BS EN 13381-6:2012

BSI Standards Publication

# Test methods for determining the contribution to the fire resistance of structural members

## Part 6: Applied protection to concrete filled hollow steel columns

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## National foreword

This British Standard is the UK implementation of EN 13381-6:2012. It supersedes DD ENV 13381-6:2002 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee FSH/22, Fire resistance tests, to Panel FSH/22/-/12, Fire resistance tests For Protection Systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.



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**Compliance with a British Standard cannot confer immunity from legal obligations.**

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EUROPEAN STANDARD

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# EN 13381-6

June 2012

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Supersedes ENV 13381-6:2002

English Version

# Test methods for determining the contribution to the fire resistance of structural members - Part 6: Applied protection to concrete filled hollow steel columns

Méthodes d'essai pour déterminer la contribution à la résistance au feu des éléments de construction - Partie 6: Protection appliquée aux poteaux métalliques creux remplis de béton

Prüfverfahren zur Bestimmung des Beitrages zum Feuerwiderstand von tragenden Bauteilen - Teil 6: Brandschutzmaßnahmen für betonverfüllte Stahlverbund-Hohlstützen

This European Standard was approved by CEN on 14 April 2012.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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# Foreword

This document (EN 13381-6:2012) 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 December 2012, and conflicting national standards shall be withdrawn at the latest by December 2012.

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 ENV 13381-6:2002.

ENV 13381-6:2002 has been revised and a completely new document, EN 13381-6, has been prepared. The main differences are as follows:

a) Loaded column omitted, since this European Standard provides thermal data only;

b) Unfilled sections are required to be tested under EN 13381-8 or ENV 13381-4;

c) The use of a specified dry sand infill to the sections may be used as an alternative to concrete;

d) Thermocouple positions redefined to follow the requirements of EN 13381-8 or ENV 13381-4;

e) New matrix of test sections included based on scope required rather than prescriptive testing;

f) Method to correct data for stickability added;

g) Method of analysing the thermal data simplified to a method using linear interpolation;

h) Extension of the results of testing added.

This European Standard is compatible with prEN 13381-4 (revision of ENV 13381-4:2002) and prEN 13381-8 (revision of EN 13381-8:2010).

This European Standard is one of a series of standards for evaluating the contribution to the fire resistance of structural members by applied fire protection materials. The 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 protection to steel members.

Part 5: Applied protection to concrete/profiled sheet steel and composite members.

Part 7: Applied protection to timber members.

Part 8: Applied reactive protection to steel members.

**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 will be produced 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 European Standard should be followed.

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

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, 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 of fire protection systems to the fire resistance of structural concrete filled hollow steel columns. The concrete can be lightweight, normal-weight or heavyweight concrete, and of all the strength classes provided for in EN 1994-1-2. The use of a dry sand is considered to be an alternative, conservative approach to the use of wet concrete. A specification for dry sand is given in 5.6.3.

The method is applicable to all fire protection systems used for the protection of concrete filled hollow columns and includes sprayed fire protection, reactive coatings, cladding protection systems and multi-layer or composite fire protection materials.

If there is no hollow section data from prEN 13381-4 (revision of ENV 13381-4:2002) or prEN 13381-8 (revision of EN 13381-8:2010), this European Standard cannot be used. For passive systems, this data can be derived using the Formula in Annex A of prEN 13381-4 (revision of ENV 13381-4:2002).

Testing to this European Standard is not required if the fire protection thicknesses for hollow sections derived from prEN 13381-4 (revision of ENV 13381-4:2002) or prEN 13381-8 (revision of EN 13381-8:2010) are to be used for concrete filled hollow sections.

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

The test method is applicable to fire protection systems which are intimately in contact with the structural column, or which include an airspace between the structural column and the protection system.

This European Standard specifies the fire tests which are carried out to determine the ability of the fire protection system to provide fire protection to composite columns. The tests produce data on the average steel temperatures of the composite column, when exposed to the time/temperature curve according to the procedures defined herein. This European Standard also provides the assessment procedure, which prescribes how the analysis of the test data should be made and gives guidance on the procedures by which interpolation is undertaken.

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 detailed in prEN 13381-8 (revision of EN 13381-8:2010). This exposure, applicable to reactive fire protection materials, is used only in special circumstances (which are specified in the national building regulations of a member state of the European Union) and is therefore not intended to be mandatory for all fire protection materials applied to concrete filled hollow steel columns.

