

FEM simulation of composite column during fire exposure

based on DIN EN 1991-1-2/NA:2010-03
using ANSYS software



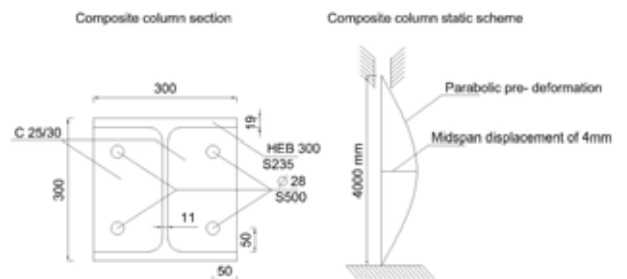
TABLE OF CONTENTS

- Software presentation
- Assumpioints: geometry description
- Assumpioints: material parameters
- Assumpioints: load description
- Analysis: schematics
- Analysis : mesh and elements
- Analysis: boundary conditions
- Results: temperature
- Results: deformation
- Conclusions

Software presentation

- CAE software based on FEM
- Initially designed for simulation of static, dynamic and thermal problems
- Founded 1970
- Nowadays consists of simulation tools: Structural Mechanics, Multiphysics, Fluid Dynamics, Explicit Dynamics, Electromagnetics, Hydrodynamics
- As well as of workflow: Workbench, Geometry Interfaces...

Assumpioints: Geometry description



Buckling coefficient – 0,5

Assumpioints: Reference Data

FAILURE TIME t_u	[min]	92
HORIZONTAL MIDSPAN	30 min	4,4
DISPLACEMENT AFTER TIME t	60 min	5,5
The temperature after fire time of 90 minutes:		
Reinforcement		535 C
Center of gravity of the steel profile		474 C

Assumpioints: Material parameters

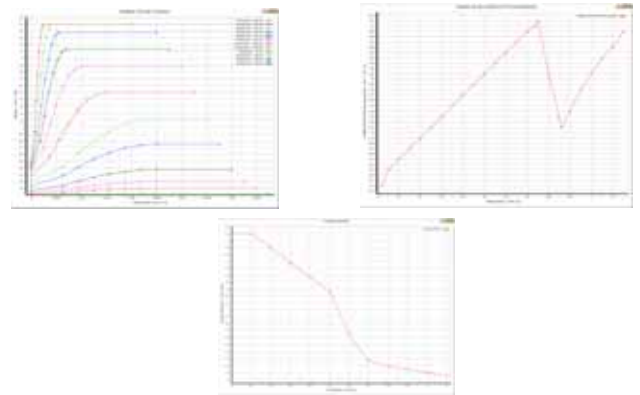
Concrete C25/30 (3 % moisture (by mass))	$f_{td}(20^{\circ}\text{C})$	N/mm ²	25
Reinforcing steel S 500	$f_{yk}(20^{\circ}\text{C})$	N/mm ²	500
Structural steel S 235	$f_{ak}(20^{\circ}\text{C})$	N/mm ²	235
Stress – strain curve	Concrete a. Reinforcing steel bars Structural steel		DIN EN 1994-1-2
Temperature load	ETK (four sides)		DIN EN 1991-1-2
Heat transfer coefficient	α_c	W/(m ² × K)	25
Emissivity	ϵ_m		0,7
Thermal and physical material properties	Concrete $\lambda, \rho, c_p, \epsilon_{m,c}$ Steel $\lambda, \rho, c_p, \epsilon_{m,s}, \epsilon_{m,s}$		DIN EN 1994-1-2 DIN EN 1994-1-2

a. Containing mainly quartzite aggregate and density $\rho=2400 \text{ kg/m}^3$
b. Hot-rolled

