BS EN 13381-5:2014

BSI Standards Publication

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

Part 5: Applied protection to concrete/ profiled sheet steel composite member

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National foreword

This British Standard is the UK implementation of EN 13381-5:2014. It supersedes DD ENV 13381-5:2002 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee 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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Prüfverfahren zur Bestimmung des Beitrages zum Feuerwiderstand von tragenden Bauteilen - Teil 5: Brandschutzmaßnahmen für profilierte Stahlblech/Beton-Verbundkonstruktionen

This European Standard was approved by CEN on 13 September 2014.

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COMITÉ EUROPÉEN DE NORMALISATION
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Foreword

This document (EN 13381-5:2014) 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of an identical text or by endorsement, at the latest by May 2015 and conflicting national standards shall be withdrawn at the latest by May 2015.

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 13381-5:2002.

In comparison with the previous edition, the entire document has been revised.

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

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. Other parts of this standard are:

— *Part 1: Horizontal protective membranes*;

— *Part 2: Vertical protective membranes*;

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

— *Part 4: Applied passive protection products to steel 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*.

Caution

The attention of all persons concerned with managing and carrying out this fire resistance test, is drawn to 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 will be made and safety precautions will be identified and provided. Written safety instructions will be issued. Appropriate training will be given to relevant personnel. Laboratory personnel will ensure that they follow written safety instructions at all times.

The specific health and safety instructions contained within this standard will be followed.

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, 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 of fire protection systems to the fire resistance of structural concrete/profiled sheet steel composite members or slabs. The concrete can be lightweight, normal-weight or heavy-weight concrete and of strength classes 20/25 (LC/C/HC) to 50/60 (LC/C/HC).

The test method and its assessment procedure are designed to permit direct application of the results to cover a range of thicknesses of the applied fire protection material.

The test method is applicable to all fire protection materials used for the protection of concrete/steel composite members or slab and includes sprayed materials, coatings, cladding protection systems and multi-layer or composite fire protection materials, with or without a cavity between the fire protection material and the concrete/steel composite members or slab.

This European Standard contains the fire test which specifies the tests which will be carried out to determine the ability of the fire protection system to remain coherent and fixed to the composite member and to provide data on the temperatures of the steel sheet, throughout the depth of the concrete (for extended application purposes) and the unexposed surface of the concrete, when exposed to the standard temperature/time curve according to the procedures defined herein.

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

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

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

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, *Concrete - Specification, performance, production and conformity*

EN 823, *Thermal insulating products for building applications - Determination of thickness*

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

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

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

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

EN 10346, *Continuously hot-dip coated steel flat products - Technical delivery conditions*

EN 12467, *Fibre-cement flat sheets - Product specification and test methods*

EN ISO 3251, *Paints, varnishes and plastics - Determination of non-volatile-matter content (ISO 3251)*

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, ISO 8421-2, EN 206 and the following apply.

3.1.1
concrete/steel composite member or slab (generally referred to as slab)
element of building construction which is loadbearing and is fabricated from a profiled steel sheet lower surface and a concrete upper layer, which may contain steel reinforcing bars

Note 1 to entry: Profiled steel sheet is specified in EN 10346 and concrete according to EN 206.

3.1.2
fire protection material
material or combination of materials applied directly or by means of fixing system to the surface of a concrete/steel composite slab for the purpose of increasing its fire resistance

3.1.3
passive fire protection materials
materials which do not change their physical form on heating, providing fire protection by virtue of their physical or thermal properties and which may include materials containing water which, on heating, evaporates to produce cooling effects

3.1.4
reactive fire protection materials
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

3.1.5
fire protection system
fire protection material together with a prescribed method of attachment to the structural concrete/steel composite slab

3.1.6
fire protection
protection afforded to the concrete/steel composite slab by the fire protection system such that the temperature throughout the depth of the structural slab and upon any steel reinforcing bars within it is limited throughout the period of exposure to fire

3.1.7
test specimen
concrete/steel composite test slab plus the fire protection system under test

3.1.8
fire protection thickness
thickness of a single layer fire protection material or combined thickness of all layers of a multilayer fire protection material

3.1.9
stickability
ability of a fire protection material to remain sufficiently coherent and in position for a well-defined range of deformations, and furnace and test specimen surface temperatures, such that its ability to provide fire protection is not significantly impaired

3.1.10
equivalent thickness of concrete
theoretical thickness of concrete which provides the same thermal insulation for a given period of test as does the given thickness of the applied fire protection system

3.1.11
limiting exposure time
time at which the adherence of a fire protection system to the concrete/steel composite test slab can be no longer considered acceptable, as indicated by a defined, significant increase in maximum recorded temperature at any point on the steel surface

3.1.12
limiting temperature
maximum value of temperature reached on the lower surface of the ribs of the profiled steel sheet when the limiting exposure time is reached

3.1.13
profiled fire protection system
material which is applied following the shape of the profiled steel sheet of the slab and directly in contact with the steel sheet

3.1.14
suspended fire protection system
system which is not directly in contact with parts of the slab

3.1.15
boxed fire protection system
system which is directly in contact with parts of the slab

3.1.16
characteristic temperature
average of the mean temperature and the maximum individual temperature [(mean + maximum)/2] for a thermocouple group or location

3.2 Symbols and units

For the purposes of this document, the following symbols and units apply.

Symbol	Unit	Designation
L_{exp}	mm	length of the test specimen exposed to the furnace
L_{sup}	mm	centre to centre distance between the supports of the test specimen
L_{spec}	mm	total length of the test specimen
W_{exp}	mm	width of test specimen exposed to the furnace
h_1	mm	thickness of concrete above the steel ribs
h_2	mm	thickness of concrete within the steel profile
h	mm	thickness of concrete in concrete/steel composite test specimen
		thickness $h = h_1 + h_2$
l_p	mm	length of the components of the trapezoidal or re-entrant profile of the steel sheet (l_{p1}, l_{p2} and l_{p3})
P	kN	loading applied to concrete/steel composite test specimen
θ	°C	characteristic temperature
$\theta_{m,l}$ ($\theta_{m,u}$)	°C	limiting temperature at the lower respectively upper part of the steel profile
h_{eff}	mm	the effective thickness of the concrete/steel composite test slab
h_e	mm	the equivalent effective thickness of the concrete/steel composite test slab
h_{eq}	mm	the equivalent thickness of concrete corresponding to the particular thickness of the fire protection system tested
t_r	min	the time at which an increase of the characteristic temperature of all thermocouples on the unexposed concrete surface of 140 K (or a maximum of 180 K from a single thermocouple) is recorded
f_y	N/mm^2	yield strength of steel
d_p	mm	thickness of fire protection material

4 Test equipment

4.1 General

The furnace and test equipment shall be as specified in EN 1363-1.

4.2 Furnace

The furnace shall be designed to permit the dimensions of the test specimen to be exposed to heating to be as specified in 6.2 and its installation to be as specified in Clause 7.

4.3 Loading equipment

Loading equipment shall conform to that specified in EN 1363-1. The loading system shall permit loading, of the magnitude defined in 5.3, to be applied along the length and width of the test specimen.

The loading equipment shall not inhibit the free movement of air above the test specimen and no part of the loading equipment, other than at the loading points, shall be closer than 60 mm to the unexposed surface of the test specimen.

5 Test conditions

5.1 General

Test specimens, subjected to predefined loading, are heated upon a furnace under specified temperature/time conditions, in horizontal orientation, with fire exposure applied from below.

Tests are carried out on a loaded large size test slab and an unloaded small size test slab to provide information on:

— the temperature of the profiled steel sheet behind the fire protection system;

— the behaviour of the fire protection system and its stickability;

— the temperature of the unexposed side of the test specimen;

— the temperature throughout the concrete (optional for extended application purposes).

It is recommended that the test be continued until the temperature of the exposed profiled steel surface reaches a mean value of at least 400 °C, (or any single maximum value of 500 °C is recorded), to give the necessary information on the stickability of the fire protection system. These temperatures may be modified if requested by the sponsor.

If the recommended termination temperatures are not reached after 6 h test duration the test shall normally be terminated.

The procedures given in EN 1363-1 and EN 1363-2 (if relevant) shall be followed in the performance of this test method unless specific contrary instruction is given.

5.2 Support and restraint conditions

5.2.1 Standard conditions

The concrete/steel composite slab test specimens shall be tested as a simply supported one way structure with two free edges and an exposed surface and span as specified in 6.3.

The concrete/steel composite slab test specimens shall be installed onto the furnace to allow freedom for longitudinal movement and deflection using at one side rolling support(s) and at the other hinge support(s).