This European Standard ignores any contribution from the concrete to the structural capability of the hollow column and therefore only deals with thermal performance. The justification for using this approach is given in Annex B.

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 concrete/steel composite members in accordance with the procedures given in EN 1994-1-2.

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/concrete composite columns, steel types and thicknesses, concrete densities, strengths, thicknesses and production techniques over the range of thicknesses of the applied fire protection system tested.

This European Standard details the fire test procedures, which should be carried out to provide data on the thermal characteristics of the fire protection system, when exposed to the European Standard temperature/time curve specified in EN 1363-1.

The assessment procedure is used to establish:

a) on the basis of temperature data derived from testing concrete filled unloaded tall columns and reference columns, 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 hollow steel sections filled with concrete, 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.

## 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 206-1, *Concrete — Part 1: Specification, performance, production and conformity*

EN 1992-1-1 *Eurocode 2: Design of concrete structures — Part 1-1: General rules and rules for buildings*

EN 1363-1:2012, *Fire resistance tests — Part 1: General requirements*

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

EN 10210-1 *Hot finished structural hollow sections of non-alloy and fine grain steels — Part 1: Technical delivery conditions*

EN 10210-2: *Hot finished structural hollow sections of non-alloy and fine grain steels — Part 2: Tolerances, dimensions and sectional properties*

EN 10219-2 *Cold formed welded structural hollow sections of non-alloy and fine grain steels — Part 2: Tolerances, dimensions and sectional properties*

ENV 13381-4:2002, *Test methods for determining the contribution to the fire resistance of structural members — Part 4: Applied passive protection products to steel members*

EN 13381-8:2010, *Test methods for determining the contribution to the fire resistance of structural members — Part 8: Applied reactive protection to steel members*

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

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 load-bearing 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, provides fire protection by thermal insulative and cooling effects

**3.1.3**
**passive fire protection material**
materials which do not change their physical form during heating and therefore provide protection by virtue of their physical or thermal properties

Note 1 to entry: These may include materials containing water which, during heating, evaporates to produce cooling effects.

**3.1.4**
**fire protection system**
fire protection material together with any supporting system including mesh reinforcement as tested and 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**
thickness of a single layer fire protection system or the combined thickness of all layers of a multi-layer fire protection system or the mean dry film thickness of the fire protection coating, excluding primer and top coat

Note 1 to entry: The thickness of the elements of the supporting system or joint **co**ver strips are not included in the fire protection thickness.

**3.1.8**
**stickability**
ability of a fire protection material to remain sufficiently coherent and in position throughout 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**
**characteristic steel temperature**
temperature of the concrete filled hollow columns which is used for the determination of the correction factor for stickability calculated as (mean temperature + maximum temperature)/2

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

**3.1.11**
**average steel temperature**
overall mean temperature to be used as input data for the analysis and calculated for concrete filled hollow section columns as the sum of the means of each measuring station

### 3.2 Symbols and units

$d_p$ is the interpolated protection thickness for time, t

$d_{pw}$ is the interpolated protection thickness for wall thickness, W

$d_{min}$ is minimum protection thickness

$d_{int}$ is intermediate protection thickness

$t_{min}$ is the time to reach the specified temperature for sections with the minimum protection thickness

$t_{int}$ is the time to reach the specified temperature for sections with the intermediate protection thickness

t is the required fire performance period

$W_{min}$ is the minimum wall thickness

$W_{int}$ is the intermediate wall thickness

W is the required wall thickness

## 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.

## 5 Test conditions

### 5.1 General

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

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 European Standard.

## 5.2 Support conditions

Unloaded concrete filled hollow column sections shall be supported vertically within the furnace stood on the furnace floor (directly or on plinths).

## 5.3 Number of test specimens

The test sections shall be chosen to suit the scope of the assessment. Depending upon the scope of the assessment, the principle of selecting the sections shall be based on the details presented in Clause 6.

## 5.4 Size of test specimens

The short unloaded hollow columns shall have a minimum height of 1000 mm.

## 5.5 Construction of steel test specimens

### 5.5.1 Short and tall concrete filled hollow columns

A 5 mm steel plate of at least the overall cross sectional dimensions of the fire protection system, but not exceeding 50 mm greater than the overall cross sectional dimensions of the fire protection system, shall be welded to the base of each column. The plate shall incorporate a vent/drain hole within the central area of the specimen of approximately 20 mm diameter. Where dry sand is used as an alternative to concrete, the vent hole shall not be required (see Figure 1).

