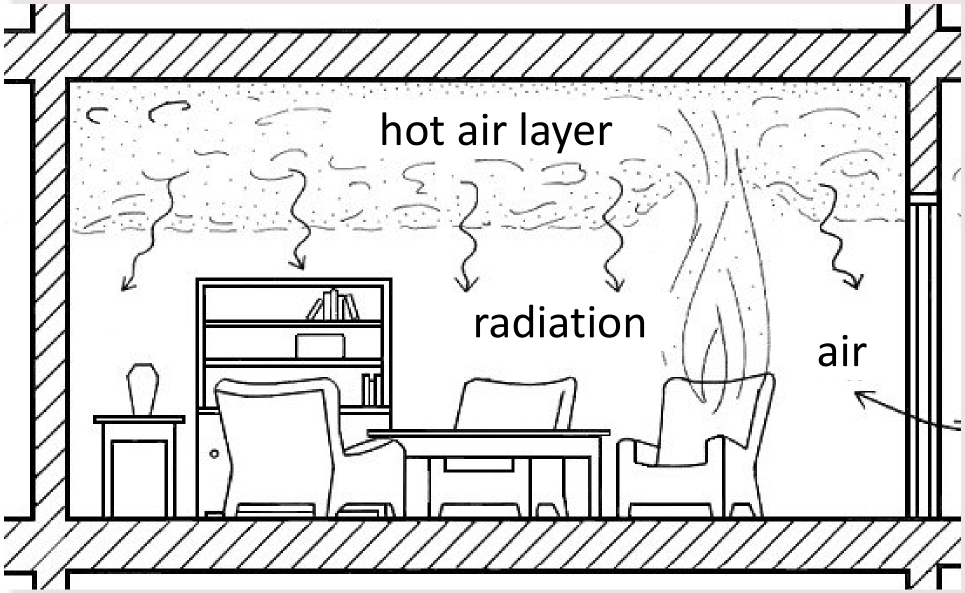
Introduction



ROOM FIRE

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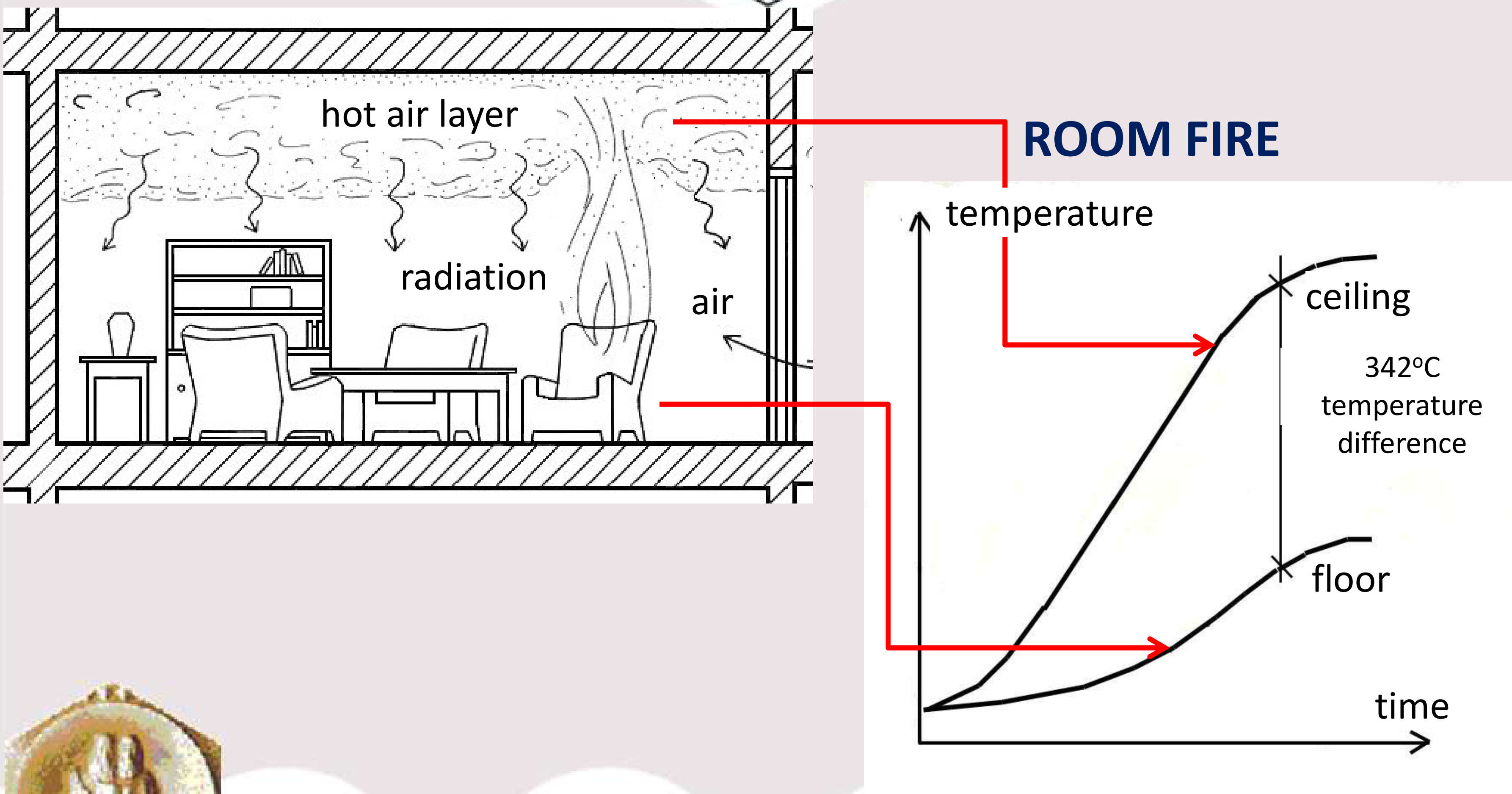
Introduction



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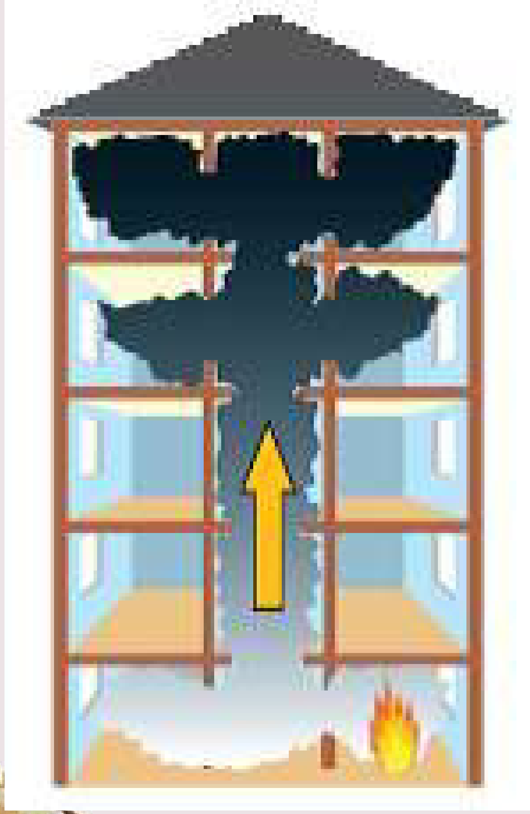
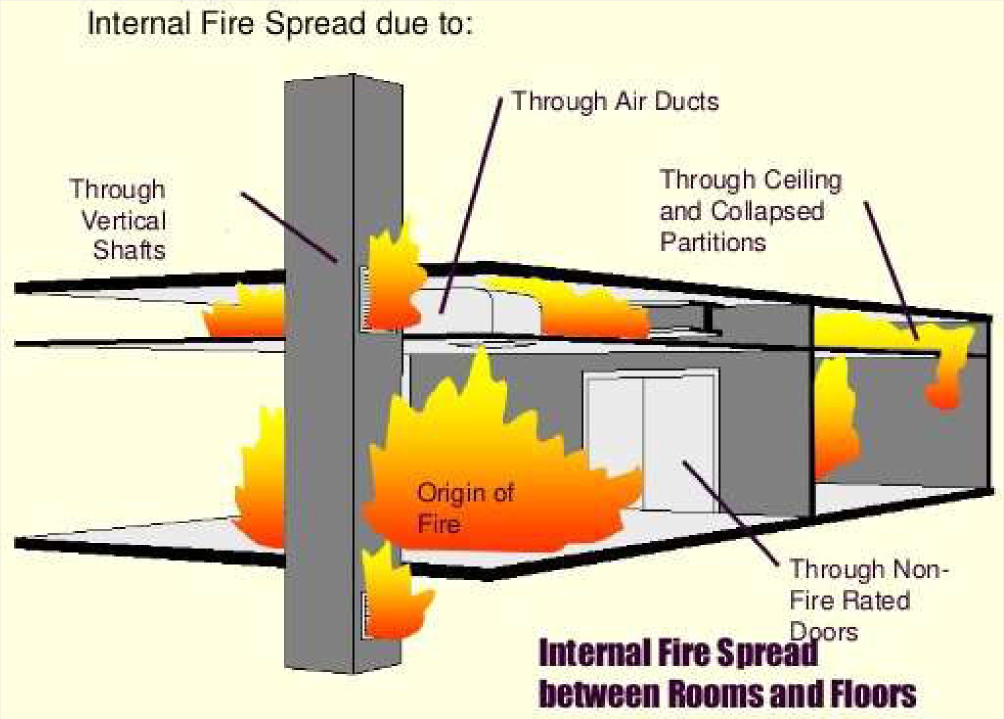
SPREAD OF FIRE





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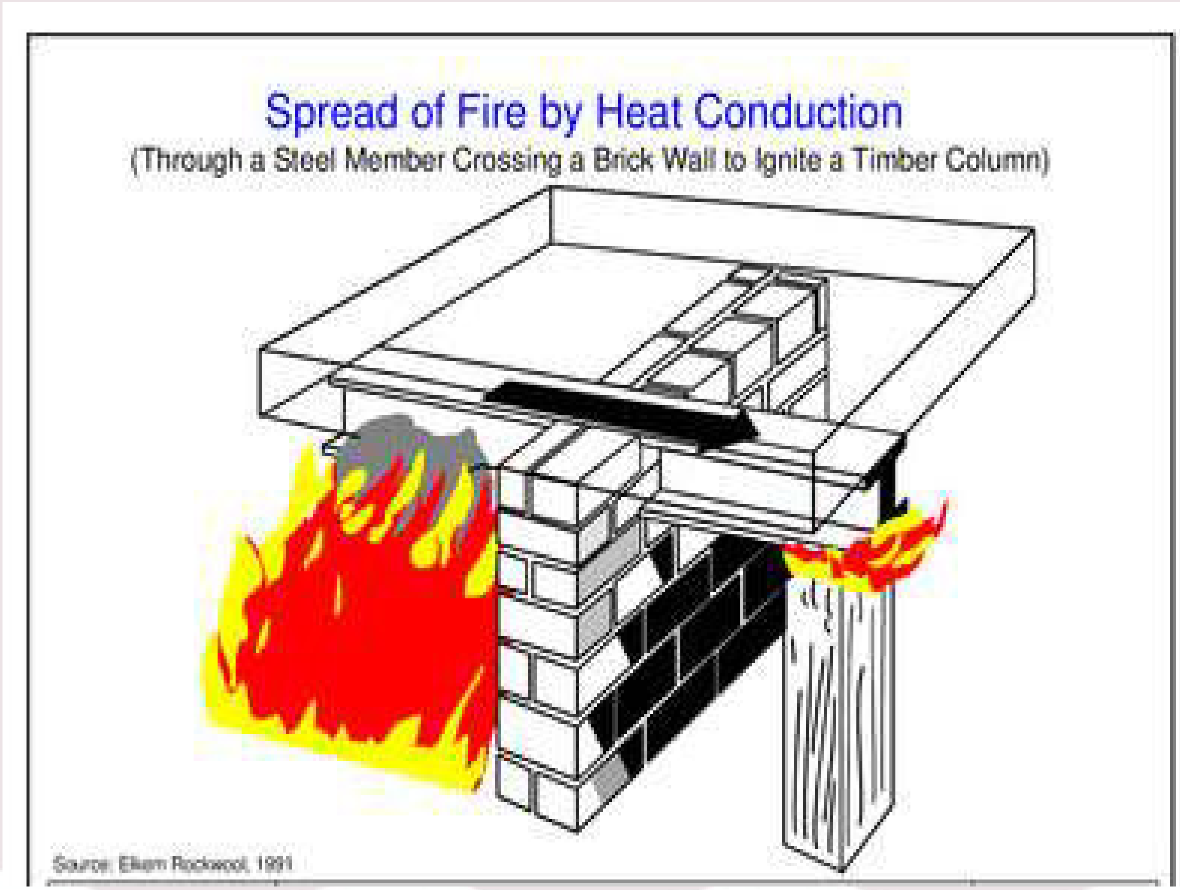
SPREAD OF FIRE



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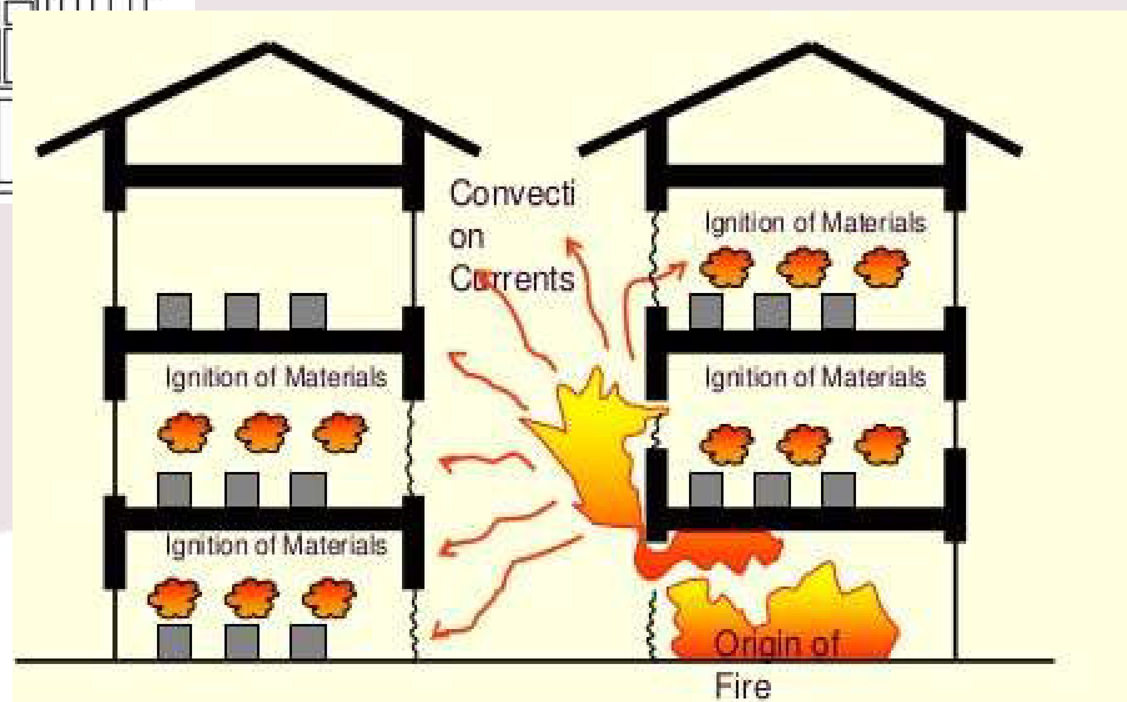
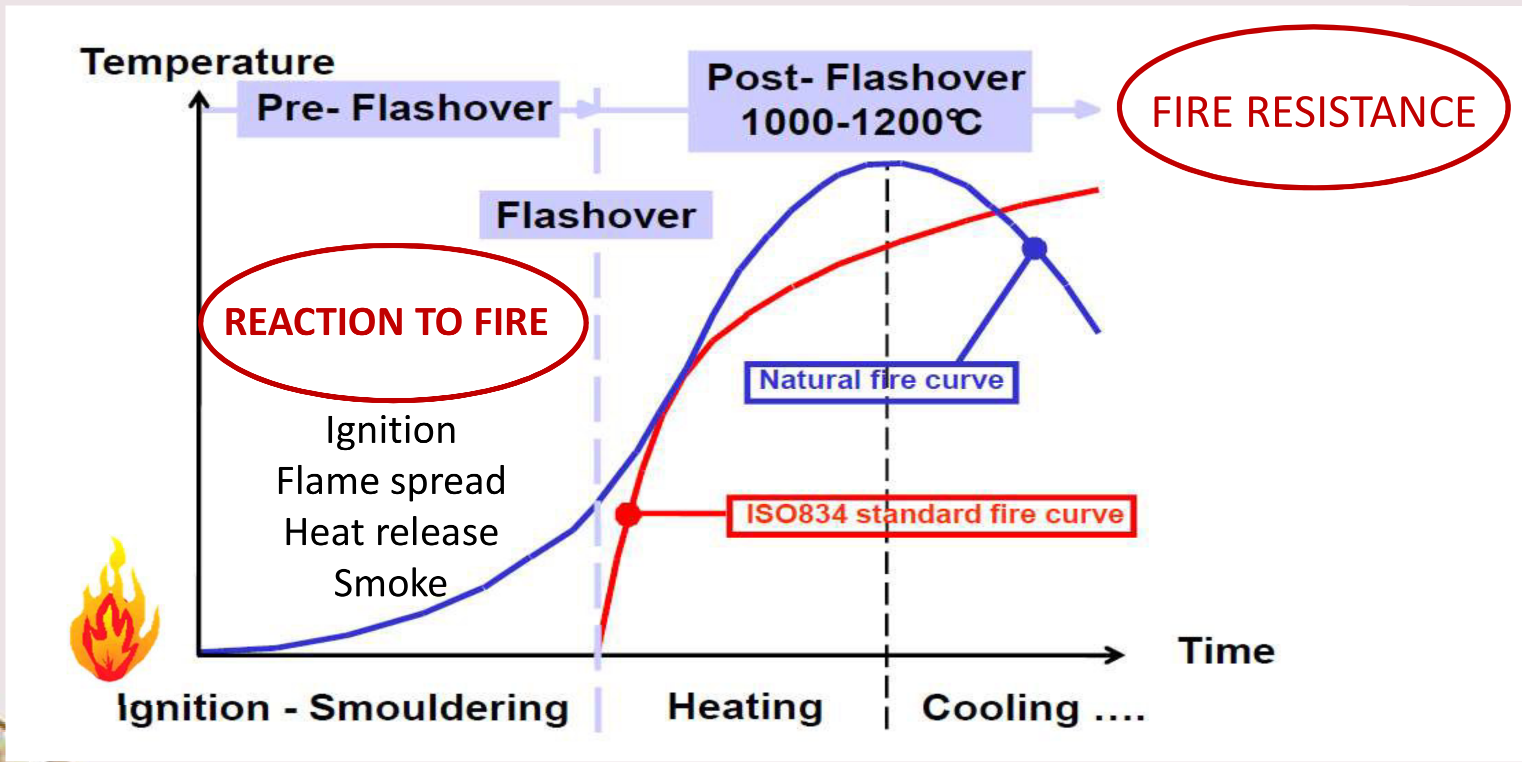
SPREAD OF FIRE



Introduction

Prije rasplamsavanja

Natural fire stages



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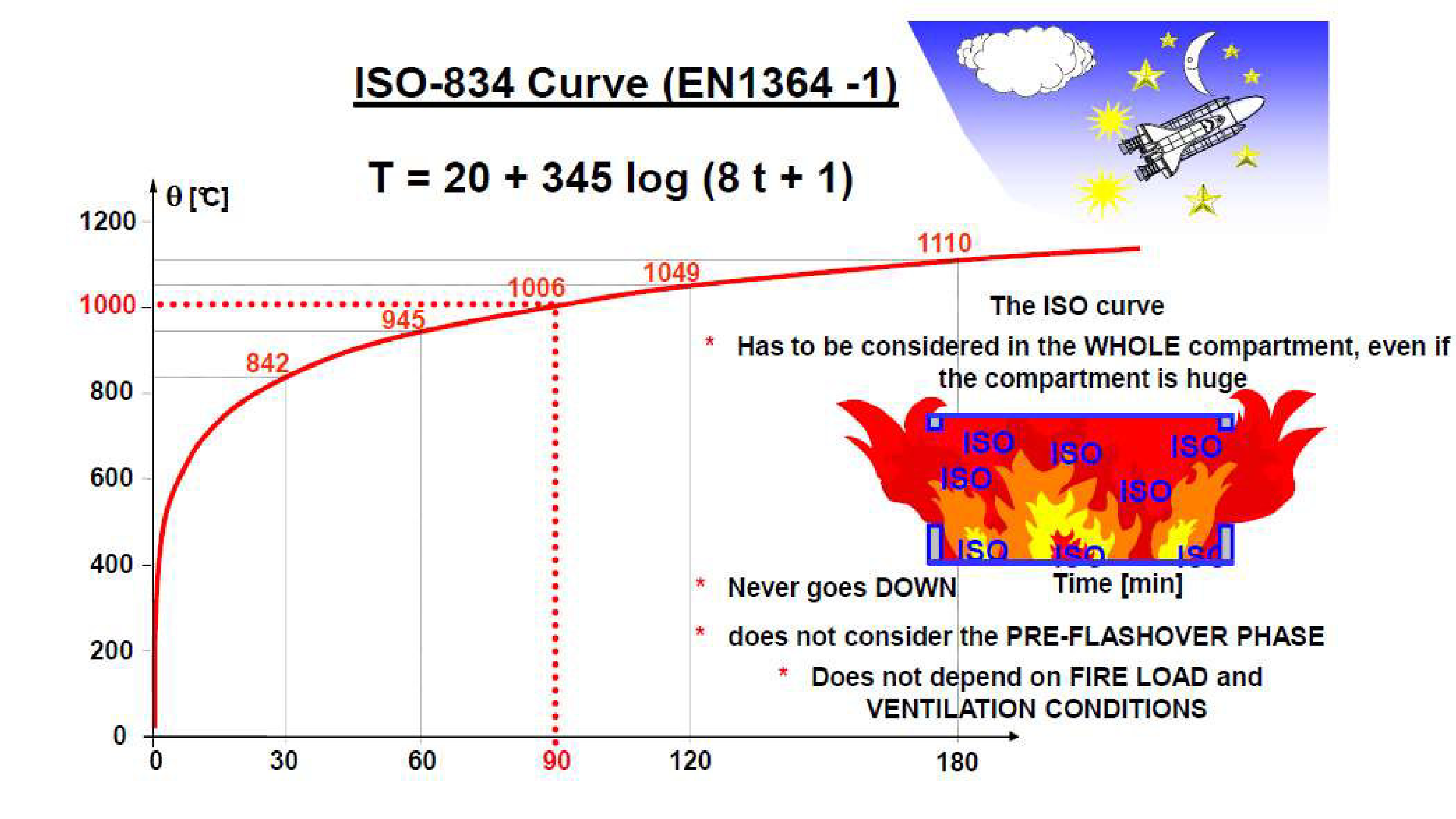
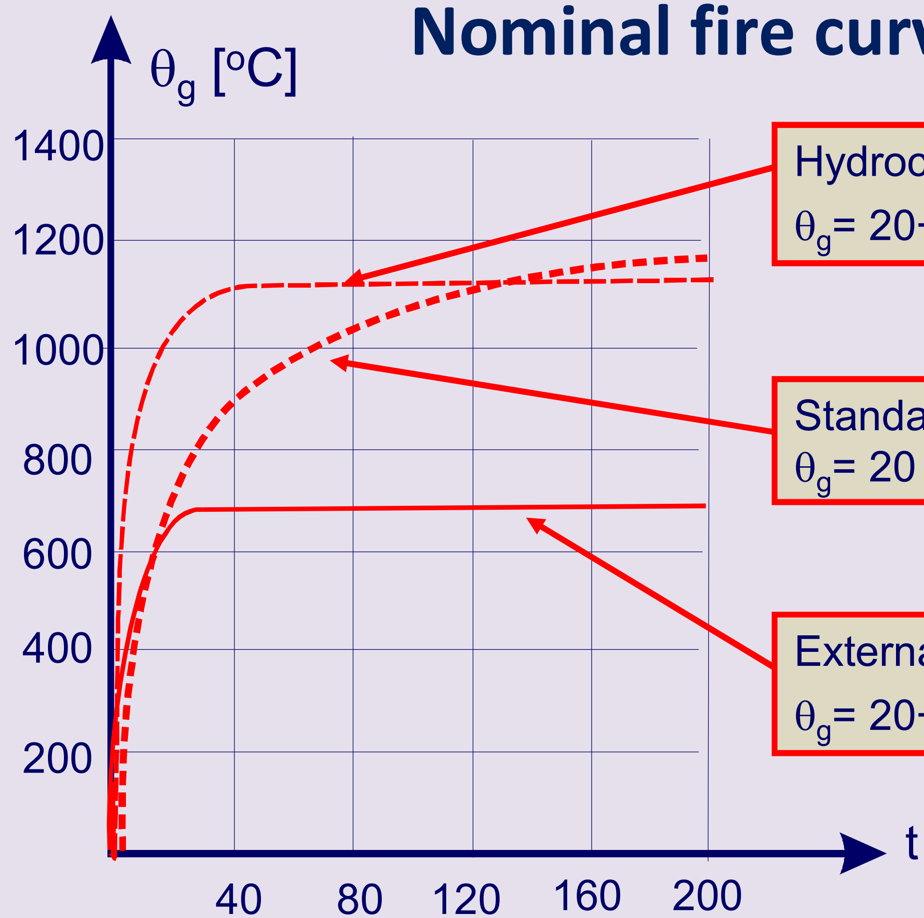
Introduction

Standard fire curve



Introduction

Nominal fire curves – EC 1, part 1-2



Hydrocarbon fire curve (α_c = 50 W/m^2 K):

θ_g= 20+1080 (1-0,325 $e^{-0,167\,t}$ - 0,675 $e^{-2,5\,t}$) [^{o}C]

Standard temperature-time curve (α_c = 25 W/m^{2}K):

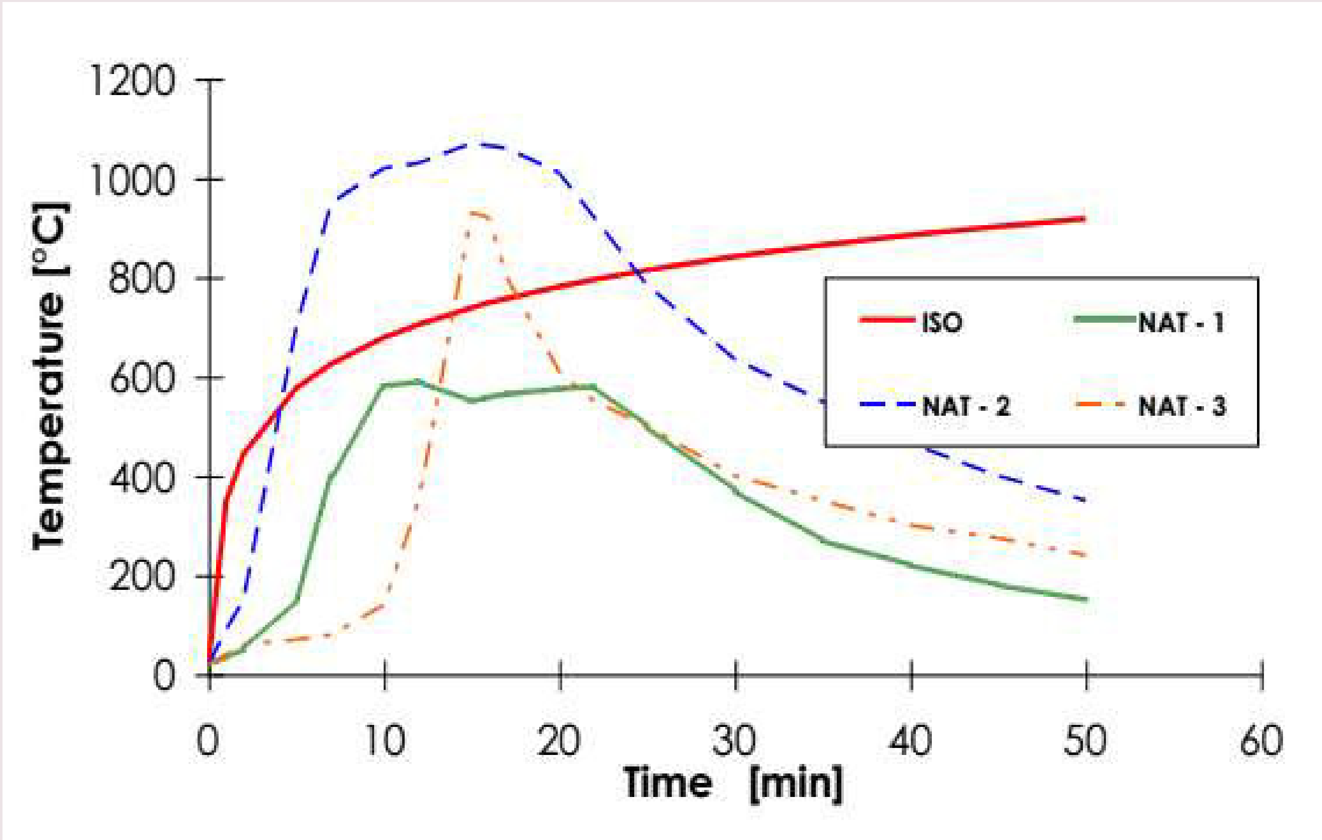
θ_g= 20 + 345 $\log_{10}$(8t+1) [^{o}C]

External fire curve (α_c = 25 W/m^2 K):

θ_g= 20+660 (1-0,687 $e^{-0,32\,t}$ - 0,313 $e^{-3,8\,t}$) [^{o}C]

Introduction

ISO versus Natural fires



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Introduction

Fire resistance of an element, of a part, or of a whole structure is: ability to fulfil the below mentioned requirements for a specified load level, for a specified fire exposure and for a specified period of time.