The surface of the bearings shall be smooth concrete or steel plates. The width of the bearings shall be the minimum representative of practice.

5.2.2 Other support and restraint conditions

If the support and restraint conditions differ from the standard conditions specified in 5.2.1, these conditions shall be described in the test report and the validity of the test results will be restricted to those tested.

For example the concrete/steel composite slab can be installed on a steel H or I profile at each end of the furnace and fixed by means of nails shot in each bottom of waves.

5.3 Loading conditions

Loading shall be applied to the full size test specimens.

The load shall be designed in order to introduce, between the two loading lines, a bending moment equivalent to the maximal allowed load designed by the manufacturer of the profiled steel sheets for the tested concrete thickness and span.

The load shall be symmetrically applied to the test specimen along two transverse loading lines, each one at a distance (L_{sup}/4) from each of the supports. The proportion of the total load applied at each loading position shall be P/2, as specified in Figure 1. Point loads shall be transferred to the test specimen through load distribution beams or plates (see Figure 1a)).

The total contact area between these and the concrete surface of the test specimen shall be as specified in EN 1363-1, provided that the load distribution beam or plate chosen has a flexural rigidity large enough to give the required distribution of the load.

Load distribution beams, for safety reasons, shall have a height to width ratio of < 1.

If the load distribution beams or plates are of steel or other high conductivity material, they shall be insulated from the concrete surface of the test specimen by a suitable thermal insulation material.

Unexposed surface thermocouples shall not be closer than 100 mm to any part of the load distribution system as shown in Figure 1a).

6 Test specimens

6.1 Number of test specimens

Two full size loaded concrete/steel composite members shall be tested.

To one member the minimum thickness of the fire protection system shall be applied and to the other member the maximum thickness. If the fire protection system is only available in a single thickness, then one test on one type of member only shall be carried out at that thickness.

Additional small scale tests (one test per variable) may be carried out to provide further test data for the fire protection system when:

— it is to be applied to a concrete/steel composite member of composite thickness less than that specified in this test method;

— it is to be applied at intermediate fire protection thicknesses between maximum and minimum thickness;

— the test is carried out to the smouldering curve, in which case a small size test slab with both maximum and minimum thickness of applied fire protection material shall be tested, according to Annex A.

6.2 Size of test specimens

The size of the test specimens shall be as specified in Table 1 and exemplified in Figure 1.

6.3 Construction of test specimens

6.3.1 Construction of concrete/steel composite test slabs

The concrete/steel composite test slabs shall comprise a trapezoidal or re-entrant steel profile plus concrete of thickness h_1, given in Table 1, over the upper ribs of the profiled steel sheet. The concrete shall contain prefabricated welded steel mesh.

The welded steel mesh, placed towards the unexposed surface in both small and large test slabs shall comprise 4,0 mm diameter ribbed bars such that the area of reinforcing steel bars is (70 to 100) mm^2 per metre of width of the concrete/steel composite test element.

The position of the welded steel mesh with respect to the unexposed concrete surfaces shall be ensured by the use of spacers, either plastic or concrete, such that the concrete cover obtained is (20,0 ± 2,0) mm.

The actual position of the welded steel mesh at the unexposed surface and the positions of the thermocouples specified under 9.3 shall be adjusted just before the casting of the concrete member.

Lifting hooks may be incorporated into the composite slab. These shall be of sufficient number and location to avoid longitudinal and transverse moments. Alternatively, the composite slabs shall be supported on steel beams for lifting purposes.

Fixtures to which hangers may be attached may be provided on the unexposed side in order to avoid the collapse of the test specimen during the test, especially where the test is continued beyond the recommended termination temperature of 400 °C. These fixtures shall not interfere with the applied load.

Table 1 — Sizes of composite steel/concrete test slabs

	Small test specimen	**Large test specimen**
Exposed length (mm) L_{exp}	≥ 1 300	≥ 3 000[a]
Span (mm) L_{sup}	≥ 1 500 $[(L_{exp} + 200) > L_{sup} < (L_{exp} + 400)]$[b]	≥ 3 200[a] $[(L_{exp} + 200) > L_{sup} < (L_{exp} + 400)]$[b]
Length (mm) L_{spec}	≥ 1 700 $[(L_{exp} + 400) > L_{sup} < (L_{exp} + 700)$[c]$]$	≥ 3 400 $[(L_{exp} + 400) > L_{sup} < (L_{exp} + 700)]$[c]
Exposed width (mm) W_{exp}	≥ 1 000	≥ 2 000
Thickness $h = [h_1 + h_2]$ (mm)	$[(h_1 = 60 \pm 5) + (h_2 =$ height of ribs$)]$	$[(h_1 = 60 \pm 5) + (h_2 =$ height of ribs$)]$
Position of loading points from support points	none	$L_{sup}/4$ (symmetrically distributed)

[a] A span of 3 000 mm is mainly valid for trapezoidal decking with height of ribs of 50/60 mm and steel thickness of 1 mm.

[b] The distance between the exposed part of the test specimen and the supports shall be kept as small as possible. For tests of short duration (less than 240 min) a distance of 100 mm at either end is recommended. For tests of longer duration, this can be increased to 200 mm at either end, to protect the test equipment from heat damage.

[c] The additional length beyond the supports, required for installation purposes, shall be kept as small as it is practically possible.

6.3.2 Fabrication of concrete/steel composite slab test members

Composite slab test members shall be prepared in a smooth surfaced framework made from steel or timber. To facilitate release of the edges of the slab from the framework, soluble oils or emulsions shall preferably be used, although wax, non-soluble oil or non-soluble emulsions may be used. The actual material used for this purpose shall be detailed in the test report.

6.3.3 Application of the fire protection system (except suspended ceiling) to the composite test slab

The steel surface of the composite test element shall be prepared as in practice. The surface of the steel face of the concrete/steel composite test slab shall normally be dried prior to the application of the fire protection system.

The fire protection system shall be uniformly applied to the test specimen, as in practice, including any required fixing aids and in the same manner for both maximum and minimum thickness.

The fire protection material shall extend over the full exposed surface of the concrete/steel composite test slab and be applied prior to the application of the test load (if any).

Where a fire protection system creates small cavities between the concrete/steel composite test element and the fire protection material, the ends shall be sealed with fire resistant material to prevent any flow of hot gases out of the cavities.

Board type fire protection systems shall include joints in accordance with the following criteria:

— large size test specimen: at least one longitudinal joint shall be situated near the longitudinal mid-width axis under a void between two waves and at least one transverse joint positioned not further than 500 mm from the transverse mid-span axis;

— small size test specimen: at least one longitudinal joint shall be situated near the longitudinal mid-width axis under a void between two waves and at least one transverse joint positioned not further than 100 mm from the transverse axis.

6.3.4 Installation of the suspended ceiling onto the composite test slab

The test specimen shall reproduce the conditions of use, including junctions between membrane and walls and edge panels, joints and jointing materials and be installed from below by the same method and procedures as given in the installation manual, or in written instructions, which shall be provided by the sponsor.

It shall be fitted with all the components for hanging, expansion and abutting, plus any other fixtures which are to be defined by the sponsor, with a frequency representative of practice.

For horizontal protective membranes which are suspended from the structural building member by hangers, the suspension system and the length of the hangers shall be representative of practice.

The profiles bearing the various panels shall be installed against each other without any gap, unless a gap (or gaps) is required for design purposes. In this case the gap (or gaps) at the junctions of main runners shall be representative of that to be used in practice and shall be installed within the main runners and not at their ends.

The profiles within the test specimen shall include a joint representative of joints to be used in practice in both longitudinal and transverse directions.

The horizontal protective membrane shall be fixed according to normal practice on all four edges, either directly to the furnace walls or to a test frame. A test frame, where used, shall be fixed directly to the horizontal structural building member being protected, or to the furnace walls.

If the construction or properties of the horizontal protective membrane are different in the longitudinal and transverse directions, the performance of the specimen may vary depending upon which components are aligned with the longitudinal axis. If known from experience, the specimen shall be installed so as to represent the most onerous condition by arranging the more critical components parallel to the longitudinal axis. If the more onerous condition cannot be identified, two separate tests shall be carried out with the components arranged both parallel and perpendicular to the longitudinal axis.

6.4 Composition of test specimen component materials

6.4.1 Profiled steel sheet

The steel used shall be of grade between S280GD and S350GD as defined in EN 10346.

