egolf The European Group of Organisations for Fire Testing, Inspection and Certification

EGOLF AGREEMENT 032-2018

Subject of Agreement	Measurement of bonding properties of fire protection materials
Related test standard	EN 13381 series
Date of issue	21/08/2018
Reference original query	
Previous publication number (if applicable)	EA 05:1999 (previously available as EGOLF SM 5:1999 – confirmed 2007)
Keywords (max. 20)	fire resistance, fire protection materials, bonding properties

Foreword

This document has been prepared by EGOLF. The method is designed to be a characterisation test for use in conjunction with fire tests.

The method may be used for the purposes of national regulation or on a voluntary basis by owners or operators of structures.

The method may be used for continued type approval and determination of the ageing properties of products under long term use, however, such ageing tests, given in Annex 1, are non-mandatory.

Design limits, such as those exemplified in Annex 2, shall be a matter for individual national regulation and are non-mandatory.

The method shall be used by all EGOLF member laboratories for the measurement of the general and bonding properties of fire protection materials and systems, other than intumescent coatings or other thin layer coating materials, applied to steel, concrete or steel/concrete composite structures.

It is recommended to other organisations and laboratories that this method be considered for use in support of all standard reaction to fire and fire resistance tests where knowledge of the bonding properties of fire protection materials applied to steel, concrete or steel/concrete structures is considered necessary.

1 Scope

Fire tests have been developed in several areas to measure the effect of applied fire protection to the fire resistance of structures.

The fire performance of such protected structures depends upon the ability of the fire protection material to remain in place. Early failure of the bonding between the applied fire protection and the protected structure will result in premature loss of fire protection.

The material properties of the applied fire protection material and the strength of its bond to the structure at ambient temperature cannot provide evidence of its likely performance at high temperature in a fire situation. However, they can provide indication of the likely durability of the material in day to day use, which if poor may lead to an unsafe situation if the material ever did become involved in fire.

This document describes a method for the measurement of material and cold bond strength properties of fire protection materials applied to steel, concrete or steel/concrete composite structures. The method is not applicable to thin coating materials, e.g. intumescent coatings.

2 References

For the purposes of this document the following references apply.

ISO 8421 Fire protection vocabulary - part 2: Structural fire protection.

EN 10147 Continuously hot dipped zinc coated structural steel, sheet and strip.

EN 206 Concrete: performance, production, placing and compliance criteria.

EN 10210-1 Steels for hot finished structural sections

3 Principle

This document describes the examination of material properties of fire protection materials and the measurement, at ambient temperature, of bond strengths of such materials when applied to test substrates corresponding to those structures to which they would be applied in the practical use situation.

4 Material properties

The sponsor shall declare the type and composition of all components of the fire protection material and the substrate to which it is to be applied in practice.

Any properties of the fire protection material required to be measured will normally be defined within product standards, within fire test methods or by the manufacturer.

Specific properties which may have a bearing on the bond strength of the fire protection material when applied to the test substrate and which should be considered include:

- density
- dimensional stability
- moisture content
- shrinkage of the applied fire protection during the course of its application, drying or cure and long term use.
- type, composition and dimension of reinforcement materials.
- properties relating to verification of type, properties and manufactured specification

The properties of a steel, concrete or steel/concrete composite substrate to which the fire protection material is to be applied for the purposes of this test will normally be those appropriate to that material used in practice.

5 Tensile bond strength

5.1 General

The bond strength of the fire protection material, at ambient temperature, when applied to an example (actual or simulated) of the steel, concrete or steel/concrete composite structure under consideration is measured by determination of the tensile force or dead weight needed to cause failure:

- of the bond between the fire protection material and the steel, concrete or steel/concrete composite test substrate.
- within the bulk of the fire protection material itself (this will apply to materials with inherently lower bulk tensile strength compared with the bond strength. It may not be indicative of poor bond strength of the material to its substrate).

5.2 Test substrates

5.2.1 General

The steel, concrete or steel/concrete composite substrate to which the fire protection material shall be applied for the purposes of this test shall be either:

- The actual substrate to which the fire protection material is applied in practice.
- A standard test substrate, which simulates the practical situation (this shall apply only when the fire protection material is to be applied to, simple, flat substrates only).

Steel, concrete or steel/concrete composite test substrates, which shall be used for measurement of bond strength, are given in 5.2.2 to 5.2.5.