According to European Standards **3 Criteria** are given to define the fire resistance of structures or structural elements:

- Criterion: Load bearing function **R (Résistance)**
- Criterion: Integrity separating function **E (Etanchéité)**
- Criterion: Thermal Insulating function **I (Isolation)**

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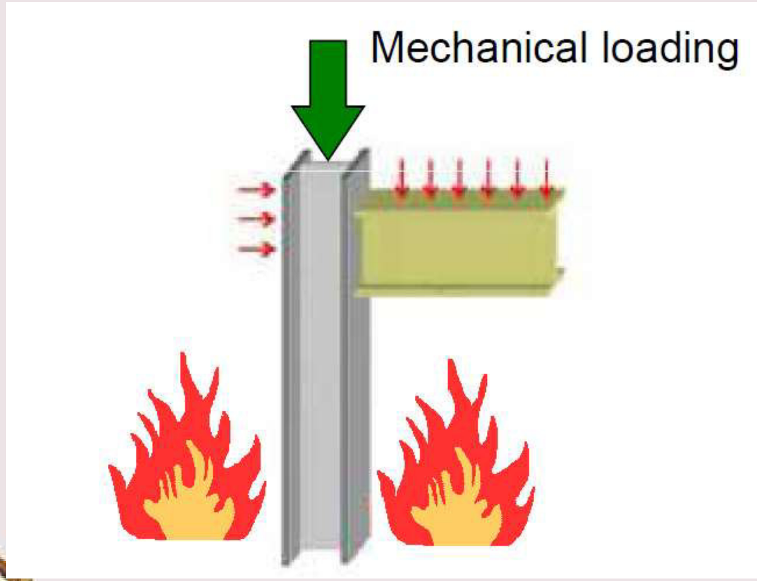
Introduction

Criterion on Load bearing function - R (Résistance)

Ability of a structure or a member to sustain specified actions during the relevant fire, according to defined criteria



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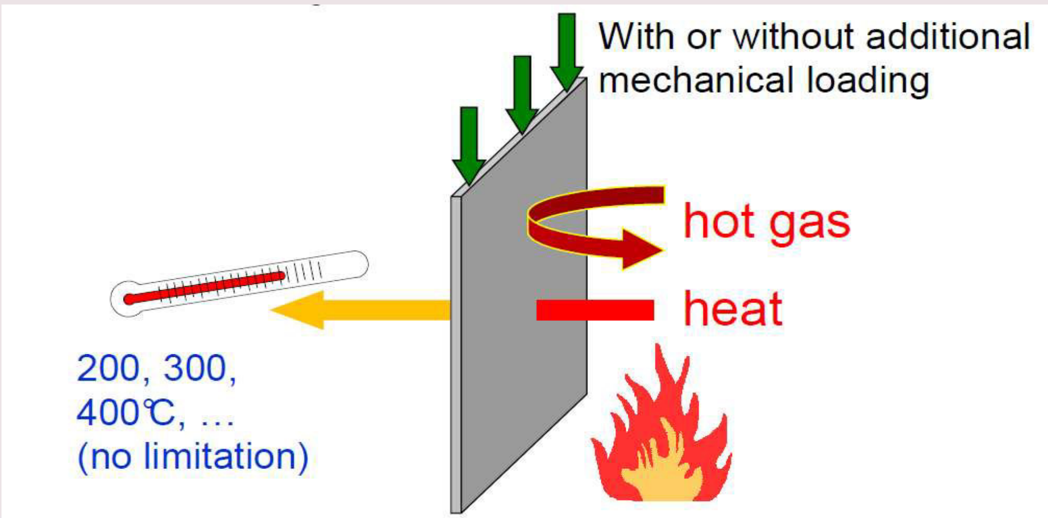
Introduction

Criterion on Integrity E (Etanchéité)

Ability of a separating element of building construction, when exposed to fire on one side, to prevent the passage through it the flames and hot gases and to prevent the occurrence of flames on the **unexposed side**



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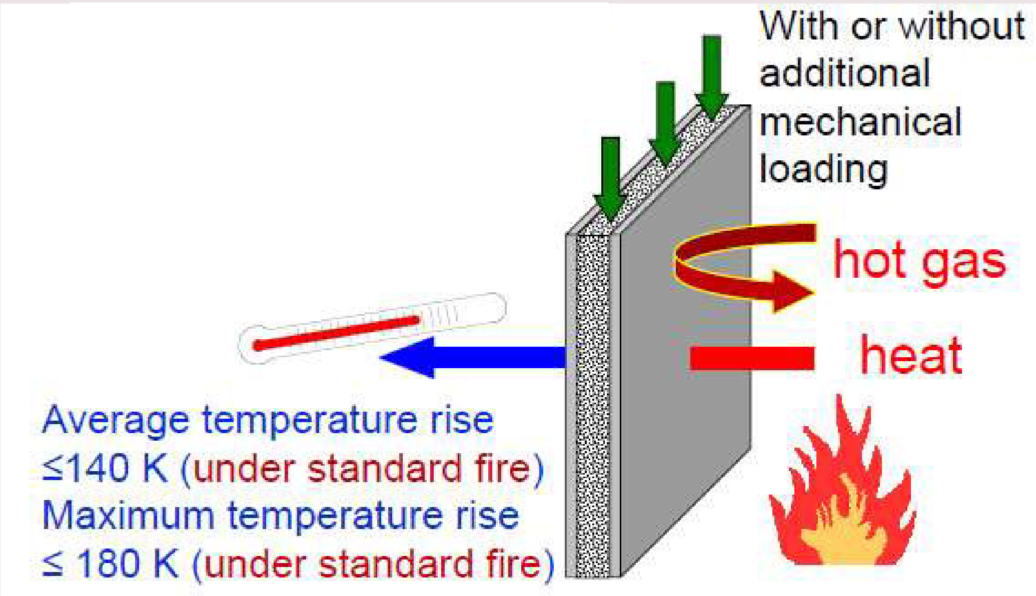
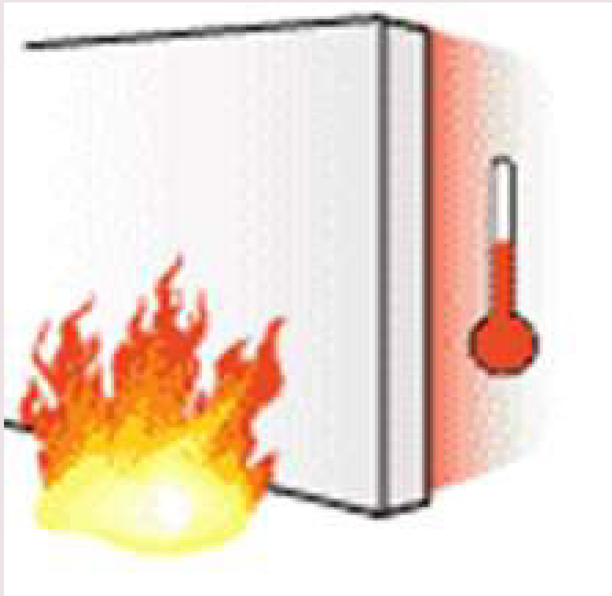
Criterion on Insulation I (Insulation)

Ability of a separating element when exposed to fire on one side, to restrict the temperature rise of the unexposed face below specified levels





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Introduction

Above criteria may be required individually or in combination:

Structural element	Criteria		
	Resistance (R)	Insulation (I)	Integrity (E)
Separating walls	-	x	x
Bearing walls	x	x	x
Doors	-	x	x
Beams	x	-	-
Slabs	x	x	x
Columns	x	-	-
Fire resistant glass	-	-	x

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RESISTANCE TO FIRE OF ELEMENTS AND STRUCTURES

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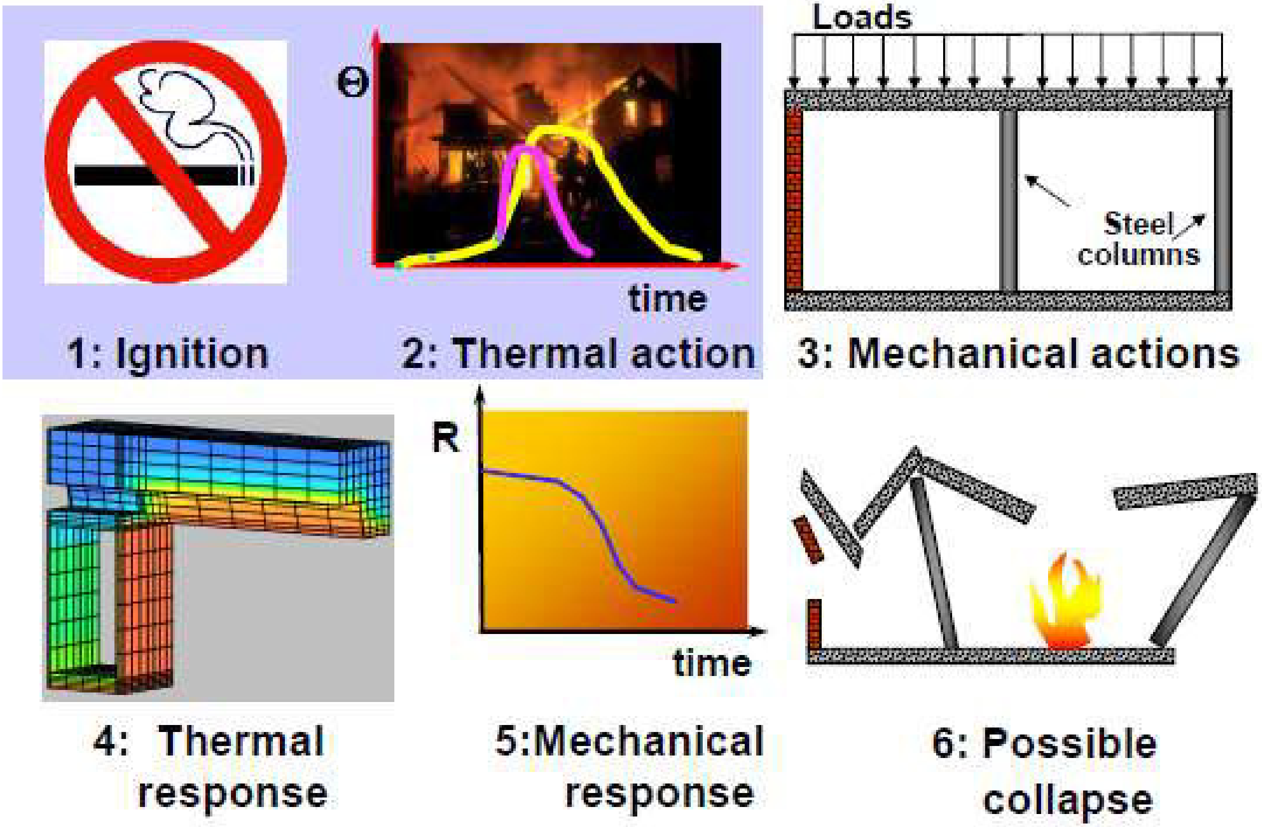
RESISTANCE TO FIRE

Resistance to Fire - Chain of Events



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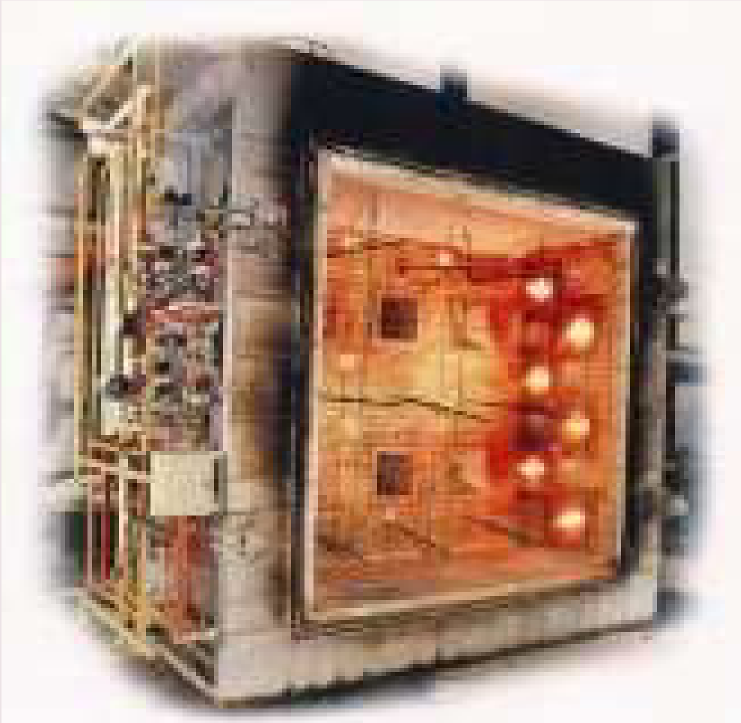
RESISTANCE TO FIRE STANDARD FIRE TESTS

Testing of walls



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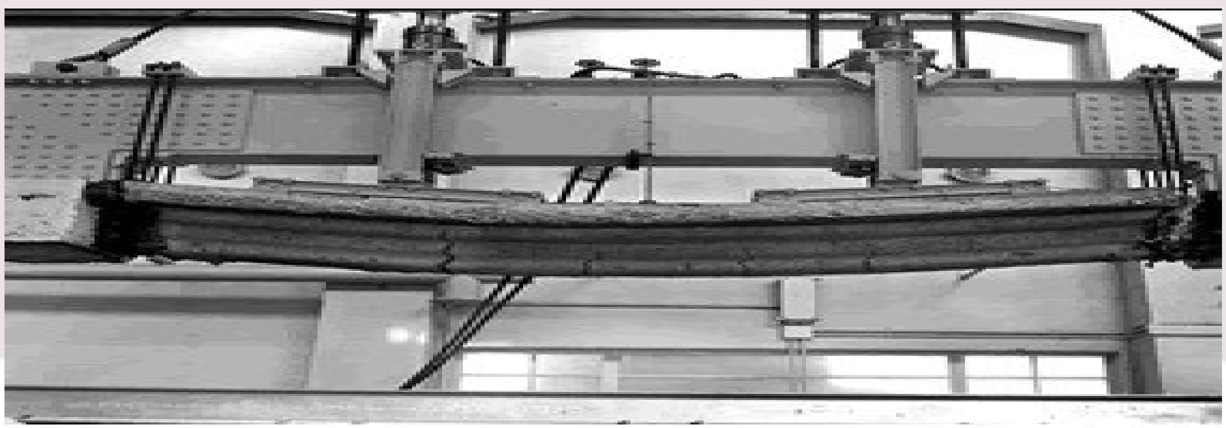
RESISTANCE TO FIRE STANDARD FIRE TESTS

Testing of beams



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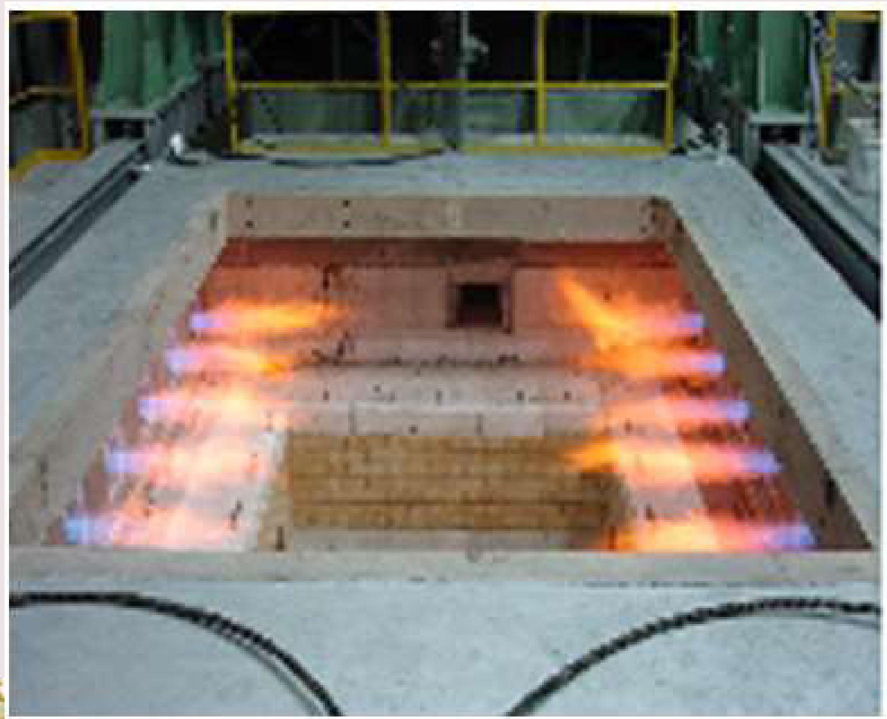
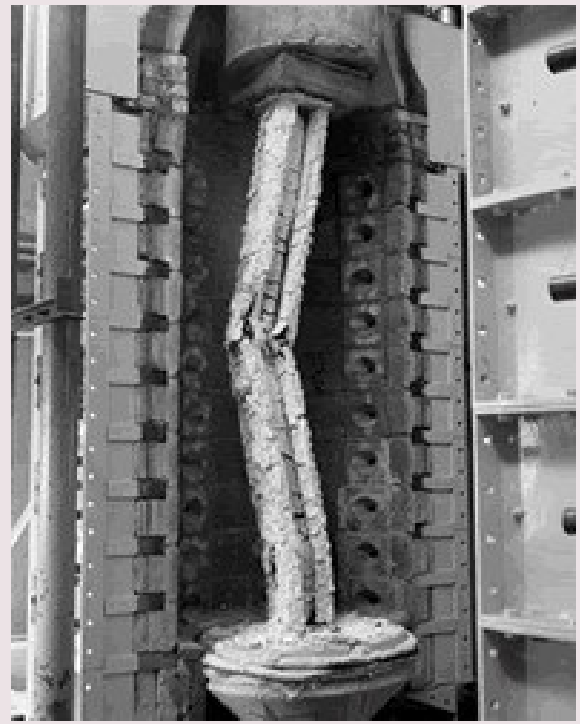
RESISTANCE TO FIRE STANDARD FIRE TESTS

Testing of slabs and columns





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RESISTANCE TO FIRE

STANDARD FIRE TESTS

Testing of houses with small dimensions

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STANDARD FIRE TEST:

DISADVANTAGES :

- Do not reliably predict behavior because actual fires and structural restraints cannot be adequately simulated
- Provide information on local behavior of the elements, but the question about the global behavior of the structure as a whole remains open
- Testing programs for investigating the response of a large variety of structural elements under different restraints, loadings, and fire conditions are impractical and expensive

NECESSARY FOR:

- Determining the mechanical properties of materials at high temperatures
- Checking the adequacy of the developed computational methods

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CALCULATION METHODS

RESISTANCE TO FIRE

SIMPLIFIED METHODS

NUMERICAL METHODS

EUROCODES

1. ACTIONS ON STRUCTURES
2. CONCRETE STRUCTURES
3. STEEL STRUCTURES
4. COMPOSITE STRUCTURES
5. TIMBER STRUCTURES
6. MASONRY
7. ALUMINIUM ALLOYS STR.

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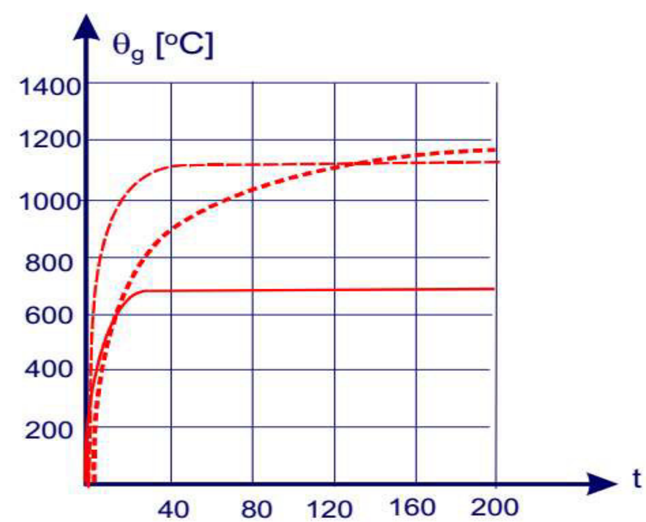
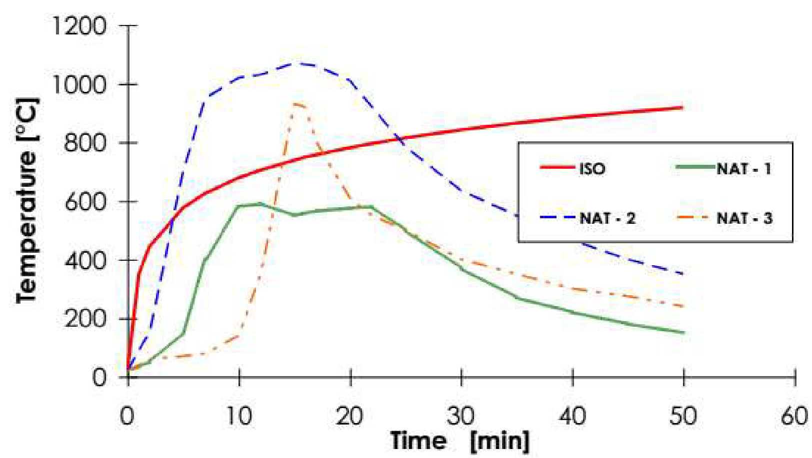
CALCULATION METHODS **RESISTANCE TO FIRE**

Project Design

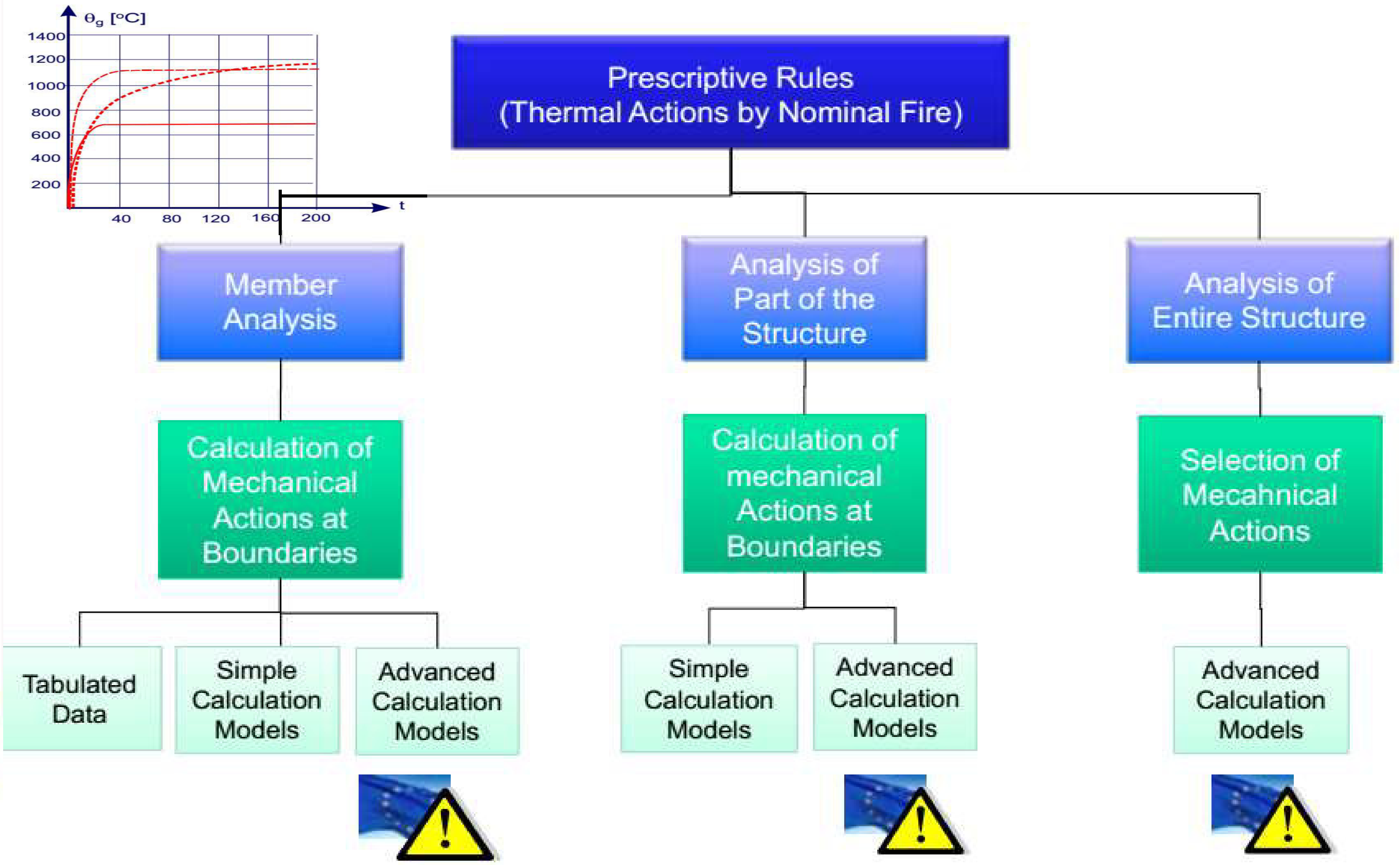
Prescriptive Regulation
(Thermal Actions given by a Nominal Fire)

Performance-Based Code
(Physical Based Thermal Actions)

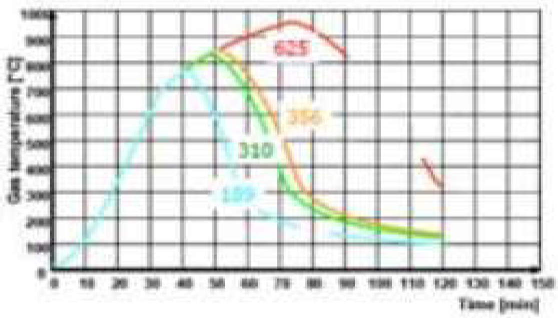




CALCULATION METHODS RESISTANCE TO FIRE



CALCULATION METHODS **RESISTANCE TO FIRE**



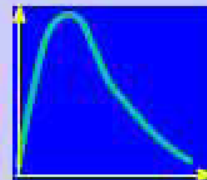
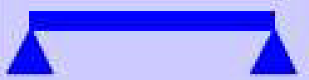
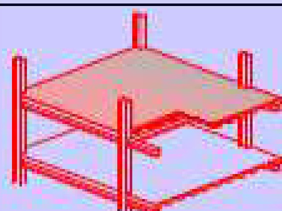
Performance-Based Code
(Physically based Thermal Actions)

Selection of Simple or Advanced Fire Development Models

- Member Analysis
  - Calculation of Mechanical Actions at Boundaries
    - Simple Calculation Models (if available)
    - Advanced Calculation Models
- Analysis of Part of the Structure
  - Calculation of mechanical Actions et Boundaries
    - Advanced Calculation Models
- Analysis of Entire Structure
  - Selection of Mecahnical Actions
    - Advanced Calculation Models

CALCULATION METHODS

RESISTANCE TO FIRE

	Prescriptive	Performance based
	standard fire 	natural fire 
	classification	fire safety eng.
	fire safety eng.	fire safety eng.