6.4.2 Concrete

The concrete in the test specimen shall normally be of type 25/30 to 30/37 [LC/C/HC] (light-weight between 800 and 2 000 kg/m^3, normal-weight between 2000 and 2600 kg/m^3 or heavy-weight concrete greater than 2 600 kg/m^3) according to EN 206 and EN 1992-1-1, although other grades within the strength range 20/25 to 50/60 may be used (see Clause 1).

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

Other non-silicious and lower density aggregates may be permitted, but the applicability of the results of the assessment will be restricted according to 15.7.

The consistency of the wet concrete shall allow for good compaction and smooth surface. The consistency shall be of type S3 or F3 determined in accordance with EN 206.

6.4.3 Fire protection system

The generic description of the fire protection system and its major components shall be specified by the sponsor, including at least the name, dimensions, the expected nominal density, thickness and moisture content according to European Technical Specifications (European Standard or ETA).

For reactive protection system, the identification of the coating shall be in accordance with the ETAG 018, Part 2, identification requirements.

6.5 Properties of test materials

6.5.1 General

The actual material properties of test specimen component materials shall be determined, according to EN 1363-1 and using appropriate product test standards, on test materials or test samples conditioned as defined in Clause 8.

6.5.2 Concrete

The density, moisture content and strength of the concrete component of each concrete/steel composite slab tested shall be measured on small samples prepared from the same concrete batch, at the same time, as that tested. The method used to prepare these samples and the means by which they were conditioned shall be reported.

The concrete strength of all batches of concrete used shall be measured at intervals during conditioning and on the day of the fire test according to one of the methods specified in EN 206.

The density and moisture content of all batches of concrete used to make each concrete/steel composite slab tested shall be measured on small samples of area at least 200 mm × 200 mm prepared in a mould using the same profiled steel sheet as that tested as the base to the mould. Each sample shall be of the same thickness (h_1 and h_2) as that tested. Each sample shall be covered after preparation with a water impermeable membrane on five sides, the top surface exposed, and conditioned, with the concrete/steel composite test slab.

Using these samples, the density and moisture content shall be measured at intervals during conditioning and on the day of the fire test to give the final density and moisture content.

The dimensions of the concrete/steel slab measured before application of the fire protection material together with the weight of steel sheet, the weight of reinforcement and the final concrete density may be used to calculate the dead-weight contribution of the concrete/steel slab to the calculation of load.

6.5.3 Fire protection material

The actual thickness, density and moisture content of the fire protection materials shall be measured and recorded, at the time of test, either directly upon the fire protection material or materials or on special test samples taken by the laboratory. These shall be conditioned as defined in Clause 8. The measurement procedures appropriate to different types of material are given in Annex B.

The thickness of a board or panel type fire protection material shall not deviate by more than 15 % of the mean value over the whole of its surface. The mean value shall be used in the assessment of the results and the limits of applicability of the assessment. If it deviates by more than 15 %, the maximum thickness recorded shall be used in the assessment.

The thickness of sprayed or coated passive type fire protection systems shall be measured on the lower steel rib (and on the upper rib in the case of trapezoidal steel profiles) at the thickness measuring points specified in Figure 1 and Figure 2. 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 thickness of a sprayed or coated passive type fire protection material shall not deviate by more than 20 % of the mean value over the whole of its surface. The mean value shall be used in the assessment of the results and the limits of applicability of the assessment. If it deviates by more than 20 %, the maximum thickness recorded shall be used in the assessment.

The density of fire protection material applied to the composite steel/concrete slabs at minimum and maximum thickness shall be recorded. The average between mean values of the density of the fire protection material at minimum and maximum thickness shall be used in the assessment of the results of the test, unless the difference between this average value and the mean values at minimal and maximal thickness is greater than 15 % of the average value, in which case the maximum mean density value recorded shall be used.

6.6 Verification of the test specimen

An examination and verification of the test specimen for conformity to specification shall be carried out as defined in EN 1363-1.

The properties of the materials used in the preparation of the test specimen shall be measured using special samples, where necessary, as described in 6.5 using the methods defined in Annex B.

The sponsor shall verify that the fire protection material has been applied correctly and in the case of sprayed or coating materials ensure, by methods appropriate to the material, that it is of the design composition and specification.

7 Installation of the test construction

The test construction, comprising the concrete/steel composite test slab, any supporting construction or test frame and the fire protection system, shall be installed onto the furnace to allow freedom for longitudinal deflection and movement, according to 5.2.1, using at one side rolling support(s) and at the other side, hinge support(s).

Special attention shall be given to the choice of size of the test specimen according to the expected duration of the test (see 6.2) and to insulation of the supports carrying the slab against the influence of heat.

Care shall be taken to ensure during installation of the test specimens onto the furnace, or as a result of any movement occurring during the test, that the fire protection system is not subjected to any expansion or restraint stresses contrary to its use in practice.

8 Conditioning of the test construction

The test construction and test samples taken for the determination of material properties (specified in 6.5) shall be conditioned according to EN 1363-1. Material properties shall be determined according to methods specified in 6.5, EN 1363-1 and Annex B.

The minimum conditioning time for concrete/steel slabs shall be 90 d.

9 Application of instrumentation

9.1 General

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

9.2 Instrumentation for measurement of furnace temperature

Plate thermometers of the type specified in EN 1363-1 shall be provided to measure the temperature of the furnace. They shall be uniformly distributed, with at least one centrally placed within every 1,5 m^2 of the exposed test specimen surface area, the exposed area being the nominal area measured in the plane of the specimen.

The plate thermometers shall be oriented so that side 'A' faces the floor of the furnace and shall be positioned according to EN 1363-1 below the lowest plane of the underside of the protective material. For test specimens with less than 6 m^2 exposed area, a minimum of four plate thermometers shall be used.

9.3 Instrumentation for measurement of test specimen temperature

9.3.1 General

Thermocouples for measuring temperatures upon the surface of the steel (spot welded at the non-exposed side of the steel sheet, between steel and concrete before casting of the concrete) and within the concrete shall be of the double glass fibre insulated bare wire type specified in EN 1363-1 and be positioned and fixed as specified in EN 1363-1. To provide protection against damage when casting concrete, such thermocouples may be encased within a secondary casing, which shall be chosen such that it will not affect the temperature history of the thermocouple throughout the test. Such thermocouples shall be new when used for this test.

Thermocouples for measuring temperatures upon the unexposed surface of the concrete shall be of the copper disc type specified in EN 1363-1. They shall be positioned and fixed as specified in EN 1363-1.

Thermocouples for measurement and recording of surface and internal temperatures of the concrete/steel slab shall be located at the measuring stations indicated in Figure 1 c).

9.3.2 Mandatory thermocouples

a) At each main measuring station, three thermocouples shall be fixed on the profiled steel sheet, as specified in Figure 2 a).

b) At each main measuring station, two thermocouples shall be fixed on the unexposed upper face of the concrete/steel composite test slab as specified in Figure 2 a). These shall not be closer than 100 mm to any part of the load distribution system.

c) At each additional measuring station, two thermocouples shall be fixed on the exposed profiled steel sheet as specified in Figure 2 b).

9.3.3 Optional thermocouples

If data are required for extended application purposes further three thermocouples shall be introduced, at each main measuring station, into the body of the concrete/steel composite test slab (see Figure 2 a)).

These thermocouples shall be rigidly mounted on tensioned U-shaped 5 mm diameter bars fixed to the upper reinforcing bars in order to guarantee their position at 25 mm centres. Such thermocouples shall be fixed to the 5 mm U-shaped bars isothermally for 50 mm. The hot junction shall be angled away from the U-shaped

bar such that it is between 5 mm to 10 mm away from and below the bar (on the exposed side during the test) and positioned accurately at the required depth (Figure 2 c)).

9.4 Instrumentation for measurement of pressure

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

9.5 Instrumentation for measurement of deformation

A suitable means of measuring the vertical deformation of the test specimen at mid-span, relative to the supports, shall be provided, located and used as specified in EN 1363-1 for loaded test specimens.

9.6 Instrumentation for measurement of applied load

Instrumentation for the measurement of applied load to loaded test specimens shall be provided and used as specified in EN 1363-1.

10 Test procedure

10.1 General

Carry out checks for thermocouple consistency and establish data points for temperature as specified in EN 1363-1 before commencement of the test and procedures given in 10.2 to 10.7.

10.2 Furnace temperature and pressure

Measure and record the furnace temperature using the thermocouples described in 9.2 and the furnace pressure in accordance with the procedures and frequency specified in EN 1363-1.

Control the furnace temperature according to the data received from the furnace temperature measurement thermocouples to the criteria of EN 1363-1.

