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Plastics — Guidance on the assessment of the fire characteristics and fire performance of fibre-reinforced polymer composites

Plastiques — Lignes directrices pour l'évaluation des caractéristiques au feu et des performances au feu de polymères composites renforcés de fibres

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 25762 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 4, *Burning behaviour*.

Introduction

The information given in this International Standard is in accordance with the principles recommended in ISO 10840 which was established to develop a general policy and philosophy for the development and use of fire tests for plastics.

Fibre-reinforced polymer (FRP) composites are produced in a wide variety of chemical and physical forms, some of which cause difficulties for fire laboratories since the specimens required for some tests are not representative of the FRP composite in its end-use configuration.

This International Standard identifies those tests which can be used for determining the fire characteristics of various FRP composites and provides guidance on how to assess the fire performance of FRP composites in different applications. Since FRP composites can be used as lightweight construction materials, the experience of users in transport applications has been valuable in the preparation of this International Standard. Test data from methods that are specified by regulators of marine and rail products have been provided to exemplify the fire performance of some FRP composites.

Plastics — Guidance on the assessment of the fire characteristics and fire performance of fibre-reinforced polymer composites

1 Scope

This International Standard gives guidelines for the assessment of the fire characteristics and fire performance of fibre-reinforced polymer (FRP) composites, particularly in structural applications in buildings and transport.

It is applicable to FRP composites prepared from thermosetting or thermoplastic resins and reinforced with inorganic fibres greater than 7,5 mm in length.

This International Standard gives guidelines on:

— the applicability of product types (e.g. sheets, laminates, profiled sections and some sandwich constructions) to end-use performance;

— the test methods and performance criteria for different physical forms of FRP test specimen.

NOTE 1 FRP composites vary widely in their physical form (e.g. in thickness, density and shape).

NOTE 2 FRP composites can also be assembled products containing other materials (such as metals or inorganic non-fibrous fillers) and as systems containing air-gaps, joints and fixing attachments.

NOTE 3 Handling and storage recommendations for the fire safety management of FRP composites are given in Annex C. In addition, some guidance on how to tackle fires involving FRP composites is provided in Annex D.

2 Normative references

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

ISO 472, *Plastics — Vocabulary*

ISO 13943, *Fire safety — Vocabulary*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms, definitions and abbreviated terms given in ISO 13943 and ISO 472 and the following apply.

3.1 General

3.1.1
fibre-reinforced polymer composite
polymer matrix composite consisting of thermosetting resin or thermoplastic materials and fibres of greater than 7,5 mm in length prior to processing

NOTE Plastics compositions containing fibres of 7,5 mm or less in length are treated as plastics.

3.1.2
load-bearing capacity
R
ability of an element to maintain its structural stability despite exposure to fire on one or more faces for a period of time

3.1.3
integrity
E
ability of an element with a separating function to withstand fire exposure on one side only without the transmission of fire to the non-fire side as a result of the passage of significant quantities of flames or hot gases from the fire to the non-fire side thereby causing ignition either of the unexposed surface or of any material adjacent to that surface

NOTE This may include the ability of an element to withstand delamination (the layers of the material separating from each other) when under load and exposed to fire.

3.1.4
insulating capacity
I
ability of an element to withstand fire exposure on one side only without significant transfer of heat from the exposed to the unexposed side

3.1.5
product
material, composite or assembly about which information is required

3.1.6
composite
structured combination of two or more discrete materials, with one of the materials (the matrix) forming a continuous phase

NOTE 1 The structure of a composite can be made up of one or more layers.

NOTE 2 For the purposes of this International Standard, at least one of the materials is a plastic or an organic-based polymer.

3.1.7
ARHE(t_n)
average rate of heat emission at time t
integrated heat emission from time 0 to time t, divided by t

NOTE It is expressed in kW/m^2 for cone calorimeter results (see ISO 5660-1).

3.1.8
MARHE
maximum average rate of heat emission
maximum value of ARHE from $t = 0$ to $t = t_{end}$

NOTE It is usually expressed in kW/m^2.

3.1.9
FIGRA index
fire growth rate index
maximum value of the quotient of the rate of heat release from the specimen and the length of time it occurs

NOTE It is usually expressed in W/s. Further details concerning its derivation are given in EN 13823.

3.1.10
SMOGRA index
smoke growth rate index
maximum value of the quotient of the rate of smoke production by the specimen and the length of time it occurs

NOTE It is usually expressed in m^2/s^2. Further details concerning its derivation are given in EN 13823.

