Evaluation of the fire resistance of steel columns, insulated by YTONG®

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ABSTRACT: In the article there are presented the results of experimental and theoretical research on the fire resistance of steel columns, insulated by YTONG®. The fire tests were conducted with open (2T-shaped) and closed (rectangular hollow) cross-sections, without load. A comparison between experimental and calculation results has been made. At the end there are conclusions and proposals for additional research.

KEY WORDS: simple calculation model, fire resistance, steel column, YTONG®

I. Foreword

The use of calculation models for determination of the fire resistance of structural members and constructions in Bulgaria is regulated in art. 10 of [1]. The same Ordinance states that for this purpose should be used the methods for determination of the fire resistance given in Eurocodes.

II. Purpose

The purpose of the research is to determine the fire resistance of steel columns, insulated by YTONG® and to verify the simple calculation model for determination of the fire resistance of insulated steel elements, presented in Eurocode 3[3].

III. Simple calculation model for determination of the fire resistance of insulated steel elements

According to БДС EN 1993-1-2 the steel temperature development for internal steelwork insulated by fire protection material can be obtained by using:

(1) $$\Delta\theta_{a,t} = \frac{\lambda_p . A_p / V . (\theta_{g,t} - \theta_{a,t})}{d_p . C_a . \rho_a . (1 + \phi/3)} . \Delta t - (e^{\phi/10} - 1) . \Delta\theta_{g,t}$$

$$(\Delta\theta_{a,t} \geq 0 \quad ако \quad \Delta\theta_{g,t} > 0)$$

$$\phi = \frac{C_p . \rho_p}{C_a . \rho_a} . d_p . \frac{A_p}{V}$$

where:

A_p / V - the section factor for steel members insulated by fire protection material [1/m];

A_p - the appropriate area of fire protection material per unit length of the member [m^2/m];

V - the volume of the member per unit length [m^3/m];

C_a - the specific heat of steel [J/kg.K];

C_p - the specific heat of the fire protection material [J/kg.K];

d_p - the thickness of the fire protection material [m];

Δt - the time interval [s];

$\theta_{a,t}$ - the steel temperature at time t [^{o}C];

$\theta_{g,t}$ - the ambient gas temperature at time t [^{o}C];

$\Delta\theta_{g,t}$ - the increase of the ambient gas temperature during the time interval [^{o}C];

λ_p - the thermal conductivity of the fire protection system [W/m.K];

ρ_p, ρ_a - the unit mass of steel and the fire protection material [kg/m^3]

IV. Use of YTONG® for fire protection of steel members

Ytong is a well-known international brand name which stands for aerated concrete products. The products have unlimited constructional possibilities and good building physical properties.Their main advanteges are:

- Excellent insulating characteristics;

- **Non-flammable -** in case of fire the **YTONG** walls do not deform and get destroyed, they do not let the heat and prevent the fire from passing into neighbouring rooms. With YTONG one can obtain the highest possible fire resistance class easily even with smaller wall thicknesses.

- **Light weight**;

- **Easily to work with ;**

- **Precise dimensions;**

The masonry blocks YTONG are produced with a length of 60 cm and a height of 25 cm. These dimensions are the same for all blocks. Only their thickness varies – within the range from 5 to 35 cm.

Usually for fire protection blocks with 5 and 7,5 cm thickness are used as an insulation for steel columns.

VI. Experimental determination of the fire resistance of steel columns insulated by YTONG®.

The fire tests were conducted in the "Research and expert analysis center" in Sofia, which is a department in the Chief Directorate Fire Safety and Civil Protection. Steel columns with open (2T-shaped) and closed (rectangular hollow) cross-sections without load were tested. The columns were insulated by YTONG® blocks with 75 mm thickness. An air gap between the columns and the protection material was left with size of 15 mm. Two specimens from every type of cross section were tested.