Control the furnace pressure to the criteria of EN 1363-1.

10.3 Application and control of load

Using the procedures of EN 1363-1 apply a constant load to the slab test specimen, of magnitude in accordance with 5.3, throughout the test period until a deformation of $L_{sup}/30$ is reached or when the rate of deflection exceeds that given in EN 1363-1 at which point the load shall be removed.

Hangers, when used to avoid collapse of the test specimen, shall not influence the deflection when the load is removed.

10.4 Temperature of test specimen

Measure and record the temperature of the test specimen, upon the exposed and unexposed surfaces of the test specimen and where required within the concrete, using the thermocouples specified in 9.3, at intervals not exceeding one minute.

10.5 Deformation

Using the procedures of EN 1363-1, for the loaded slab test specimen, identify an initial deformation datum point, relative to the supports, before application of the load. Then apply the test load and measure the zero point for deformation after applying the load and before commencement of heating. Monitor the deformation and rate of change of deformation continuously throughout the test. Record the results according to EN 1363-1.

10.6 Observations

Wherever practical, monitor the general behaviour of the test specimen, especially the fire protection, throughout the test and record the occurrence of cracking, fissuring, deterioration, detachment or similar behaviour as described in EN 1363-1.

10.7 Termination of test

Terminate the test when at unexposed side of specimen characteristic temperature increase has exceeded 140 °C or maximal temperature increase has reached 180 °C. These temperatures may be modified by mutual agreement between laboratory and client. If the recommended termination temperature is not reached after 6 h test duration, the test shall normally be terminated. Otherwise terminate the test when one or more of the reasons for termination which are specified in EN 1363-1 occurs.

11 Test results

11.1 Acceptability of test results

It is possible that within any test apparently erroneous results may 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:

Slabs:

a) At least 12 of 15 thermocouples on profiled steel sheet as specified in 9.3.2 a). with:

   1) At least 3 of 5 thermocouples on the upper side profiled steel sheet as specified in 9.3.2 a).

   2) At least 3 of 5 thermocouples on the middle side sheet as specified in 9.3.2 a).

   3) At least 3 of 5 thermocouples on the lower side sheet as specified in 9.3.2 a).

b) At least 8 of 10 thermocouples on the upper concrete surface of the concrete/steel composite test slab as specified in 9.3.2 b).

c) At least 9 of 12 thermocouples on the profiled steel sheet as specified in 9.3.2 c) (considered equivalent to those given in 9.3.2 a));

   1) At least 4 of 6 thermocouples on the upper side profiled steel sheet as specified in 9.3.2 c).

   2) At least 4 of 6 thermocouples on the lower side sheet as specified in 9.3.2 c).

d) At least 12 of 15 optional thermocouples on the thermocouple spacer grids, when used, as specified in 9.3.3 with,

   1) At least 3 of 5 thermocouples in the concrete above the wave void (D) as specified in 9.3.3

2) At least 3 of 5 thermocouples in the concrete above the wave (E) as specified in 9.3.3.

3) At least 3 of 5 thermocouples in the concrete under the previous thermocouple (F) in 9.3.3.

11.2 Presentation of test results

The following shall be reported within the test report:

a) the results of measured dimensions and actual material properties, especially the properties of the concrete and the thickness, density and moisture content of the fire protection together with those values to be used in the assessment, according to 6.5;

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

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

d) the individual results and the mean of all individual results of all temperature measurement thermocouples at the equivalent locations given in 9.3.2 and 9.3.3, all graphically presented. Evidence of compliance with the validity criteria of 11.1;

e) the individual results and the mean of all individual results of all the deformation measurements, specified in 10.5, all graphically presented. If the load is removed according to 10.3, the time at which this occurred;

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

These results (b to e) 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 upon computer media. In the latter case this shall 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.

12 Test report

The test report shall include the following statement:

“This report provides the constructional details, the test conditions, the results obtained and the interpolated data obtained when a specific form of construction was tested following the procedures of EN 13381-5. Any deviation with respect to thickness and density of fire protection system, concrete type, thickness and geometry of steel sheet and reinforcing steel type and positioning could invalidate the assessment of 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 of the protection system, preparation details including surface preparation, thickness of primer or bonding agent, thickness of coating or rendering or board, thickness of top coat;

c) description of the fabrication of the composite member, any surface preparation or treatment, description of the conditioning of the test construction and its installation onto the test furnace;

d) the results of the measurements obtained in 11.2 a) to e) during the tests presented in graphical format (and any other optional format), as required in 11.2;

e) if possible a description of significant behaviour of the test specimen observed during the test period, including observations of the time(s) and magnitude of any detachment of fire protection material;

f) the magnitude of the load applied to each test specimen, as a function of time, and if removed (loaded beams and columns), the time at which this occurred;

g) the reason, on the basis of 10.7 of this test method, for the termination of the test and the time elapsed when the test was terminated;

h) the results of any other testing carried out such as the smouldering fire (slow heating curve) test as described in Annex A should be reported separately;

i) details of the calculations used to determine the test load or loading conditions defined by the limit deflection according to 5.3;

j) a statement of the validity of the test results according to the principles of 11.1.

13 Assessment

13.1 General

The assessment method details the means whereby the results of temperature measurement and observations made throughout the test are used to provide the following:

a) the relationship between steel sheet temperature, time and thickness of fire protection material;

b) the equivalent thickness of concrete, related to thermal insulation criteria;

c) information on stickability and limiting exposure times.

The data obtained by continuing the test after removal of the load can only be used for the assessment of non-loadbearing floors.

From the temperature data collected and reported in 11.2 and Clause 12, the following shall be identified:

— the graphs of the mean of all individual temperatures for each thermocouple group or location defined in 11.2 d);

— the graphs of the individual thermocouples giving rise to the highest individual temperature for each thermocouple group or location defined in 11.2 d).

The characteristic temperature for each thermocouple group or location, as defined in 11.2 d), shall be calculated and similarly presented. These results shall be used as the characteristic temperature curves and used in the assessment under 13.2 and 13.3.

13.2 Profiled steel sheet temperature

The time for the characteristic profiled steel sheet temperature to rise to 350 °C is plotted on a graph versus thickness of fire protection system (from the two standard tests at maximum and minimum thickness there will be two data points only but if additional tests were performed more than two points would be included).

For intermediate thicknesses of fire protection system the time for the characteristic temperature to rise to 350 °C is obtained by linear interpolation (Figure 3).

13.3 Equivalent thickness of concrete

The characteristic temperature curve for the upper concrete surface is used to determine the equivalent thickness of concrete, for a given thickness of fire protection system protecting a large or small test specimen, together with the following procedure:

a) the effective thickness of the concrete/steel composite test slab (h_{eff}) is defined according to the following formula:

$$h_{\text{eff}} = h_1 + [h_2 \times \frac{(l_{\text{p1}} + l_{\text{p2}})}{2}] / [(l_{\text{p1}} + l_{\text{p3}})]$$

where

h_1 is the actual thickness of concrete over the ribs of the profiled steel sheet, h_2 is the depth of the profile and l_{p1}, l_{p2} and l_{p3} are the dimensions of the steel profile (see Figure 4);

b) determine the time (t_r) at which an increase of the characteristic temperature of 140 °C of all thermocouples on the unexposed concrete surface, or of 180 °C from a single individual maximum temperature curve on that surface, is recorded, whichever is the lesser;

c) the equivalent effective thickness of the concrete/steel composite test slab with its fire protection system (h_e) is obtained according to Figure 5, by putting as ordinate, t_r or according to Table 2 using linear interpolation.

If the test specimen was made with lightweight concrete, the value obtained shall be multiplied by 0,9 to give h_e;

Table 2 — Numerical values of time t_r versus equivalent effective thickness h_e

Time t_r (min)	**Equivalent effective thickness h_e** (mm)
30	60
60	80
90	100
120	120
180	150
240	175

d) the equivalent thickness of concrete corresponding to the particular thickness of the fire protection system tested (h_{eq}) is determined according to:

$$h_{\text{eq}} = h_{\text{e}} - h_{\text{eff}}$$

e) plot the equivalent thickness of concrete h_{eq} for the thickness(es) of the fire protection system against the actual thicknesses of fire protection system tested. Equivalent thicknesses of concrete for intermediate fire protection thicknesses are obtained by linear interpolation (see Figure 6).

