Application of Structural Fire Engineering, 19-20 February 2009,
Prague, Czech Republic

Civil Engineering Faculty
Skopje, Macedonia

NUMERICAL AND EXPERIMENTAL DETERMINATION OF RESIDUAL CONCRETE STRENGTH AFTER ACTION OF FIRE

Meri Cvetkovska, Petar Cvetanovski, Viktor Mihajlov

NUMERICAL PROCEDURE FOR RESIDUAL CONCRETE STRENGTH DETERMINATION

THERMAL ANALYSIS: MODUL "FIRE-T"

Governing differential equation of heat transfer in conduction:

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

where:

- $\lambda_{x,y,z}$ - is a thermal conductivity (temperature dependent)
- ρ - is a density of the material (temperature dependent)
- c - is a specific heat (temperature dependent)

The heat flow caused by convection:

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

The heat flow caused by radiation:

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

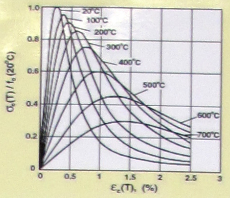
The solution of the differential equation in FEM is:

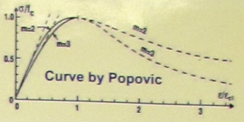
$$[C] \cdot \dot{\bar{T}} + ([K_1] + [K_2]) \cdot \bar{T} + [R] \cdot \bar{T} = \bar{P}$$

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

STRESS-STRAIN LAW FOR CONCRETE AT HIGH TEMPERATURES

recommended by EC2, Part 1.2





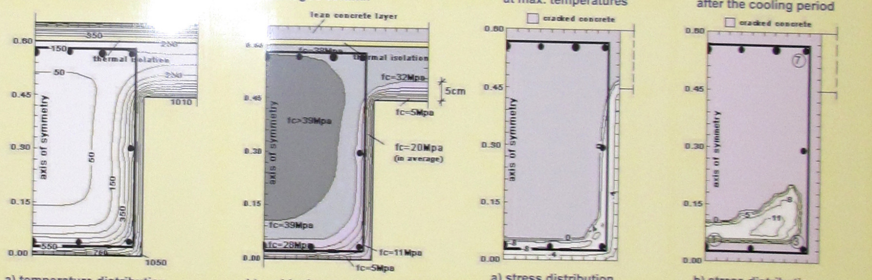
Ascending branch

$$\frac{\sigma_c}{f_c} = \frac{\varepsilon_c}{\varepsilon_{c1}} \cdot \frac{m}{m - 1 + (\varepsilon_c / \varepsilon_{c1})^m}$$

TEST EXAMPLE FOR NUMERICAL PROCEDURE

a) temperature distribu… in the cross s… b) …esidual concrete strength …damaged column

a) stress distribution at max. temperatures b) stress distribution after the cooling period

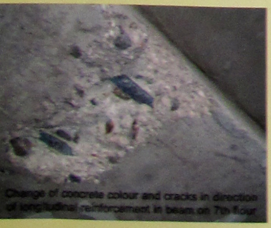


a) temperature distribution b) residual concrete strength in the cross section of the most damaged beam

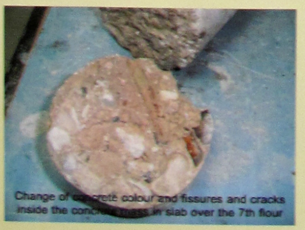
a) stress distribution at max. temperatures b) stress distribution after the cooling period

EXPERIMENTAL DETERMINATION OF THE RESIDUAL CONCRETE STRENGTH

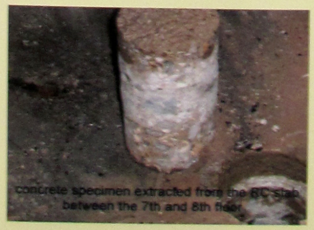
Change of concrete colour and deterioration of surface layers of specimens



Change of concrete colour and cracks in direction of longitudinal reinforcement in beam on 7th floor

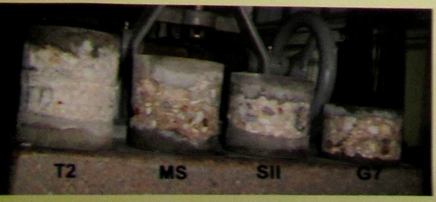


Change of concrete colour and fissures and cracks inside the concrete mass in slab over the 7th floor



concrete specimen extracted from the RC slab between the 7th and 8th floor

Deteriorated concrete specimens, prepared for testing



Concrete strength testing results

Position	Dimensions of specimens (cm)			Concrete compressive strength (MPa)		Concrete strength (MB)
	total H	h (testing)	D	cylinder	reduc.to cube 20/20/20	
RC wall (B8)	15	9.9	9.9	**26.0**	26.5	**20.0**
(after fire expose)		3.5		**15.8***	16.1	**12.0**
RC slab (MS)	18	10.3	9.9	**33.8**	34.5	**26.0**
(after fire expose)		6.5		**12.5***	12.8	**9.5**
RC slab (SII)	18	9.6	9.9	**38.4**	39.1	**29.4**
(after fire expose)		4		**13.0***	13.3	**10.0**
RC wall (V7)	25	9.9	9.9	**35.4**	36.1	**27.0**
(after fire expose)		5		**14.5***	14.8	**11.0**
RC wall (G7)	19.4	10	9.9	**25.4**	25.9	**20.0**
(after fire expose)		3.5		**14.5***	14.5	**11.0**
RC wall (D7)	18	10	9.9	**30.7**	31.3	**24.0**
(after fire expose)		3.5		**14.5***	14.8	**11.0**
RC wall (E7)	16	10	9.9	**31.9**	32.6	**25.0**
(after fire expose)		3		**14.1**	14.4	**10.5**

* Values are reduced with coefficients depending on the shape and height (h) of the deteriorated concrete specimens.