COMPUTER PROGRAM FOR FIRE CHECK OF CONCRETE MEMBERS

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INTRODUCTION

In the paper, the computer program **FRCB500** (**F**ire **R**esistance of **C**oncrete **B**eams – **500**°C Isotherm Method) for fire check of reinforced concrete beams is described. A temperature distribution through a cross section to-be-checked is calculated by means of the finite elements method using the material models suggested by EN 1992-1-2. A design resistance in the fire situation is determined by means of the 500°C isotherm method given in the Annex B.1 of EN 1992-1-2. The program may be used in a conjunction with both standard and parametric fires (see EN 1991-1-2) and it is possible to enter cross sections with a protective layer.
The program **FRCB500** is developed in the MATLAB environment. It is a non stand-alone application (that means the program **FRCB500** can't run without MATLAB), but presently, a stand-along version will be developed. The source files (so-called M-files) of the application **FRCB500** are available in the Department of Concrete and Masonry Structures, Faculty of Civil Engineering CTU in Prague. Together with the program **FRCB500**, the application for fire check of RC slabs (**FRCS500**) was developed. Stand alone versions of the programs **FRCB500** and **FRCS500** will be available via the CTU web pages.

TEMPERATURE ANALYSIS

Before a fire resistance check can be performed, it is necessary to determine temperatures in the cross section to-be-checked. The dialog window "FRCB500 – Temperature Analysis" is shown in the ***Fig. 1***. A user can define dimensions of a beam, properties of concrete, a thickness and properties of insulation (if the cross section is considered insulated), a design fire scenario, a fire exposure (two- three- or four-sided) and a time in fire exposure.
By means of the window "FRCB500 – Temperature Analysis", the temperature-time curve or the temperature profile can be displayed and the temperature in a point given by coordinates (x, y) can be calculated.

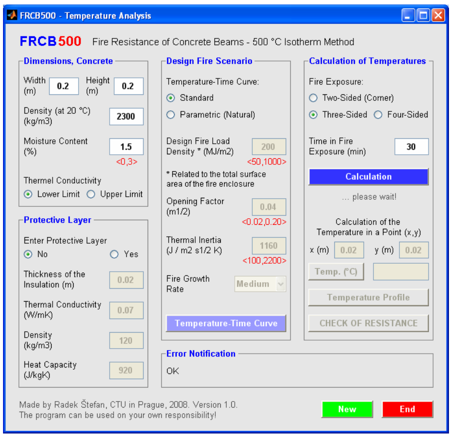

Fig. 1 *Dialog window "FRCB500 – Temperature Analysis"*

Dimensions, Concrete

The beam to-be-checked is given by a width, b (m), and a height, h (m), of the beam's cross-section.
Concrete is defined by a density at 20 °C, $\rho(20)$ ($kg \cdot m^{-3}$), by a moisture content, u (% of concrete weight), and by a thermal conductivity, λ_c ($W \cdot m^{-1} \cdot K^{-1}$). The thermal conductivity is defined by means of the lower or upper limit suggested by EN 1992-1-2.
A variation of a density with a temperature and a variation of a heat capacity (specific heat) with a temperature and with a moisture content is described in EN 1992-1-2.

Protective Layer

If the cross section is considered insulated, the protective layer is given by a thickness of the insulation, d_{iz} (m), and by constant values of a thermal conductivity, λ_{iz} ($W \cdot m^{-1} \cdot K^{-1}$), a density, ρ_{iz} ($kg \cdot m^{-3}$), and by a heat capacity (specific heat), $c_{p,iz}$ ($J \cdot kg^{-1} \cdot K^{-1}$). The protective layer is considered on all sides of the cross section that are exposed on fire.

Design Fire Scenario

A fire exposure is represented by the standard temperature-time curve (ISO 834) or alternatively by the parametric temperature-time curve given by a design fire load density, $q_{t,d}$ ($MJ \cdot m^{-3}$), related to the total surface area of the fire enclosure, by an opening factor, O ($m^{1/2}$), by a thermal inertia, b ($J \cdot m^{-2} \cdot s^{1/2} \cdot K^{-1}$), and by a fire road rate, according to EN 1991-1-2.
Using the push button "Temperature-Time Curve", the design fire scenario is displayed (***Fig. 2a, b***).