For reactive coatings, a steel ring shall be welded around the neck of the top of the columns to leave the top open after filling with concrete and also enable the application of reactive coatings while the concrete is curing (see Figure 1). The steel ring should overlap the edge of the column for 25 mm and be of sufficient size so that 90 % of its cross section remains open (see Figure 1).

For passive fire protection materials the ring is not required and the column may be left open.

Threaded rods may be fixed at the inside of the steel column for lifting and for fixing of the insulation material.

Insulation board or similar shall be provided to minimize heat transfer to the top of the column sections. At elevated temperatures, such board is capable of providing equivalent or greater insulation than that of the fire protection material provided over the height of the column.

The size of the end protection shall be greater than the total overall dimensions of the fire protection (see Figure 2).

### 5.5.2 Application of the fire protection material

The surface of the steel shall be prepared and the fire protection system shall be applied to the columns in a manner representative of practice.

## 5.6 Composition of test specimen component materials

### 5.6.1 Steel specification

The grade of steel used shall be any structural grade (S designation) according to EN 10210-1, EN 10210-2, EN 10025-1 and EN 10219-2.

The dimensions and wall thickness of the steel sections shall be measured.

#### 5.6.2 Concrete grade

The concrete in the test specimen shall normally be of type 25/30 to 30/37 (LC/C/HC - (light-weight, normal-weight or heavy-weight concrete) according to EN 206-1 and EN 1992-1-1), although other grades within the strength range 20/25 to 50/60 may be used.

The applicability of the results of the assessment arising from the testing of a particular concrete that is not within the above specification shall be restricted to the grade of concrete that was tested.

The concrete shall be prepared from calcareous aggregates, of maximum aggregate size of 20 mm, and Portland cement. The composition and properties of the concrete used shall be appropriate to those specified in EN 206-1 and EN 1992-1-1.

Other non-calcareous and lower density aggregates may be permitted, but the applicability of the results of the assessment shall be restricted accordingly.

The consistency of the wet concrete, which shall be poured into the hollow steel column positioned in a vertical orientation, shall be of type S3 or F3, determined in accordance with EN 206-1, to allow for good compaction and contact with the steel.

The concrete shall be poured at least 28 days prior to fire testing. The fire protection material may be applied prior to pouring the concrete in which case care shall be taken not to contaminate the fire protection material.

It is recommended that all the steel thermocouples be fitted prior to pouring the concrete.

#### 5.6.3 Dry sand

Dry sand may be used provided the total moisture content does not exceed 1 %. Fire testing has demonstrated clearly that the use of dry sand is a more conservative approach than using cured concrete and has many practical advantages.

The dry sand shall be added to the hollow column and shall be compacted to minimise settlement at a later stage.

It is recommended that all the steel thermocouples be fitted prior to filling with dry sand.

### 5.7 Properties of test specimen component materials

#### 5.7.1 Fire protection materials - General

The composition, dimensions, (including thickness), verification and properties of the fire protection materials shall be determined in accordance with the requirements of ENV 13381-4:2002, 6.5 or EN 13381-8:2010, 6.5.

#### 5.7.2 Fire protection materials - Thickness of applied reactive protection material

For reactive fire protection materials, the average primer thickness should be first measured and then subtracted from the total average primer and reactive coating thickness. The resulting permitted thickness tolerances excluding primer and topcoat shall be in accordance with the requirements of EN 13381-8.

### 5.8 Selection of test specimens - Principle of selection

The basic minimum test package for a given diameter is detailed in Table1. The manufacturer may choose the minimum and maximum wall thicknesses for which he wishes to provide protection.

If a wider scope is required, additional testing must be carried out.

**Table 1 — Minimum test package**

| Steel Wall Thickness Range | Protection Thickness Range | | |
|---|---|---|---|
| | Minimum | Intermediate | Maximum |
| Minimum | ✓ | | ✓ |
| | | | |
| Maximum | ✓ | | ✓ |

Table 1 applies to a single CHS diameter which is selected by the manufacturer to suit the scope of the assessment.

Test specimens with intermediate protection thickness and intermediate wall thickness may be included to increase the scope of the assessment.