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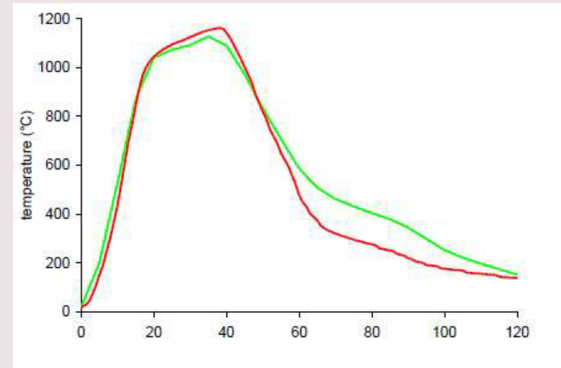
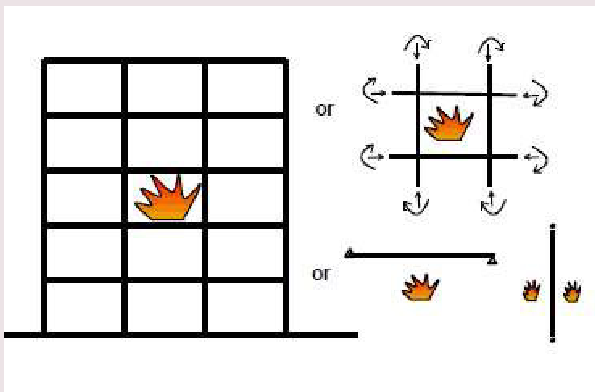
CALCULATION METHODS

Fire Safety Eng.

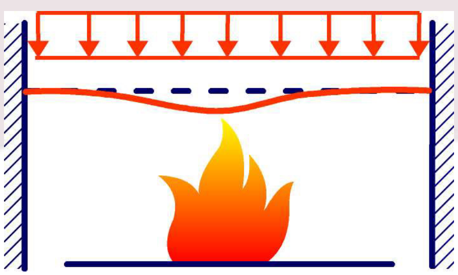


1. Fire Development and propagation



2. Structural schematisation

3. Heat transfer to structural elements



4. Mechanical behaviour at elevated temperatures

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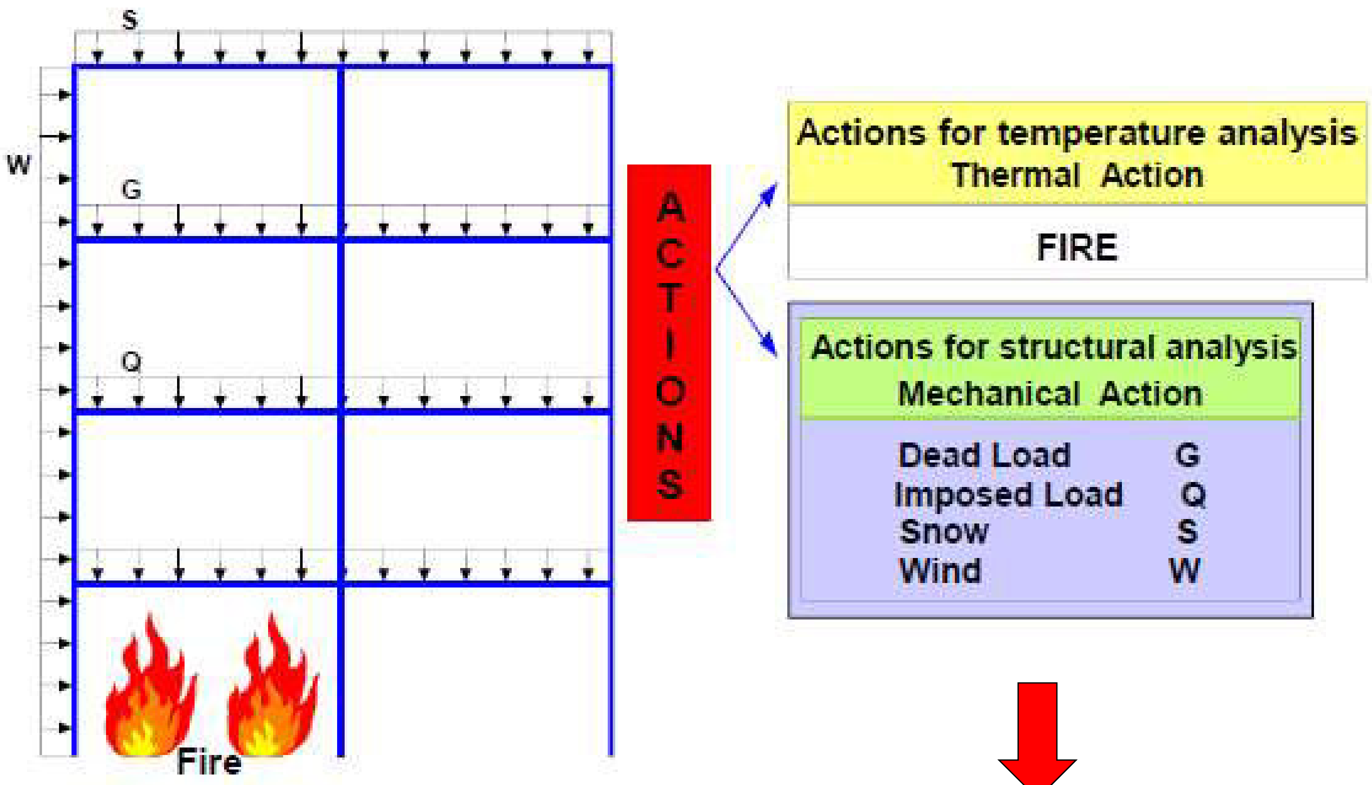
CALCULATION METHODS

Mechanical behaviour at elevated temperatures



Computer programs: SAFIR and FIRE

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THERMAL ANALYSIS

Governing differential equation of heat transfer in conduction:

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

where:

$\lambda_{x,y,z}$ - is a thermal conductivity

ρ - is a density of the material

c - is a specific heat

Fire boundary conditions:

- convective heat transfer mechanism
- radiative heat transfer mechanism

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STRESS-STRAIN ANALYSIS

The nonlinear equations governing behaviour of a structural system are temperature and history dependent

$$F_i\left(U_i, T_i, H_{i-1}\right) = R_i$$

F_i - are internal forces at current time

U_i - is current deformed shape

T_i - is current temperature distribution

H_{i-1} - is prior response and thermal history

R_i - is external loading at current time

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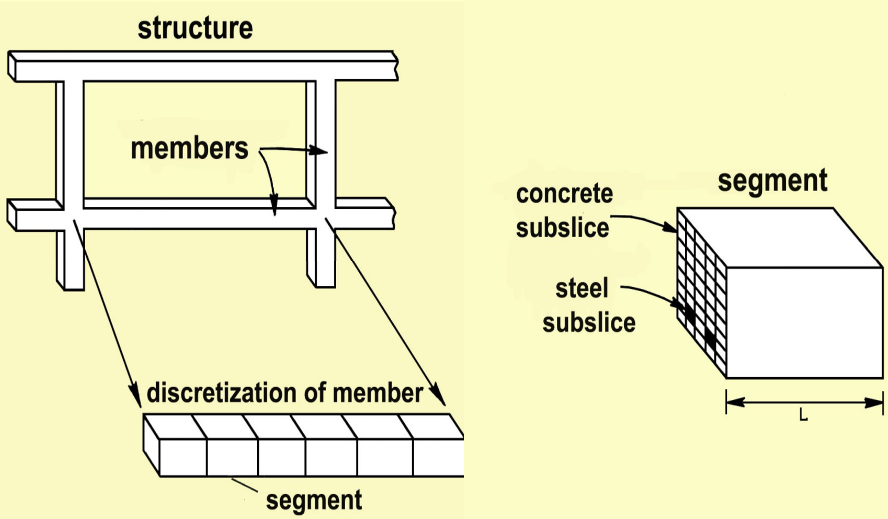
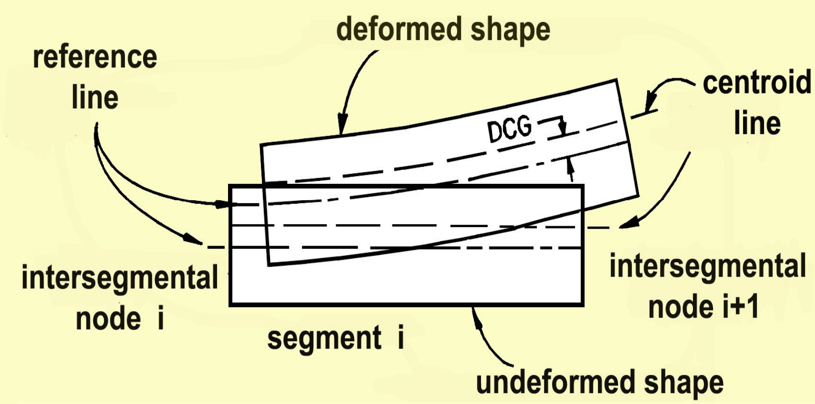
STRESS-STRAIN ANALYSIS

Geometric idealization



Deformed mode of segment



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FIRE RESISTANCE OF CONCRETE STRUCTURES

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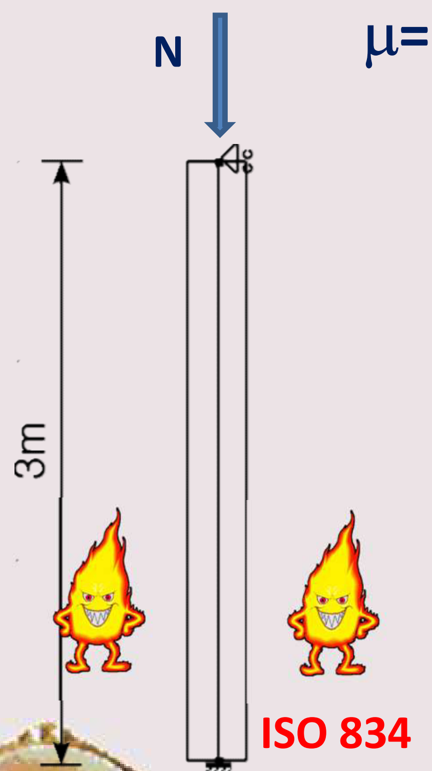
CENTRICALLY LOADED RC COLUMNS

$\mu=1\%$, RA 400/500, $a=2.5cm$, $f_{c(20^{o}C)}=30$ Mpa



- Cross-sectional size
  - 30x30 cm
  - 36x25 cm
  - 45x20 cm
  - 60x15 cm (RC wall)
- Axial load ratio
  - α=0,1
  - α=0,2
  - α=0,3
  - α=0,4
  - α=0,5

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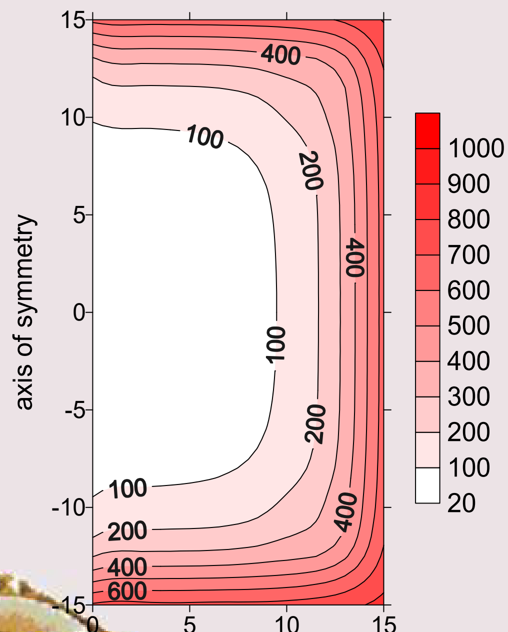
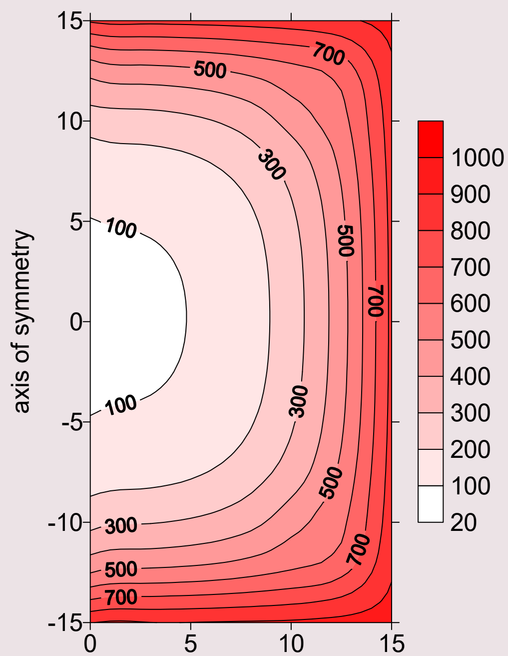
CENTRICALLY LOADED RC COLUMNS

Temperature distribution in the cross section of the column 30x30cm, at different moments



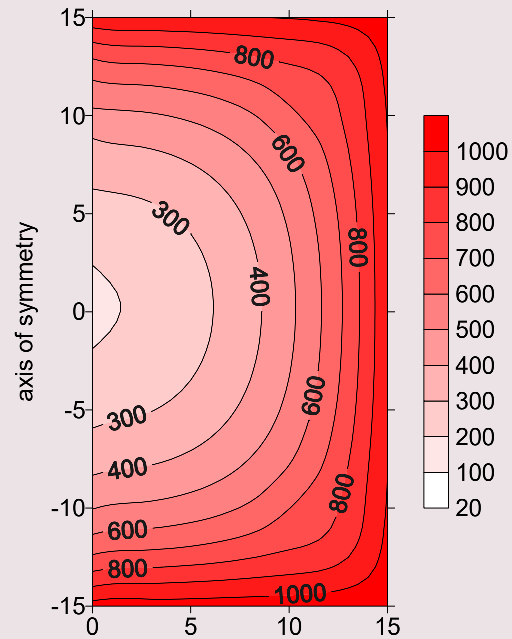
t=0.5 h

T_{aver}=277°C



t=1.0 h

T_{aver}=432°C

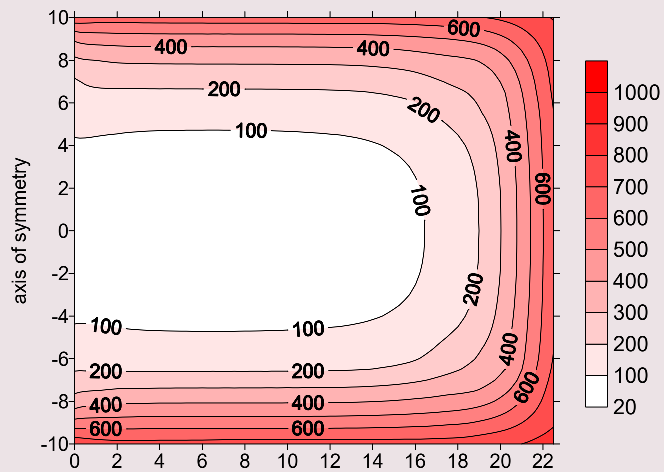


t=2.0 h

T_{aver}=627°C

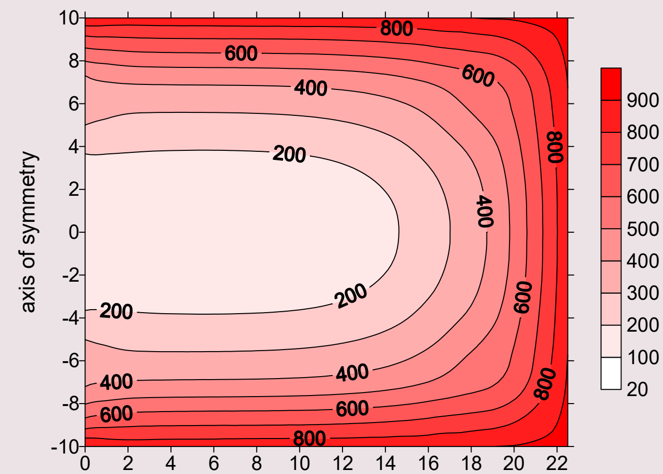
CENTRICALLY LOADED RC COLUMNS

Temperature distribution in the cross section of the column 45x20cm, at different moments



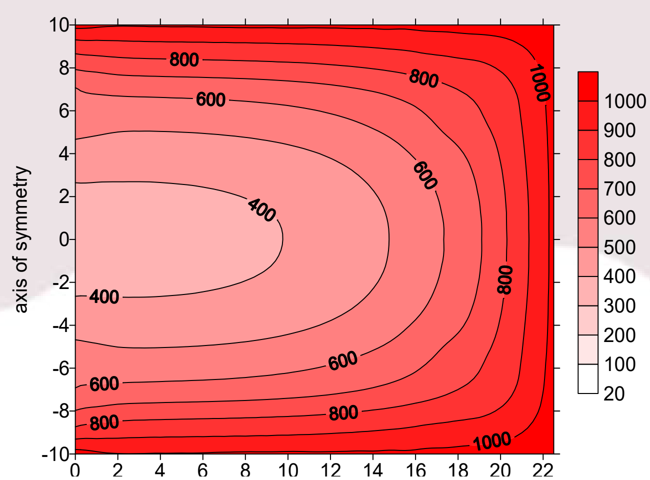
t=0.5 h

T_{aver}=258°C



t=1.0 h

T_{aver}=419°C

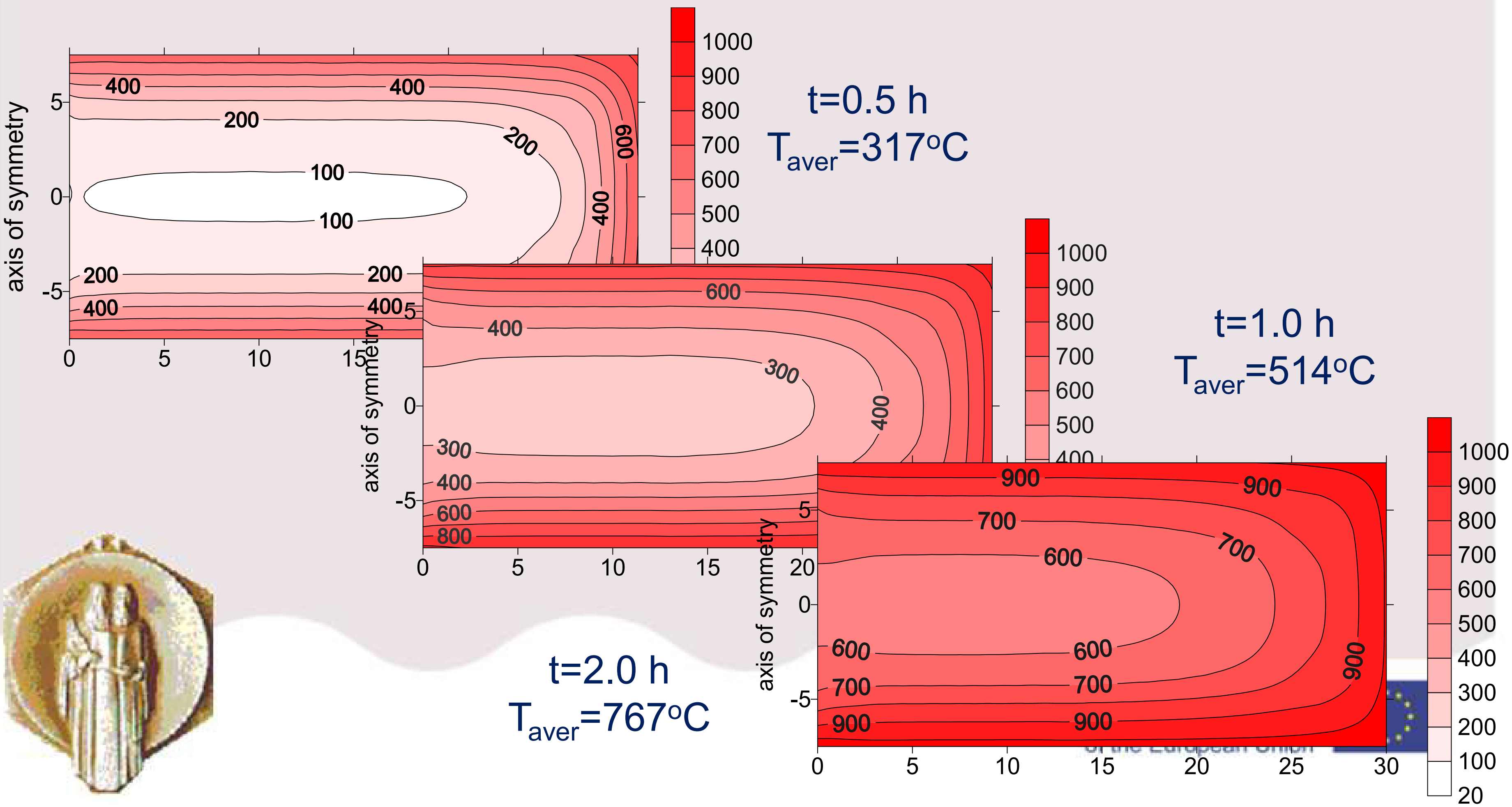


t=2.0 h

T_{aver}=648°C

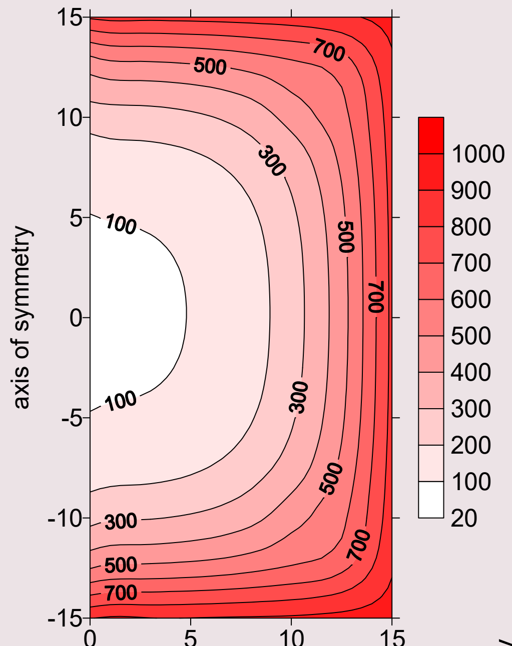
CENTRICALLY LOADED RC COLUMNS

Temperature distribution in the cross section of the column 60x15cm, at different moments

