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Corrosion protection of steel structures by protective paint systems — Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating —

Part 1: Pull-off testing

Anticorrosion des structures en acier par systèmes de peinture — Évaluation et critères d'acceptation de l'adhésion/cohésion (résistance à la rupture) d'un revêtement —

Partie 1: Essai de traction

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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 16276-1 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 139, *Paints and varnishes*, in collaboration with Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 14, *Protective paint systems for steel structures*.

ISO 16276 consists of the following parts, under the general title *Corrosion protection of steel structures by protective paint systems — Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating*:

— *Part 1: Pull-off testing*

— *Part 2: Cross-cut testing and X-cut testing*

Introduction

The main purpose of this part of ISO 16276 is to supplement the ISO 12944 series with regard to the field assessment of, and acceptance criteria for, the adhesion/cohesion of a coating.

To comply with this part of ISO 16276, laboratory testing of panels might be required.

This part of ISO 16276 introduces the term “fracture strength” which includes both adhesion and cohesion. Adhesion and cohesion are defined in ISO 4618, whereas the ISO 12944 series uses the term “adhesion” only.

NOTE This part of ISO 16276 is intended for the assessment of pull-off testing of paint coatings on steel structures on site. ISO 4624 specifies a pull-off test for laboratory use, without instructions for interpretation of the results and without acceptance or rejection criteria.

Fracture strength testing is normally destructive and therefore requires repair work, the extent of which will depend on the specification and on the durability required of the protective paint coating.

An objective of this part of ISO 16276 is to provide uniformity in the assessment of the fracture strength of a coating and to establish acceptance/rejection criteria for protective paint coatings. The method uses test equipment based on the pull-off principle.

Protective paint systems which have poor adhesion/cohesion will normally fail at fracture strength values significantly lower than the values quoted in the specification.

For a protective paint system with a particular fracture strength, a range of test values will be obtained from different types of equipment.

Specifying test equipment that gives, for a particular fracture strength, the highest test values does not necessarily indicate a higher durability for that protective paint system. Also, high test values for a particular fracture strength do not necessarily indicate a high durability for that protective paint system.

Corrosion protection of steel structures by protective paint systems — Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating —

Part 1: Pull-off testing

1 Scope

This part of ISO 16276 specifies procedures for assessing the fracture strength of a protective paint coating of any thickness on a steel substrate of thickness not less than 10 mm. The procedures given in this part of ISO 16276 are based on methods used with different types of pull-off test equipment. The results obtained using such different types of equipment are not comparable.

NOTE 1 Substrates of less than 10 mm in thickness can be tested if they are strengthened by the sandwich technique (see ISO 4624) or by the nature of the structure (e.g. I-beam or backing-plate). Otherwise, test panels with a thickness of at least 10 mm coated in the same way as the structure can be used, or the method specified ISO 16276-2 can be used.

This part of ISO 16276 is only applicable if a fracture strength value is specified, together with the type of test equipment and the manufacturer of the equipment. Usually, this information is included in contract documentation.

NOTE 2 A value for the fracture strength is only meaningful if the requirements concerning the ambient conditions (see 6.4.2) are met.

This part of ISO 16276 also specifies suitable equipment and defines inspection areas, sampling plans and acceptance/rejection criteria.

It does not give any values of the fracture strength of different protective paint coatings.

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 4624, *Paints and varnishes — Pull-off test for adhesion*

ISO 12944-7, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 7: Execution and supervision of paint work*

ISO 12944-8, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 8: Development of specifications for new work and maintenance*

ISO 19840, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
fracture strength
force required to exceed the attachment forces

— between coats or between coat and substrate (adhesion) and/or

— within a coat (cohesion)

3.2
adhesion
phenomenon of attachment at the interface between a solid surface and another material caused by molecular forces

NOTE Adhesion should not be confused with cohesion.

[ISO 4618:2006]

3.3
cohesion
forces that bind a film into an integral entity

NOTE Cohesion should not be confused with adhesion.

[ISO 4618:2006]

3.4
coat
continuous layer of a coating material resulting from a single application

[ISO 4618:2006]

3.5
coating
continuous layer formed from a single or multiple application of a coating material to a substrate

[ISO 4618:2006]

3.6
inspection area
designated area to which a sampling plan has been applied, which can be the whole structure or a selected section of the structure

4 Principle

Test cylinders (dollies) are fixed to the coating using a suitable adhesive and a force is exerted in order to cause a fracture. This force is measured by the equipment.