13.4 Limiting exposure time

The limiting exposure times for the thickness(es) of fire protection system are plotted against the actual thickness. From this plot the maximum fire exposure rating for the use of equivalent thicknesses of concrete as given in 13.3 are found by linear interpolation.

a) Loaded large test specimen:

The limiting exposure time shall be the lowest time of exposure between:

1) the time when the maximum temperature ($\theta_{m,l}$) recorded at any point on the lower part of the profiled steel sheet ribs (after reaching 200 °C) is continuously more than 50 % above the mean of the mean temperature and the maximum temperature [(mean + maximum)/$_2$], from the individual results of all thermocouples at the lower part of the profiled steel sheet ribs, indicating significant detachment of fire protection system. The value of ($\theta_{m,l}$), at that time, shall be the limiting temperature for calculation purposes;

2) the time when the maximum temperature ($\theta_{m,u}$) recorded at any point on the upper part of the profiled steel sheet ribs (after reaching 200 °C) is continuously more than 50 % above the mean of the mean temperature and the maximum temperature [(mean + maximum)/$_2$], from the individual results of all thermocouples at the upper part of the profiled steel sheet ribs, indicating significant detachment of fire protection system. The value of ($\theta_{m,u}$), at that time, shall be the limiting temperature for calculation purposes;

3) the time when the load was removed;

4) if none of these criteria are reached before the test is terminated, the limiting exposure time shall be the time of termination of the test.

b) Unloaded small test specimen:

The limiting exposure time for the unloaded small test specimen (protected with intermediate thicknesses if additional tests are made at intermediate thicknesses) shall be the time for the unloaded specimen to reach the limiting temperature ($\theta_{m,l}$) or ($\theta_{m,u}$).

The choice of limiting temperature ($\theta_{m,l}$) or ($\theta_{m,u}$) to be used shall be made according to whether ($\theta_{m,l}$) or ($\theta_{m,u}$) was found to be decisive in 13.4 a).

13.5 Insulation

The assessment for insulation shall be carried out according to EN 1363-1.

14 Report of the assessment

The report of the assessment shall include the following:

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

b) the name(s) and address(es) of the sponsor(s). The name of the manufacturer of the product or products and the manufacturer or manufacturers of the test construction;

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

d) general description of the fabrication of the steel/concrete composite member, any surface preparation or treatment, including releasing oils, etc. used during its fabrication. General description of the fixing details of the fire protection system. General description of the conditioning of the test construction and the installation of the test construction onto the furnace;

e) reason of omission of any test data;

f) general description of the test specimen with drawings, including the dimensions of the test specimen and photographs and written instructions, provided by the sponsor;

g) the composition and measured properties, especially density (except for reactive coating), thickness and moisture content (except for reactive coating), of components of the test specimen which are required to be determined and their method of determination;

h) graphs of mean temperature, maximum temperature and characteristic temperature derived according to 13.1;

i) the measured time for the characteristic temperature of the profiled steel sheet to rise to 350 °C for each thickness of fire protection material tested.

   The graphical plot of the measured time for the profiled steel sheet to rise to 350 °C against fire protection material thickness between its maximum and minimum thickness and at all intermediate thicknesses by interpolation, derived in accordance with 13.2;

j) the values and the plot of equivalent thickness h_{eq} of concrete for each thickness of fire protection material between its maximum and minimum thickness, derived in accordance with 13.3;

k) the values and the plot of limiting exposure time for each thickness of the fire protection material between its maximum and minimum thickness derived in accordance with 13.4;

l) a statement on insulation performance according to the criteria of EN 1363-1;

m) a statement on any results arising from temperature measurement throughout the depth of the concrete, using the thermocouples given in 9.3.2, which may be used for extended application purposes;

n) a statement regarding the limit of direct application of the assessment procedure.

15 Limits of applicability of the results of the assessment

15.1 The test results from the performance of the fire protection system tested according to this method are applicable to concrete/steel composite slabs with profiled steel sheet which may or may not contain additional reinforcing steel bars for loadbearing purposes.

15.2 The results of the assessment on concrete/steel composite slabs built with trapezoidal profiled steel sheet may only be applied to concrete /steel composite slabs built with trapezoidal profiled steel sheet.

Results of the assessment on concrete/steel composite slabs built with re-entrant profiled steel sheet may only be applied on concrete/steel composite slabs built with re-entrant profiled steel sheet.

15.3 The results of the assessment are applicable to concrete/steel composite slabs with fire exposure from the steel side and with the following conditions:

a) the thickness of the profiled steel sheet is greater than or equal to that tested;

b) the width of the rib (l_{p1}), on which the fire protection material is directly attached, is not greater than 1,5 times the width of that tested;

c) the height of the rib (h_2) is not higher than 1,5 times the height of that tested.

15.4 The equivalent thickness of concrete for a given thickness of fire protection system is applicable up to the relevant limiting time of exposure.

15.5 The results of the assessment may only be applied to concrete/steel composite slabs in which the concrete is of density within the range 0,85 to 1,15 times that tested.

15.6 The results of the assessment are applicable to concrete members in which the concrete strength is equal to or one strength grade higher than that tested.

15.7 The results of the assessment are applicable to all concrete members in which the concrete is prepared with the same type of aggregates.

15.8 The results of the assessment may only be applied to concrete/steel composite slabs with effective slab thicknesses equal to or greater than that tested.

15.9 The results of the assessment may only be applied to fire protection systems where the fixing system used is the same as that tested.

15.10 The results of the assessment may only be applied to fire protection systems where the jointing system used is the same as that tested.

15.11 The results of the assessment from a test using a single layer fire protection system are applicable only to single layer fire protection systems.

The results of the assessment from testing a multi-layer fire protection material are applicable to that material in multi-layer format, provided that the number of layers is the same than tested, the composition of layers and the fixing pattern is unchanged.

15.12 The test results for sprayed fire protection materials, tested with suitable lathing (e.g. wire mesh) secured to the concrete/steel composite slab, may only be applied to slabs incorporating this type of lathing.

15.13 The maximum permitted thickness of the total protection: up to 5 % above the maximum thickness tested on a loaded element. The minimum permitted thickness of the total protection: up to 5 % below the minimum thickness tested on a loaded element. If only one thickness of protection system was tested, the results of assessment are applicable only to this thickness.

15.14 The test results are only valid for thicknesses of protection material between the minimum and maximum tested thicknesses. If only one thickness was tested the results are only valid for this tested thickness.

15.15 Fire resistance results for suspended system only is applicable to cavities with equal or greater height than that tested, provided no changes are made to the building member supporting the horizontal protective membrane.

16 Additional limits of applicability of the results of the assessment for suspended ceilings used as protection system

16.1 Height of the cavity

Fire resistance obtained by direct application shall be applicable to cavities with equal or greater height than that tested.

16.2 Exposed width of test specimen

Where the exposed width in the test is less than 3 000 mm the results shall not be applicable to structures of width greater than that tested.

16.3 Properties of the horizontal protective membrane

The result of the assessment is only applicable to the horizontal protective membrane construction tested and at the density and thickness tested ± 5 %.

Components of supporting steel frame and installation conditions shall be the same as those tested.

16.4 Size of panels within the horizontal protective membrane

Where panels are produced in a range of sizes and if the minimum and maximum sizes are tested, in separate tests, then the results giving the lowest values are directly applicable to all intermediate sizes.

16.5 Fixtures and fittings

If the test was performed without fittings and fixtures, the result is not applicable to membranes with fittings and fixtures. A separate test including the fixtures and fittings as defined in 6.3 shall be required. Fixtures and fittings at intermediate spacings may be directly applied as a result of this additional test.

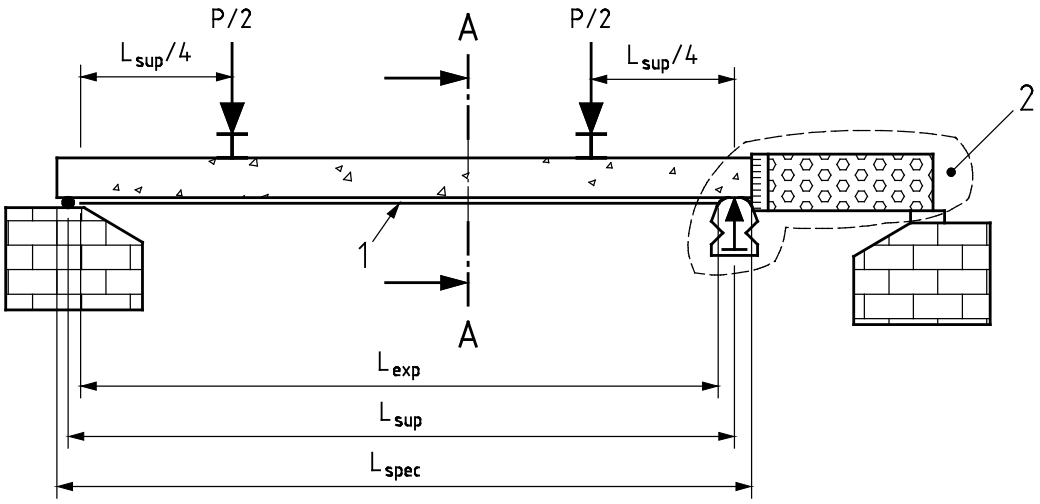
Test results on membranes containing fittings and fixtures with their own suspension devices may be applied to membranes containing such suspension devices provided the distribution does not exceed those tested.