Assumpioints: Material parameters

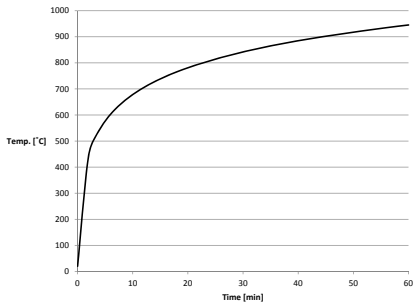
Property	Value	Units
Young's Modulus	210	10 ⁹ N/m ²
Poisson's Ratio	0.3	
Thermal Expansion Coefficient	12	10 ⁻⁶ /K
Thermal Conductivity	45	W/m-K
Specific Heat	470	J/kg-K
Density	7850	kg/m ³
Yield Strength	235	N/mm ²
Tensile Strength	450	N/mm ²
Ultimate Tensile Strength	570	N/mm ²
Modulus of Elasticity	210000	N/mm ²
Modulus of Resilience	0.0001	N/mm ²
Modulus of Toughness	100	N/mm ²
Modulus of Rupture	100	N/mm ²
Modulus of Elasticity (Plane Stress)	210000	N/mm ²
Modulus of Elasticity (Plane Strain)	210000	N/mm ²
Modulus of Elasticity (Shell)	210000	N/mm ²
Modulus of Elasticity (Beam)	210000	N/mm ²
Modulus of Elasticity (Wire)	210000	N/mm ²
Modulus of Elasticity (Joint)	210000	N/mm ²
Modulus of Elasticity (Surface)	210000	N/mm ²
Modulus of Elasticity (Volume)	210000	N/mm ²
Modulus of Elasticity (Mass)	210000	N/mm ²
Modulus of Elasticity (Area)	210000	N/mm ²
Modulus of Elasticity (Moment)	210000	N/mm ²
Modulus of Elasticity (Torsion)	210000	N/mm ²
Modulus of Elasticity (Bending)	210000	N/mm ²
Modulus of Elasticity (Twisting)	210000	N/mm ²
Modulus of Elasticity (Stretching)	210000	N/mm ²
Modulus of Elasticity (Compression)	210000	N/mm ²
Modulus of Elasticity (Tension)	210000	N/mm ²
Modulus of Elasticity (Shear)	210000	N/mm ²
Modulus of Elasticity (Bulging)	210000	N/mm ²
Modulus of Elasticity (Flattening)	210000	N/mm ²
Modulus of Elasticity (Distortion)	210000	N/mm ²
Modulus of Elasticity (Expansion)	210000	N/mm ²
Modulus of Elasticity (Contraction)	210000	N/mm ²
Modulus of Elasticity (Deformation)	210000	N/mm ²
Modulus of Elasticity (Recovery)	210000	N/mm ²
Modulus of Elasticity (Relaxation)	210000	N/mm ²
Modulus of Elasticity (Creep)	210000	N/mm ²
Modulus of Elasticity (Fatigue)	210000	N/mm ²
Modulus of Elasticity (Fracture)	210000	N/mm ²
Modulus of Elasticity (Failure)	210000	N/mm ²
Modulus of Elasticity (Damage)	210000	N/mm ²
Modulus of Elasticity (Degradation)	210000	N/mm ²
Modulus of Elasticity (Degradation Rate)	210000	N/mm ²
Modulus of Elasticity (Degradation Time)	210000	N/mm ²
Modulus of Elasticity (Degradation Distance)	210000	N/mm ²
Modulus of Elasticity (Degradation Temperature)	210000	N/mm ²
Modulus of Elasticity (Degradation Humidity)	210000	N/mm ²
Modulus of Elasticity (Degradation Pressure)	210000	N/mm ²
Modulus of Elasticity (Degradation Concentration)	210000	N/mm ²
Modulus of Elasticity (Degradation Potential)	210000	N/mm ²
Modulus of Elasticity (Degradation Risk)	210000	N/mm ²
Modulus of Elasticity (Degradation Severity)	210000	N/mm ²
Modulus of Elasticity (Degradation Impact)	210000	N/mm ²
Modulus of Elasticity (Degradation Frequency)	210000	N/mm ²
Modulus of Elasticity (Degradation Duration)	210000	N/mm ²
Modulus of Elasticity (Degradation Intensity)	210000	N/mm ²
Modulus of Elasticity (Degradation Magnitude)	210000	N/mm ²
Modulus of Elasticity (Degradation Scale)	210000	N/mm ²
Modulus of Elasticity (Degradation Level)	210000	N/mm ²
Modulus of Elasticity (Degradation Grade)	210000	N/mm ²
Modulus of Elasticity (Degradation Class)	210000	N/mm ²
Modulus of Elasticity (Degradation Category)	210000	N/mm ²
Modulus of Elasticity (Degradation Group)	210000	N/mm ²
Modulus of Elasticity (Degradation Family)	210000	N/mm ²
Modulus of Elasticity (Degradation Series)	210000	N/mm ²
Modulus of Elasticity (Degradation Set)	210000	N/mm ²
Modulus of Elasticity (Degradation Collection)	210000	N/mm ²
Modulus of Elasticity (Degradation System)	210000	N/mm ²
Modulus of Elasticity (Degradation Scheme)	210000	N/mm ²
Modulus of Elasticity (Degradation Plan)	210000	N/mm ²
Modulus of Elasticity (Degradation Policy)	210000	N/mm ²
Modulus of Elasticity (Degradation Procedure)	210000	N/mm ²
Modulus of Elasticity (Degradation Process)	210000	N/mm ²
Modulus of Elasticity (Degradation Method)	210000	N/mm ²
Modulus of Elasticity (Degradation Technique)	210000	N/mm ²
Modulus of Elasticity (Degradation Approach)	210000	N/mm ²
Modulus of Elasticity (Degradation Strategy)	210000	N/mm ²
Modulus of Elasticity (Degradation Tactic)	210000	N/mm ²
Modulus of Elasticity (Degradation Action)	210000	N/mm ²
Modulus of Elasticity (Degradation Measure)	210000	N/mm ²
Modulus of Elasticity (Degradation Step)	210000	N/mm ²
Modulus of Elasticity (Degradation Phase)	210000	N/mm ²
Modulus of Elasticity (Degradation Stage)	210000	N/mm ²
Modulus of Elasticity (Degradation Step)	210000	N/mm ²
Modulus of Elasticity (Degradation Phase)	210000	N/mm ²
Modulus of Elasticity (Degradation Stage)	210000	N/mm ²
Modulus of Elasticity (Degradation Step)	210000	N/mm ²
Modulus of Elasticity (Degradation Phase)	210000	N/mm ²
Modulus of Elasticity (Degradation Stage)	210000	N/mm ²