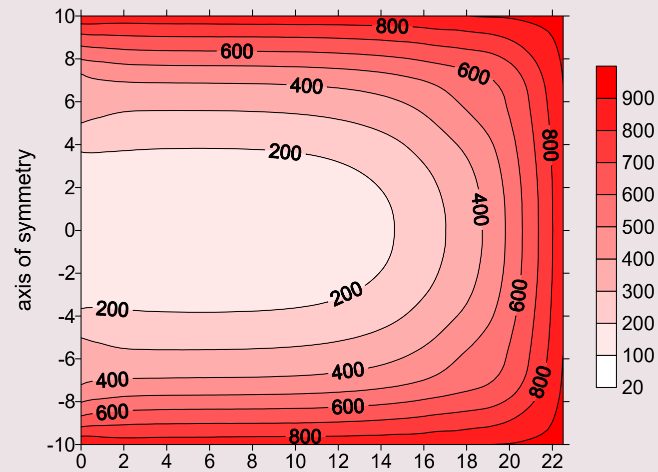


CENTRICALLY LOADED RC COLUMNS

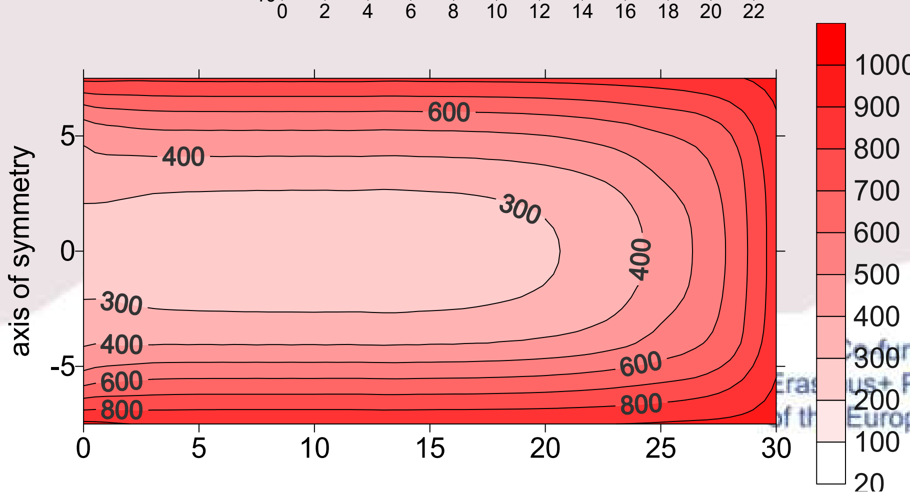
Temperature distributions in the cross sections of the columns, at moment t=1.0 hour



t=1.0 h
T_{aver}=432°C



t=1.0 h
T_{aver}=419°C



t=1.0 h
T_{aver}=514°C

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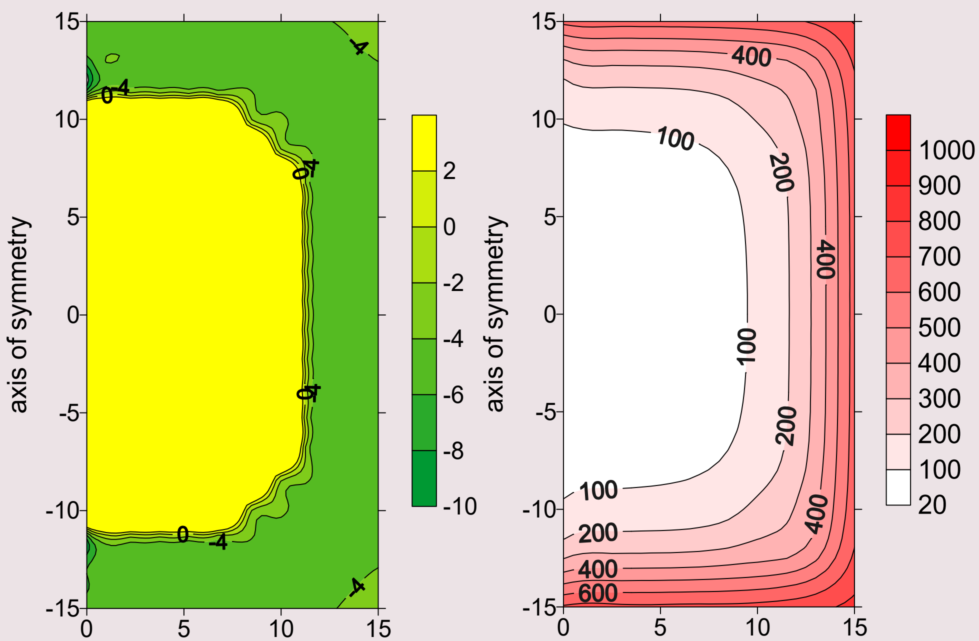
CENTRICALLY LOADED RC COLUMNS

Temperature and stress distribution in the cross section of the column 30x30cm, after 0.5 hours of fire exposure



t=0.5 h
$\alpha = 0.25$

t=0.5 h
T_{aver}=277°C

-cracked concrete

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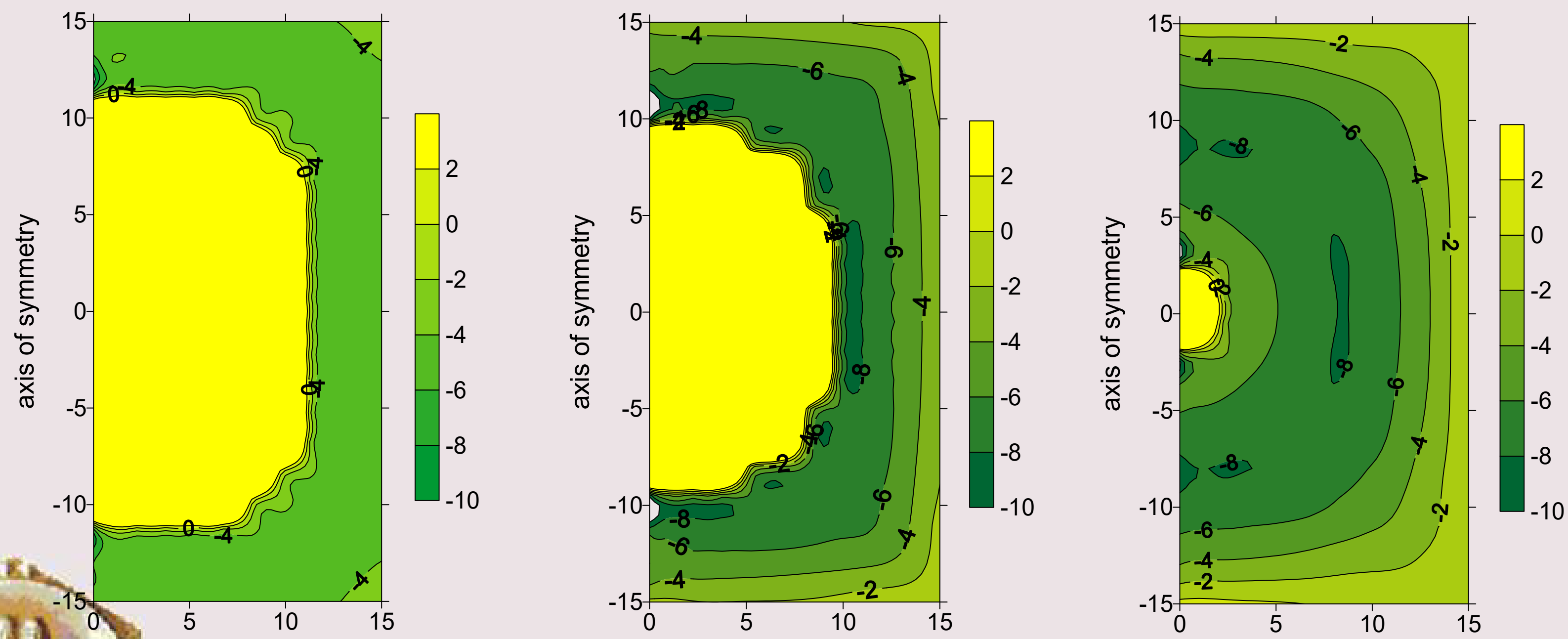
CENTRICALLY LOADED RC COLUMNS

Stress distribution in the cross section of the column 30x30cm, at different moments

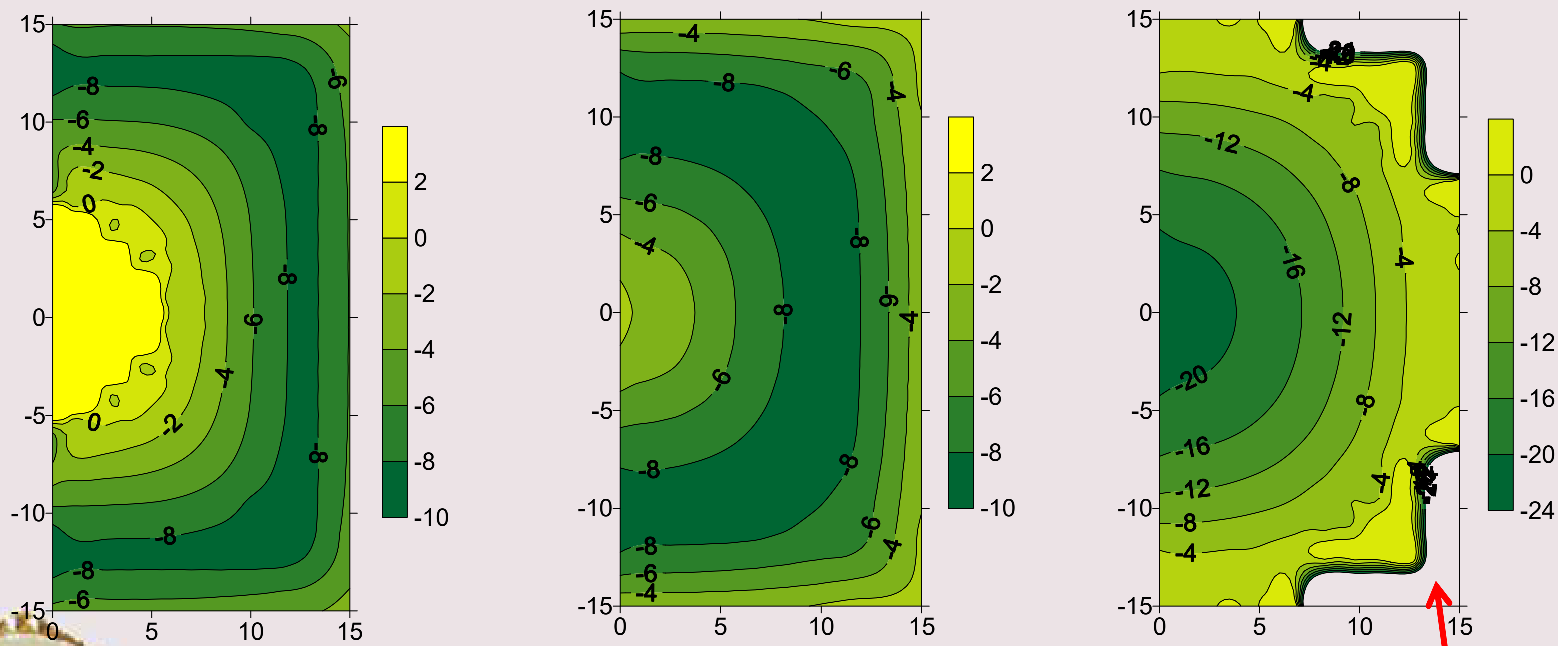


t=0.5 h	t=1.0 h	t=2.0 h
α = 0.25	α = 0.25	α = 0.25
		t_{max}=4h

-cracked concrete

CENTRICALLY LOADED RC COLUMNS

Stress distribution in the cross section of the column 30x30cm, at different moments



t=0.5 h
α = 0.35

t=1.0 h
α = 0.35

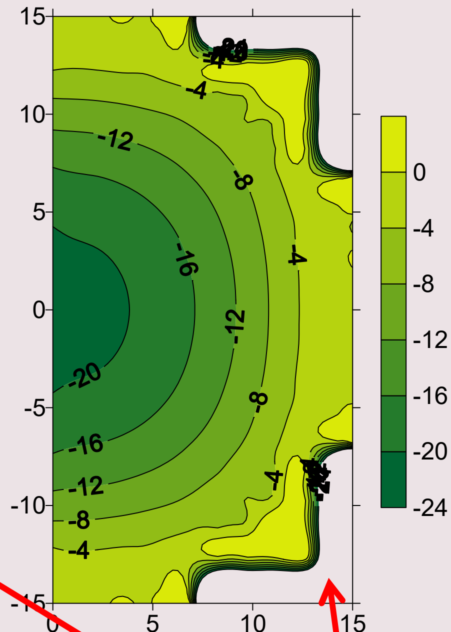
t=3.1 h
α = 0.35

-cracked concrete

crashed concrete-

CENTRICALLY LOADED RC COLUMNS

Stress distribution in the cross section of the column 30x30cm, at moment of failure



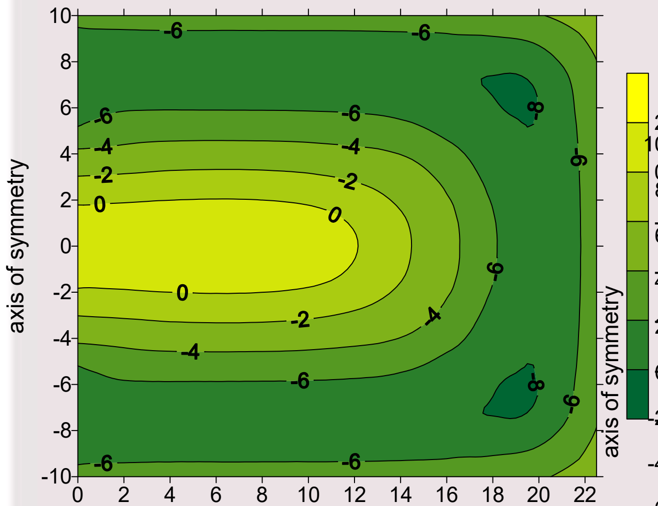
t=3.1 h

α = 0.35

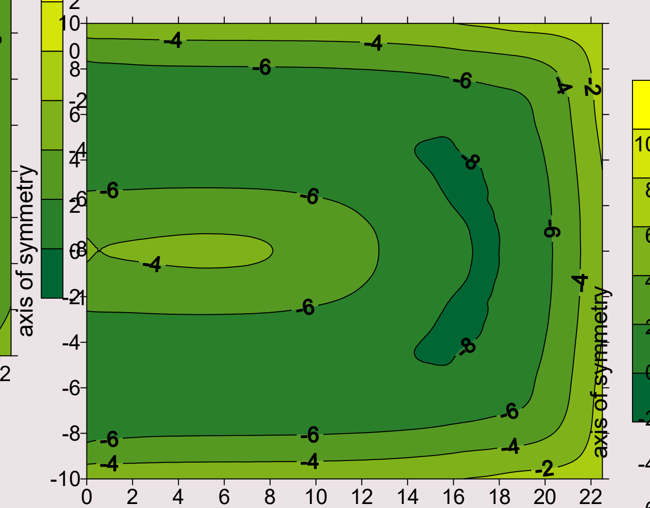
crashed concrete-

CENTRICALLY LOADED RC COLUMNS

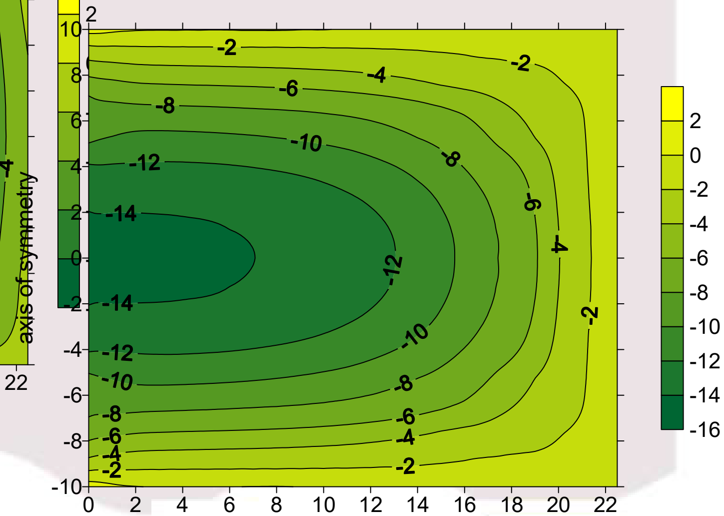
Stress distribution in the cross section of the column 45x20cm, at different moments



t=0.5 h
$\alpha = 0.25$



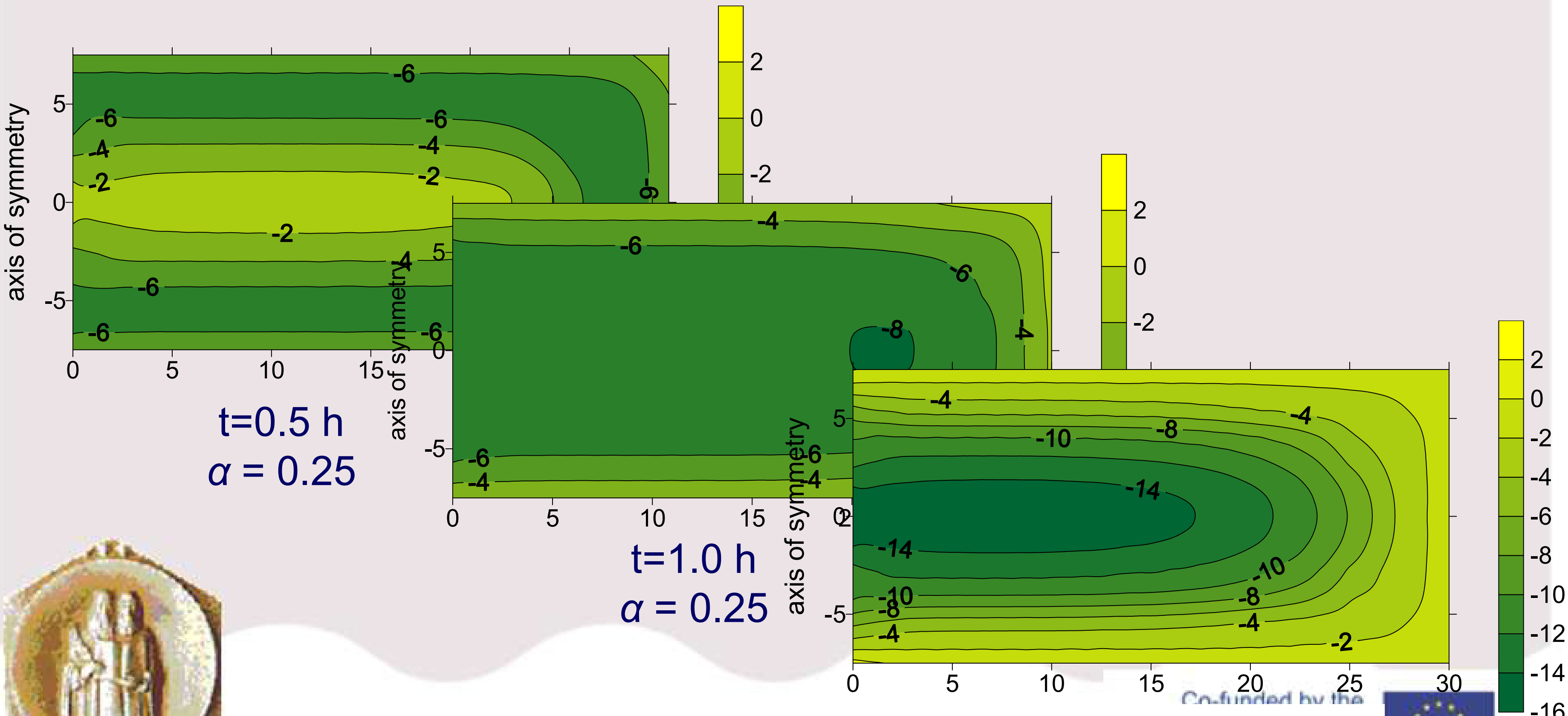
t=1.0 h
$\alpha = 0.25$



t=2.0 h
$\alpha = 0.25$

CENTRICALLY LOADED RC COLUMNS

Stress distribution in the cross section of the column 60x15cm, at different moments



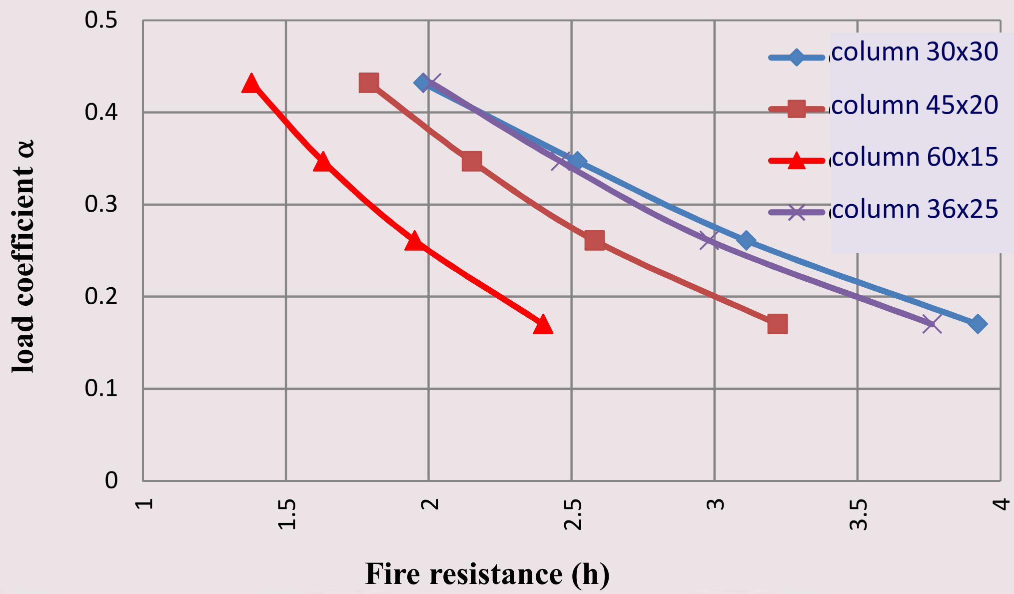
t=0.5 h
$\alpha = 0.25$

t=1.0 h
$\alpha = 0.25$

t=2.0 h
$\alpha = 0.25$

CENTRICALLY LOADED RC COLUMNS

Fire resistance curves for centrically loaded RC columns exposed to fire from all sides, as function of the shape of the cross section and the load coefficient α



$$\alpha = \sigma_b / f_c(20^0 C) \leq 0.3$$

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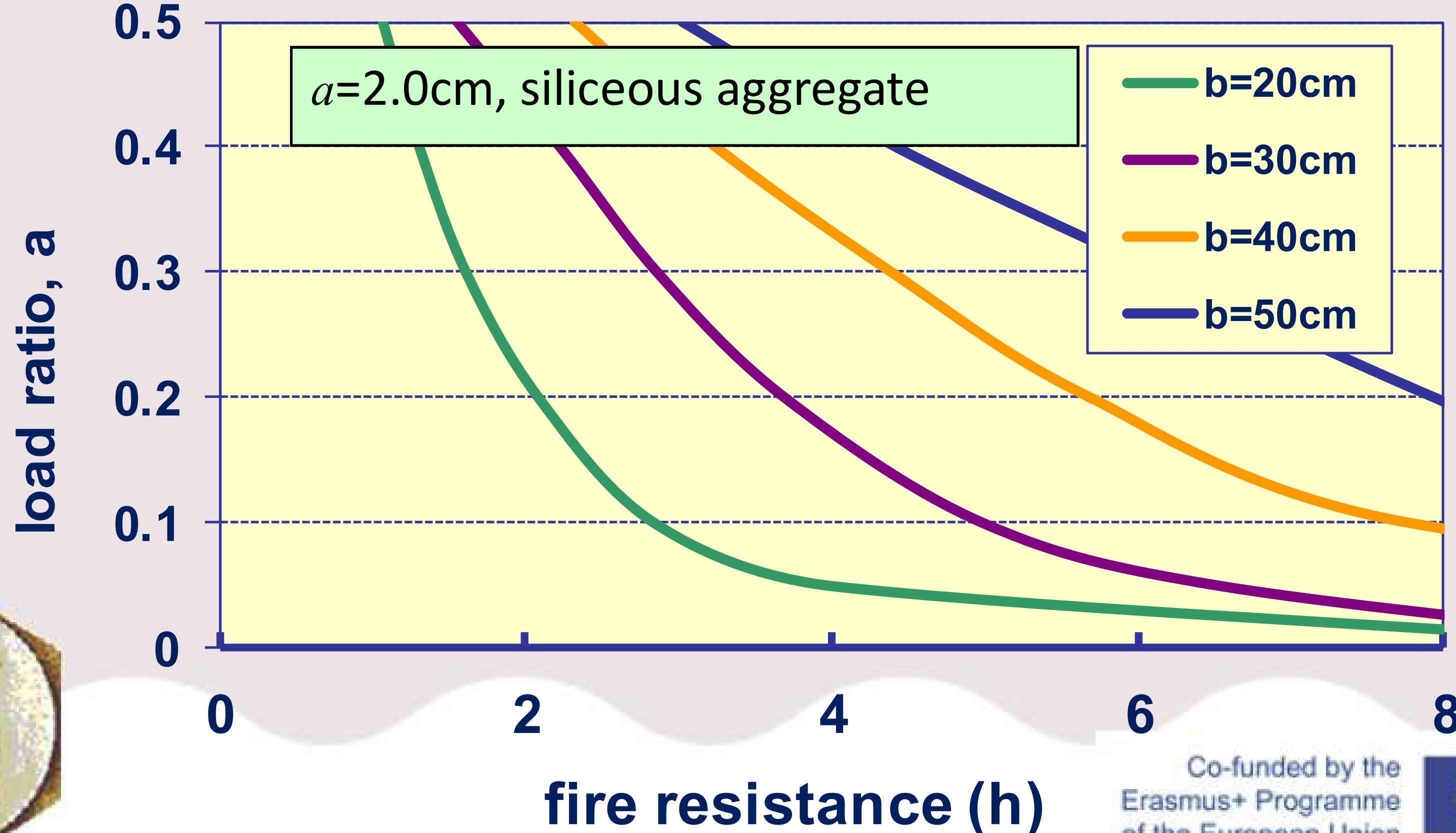
CENTRICALLY LOADED RC COLUMNS

Effect of cross section dimensions and load ratio on the fire resistance of columns



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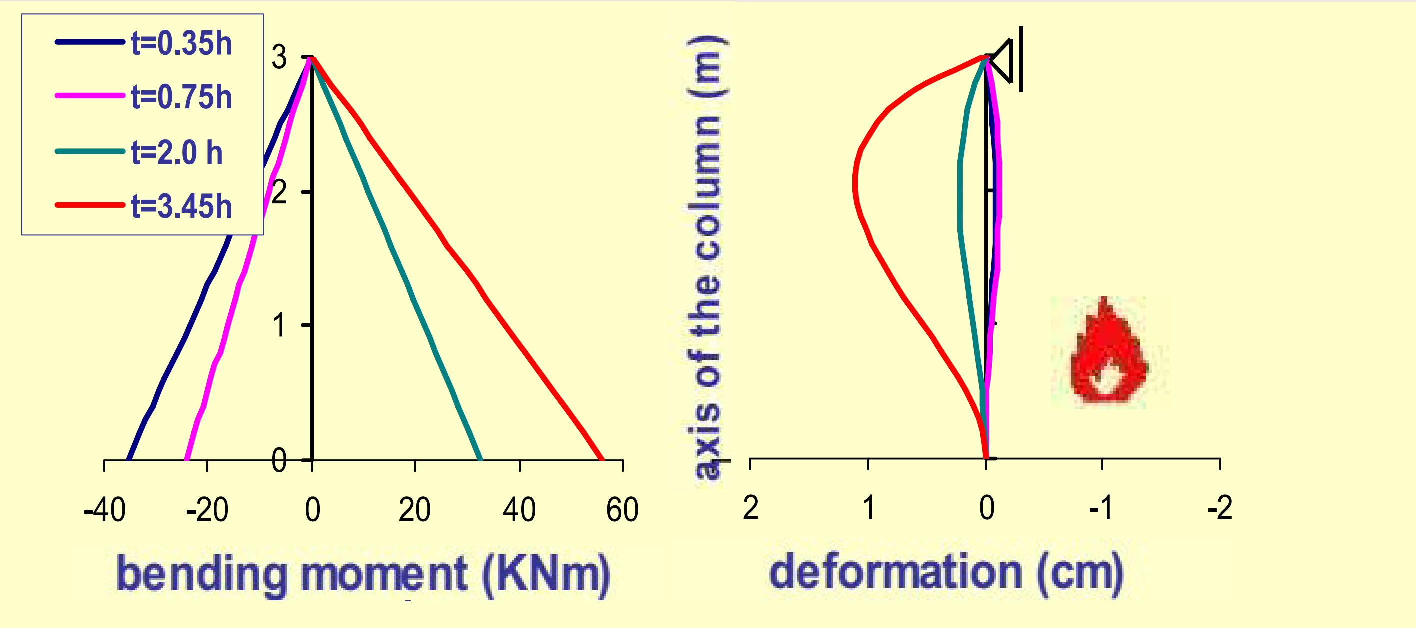
CENTRICALLY LOADED RC COLUMNS

Fire exposure only from one side

Time redistribution of bending moment and deformation of siliceous concrete column 30*30cm, *a* =2cm, μ=1% , RA 400/500, α=0.3



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CENTRICALLY LOADED RC COLUMNS

CONCLUSIONS

Based on the results of the analysis conducted in this study it was found out that in case of fire exposure from all four sides and action of axial compressive force there is a significant difference in the behavior of the columns with same cross sectional areas, but different shapes of the cross sections.

