Benchmark Example No. 32

Thermal Extension of Structural Steel in case of Fire

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VERiFiCATiON
BE32 Thermal Extension of Structural Steel in case of Fire

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SOFiSTiK AG

HQ Nuremberg
Flataustraße 14
90411 Nürnberg
Germany

T +49 (0)911 39901-0
F +49(0)911 397904

Office Garching
Parkring 2
85748 Garching bei München
Germany

T +49 (0)89 315878-0
F +49 (0)89 315878-23

info@sofistik.com
www.sofistik.com

Front Cover

Volkstheater, Munich Photo: Florian Schreiber

Overview	
Element Type(s):	BF2D, SH3D
Analysis Type(s):	STAT, MNL
Procedure(s):	LSTP
Topic(s):	FIRE
Module(s):	TALPA, ASE
Input file(s):	thermal_extension, quad_32.dat

1 Problem Description

This benchmark is concerned with the validation of the structural analysis in case of fire with respect to the general calculation method according to DIN EN 1992-1-2. Therefore test case 4 is employed as presented in Annex CC of the standard DIN EN 1992-1-2/NA:2010-03 [1]. In this example the validation of the extension of structural steel, for the model of Fig. 1, at different constant temperature exposures is examined.

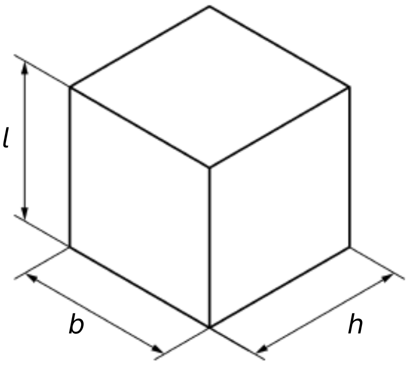

Figure 1: Problem Description

2 Reference Solution

The physical, mechanical and mathematical basics of engineering-based fire design programs, should be validated in terms of thermal, cross-sectional and system analysis. The aim of Annex CC [1] is, through a collection of test cases, to check their applicability for fire proof evaluation on real structures. For every example a parameter-dependent test matrix, for the relevant assessment criteria, is provided, where the computational accuracy of the program is examined. Results of existing analytical solutions or of approved programs are also provided, as well as the acceptable specified tolerances.

3 Model and Results

The properties of the model are defined in Table 1. A fictional beam, as depicted in Fig. 1, with cross-sectional dimensions b / h = $100/100\ mm$ and the length of $100\ mm$ is examined. Different temperatures are assigned to the material S 355 of the cross-section. The analysis is performed with TALPA, where the FIBER beam element is utilised, as well as with ASE, where the QUAD element is tested. The computed and the reference results are presented in Table 2, Fig. 2 and Table 3 for the FIBER beam and QUAD element, respectively.

Table 1: Model Properties

Material Properties	Geometric Properties	Test Properties
S 355	$l = 100\,mm$	Initial Conditions:
$f_{yk(20°C)} = 355\,N/mm^2$	$h = 100\,mm$	$\Theta = 20°C$
Stress-strain curve according to DIN EN 1993-1-2	$b = 100\,mm$	Homogeneous temperature component: $\Theta = 100, 300, 500, 600, 700, 900°C$

Table 2: Results for Thermal Elongation of Steel - FIBER

Θ [° C]	Ref. [1] Δl [mm]	SOF. $\Delta l'$ [mm]	$\lvert e_r \rvert$ [%] or e [mm]	Tol.
100	0.09984	0.09984	0.000 mm	for $\Theta \leq 300$ ° C
300	0.37184	0.37184	0.000 mm	± 0.05 mm
500	0.67584	0.67584	0.000 %	
600	0.83984	0.83984	0.000 %	for $\Theta > 300$ ° C
700	1.01184	1.01184	0.000 %	± 1 %
900	1.18000	1.18000	0.000 %	

Table 3: Results for Thermal Elongation of Steel - QUAD

Θ [° C]	Ref. [1] Δl [mm]	SOF. $\Delta l'$ [mm]	$\lvert e_r \rvert$ [%] or e [mm]	Tol.
100	0.09984	0.09984	0.000 mm	for $\Theta \leq 300$ ° C
300	0.37184	0.37184	0.000 mm	± 0.05 mm
500	0.67584	0.67584	0.000 %	
600	0.83984	0.83984	0.000 %	for $\Theta > 300$ ° C
700	1.01184	1.01184	0.000 %	± 1 %
900	1.18000	1.18000	0.000 %	

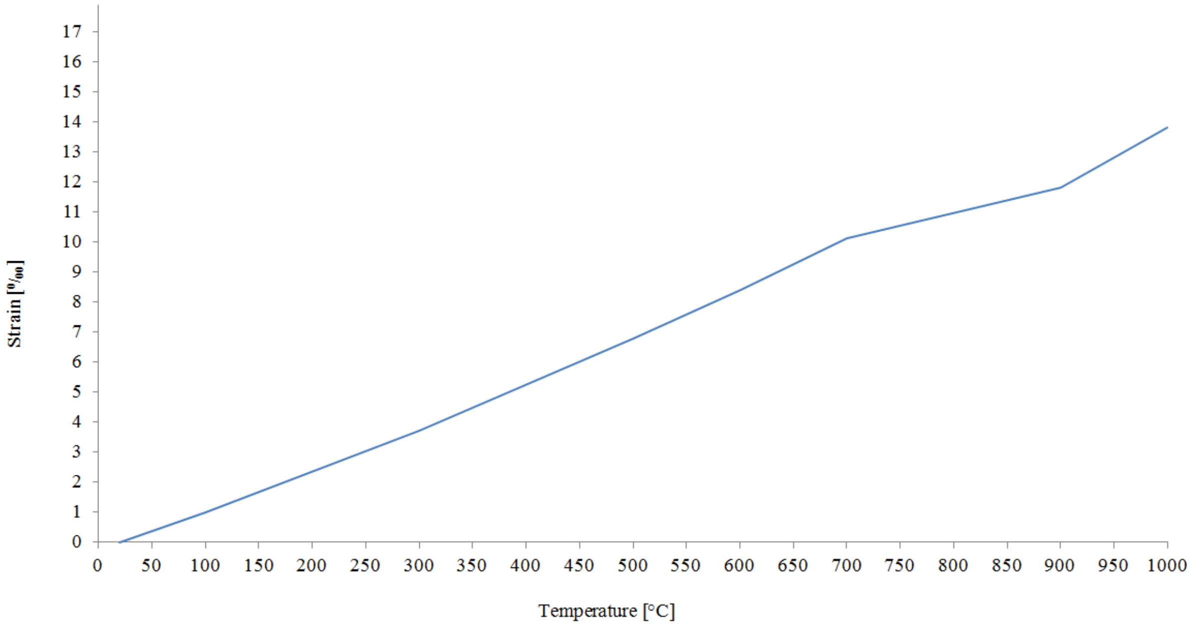

Figure 2: Temperature Strains

4 Conclusion

This example verifies the extension of structural steel at different constant temperature exposures. It has been shown that the calculation results are in excellent agreement with the reference results.

5 Literature

[1] *DIN EN 1991-1-2/NA: Eurocode 1: Actions on structures, Part 1-2/NA: Actions on structures exposed to fire*. CEN. 2010.