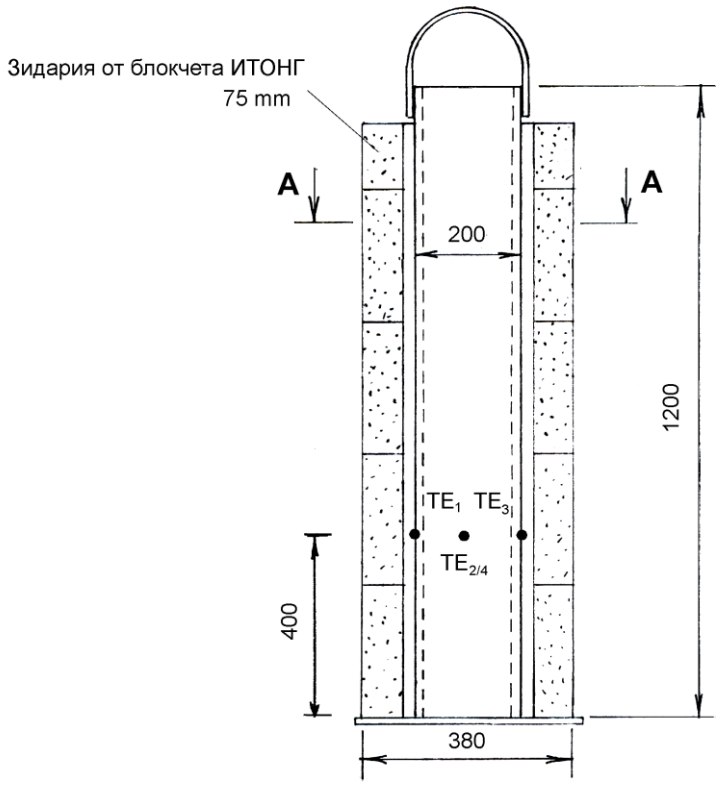
The fire tests were conducted according to the requirements of BDS EN 1363-1[2]. The furnace temperature followed the standard time-temperature curve as given in ISO 834. The experimental results were provided by the manufacturer of the YTONG blocks.

Figures 1 and 2 show the positions of the thermocouples for the two cross-sections.

In table 1 are given the dimensions of the cross-sections and the values of the properties of the steel and the fire protection materials, used for the the theoretical research. The theoretical research on the development of the temperature in the cross-section was conducted using equation (1). Figures 3 and 4 present the results from the theoretical and experimental study of the development of the temperature in the steel columns cross-sections.

Table 1. Data used for theoretical determination of the fire resistance of the steel columns

Dimensions, Properties	cross-section	
	Rectangular hollow	2T
$b \quad [mm]$	200	260
$h \quad [mm]$	150	300
$t_w \quad [mm]$	8	10
$t_f \quad [mm]$	-	16
$A_p / V \quad [1/m]$	131	101,8
$C_a \quad [J/kg.^O C]$	600	600
$\rho_a \quad [kg/m^3]$	7850	7850
$d_p \quad [mm]$	75	75
$C_p \quad [J/kg.^O C]$	1050	1050
$\rho_p \quad [kg/m^3]$	500	500
$\lambda_p \quad [W/m.^O C]$	0,16	0,16



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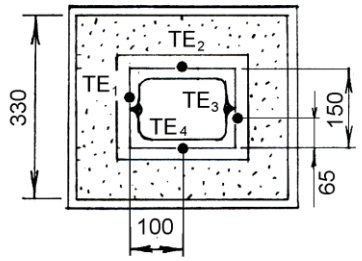

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Fig. 1 Positions of the thermocouples during the fire tests of steel columns with rectangular hollow cross-sections

