Date: 27-06-2017

Place: Technical University of Denmark

Knowledge FOr Resilient soCiEty

MiB Courses 11B12 and 11B01 (11023)

Luisa Giuliani

Technical University of Denmark

Department of Civil Engineering (DTU-BYG)

DTU Civil Engineering
Department of Civil Engineering

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

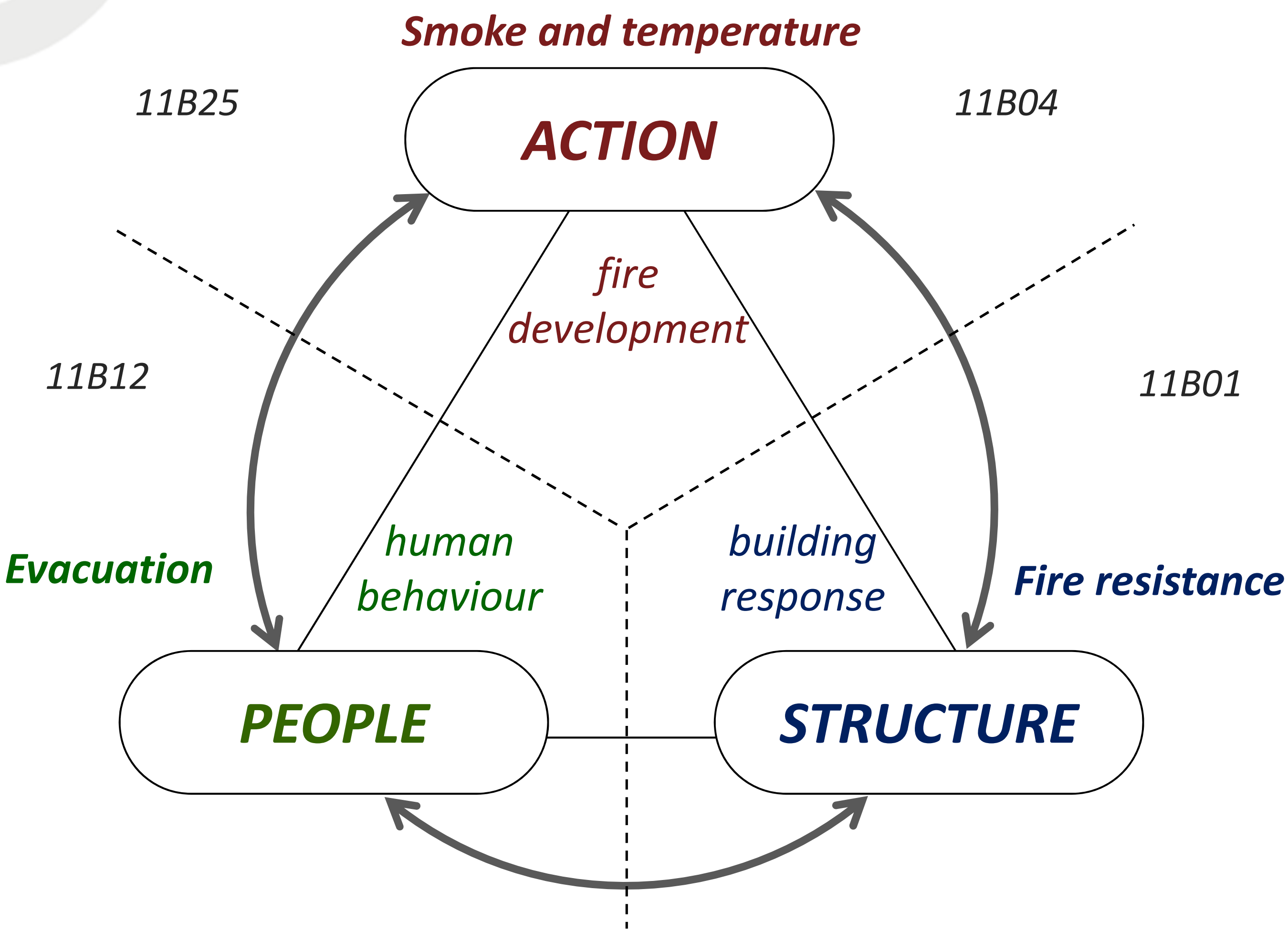
Integrated CAD for fire safety:

11B12: Brandmodellering (CAD Fire)

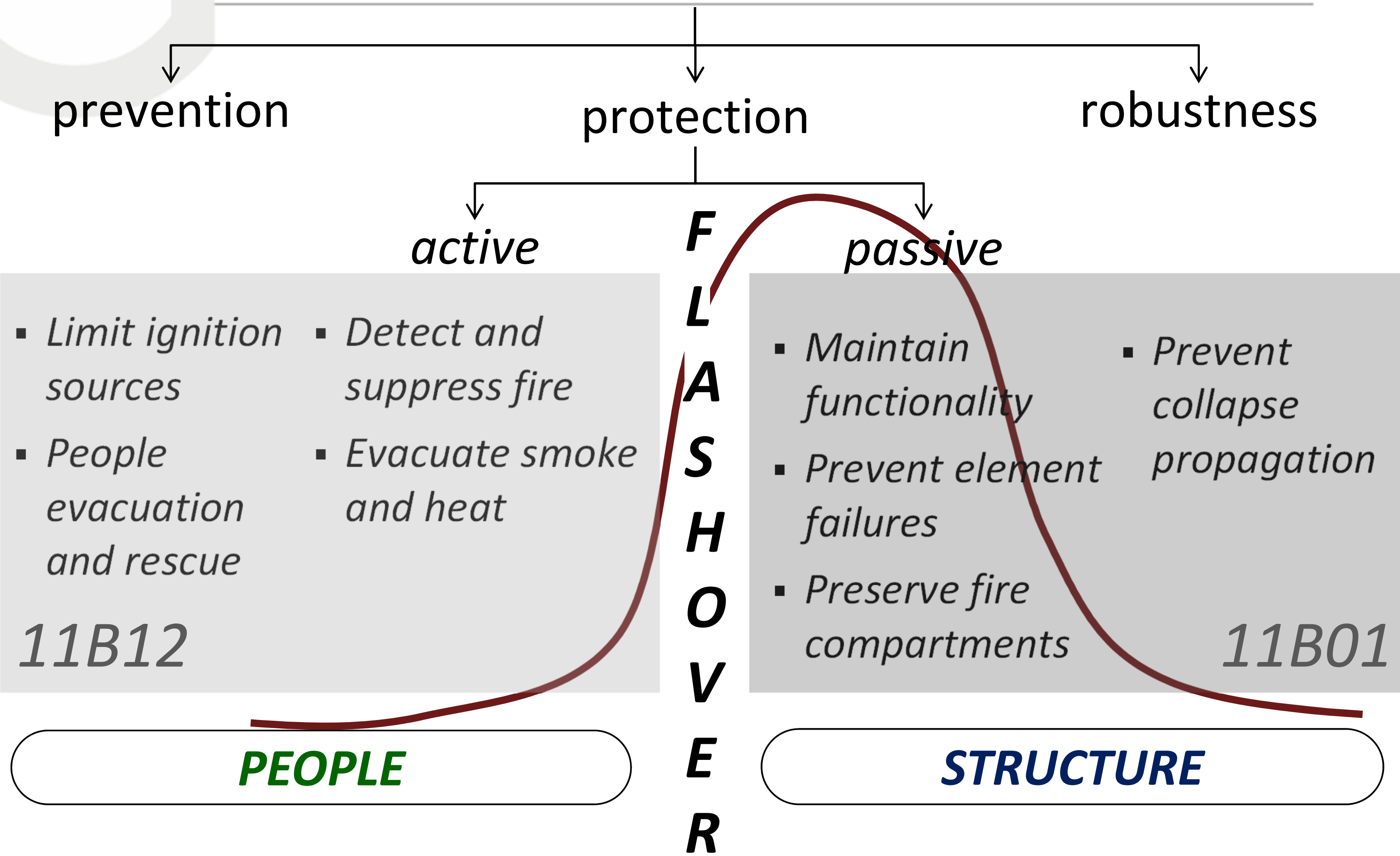
Structural fire safety design :

11B01 & 11023 Konstruktionbrandteknik

Interdisciplinarity in Fire Safety Design



Fire Safety Design Strategies



Integrated CAD for fire safety:

11B12: Brandmodellering (CAD Fire)

11B12 - Brandmodellering

Education: MIB (Master I Brandsikkerhed)

ECTS points: 5

Work load: 280 hours

Lectures: 27 hours (3 modules of 1 ½ day each)

Duration: August - November + examination in January

Course responsible: Luisa Giuliani

Teachers: Luisa Giuliani (fire) and Christian Kindler (evacuation)

Feedback: Report on fire spread (I module) + Report on Evacuation (II module)

Evaluation: Report on Final Assigment

11B12 - Brandmodellering

	I MODULE		II MODULE		III MODULE	
9-10.30	INTRO FDS-INPUT	FDS-THEORY	EVACUATION BASICS	VALIDATION MODEL REF.	ASS.1 - SOLU RECAP	EVAC&STEPS ADVANCED
10.45-12	EX1-INPUT	ASS.1 – FIRE Q&A	EVACUATION MODELING	ASS.2 - EVAC Q&A	VALIDATION ADVANCED	FINAL ASS. Q&A. EVAL.
13-14.30	FDS-OUTPUT EX2-OUTPUT		STEPS - HANDS ON		FDS ADVANCED	
14.45-16	VALIDATION EX3-MESH		STEPS - STAIRS		ASS.2 - SOLU RECAP	

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11B12 – Characteristic of a CFD solver

AXISIMMETRIC	Two-dimensional	*F*	Three-dimensional	GASSES
BUIDLING ENERGY	Steady-state	*L*	Time-dependent	VARIABLE (WAVES) OSCILL. (VORTEX) TRANSIENT (FIRE)
STRATIFIED GASES, LIQUIDS	Incompressible	*U* *I*	Compressible	SOUND, EXPLOSION
NO FLOW SEPARATION	Inviscid	*D*	Viscous	FRICTION BOUNDARIES
	Linear	*F*	Turbulent	FLOW MIXING OR SEPARATION, SMOKE, WAVES
LIQUID, COLD GASSES	Convection and conduction	*L* *O*	Radiation too	HOT GASSES
NO FLAME	Temperature-driven	*W*	Combustion-driven	MASS/ENERGY TRANFER

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

Hydrodynamic model

The problem is to predict the evolution of the fluid flow, given a set of initial and boundary conditions.

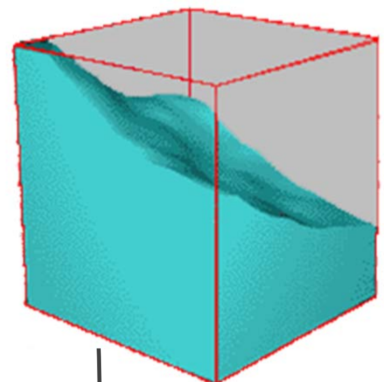
"Rien ne se perd, rien ne se crée…"

Conservation of mass:

RATE OF CHANGE inside V = FLUX through surfaces + ~~SOURCE inside V~~

FLUX through surfaces → CONVECTION /ADVECTION through surfaces + ~~CONDUCTION/ DIFFUSION through surfaces~~

$$\frac{\partial \rho}{\partial t} + \nabla(\rho \cdot \mathbf{v}) = 0$$



reference volume V

11B12 – FDS Syntax

start character

separator (blank space or enter)

```
&<NAME LIST GROUP>
  <PROPERTY1 NAME> = <property1 value>
  ..............................   ......................
  <PROPERTYn NAME> = <propertyn value> /
```

← group of data

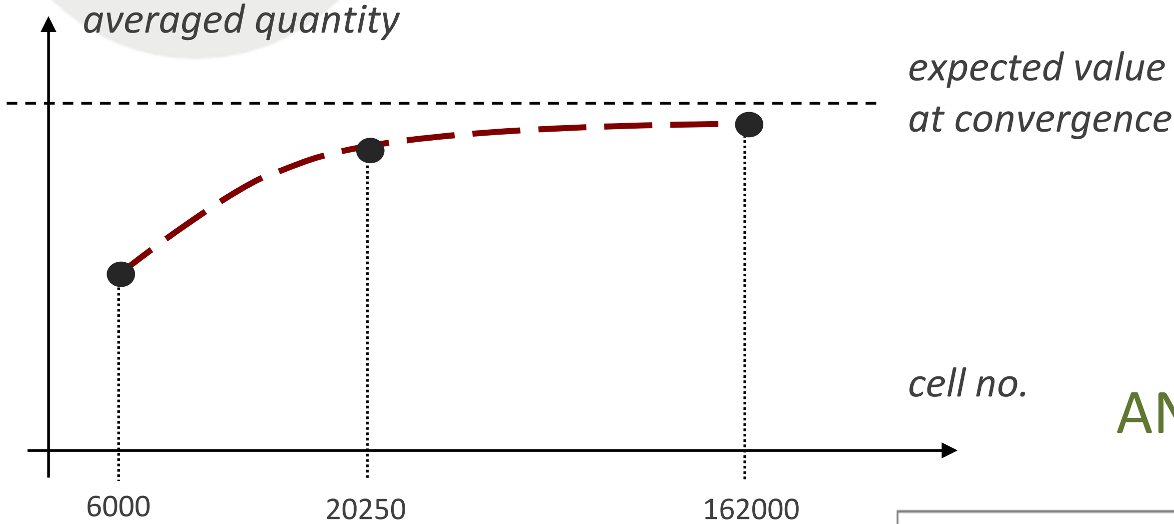
← attributes for the group

assignment

end character

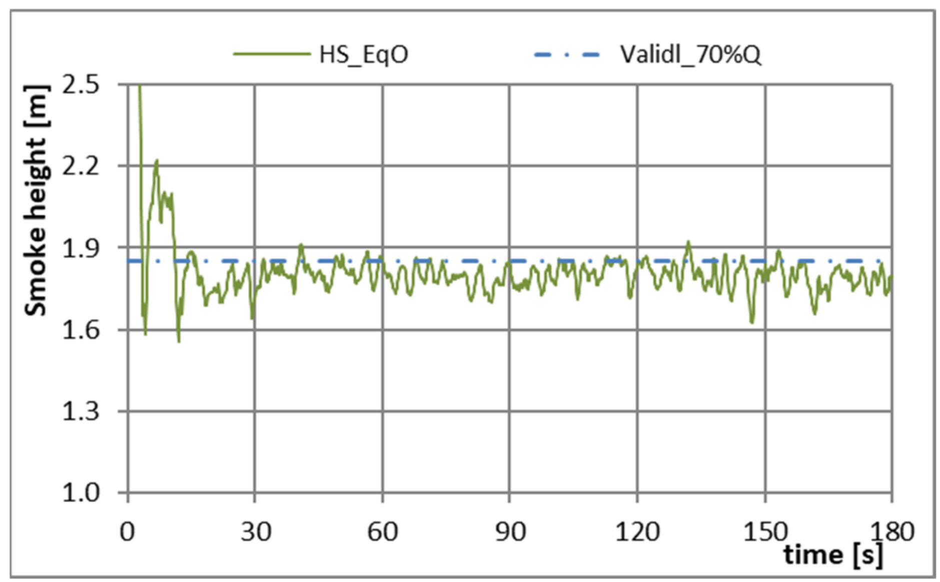
label identified by apices such as: **‘name’**