## 6 Installation of the test specimens

### 6.1 Test specimen installation patterns

The sections should be positioned within the furnace to ensure the sections are not shielded or affected by furnace walls, other test specimens and other obstacles. A minimum distance of separation of 300 mm is required.

### 6.2 Furnace Load

In order to ensure that the specified furnace temperature/time relationship is complied with, it may be necessary to control the amount of steel sections within the furnace and their location.

For example, a typical furnace of size 4 m by 3 m by about 2 m deep can accommodate up to 45 kg/m$^3$ of steel sections without adverse affect.

### 6.3 Specimen mounting

The short sections shall be stood on the furnace floor or on plinths as required.,To ensure that they have the ability to drain/vent the water/steam at the base of the specimen, there shall be a layer of permeable insulation material or sand between the section and the floor or plinth.

## 7 Conditioning of the test specimens

The fire protection system, its components and any test samples taken for determination of material properties shall be conditioned as required by EN 1363-1 or for a period specified by the manufacturer for adequate curing.

# 8 Application of instrumentation

## 8.1 General

The instrumentation for measurement of temperature and furnace pressure shall comply with the requirements of EN 1363-1.

## 8.2 Instrumentation for measurement and control of furnace temperature

### 8.2.1 General

Plate thermometers, of the type specified in EN 1363-1, shall be provided to measure and control the temperature of the furnace. They shall be uniformly distributed, as specified in EN 1363-1, to give a reliable indication of the temperature in the region of the test specimens. They shall not be placed in positions where they are unable to measure the furnace temperature correctly because they are obstructed by test specimens.

### 8.2.2 Furnace temperature in the region of test specimens

The location of the plate thermometers shall be one either side of each short column at mid height at a distance of 100 mm from the side of each column (see Figure 2). For tall columns, thermocouples shall be provided as required by ENV 13381-4 and EN 13381-8.

### 8.2.3 Instrumentation for the measurement of steel temperatures

Thermocouples for measurement and recording of steel temperatures of the short and tall columns shall be of the type, fixing and location given in ENV 13381-4 and EN 13381-8.

## 8.3 Instrumentation for the measurement of pressure

Equipment for measuring pressure within the furnace shall be provided, located and used as specified in EN 1363-1.

# 9 Test procedure

## 9.1 General

Assemble the required number of unloaded hollow sections forming the testing package appropriate to the scope of the assessment as detailed in 6.1.

Incorporate these in several tests according to the capacity of the furnace and the criteria of 6.1.

Before commencement of the test, carry out checks for thermocouple consistency and establish data points for the temperature as specified in EN 1363-1 and for the procedures defined in EN 1363-1:2012,10.2 to 10.7.

## 9.2 Furnace temperature and pressure

Control the furnace and measure and record the furnace temperature in the region of the test specimens using the plate thermometers defined in 8.2.1 and the furnace pressure in accordance with EN 1363-1. The plate thermometers as specified in 8.2.2 to 8.2.3 will be used to control the furnace to the criteria of EN 1363-1.

The location of plate thermometers to be used to control the furnace temperature is dependent upon the specimens incorporated within the furnace (see 8.2.2).

### 9.3 Temperature of steelwork

Measure and record the temperature of the concrete filled hollow sections using the thermocouples attached to the steelwork, as specified in 8.3, at intervals not exceeding 1 min.

### 9.4 Observations

Monitor the general behaviour of each of the specimens throughout the test and record the occurrence of cracking, fissuring, delamination or detachment of the fire protection material and similar phenomena as described in EN 1363-1.

### 9.5 Termination of test

All tests should provide thermal data up to the maximum temperature required for the scope of the assessment.

Terminate the test when the temperature of the steel surface reaches a mean value of at least 750 °C or any agreed higher value at the request of the sponsor. If the recommended termination temperature is not reached after 6 h of test duration, the test shall normally be terminated. Otherwise, terminate the test when one or more of the reasons for termination specified in EN 1363-1 occurs.

## 10 Test results

### 10.1 Acceptability of test results

It is possible that, within any test package, apparently erroneous results might occur through failure of thermocouples, incorrect assembly of the test specimen, etc. If any results are to be disregarded, i.e. become invalid, the laboratory, in consultation with the sponsor, shall justify this and apply the following rules:

— from the eight thermocouples on each short column at least six results shall be valid

— from the fifteen thermocouples on the tall column at least nine results shall be valid, with at least three valid

results at each temperature measurement station.

