MFPA Leipzig GmbH

Testing, Inspection and Certification Authority for Construction Products and Construction Types
Notified testing laboratories, inspection and certification bodies recognized according to the Construction Products Law (NB 0800) and the State Building Code (SAC 02)

Leipzig Institute for Materials Research and Testing
Business Division III: Structural Fire Protection

MFPA Leipzig GmbH – PO Box 74 11 06 – 04323 Leipzig

Hilti Corporation
Business Unit Installation
Feldkircherstrasse 100
9494 Schaan
Liechtenstein

Your ref.	Your message of	Our ref.	Date
		G 3.2/15-291-1	12 November 2015

Re.: Calculation of the deformation of mounting rails in the event of a fire

Dear Sirs,

§40 of the MBO (Prototype Building Regulation) [1] states that conduit systems over necessary corridors are only allowed if the use of the escape route can be guaranteed for a sufficiently long period of time in the event of a fire. Compliance with this protective goal is required in section 3.5.3 of the Model Conduit Systems Guideline (MLAR):

> *... the special requirements with respect to the fireproof fastening of line laid in the area between the intermediate floors and suspended ceilings must be observed.*

In the event of a fire in the area of the suspended ceiling it thus has to be ensured by appropriate means that pipe fastenings/supporting systems do not deform to such an extent that the underlying suspended ceiling is mechanically damaged.

Proof of the limited deformation can be verified by fire tests with exposure to fire in accordance with DIN EN 1363-1 [2]. Alternatively, the deformation of structural steel parts is calculated with the help of the stress-strain relationship in accordance with DIN EN 1993-1-2 [3] (in short: EC3-1-2).

However, it has to be noted here that it cannot readily be ensured by calculation that underlying components such as suspended ceilings remain mechanically undamaged in the event of a fire since the deformations to thin-walled mounting rails that occur in reality are generally much greater than those determined by calculation with EC3-1-2. Explanations can be found in the Enclosure.

Proof of the limited deformation should thus always be verified by fire tests with exposure to fire in accordance with DIN EN 1363-1 [2].

Gesellschaft für
Materialforschung und
Prüfungsanstalt für das
Bauwesen Leipzig mbH

Leipzig Institute for Materials
Research and Testing

Hans-Weigel-Str. 2 b
04319 Leipzig / Germany

Managing Director:
Prof. Dr.-Ing. Frank Dehn

Commercial register:
Local Court Leipzig
HRB 17719
VAT-ID: DE 813200649

General terms and conditions of
MFPA Leipzig GmbH are valid.

Banking account:
Sparkasse Leipzig
IBAN: DE47860555921100560781
BIC: WELADE8LXXX

Business Division III:
Structural Fire Protection

Tel.: +49 (0) 341-6582-134
Fax: +49 (0) 341-6582-197
brandschutz@mfpa-leipzig.de

Head of Division:
Dipl.-Ing. Sebastian Hauswaldt

Work Groups:

- **Fire Behaviour of Building Products**
- **Fire Behaviour of Building Components and special Constructions**

DAkkS
Deutsche
Akkreditierungsstelle
D-PL-11021-01-00
D-ZE-11021-01-00
D-IS-11021-01-00

Accredited by DAkkS GmbH, DIN EN ISO/IEC 17025 accredited testing laboratory, DIN EN ISO/IEC 17020 accredited inspection body, DIN EN ISO/IEC 17065 accredited certification body. The accreditation only applies to the methods listed in the certificate (in this document marked with *) which can be seen on www.mfpa-leipzig.de

Yours sincerely

SAC 02
NB 0800

Dipl.-Ing. S. Hauswaldt
Head of Division

Enclosure 1: Calculation of the deformation of thin-walled mounting rails in the event of a fire (4 pages)

1 Literatur

[1] Model Building Code: 2002-11.

[2] DIN EN 1363-1: 2012-10: Fire Resistance test - Part 1: General Requirements.

[3] DIN EN 1993-1-2: 2010-12: Design of steel structures - Part 1-2: General rules - Structural fire design.

[4] Lange, J., Wohlfeil, N.: *Untersuchungen zum Werkstoffverhalten des Feinkornbaustahls S 460 unter erhöhten Temperaturen.* Bautechnik 84 (2007).

[5] Hauswaldt, S., Korzen, M.: *A constitutive model for the use of Finite Element Method in structural fire design. Formulation, benefit and limits shown on a numerical steel model based on Eurocode 3*, International fire prevention symposium, Leipzig (2010).

[6] Outinen, J., Makeläinen, P.: *A Study for the Development of the Design of Steel Structures in Fire Conditions*, First International Workshop "Structures in Fire", Copenhagen (2000).