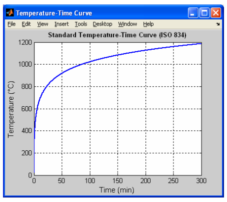

Fig. 2a *Window with the standard temperature-time curve*

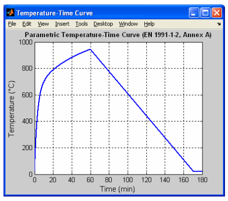

Fig. 2b *Window with the parametric temperature-time curve*

Calculation of Temperatures

At first, it is necessary to define a fire exposure (two-sided, three-sided or four-sided exposed cross section) and a time in fire exposure, t (min).
The temperature distribution through the cross section to-be-checked is calculated by means of the finite elements method (time approximation is based on the finite difference method).
The temperature distribution through the cross section is determined without taking into account steel bars. The reinforcement temperature is assumed to coincide with the concrete temperature in the same point.
Using the push button "Calculation" (see ***Fig. 1***), the temperature analysis is started. After calculation, the temperature profile (or temperature field, see ***Fig. 3a, b***) can be displayed and the temperature in the point given by coordinates (x, y) can be calculated. Also, using the push button "CHECK OF RESISTANCE", the window "FRCB500 – Check of Resistance" (see ***Fig. 5***) is displayed.

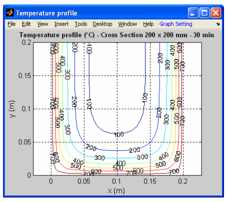

Fig. 3a Temperature profile

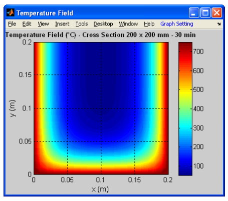

Fig. 3b Temperature field

As shown in ***Fig. 4***, the temperature profiles provided by the program **FRCB500** (for the standard fire) are in agreement with the temperature profiles given by EN 1992-1-2.

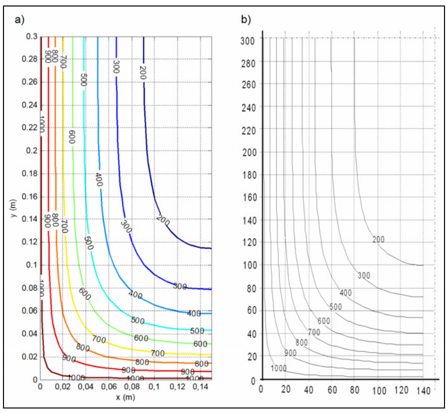

Fig. 4 *Comparison of the temperature profiles for the cross section 300 x 600 mm, t = 120 min,*
a) **FRCB500**, *b) EN 1992-1-2*

CHECK OF RESISTANCE

It is possible to check only three- or four-sided exposed cross sections. Also, the requirements on a minimum width of the cross-section as a function of a fire resistance (for the standard fire exposure) or a fire load density (for the parametric fire exposure) have to be fulfilled. The dialog window "FRCB500 – Check of Resistance" is shown in the ***Fig. 5***.

Fig. 5 *Dialog window "FRCB500 – Check of Resistance"*

Load-Bearing Function at Normal Temperature

At first, an assessment of the load-bearing function at normal temperature is determined. The assessment consists of verification of detailing rules and comparing the design bending moment with the moment of resistance, according to EN 1992-1-1. Outputs are displayed on the right part of the window.

Fire Resistance

The beam can be checked at fire situation, if all requirements at normal temperature are fulfilled. A design effect of actions for the fire situation (bending moment $M_{Ed,fi}$) is determined using a reduction factor η_{fi}. The reduction factor is computed using the equation (2.5) given in EN 1992-1-2. Alternatively, a value η_{fi} = = 0,7 may be used.
The moment of resistance $M_{Rd,fi}$ is calculate using the 500°C isotherm method. Outputs are displayed on the right part of the window (see ***Fig. 6***).

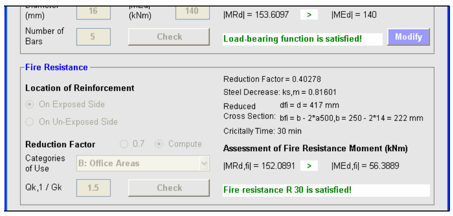

Fig. 6 *Check of fire resistance*

SUMMARY

Member analysis using the 500°C isotherm method is one of the methods suggested by EN 1992-1-2 for a verification of structural fire resistance of concrete members.
In the paper, the computer program **FRCB500** for fire check of RC beams was described.

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