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Epoxy powder and sealing material for the coating of steel for the reinforcement of concrete

Poudre époxy et matériau de réparation pour le revêtement des armatures en acier pour béton

Reference number
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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 14656 was prepared by Technical committee ISO/TC 17, *Steel*, Subcommittee SC 16, *Steels for the reinforcement and prestressing of concrete.*

Epoxy powder and sealing material for the coating of steel for the reinforcement of concrete

1 Scope

This International Standard specifies requirements for epoxy powders for use in preparing fusion-bonded epoxy-coated steel reinforcing bar, wire and welded fabric. This International Standard also includes requirements for sealing material used to repair damaged areas and cut ends on reinforcing steel.

This International Standard defines a flexible (type A) coating and a nonflexible (type B) coating. The adhesion and moisture resistance of fusion-bonded epoxy powder coatings can be enhanced by certain formulation designs. These coating enhancements typically result in a reduction of the coating's flexibility.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 6272:1993, *Paints and varnishes — Falling weight test.*

ISO 9352:1995, *Plastics — Determination of resistance to wear by abrasive wheels.*

3 Terms and definitions

For the purpose of this International Standard, the following terms and definitions apply.

3.1
coated bar
steel reinforcing bar which has been coated with a fusion-bonded epoxy coating

3.2
disbonding
loss of adhesion between the fusion-bonded epoxy coating and the steel reinforcing bar, wire or welded fabric

3.3
fusion-bonded epoxy coating
coating containing pigments, thermosetting epoxy resins, crosslinking agents and other additives, which have been applied in the form of a powder on to a clean, heated metallic substrate and fused to form a continuous barrier

3.4
holiday
discontinuity in a coating which is not discernible to a person with normal or corrected vision

3.5
longitudinal rib
uniform continuous rib parallel to the axis of the steel reinforcing bar

3.6
manufacturer
any organization which produces coated steel reinforcing bars, wire or welded fabric

3.7
sealing material
a coating system, formulated to be compatible with the fusion-bonded epoxy coating, used to repair damaged areas and cut ends

3.8
transverse rib
any rib on the surface of the steel reinforcing bar or wire other than a longitudinal rib

4 Materials

4.1 Coating material

The coating material shall be a thermosetting epoxy powder.

4.2 Sealing material

The coating system, for use as sealing material, shall be compatible with the fusion-bonded epoxy coating, inert in concrete, and recommended by the epoxy powder manufacturer. The sealing material shall be suitable for repairing damaged coating at the manufacturer or fabricator, or at the site.

5 Coating requirements

5.1 Chemical resistance

5.1.1 General

The ability of the coating to resist disbonding, blistering and corrosion in solutions that simulate potential exposure environments shall be evaluated by immersing coated, 20 mm diameter steel reinforcing bars in each of the following solutions:

a) deionized water;

b) an aqueous solution containing 3 % NaCl;

c) an aqueous solution containing 0,3 KOH and 0,05 N NaOH;

d) an aqueous solution containing 0,3 N KOH, 0,05 N NaOH and 3 % NaCl.

5.1.2 Type A coating

If the coating is classified as flexible, sixteen pieces of damage-free coated 20 mm diameter ribbed steel reinforcing bar, 300 mm in length, shall be selected for testing. Also, sixteen additional coated bars shall be bent 180° around a 100 mm diameter mandrel. The bend shall be made at a uniform rate and completed within 5 s. The overall (developed) length of the bent coated bars shall be 300 mm. After bending, the number of bending-induced holidays shall be determined using a 67,5 V, 80 000 Ω, wet-sponge type, direct current holiday detector and recorded. Prior to testing, all holidays and coated bar ends shall be coated with sealing material.

5.1.3 Type B coating

If the coating is classified as non-flexible, sixteen pieces of damage-free coated 20 mm diameter ribbed steel reinforcing bar, 300 mm in length, shall be selected for testing. Also, sixteen additional uncoated bars shall be bent 180° around a 100 mm diameter mandrel. These bars shall then be coated according to 7.5. The overall (developed) length of the bent, coated bars shall be 300 mm. The number of holidays shall be determined using a 67,5 V, 80 000 Ω, wet-sponge type, direct current holiday detector and recorded. Prior to testing, all holidays and coated bar ends shall be coated with sealing material.

5.1.4 Type A and B coatings

A 3 mm diameter hole shall be drilled through the coating of each of the thirty-two test specimens down to the underlying steel prior to solution immersion. This hole shall be located between the transverse ribs on the centre-line of each of the bars and at the midpoint of the bend for the bent bars.

Four straight and four bent bars shall be soaked in each solution for a period of 28 d at 55 °C ± 4 °C. The pH of the solutions shall be checked and recorded daily, and adjusted to ± 0,2 pH units of initial solution value. The bars shall be visually examined for swelling, colour changes, splitting and blisters after 28 d of solution immersion. If the coating blisters or splits, the product shall be disqualified.

At the end of the 28 d test period, the adhesion of the coating to the steel reinforcing bars shall be evaluated. Two intersecting cuts shall be made through the coating forming two 45° wedges. The coating at the intersection of the cuts shall be lifted using a sharply-pointed copper probe, 3 mm in diameter. Once the coating is lifted from the bar surface, the coating shall be grasped with tweezers and lifted. The distance the coating can be readily lifted between the two cuts using tweezers shall be measured from the edge of the intentional hole to the maximum disbondment point.