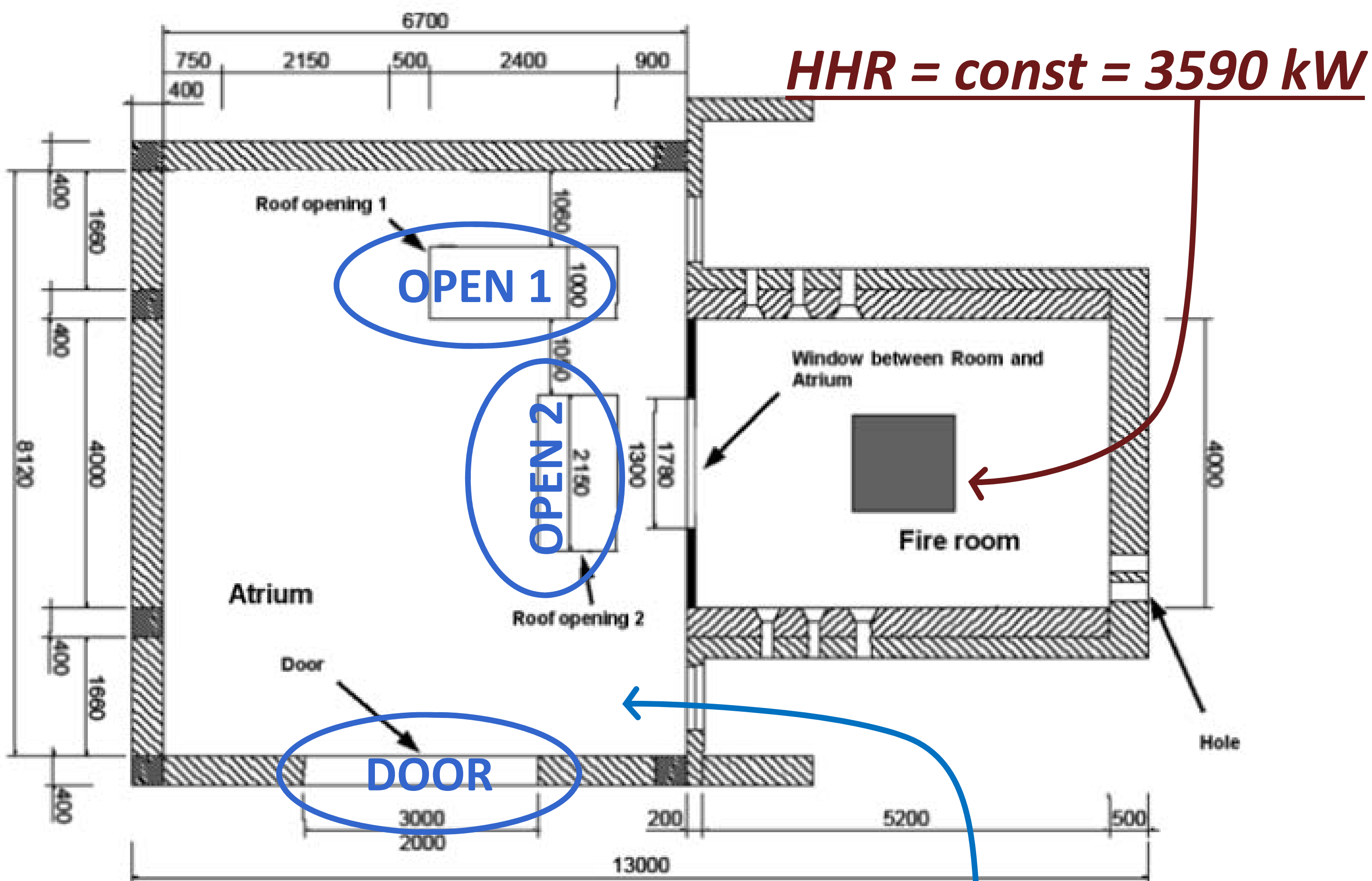
numbers (use “.” for decimal) separated by “,”: **0.0, 4.5, …**



MESH CALIBRATION

ANALYTICAL VALIDATION





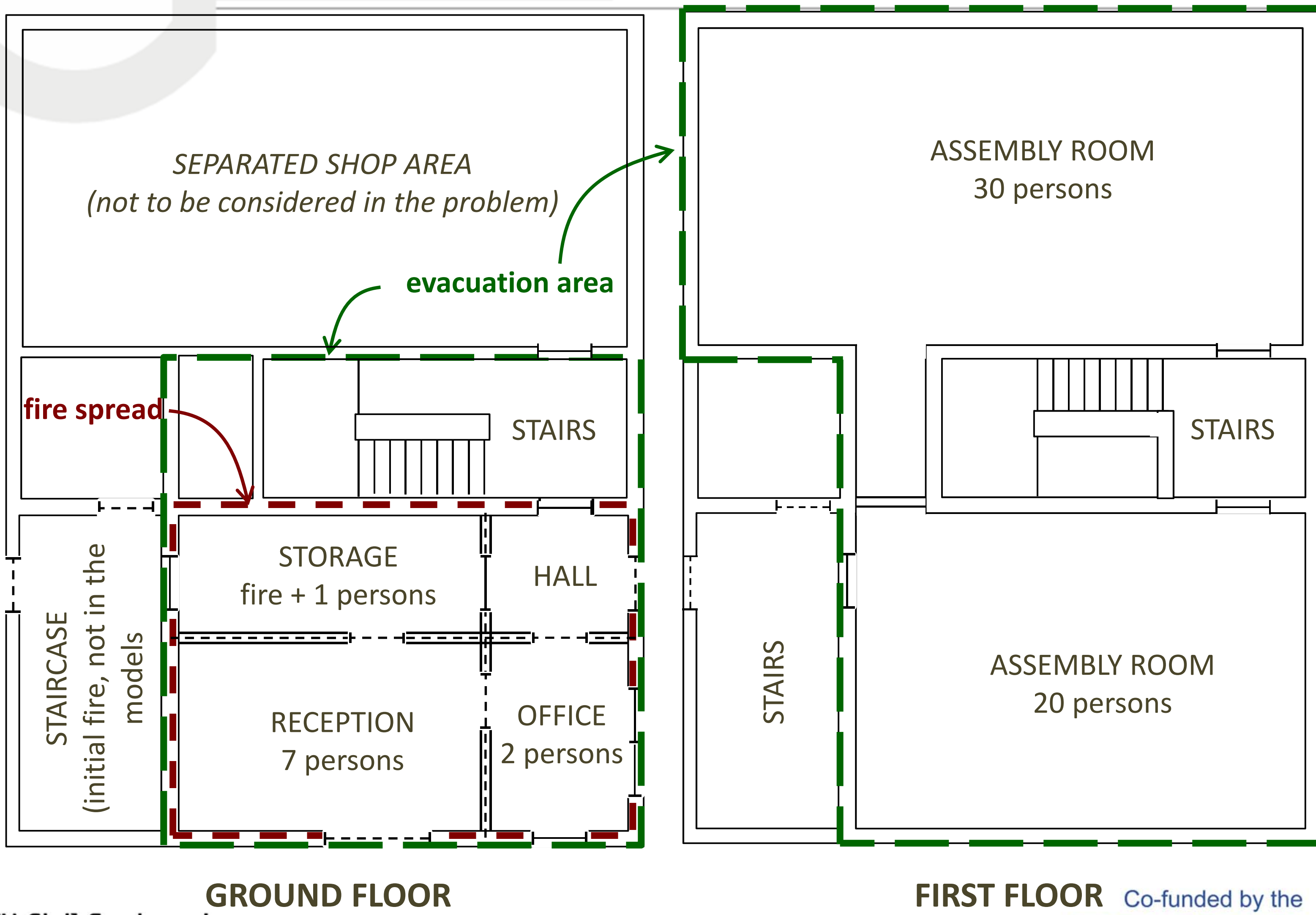
AIR FLOWS & TEMPERATURES?

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

11B12 – Blind Test Contest

MODEL	CFD			2 ZONES		EXPERIMENTAL
Software	CFX	CFX	FDS4	MFRC	ARGOS	LAB
Author	ETH	AFC			COWI	IMTECH
Smoke height (m)	7.5 +/- 0.5	6.0 +/- 1	5.5 +/- 1	7.4 +/- 0.2	0	6.9 +/- 1
Air flow at door (m^3/h)	42'000 +/- 1'900	37'000 +/- 5'000	35'000 +/- 5'000	-	-	56'000
Temp. at open.1 (C)	227 +/-10	165 +/- 10	65 +/- 5	130 +/- 10	200 +/- 10	113
Air flow at open.1 (m^3/h)	36'000 +/-900	27'000 +/- 7'000	19'000 +/- 5'000	-	-	29'000
Temp. at open.2 (C)	272 +/- 17	220 +/- 10	75 +/- 5	130 +/- 10	200 +/- 10	120
Air flow at open.2 (m^3/h)	40'000 +/- 2'100	37'000 +/- 5'000	22'000 +/- 5'000	-	-	37'000

11B12 - Final assignment



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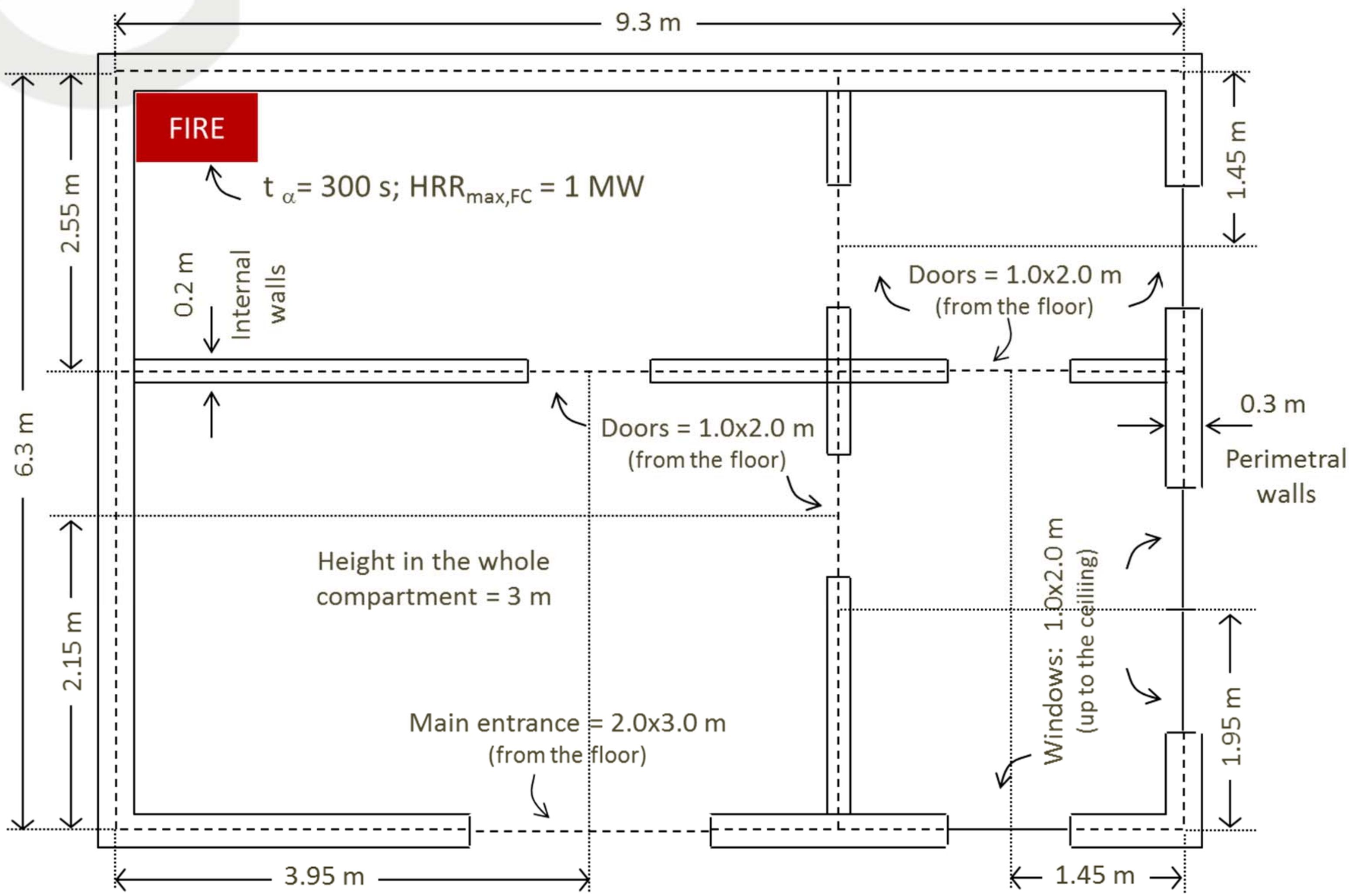
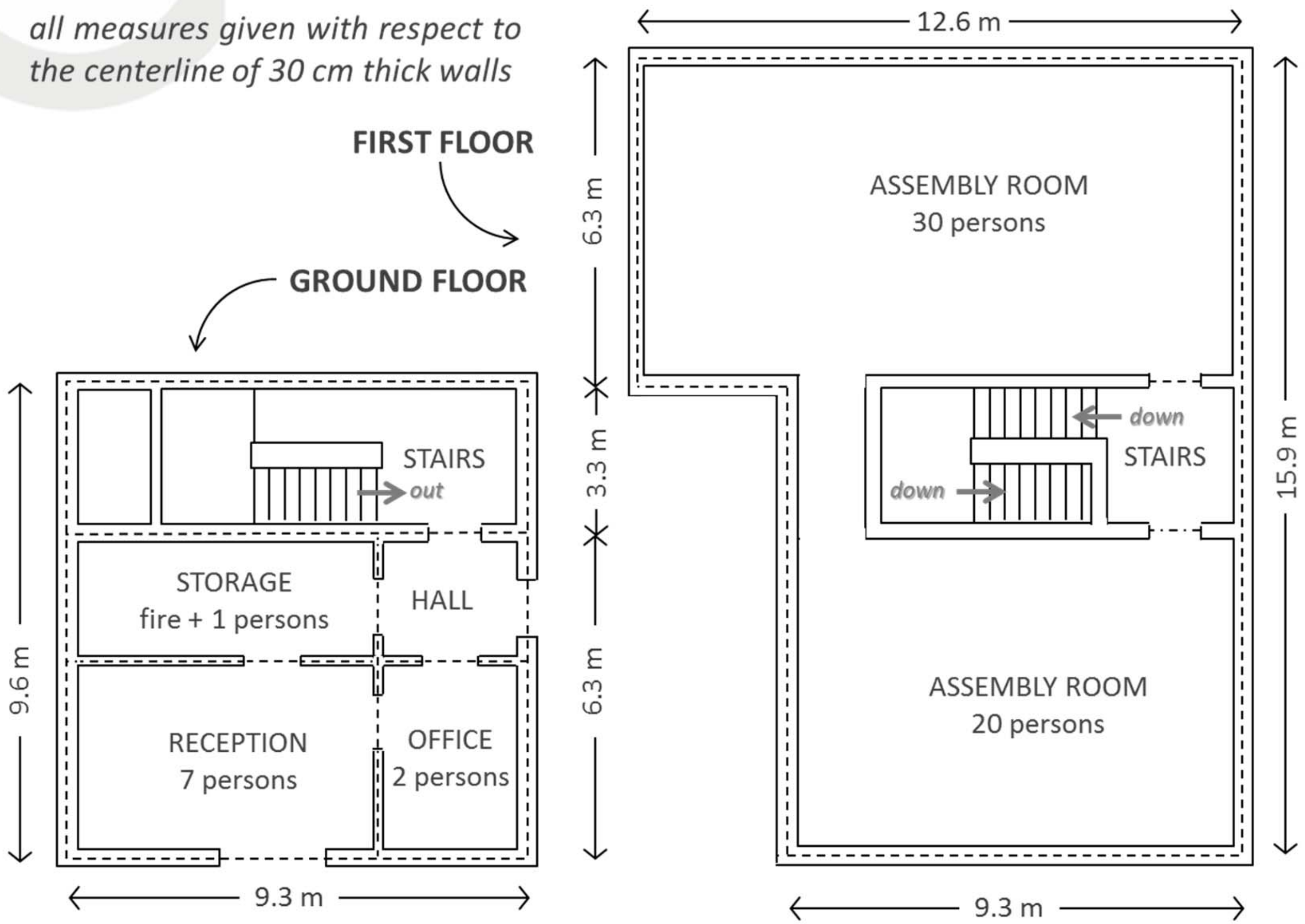
11B12 - Data for fire model