### 10.2 Presentation of test results in the test report

The test report shall include the following statement:

“This report provides the constructional details, the test conditions, the results obtained when the specified fire protection system described herein was tested following the procedures of EN 13381-6. Any deviation with respect to thickness of fire protection material and constructional details, other than those allowed under the field of application, could invalidate the test result”.

In addition to the items required by EN 1363-1, the following shall also be included in the test report:

a) the generic description and accurate details of the fire protection system;

b) full details of the test specimens including application method e.g. brush or spray, number of coats and preparation details including surface preparation and thickness of primer, reactive coating and top-coat;

c) description of the fabrication of the test construction, as well as a description of the conditioning of the test construction and its installation onto the test furnace;

d) the results of measured dimensions especially the thickness of the fire protection together with those values to be used in the assessment, according to 6.2;

e) individual furnace temperature and pressure measurements and the mean of all individual furnace temperature and pressure measurements, taken as specified in EN 1363-1, graphically presented and compared with the specified requirements and tolerances given in EN 1363-1;

f) observations made and times at which they occur shall be reported;

g) individual temperature measurements and the mean temperature of each section;

These results may be presented as a selection of the measured data sufficient to give a history of the performance of the test specimen according to EN 1363-1.

These results may also be prepared and printed in tabular form and/or presented on computer media. In the latter case, this should be prepared in an appropriate, secure “read only” format to prevent alteration. Only data maintained in the laboratory files shall be used in the assessment.

## 11 Assessment

### 11.1 General

The temperature data obtained from the unloaded sections are used as a basis for relating the time to reach a specified steel temperature, the thickness of fire protection material and the wall thickness. The data from the short concrete filled sections shall be corrected for stickability using the appropriate correction factor determined in accordance with Annex B.

### 11.2 Assessment procedure for thermal performance

Assessment of thermal performance shall be carried out on the basis of the corrected times to reach the design temperatures of each concrete filled hollow short section.

The input data shall be analysed using point to point interpretation in accordance with Annex A.

## 12 Report of the assessment

The report of the assessment shall include the following:

a) name/address of the body providing the assessment and the date it was carried out, as well as reference to the name/address of the test laboratory, the unique test reference number and report number(s);

b) name(s) and address(es) of the sponsor(s), as well as the name of the manufacturer of the product(s) and the manufacturer(s) of the construction;

c) the generic description of the product(s), particularly the fire protection system and any component parts (where known; if unknown this shall be stated);

d) general description of the test specimens forming the basis of the assessment including the dimensions of the test specimens;

e) reason for the omission of any test data;

f) the composition and measured properties of test specimen components required to be determined from 6.2;

g) the thermal analysis shall produce a table of protection thicknesses for each design temperature, fire performance period, wall thickness and diameter (an example of the presentation of such tabulated information is given in Table 1);

h) a statement regarding the limits of direct application of the assessment procedure.

## 13 Limits of the applicability of the results of the assessment

### 13.1 General

The results from this test method and the assessment procedure are applicable to fire protection systems over the range of fire protection thicknesses tested in this European Standard and no greater than those tested in ENV 13381-4 or EN 13381-8.

The maximum temperatures established during the test shall be no greater than the range established in ENV 13381-4 or EN 13381-8.

The fire protection period resulting from the test and assessment is either limited to the maximum period of testing or else to some shorter period for which the sponsor requires approval.

Nominal extension is permitted only beyond those variables evaluated during the test. All permitted extensions must be applied concurrently and are given as follows.

### 13.2 Permitted fire protection thickness range

The range shall be between the minimum and maximum fire protection thickness tested in accordance with this European Standard.

### 13.3 Permitted minimum wall thickness

The minimum wall thickness shall be the minimum tested in accordance with this European Standard.

### 13.4 Permitted maximum wall thickness

If the maximum wall thickness tested is less than 20 mm, the results shall apply only up to the maximum wall thickness tested. If the wall thickness tested is at least 20 mm then the results apply to any greater wall thickness.

### 13.5 Permitted minimum diameter

The minimum diameter shall be the minimum tested in accordance with this European Standard.

### 13.6 Permitted maximum diameter

The maximum diameter shall be any diameter greater than that tested in this European Standard and can be greater than that tested in ENV 13381-4 or EN 13381-8. For any diameter greater than that tested, the required fire protection thickness shall be that used on the maximum diameter tested.

