



Benchmark Example No. 33

Work Laws in case of Fire for Concrete and Structural Steel

VERiFiCATION
BE33 Work Laws in case of Fire for Concrete and Structural Steel

VERiFiCATION Manual, Service Pack 2023-10 Build 44

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The manual and the program have been thoroughly checked for errors. However, SOFiSTiK does not claim that either one is completely error free. Errors and omissions are corrected as soon as they are detected.

The user of the program is solely responsible for the applications. We strongly encourage the user to test the correctness of all calculations at least by random sampling.

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):	temperature_compression.dat , quad_33.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 5 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 change in length of structural steel and concrete in compression, for the model of Fig. 1, at varying temperature and load capacity levels, is investigated.

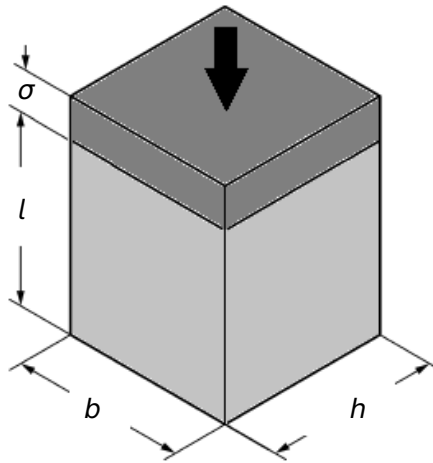


Figure 1: Problem Description

2 Reference Solution

The aim of Annex CC [1] is to check the applicability of the programs for engineering-based fire design on real structures. In this case the influence of the combination of increasing temperature and compressive loading with respect to the loading capacity of the structure is examined.

3 Model and Results

The properties of the model are defined in Table 1. A fictional beam as depicted in Fig. 1 is examined here, for the case of structural steel S 355 and of concrete C 20/25, with cross-sectional dimensions $b / h = 10 / 10 \text{ mm}$, $l = 100 \text{ mm}$ and $b / h = 31.6 / 31.6 \text{ mm}$, $l = 100 \text{ mm}$, respectively. Different temperatures and load levels are investigated. The boundary conditions are set such that stability failure is ruled out. The analysis is performed with TALPA, where the FIBER beam element is utilised. The computed and the reference results are presented in Table 2 for structural steel and in Table 3 for concrete. Fig. 2 presents stress-strain curves for structural steel for different temperature levels.

Table 1: Model Properties

Material Properties		Geometric Properties		Test Properties
Steel	Concrete	Steel	Concrete	
S 355	C 20/25	$l = 100 \text{ mm}$	$l = 100 \text{ mm}$	Initial Conditions:
$f_{yk} = 355 \text{ MPa}$	$f_{ck} = 20 \text{ MPa}$	$h = 100 \text{ mm}$	$h = 31.6 \text{ mm}$	$\Theta = 20^\circ\text{C}$
Stress-strain:	Stress-strain:	$b = 10 \text{ mm}$	$b = 31.6 \text{ mm}$	Homog. temp.:
DIN EN 1993-1-2	DIN EN 1992-1-2			20, 200, 400, 600, 800°C
				Loading:
				$\sigma_{s(\Theta)} / f_{yk(\Theta)}$
				or
				$\sigma_{c(\Theta)} / f_{ck(\Theta)} =$ 0.2, 0.6, 0.9

Table 2: Results for Structural Steel - FIBER

Θ [° C]	Ref. [1]		SOF.	e_r [%]	Tol. [%]
	$\sigma_{s(\Theta)} / f_{yk(\Theta)}$	Δl [mm]	$\Delta l'$ [mm]		
20	0.2	0.034	0.034	0.560	
	0.6	0.101	0.101	-0.424	
	0.9	0.152	0.152	-0.094	
200	0.2	-0.194	-0.194	-0.141	
	0.6	-0.119	-0.119	-0.119	
	0.9	0.159	0.156	1.794	
400	0.2	-0.472	-0.472	0.097	
	0.6	-0.293	-0.294	-0.305	$\pm 3 \%$
	0.9	0.451	0.449	0.525	
600	0.2	-0.789	-0.789	0.053	
	0.6	-0.581	-0.581	-0.054	
	0.9	0.162	0.160	1.245	
800	0.2	-1.059	-1.059	0.030	
	0.6	-0.914	-0.914	-0.028	
	0.9	-0.170	-0.172	-1.164	

Table 3: Results for Concrete - FIBER

Θ [° C]	$\sigma_{s(\Theta)} / f_{yk(\Theta)}$	Ref. [1]	SOF.	e_r [%]	Tolerance [%]
		Δl [mm]	$\Delta l'$ [mm]		
20	0.2	0.0334	0.0334	0.074	
	0.6	0.104	0.1036	0.428	
	0.9	0.176	0.1763	-0.173	
200	0.2	-0.107	-0.1070	0.024	
	0.6	0.0474	0.0474	-0.035	
	0.9	0.2075	0.2075	0.014	
400	0.2	-0.356	-0.3557	0.085	
	0.6	-0.075	-0.0750	0.016	± 3 %
	0.9	0.216	0.2160	-0.009	
600	0.2	-0.685	-0.6850	-0.007	
	0.6	0.0167	0.0167	-0.182	
	0.9	0.744	0.7442	-0.033	
800	0.2	-1.066	-1.0662	-0.023	
	0.6	-0.365	-0.3645	0.145	
	0.9	0.363	0.363	-0.010	

Next step is the analysis of the same example with ASE where the QUAD element is now tested. The results are presented in Table 4 for structural steel and in Table 5 for concrete.