Assumpioints: Material parameters



Assumpioints: Load description

Standard ISO fire curve
 $T=20+345 \cdot \log_{10}(8t+1)$



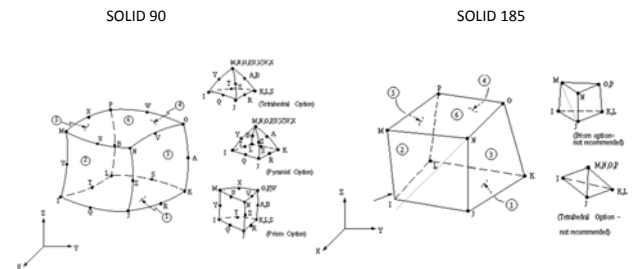
t	T
0	20
6	603.1176
12	705.4362
18	765.672
24	808.5173
30	841.7959
36	869.0098
42	892.0323
48	911.984
54	929.5883
60	945.3401
66	959.5922
72	972.6057
78	984.5786
84	995.6652
90	1005.988

Analysis: schematics



- Same geometry
- Same mesh
- Same engineering data
- Different finite elements
- Load transfer

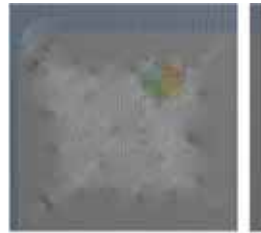
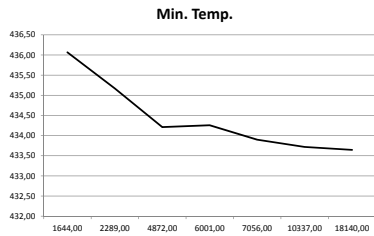
Analysis : mesh and elements



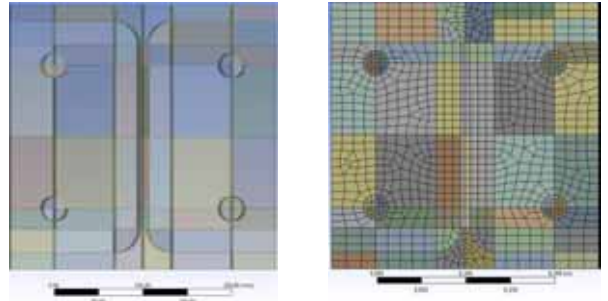
Source: ANSYS MANUAL

Analysis : mesh and elements

Analysis nr	Element Type	Element size [m]	Number of Elements	Min. Temp.
1	shell 57	0,02	1644,00	436,07
2	shell 57	0,01	2289,00	435,17
3	shell 57	0,007	4872,00	434,21
4	shell 57	0,006	6001,00	434,26
5	shell 57	0,005	7056,00	433,90
6	shell 57	0,004	10337,00	433,72
7	shell 57	0,003	18140,00	433,65