5 Apparatus and materials

5.1 Tensile/pull-off test apparatus, meeting the requirements specified in 6.1.6. The manufacturer and the model of the apparatus shall be as specified or as agreed between the interested parties.

5.2 Test cylinders (dollies), made of stainless steel or aluminium alloy, of suitable diameter (normally 20 mm), of sufficient thickness to ensure freedom from distortion during the test and suitable for use with the test apparatus. It is recommended that the length of the test cylinder be not less than half its diameter. The end faces shall be machined perpendicular to the long axis of the cylinder.

5.3 Adhesives, suitable for use with both the test cylinder and the protective paint system, e.g. 2-pack epoxy or 1-pack cyanoacrylate (see ISO 4624). Care shall be taken to avoid adhesives which might damage, or penetrate through, the coating.

5.4 Circular cutting device, the internal diameter of which shall not exceed the diameter of the test cylinder by more than 2 mm.

6 Procedure

6.1 General

6.1.1 As pull-off tests are destructive test methods, repair work will be necessary when they are used on coated structures.

NOTE To avoid damage to the coated structure, test panels can be used (see 6.4.2).

6.1.2 The results of each of the procedures described are influenced by different aspects of the test conditions. There are some aspects that are common to all the procedures, and these are described below.

6.1.3 The test cylinders are supplied in various shapes and the force can be applied in various ways, such as hydraulic pressure, pneumatic pressure or using compressed-spring assemblies.

6.1.4 The measurement equipment used shall be calibrated. If a calibration certificate is required, it shall be checked to ensure that it is current and relates to the instrument in use, i.e. has the same serial number.

NOTE Adjustment and calibration are carried out by the manufacturer or by an authorized organisation.

6.1.5 Prior to testing, a recently applied coating shall be dried/cured in accordance with the manufacturer's recommendations.

In the absence of manufacturer's recommendations, the coating shall be dried/cured for at least 10 days in well-ventilated conditions and at a substrate temperature in excess of 15 °C and a relative humidity of less than 80 % prior to testing.

NOTE 1 The age of the coating can affect the result of the test. Freshly applied coatings can have a lower fracture strength than those tested two or three months after application. The temperature, humidity and ventilation during drying/curing of the coating will also affect the fracture strength obtained.

NOTE 2 If a coating is exposed to high humidity or water, it will absorb water, which can reduce its fracture strength. Upon drying, the strength will increase again to a certain extent, unless the coating has started to degrade or corrosion of the substrate has occurred.

6.1.6 The rate at which the force is applied to remove the test cylinder will affect the fracture strength obtained. The tensile stress shall therefore be applied in a direction perpendicular to the plane of the coated substrate and shall be increased at a uniform rate, not greater than 1 MPa/s, such that fracture occurs within 90 s. Test equipment which does not meet this requirement is not suitable.

Erratic or uneven application of the force can cause premature failure of the coating and give misleading results.

NOTE Manually operated equipment will not necessarily provide a uniform increase in the applied force.

6.1.7 If the test cylinder is of the type which is bored with a central hole, it is important to remove any adhesive in the central hole in order to obtain the optimum result.

6.1.8 If the coated structure is fabricated using high-strength steel, care shall be taken not to damage the steel surface. Damage to the steel surface could result in failure of the structure due to the effects of corrosion.

6.2 Field tests on coated structures

Prior to testing, a recently applied protective paint coating shall be dried/cured in accordance with 6.1.5.

The following conditions shall be monitored and reported over a period of 24 h before testing (an indication of the estimated conditions is sufficient):

— the weather conditions, e.g. the air temperature and relative humidity;

— the surface temperature of the coated structure;

— the condition of the surface (wet/dry).

The following conditions shall be measured and reported at the time of testing:

— the air temperature;

— the relative humidity;

— the surface temperature of the coated structure.

If the surface is wet, it shall be dried and the fact that it was dried shall be recorded in the test report (see 6.1.5, Note 2).

6.3 Preparation

Before use, check that the test equipment is in good working order.

Measure the rate at which the force increases to ensure it meets the requirements.

Clean the surface of the test cylinder and of the protective paint coating before testing. The cleaning process shall include thorough degreasing.

To reduce the likelihood of adhesive failure, abrasion of the face of the test cylinder (e.g. by blast cleaning) and of the surface of the protective paint coating (e.g. with fine emery paper) can be carried out. If such abrasion is carried out, clean the surfaces afterwards.

Apply the adhesive thinly and evenly to the whole end surface of the test cylinder in sufficient quantity to ensure a good bond to the paint coating. Avoid applying excessive adhesive, as uneven application of the adhesive can lead to the pull-off force not being applied perpendicularly to the coating surface.