11B12 – Data for evacuation model

all measures given with respect to the centerline of 30 cm thick walls



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- *Integrated CAD for fire safety:*

  11B12: Brandmodellering (CAD Fire)

- *Structural fire safety design :*

  11B01 & 11023 Konstruktionbrandteknik

11B01 - Konstruktionsbrandteknik

Education: MIB (Master I Brandsikkerhed) / MSc Civil Engineering (as 11023)

ECTS points: 5

Work load: 280 hours

Lectures: 27 hours (3 modules of 1 ½ day each)

Duration: August - November + examination in December

Course responsible: Kristian Hertz

Teachers: Luisa Giuliani (steel and wood) and Kristian Hertz (concrete)

Structure: 2 hours lecture + 2 hours tutorial

Evaluation: Written examination with censor

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

Design for

TIME	FAILURE	COLLAPSE
CLASS OF RESISTANCE	**FULLY DEVELOPED FIRE**	**ADVANCED DESIGN**
verifications for a limited time of *standard fire*	verification for the whole duration of a *compartment fire*	building response under different *fire scenarios*

knowledge →

complexity

Co-funded by the
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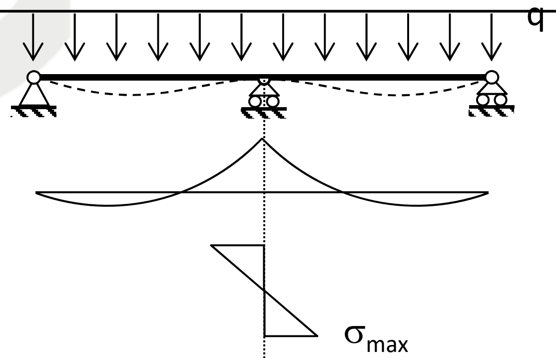
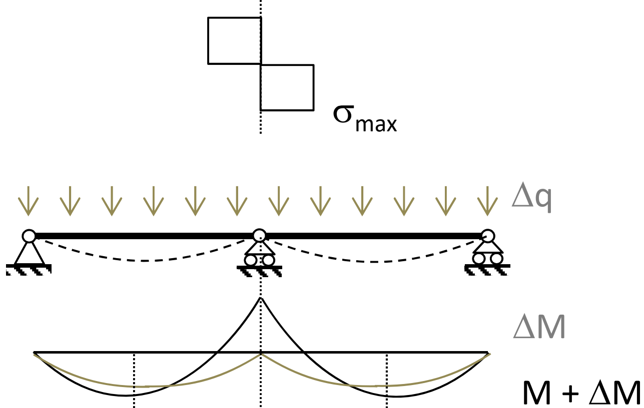
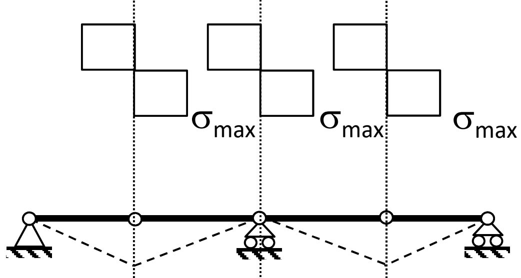
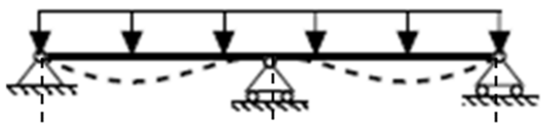
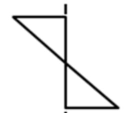
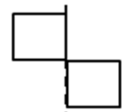
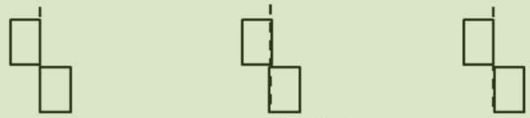
11B01 – Design criterion

LEVEL		VERIFICATION	MATERIAL MODEL	
fiber		$\sigma_{max} \leq f_d = f_{yk} / \gamma_M$	linear-elastic	SLS
section		$M_{sd} \leq M_{pl} = f_{yd} W_{pl}$ plastic modulus of resistance $W_{pl} = \zeta W_{el} = \zeta I / y_{max}$ section plastic benefit > 1	plastic	ULS
element		$q \leq q_{lim} = f_{yk} W_{pl} r / L^2$ redistribution factor ≥1	limit analysis	ALS

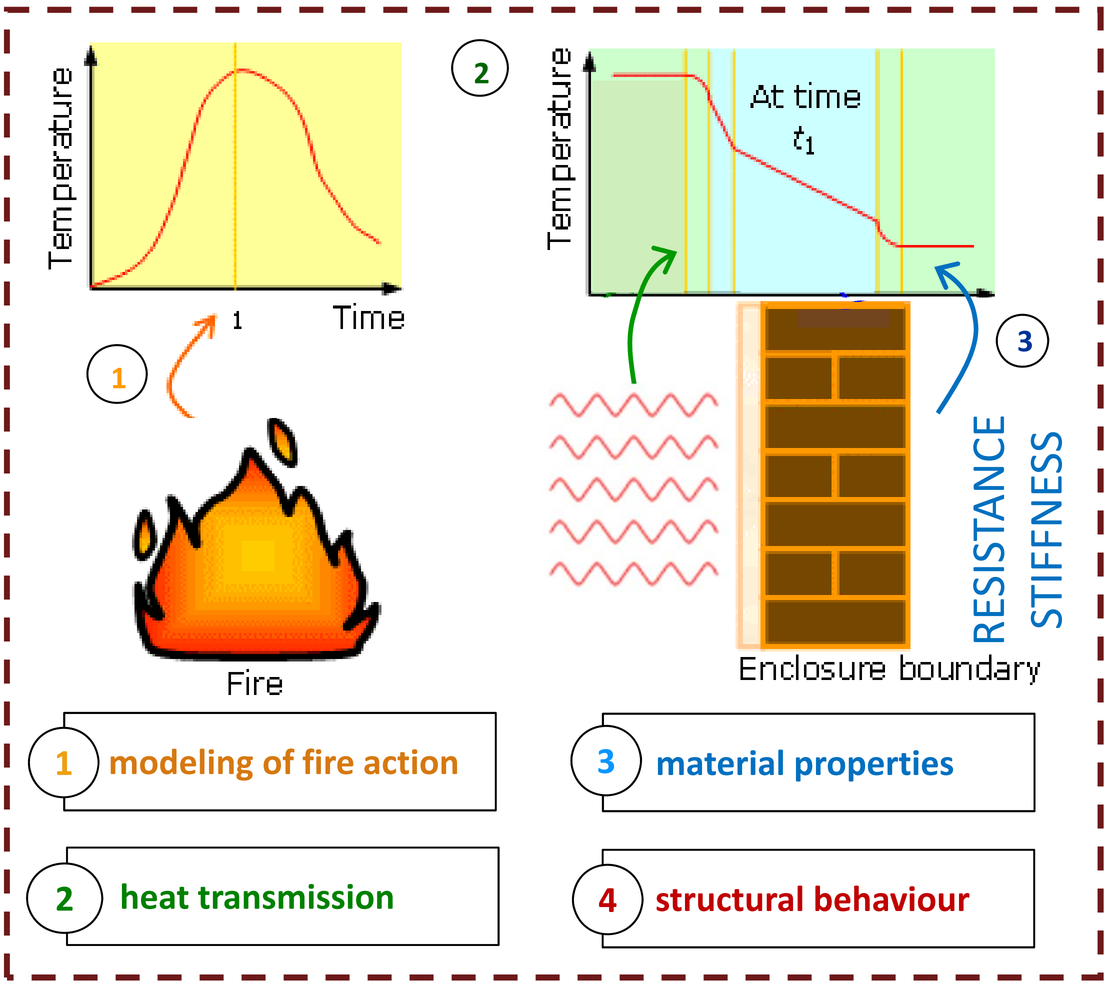
11B01 – Design criterion

DESIGN		VERIFICATION	LEVEL
elastic	 f_{yd}	$\sigma_{sd}^{SLS} < f_{yd}$	fiber
plastic	 f_{yd}	$M_{sd}^{ULS} < f_{yd}\,W_{pl}$	section
thermo-plastic with limit analysis	 $k_y^T \cdot f_{yk}$	$p_{sd}^{fi} < k_y^T \cdot p_{lim}$	element
global behaviour	hindered thermal expansion (on column, by beam)		structure