Due to the compactness of the cross section the column with dimensions 30x30 cm has the lowest average temperature, consequently the highest fire resistance. It is not a case with the column 15x60cm (RC wall) because in this case the temperature easier penetrates deeper into the cross section, the column reaches the highest average temperature and has the smallest fire resistance.

These fire resistance curves indicate that the highest fire resistance achieves the column with lowest ratio between the two sides of the cross section. The reason for that is the lowest average temperature of the column’s cross section.

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CENTRICALLY LOADED
RC COLUMNS

PARAMETERS THAT INFLUENCE THE FIRE RESISTANCE OF CENTRICALLY LOADED COLUMNS

1. Dimensions of the cross section
2. Shape of the cross section (ratio between the both sides)
3. Load level
4. Fire scenario
5. Support conditions
6. Concrete cover thickness and steel ratio (only when fire is from one side)

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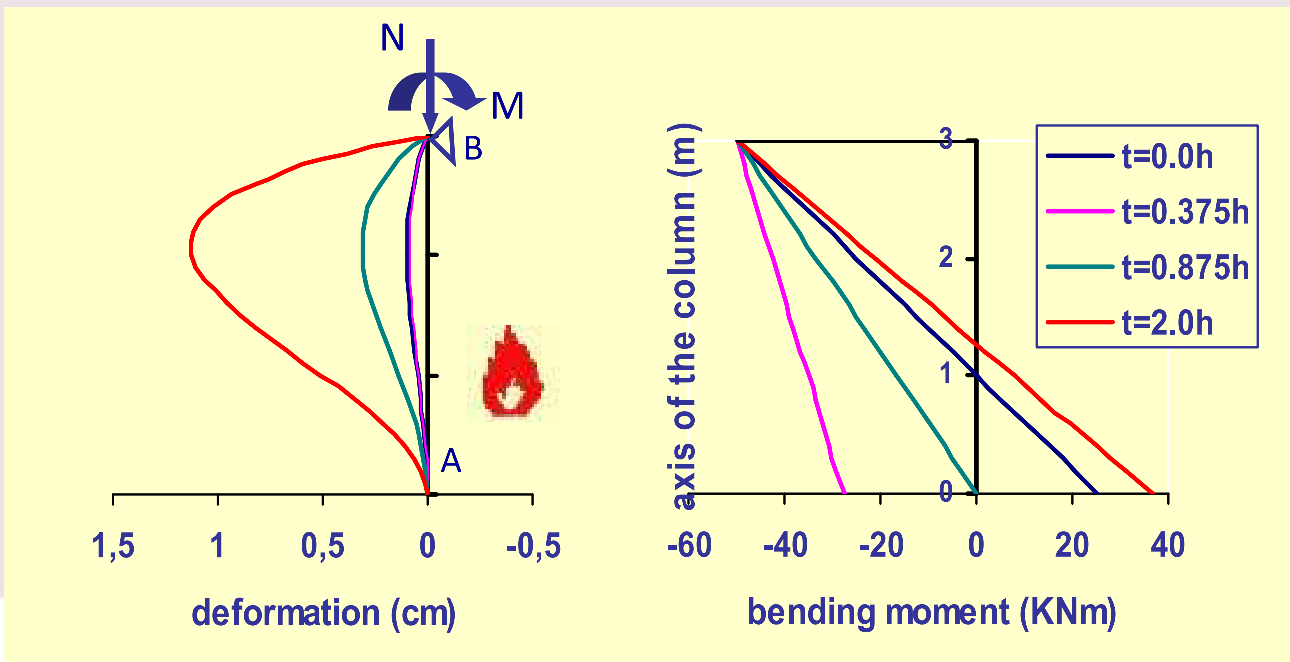
ECCENTRICALLY LOADED RC COLUMNS

Fire exposure only from one side

Time redistribution of bending moment and deformation of siliceous concrete column 30*30cm, *a* =2cm, μ=1% , RA 400/500, η=0.2, β=0.4



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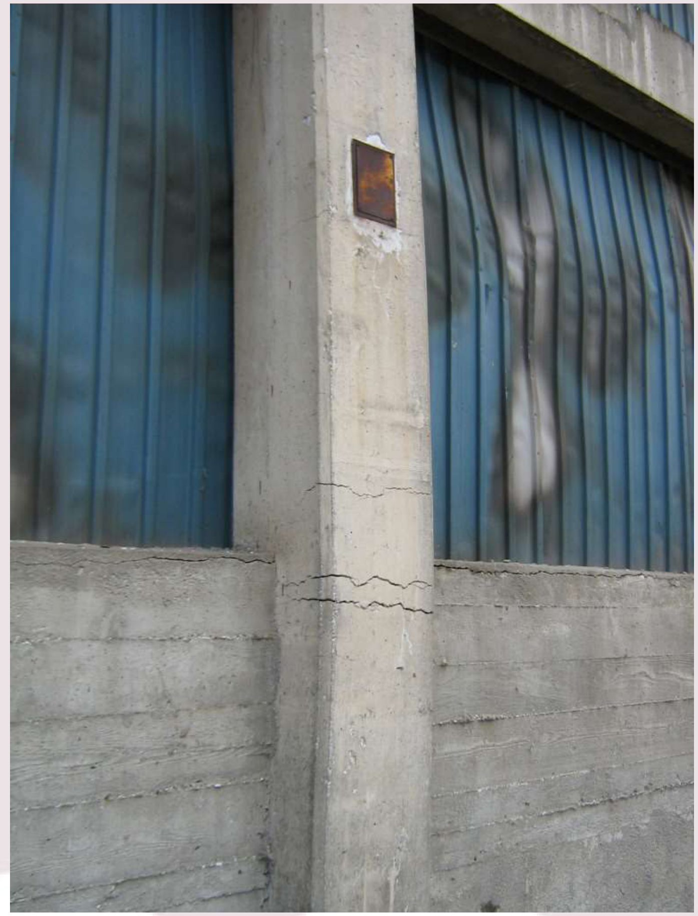
ECCENTRICALLY LOADED RC COLUMNS

EFFECTS OF REAL FIRE



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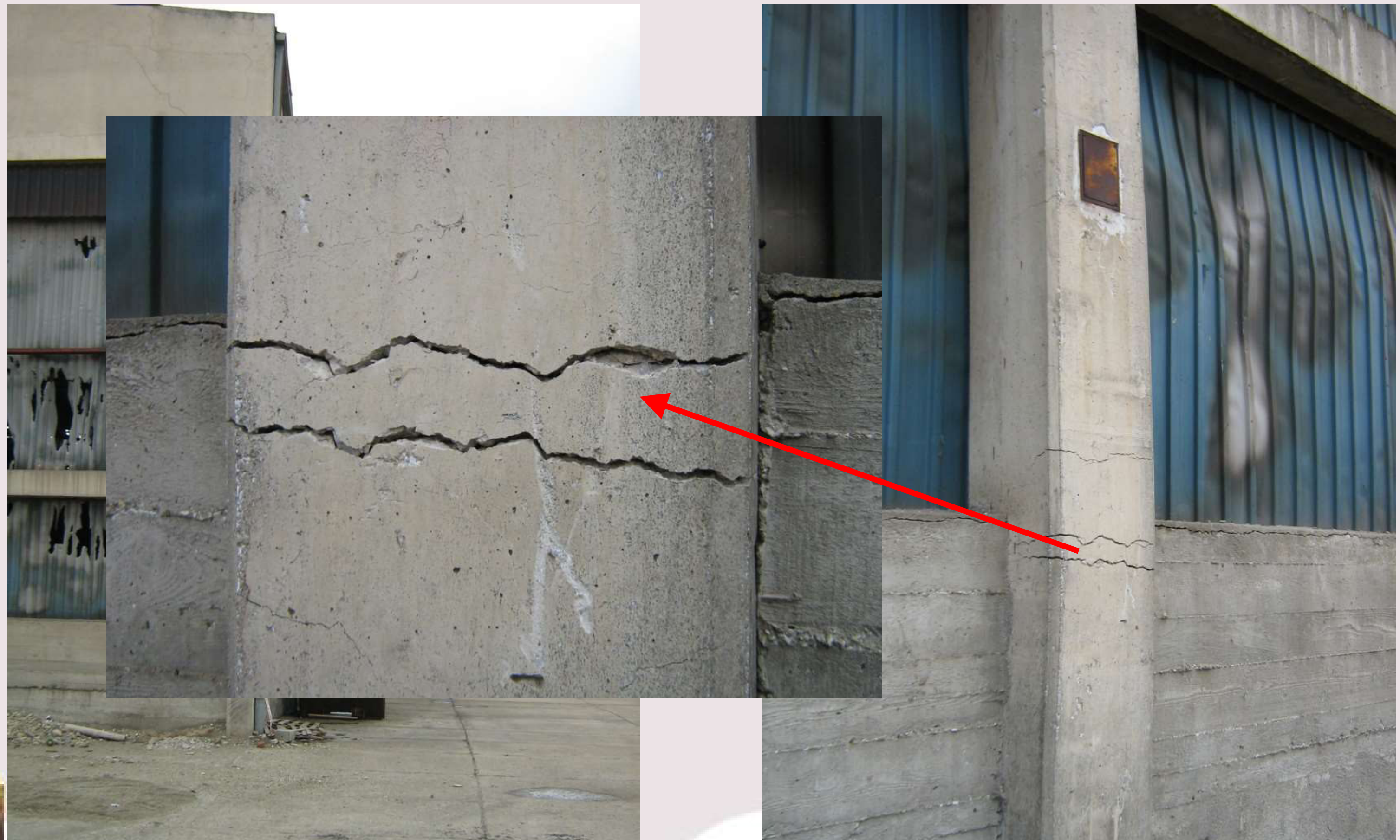
ECCENTRICALLY LOADED RC COLUMNS

EFFECTS OF REAL FIRE



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ECCENTRICALLY LOADED
RC COLUMNS

PARAMETERS THAT INFLUENCE THE FIRE RESISTANCE OF ECCENTRICALLY LOADED COLUMNS

1. Dimensions of the cross section
2. Shape of the cross section (ratio between the both sides)
3. Load level
4. Fire scenario
5. Support conditions
6. Concrete cover thickness and steel ratio

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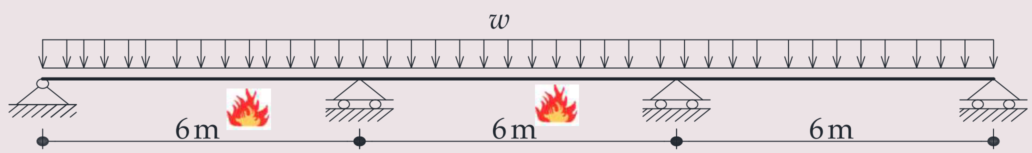
CONTINUOUS RC BEAMS AND SLABS

DIFFERENT FIRE SCENARIOS

PARAMETERS THAT INFLUENCE THE FIRE RESISTANCE OF RC BEAMS AND SLABS

1. Dimensions of the cross section
2. Shape of the cross section
3. Load level
4. Fire scenario



5. Support conditions
6. Concrete cover thickness and steel ratio

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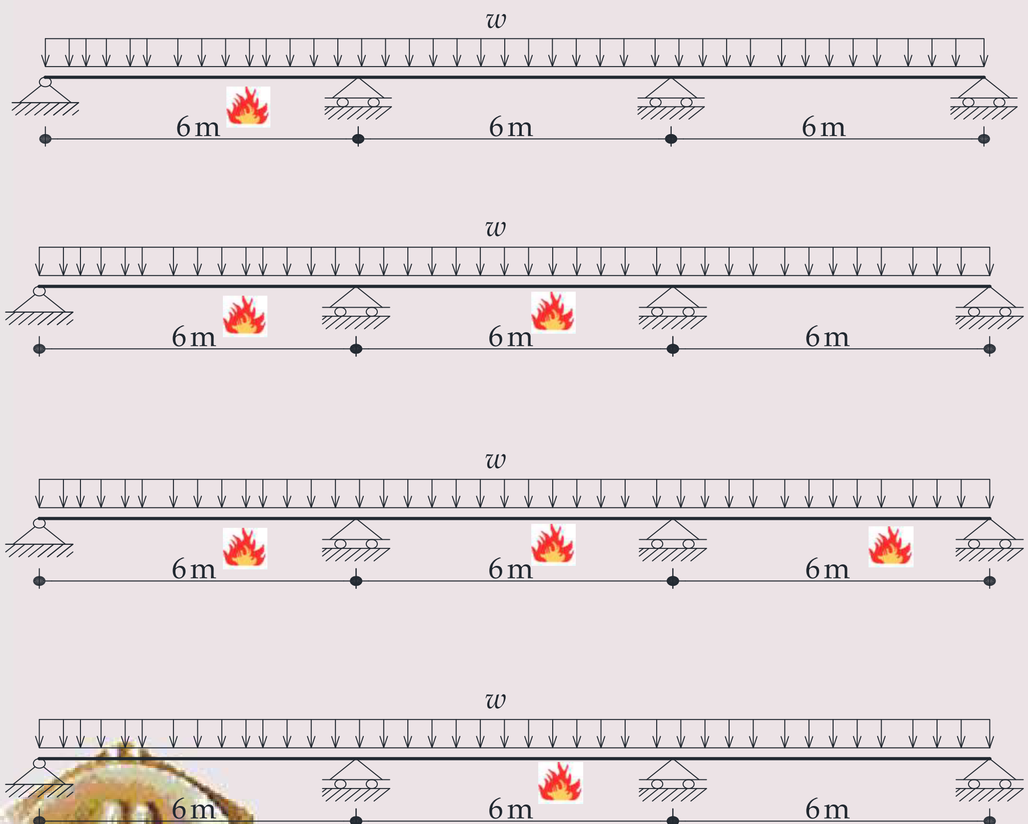
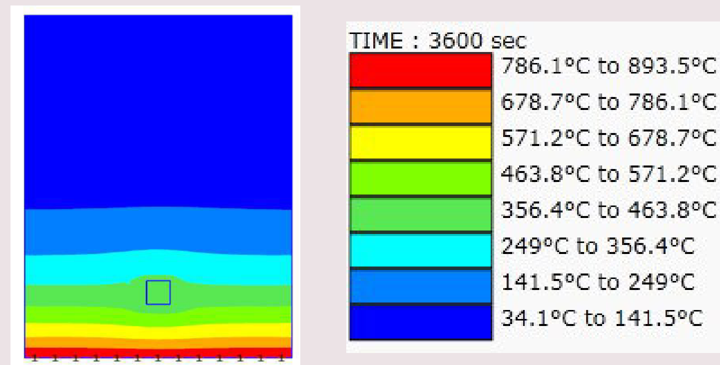
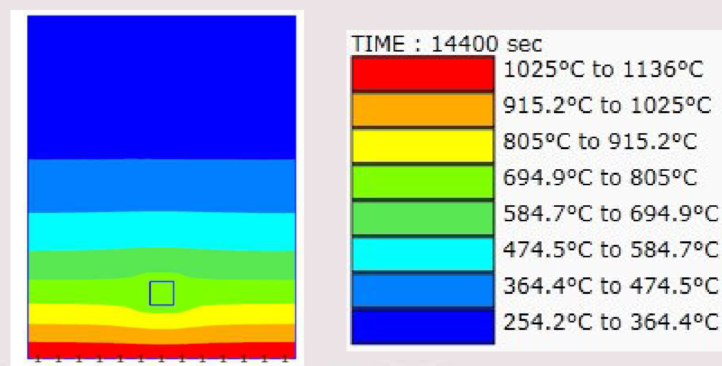
CONTINUOUS RC SLABS

DIFFERENT FIRE SCENARIOS







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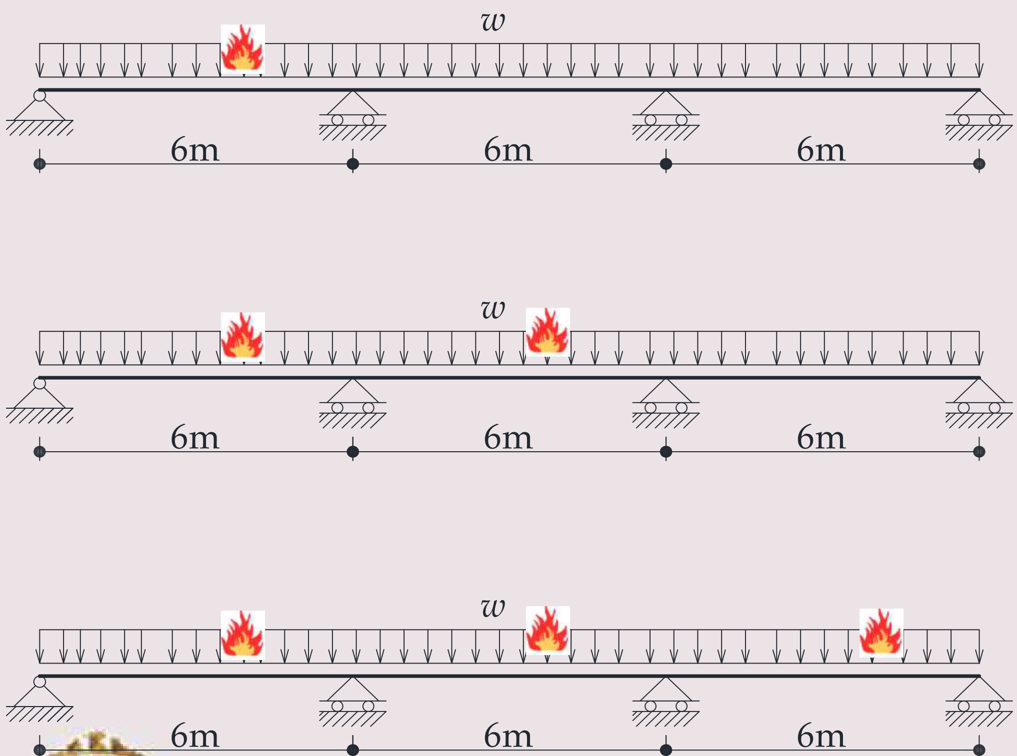
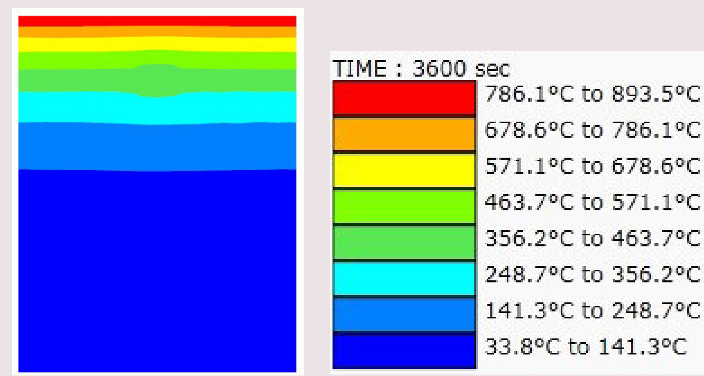
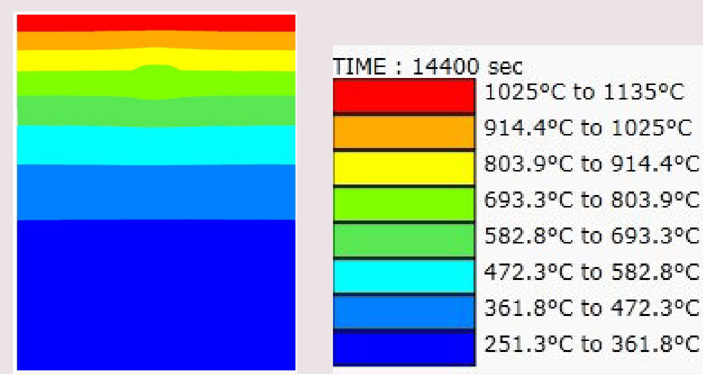
CONTINUOUS RC SLABS

DIFFERENT FIRE SCENARIOS







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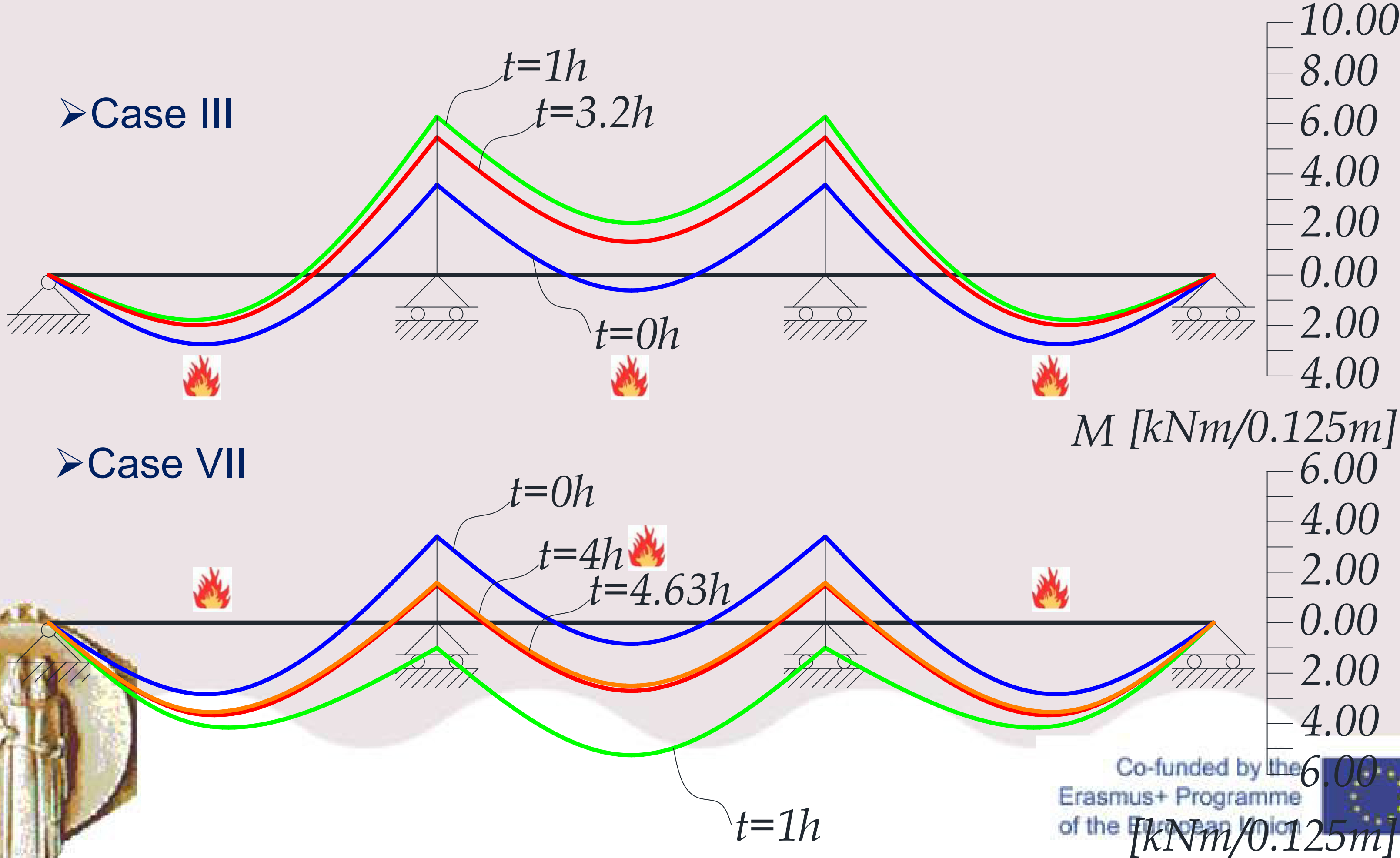
CONTINUOUS RC SLABS