Follow the instructions for use supplied with the adhesive to ensure correct usage.

Cut the paint coating round the test cylinder down to the substrate, using a cutting device of the type specified in 5.4, to separate the test area from the rest of the coating.

6.4 Testing

6.4.1 General

For the purposes of this part of ISO 16276, a measurement is understood to be a single fracture strength value.

Pull-off tests can be carried out in two ways:

— testing the coating on the structure;

— using test panels prepared at the same time and in the same way as the coating on the structure.

The method using test panels is intended to be used only if specified or if agreed between the interested parties.

6.4.2 Test panels for use on site

The size of the steel panels shall be at least 100 mm × 100 mm × 10 mm.

NOTE 1 To achieve the thickness required, test panels can be glued together to form a composite panel of at least 10 mm thickness. The sandwich technique described in ISO 4624 can also be used.

Test panels shall be prepared, coated and cured/dried under the same conditions and in the same way as for the structure and shall be traceable to a location on the structure. Two alternative methods for conditioning the test panels are described in a) and b) below. Any variation in the conditions shall be agreed with the coating material manufacturer. The choice of method shall be agreed between the interested parties.

a) The coated panels remain on site for one day and are then removed for storage under standard conditions [(23 ± 2) °C, (50 ± 5) % relative humidity] for a further period of at least 10 days prior to testing.

b) The coated panels remain on site for at least 10 days. The atmospheric conditions at the site shall be in accordance with the recommendations of the paint system manufacturer. At the end of this period, the panels are then removed for storage under standard conditions [(23 ± 2) °C, (50 ± 5) % relative humidity] for a further period of at least 16 h prior to testing.

   If the required atmospheric conditions are not fulfilled at the site over the specified time period, seek the advice of the paint system manufacturer. If no advice is offered by the paint system manufacturer, a possible solution would be to remove the panels from the site and store them as described in a). In that case, the atmospheric conditions are not taken into consideration.

NOTE 2 The difference between these two options lies in the atmospheric conditions for the drying/curing process of the coating. Method a) enables the quality of the surface preparation, the coating and its application to be assessed. Method b) also includes the effects of the atmospheric conditions on the drying/curing process.

6.4.3 Sampling plan

6.4.3.1 General

The sampling plan defines the number of measurements to be taken in an inspection area.

6.4.3.2 Inspection areas

Inspection areas will normally be defined in the project specification (see also ISO 12944-7 and ISO 12944-8). Unless the structure has been divided into individual inspection areas, the whole structure is considered as the inspection area for measurement purposes.

NOTE It is recommended that areas where the specified fracture strength is difficult to achieve (e.g. areas where access for painting is difficult) be treated as individual inspection areas.

6.4.3.3 Minimum number of measurements

The minimum number of measurements, to be made at random over an inspection area in order to assess the fracture strength of the protective paint coating, is given in Table 1. For the purposes of this part of ISO 16276, the number of measurements given is considered as being representative of the inspection areas. The measurements shall also cover those areas where the specified fracture strength is difficult to achieve, e.g. areas where access for painting is difficult (see the Note to 6.4.3.2).

Table 1 — Minimum number of valid measurements within an inspection area

Inspection area m^2	Number of valid measurements
$\leqslant$ 1 000	3 for each 250 m^2 area or part thereof
$>$ 1 000	12, plus 1 for each additional 1 000 m^2 area or part thereof [a]
[a] Subdivision into smaller inspection areas is recommended.	

When test panels are used, the number of panels shall be equal to the number of measurements related to inspection areas.

6.5 Interpretation of results

Visually inspect the fracture surfaces to establish the nature of the fracture, assessing the type of fracture as follows:

A cohesive failure of substrate;

A/B adhesive failure between substrate and 1st coat (primer);

B cohesive failure of 1st coat;

B/C adhesive failure between 1st coat and 2nd coat;

C cohesive failure of 2nd coat;

C/*m* adhesive failure between 2nd coat and *m*th coat of a multicoat system;

m cohesive failure of *m*th coat of a multicoat system;

m/*n* adhesive failure between *m*th coat and *n*th coat of a multicoat system;

n/– adhesive failure between *n*th coat and topcoat of a multicoat system;

– cohesive failure of topcoat;

–/Y adhesive failure between topcoat and adhesive;

Y cohesive failure of adhesive;

Y/Z adhesive failure between adhesive and dolly.

Figure 1 shows the interfaces between the test cylinder, the adhesive, the top coat, the intermediate coats, the primer and the substrate.