	BEAMS	COLUMNS	CONNECTIONS
STEEL	Y	N	N
TIMBER	Y	Y	Y
CONCRETE	Y	Y	N

11B01 – Design steps

Ponticelli&Caciolai, 2008



FIRE ACTION

1

FIRE COURSE

2

ELEMENT TEMPERATURE

3

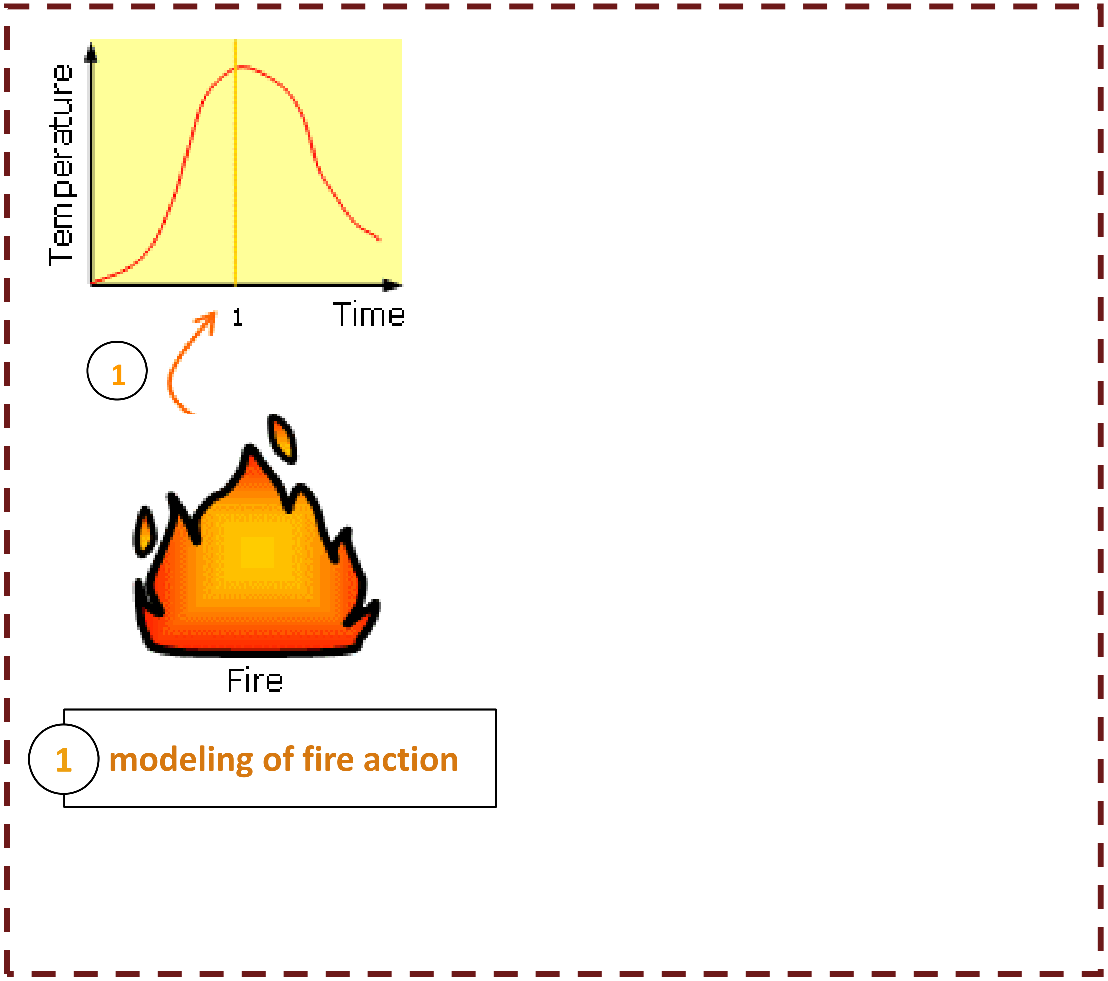
MATERIAL DEGRADATION

4

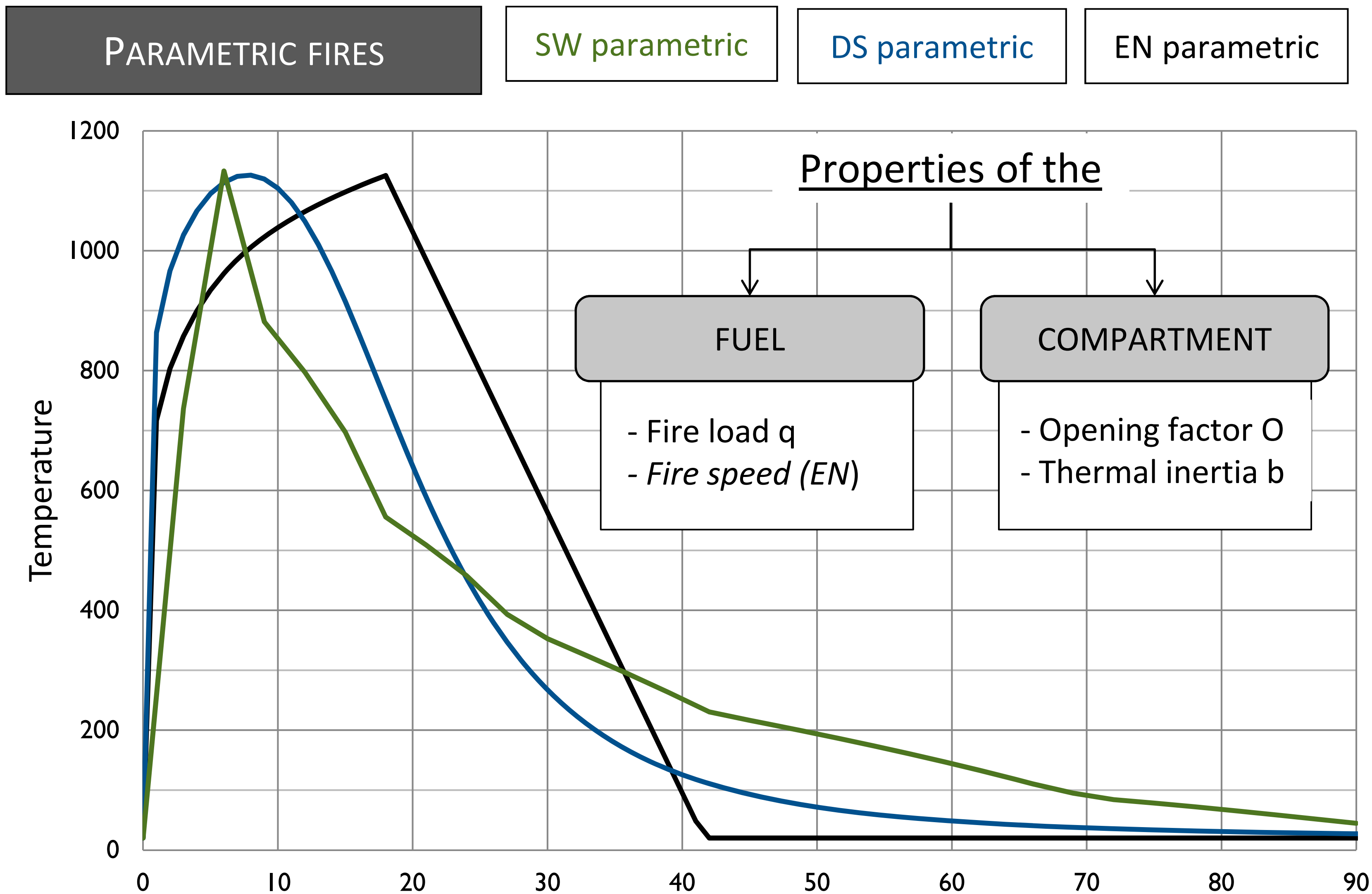
VERIFICATION OR DESIGN

Structural fire design: main steps

Ponticelli&Caciolai, 2008

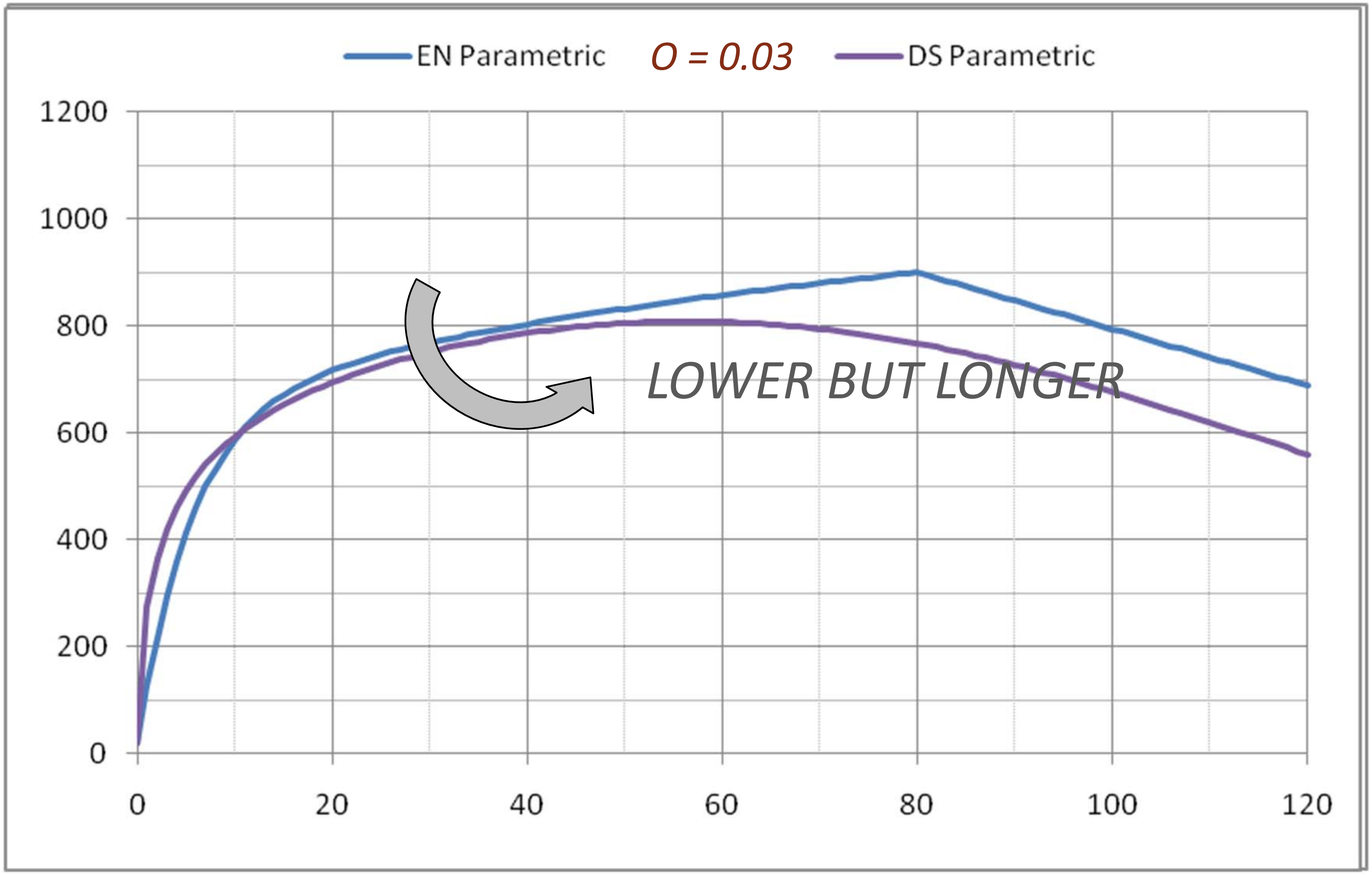


1. Fire action: comparison with other curves



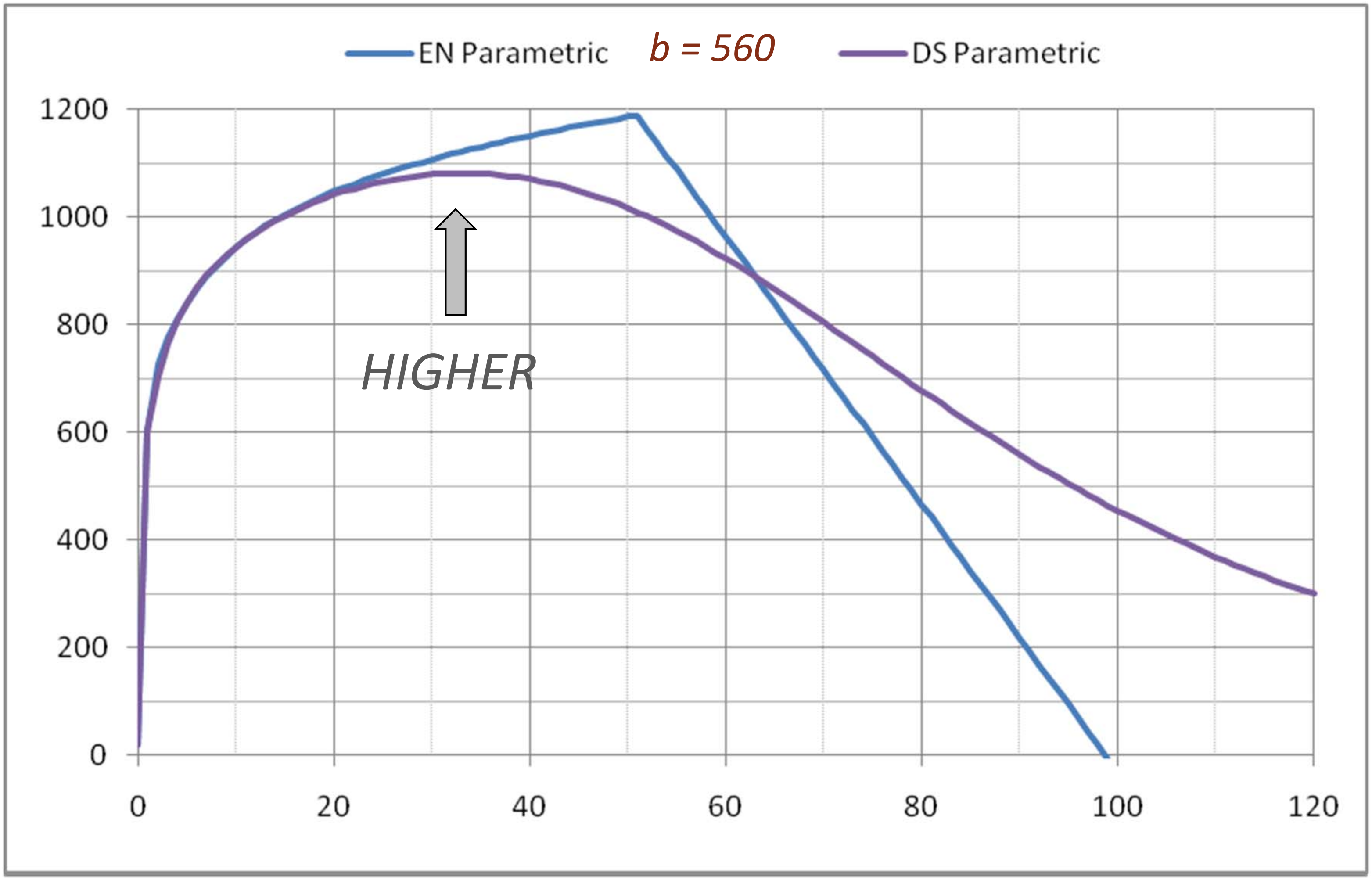
1b. Fire action: Opening factor

EFFECT OF LOW ENERGY WINDOWS



