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STUDY OF SLAB FIRE RESISTANCE ACCORDING TO EUROCODE
Using different computational methods

Introduction: Eurocode 1992-1-2 includes the following alternative design methods: detailing according to tabulated data, simplified calculating method for specific types of members and general calculating method for simulating the behavior of structural members, parts of structure or the entire structure. For determining the fire resistance of reinforced concrete slab structure the tabulated data and the simplified calculating method are used. Temperature distribution in concrete cross-section is determined using FEM analysis (ANsys) and numerical solution (Nonstac) of differential equation of heat transfer. Calculated temperatures are compared with temperature profiles given in annex A. Structural response of slab cross-section is determined using “500°C” isotherm method.

Study example:

Study example of slab cross-section with thickness 200 mm is analysed. The slab is reinforced with profile 10/100 mm, concrete cover is 25 mm, distance between the reinforcement centre of gravity and exposed side of the slab is 30 mm. Slab is made of concrete C20/25 and steel B420B.

Heat exposure model – input data according to Eurocode 2:

Heat conductivity λ:

Heat concuctivity of concrete is assumed as temperature dependant and is given with upper (1) and lower (2) limit value:

$\lambda_c = 2.0 - 0.2451(\theta/100) + 0.0107(\theta/100)^2$ (1)

$\lambda_c = 1.36 - 0.136(\theta/100) + 0.0057(\theta/100)^2$ (2)

Concrete specific heat c:

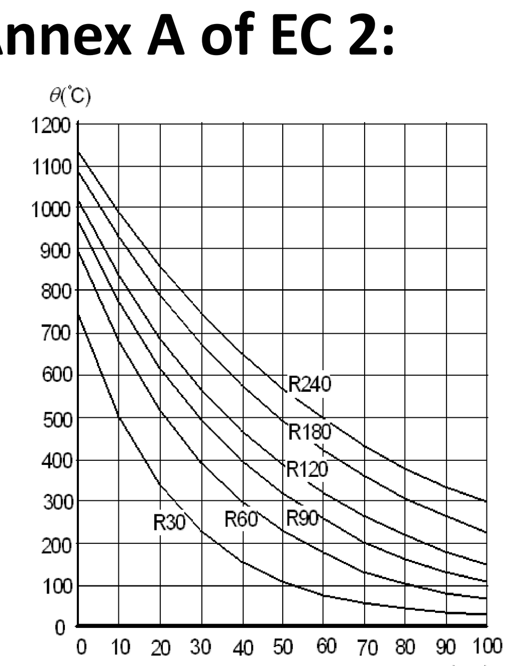
Basic value of concrete specific heat is 900 (J/kg.K). With increasing temperature concrete specific heat growths to the value 1100 (J/kg.K). It is possible to take into account the initial humidity with local significant increasing of specific heat in the temperature interval 100°C-115°C. In this study example zero initial humidity is assumed on the safe side.

Concrete density ρ:

According to P ENV version of Eurocode 2 it is recommended to use the value 2300 kg/m^3, without the temperature dependence.
According to Eurocode the density is given as a function of temperature, but without the recommended value for the initial density. The common concrete density is given also in Eurocode 1, part 1-1 (2004) with the value 2400 kg/m^3.

Heat exposure model – temperature profiles – Annex A of EC 2:

As for the slab structures, the temperature profile is given only for the slab of thickness 200 mm.
The temperatures were appointed for lower value of heat conductivity, specific heat with assuming the initial humidity 1.5% and the density 2400 kg/m^3.



Heat exposure model – FEM analysis – Ansys

The FEM analysis is provided using ANsys computer program. In the Table 1 there are sequenced temperatures in reinforcement for different input data.

Tab. 1 Temperatures in reinforcement – Ansys

	temperature dependent			constant		
λ	2.0	1.36	2.0	2.0	1.36	2.0
density	2400	2400	2300	2400	2400	2300
Time	**Temp.**	**Temp.**	**Temp.**	**Temp.**	**Temp.**	**Temp.**
min	**C**	**C**	**C**	**C**	**C**	**C**
0	20	20	20	20	20	20
30	271	245	277	370	332	367
60	423	402	430	574	533	574
90	517	502	524	687	647	689
120	585	575	592	765	726	767