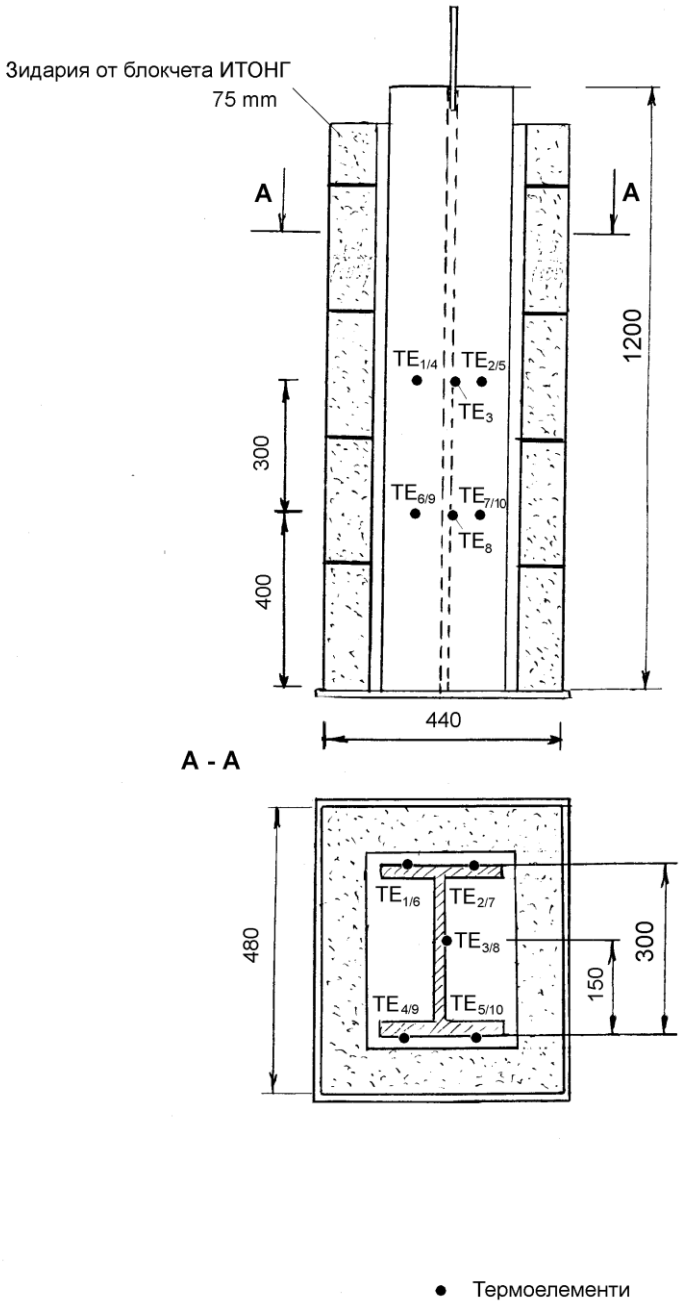
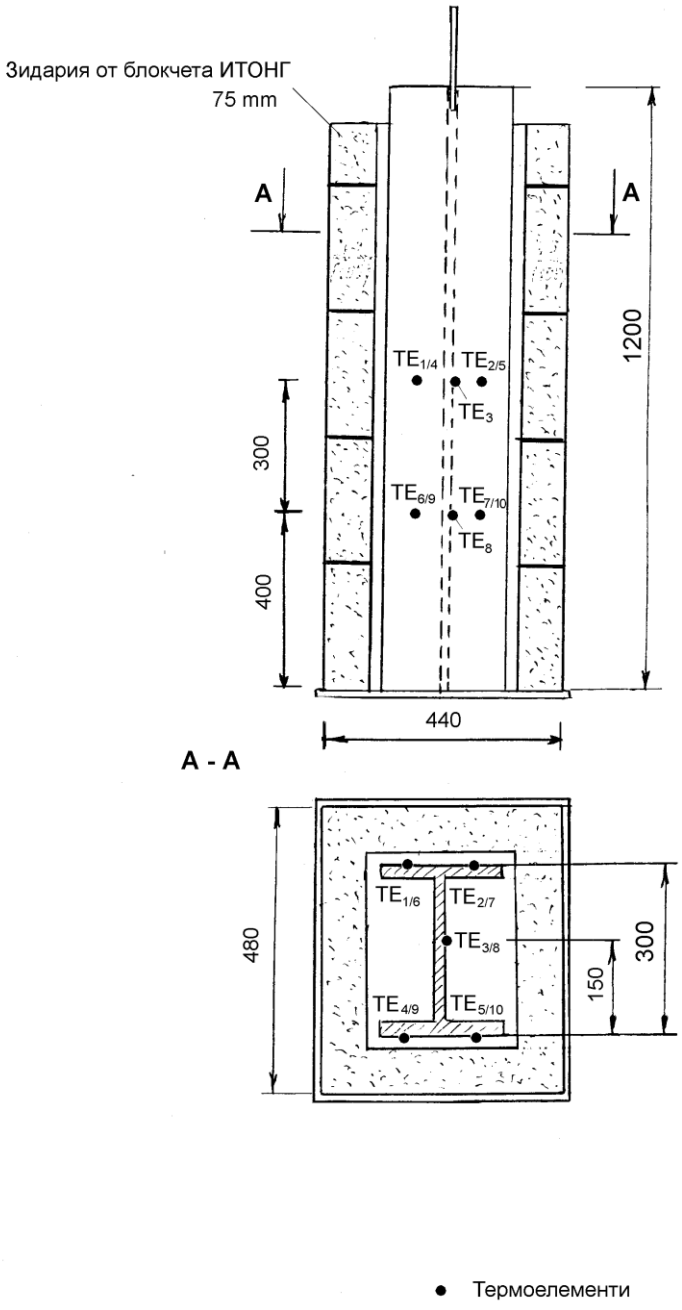


