DIN EN 1991-1-2 procedure for verification of advanced models for fire design

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DIN EN 1991-1-2 (2010)

The document presents 11 verification examples assembled in Annex CC, concerning:

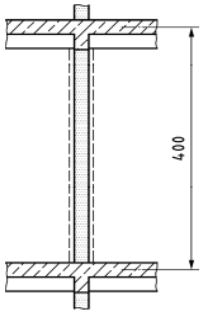
- **heat transfer for different sections and material properties;**
- **temperature induced expansion for different material laws;**
- **internal forces and stresses induced by thermal action;**
- **fire resistance time.**

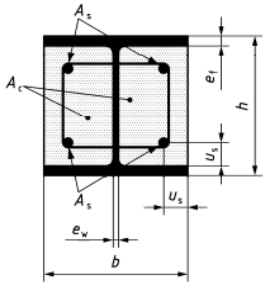
These examples include steel, concrete and composite steel-concrete sections.

Each example offers a set of results and the acceptable tolerances for the results.

EXAMPLE 11 - SAFIR

- *The verification of SAFIR program through the DIN EN1991-1-2 procedure was presented in the COST Meeting of Zadar, Croatia, 2012.*
- **This example analyses a composite column with partially encased steel section, subjected to ISO fire on 4 sides. The column is centrically loaded and a parabolic imperfection with peak value of l/1000 is considered.**
- **The column cross-section consists of an S235 HE300B profile and reinforced encasing concrete C25/30 with S500 steel reinforcement 4 ∅ 28. Both ends are rotationally constrained in case of fire.**

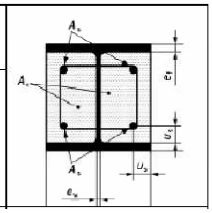


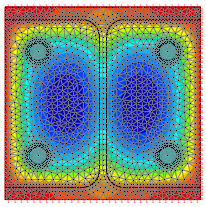


EXAMPLE 11 - SAFIR

- **The reference results, for which a limit deviation is provided, are: the fire resistance and the horizontal displacement at the mid-span of the column at t = 30 and 60 minutes.**
- **2D BEAM elements were considered for the structural analysis**

Requested results		Reference value		Calculated value	Deviation [%]	Limit [%]
Failure time		92	>	88	−4.35	± 5
Displ. [mm]	30 min	4.40	<	4.44	+0.82	
	60 min	5.50	>	5.04	**−8.18**	

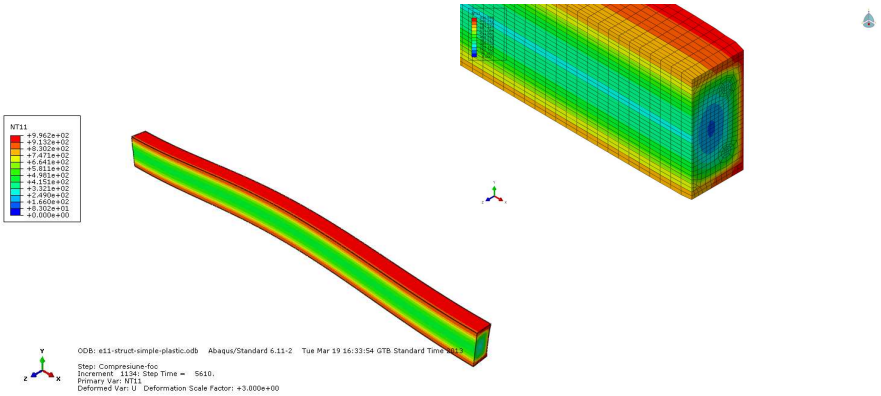




- **The criterion is not fulfilled for the displacement corresponding to 60 minutes of ISO fire. This deviation is not consistent with the other results:**
  - **the displacement at 60 minutes is lower than the reference value (-8.18%), while for 30 minutes the displacement is slightly higher (+0.82%);**
  - **it would be expected that lower displacements lead to a higher failure time, which is not the case, the calculated failure time being lower than the reference one.**

EXAMPLE 11 - ABAQUS

- Example 11 was also introduced in ABAQUS.
- 3D solid C3D8T elements were considered (8 node thermally coupled brick, trilinear displacement and temperature).



EXAMPLE 11 – ABAQUS/ SAFIR

- For ABAQUS model using 3D elements, the criterion is not fulfilled for 2 results: the failure time and the displacement corresponding to 60 minutes of ISO fire.

ABAQUS		Reference value X		Calculated value X′	Deviation [%]	Limit [%]
Failure time		92	>	87	-5.43	± 5
Displ. [mm]	30 min	4.40	<	4.56	+3.52	
	60 min	5.50	<	7.82	+42.16	

- It may be observed that, as in case of SAFIR, the failure time is lower than the reference time. However, the displacement corresponding to 60 minutes is much higher than the reference value (in these conditions, the results given by ABAQUS are consistent: the model offers lower failure time, together with higher displacements, in comparison with the reference values).

SAFIR		Reference value		Calculated value	Deviation [%]	Limit [%]
Failure time		92	>	88	−4.35	± 5
Displ. [mm]	30 min	4.40	<	4.44	+0.82	
	60 min	5.50	>	5.04	−8.18	

CONCLUSIONS

- **It would be helpful to identify the origin of the results given in DIN 1991-1-2 for Example 11.**
- **It would be also of interest to verify this Example using another computer programs as VULCAN and ANSYS.**
- **All examples of DIN EN1991-1-2 procedure will be also analysed with ANSYS program at Warsaw University of Technology**
- **LS-DYNA – problems with finding a proper material model for concrete.** **(*MAT_CONCRETE_EC2 - t**he material model can represent plain concrete only, reinforcing steel only, or a smeared combination of concrete and reinforcement. The model includes concrete cracking in tension and crushing in compression, and reinforcement yield, hardening and failure. Properties are thermally sensitive; the material model can be used for fire analysis.)

Thank you for your attention !