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Preskusne metode za ugotavljanje prispevka k požarni odpornosti konstrukcijskih elementov - 8. del: Zaščita jeklenih elementov

Test methods for determining the contribution to the fire resistance of structural members - Part 8: Applied reactive protection to steel members

Prüfverfahren zur Bestimmung des Beitrages zum Feuerwiderstand von tragenden Bauteilen - Teil 8: Reaktive Ummantelung von Stahlbauteilen

Méthodes d'essai pour déterminer la contribution à la résistance au feu des éléments de construction - Partie 8 : Protection réactive appliquée aux éléments en acier

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Foreword

This document (EN 13381-8:2013) has been prepared by Technical Committee CEN/TC 127 “Fire safety in buildings”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2013, and conflicting national standards shall be withdrawn at the latest by November 2013.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 13381-8:2010.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

With respect to the previous version, the following changes have been made:

— A change has been made to the test method to introduce of a means allowing loaded beams to reach a deflection of L/30.

— In addition the graphical assessment method now includes a point to point method of constructing lines and a new virtual data point related to furnace temperature.

This document is compatible with EN 13381-4 and specifically deals with the testing and assessment of reactive coatings designed to protect structural steel.

This document is part of the EN 13381 series with the general title *Test methods for determining the contribution to the fire resistance of structural members*. Other parts of this series are:

— *Part 1: Horizontal protective membranes*;

— *Part 2: Vertical protective membranes*;

— *Part 3: Applied protection to concrete members*;

— *Part 4: Applied passive protection to steel members*;

— *Part 5: Applied protection to concrete/profiled sheet steel composite members*;

— *Part 6: Applied protection to concrete filled hollow steel columns*;

— *Part 7: Applied protection to timber members*;

— *Part 8: Applied reactive protection to steel members* (the present document).

Caution

The attention of all persons concerned with managing and carrying out this fire resistance test, is drawn to the fact that fire testing can be hazardous and that there is a possibility that toxic and/or harmful smoke and gases can be evolved during the test. Mechanical and

operational hazards can also arise during the construction of test elements or structures, their testing and the disposal of test residues. An assessment of all potential hazards and risks to health should be made and safety precautions should be identified and provided. Written safety instructions should be issued. Appropriate training should be given to relevant personnel. Laboratory personnel should ensure that they follow written safety instructions at all times. The specific health and safety instructions contained within this standard should be followed.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This European Standard specifies a test method for determining the contribution made by applied reactive fire protection systems to the fire resistance of structural steel members, which can be used as beams or columns. It considers only sections without openings in the web. It is not directly applicable to structural tension members without further evaluation. Results from analysis of I or H - sections are directly applicable to angles, channels and T-sections for the same section factor, whether used as individual elements or as bracing. This standard does not apply to solid bar or rod.

It covers fire protection systems that involve only reactive materials and not to passive fire protection materials as defined in this document.

The evaluation is designed to cover a range of thicknesses of the applied fire protection material, a range of steel sections, characterised by their section factors, a range of design temperatures and a range of valid fire protection classification periods.

This European Standard contains the fire test procedures, which specifies the tests which should be carried out to determine the ability of the fire protection system to remain coherent and attached to the steelwork, and to provide data on the thermal characteristics of the fire protection system, when exposed to the standard temperature/time curve specified in EN 1363-1.

In special circumstances, where specified in National Building Regulations, there can be a need to subject reactive protection material to a smouldering curve; the test for this and the special circumstances for its use are described in Annex A.

The fire test methodology makes provision for the collection and presentation of data, which can be used as direct input to the calculation of fire resistance of steel structural members in accordance with the procedures given in EN 1993-1-2 and EN 1994-1-2.

This European Standard also contains the assessment, which prescribes how the analysis of the test data shall be made and gives guidance on the procedures by which interpolation should be undertaken.

The assessment procedure is used to establish:

a) on the basis of temperature data derived from testing loaded and unloaded sections, a correction factor and any practical constraints on the use of the fire protection system under fire test conditions, (the physical performance);

b) on the basis of the temperature data derived from testing short steel sections, the thermal properties of the fire protection system, (the thermal performance).

The limits of applicability of the results of the assessment arising from the fire test are defined, together with permitted direct application of the results, to different steel sections and grades and to the fire protection system.