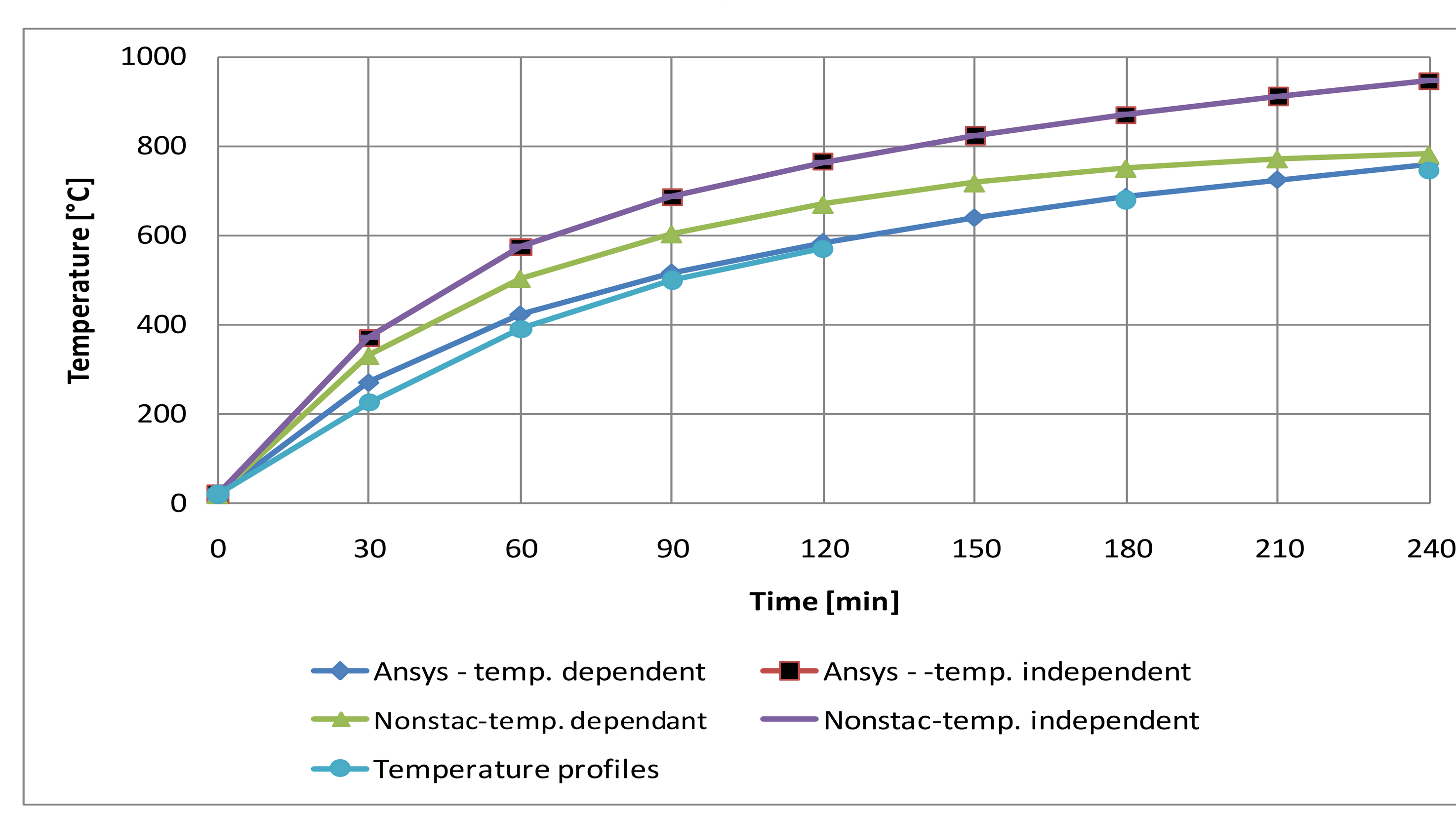
Heat exposure model – numerical analysis – Nonstac

Numerical analysis is provided using Nonstac computer program. Nonstac computer program solves numerically Fourier differential equation of one dimensional heat transfer using Runge-Kutta method

Tab. 2 Temperatures in reinforcement – NONSTAC

	temperature dependent		constant		
λ	2.0	1.36	2.0	1.36	2.0
density	2400	2400	2400	2400	2300
Time	**Temp.**	**Temp.**	**Temp.**	**Temp.**	**Temp.**
min	**C**	**C**	**C**	**C**	**C**
0	20	20	20	20	20
30	331	291	370	332	340
60	504	465	574	533	540
90	604	569	687	647	654
120	670	643	765	726	732

Heat exposure model – comparing the temperatures



Structural response - fire resistance in time 90 minutes

			Profiles	Ansys	Ansys	Nonstac
Heat conductivity - temp. dep.	λ	kJ/kg.K		2.0	2.0	2.0
Density – temp. dep.	ρ	kg/m^3		2400	2300	2400
Temperature in reinforcement,	θ_R	C	500	517	524	604
Steel strength	$f_{yd,fi}$	Mpa	328	305	232	193
B. moment - capacity	$m_{Rd,fi}$	kNm/m	42	39	30	25
B. moment – action ef.	$m_{Ed,fi}$	kNm/m	32	32	32	32
Assessment			OK	OK	X	X

Conclusion:

- In the paper the study example of reinforced concrete slab is analyzed. Temperature in reinforcement is settled using temperature profiles and Ansys and Nonstac software.
- Input data for thermal analysis are not given strictly.
- Table fire resistance of analyzed slab is 90 minutes.
- As the simplified method is more advanced then detailing according to tabulated data, it is expected that resulting fire resistance of slab structure gives more favorable values
- This study would like to point out that in some cases design according to tabulated data is more favorable than simplified method.

Application of Structural Fire Engineering, 29th of April 2011 Prague, Czech Republic