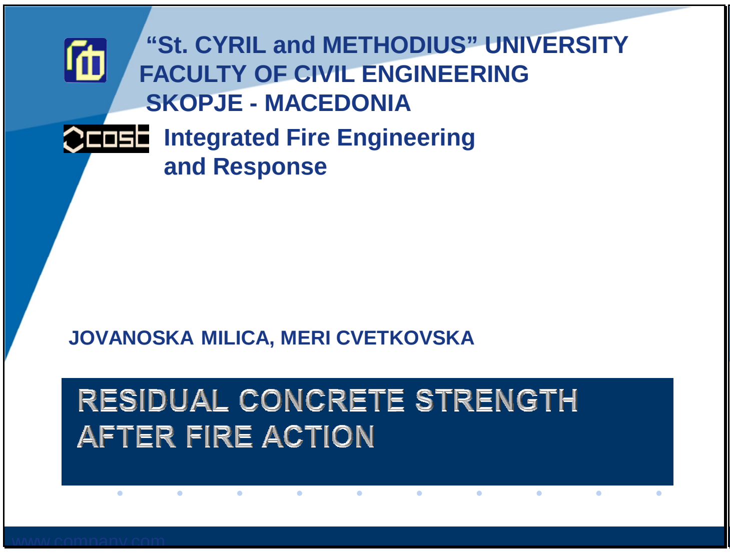
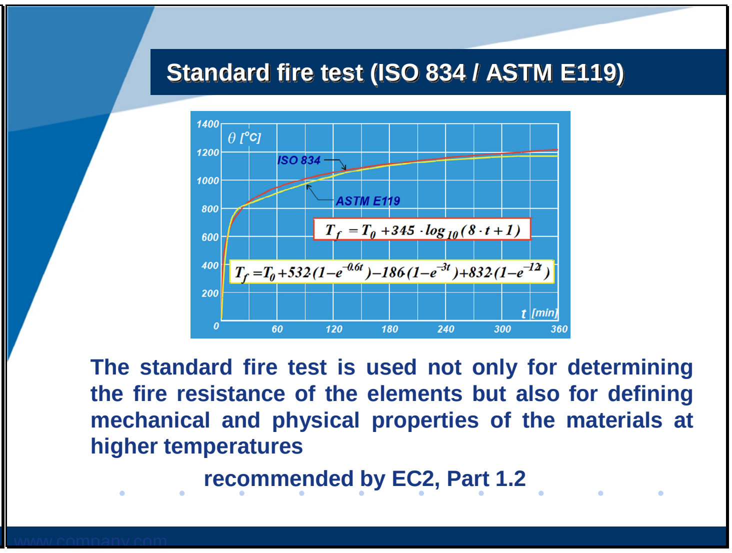
2.11 Residual concrete strength after fire action (short version)