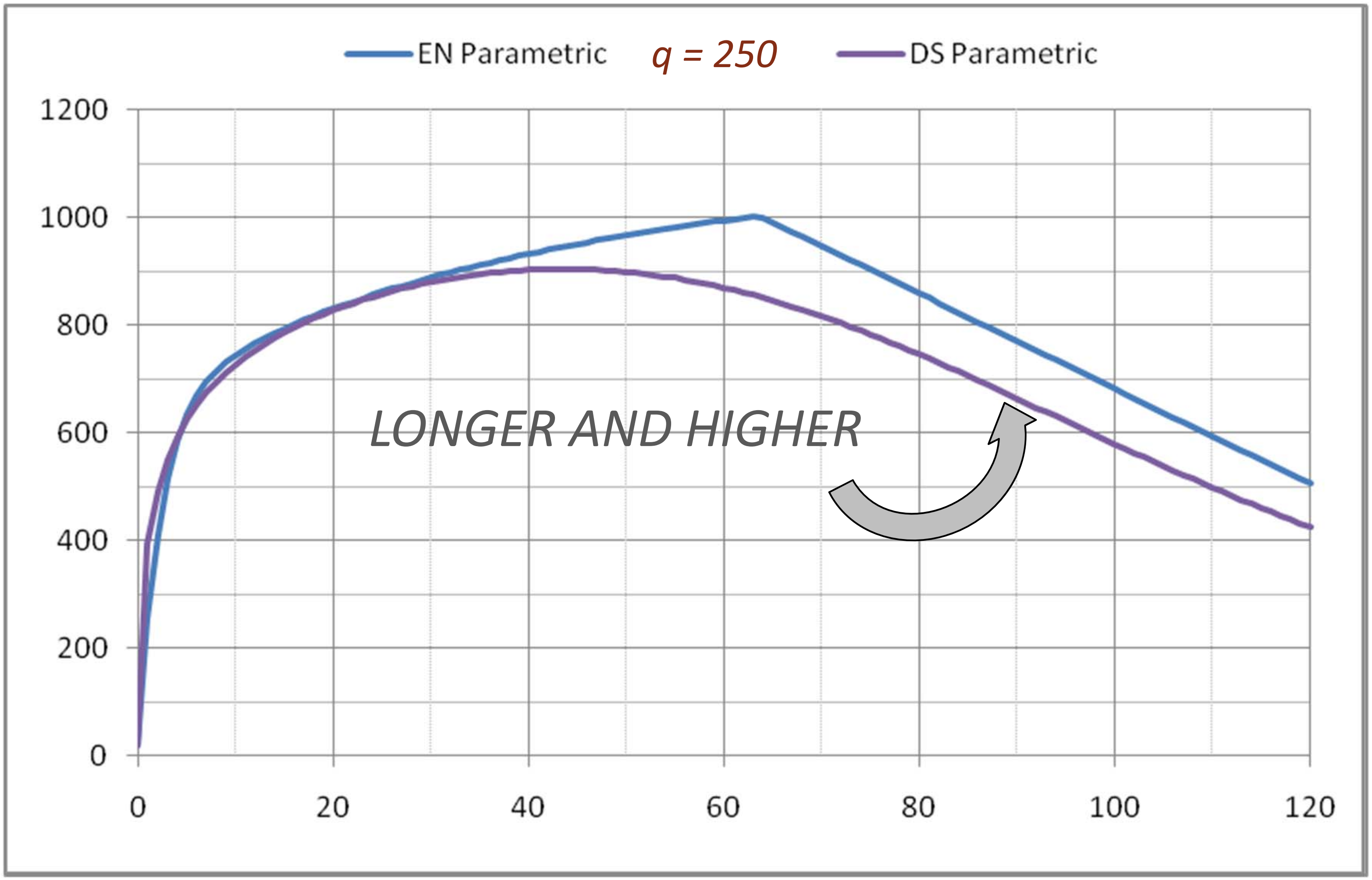
1c. Fire action: Thermal inertia

EFFECT OF WALL INSULATION



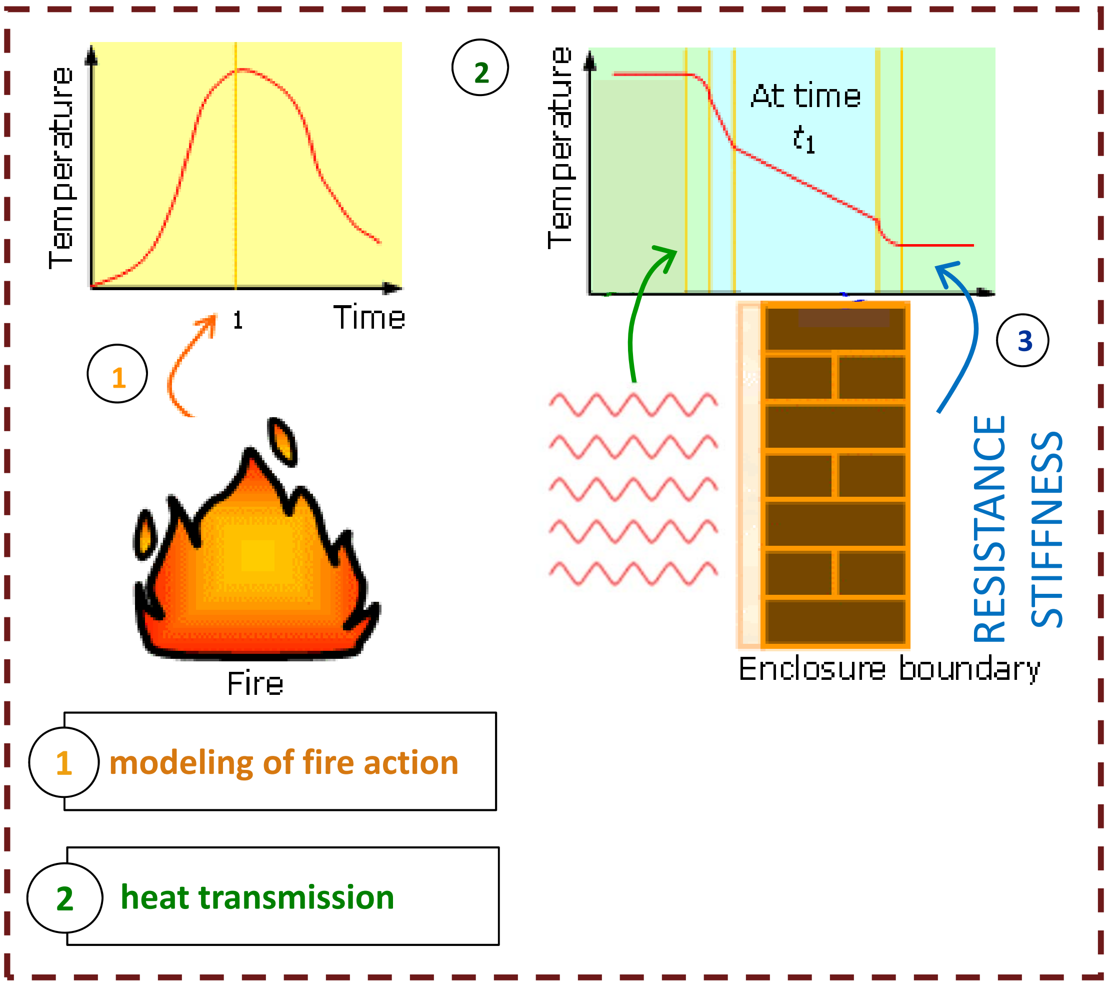
1d. Fire action: Fuel load density

EFFECT OF HIGHER FUEL LOAD



Structural fire design: main steps

Ponticelli&Caciolai, 2008



FIRE ACTION

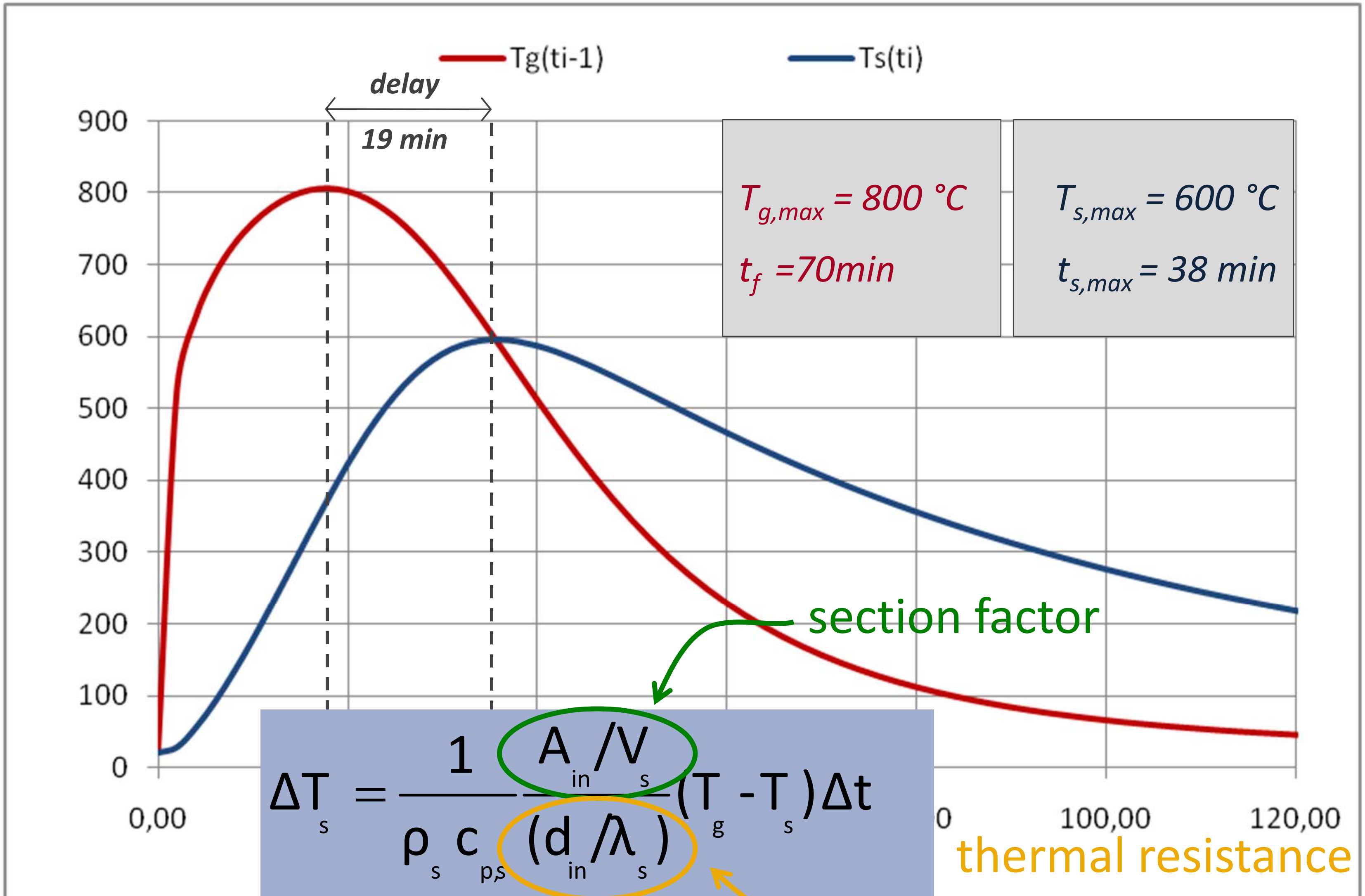
1

FIRE COURSE

2

ELEMENT TEMPERATURE

2. Element temperature: steel



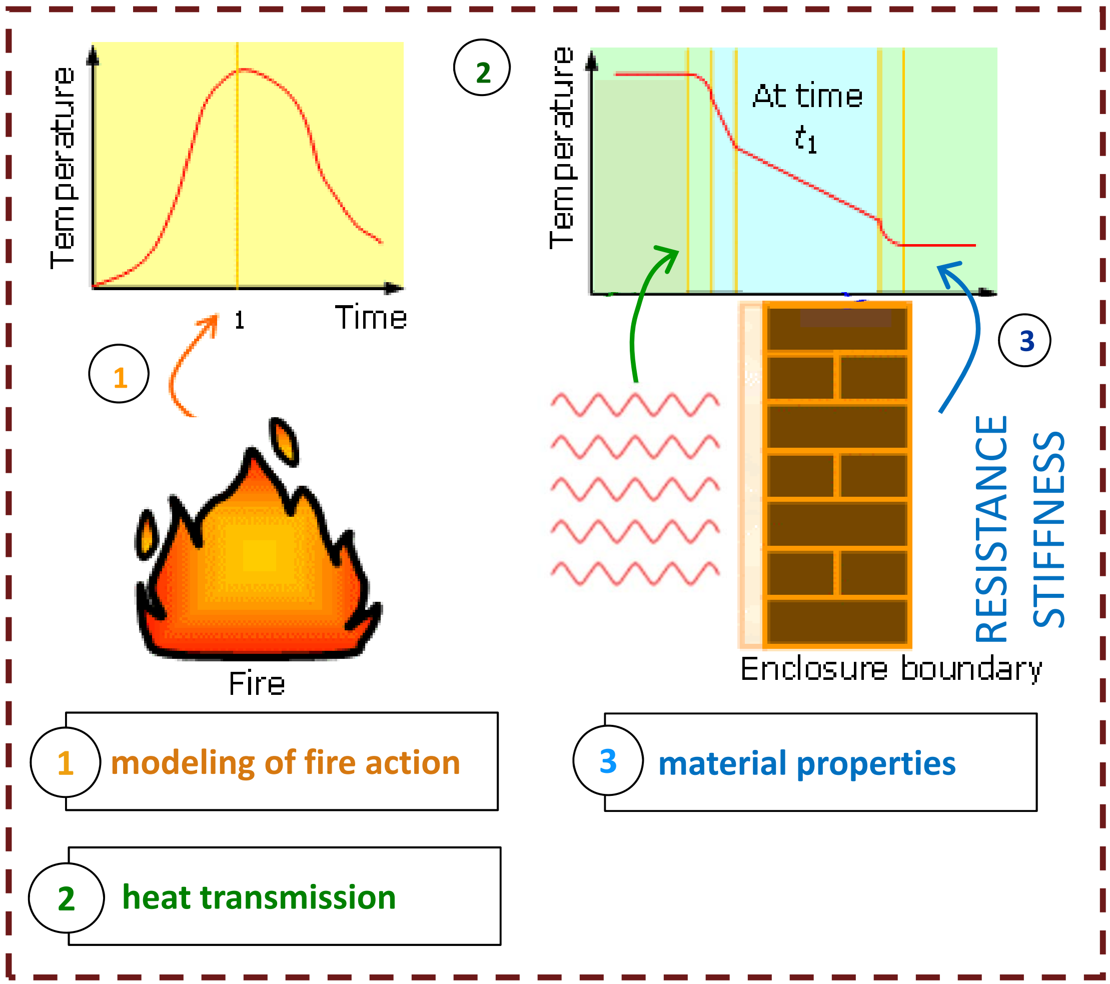
$$\Delta T_s = \frac{1}{\rho_s c_{p,s}} \frac{A_{in}/V_s}{(d_{in}/\lambda_s)} (T_g - T_s) \Delta t$$