The total area occupied by fixtures and fittings related to the area of the membrane lining is not increased and the maximum tested opening area is the lining is not exceeded.

If the test was performed with fittings and fixtures, the result is not applicable to membranes without fittings and fixtures.

16.6 Gaps between grid members and test frame or walls

Test results obtained with no expansion gap between grid members and the test frame or furnace walls shall be applicable to practical situations where such gaps are used, providing these are no greater than 5 mm in size.

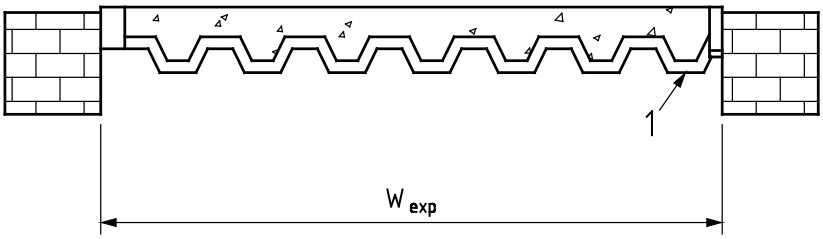


Key

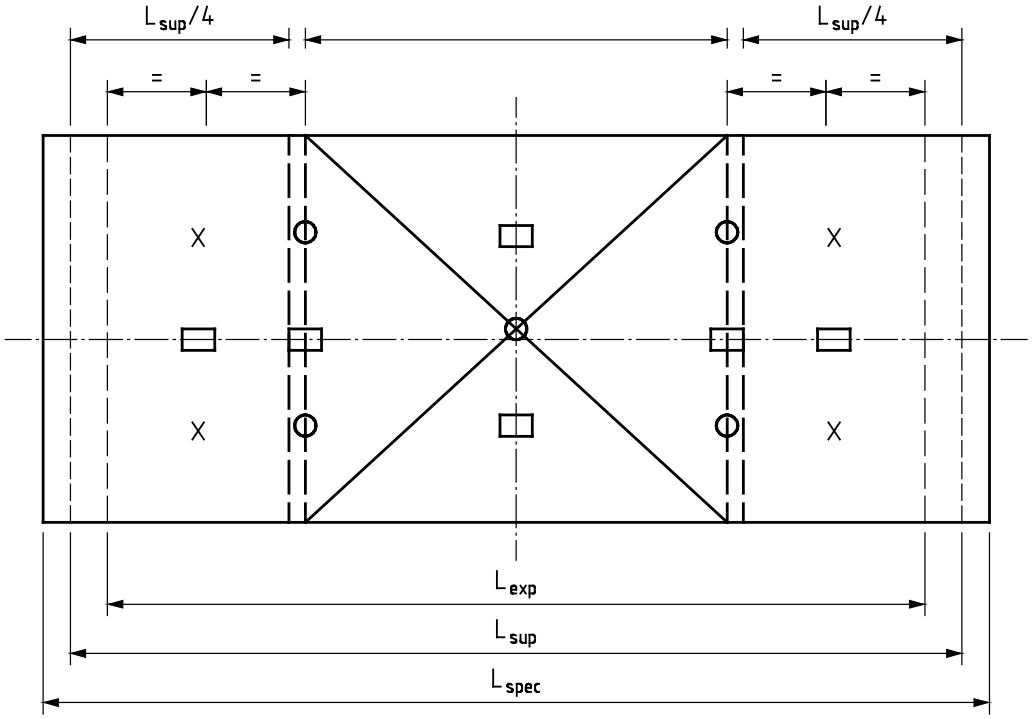
1 fire protection

2 if necessary

a) Longitudinal section



b) Cross section AA



Key

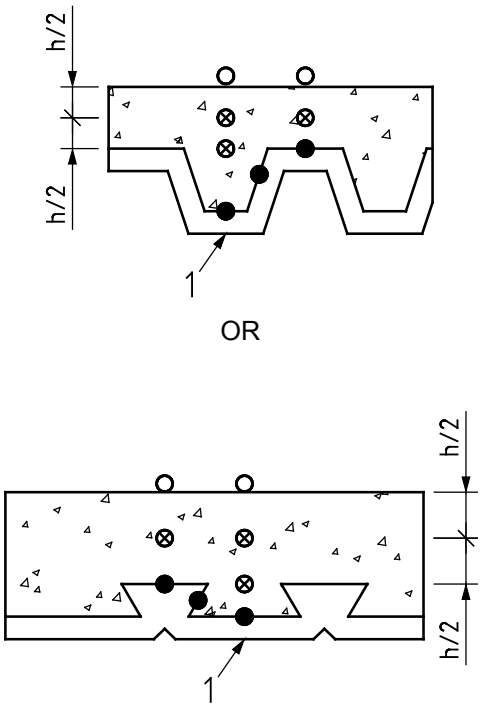
○ temperature measurement stations

□ additional temperature measurement stations

x additional thickness measurement points

c) Location of measuring stations

Figure 1



Key

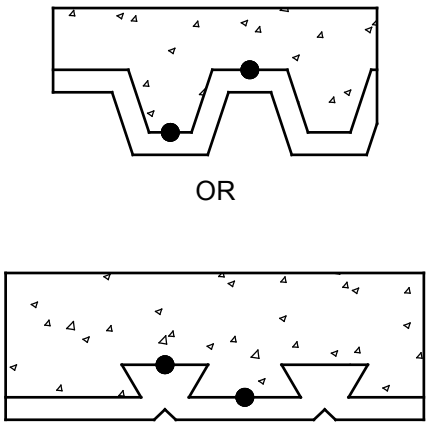
1 axis of the rib

• thermocouple on steel sheet [thickness measurement points (50 mm – 100 mm distant)]

❍ thermocouple on unexposed side of slab

⊗ thermocouple in concrete

a) Main measuring stations

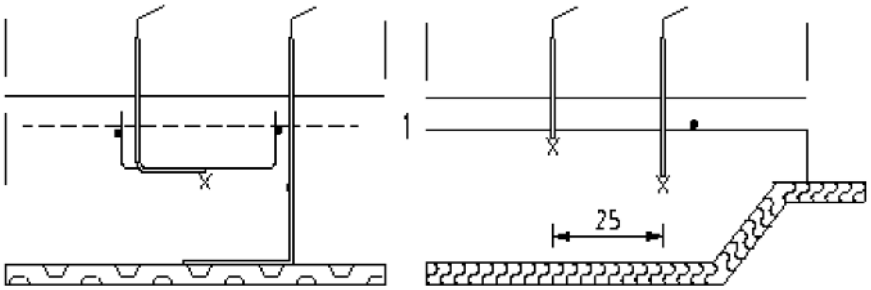


Key

• thermocouple on steel sheet [thickness measurement points (50 mm – 100 mm distant)]

b) Additional measuring stations

Dimensions in millimetres



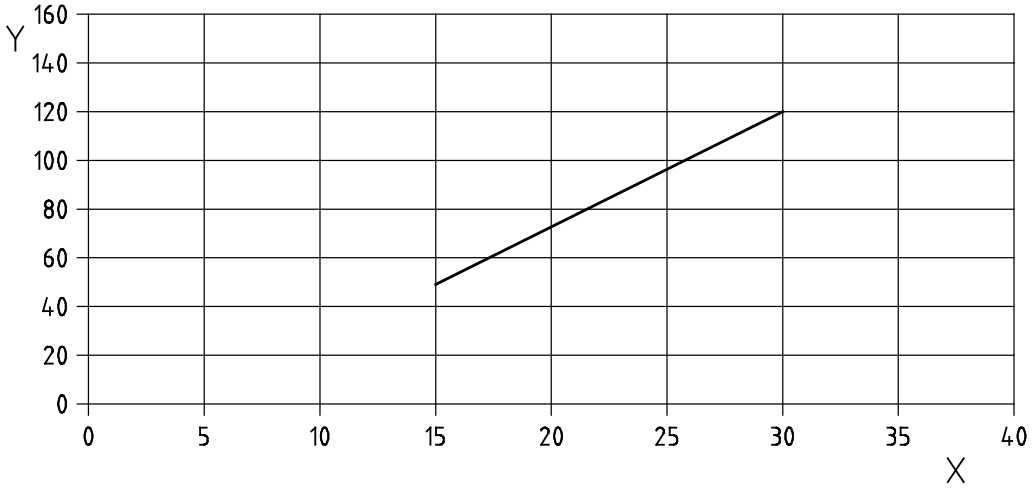
Key

1 ø = 4 mm ribbed bars mesh (all slabs)