3.1.11
resistance to radiation
W
ability of a product/construction element to withstand fire exposure on one side only, thus reducing the probability of the transmission of fire as a result of significant radiated heat either passing through the product/element to adjacent materials or being radiated from its unexposed surface to adjacent materials

NOTE 1 The product/element might also need to protect people in the vicinity. A product/element which satisfies the insulating-capacity criterion, I, is also deemed to satisfy the W requirement for the same period.

NOTE 2 Failure of integrity under the “cracks or openings in excess of given dimensions” criterion or the “sustained flaming on the unexposed side” criterion (see 5.2.1) automatically means failure under the resistance to radiation criterion.

3.1.12
TSP_{600s}
total smoke production from the specimen in the first 600 s of exposure to the burner flames

3.2 Types of material

3.2.1
thermosetting material
material capable of being changed into a substantially infusible and insoluble product when cured by heat or by other means, such as radiation and catalysts

NOTE 1 These materials are resins and include polymers such as polyesters, epoxides, acrylics, urethanes and phenolics.

NOTE 2 The resins may incorporate non-fibrous fillers, flame-retardants, pigments and stabilizers.

3.2.2
thermoplastic material
polymeric material that becomes soft and plastic when heated

NOTE 1 These polymers include polypropylene (PP), polyetheretherketone (PEEK) and polyethersulfone (PES).

NOTE 2 The polymers can incorporate non-fibrous fillers, flame-retardants, pigments and stabilizers.

3.2.3
reinforcing fibre
fibrous material added to a matrix resin or polymer in order essentially to improve its mechanical properties

NOTE These materials include glass, carbon, aramid, thermoplastic fibres (such as polypropylene, polyamide and polyester) and natural fibres (such as cellulose and wood).

4 Fibre reinforcement

4.1 Form

The reinforcement can be in the form of unidirectional rovings or yarns, fabrics, chopped strands (individual or in mats), fully aligned layers or knits, braids or continuous-filament mats.

NOTE The type of fibre and its form should be described in all test reports on the FRP composite.

4.2 Fibre content

The fibre content in the composite can be as low as 10 % by volume and as high as 75 % by volume.

4.3 Core materials

These can include:

a) honeycomb structures (aluminium, aramid, paper, polypropylene or phenolic-resin-impregnated fibreglass);

b) plywood;

c) foam (cellulose acetate, polystyrene, polyurethane, phenolic or PVC);

d) balsa wood.

4.4 Production methods

FRP composites can be produced by a variety of processes as described in the various parts of ISO 1268, for example:

a) pultrusion;

b) wet lay-up (by hand or spray application);

c) filament winding;

d) compression moulding;

e) moulding using prepregs;

f) resin transfer moulding;

g) vacuum infusion;

h) continuous lamination.

Some FRP composites have gel-coats on their surfaces. The gel-coat might be similar to the unreinforced resin but, in many cases, a different resin is used.

FRP composites are often used as skins in sandwich constructions in combination with plastic foams or honeycomb core material. When FRP composite products are manufactured or installed, the fire laboratory performing a test or assessment should record details of the composition and assembly of the test specimen that are typical of the end-use application of the product. These details could include the types of joint or fixing attachment, air-gaps, edge coverings, skins or facings and metal inserts or reinforcements.

5 Fire characteristics

5.1 Reaction to fire

5.1.1 General

More than one fire test should be performed to characterize adequately the reaction-to-fire properties of FRP composites.

NOTE Reaction-to-fire test results on some typical FRP composites are shown in Annex B. These data back up the recommendations given in 5.1.1 to 5.1.7.

5.1.2 Combustibility

When tested in accordance with ISO 1182, all grades, types and densities of FRP composite are usually classified as combustible due to the contribution of their polymer content.

5.1.3 Ignitability

Under certain conditions of heat, orientation and ventilation, a naked flame can ignite FRP composites. Care should be taken to avoid contact with naked-flame sources when handling and storing these composites before and during installation.

The ignitability of FRP composites can be tested using the standard ignition sources described in ISO 10093, which include flaming, radiant heat and electrical sources. These sources can be used in standard fire tests (see ISO 10840) or in *ad hoc* tests, some of which might provide information on the ignitability of the FRP composites under end-use conditions.