5.2.2 Steel structures

Flat steel sheets, of size 500 mm x 500 mm x 5 mm, may be used as standard test substrate for the assessment of the bonding behaviour of fire protection material to flat steel sheets, beams and columns.

The steel shall be of grade between Fe E 280 G and Fe E 350G as defined in EN 10147.

The standard test substrate may not be used for the assessment of the bonding behaviour of fire protection material to trapezoidal or re-entrant steel sections (see 5.1).

Only the actual trapezoidal or re-entrant steel section to be used in practice shall be used as test substrate. The test piece shall be of size 500 mm x 500 mm and thickness as practice.

5.2.3 Concrete structures

The standard test substrate for the assessment of the bonding behaviour of fire protection materials to concrete, shall comprise concrete slabs of size 500 mm x 500 mm x 30 mm, with a smooth, non-porous, surface.

The concrete used shall be normal-weight, of type 25/30 to 30/37. Its composition, method of preparation and assessment of concrete properties shall be as defined in EN 206.

Concrete test substrates shall be prepared in a smooth surfaced steel or timber framework. Soluble oils or emulsions shall be used to ensure release of the concrete test substrate from the framework. The actual release material used shall be reported.

5.2.4 Steel/concrete composite slabs

A standard test substrate considered suitable for the assessment of the bonding behaviour of the fire protection material to flat steel/concrete composite slabs shall comprise composite slabs of size 500 mm x 500 mm x 30 mm.

The flat steel used shall be of grade between Fe E 280 G and Fe E 350G as defined in EN 10147, and thickness 0.7 to 1 mm.

The concrete used, its composition, method of preparation and assessment of concrete properties shall be as defined in 5.2.3.

The standard test substrate may not be used for the assessment of the bonding behaviour of fire protection material to steel/concrete composite slabs incorporating trapezoidal or re-entrant steel sections (see 5.2). In this case the steel sheet used to prepare the test piece shall be that used in practice.

5.2.5 Steel / concrete composite columns

Test substrates considered suitable for the assessment of the bonding behaviour of the fire protection material to steel/concrete composite columns, shall comprise composite columns of length 500 mm and external / internal diameter as in practice.

The steel used shall be at least of grade S235 or comparable grade according to EN 10210-1.
The concrete used shall be normal-weight, of type 25/30 to 30/37. Its composition, method of preparation and assessment of concrete properties shall be as defined in EN 206.

5.3 Application of the fire protection material to the test substrate

The surface to which the fire protection material is to be applied shall be prepared as in practice according to the recommendation of the supplier of the fire protection material.

The fire protection material shall be applied (and / or secured) to the whole surface of the test substrate by the method used in practice.

If the fire protection material is to be subjected to fire testing, then the test specimens shall be prepared at the same time as those for that test.

The thickness of the fire protection material applied shall be defined by the sponsor and include both the minimum and maximum thickness to be used in practice.

The test substrate with its applied fire protection material shall be conditioned according to practice. Testing shall not be commenced until the requisite conditioning has been completed.

5.4 Preparation of test pieces

Circular test pieces of 100 mm diameter shall be cut in the applied fire protection material, the cut being made to the surface of the steel, concrete or steel/concrete test substrate.

Such test pieces shall be cut no closer than 50 mm to the edge of the test substrate or to any other circular test piece.

Great care must be taken when cutting test pieces to avoid damage to the bond between the fire protection material and the test substrate.

Where bonding between layers in a multilayer system is to be measured then the 100 mm diameter circular test piece shall be cut down to the surface of the lower layer of the layers between which the bond strength is required.

A circular steel plate of 100 mm diameter and 2 mm thickness, containing a centrally placed eyelet for application of tension, shall be attached to the fire protection surface of the cut circular test piece using a suitable adhesive.

The choice of adhesive shall be such that the bond strength between the circular plate and the surface of the fire protection (including allowance for surface irregularities on the fire protection) is greater than that:

- between the fire protection material and the steel, concrete or steel/concrete composite test substrate
- between the layers of a multilayer fire protection system.

The full adhesive bond between the surface of the fire protection material and the tensile steel plate shall be allowed to form according to the adhesive manufacturer's instructions.

5.5 Test apparatus

There shall be provided either a tensiometer or a system of dead weights to measure the force needed to be applied to the interface between the fire protection material and the test substrate to break the bond between these.

A typical tensiometer shall comprise:

- an inverted U-shaped frame and a means of application of tension to the test piece (either manually or automatically) via a draw bar or spindle.
- a load cell of appropriate capacity (1kN to 10kN) inserted between the eyelet of the circular steel plate and a similar eyelet attached to the draw bar or spindle.