Fig. 2 Positions of the thermocouples during the fire tests of steel columns with open 2T-shaped cross-sections



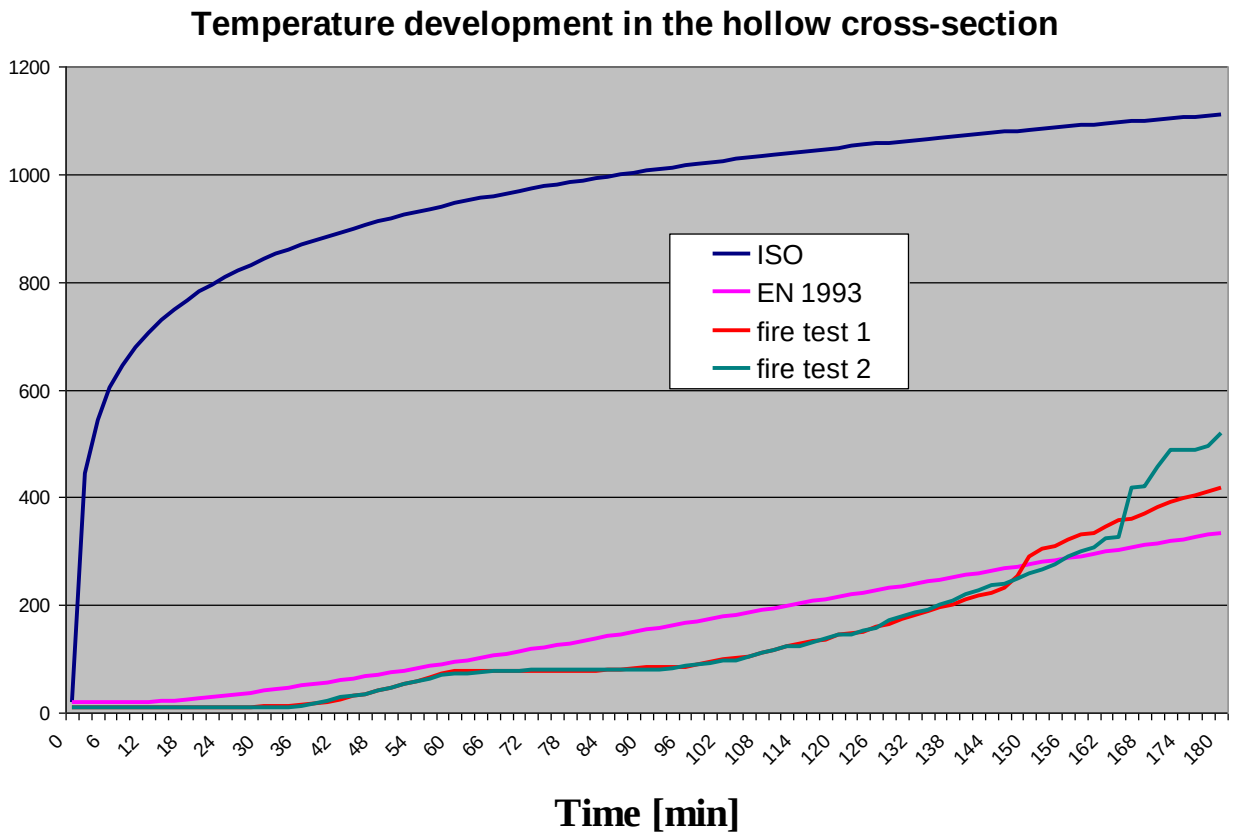


Fig. 3. Temperature development in the rectangular hollow cross-section

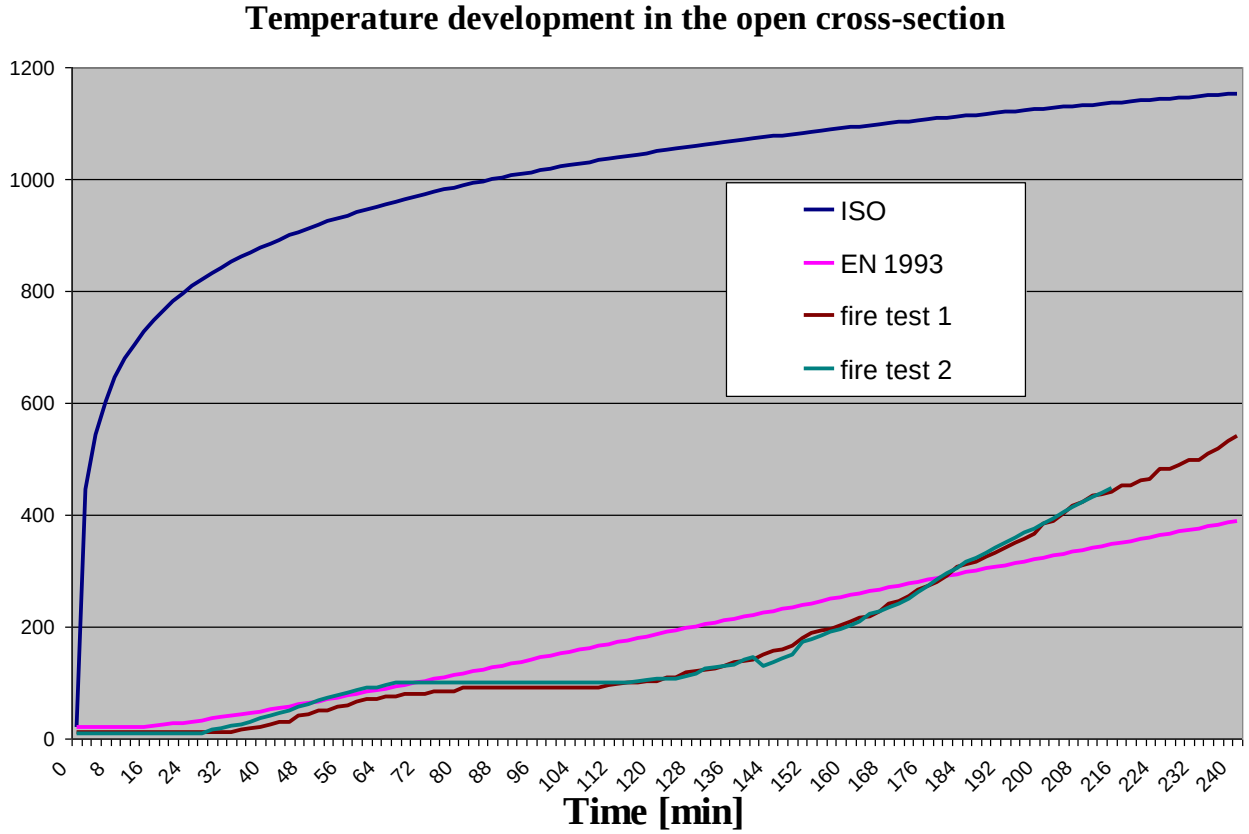


Fig. 4. Temperature development in the open 2T cross-section

VI. Summary

The fire resistance of the columns with hollow cross-sections is 180 min, with average temperature measured at this time 470 ^{o}C.

The fire resistance of the columns with open 2T cross-sections is 208 min, with average temperature measured at this time 470 ^{o}C.

It is visible from the graphs that there is a difference between the temperature-time curves for temperatures of the steel members over 400 ^{o}C. The reason for this difference is that we use constant values of the thermal properties of the YTONG, obtained for normal temperatures.

VII. Conclusion and recommendations

The fire resistance of the tested steel columns, insulated by YTONG® fulfills the highest legislative requirements for fire resistance of columns given in [1] – 180 min.

There is a need for additional research in order to obtain the thermal properties of YTONG for high temperatures.

VIII. References

1. Naredba Iz-1971 ot 29.10.2009 g. „Za stroitelno-tehnicheskite pravila I normi za osiguryavane na bezopasnost pri pojar. (**Ordinance Iz-1971 on the constructional and technical rules and standards to ensure fire safety)**, S., 2013

2. BDS EN 1363-1:2001 "Fire resistance tests - Part 1: General requirements"

3. BDS EN 1993-1-2:2005 Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design