5.1.4 Rate of heat release

The rate of heat release of FRP composites should be determined by the following standard tests:

a) For small test specimens, ISO 5660-1 or ISO 13927 should be used.

b) For intermediate-scale test specimens, the guidance in ISO 15791-1 should be followed. Tests such as ISO 21367 or EN 13823 could be used.

c) For large test specimens, either ISO 9705 and ISO/TR 9705-2 or ISO 24473 should be used.

NOTE Additional information on rate of heat release measurements is given in Annex A.

5.1.5 Flame spread

ISO/TS 5658-1 should be referred to for guidance on the appropriateness of a flame spread test (especially concerning the nature of the ignition source, the orientation of the test specimen and the ventilation conditions in the vicinity of the test specimen). Lateral flame spread across a vertically oriented specimen can be determined in accordance with ISO 5658-2, and flame spread over horizontally mounted floorings can be determined in accordance with ISO 9239-1.

NOTE 1 The extent and rate of flame spread depend largely on the ignitability of, and rate of heat release from, a combustible product.

NOTE 2 Since the fire performance of products, including flame spread, is to a great extent dependent on the composition of the product (such as the type of substrate), including any fixings or mountings relevant to the end-use application, standard small-scale tests are not always appropriate for the evaluation of FRP composites. Large-scale test methods, which more appropriately reflect end-use conditions for composites in structural applications, are briefly discussed in 6.4.

5.1.6 Smoke

Burning some FRP composites can generate dense, black smoke. When assessing potential smoke emission from FRP composites in a building or other enclosure under fire conditions, essential factors that should be considered include the possible extent of flame spread over the surface of the composite, the ventilation conditions and the rate of decomposition of the resin.

Smoke density can be measured in a dynamic test involving a well-ventilated fire (such as that described in ISO 5660-2) or in a test carried out in a chamber in which the smoke accumulates (such as that in ISO 5659-2).

NOTE Prediction of the precise smoke-producing potential of FRP composites is difficult because of the wide range of combustion conditions likely to be met within an actual fire. Generalized conclusions from small-scale tests have been substantiated by evidence from fire incidents. The density of the smoke produced increases with increasing temperature and with the intensity of the heat flux incident on the material. In a smouldering fire, where decomposition occurs in oxygen-deficient conditions, small grey spherical particles predominate and the specific optical-density values can be lower than for flaming conditions.

5.1.7 Toxicity

ISO Technical Committee TC 92/SC 3 guidelines, as given in ISO 16312-1, ISO 16312-2, ISO 13571 and ISO 19706, should be followed in the assessment of the likely toxic hazard of a defined scenario.

NOTE When organic materials such as wood, paper or plastics are burned, hot gases and smoke are evolved. All combustion gases produced can prove fatal in a short time if inhaled in sufficient concentration. However, the toxicity hazard in a fire arises through many factors, including the rate of fire growth and the ambient ventilation conditions, as well as the inherent toxicity of the combustion products, and this philosophy is embodied in the ISO/TC 92/SC 3 guidelines.

A stepwise approach should usually be taken, including such factors as risk of ignition, rate of fire growth, flame spread, smoke-producing potential, location and mobility of occupants and fire protection measures. An estimation of the risk (that is, the likelihood of that hazard occurring) should also be made.

Some small-scale tests can be used to determine the composition of fire effluents from burning FRP composites. For example, ISO 5659-2 could be used as a fire model with gas analysis performed using Fourier transform infrared spectroscopy or another method (such as ion chromatography). From the results, a toxicity index can be derived for up to 10 common fire gases.

5.2 Structural performance

5.2.1 General

A very important regulatory requirement in buildings and other enclosures (such as ships and trains) is the need to ensure that fires are, wherever possible, confined to the compartment of fire origin. The required structural performance is usually assessed by fire resistance tests on elements of the building structure. Various levels of thermal action can be used to simulate different fire scenarios. Probably the most widely used is the standard temperature/time curve, which serves as a simulation for a fully developed fire (see ISO 834-1). Other test fires used in certain situations include the smouldering fire, the semi-natural fire, the hydrocarbon fire and the external fire (such as exposure to fire emerging from a window of a building or from a free-burning external fire).

Resistance-to-fire performance characteristics which should be assessed include load-bearing capacity, R, integrity, E, and insulating capacity, I (see 3.1.2 to 3.1.4). Other characteristics which might be specified under certain conditions for some elements are resistance to radiation, W (see 3.1.11), mechanical aspects, self-closing ability and smoke leakage.