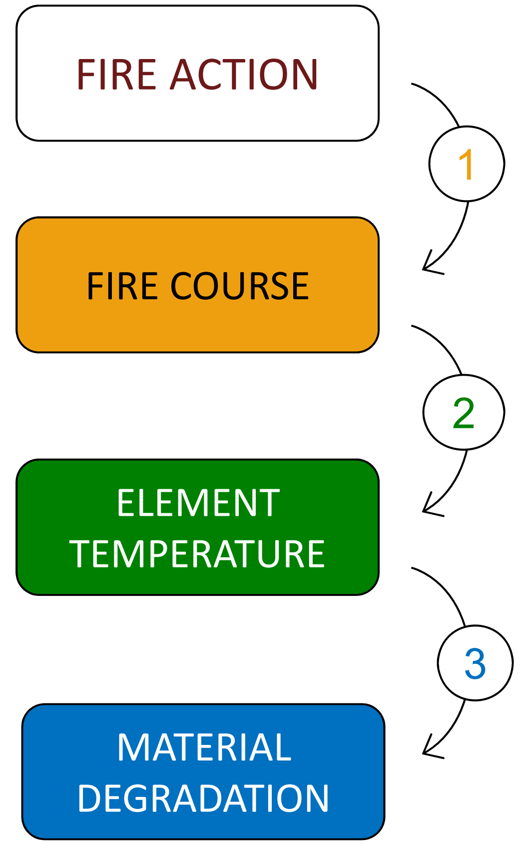
section factor

thermal resistance of the insulation

Structural fire design: main steps

Ponticelli&Caciolai, 2008

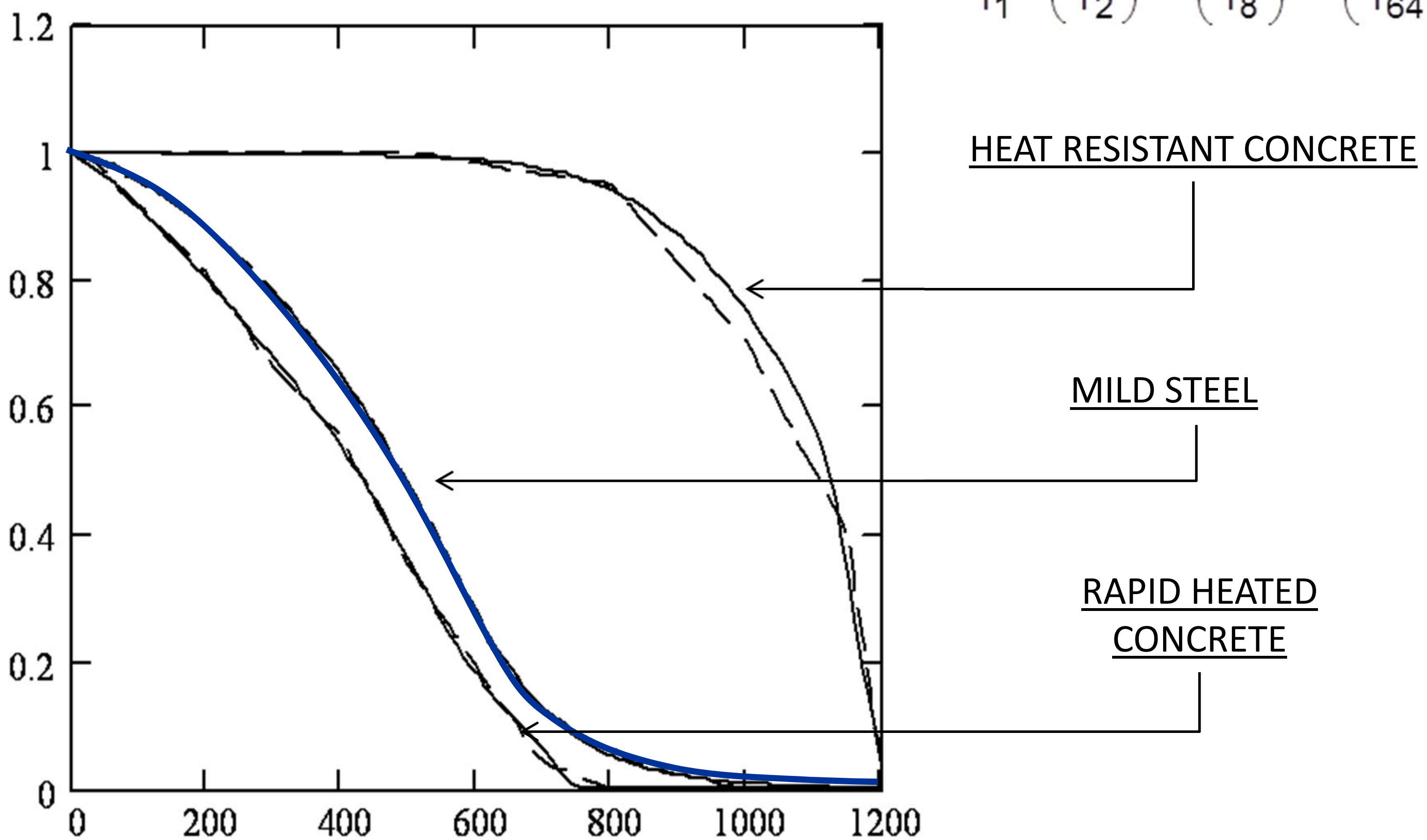




3. Material degradation: coeff. for steel and concrete

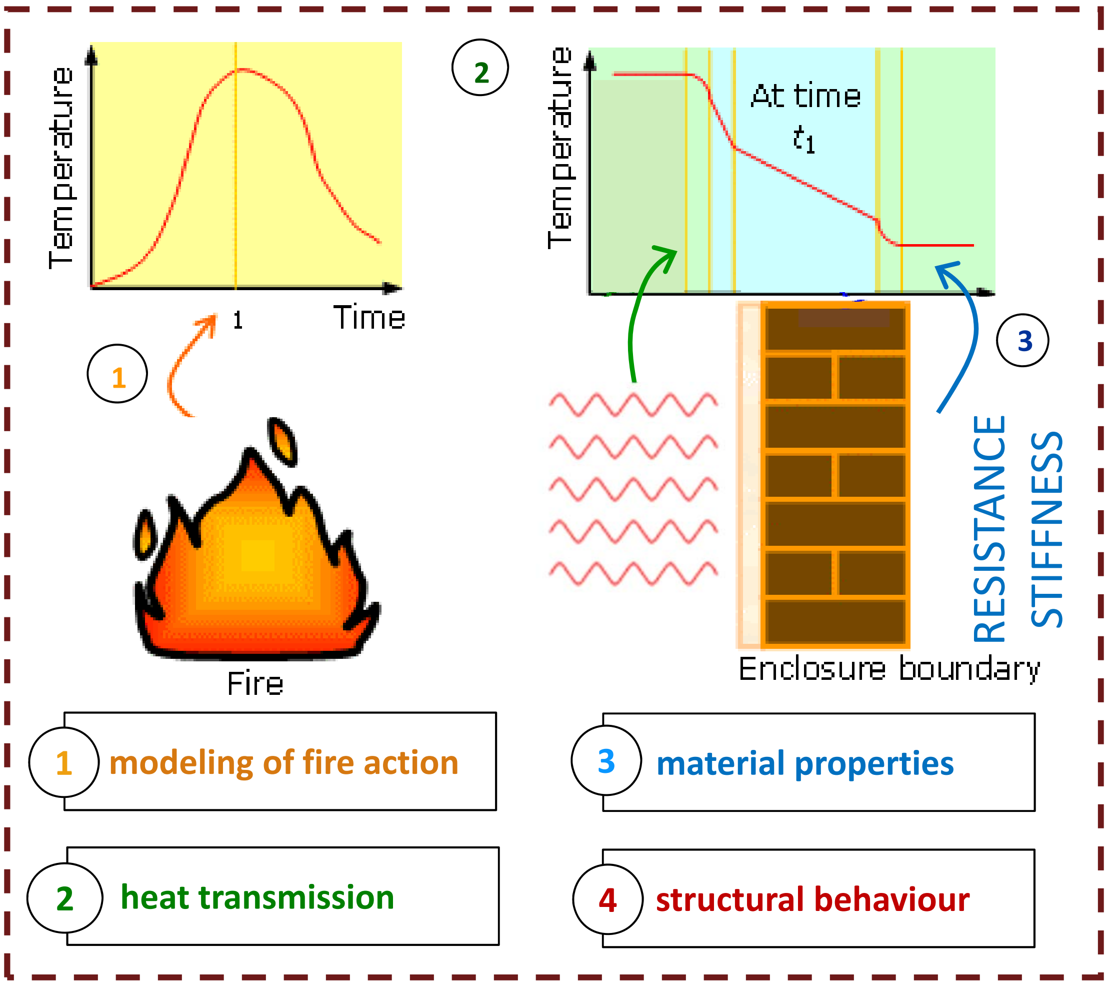
DEG. FACTOR(Hertz's formula)

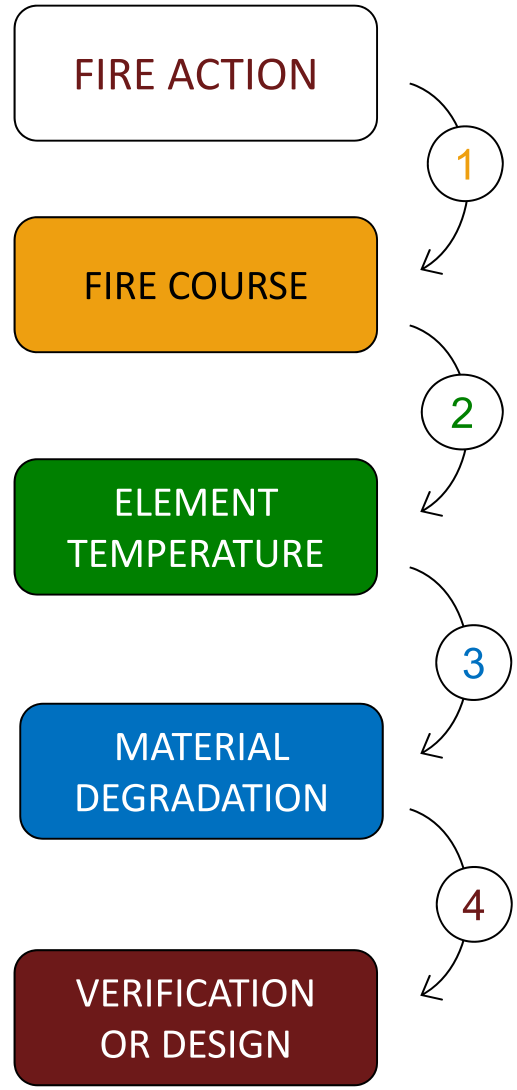
$$\xi_{s,0.2}(T) = k + \frac{1-k}{1+\frac{T}{T_1}+\left(\frac{T}{T_2}\right)^2+\left(\frac{T}{T_8}\right)^8+\left(\frac{T}{T_{64}}\right)^{64}}$$



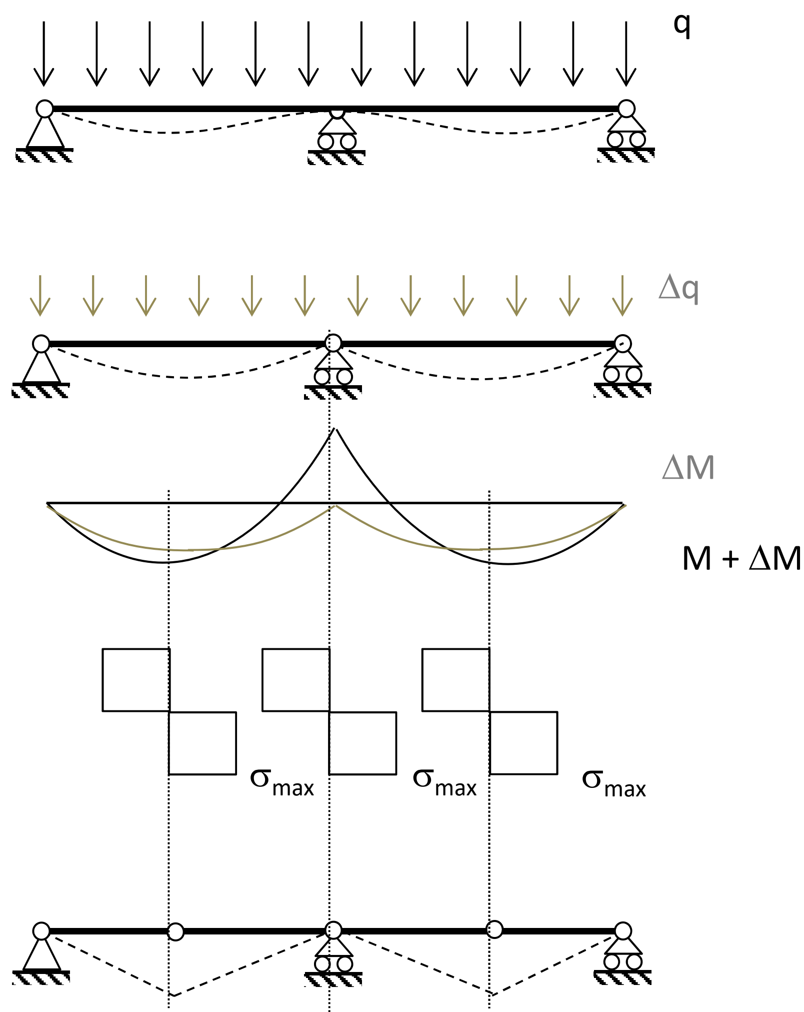
Structural fire design: main steps

Ponticelli&Caciolai, 2008



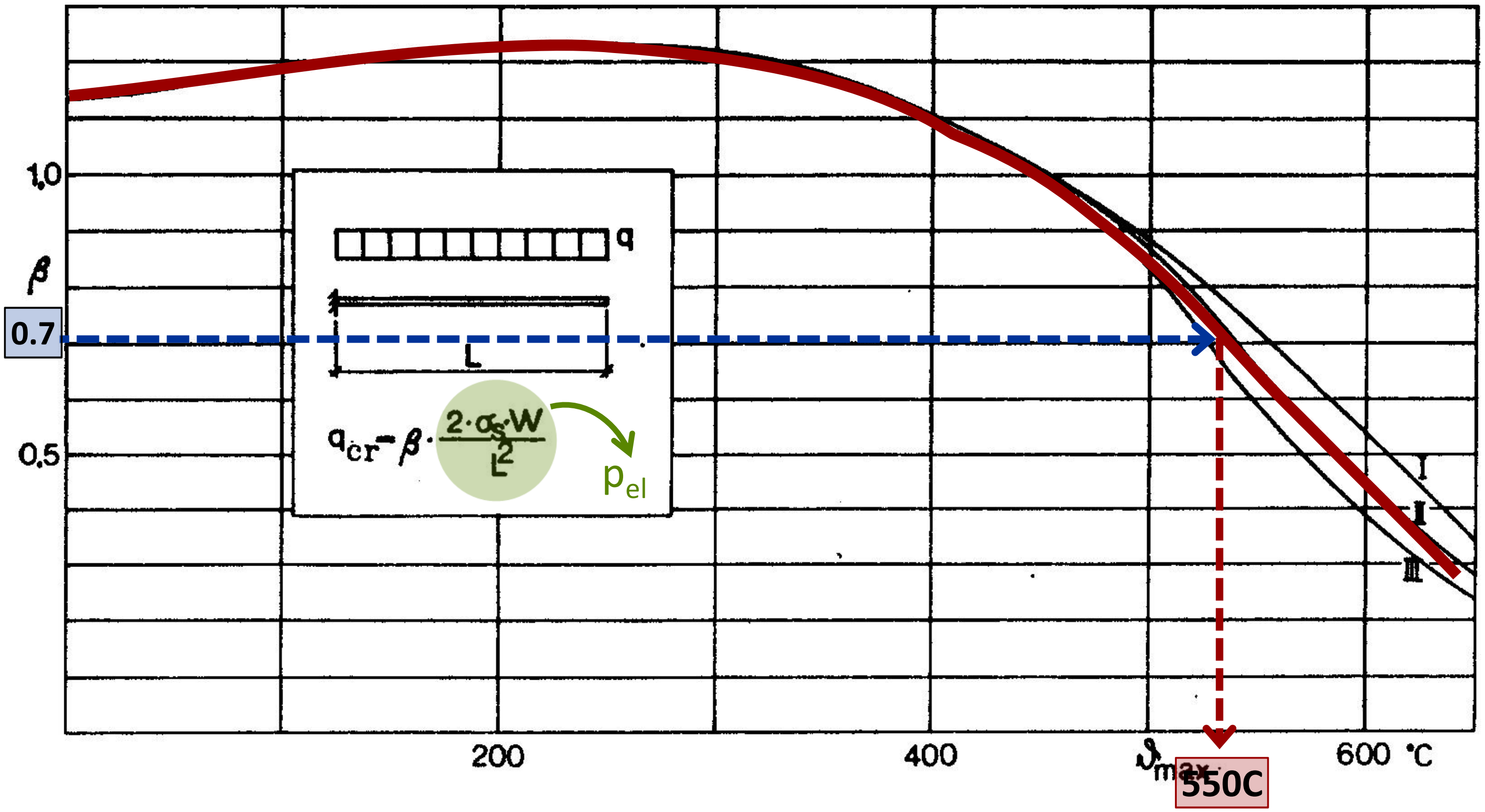


4. Design: steel insulation - beam



4. Design: steel insulation - beam

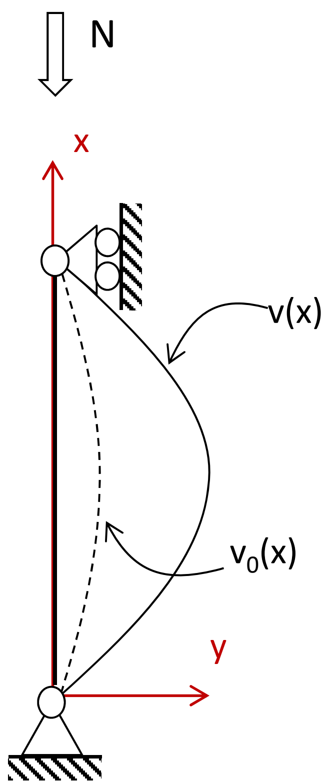
Total plastic benefit in fire: $\beta^T = p_{lim}^T / p_{el}^{20}$