Enclosure 1: Calculation of the deformation of mounting rails in the event of a fire

1 Example of the calculation of the deformation of mounting rails in the event of a fire

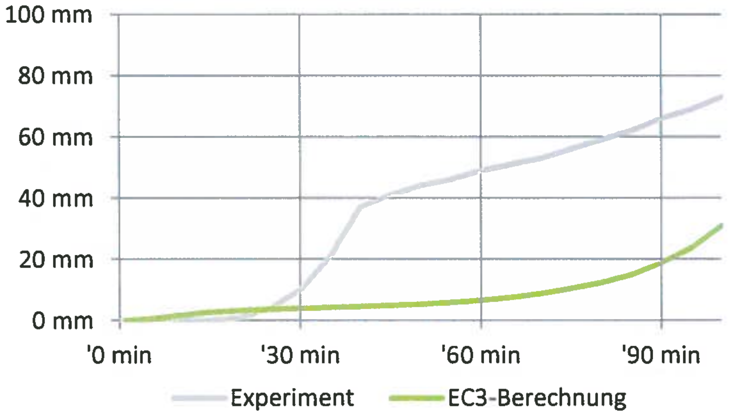

Figure 1: Comparison between the deformation determined by experiments and those calculated with the EC3-1-2 model on a selected mounting rail under the effect of fire with a standard temperature-time curve

Figure 1 compares the deformations of a cold-formed, thin-walled open mounting rail of carbon steel during a fire resistance test pursuant to [2] and a numerical calculation with the stress-strain relationship of EC3-1-2 [3] . This exemplary comparison shows significant differences between the experimental and numerical results after 30, 60 and 90 minutes. The calculated deformations are lower than those determined in the experiment. Simulations and evaluations of numerous other tests confirm this observation.

2 FE simulation of structural steel parts in the event of a fire

Simulations using the Finite Elements (FE) method allow basic component calculations that cannot be solved with purely analytical methods. The reference to reality of a simulation depends not just on a careful consideration of the **structure** but also, and decisively, on the description of the material behaviour in the form of the **material model**.

- Structural analyses with the FE method are a standard tool today. Experienced users can view realistic deformation patterns with the help of tested FE programs. During an error analysis with respect to the calculation of the deformation of thin-walled profiles, it first has to be investigated whether cases of stability failure such as buckling of the webs is described realistically. However, this is not the subject matter of this statement.
- Every material model describes an idealised material behaviour. Depending on the choice of model and the process to be mapped, the behaviour of the material in experiments will be described more or less realistically. For a material model to provide as realistic material answers as possible, the choice of the model has to be identified by not only experimental measurement data; it is much more important to understand which model is suitable to simulate a certain scenario.

It therefore first has to be clarified whether the established and known non-linear stress-strain relationship of EC3-1-2 is suitable to realistically describe the deformation of a thin-walled mounting rail after 30, 60 or 90 minutes exposure to fire according to the standard temperature-time curve.

3 Stress-strain relationship of EC3-1-2

EC3-1-2 regulates the structural design of steel constructions in the event of a fire and offers various design methods for this purpose. The simplified design method is normally used (see EC3-1-2, Part 4.2). The component limit state is hereby determined by calculating the reduction of the strength of the steel. The temperature-dependent stress-strain relationship for carbon steel required for this is the key point in EC3-1-2. It is described by a non-linear function phrased in sections. Figure 2 evaluates the stress-strain lines in 100-degree steps up to 800 °C in the non-linear range up to a mechanical expansion of 0.2 %.

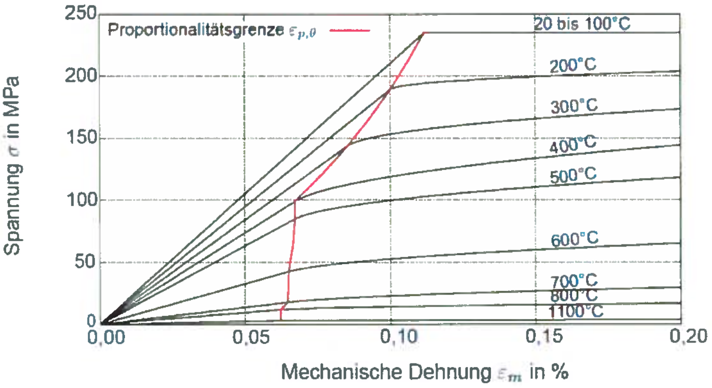

Figure 2: Stress-strain curves acc. to EC3-1-2 for carbon steel with 235 MPa flow stress

It is important to remember that this material law was developed for the structural dimensioning of structural steel parts. The stresses of structural steel parts are normally up to 70 % utilisation of the effective flow stress (relation to the initial value at room temperature), utilisation factors of 50 % or lower are rarely observed.