The results of the test and assessment obtained according to this standard are directly applicable to steel sections of I and H cross sectional shape and hollow sections.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1363-1, *Fire resistance tests — Part 1: General requirements*

EN 1363-2, *Fire resistance tests — Part 2: Alternative and additional procedures*

EN 1365-3, *Fire resistance tests for loadbearing elements — Part 3: Beams*

EN 1365-4, *Fire resistance tests for loadbearing elements — Part 4: Columns*

EN 1993-1-1, *Eurocode 3: Design of steel structures — Part 1-1: General rules and rules for buildings*

EN 1993-1-2, *Eurocode 3: Design of steel structures — Part 1-2: General rules — Structural fire design*

EN 10025-1, *Hot rolled products of structural steels — Part 1: General technical delivery conditions*

EN 13501-1, *Fire classification of construction products and building elements — Part 1: Classification using data from reaction to fire tests*

EN ISO 13943, *Fire safety — Vocabulary (ISO 13943)*

ETAG 018-Part 2, *Guideline for European Technical Approval of Fire Protective Products — Part 2: Reactive Coatings for Fire Protection of Steel Elements*

ISO 8421-2, *Fire protection — Vocabulary — Part 2: Structural fire protection*

3 Terms and definitions, symbols and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1363-1, EN ISO 13943 and ISO 8421-2 and the following apply:

3.1.1
steel member
element of building construction which is loadbearing and fabricated from steel

Note 1 to entry: For the purpose of this document, the steel used in the testing should be of the same type.

3.1.2
reactive fire protection material
reactive materials which are specifically formulated to provide a chemical reaction upon heating such that their physical form changes and in so doing provide fire protection by thermal insulative and cooling effects

3.1.3
passive fire protection material
materials which do not change their physical form on heating, providing protection by virtue of their physical or thermal properties

Note 1 to entry: They may include materials containing water which on heating evaporates to produce cooling effects.

3.1.4
fire protection system
fire protection material together with a specified primer and top coat if applicable

3.1.5
fire protection
protection afforded to the steel member by the fire protection system such that the temperature of the steel member is limited throughout the period of exposure to fire

3.1.6
test specimen
steel test section plus the fire protection system under test

Note 1 to entry: The steel test section, representative of a steel member, for the purposes of this test, comprises short steel columns, or beams.

3.1.7
fire protection thickness
mean dry film thickness of the reactive fire protection material excluding primer and top coat

3.1.8
stickability
ability of a fire protection material to remain sufficiently coherent and in position for a well defined range of deformations, furnace and steel temperatures, such that its ability to provide fire protection is not significantly impaired

3.1.9
section factor
ratio of the fire exposed outer perimeter area of the steel structural member itself, per unit length, to its cross sectional volume per unit length

Note 1 to entry: See Figure 1.

3.1.10
design temperature
temperature of a steel structural member for structural design purposes

3.1.11
characteristic steel temperature
temperature of the steel structural member which is used for the determination of the correction factor for stickability calculated as (mean temperature + maximum temperature)/2

3.1.12
steel temperature
overall mean temperature to be used as input data for the analysis is calculated:

— for I and H section beams as the mean of the upper flange plus the mean of the web plus the mean of the lower flange divided by three;

— for I, H and hollow section columns as the sum of the means of each measuring station divided by the number of measuring stations;

— for hollow section beams as the mean of the sides plus the mean of the bottom face divided by two

3.2 Symbols and units

Symbol	Unit	Description
LB		loaded beam section
UB		unloaded short beam section
LC		loaded 3 m column section
TC		unloaded tall (2 m) column section
SC		unloaded short column section
p		fire protection material
a		steel
f		furnace
d		thickness
ρ		density
t_l	min	time for the loaded or tall section to reach the design temperature
t_1	min	time for the reference section to reach the design temperature
S	m^{-1}	section factor of the loaded or tall section
S_1	m^{-1}	section factor of the reference section
D	mm	protection thickness for the loaded or tall section
D_1	mm	protection thickness for the reference section
d_{max}	mm	maximum protection thickness of the loaded or tall section
d_{min}	mm	minimum protection thickness of the loaded or tall section
d_i	mm	protection thickness of the short section
k_{imax}		stickability correction factor at maximum protection thickness
k_{imin}		stickability correction factor at minimum protection thickness
k_i		stickability correction factor for the short section at thickness d_i
A_m/V	m^{-1}	section factor of the unprotected steel section
A_p/V	m^{-1}	section factor of the protected steel section
A	m^2	cross sectional area of the steel section
V	m^3/m	volume of the steel section per unit length
V_v	m^3/m	volume of the fire protection material per unit length
H	mm	height of the steel column
h	mm	depth of the steel section
B	mm	breadth of the steel section
t_w	mm	thickness of the web of the steel section
t_f	mm	thickness of the flange of the steel section
t	mm	thickness of the wall of a hollow steel section
L_{exp}	mm	length of beam specimen exposed to heating
L_{sup}	mm	length of beam specimen between supports