Table 4: Results for Structural Steel - QUAD

Θ [° C]	$\sigma_{s(\Theta)} / f_{yk(\Theta)}$	Ref. [1]	SOF.	e_r [%]	Tolerance [%]
		Δl [mm]	$\Delta l'$ [mm]		
20	0.2	0.034	0.034	0.560	
	0.6	0.101	0.101	-0.424	
	0.9	0.152	0.152	-0.094	
200	0.2	-0.194	-0.194	-0.208	
	0.6	-0.119	-0.120	-0.448	
	0.9	0.159	0.151	5.341	
400	0.2	-0.472	-0.472	0.010	
	0.6	-0.293	-0.297	-1.447	± 3 %
	0.9	0.451	0.422	6.396	
600	0.2	-0.789	-0.790	-0.103	

Table 4: (continued)

Θ [° C]	$\sigma_{s(\Theta)} / f_{yk(\Theta)}$	Ref. [1]	SOF.	e_r [%]	Tolerance
		Δl [mm]	$\Delta l'$ [mm]		[%]
800	0.6	-0.581	-0.589	-1.302	
	0.9	0.162	0.130	19.626	
	0.2	-1.059	-1.060	-0.093	
	0.6	-0.914	-0.920	-0.657	
	0.9	-0.170	-0.202	-18.540	

Table 5: Results for Concrete - QUAD

Θ [° C]	$\sigma_{s(\Theta)} / f_{yk(\Theta)}$	Ref. [1]	SOF.	e_r [%]	Tolerance
		Δl [mm]	$\Delta l'$ [mm]		[%]
20	0.2	0.0334	0.0334	0.081	
	0.6	0.1040	0.1036	0.429	
	0.9	0.1760	0.1763	-0.173	
200	0.2	-0.1070	-0.1070	0.019	
	0.6	0.0474	0.0474	-0.037	
	0.9	0.2075	0.2075	0.015	
400	0.2	-0.3560	-0.3557	0.082	
	0.6	-0.0750	-0.0750	0.014	± 3 %
	0.9	0.2160	0.2160	-0.008	
600	0.2	-0.6850	-0.6851	-0.010	
	0.6	0.0167	0.0167	-0.207	
	0.9	0.7440	0.7442	-0.033	
800	0.2	-1.0660	-1.0663	-0.025	
	0.6	-0.3650	-0.3645	0.147	
	0.9	0.3631	0.3630	-0.014	

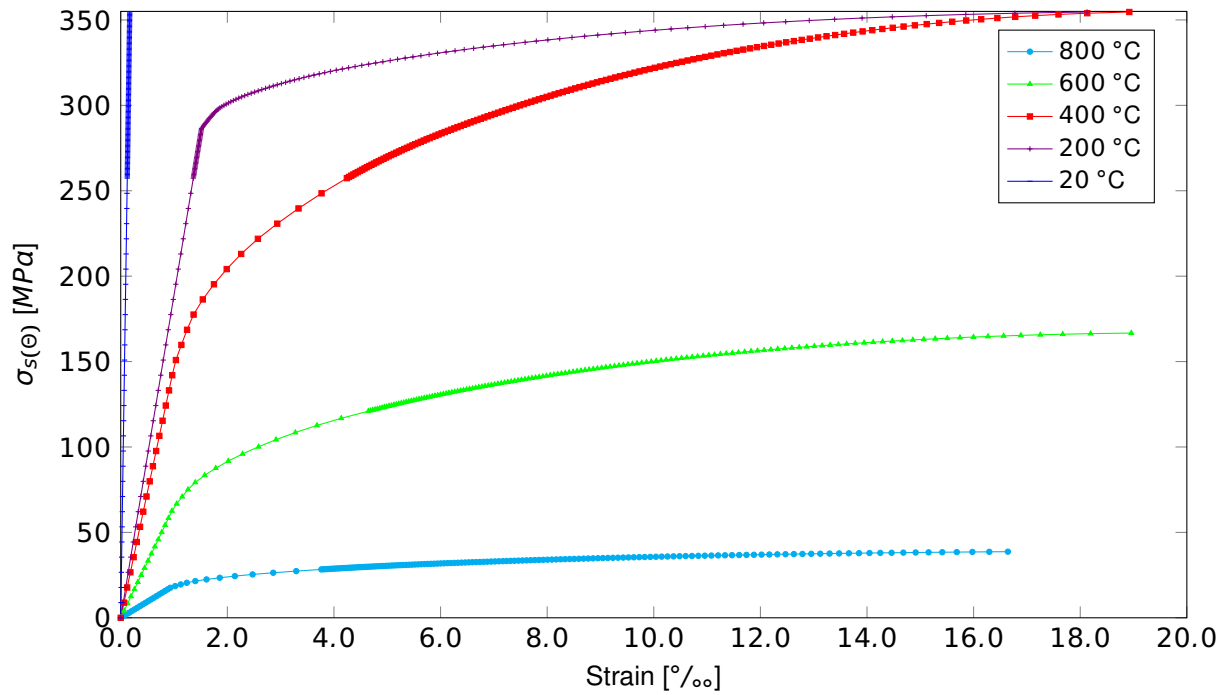


Figure 2: Steel Loading Strains

4 Conclusion

This example verifies the change in length of structural steel and concrete at different temperature and load levels. It has been shown that the calculation results with TALPA and the FIBER beam element are in very good agreement with the reference results. For the case of the QUAD layer element the results present some deviation only for the structural steel and specifically for the case of a high stress level, reaching the 90% of the steel strength.

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.