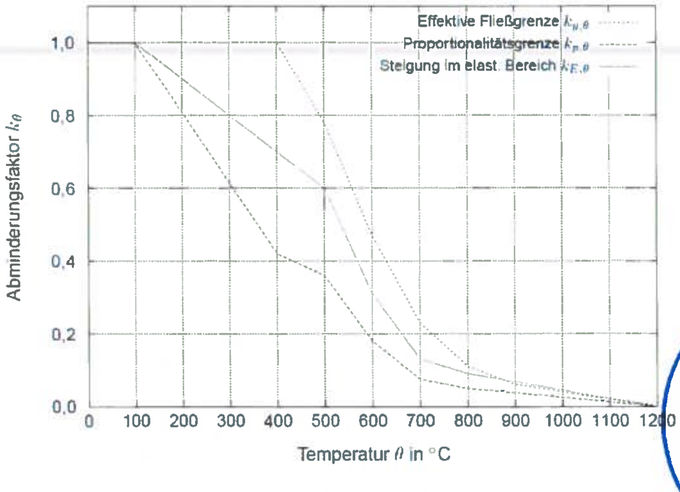

Figure 3: Temperature-dependent reduction factors of EC3-1-2

The reduction factors for EC3-1-2 shown in Figure 3 show that this limit is already reached at a steel temperature of approx. 590 °C. Up to this there is sufficiently detailed experience as regards the numerical and experimental investigation of steel constructions with exposure to fire according to the standard temperature-time curve. The EC3-1-2 material model has been sufficiently validated for this temperature range.

However, in order to calculate the deformation of thin-walled profiles it is important that the expansion behaviour of transient creep tests are also described realistically at higher temperatures

Figure 4 compares the expansion-temperature curves determined with the EC3-1-2 stress-strain relationship with measured values form transient creep tests at a constant heating rate from [4]. The experimental deformation behaviour is plausibly reflected up to 590 °C. For example, the typical form of the stress-temperature curve for a transient creep test with a very great increase in expansion and change in curvature between 100 °C and 200 °C at stresses near the effective flow limit is correctly described.

But with an increasing temperature, the stress-temperature lines determined by experiment and modelling drift further and further apart. These deviations are relevant for the calculation of the deformation of thin-walled structural steel parts since the temperature of the steel follows the temperature of the fire area with only a short delay, and this is already exceeded in a standard temperature-time curve experiment in the 6th minute of the test at 590 °C.

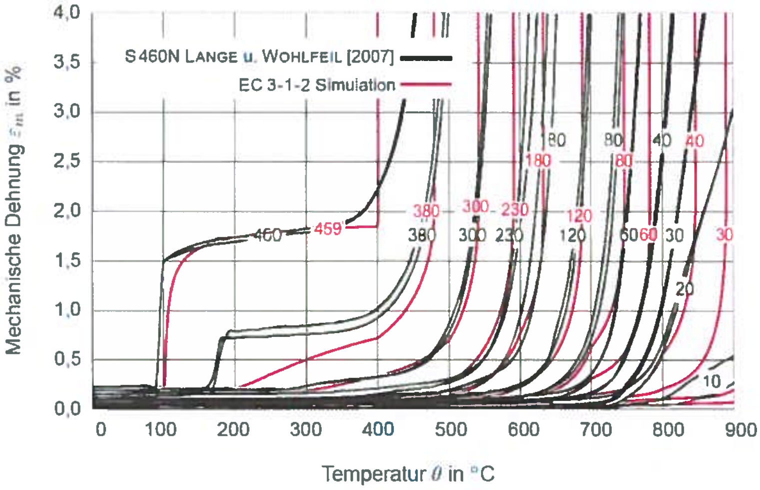

Figure 4: Comparison between expansion-temperature curves of transient creep tests on S460N (from [4]) and expansion-temperature curves calculated with the EC3-1-2 formulation (Figure from [5])

The stress-strain lines at high temperatures are flat; when the effective flow limit is reached at 2 % mechanical expansion a constant stress curve is even assumed. If the model stress only slightly overestimates the real material behaviour in this range, the mechanical expansion is greatly underestimated.

4 Summary

The EC3-1-2 stress-strain relationship was developed for the hot dimensioning of structural steel parts. The strength of a steel construction is hereby calculated under the effect of fire in accordance with DIN EN 1363-1. Steel temperatures over 590 °C are only rarely considered when dimensioning structural steel parts.

In accordance with EC3-1-2, Part 4.3, computer-aided models can also be used for calculating structural steel parts under exposure to fire. It is required that the models be validated on the basis of test results. However, it could be shown here that the EC3-1-2 stress-strain relationship is not suitable to realistically calculate deformations in thin-walled, open mounting rails of carbon steel after exposure to fire of 30 minutes or more since the deformations are underestimated. The function of an underlying suspended ceiling with effective fire protection cannot be guaranteed in the event of a fire since mechanical damage cannot be ruled out.

The temperature-dependent stress-strain relationship of EC3-1-2 has to be adjusted and validated for steel temperatures over 590°C, such as certainly occur with thin-walled profiles if exposed to fire for more than 15 minutes according to the standard temperature-time curve (see also [6]).

Without such an adjustment the aforementioned protective goal can only be achieved on the basis of an evaluation of corresponding fire-resistance tests by an engineer.

SAC 02
NB 0800