L_{isped}	mm	length of beam specimen
d_{UB}	mm	thickness of fire protection material on an unloaded beam section
d_{SC}	mm	thickness of fire protection material on an unloaded column section
d_p	mm	thickness of fire protection material concerned
$d_{p(max)}$	mm	maximum thickness of fire protection material used
$d_{p(min)}$	mm	minimum thickness of fire protection material used
$\rho_{protection}$	kg/m^3	density of fire protection material
ρ_{UB}	kg/m^3	density of fire protection material on an unloaded beam section
ρ_{SC}	kg/m^3	density of fire protection material on an unloaded column section
ρ_{LB}	kg/m^3	density of fire protection material on a loaded beam
ρ_a	kg/m^3	density of steel (normally 7 850 kg/m^3)
θ_{LB}	°C	characteristic steel temperature of a loaded beam
θ_{UB}	°C	characteristic steel temperature of a short unloaded reference beam
θ_{LC}	°C	characteristic steel temperature of a loaded column
θ_{TC}	°C	characteristic steel temperature of a tall column
θ_{SC}	°C	characteristic temperature of a short reference column
$\theta_{c(UB)}$	°C	corrected mean temperature of an unloaded beam section
$\theta_{c(SC)}$	°C	corrected mean temperature of an unloaded column section
θ_t	°C	average temperature of the furnace at time t
θ_{at}	°C	average temperature of the steel at time t
$\Delta\theta_t$	°C	increase of furnace temperature during the time interval Δt
$\theta_{m(SC)}$	°C	modified steel temperature of an unloaded section
θ	°C	design temperature
K_d		range factor for thickness
K_s		range factor for section factor
c_a	J/(kgK)	temperature dependant specific heat capacity of steel as defined in EN 1993-1-2
c_p	J/(kgK)	temperature independent specific heat capacity of the fire protection material
μ		ratio of heat capacity of the fire protection material to that of the steel section
t	min	time from commencement of the start of the test
t_e	min	time for an unloaded section to reach an equivalent temperature to the loaded beam at time t
Δt	min	time interval
t_d	min	time required for a short section to reach the design temperature
λ_p	W/(mK)	effective thermal conductivity of the fire protection material
$\lambda_{char(p)}$	W/(mK)	characteristic value of effective conductivity of the fire protection material
$\lambda_{ave(p)}$	W/(mK)	mean value of λ_p calculated from all the short sections at a temperature θ
$\lambda_{\delta(p)}$		standard deviation of λ_p calculated from all the short sections at a

		temperature θ
$C_{n(\theta)}$		constant derived for short section at temperature (θ)
K		constant applied to $\lambda_{\delta(p)}$

4 Test equipment

4.1 General

The furnace and test equipment shall conform to that specified in EN 1363-1.

4.2 Furnace

The furnace shall permit the dimensions of the test specimens to be exposed to heating, as specified in Clause 6 and their installation upon or within the test furnace to be as specified in Clause 7.

4.3 Loading equipment

Loading shall be applied according to EN 1363-1. The loading system shall permit loading to be applied to beams as specified in 5.2.1 and to columns as specified in 5.2.3.

5 Test conditions

5.1 General

A number of short steel, I or H or hollow test sections, protected by the fire protection system, are heated in a furnace according to the protocol given in EN 1363-1.

Loaded and unloaded beams or columns that are likewise heated provide information on the ability of the fire protection system to remain intact and adhere to the steel test sections (stickability).

The method of testing loaded beams in this part of the test method is designed to provide maximum deflection (span/30) under the influence of load and heating. If the rate of deflection exceeds that given in EN 1363-1, then it may not be possible to reach span/30.

It is recommended that the tests be continued until the steel temperature reaches the maximum value commensurate with application of the data.

Where several test specimens are tested simultaneously, care shall be taken that each is adequately and similarly exposed to the specified test conditions.

The procedures given in EN 1363-1 shall be followed in the performance of this test unless specific contrary instructions are given in this standard.