**Table 2 — Example of tabulated data**

| Fire Performance Period – 30 Minutes Minimum diameter – 219 mm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Design Temperature °C** | **350** | **400** | **450** | **500** | **550** | **600** | **650** | **700** |
| **Wall thickness mm** | **Thickness of Fire Protection Material to Maintain Steel Temperature Below Design Temperature** | | | | | | | |
| **4.0** | | | | | | | | |
| **5.0** | | | | | | | | |
| **6.0** | | | | | | | | |
| **7.0** | | | | | | | | |
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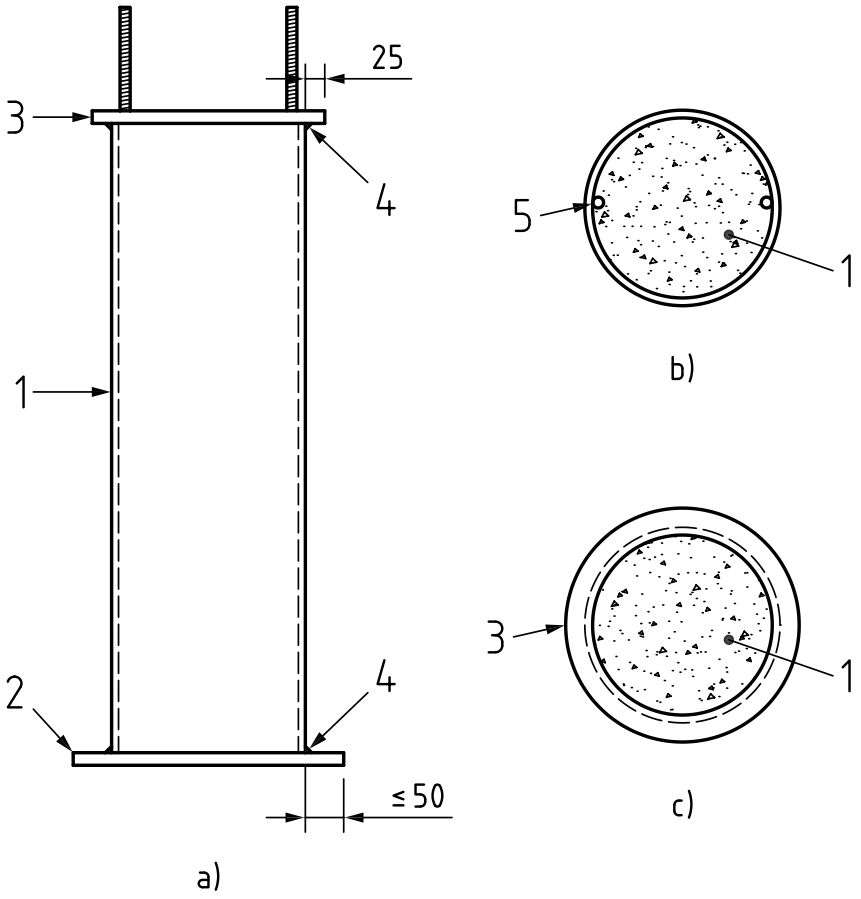
| **17.0** | | | | | | | | |
| **18.0** | | | | | | | | |
| **19.0** | | | | | | | | |
| **20.0** | | | | | | | | |

NOTE This temperature range is for the purposes of illustration only. The actual range is to be determined by the scope of the assessment.