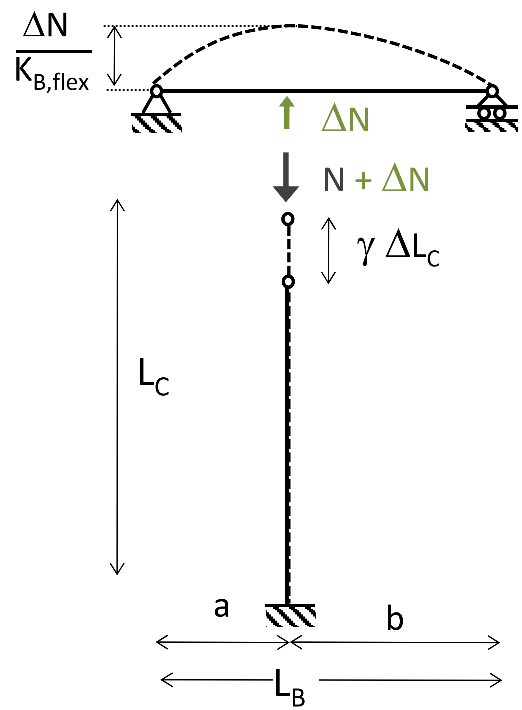
I, II, III: different rate of heating (from higer to lower hr)

4. Design: steel insulation - columns

Ayrton-Perry formulation

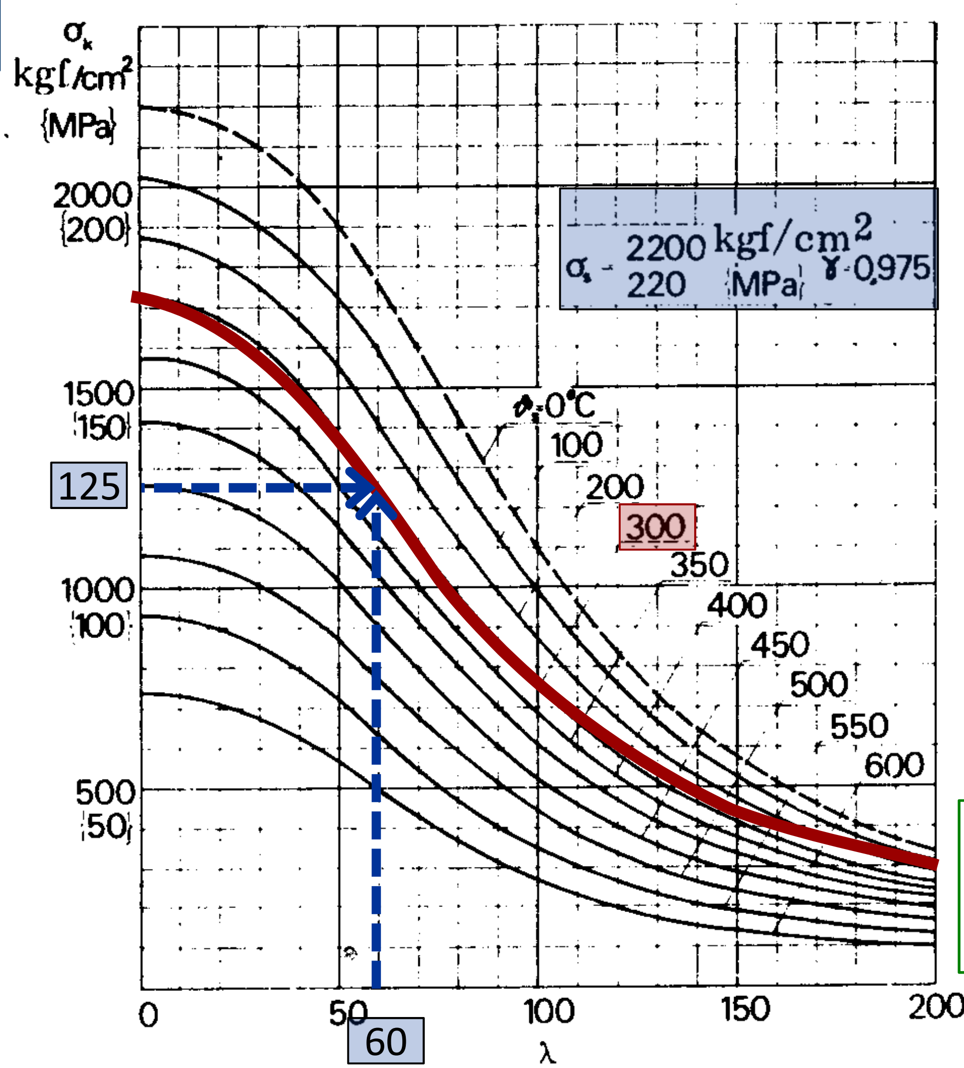


Effects of hindered thermal expansion



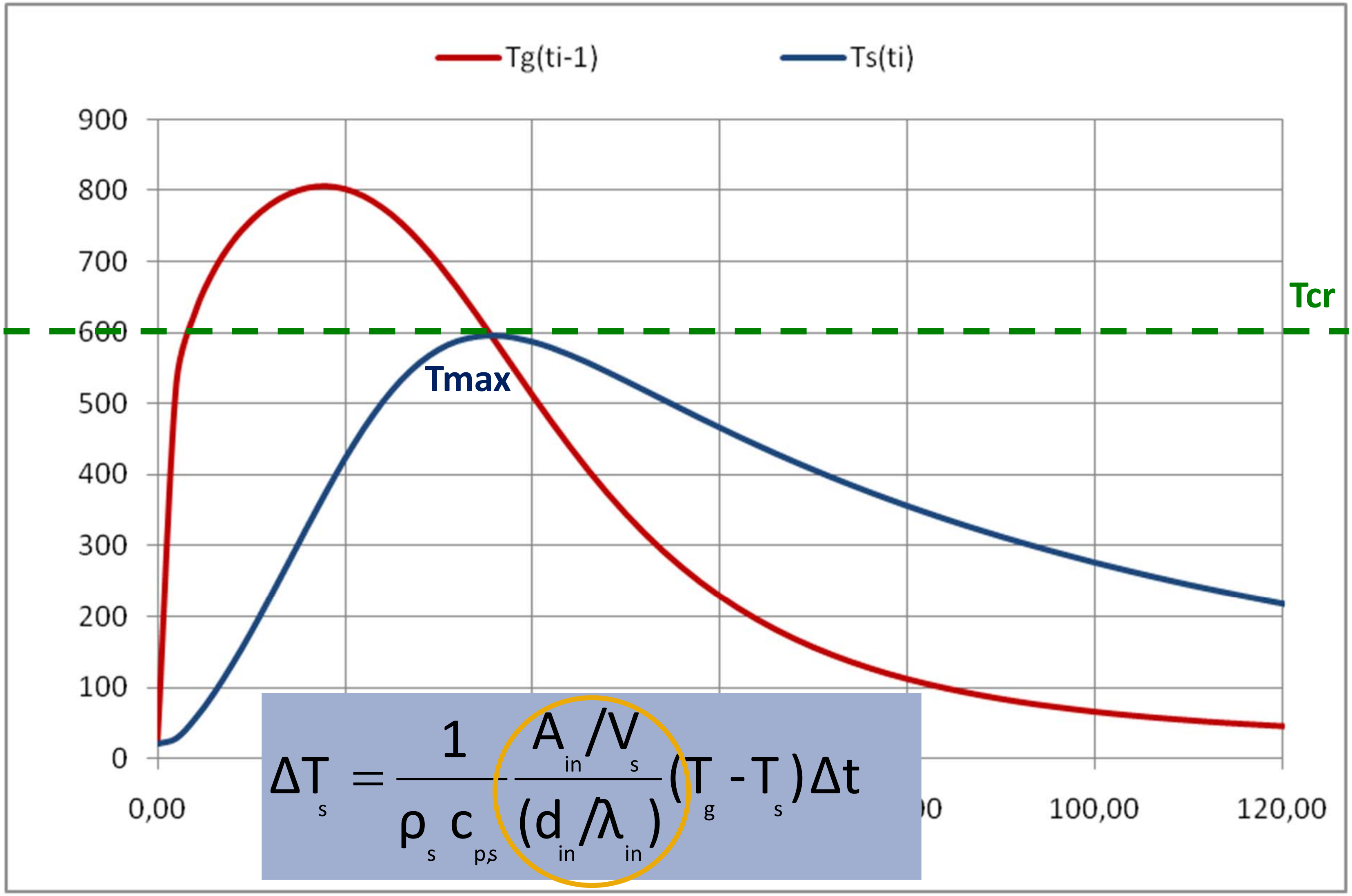
4. Design: steel insulation - column

Critical stress:
$\sigma_k = p_{lim}^T / A$



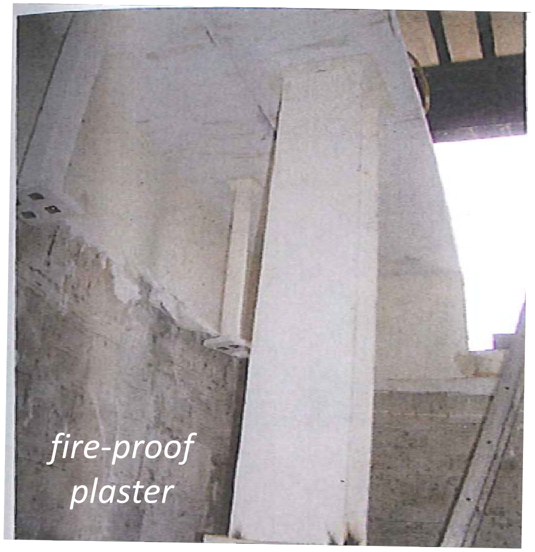
Slenderness:
$\lambda = L_{buck} / \sqrt{(I_{min}/A)}$

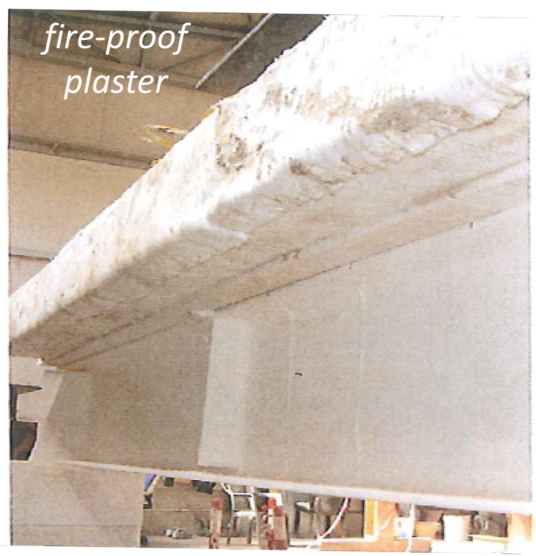
4. Design: steel insulation

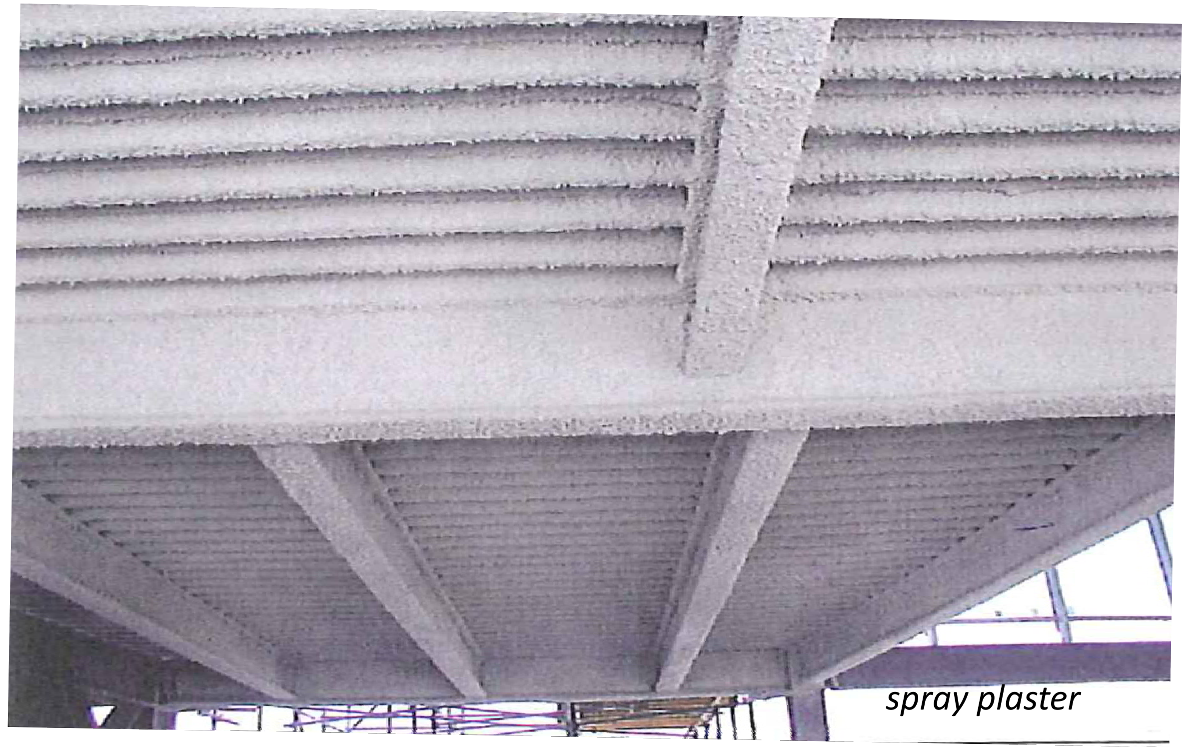


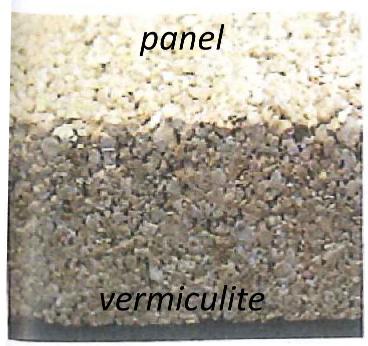
$$\Delta T_s = \frac{1}{\rho_s c_{p,s}} \frac{A_{in}/V_s}{(d_{in}/\lambda_{in})}(T_g - T_s)\Delta t$$