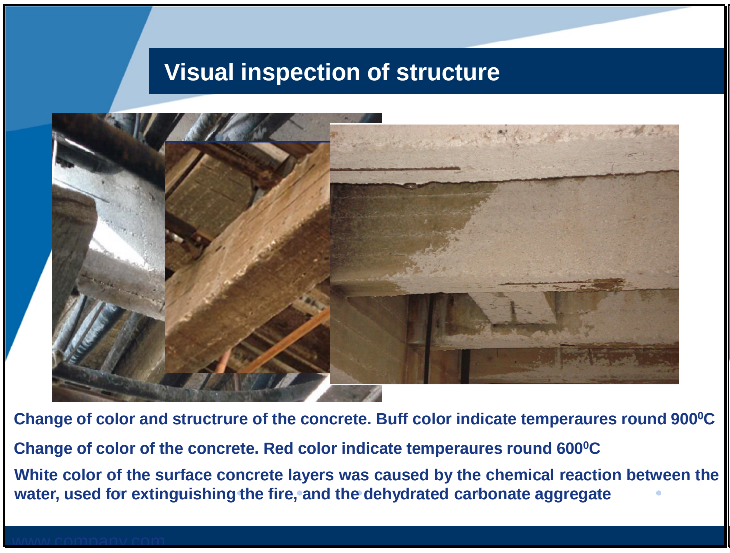
Jovanoska M., Macedonia



1

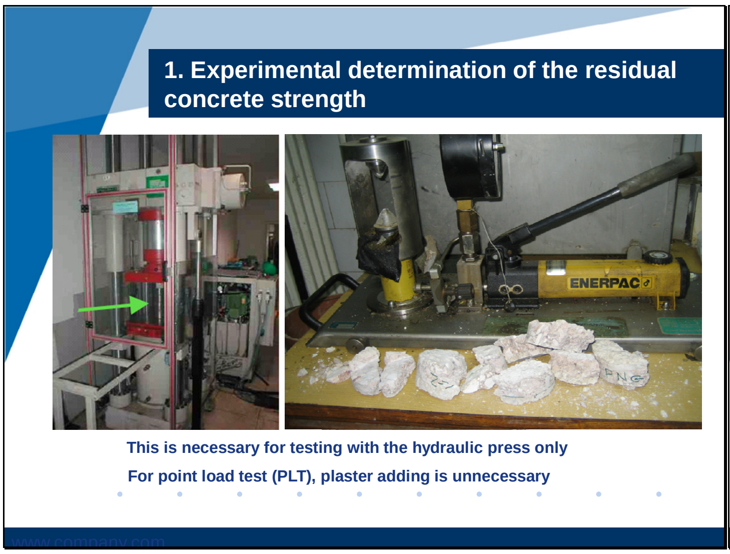


2

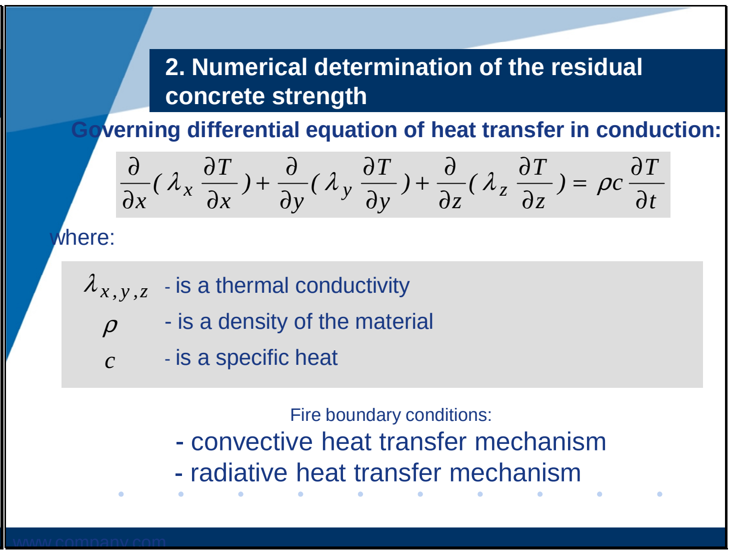


3

4



5



6

2. Numerical determination of the residual concrete strength

Governing differential equation of heat transfer in conduction:

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

The heat flow caused by convection:

$$q_c = \alpha_c (T_z - T_f)$$

where:

α_c	- is coefficient of convection ($\alpha_c = 25 W/m^2 C$)
T_z	- is the temperature on the boundary of the element
T_f	- is the temperature of the fluid around the element

2. Numerical determination of the residual concrete strength

Governing differential equation of heat transfer in conduction:

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

The heat flow caused by radiation:

$$q_r = V \varepsilon \sigma_c (T_{z,a}{}^4 - T_{f,a}{}^4) = \alpha_r (T_z - T_f)$$

where:

α_r	- is coefficient of radiation
T_z	- is the temperature on the boundary of the element
T_f	- is the temperature of the fluid around the element

2. Numerical determination of the residual concrete strength

The solution of the differential equation in FEM is:

$$[C] \cdot \dot{\vec{T}} + ([K_1] + [K_2]) \cdot \vec{T} + [R] \cdot \vec{T} = \vec{P}$$

$[K_1]$	-conductivity matrix (temperature dependent)
$[K_2]$	- convection matrix
$[C]$	- capacity matrix (temperature dependent)
$[R]$	- radiation matrix (temperature dependent)
$\vec{P}$	- vector of temperature loads (convection and radiation included)
$\vec{T}$	- vector of unknown nodal temperatures
$\dot{\vec{T}}$	- vector of temperature derivatives over time

2. Numerical determination of the residual concrete strength

The solution of the differential equation in FEM is:

$$[C] \cdot \dot{\vec{T}} + ([K_1] + [K_2]) \cdot \vec{T} + [R] \cdot \vec{T} = \vec{P}$$

Iterative procedure recommended by Wilson and Nickell

$$\dot{T}_i = \dot{T}_{i+\Delta i} = \frac{T_{i+\Delta i} - T_i}{\Delta t}$$

$$[K_1]_{t+\Delta t} = [K_1]_t \qquad [C]_{t+\Delta t} = [C]_t \qquad [R]_{t+\Delta t} \neq [R]_t$$

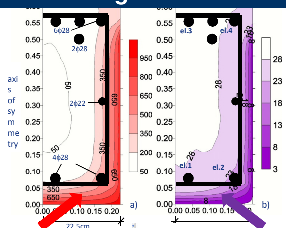
$$\left([K]_{t+\Delta t} + \frac{2}{\Delta t}[C]_t\right)\vec{T}_{t+\Delta t} = \left(-[K]_t + \frac{2}{\Delta t}[C]_t\right)\vec{T}_t + \vec{P}_{t+\Delta t} + \vec{P}_t$$

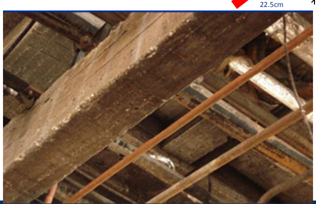
2. Numerical determination of the residual concrete strength

Following assumptions are made to determine the fire-induced thermal fields :

- A fire can be modeled by a single valued gas temperature history
- Temperature dependent material properties are known
- Two dimensional heat transfer is assumed
- No contact resistance to heat transmission at the interface between the reinforcing steel and concrete occurs
- The easier heat penetration, while cracks appear, or some parts of the cross section crush, is neglected

2. Numerical determination of the residual concrete strength





Values of concrete strength			
No.	D_e [mm]	J_s [MPa]	$J_{s(50)}$ [MPa]
Deteriorated slices			
1.	47.65	0.83	0.81
2.	47.63	0.51	0.50
3.	47.67	0.77	0.75
4.	46.91	0.33	0.32
5.	43.70	0.99	0.93
Average of $J_{s(50)}$=0,662 MPa			
Compact slices			
6.	52.84	2.28	2.34
7.	51.46	1.75	1.77
8.	49.06	2.23	2.21
Average of $J_{s(50)}$=2,107 MPa			
κ= 2,107 / 0,662 = 3,18			
Average strength of burned slices fbo= fb/k= 29,375 / 3,18 **= 9, 24 MPa**			