All dimensions in millimetres

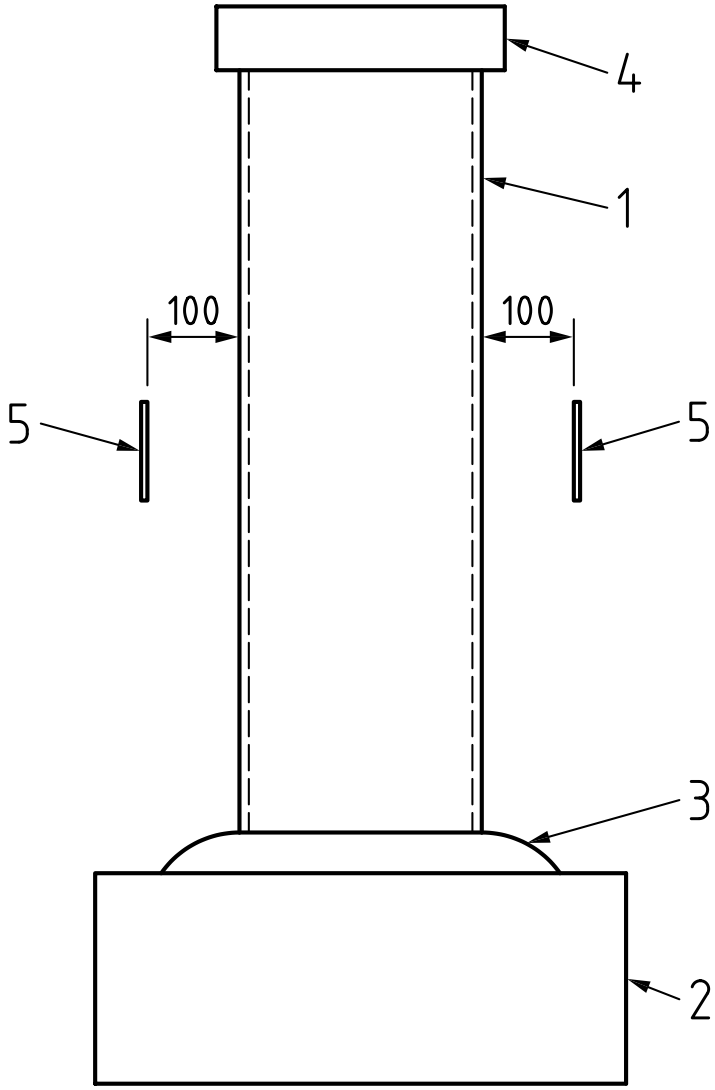



**Key**

| | |
|---|---|
| 1 | Concrete filled column |
| 2 | Steel base plate 5 mm thick with 20 mm diameter in hole centre. Plate to be at least overall cross-sectional size a column and protection material but not exceeding 50 mm greater |
| 3 | Steel top ring 5 mm thick for reactive protection system. Ring to be of a size that allows 90 % of cross-section to be open |
| 4 | Welding |
| 5 | Steel threaded rod may be welded to column wall for lifting and supporting end protection |
| a) | Elevation |
| b) | Plan – passive systems |
| c) | Plan – reactive coatings |

**Figure 1 — Test specimen construction**

All dimensions in millimetres




a)

**Key**

1 Concrete filled column

2 Plinth on furnace floor supporting column

3 Permeable insulation material or sand

4 Permeable insulation material of cross-section greater than the column plus protection material

5 Plate thermocouples at mid-height of column

a) Elevation

**Figure 2 — End protection and Test Specimen Insulation and Positions of Plate Thermocoples**

# Annex A
(normative)
# Linear interpolation analysis

According to the following methodology, steps 1 to 4 shall be performed:

Steps 1 to 3 : Use of input data from test results.
Step 4 : Reporting of the results.

Input data includes the following:

a) the design temperatures as defined in Table 2;

b) the corrected times to reach the design temperatures;

c) the wall thickness for the steel members;

d) the mean thickness of the fire protection.

**Steps 1 to 5: Use of input data from test results**

**Step 1**

Determine the corrected time to reach each specified steel temperature for each wall thickness and protection thickness. An example of the required data for a test matrix that included specimens with intermediate protection thickness and wall thickness is given in Table A.1.

**Table A.1**

| Temperature 550 $^{o}$C | Time to reach specified temperature (min) | | |
|---|---|---|---|
| | Wall thickness (mm) | | |
| Protection thickness (mm) | Minimum (eg 5 mm) | Intermediate (eg 12,5 mm) | Maximum (eg 20 mm) |
| Minimum (eg 0,4 mm) | 41,8 | 49,3 | 61,4 |
| Intermediate (eg 1,0 mm) | 77,3 | 96,9 | 112,9 |
| Maximum (eg 1,6 mm) | 98,7 | 123,4 | 143,8 |

**Step 2**

For each wall thickness, determine by linear interpolation the protection thickness for each of the specified temperatures and fire performance periods, using Formula A.1.

Formula A.1

For a protection thickness between minimum and intermediate thicknesses.

$$d_p = [(d_{int} - d_{min})/(t_{int} - t_{min})]x(t-t_{min}) + d_{min} \quad (A.1)$$

where

$d_p$ is the interpolated protection thickness for time, t;

$d_{min}$ is minimum protection thickness;

$d_{int}$ is intermediate protection thickness;

$t_{min}$ is the time to reach the specified temperature for section with the minimum protection thickness;

$t_{int}t$ is the time to reach the specified temperature for section with the intermediate protection thickness;

t is the required fire performance period.