X thermocouple in concrete

c) Location and fixing of thermocouples in concrete

Figure 2 — Measurements of temperatures and thicknesses

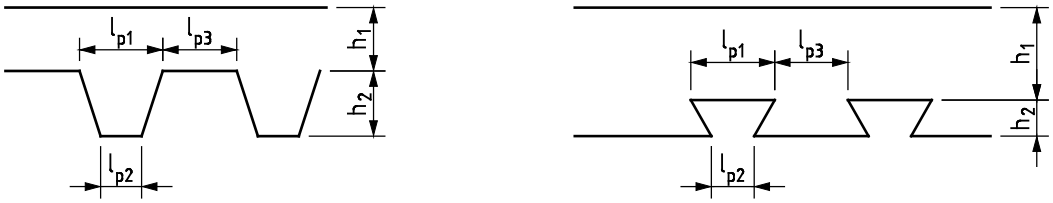


Key

X thickness of insulation (mm)

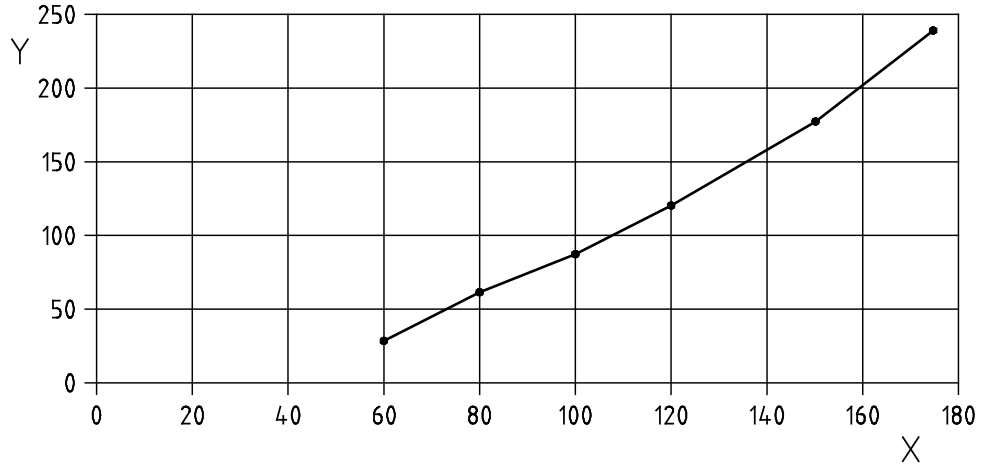
Y time to rise to 350 °C (min)

Figure 3 — Profiled steel sheet temperature



a) Trapezoidal **b) Re-entrant**

Figure 4 — Example of dimensions of cross-sections

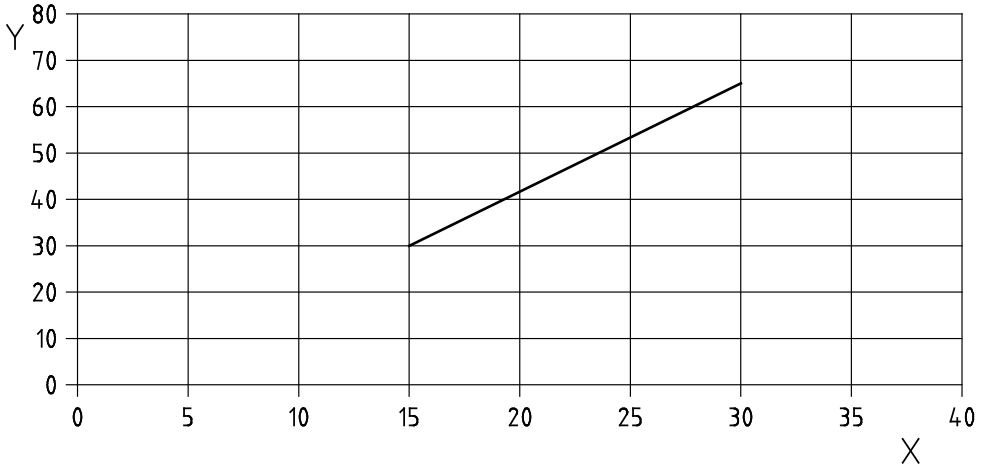


Key

X effective thickness (h_{eff} in mm) (for dense concrete only; from EN 1994–1-2)

Y time (min)

Figure 5 — Determination of equivalent effective thickness



Key

X thickness of insulation (mm)

Y equivalent thickness of concrete (mm)

Figure 6 — Determination of equivalent thicknesses of concrete for intermediate fire protection thickness

Annex A
(normative)

Test method to the smouldering fire or slow heating curve

A.1 General

Fire protection products activated by the heat flux of the fire may be required to be subjected to a test to a smouldering curve (slow heating curve as defined in EN 1363-2), with a rate of temperature increase less than that of the standard temperature/time curve.

NOTE See Council Directive 89/106/EEC, ID No 2: Safety in case of fire, 3.2.4 and 4.3.1.3.4 (b).

This exposure, applicable to reactive fire protection materials, is used only in special circumstances, where it might be expected that the performance of the product when exposed to a smouldering fire might be substantially less than when it is exposed to the standard temperature/time curve, and where such a test is specified in the national building regulations of the Member State of designation.

It is not intended to be mandatory for all fire protection materials applied to structural concrete/steel composite members.

A.2 Test conditions

The test is carried out on small concrete/steel composite slabs, the definition of which is given in Table 1, one for each of maximum and minimum thickness of applied reactive fire protection material (unless the material is available in one thickness only).

Each slab shall be similarly exposed to the smouldering curve (slow heating curve).

The smouldering curve (slow heating curve) as specified in EN 1363-2 provides a heating regime wherein during the period t = 0 min to 20 min the furnace temperature (T) follows the relationship:

$$T = 154\ \sqrt[4]{t} + 20$$

After t = 20 min and for the remainder of the test, the furnace temperature (T) follows the temperature/time relationship:

$$T = 345 \log_{10} [8(t\text{-}20) + 1] + 20$$

This heating protocol is shown graphically in Figure A.1.

A.3 Termination of the test

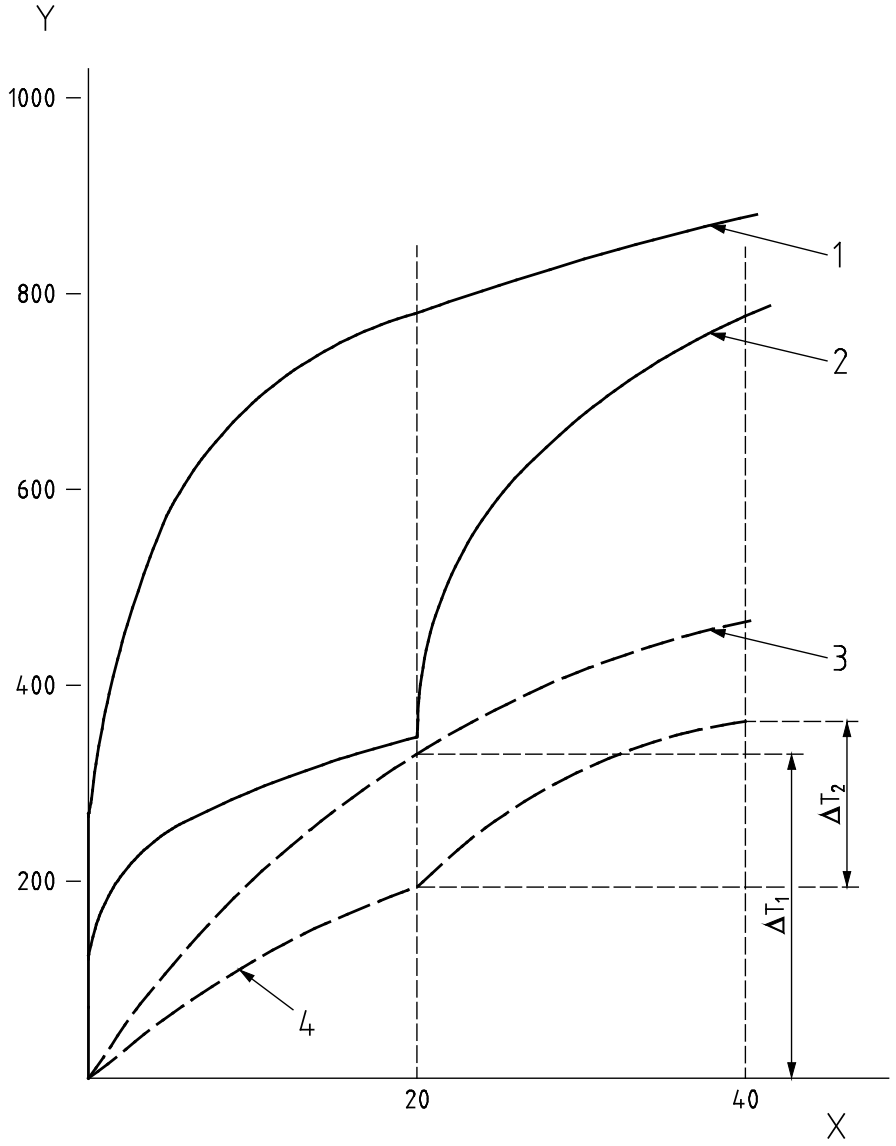
Terminate the test after 40 min or if it becomes unsafe to continue according to EN 1363-1.