A typical dead weights system shall comprise:

- the test piece being firmly secured horizontally with the fire protection material surface uppermost
- weights attached, via a pulley system, to the eyelet of the circular steel plate.

There shall be provided an appropriate means of recording the tensile force applied to the test piece by either method.

5.6 Test method

The steel, concrete or steel/concrete composite test substrate to which the fire protection material has been applied shall be fixed securely around its edges to the test frame or workbench used, to avoid deflection during the tensile bond test.

Tensile force shall be applied to the test piece, manually or automatically, at a steady rate according to the performance rating of the load cell, or by steady application of increasing dead weights.

The test shall be terminated when the bond fails between the fire protection material and the steel, concrete or steel/concrete test substrate, between layers in a multilayer fire protection system or within the fire protection itself in a single layer fire protection material.

The force applied at the time of failure and the method of failure, i.e. surface bond, between layers, internal failure etc. shall be recorded.

5.7 Number of tests

At least 8 test pieces, at every thickness of the fire protection material under examination, prepared according to 5.4 shall be tested for every steel, concrete or steel/concrete composite test substrate examined.

The single highest and single lowest recorded results shall de discarded.

The average value of tensile bond strength from the remaining 6 values shall be calculated.

6 Report

The report shall contain at least:

a) Reference to this document.
b) The name of the test laboratory.
c) The name of the sponsor.
d) The date of the test.
e) Full details of the fire protection materials and substrate materials in practical use as provided by the sponsor.
f) A full description of all fire protection materials and substrate materials used in the test and any properties measured according to clause 4.
g) For the tensile bond test, carried out according to clause 5, a full description of:

- the substrate(s) used, whether actual or standard (see 5.2)
- the method of application and conditioning of the test pieces (see 5.3)
- the preparation of the test pieces, including adhesives used, and their properties (5.4)
- the test apparatus (see 5.5)
- the test method applied (see 5.6)
- number of tests (see 5.7)

h) The individual and average measured tensile bond strength results.
i) The failure mode of each test piece.

In addition, there shall be reported any testing carried out according to the non-mandatory items given in Annexes 1 and 2:

a) Any ageing trials carried out according to Annex 1, (optional).
b) Any design limits of acceptability according to Annex 2, (optional).

ANNEX 1 (Informative)

Ageing of fire protection materials in use

The bond strength of the fire protection material to the substrate as measured by this test method may be used for continued type approval and determination of the ageing properties of products under long term use.

At the same time as the test specimens were prepared for testing according to this test method, additional test specimens may be prepared.

These additional test specimens shall be stored under conditions approximating to those expected to occur in practice.

The bond strength of these may be measured according to the method given within the body of this test method at intervals appropriate to the needs of the client, e.g. 2 years, 5 years, and 10 years.

ANNEX 2 (Informative)

Design limits of acceptability of measured tensile bond strength

The measured average tensile bond strength might indicate the risk of the fire protection material failing to remain in place under normal ambient use conditions.

Certain National Regulations may require an analysis of the results from the measured tensile bond strength of the fire protection material to the test substrate and calculation of values which might be used as safety factors, constants etc. in national building practice.

Additionally, from this analysis of the results, there may be required a statement whether the result is better than or equal to recommended values of safety factors, constants etc. derived from calculation and / or any known data from performance in real buildings.

For example (German practice) - where the measured average tensile bond strength, β_{H6}, is considered indicative of the risk of the fire protection material failing to remain in place under normal ambient use conditions, when, according to the equations:

$\beta_{H6} \geq \gamma \times (v \times g)\ \rho_{max} \times (d_{max} + \delta d) \times 10^{-6}$ (N/mm^2) (LOW RISK)

$\beta H6 < \gamma \times (v \times g)\ \rho_{max} \times (d_{max} + \delta d) \times 10^{-6}$ (N/mm^2) (HIGH RISK)

Factors used in this equation are:

β_{H6} = average value of tensile bond strength (from 6 readings) (N/mm^2)
γ = 2 (safety factor taking account of mechanical factors)
v = 3 (safety factor taking account of fatigue factors)
g = 10 (approximate acceleration due to gravity) (m/sec^2)
ρ_{max} = maximum bulk density of the fire protection material (kg/m^3)
d_{max} = maximum thickness of the fire protection material (mm)
δd = “additional thickness” factor to take account of “possible over-dimensions”. (mm)