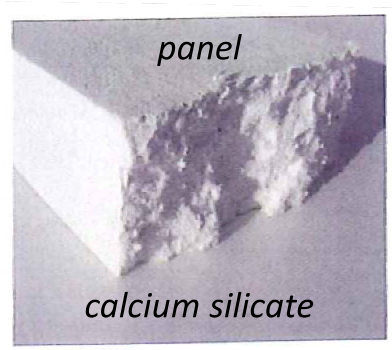
4. Design: steel insulation

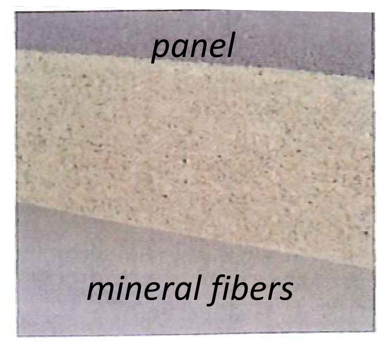






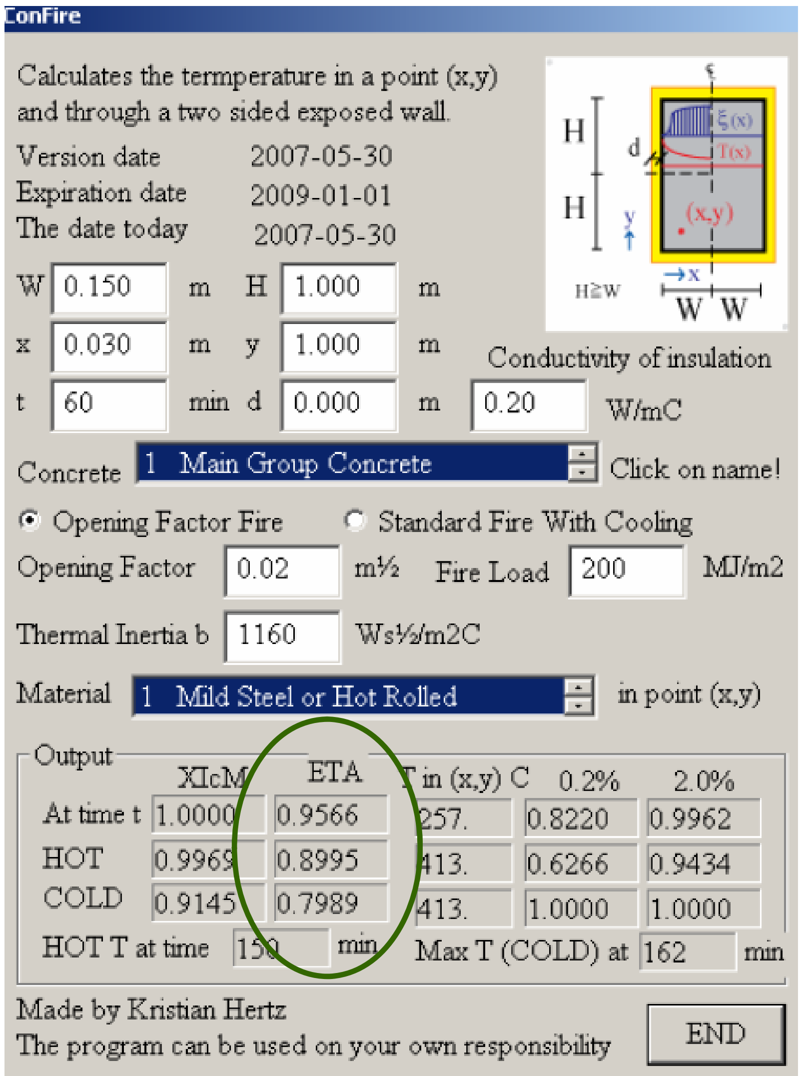


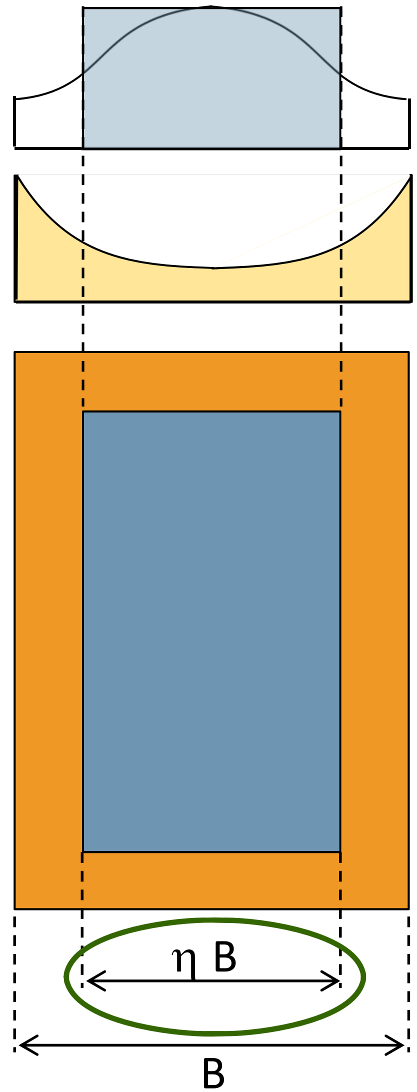




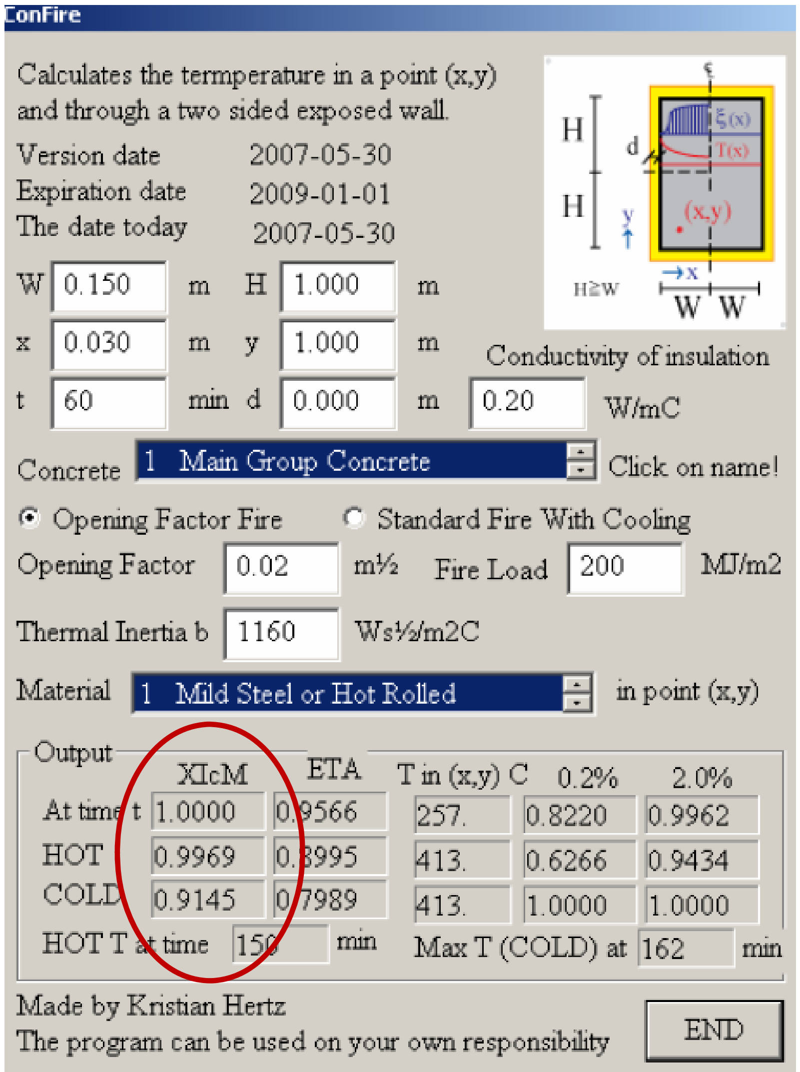
Ponticelli&Caciolai, 2008

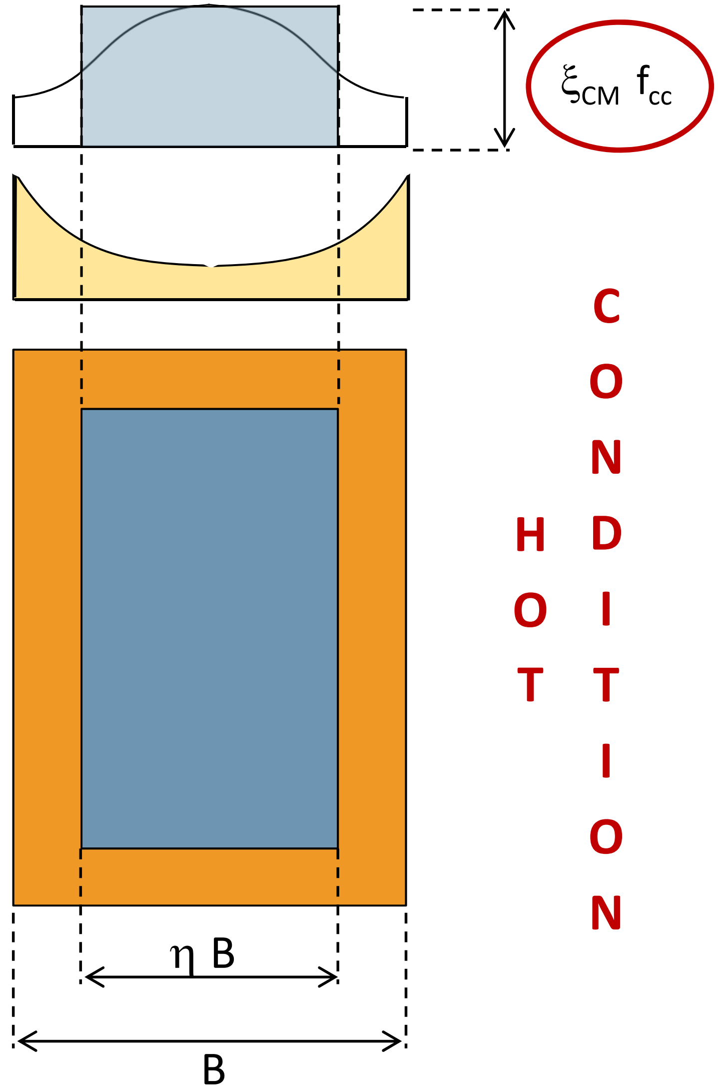
4. Verification: concrete zone model (CONFIRE)





4. Verification: concrete zone model (CONFIRE)

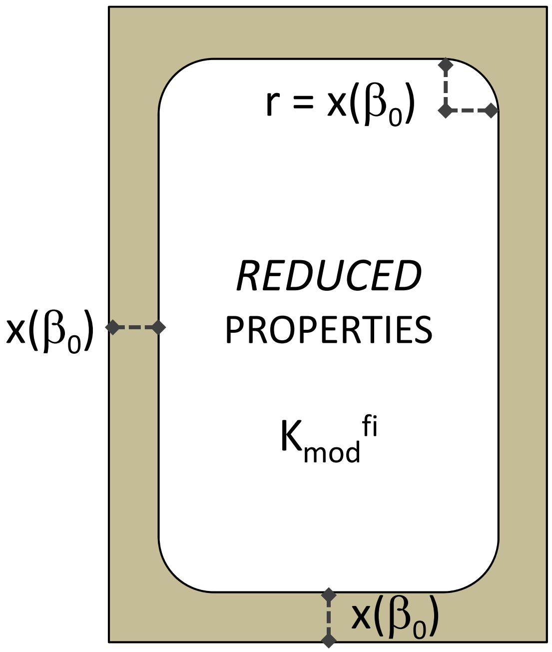




4. Verification: timber

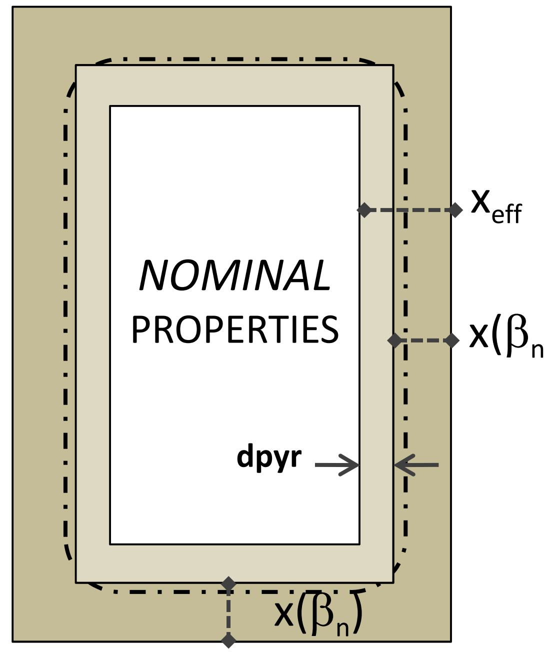
STRENGTH REDUCTION

more realistic section and properties



REDUCED CROSS SECTION

conventional section and properties



4. Verification: timber connections

Connections should carry the same as the adjacent parts of the structure!

In fact connection are often the weakest link in wood structures

(the section is weakened by the charring from the many steel parts)

Date: 27-06-2017

Place: Technical University of Denmark

Knowledge FOr Resilient soCiEty

MiB Courses 11B12 and 11B01 (11023)

Luisa Giuliani

Technical University of Denmark

Department of Civil Engineering (DTU-BYG)

DTU Civil Engineering
Department of Civil Engineering

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