5.2 Support and loading conditions

5.2.1 Loaded beams

Each loaded beam test specimen shall be simply supported and allowance shall be made for free expansion and vertical deflection of the beam. The beam shall not be provided with additional torsional restraint except where deemed necessary as defined in 6.3.1. The simply supported span shall not be greater than the length exposed to heating by more than 400 mm at each end.

The loading shall be applied using either of the two methods described in Figure 2.

The ends of loaded beams outside the furnace shall be insulated with a suitable insulation material.

5.2.2 Unloaded beams

Each unloaded beam test specimen shall be supported as shown in Figure 3.

5.2.3 Loaded columns

For each loaded column, provision shall be made for the proper support, positioning and alignment of the column test specimen in the furnace in accordance with EN 1365-4 subject to any amended or additional requirements of this standard; an example is given in Figure 8.

5.2.4 Unloaded columns

Unloaded column sections shall be supported vertically within the furnace, either installed to the soffit of the furnace cover slabs, (see example in Figure 10), or stood on the furnace floor (directly or on plinths).

5.3 Loading

The loaded beam test specimens shall be subjected to a total load which represents 60 % of the design moment resistance, according to EN 1993-1-1, calculated using the actual steel yield strength from the batch certificate of conformity or an actual measured value. The actual load applied shall be the calculated total load less the dead weight of the beam, concrete topping and fire protection material etc.

The method of loading shall be by a system which will produce a bending moment, which is uniform over at least 20 % of the span of the beam around mid-span.

The loaded column shall be subjected to an applied test load which represents 60 % of the design buckling resistance, according to EN 1993-1-1, calculated using the actual steel yield strength from the batch certificate of conformity or an actual measured value. Details of the calculation made to define the test loads shall be included in the test report.

Loaded steel test sections shall be tested in accordance with EN 1365-3 or EN 1365-4 subject to any amended or additional requirements of this standard.

6 Test specimens

6.1 General

The test sections shall be chosen to suit the scope of the assessment and will include both loaded and unloaded sections. The testing of loaded and tall and reference sections provides the basis for the stickability correction to be applied to the thermal data generated from the unloaded short sections.

Depending upon the scope of the assessment, the principle of selecting the loaded and unloaded sections shall be based on the details presented in 6.6. The test sections shall be chosen from the tables in Annex F.

For each test involving a loaded beam or column or tall column, an equivalent unloaded reference beam or column section respectively shall be included and tested in the furnace at the same time whenever possible.

Where it is not possible to test a loaded column and reference section together in the furnace then there shall be an equivalent tall and reference column of the same size and protection thickness as the loaded column and they shall be tested together in the same furnace.

Where an assessment is required only for I or H columns and the reference sections cannot be tested in the same furnace then a tall and reference column at both minimum and maximum thickness shall be tested together in the furnace at the same time.

For both the maximum and the minimum thickness of the fire protection system, a loaded beam shall be tested to examine stickability during maximum deflection of the steel section around 550 °C, up to a maximum anticipated steel temperature. The two loaded steel beams do not have to be the same size as each other.

The data from the loaded and tall sections and equivalent unloaded reference sections shall be used to determine the correction factors for stickability across the range of thickness in accordance with Annex D.

6.2 Size of test specimens

6.2.1 Loaded beams

Loaded beams shall have an I or H cross sectional shape, or hollow rectangular section.

Each beam shall have a total length, which shall provide for a length exposed to heating of not less than 4 000 mm.

The supported length and specimen length shall be specified as follows:

— The span between the supports [L_{sup}] shall be the exposed length plus up to a maximum of 400 mm at each end.

— The length of the specimen [L_{spec}] shall be the exposed length plus up to a maximum of 500 mm at each end (see Figure 9).

— The additional length, required for installation purposes, shall be kept as small as practically possible.

6.2.2 Reference sections

Where practical, each unloaded reference section shall be taken from the same length of steel as its equivalent loaded section, thereby ensuring that it is of the same dimensions and characteristics. If this cannot be achieved, the test laboratory should ensure that the reference section is of similar dimensions and characteristics.

6.2.3 Loaded column

All loaded columns shall have a minimum height, exposed to heating, of 3 000 mm.

6.2.4 Short sections

The short beams and columns shall have a length of 1 000 mm ± 50 mm.

6.2.5 Tall columns

The tall column sections shall have a height of 2 000 mm ± 50 mm.