DIFFERENT FIRE SCENARIOS

BENDING MOMENTS OF CONTINUOUS SLABS



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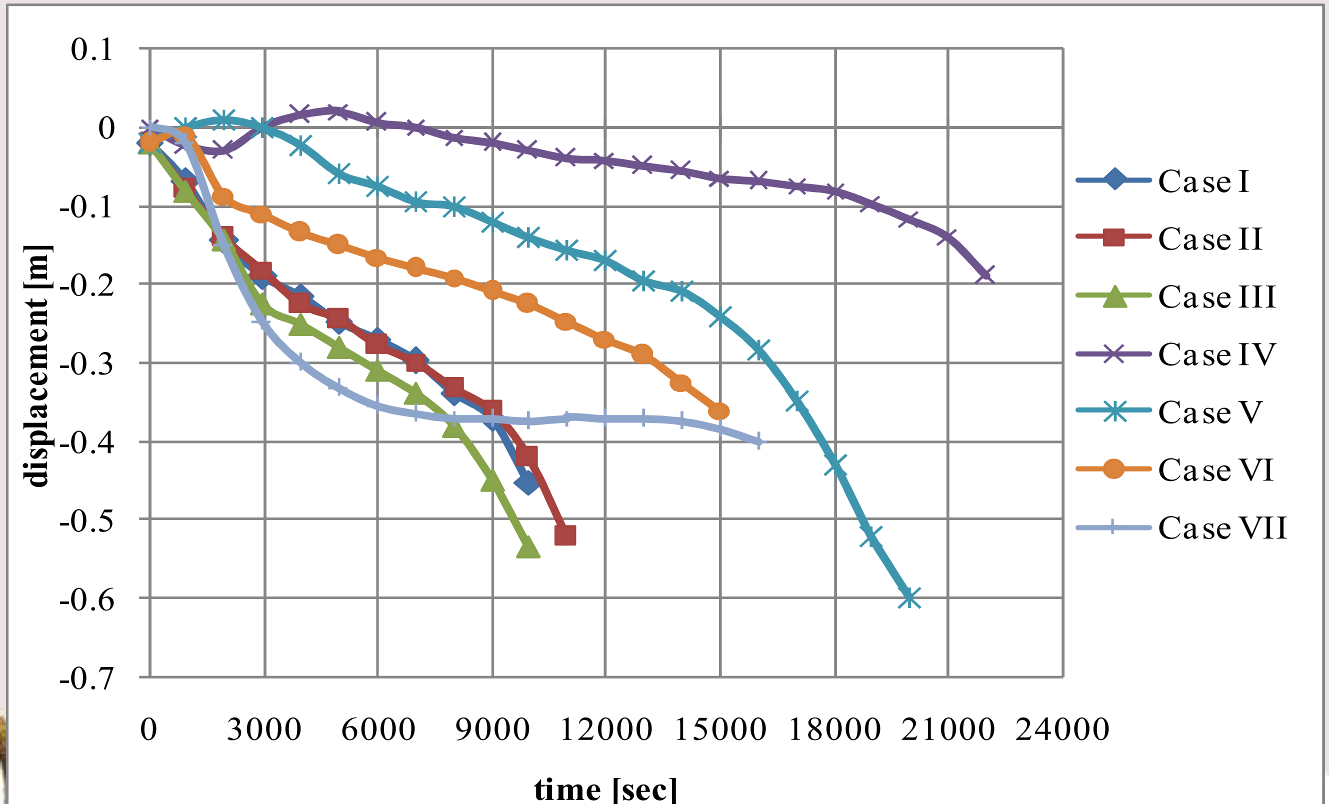
CONTINUOUS RC SLABS

DIFFERENT FIRE SCENARIOS

VERTICAL DISPLACEMENTS AT LOCATION OF MAXIMUM POSITIVE MOMENT



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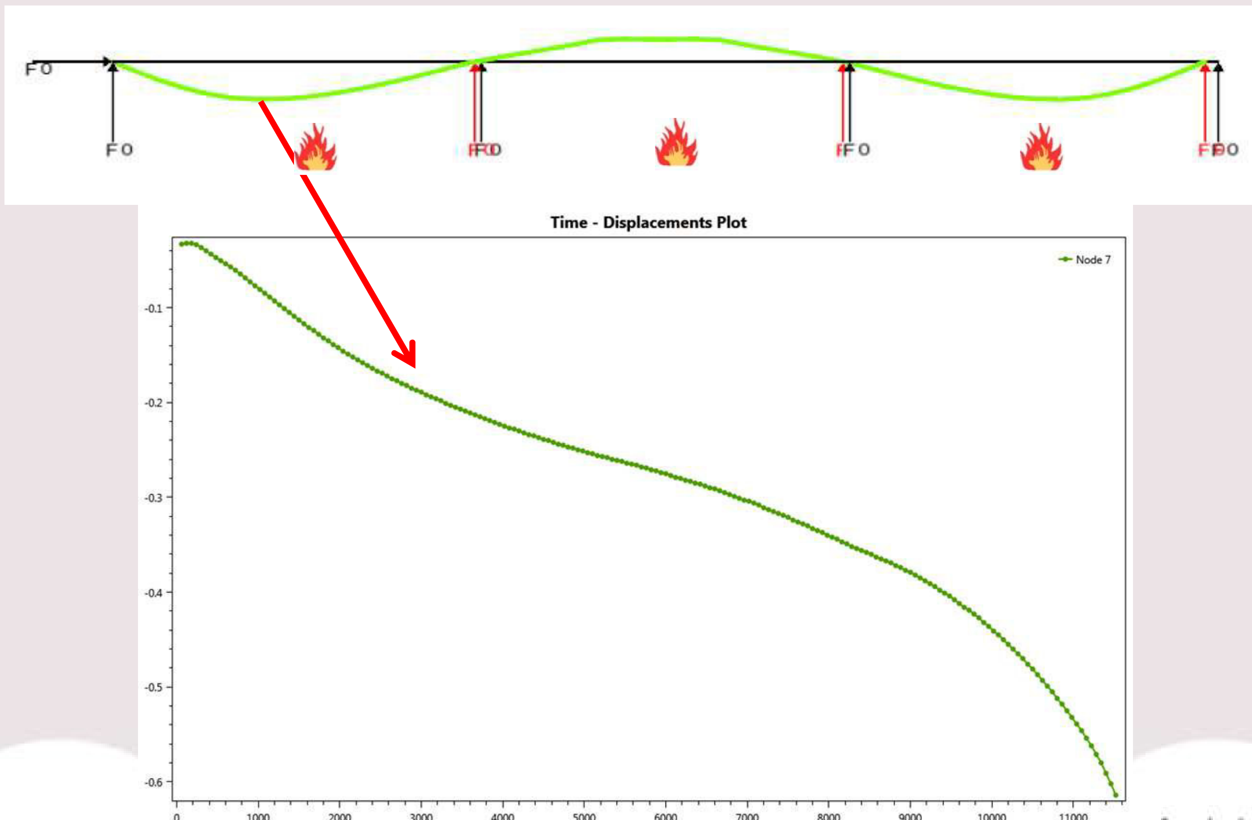
CONTINUOUS RC SLABS

DIFFERENT FIRE SCENARIOS

DEFLECTED SHAPE OF SLAB AT FAILURE AND TIME-DISPLACEMENT OF NODE AT MIDSPAN FOR CASE III



CONTINUOUS RC SLABS

DIFFERENT FIRE SCENARIOS

DEFLECTED SHAPE OF SLAB AT FAILURE AND TIME-DISPLACEMENT OF NODE AT MIDSPAN FOR CASE VII

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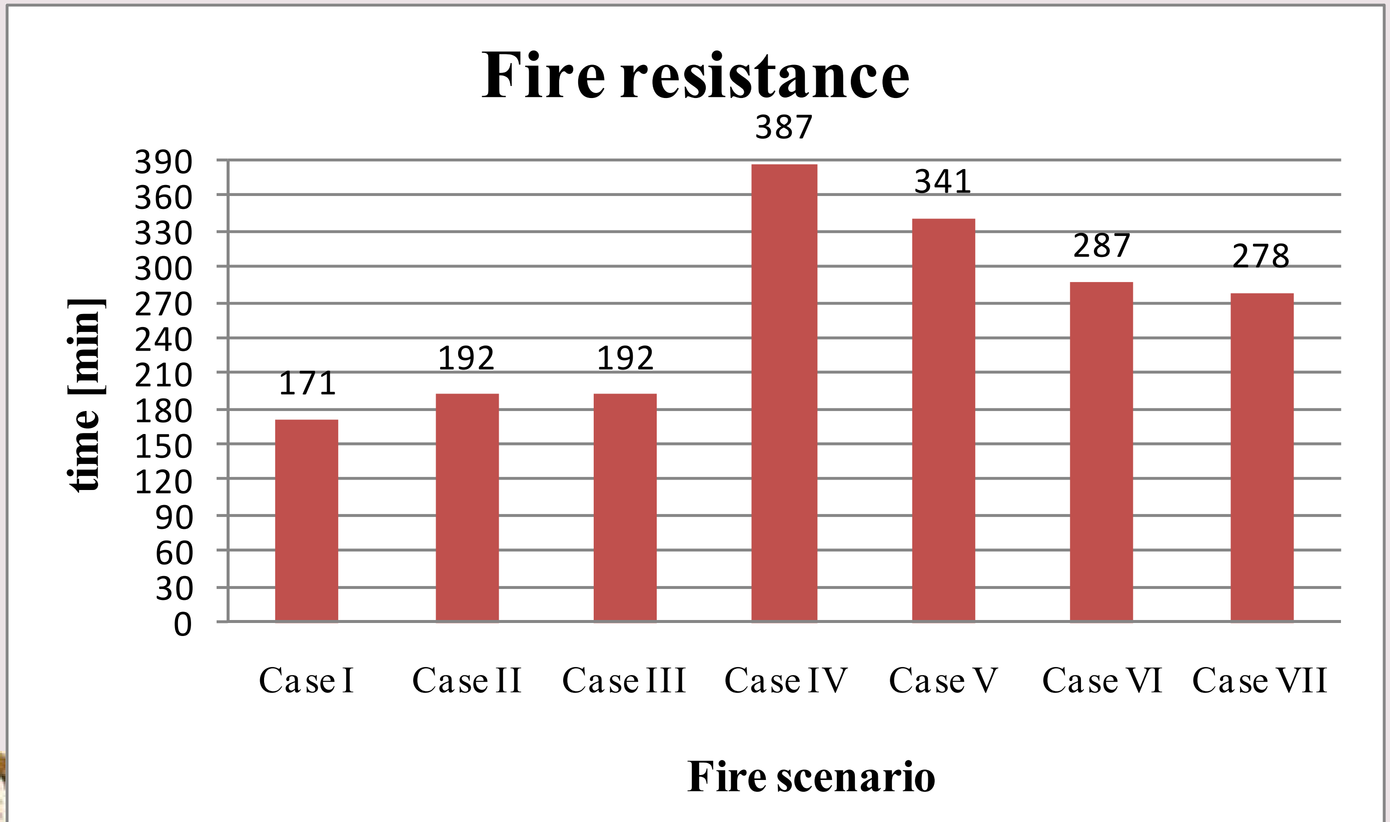
CONTINUOUS RC SLABS

DIFFERENT FIRE SCENARIOS

FIRE RESISTANCE OF SLABS FOR VARIOUS FIRE SCENARIOS



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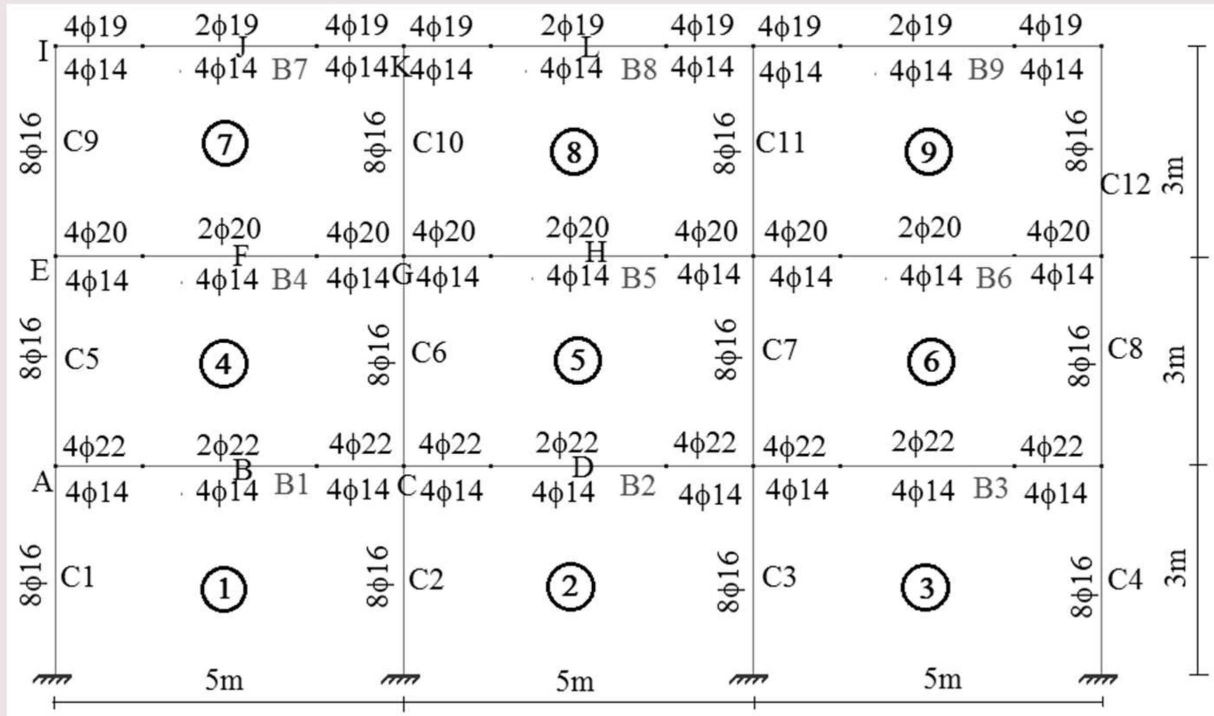
Fire resistance of RC frame structure

Case of different fire scenarios

Description of the problem



- Cross-sections:
  All beams: 35/45 cm
  All columns: 40/40 cm
- Loading:
  beams q=50 kN/m or q=67 kN/m

- Concrete: f_c=30 Mpa
- Steel: f_y=400 MPa

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Fire resistance of RC frame structure

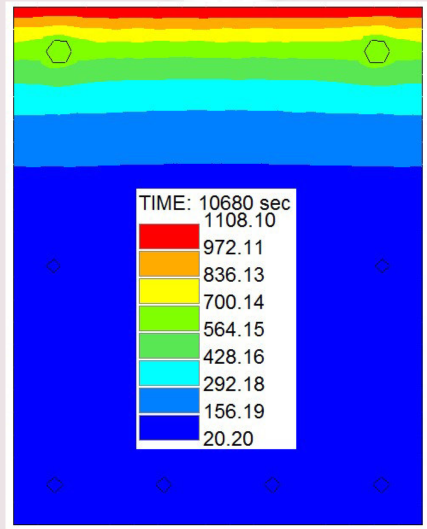
Thermal analysis

<u>Fire scenario II</u>

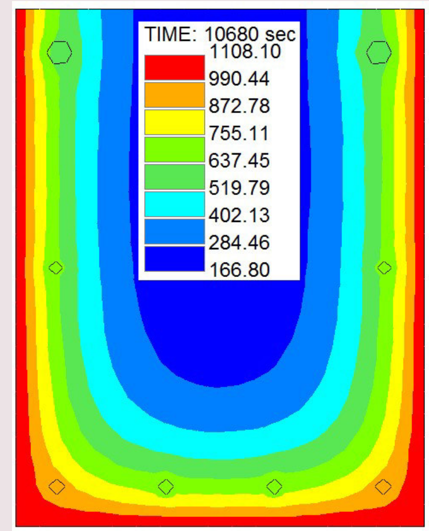
$(q/q_u=0.6)$

at the moment of failure of structure

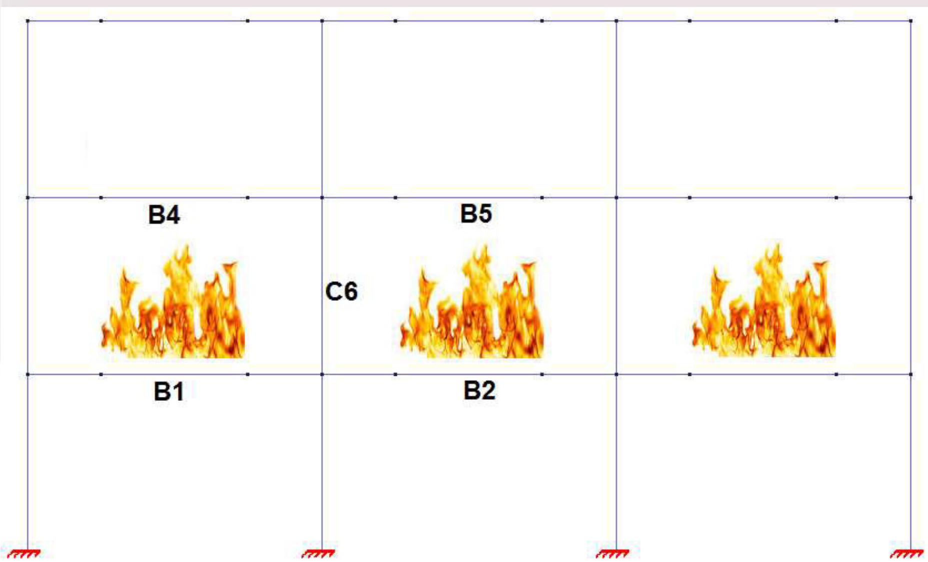
t = 2.97 hours

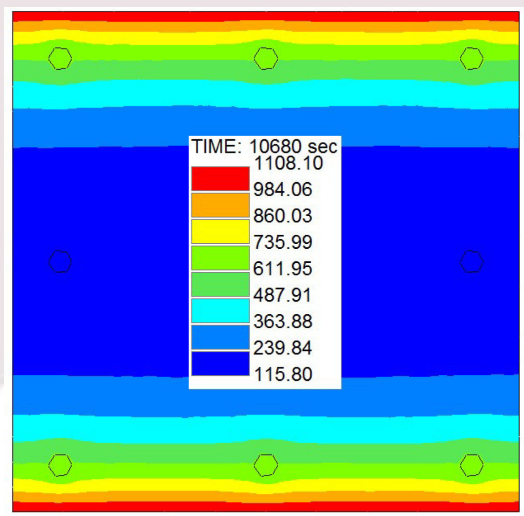


Beam B1



Beam B4





Column C6

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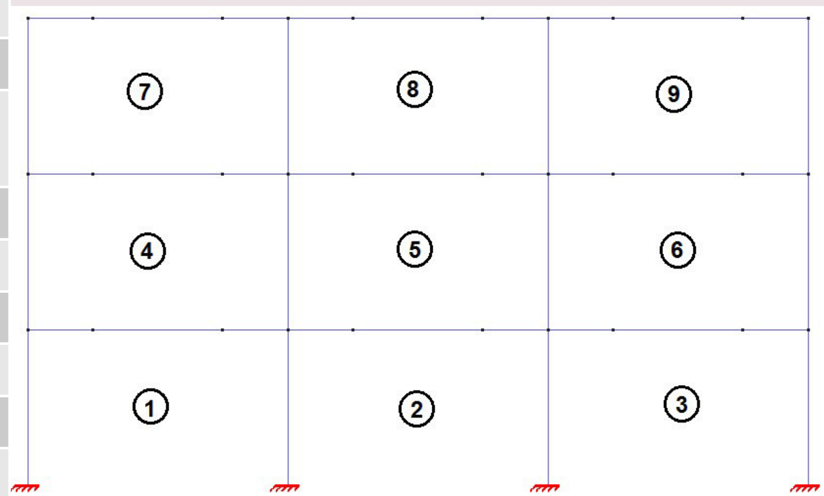
Fire resistance of RC frame structure

Structural analysis

Fire scenario	Spans involved in the fire compartment	Fire resistance for q/q_u=0.6	Fire resistance for q/q_u=0.8
I	1, 2, 3	3.60 hours	2.31 hours
II	4, 5, 6	2.97 hours	1.93 hours
III	7, 8, 9	2.12 hours	1.25 hours
IV	1, 2	3.6 hours	2.31 hours
V	1	3.59 hours	2.29 hours
VI	2	No failure before 5 hours	3.33 hours
VII	4, 5	2.95 hours	1.94 hours
VIII	4	2.99 hours	1.95 hours
IX	5	4.15 hours	2.52 hours
X	7, 8	2.13 hours	1.27 hours
XI	7	2.10 hour	1.25 hours
XII	8	2.49 hours	1.55 hours



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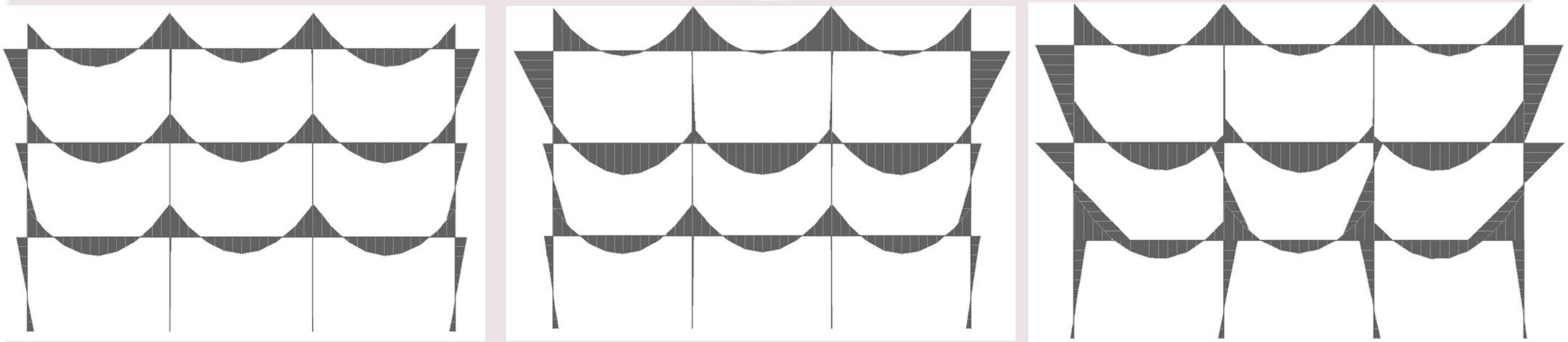
Fire resistance of RC frame structure

Structural analysis: Bending moments

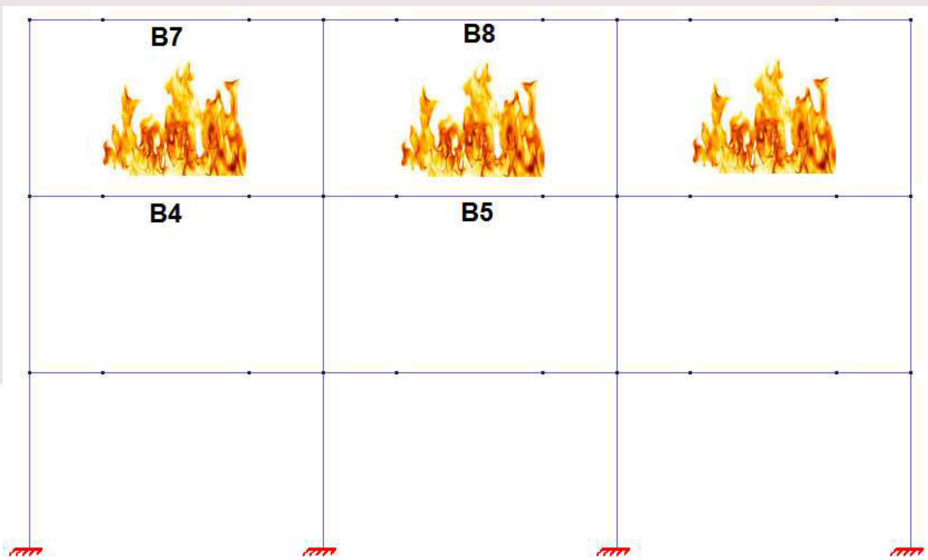


M - diagram at t=24 sec

M - diagram at t=9 min

M - diagram at t=2.12 hours (failure of structure)

Fire scenario III



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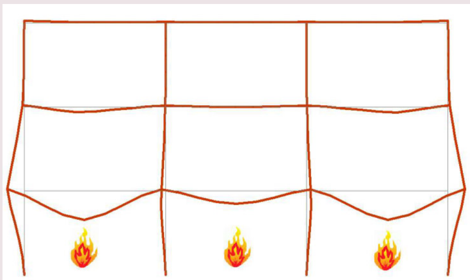
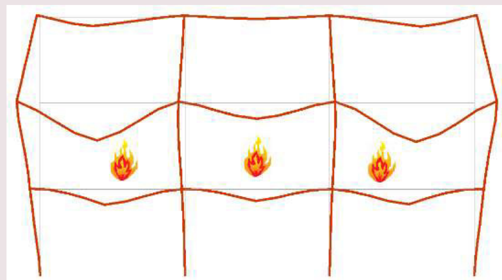
Fire resistance of RC frame structure

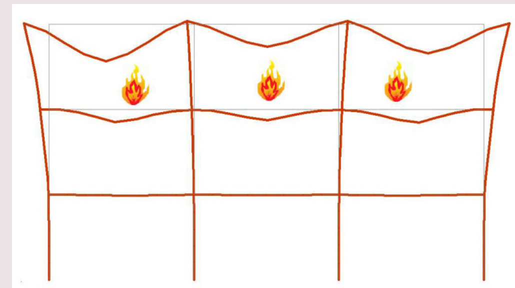
Structural analysis: Deflections

Fire scenario I, II and III



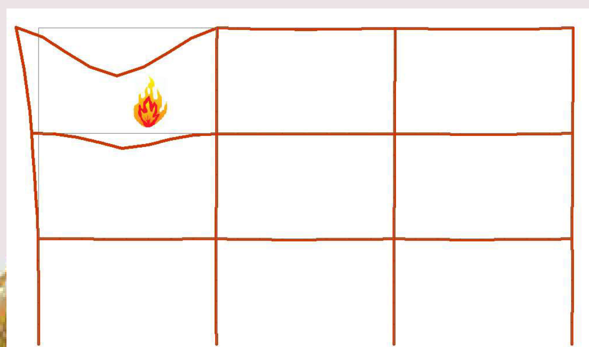
The best fire scenario



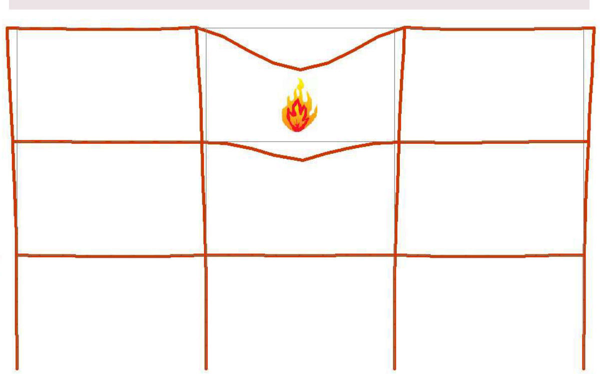


The worst fire scenario

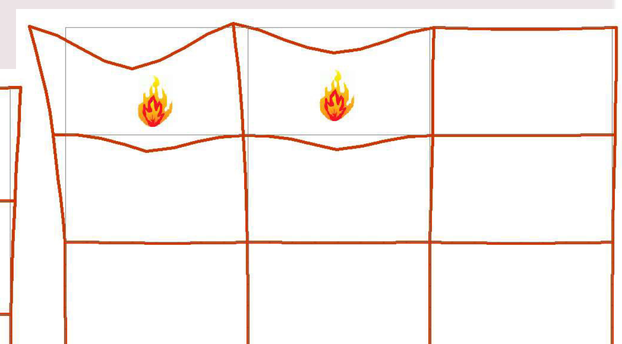
Fire scenario X, XI and XII



The worst fire scenario



The best fire scenario



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Fire resistance of RC frame structure

CONCLUSIONS

- The higher the fire compartment is, the lower fire resistance of the structure is reached.
- In all fire scenarios for a particular floor there is no difference in the fire resistance of the frame, except in the case when the fire compartment involves only the central span. Then, drastic improvement of the fire resistance is reached and lower lateral displacements occur (because of the high compression forces induced in the middle beams).
- Different levels of restrain from surrounding cold frame elements affect the deflections and the thermal expansions of the fire exposed beams.