A.4 Evaluation of the results

The characteristic temperature test data obtained for each small concrete/steel slab tested, when subjected to both the standard temperature/time curve (according to the principal test) and the smouldering curve (this test), shall be compared, at each thickness tested, each with the other.

The results from all thermocouples in each comparable location shall be examined and recorded by tabulation. The results for each comparable location shall be presented graphically, in a manner similar to that given in Figure A.1 and the performance of the fire protection material to the two fire sources compared and recorded. The values of ΔT_1 and ΔT_2 shall be measured and recorded for all comparable locations.

The results of tests carried out according to the standard temperature/time curve for the particular reactive fire protection material under test shall only be valid and applicable if $\Delta T_1 > \Delta T_2$ in each and every comparable location.



Key

1 standard temperature/time curve

2 smouldering (slow heating) curve

3 test element temperature to standard temperature/time curve

4 test element temperature to smouldering (slow heating) curve

X time (min)

Y temperature (°C)

Figure A.1 — Comparison of performance to the standard and smouldering fire curves

Annex B
(normative)

Measurement of properties of fire protection materials

B.1 General

Determination of the thickness, density and moisture content of fire protection materials and other materials used in this fire resistance test is important to the accurate prediction of fire protection performance from the test result. The methods used to establish these properties shall, therefore, be consistent and this annex gives guidance on appropriate procedures to be used.

Any special test samples used to determine thickness, density and moisture content shall be conditioned as described in Clause 8.

Any specific product standard existing for the measurement of such properties shall be followed.

The procedures given in EN 1363-1 shall be followed together with the provisions of B.2 to B.4.

B.2 Thickness of fire protection materials

B.2.1 For board or panel fire protection materials, the nominal thickness of each material shall be measured using suitable gauges or callipers in accordance with EN 12467 or EN 823.

The measurement shall be carried out either on the actual materials during assembly of the test specimen or on a representative special test sample, the minimum linear dimensions of which shall be 300 mm × 300 mm. At least nine measurements shall be made including measurements around the perimeter and over the surface of the material.

The design thickness used in the assessment shall be as defined in 6.5.3.

B.2.2 For sprayed passive fire protection materials, the thickness shall be measured using a 1 mm diameter probe or drill, which shall be inserted into the material at each measurement position until the tip of the probe or drill touches the surface of the building element. The probe or drill shall carry a circular steel plate of diameter 50 mm upon it, for accurate determination of the surface level.

The thickness of sprayed or coated passive fire protection material shall be measured in the vicinity of (between 50 mm to 100 mm away from) each of the thermocouples fixed to the steel surface of the steel/concrete composite, beneath the applied fire protection system, see 9.3. They shall be regarded as the minimum number of thickness measurement points.

For sprayed fire protection materials, the design thickness used in the assessment shall be as specified in 6.5.3.

B.2.3 For reactive fire protection coating materials applied to concrete/steel composite test slabs, the thickness shall be determined directly upon the test element. Measurements shall be taken at those points specified for passive fire protection materials applied to slabs as given in B.2.2.

The thickness shall be measured using an instrument employing either the electro-magnetic induction principle or the eddy current principle. Reactive fire protection materials applied as coatings typically range

from 0,25 mm to 4 mm thickness and the choice of instrument shall be appropriate to the thickness of coating used.

Other verifiable and validated methods proposed by the sponsor may be used.

The design thickness used in the assessment shall be as specified in 6.5.3.

B.3 Density of applied fire protection materials

B.3.1 The density of each fire protection material shall be determined from measurements of mass and dimensions using the following:

For board or panel passive fire protection materials, the density can be obtained from values of mass, mean thickness (from nine measurements) and area measured either on the actual materials during assembly or on a representative special test sample, the minimum linear dimensions of which shall be 300 mm x 300 mm. The mass of the board shall be obtained using a balance having an accuracy equivalent to 0,1 % of the total mass of the sample being weighed or 0,1 g (the sample size shall be sufficient such that the minimum sample mass is 100 g) whichever is the greater.

The density of fibrous or compressible fire protection material shall be related to nominal thickness.

B.3.2 For spray applied fire protection materials, the density of the material shall be determined from samples of the material sprayed, from beneath, into two metal trays, horizontally orientated, at the same time as the fire protection system is applied to the composite test specimen. These two trays shall be of size (300 ± 5) mm x (300 ± 5) mm, made from 1 mm thick steel plate. The depth of the trays shall be the same as the design thickness of the spray applied protection.

For each thickness of material two such trays shall be prepared with the material applied to the same thickness as that applied to the composite. One of these trays is dried to provide a reference for dry density and moisture content. The second tray shall be used to determine density at the time of test.

The thickness of the specimen within the trays shall be determined at nine points over the surface of the trays according to:

— one at the centre;

— two along each centre to corner axis, equidistant from each other, the centre and the corner.

The arithmetic mean of all measurements made shall be used in the calculation of density.

The mass of the fire protection within the tray shall be obtained using a balance having an accuracy equivalent to 0,1 % of the total mass of the sample being weighed or 0,1 g (the sample size shall be sufficient such that the minimum mass is 100 g) whichever is the greater.

B.3.3 The design density used in the assessment shall in all cases be as specified in 6.5.3.

The density of reactive coating shall be measured according to EN ISO 3251.

B.4 Moisture content of applied fire protection materials

B.4.1 The samples and materials used to measure moisture content shall be stored together with and under the same conditions as the test specimens. The measurement of final moisture content shall be made on the day that fire testing takes place.

B.4.2 For board or slab passive fire protection materials, special test samples shall be taken measuring minimum 300 mm x 300 mm and of each thickness of the material used. They shall be weighed and dried in a ventilated oven, using the temperatures and techniques specified in EN 1363-1. The moisture content of the specimen shall be calculated as a percentage of its moisture equilibrium weight.

For gypsum based and similar materials drying shall take place at (40 ± 5) °C.

Repeated weighings shall be taken until moisture equilibrium or constant mass, (W_2), as defined in EN 1363-1, is reached. The moisture content (W_1 - W_2) of the specimen shall be calculated as a percentage of its moisture equilibrium or constant mass.

B.4.3 For spray applied passive fire protection materials, the moisture content of the material shall be determined from oven drying of one of the sample trays referred to in B.3.2, for each thickness tested.

They shall be weighed and dried in a ventilated oven, using the temperatures and techniques specified in EN 1363-1. The moisture content of the specimen shall be calculated as a percentage of its moisture equilibrium weight.

Should the product contain, or be based on, gypsum and similar materials, drying shall take place at (40 ± 5) °C.

The moisture of reactive coating is not relevant.

Bibliography

[1] EN 1994-1-1, *Eurocode 4: Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings*

[2] EN 10080, *Steel for the reinforcement of concrete - Weldable reinforcing steel - General*

[3] EN 13381-1, *Test methods for determining the contribution to the fire resistance of structural members - Part 1: Horizontal protective membranes*

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