



Benchmark Example No. 34

Ultimate Bearing Capacity of Concrete and Steel under Fire

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VERiFiCATION
BE34 Ultimate Bearing Capacity of Concrete and Steel under Fire

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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

Arnulfsteg, Munich Photo: Hans Gössing

Overview

| | |
|--------------------------|--|
| Element Type(s): | BF2D, SH3D |
| Analysis Type(s): | STAT, MNL |
| Procedure(s): | LSTP |
| Topic(s): | FIRE |
| Module(s): | TALPA, ASE |
| Input file(s): | capacity.dat , quad_34.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 6 is employed as presented in Annex CC of the standard DIN EN 1992-1-2/NA:2010-03 [1]. In this example the ultimate bearing capacity of structural steel and concrete in compression, for the model of Fig. 1, at varying temperature levels, is investigated.

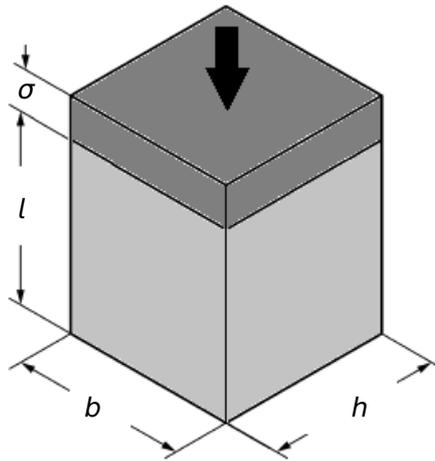


Figure 1: Problem Description

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 temperature and compressive loading, on the ultimate bearing capacity 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. 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.

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: DIN EN 1993-1-2 | Stress-strain: DIN EN 1992-1-2 | $b = 10 \text{ mm}$ | $b = 31.6 \text{ mm}$ | Homog. temp.: 20, 200, 400, 600, 800°C |

Table 2: Results for Structural Steel - FIBER beam

| Θ [° C] | Ref. [1] $N_{R,fi,k}$ [kN] | SOF. $N_{R,fi,k'}$ [kN] | e [kN] | e_r [%] | Tol. |
|----------------|-------------------------------|----------------------------|--------|-----------|----------------|
| 20 | -35.5 | -35.5 | 0.000 | 0.000 | |
| 200 | -35.5 | -35.5 | 0.000 | 0.000 | $\pm 3 \%$ |
| 400 | -35.5 | -35.5 | 0.000 | 0.000 | and |
| 600 | -16.7 | -16.7 | -0.015 | 0.090 | ± 0.5 [kN] |
| 800 | -3.9 | -3.9 | 0.005 | -0.128 | |

Table 3: Results for Concrete - FIBER beam

| Θ [° C] | Ref. [1] $N_{R,fi,k}$ [kN] | SOF. $N_{R,fi,k'}$ [kN] | e [kN] | e_r [%] | Tol. |
|----------------|-------------------------------|----------------------------|--------|-----------|----------------|
| 20 | -20.0 | -20.0 | -0.029 | 0.144 | |
| 200 | -19.0 | -19.0 | -0.027 | 0.144 | $\pm 3 \%$ |
| 400 | -15.0 | -15.0 | -0.022 | 0.144 | and |
| 600 | -9.0 | -9.0 | -0.013 | 0.144 | ± 0.5 [kN] |
| 800 | -3.0 | -3.0 | -0.004 | 0.144 | |

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] | Ref. [1] | SOF. | e [kN] | e_r [%] | Tol. |
|----------------|-------------------|--------------------|--------|-----------|------------|
| | $N_{R,fi,k}$ [kN] | $N_{R,fi,k'}$ [kN] | | | |
| 20 | -35.5 | -35.5 | 0.000 | 0.000 | |
| 200 | -35.5 | -35.5 | 0.000 | 0.000 | ± 3 % |
| 400 | -35.5 | -35.5 | 0.000 | 0.000 | and |
| 600 | -16.7 | -16.7 | -0.015 | 0.090 | ± 0.5 [kN] |
| 800 | -3.9 | -3.9 | 0.005 | -0.128 | |

Table 5: Results for Concrete - QUAD

| Θ [° C] | Ref. [1] | SOF. | e [kN] | e_r [%] | Tol. |
|----------------|-------------------|--------------------|--------|-----------|------------|
| | $N_{R,fi,k}$ [kN] | $N_{R,fi,k'}$ [kN] | | | |
| 20 | -20.0 | -20.0 | -0.029 | 0.144 | |
| 200 | -19.0 | -19.0 | -0.037 | 0.193 | ± 3 % |
| 400 | -15.0 | -15.0 | -0.023 | 0.156 | and |
| 600 | -9.0 | -9.0 | -0.013 | 0.150 | ± 0.5 [kN] |
| 800 | -3.0 | -3.0 | -0.015 | 0.489 | |

4 Conclusion

This example verifies the influence of compressive loading on the ultimate bearing capacity under different temperature levels. It has been shown that the calculation results are in very good agreement with the reference results for both the QUAD layer element and the FIBER beam element.

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.