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RC STRUCTURES

EFFECTS OF REAL FIRE

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RC STRUCTURES

EFFECTS OF REAL FIRE

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RC STRUCTURES

EFFECTS OF REAL FIRE

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RC STRUCTURES

EFFECTS OF REAL FIRE

FIRE RESISTANCE OF STEEL STRUCTURES

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UNPOTECTED
STEEL STRUCTURES

STEEL STRUCTURE AFTER FIRE

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UNPOTECTED
STEEL STRUCTURES

Only load bearing function **R** of steel structures is covered by the design rules of the fire part of Eurocode 3

Load bearing function of a structure is satisfied only if during the relevant duration of fire exposure **t**

$$E_{fi,d,t} \leq R_{fi,d,t}$$

where

$E_{fi,d,t}$: design effect of actions (Eurocodes 0 and 1)

$R_{fi,d,t}$: corresponding design resistance of the structure at instant **t**

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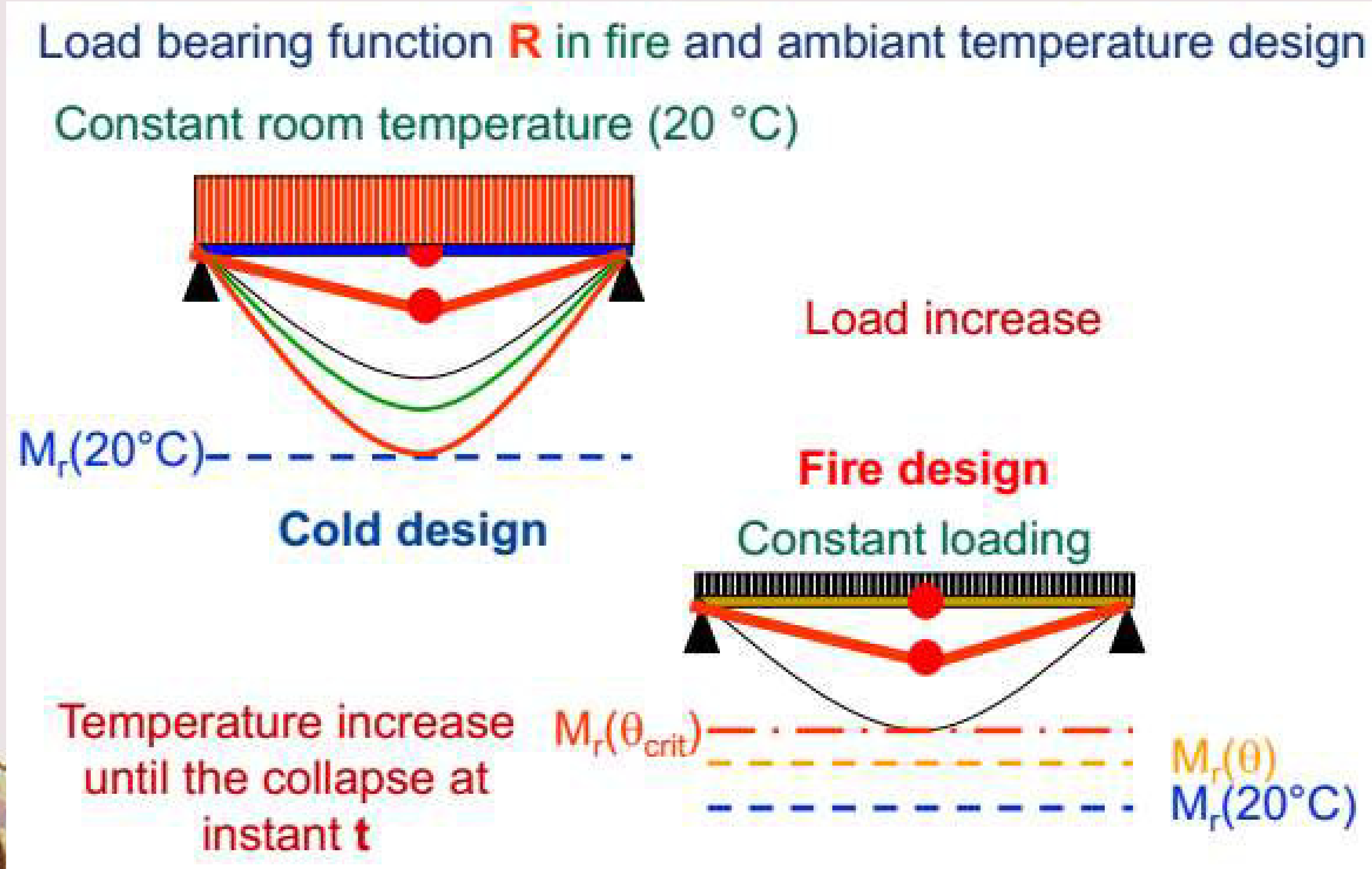
UNPOTECTED STEEL STRUCTURES



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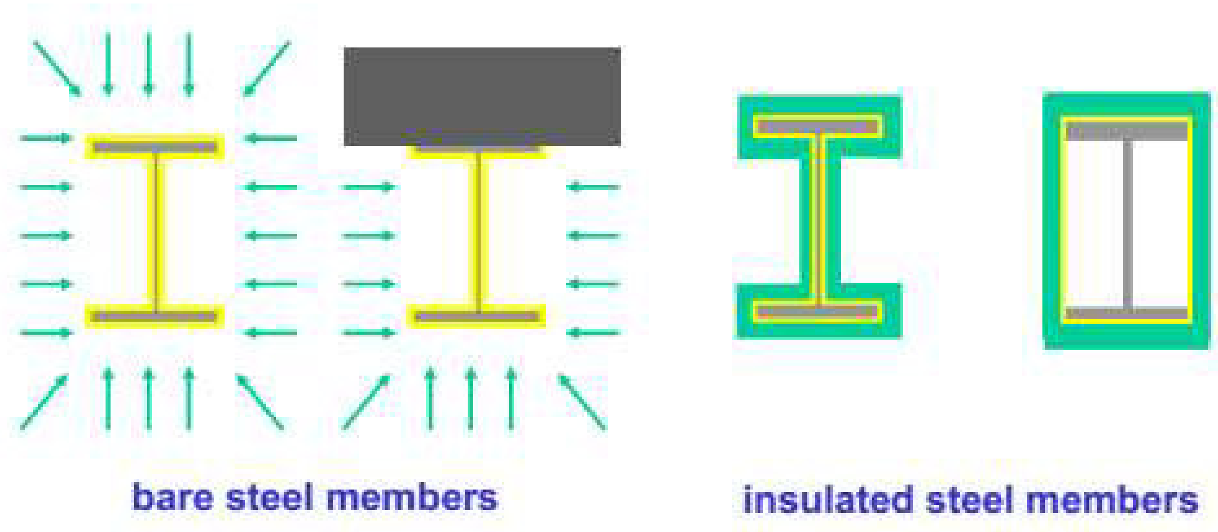
UNPOTECTED STEEL STRUCTURES

Section factor:



Definition: **ratio between "perimeter through which heat is transferred to steel" and "steel volume"**

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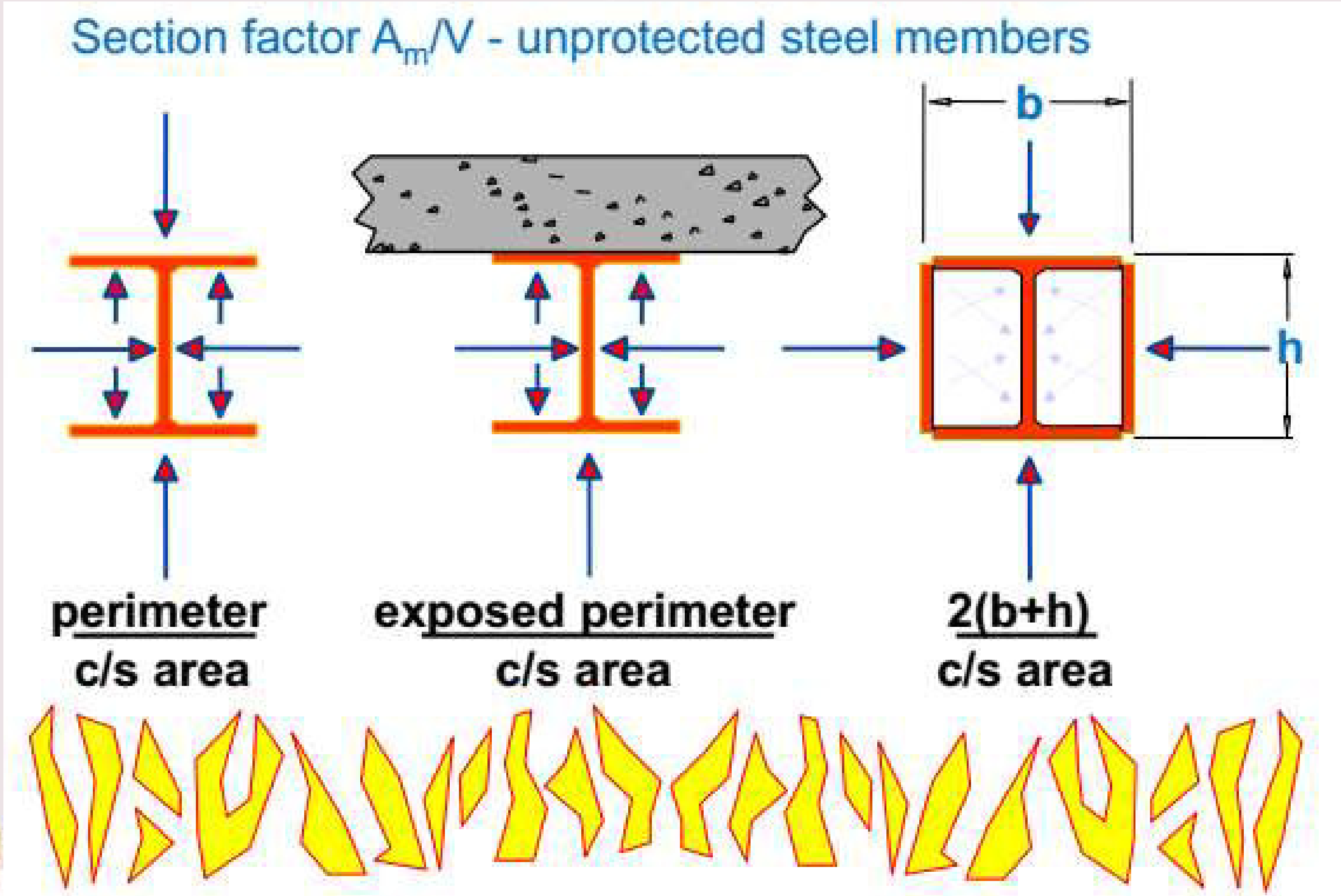
UNPOTECTED
STEEL STRUCTURES



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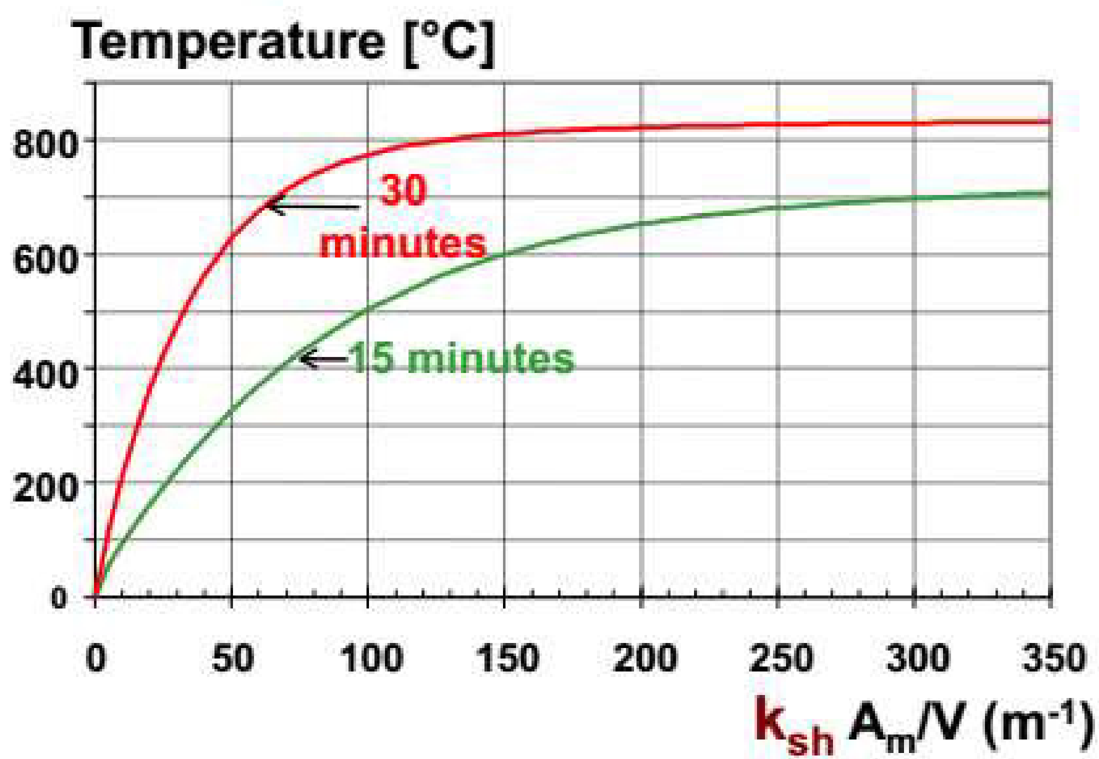
UNPOTECTED STEEL STRUCTURES

Steel temperature as function of Section Value

- Bare steel profiles



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FIRE RESISTANCE OF ENERGY EFFICIENT STRUCTURES

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FIRE RESISTANCE OF DIFFERENT TYPES OF SIMPLY SUPPORTED FLOOR STRUCTURES

- Comparing with the traditional one, the new contemporary materials are lightweight and have better thermal and acoustic properties, but it doesn’t mean that in case of fire the higher fire resistance should be achieved.
- Some of these materials (Styrodur, Styrofoam, etc) are thermally unstable when exposed to high temperatures.
- From that reason general recommendations on how to use these materials and the need for the fire protection of the floor structurs should be provided.

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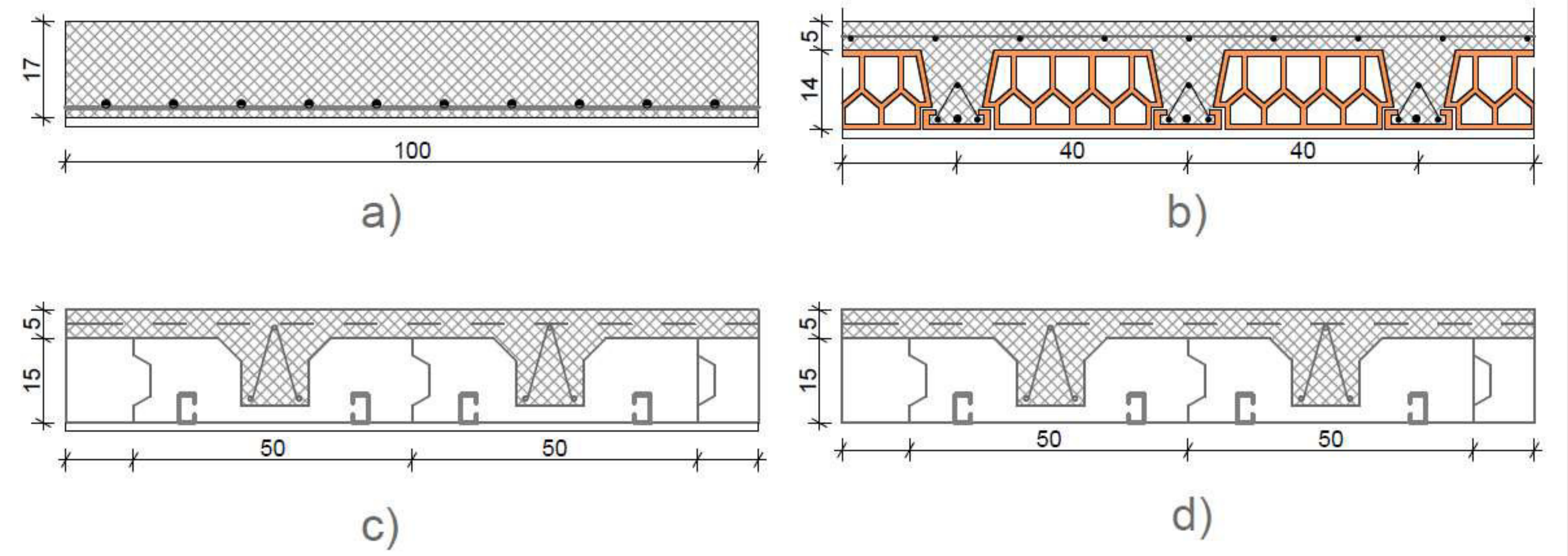
FIRE RESISTANCE OF ENERGY EFFICIENT STRUCTURES

Different types of floor structures:

a) RC slab;
b) slab system FERT;
c) slab system STIRODOM with plasterboard as thermal insulation;
d) slab system STIRODOM



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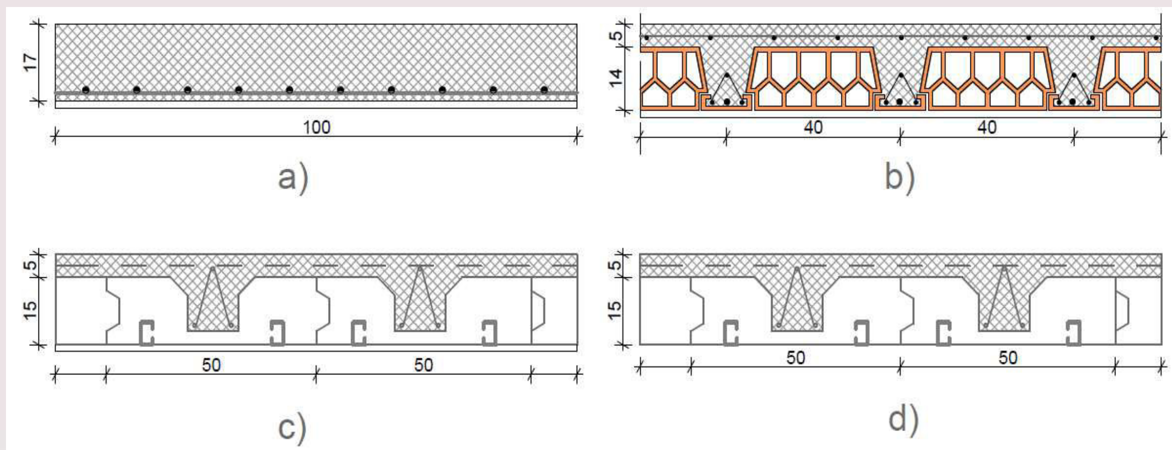
FIRE RESISTANCE OF ENERGY EFFICIENT STRUCTURES

Does the floor structure meet the required fire resistance criteria mainly depends on:

- mechanical and thermal characteristics of the materials used for the construction;
- initial loading level;
- support conditions;
- dimensions of the cross section;
- steel ratio;
- concrete cover thickness
- fire scenario.



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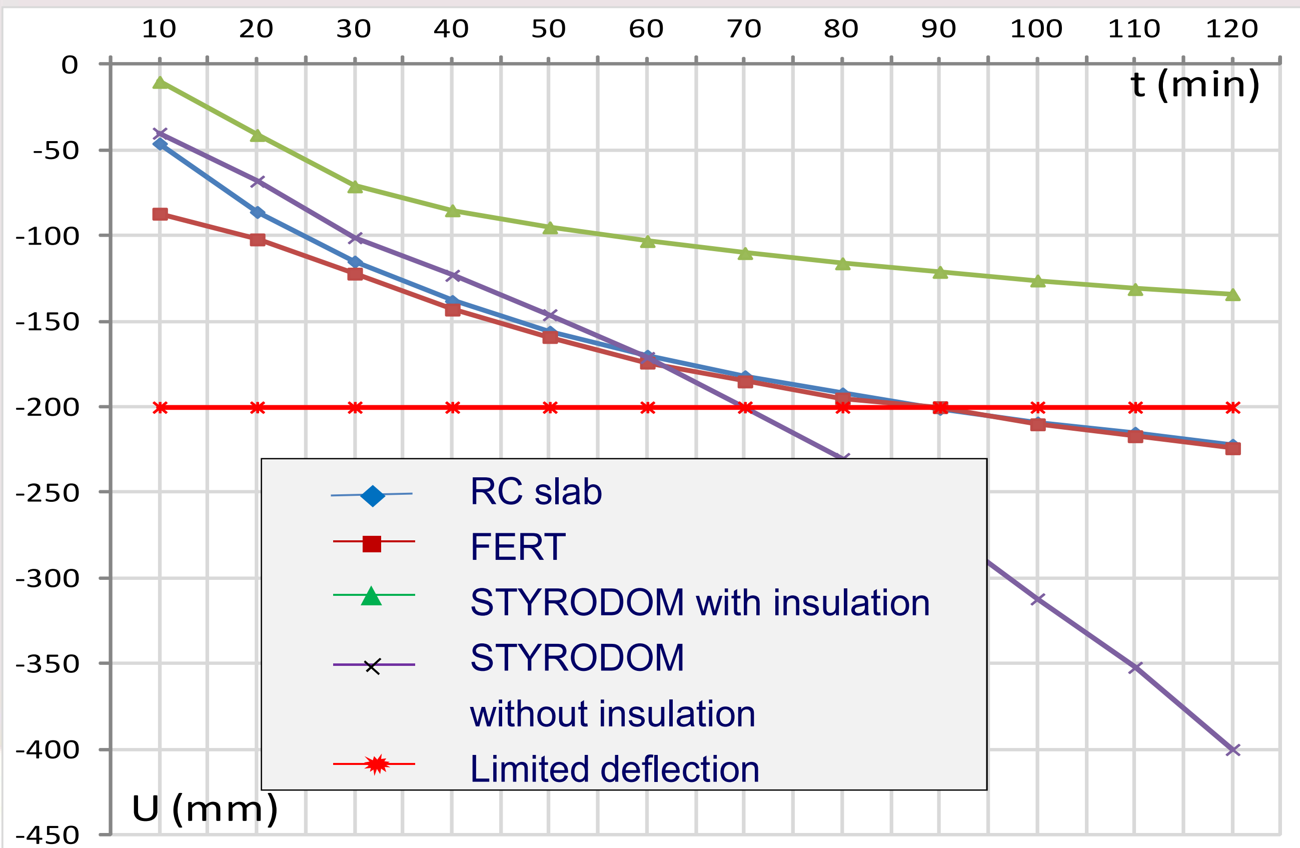
Criterion R

Time dependent vertical deflections of the simply supported floor structures exposed to fire from the bottom side



- Melting of the infill of extruded polystyrene-XPS starts at temperatures T=300°C.
- At temperatures T=450-500°C the infill is completely burned

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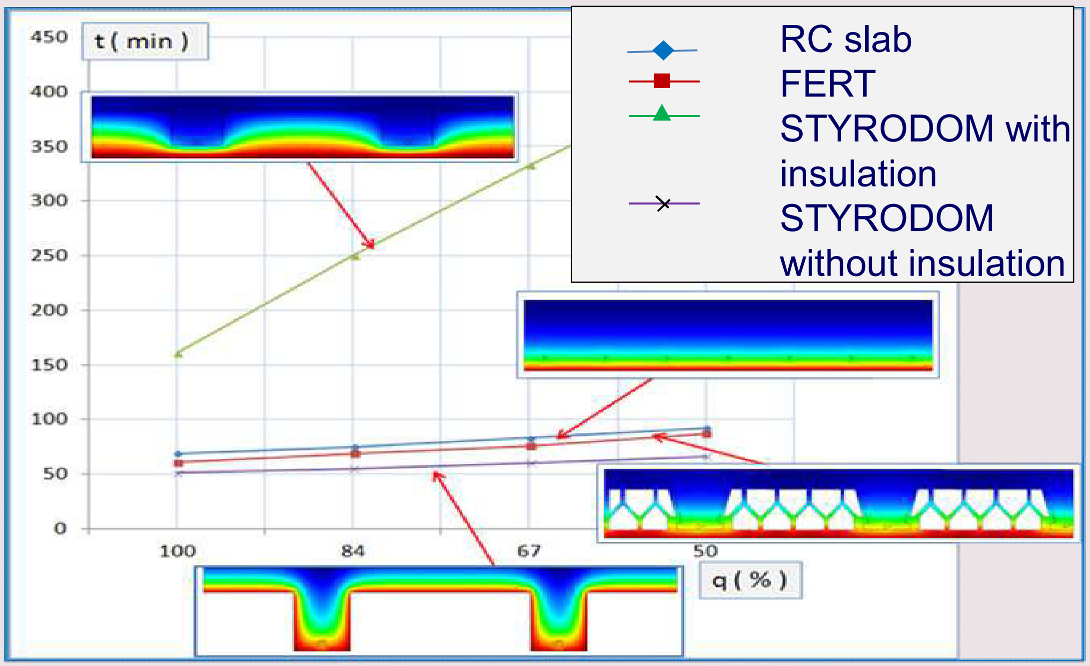
Criterion R

Fire resistance as function of the applied loads expressed as percentage of the design loads that cause deflections L/250