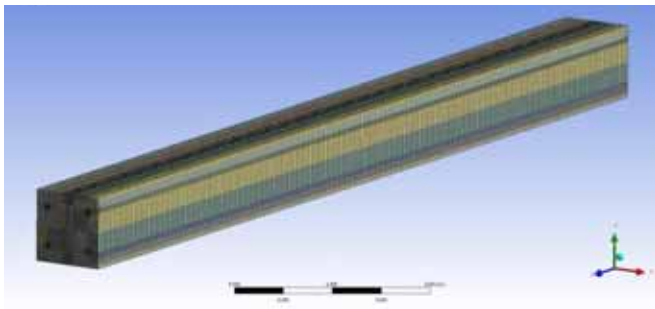


Analysis : mesh and elements

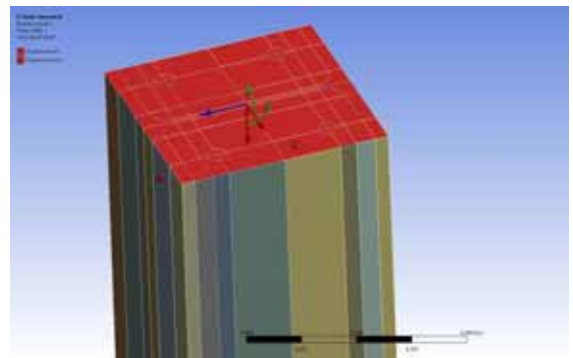


184 440 finite elements on column

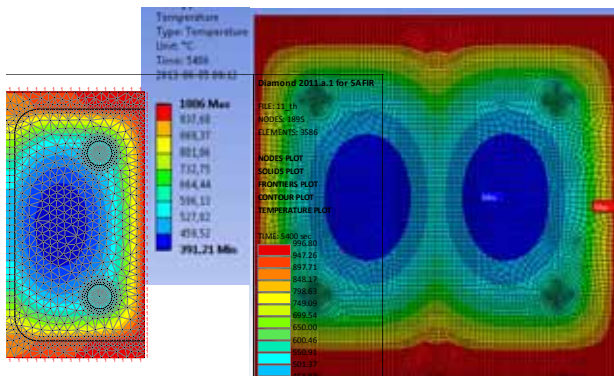
Analysis : mesh and elements



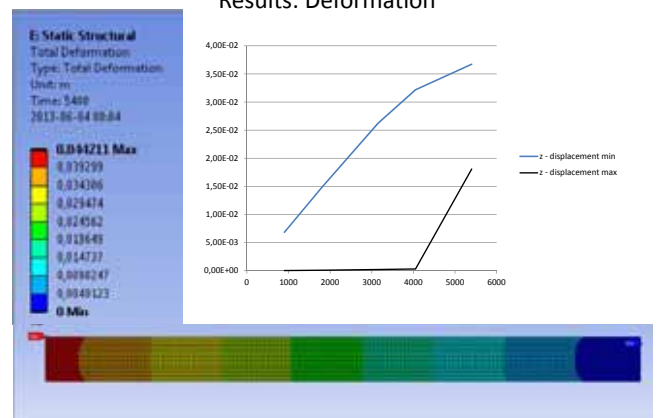
Analysis: boundary conditions



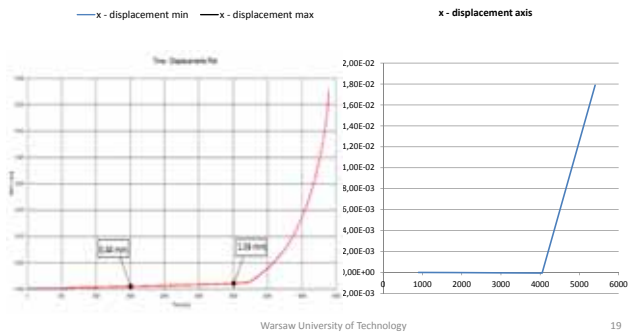
Results: Temperature



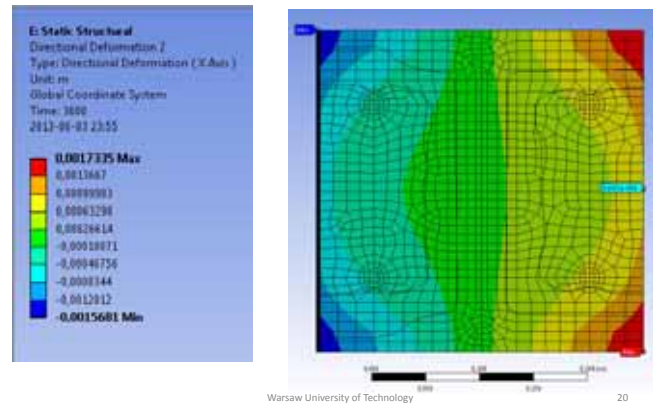
Results: Deformation



Results: Deformation



Results: Deformation



Conclusions

- mesh sizing is secondary factor when it comes to temperature field
- there is no difference in temperature result in 2D and 3D analysis beside computation cost
- the problem of applying temperature field on 2D model of cross-section on the model for static analysis
- differences in temperature mainly affected by the load application

TIPS FOR THE FUTURE:

- Find a way to apply 2D results of heat transfer analysis for the 3D model in ANSYS software to save computational cost
- Create standard schematic workflow in Ansys Workbench to conduct range of analysis for different geometry or engineering data