For a protection thickness between intermediate and maximum thicknesses Formula A.1 is modified to give Formula A.2.

$$d_p = [(d_{max} - d_{int})/(t_{max} - t_{int})]x(t-t_{int}) + d_{int} \quad (A.2)$$

Table A.2 is an example of the data derived from Formulas A.1 and A.2 using the data given in Table A.1.

**Table A.2**

| Wall thickness (mm) | Calculated Protection thickness (mm) for a Performance Period of | | |
|---|---|---|---|
| | 60 min | 90 min | 120 min |
| 5,0 | 0,708 | 1,356 | - |
| 12,5 | 0,535 | 0,913 | 1,523 |
| 20,0 | 0,400 | 0,733 | 1,138 |

No data as thickness is greater than that tested. In this case, no performance can be given for this period and this wall thickness.

Where the calculated thickness is less than the minimum protection thickness, the minimum protection thickness shall be used.

**Step 3**

Obtain the required protection thickness for sections with wall thicknesses between the minimum, intermediate (if tested) and the maximum tested by linearly interpolating between the values derived from step 2 using Formula A.3 and Formula A.4, as appropriate.

For section wall thickness between minimum and intermediate thicknesses

$$d_{pw} = [(d_{int} - d_{min})/(W_{int} - W_{min})]x(W-W_{min}) + d_{min} \quad (A.3)$$

where

$d_{pw}$ is the interpolated protection thickness for wall thickness, W;

$d_{min}$ is minimum protection thickness;

$d_{int}$ is intermediate protection thickness;

$W_{min}$is the minimum wall thickness;

$W_{int}$ is the intermediate wall thickness;

W is the required wall thickness.

For section wall thickness between intermediate and maximum thicknesses, Formula A.3 is modified to give Formula A.4:

$$d_{pw} = [(d_{max} - d_{int})/(W_{max} - W_{int})]x(W-W_{int}) + d_{int} \quad (A.4)$$

**Step 4**

Report the results of the assessment according to Clause 12.

# Annex B
(normative)
# Application, assumptions and limitations of this European Standard

## B.1 Structural contribution from the concrete core

This European Standard ignores any contribution from the concrete to the structural capability of the hollow column and only deals with thermal performance. There is no requirement therefore to carry out loaded testing of concrete filled hollow sections. This European Standard thus provides a simple but conservative approach to assessing the performance of concrete filled hollow sections by only using the steel temperature.

This European Standard provides thermal data for a multi-temperature analysis for a range of hollow section diameter and wall thicknesses.

## B.2 Stickability correction

This European Standard requires testing of tall filled hollow columns and short filled reference columns at both maximum and minimum protection thickness, to determine stickability corrections following the rules defined in ENV 13381-4 or EN 13381-8.

For passive fire protection systems, the shape shall be CHS. The stickability correction factors generated from testing to ENV 13381-4 may be used to correct the data derived from this document, providing the fixing systems are the same.

## B.3 Thermal analysis of circular and rectangular concrete filled hollow sections

The data derived from testing circular sections can be applied to rectangular sections subject to the introduction of rules regarding equivalent size, the details of which are given in this Annex.

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

Testing and thermal modelling have identified that generally circular sections with the same diameter and wall thickness as the length of a side of a square hollow section heat up faster. In such cases, the data derived from testing circular sections could be applied to rectangular sections subject to the introduction of rules regarding equivalent size.

However, some reactive coating manufacturers have demonstrated that concrete filled circular hollow sections heat up faster than square hollow sections of the same side length. This is because the additional volume of concrete has a greater effect on the rate of heating than the corners of rectangular sections which get hotter faster than the wall of a circular hollow section of the same wall thickness.

Finite element analysis has also confirmed this; it is therefore considered to be a conservative approach to use thermal data from concrete filled circular hollow sections to predict the performance of rectangular hollow sections of the same wall thickness and where the shortest side of the rectangle is equal to or greater than the diameter of the circular hollow section.

# Bibliography

IEC 60584-1, *Thermocouples — Part 1: Reference tables (IEC 60584-1)*

EN 1994-1-2, *Eurocode 4 — Design of composite steel and concrete structures — Part 1-2: General rules — Structural fire design*

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