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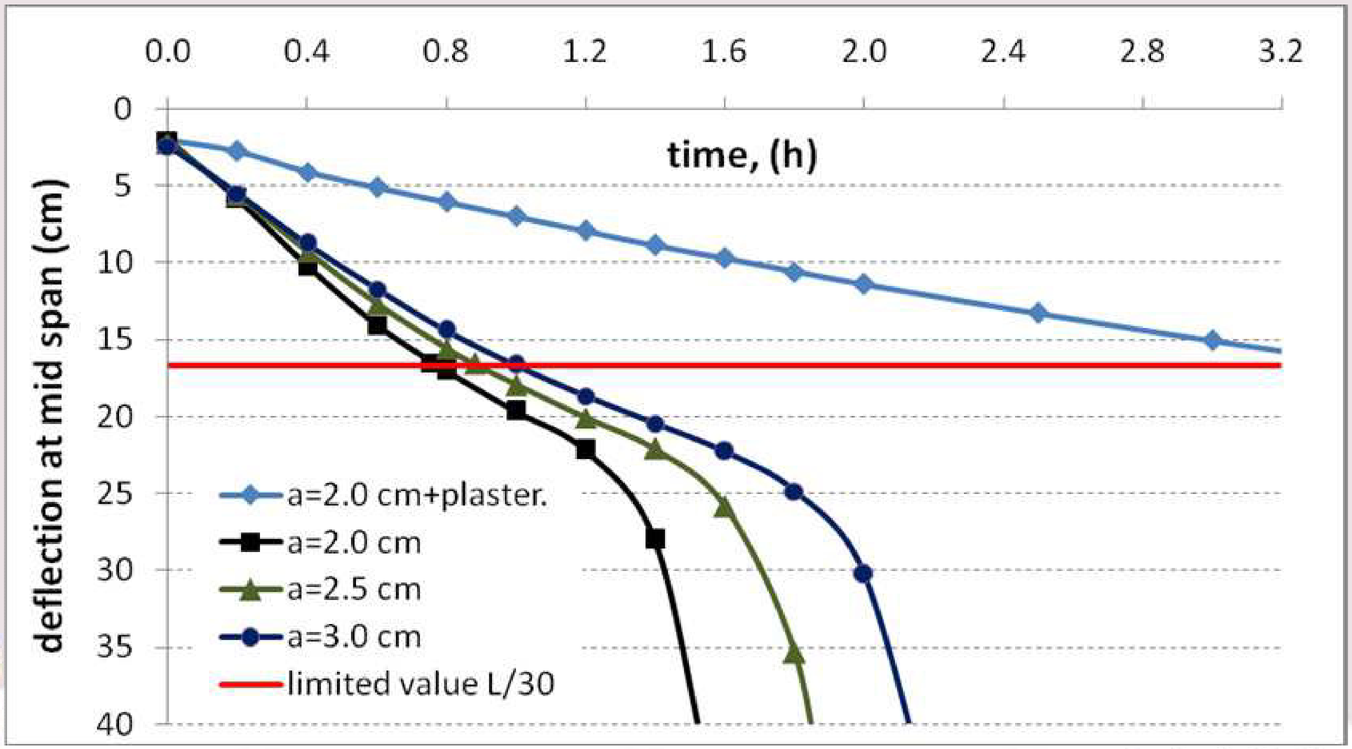
Criterion R

Deflection at the mid span of a simply supported RC beam as function of the concrete cover thickness "a" and insulation with plasterboard



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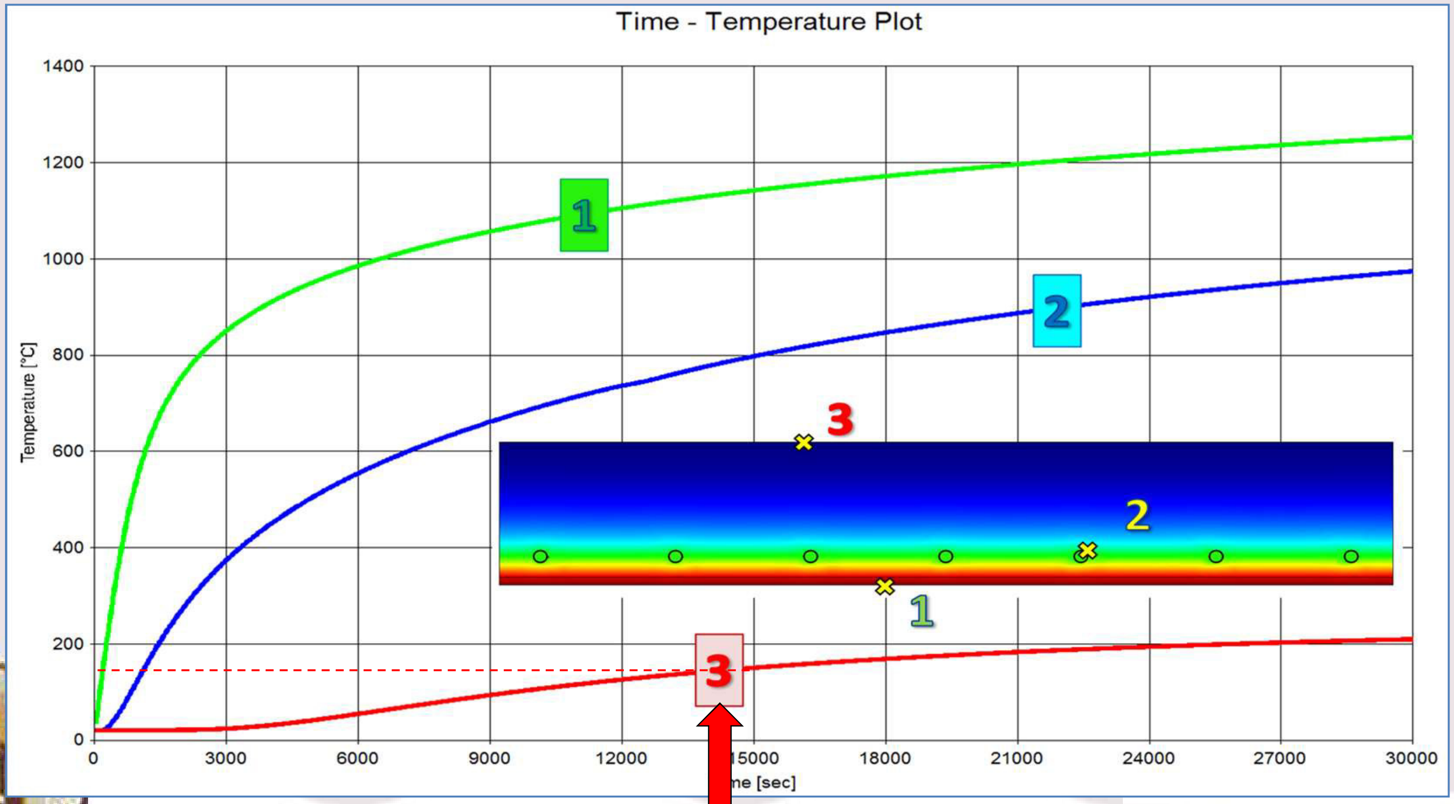
Criterion I

Temperatures in characteristic points of the cross section of RC slab



t=250min ⇒T=160°C

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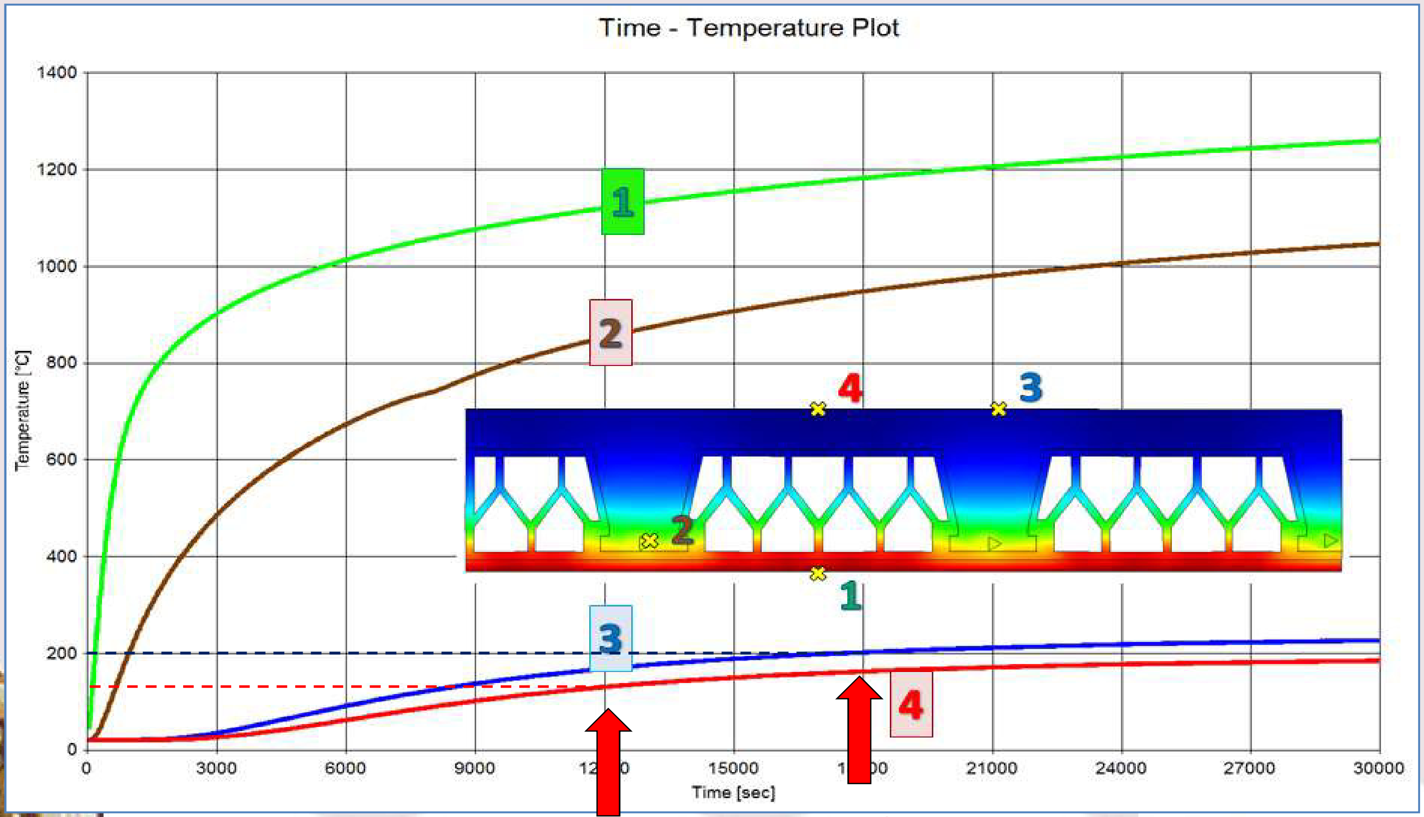
Criterion I

Temperatures in characteristic points of the cross section of the slab system FERT



t=300min ⇒T=200°C

t=200min ⇒T=160°C

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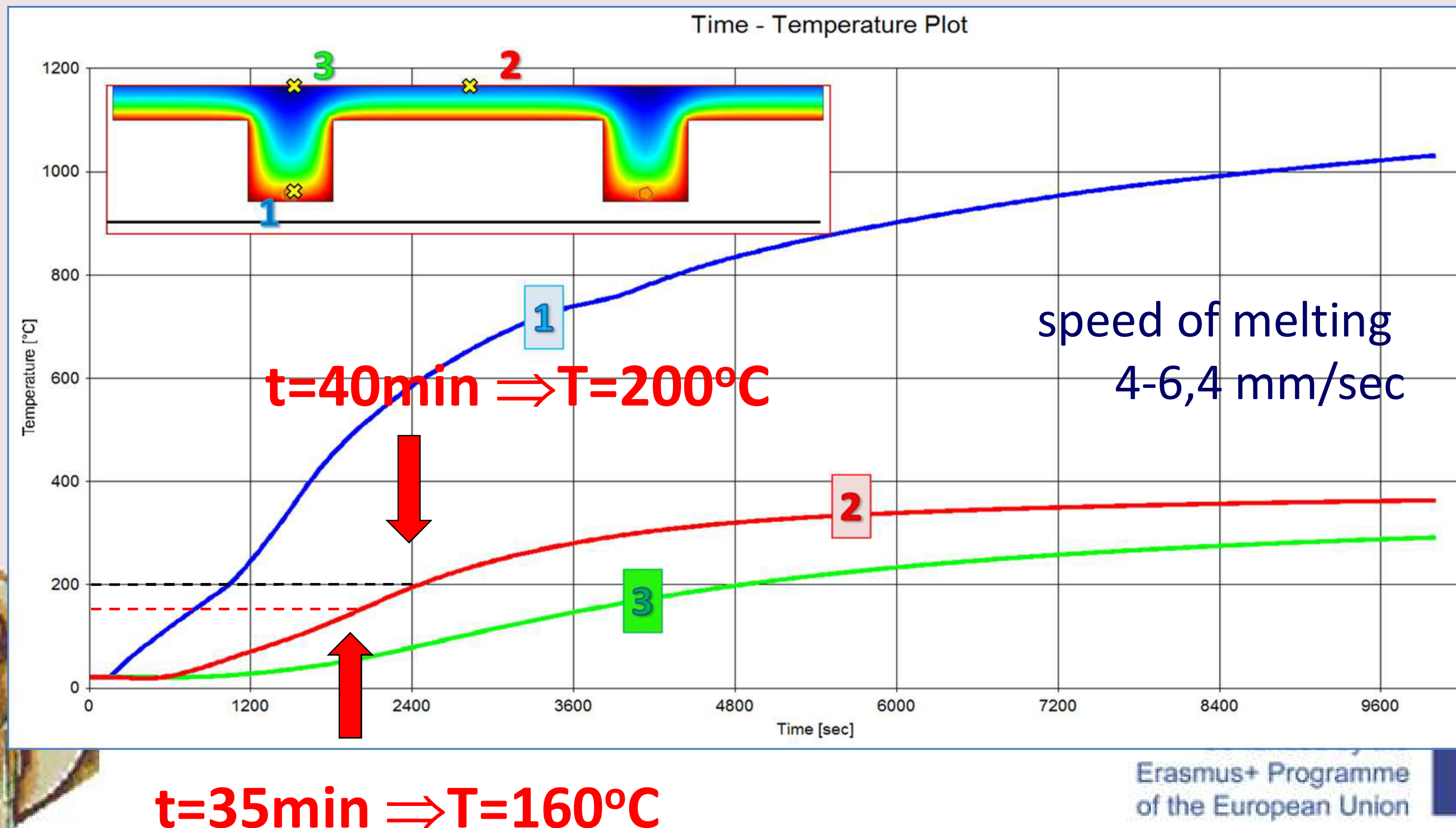
Criterion I

Temperatures in characteristic points of the cross section of the slab system STYRODOM

without plasterboard



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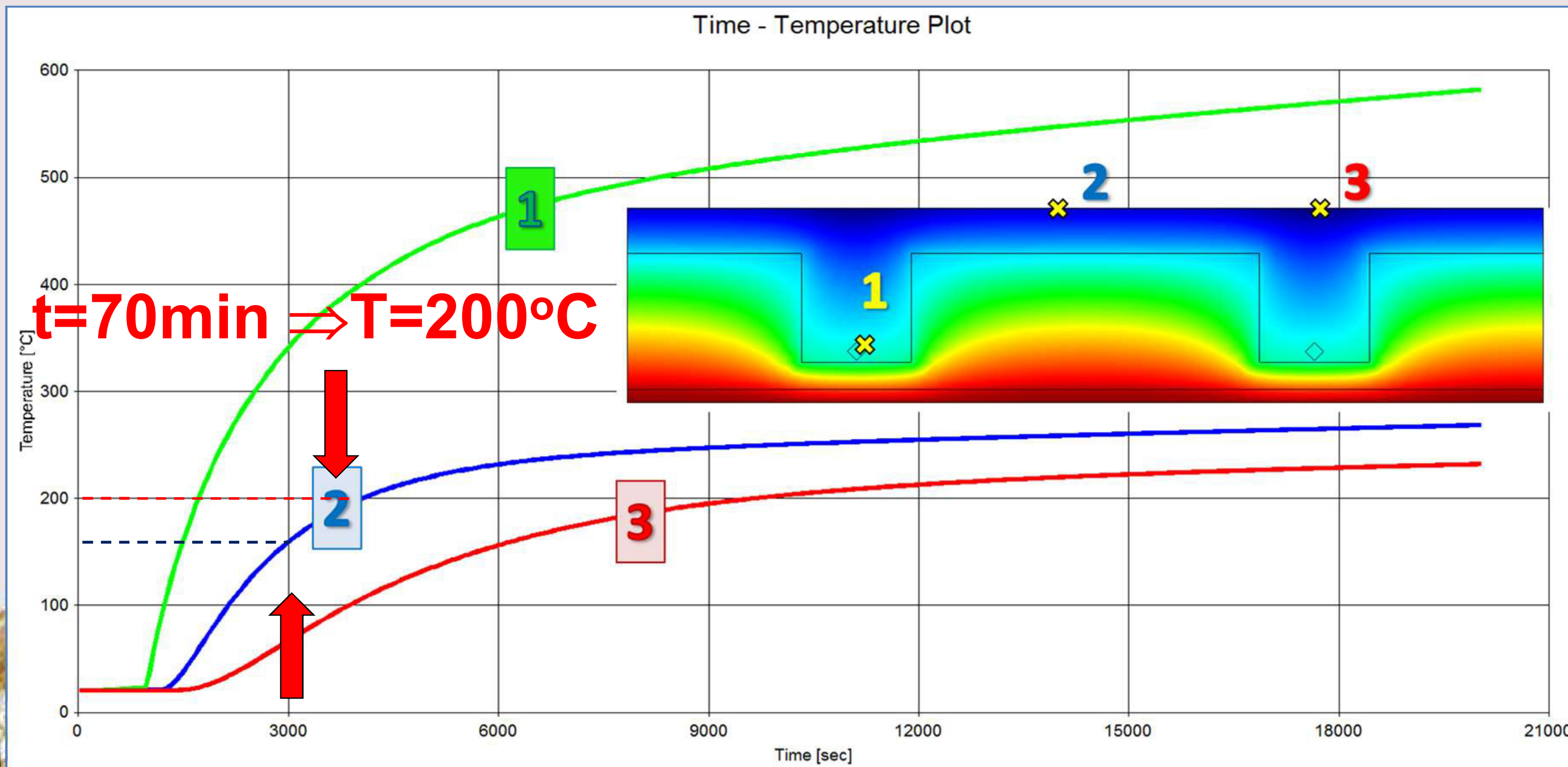
Criterion I

Temperatures in characteristic points of the cross section of the slab system STYRODOM

with plasterboard d=1.5cm



t=50min ⇒T=160°C

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CONCLUSIONS

- RC slabs have the best performance at ambient temperature, as well as in case of fire.
- The performance of the slab system FERT when exposed to fire is satisfactory too, but we should not neglect its lower stiffness and greater deflections at ambient temperatures.
- The fire resistance of the contemporary floor structures (STYRODOM, ITONG, etc.) depends on the thermal insulation of the slab.
- The infill of extruded polystyrene-XPS is sensitive on temperatures over 300^{o}C, therefore we should no avoid these structures, but it is necessary to provide protective measures.
- Findings in this paper underline the positive effect of using a thicker concrete cover thickness or thermal insulation on increasing the fire resistance of simply supported RC slabs.

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GENERAL CONCLUSIONS

- Treating fire only through architectural and urban design recommendations and fire protecting elements with isolation materials was not enough.
- There is a necessity of understanding the behavior of fire exposed:

  construction materials,

  structural elements,

  assemblies and whole structures.

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FIRE RESISTANCE OF ENERGY EFFICIENT STRUCTURES

ARE THE ENERGY EFFICIENT FASADES SAFE IN CASE OF FIRE???

After 12 minutes
„flash-over“ 1st floor

After 20 minutes
„flash-over“ 2nd floor

After 25 minutes

FIRE RESISTANCE OF ENERGY EFFICIENT STRUCTURES

SKOPJE 2016

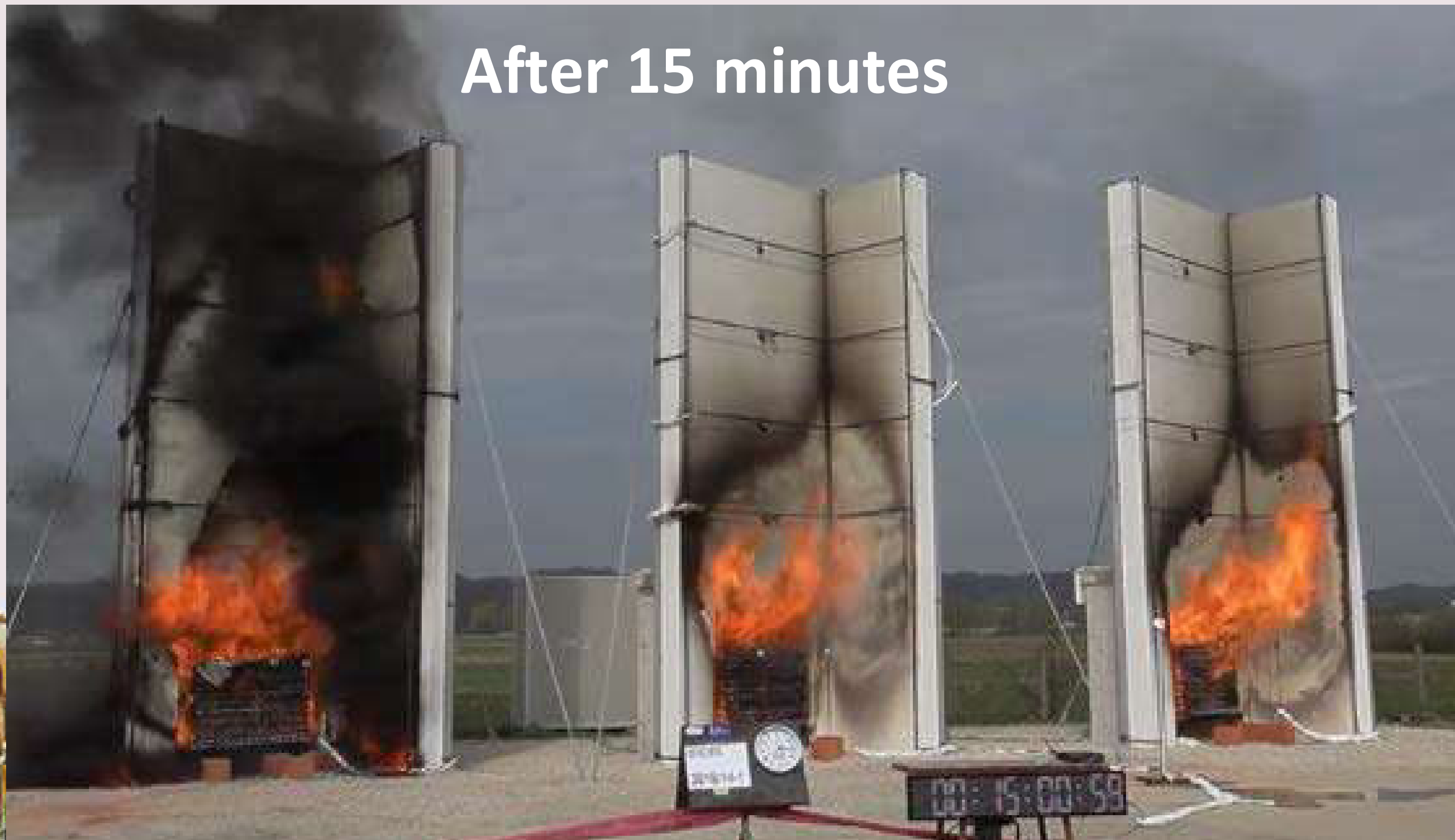
FIRE RESISTANCE OF
ENERGY EFFICIENT STRUCTURES

FFT PROJECT (Façade Fire Testing)

BS 8414 standard test

FIRE RESISTANCE OF
ENERGY EFFICIENT STRUCTURES

FFT PROJECT (Façade Fire Testing)

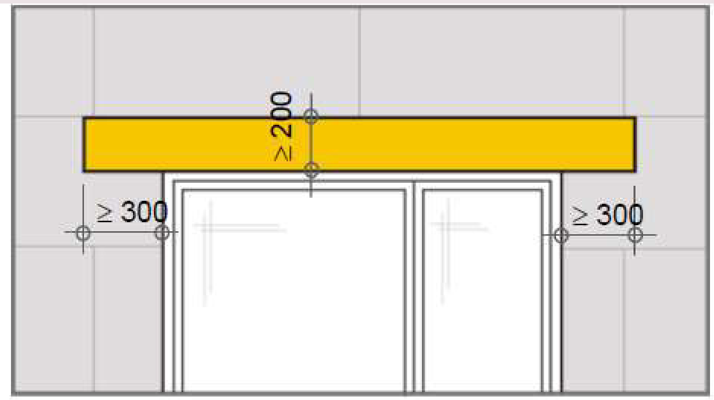


FIRE RESISTANCE OF ENERGY EFFICIENT STRUCTURES

FFT PROJECT (Façade Fire Testing)

FIRE RESISTANCE OF ENERGY EFFICIENT STRUCTURES

HOW WE CAN SOLVE THE PROBLEM ?



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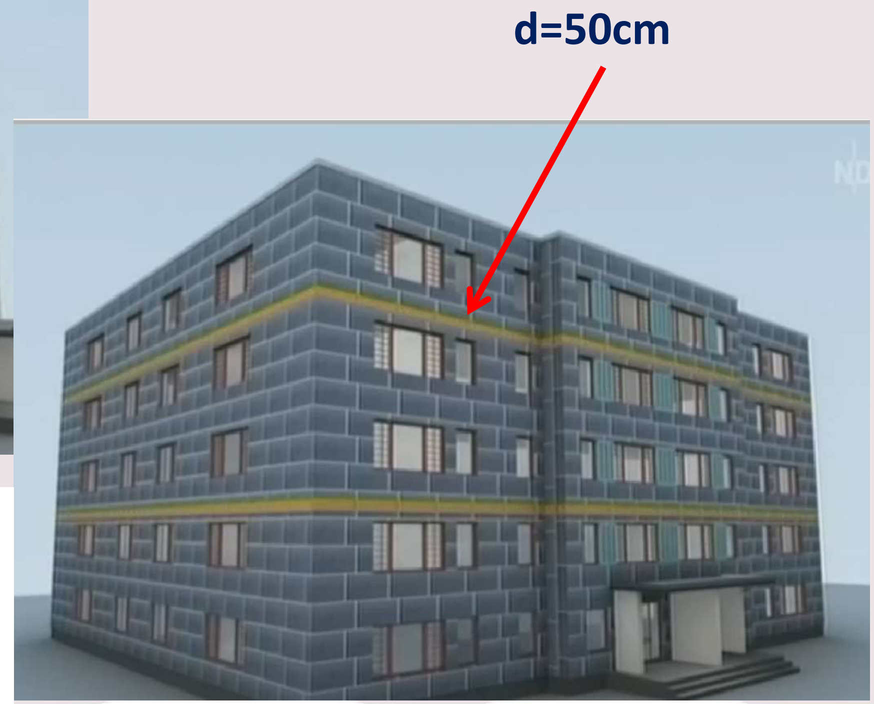
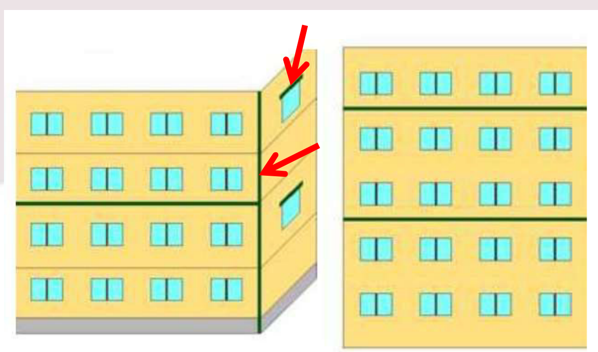
HOW WE CAN SOLVE THE PROBLEM ?





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SOMEBODY DID IT CORRECTLY

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FIRE RESISTANCE OF
ENERGY EFFICIENT STRUCTURES

BUT SOMEBODY DID’T !!!

SOMEBODY UNDERSTOOD OPOSITE !!!

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K-FORCE

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Thank you for your attention!

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