The coating adhesion shall be determined by the preceding process for two straight and two bent bars immediately after removal of the bars from solution and while the coating is still moist. After 7 d of air drying at 23 °C ± 2 °C and (50 ± 5) % relative humidity, the coating adhesion shall be determined for the remaining two straight and two bent bars in a similar manner to that conducted immediately after removal from solution.

5.1.5 Acceptance criteria

After 28 d of solution immersion testing, the average maximum disbondment determined for 95 % of the bars tested shall be 4 mm or less.

5.2 Cathodic disbondment

The coating's ability to resist loss of adhesion under an applied voltage at ambient temperature shall be evaluated by this 168 h cathodic disbondment test.

5.2.1 Equipment

5.2.1.1 Filtered direct-current variable power supply, with a controlled voltage output of between 0 V and 12 V and a current capacity of 200 mA.

5.2.1.2 Voltmeter, with a minimum input impedance of 10 MΩ and capable of measuring in the range between 0 V and 2 V to the nearest 1 mV.

5.2.1.3 10 Ω shunt resistor, 0,5 watt, 1 % tolerance.

5.2.1.4 Calomel reference electrode.

5.2.1.5 Solid platinum anode, 150 mm long, 1,6 mm nominal diameter or **platinized wire,** 3,2 mm nominal diameter.

5.2.1.6 Electrolyte, NaCl, 3 % (*m*/*m*) dissolved in distilled water.

5.2.1.7 **Plexiglass beaker,** 1 l, with a plexiglass cover.

5.2.1.8 **Thermometer.**

5.2.1.9 **Utility knife,** with a sharp blade.

5.2.1.10 **Coated steel reinforcing bars,** each 200 mm long and free from holidays.

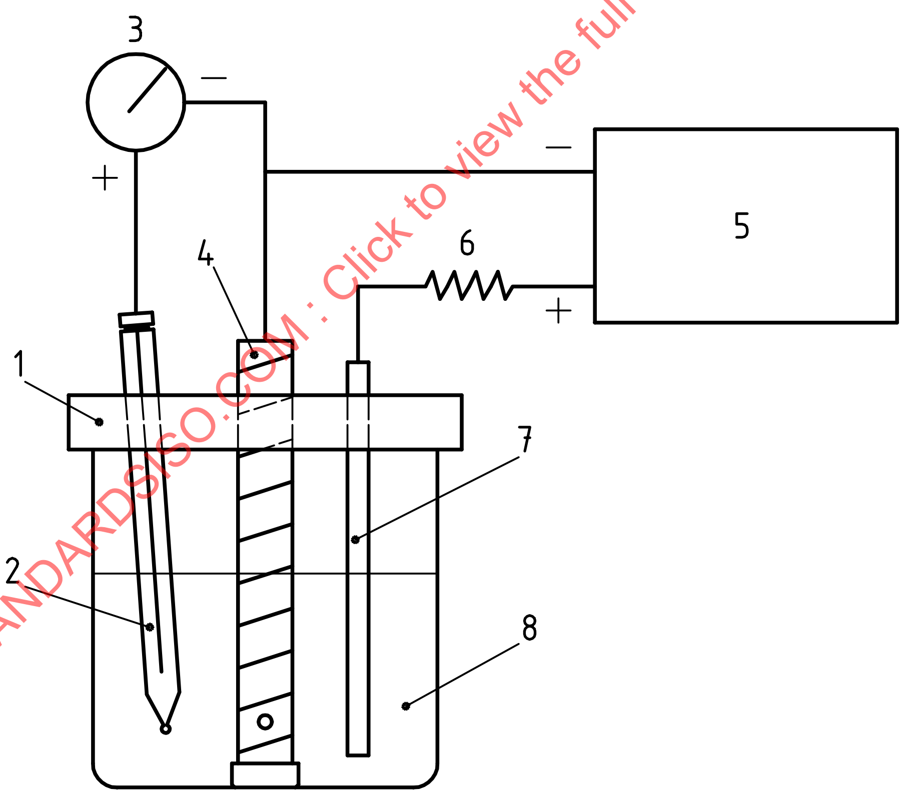
5.2.2 Procedure

5.2.2.1 On each test bar (5.2.1.10), drill a 3 mm diameter hole approximately 50 mm from one end. The hole shall be centered between transverse ribs and just deep enough to expose the steel over the full 3 mm diameter. Seal the end of the steel reinforcing bar closest to the hole completely with sealing material. Drill a 3 mm diameter hole and attach a self-tapping screw to the other end of the bar for the earth connection.

5.2.2.2 Perform the cathodic disbondment test using the equipment arrangement shown in Figure 1.

5.2.2.3 Add approximately 500 ml of electrolyte (5.2.1.6) to the beaker (5.2.1.7). Place the plexiglass cover on the beaker.

5.2.2.4 Insert a test bar into the beaker, with the sealed end of the bar resting on the bottom of the beaker. Add the electrolyte until 100 mm of the bar length is submerged. Connect the negative lead from the direct-current power supply (5.2.1.1) to the earthing screw of the bar.



Key

1 Cover
2 Calomel electrode
3 Voltmeter
4 Test bar
5 Direct-current power supply
6 Shunt resistor
7 Anode
8 Electrolyte

Figure 1 — Equipment arrangement for cathodic disbondment test

5.2.2.5 Insert 75 mm of the anode (5.2.1.5) into the electrolyte. (If a platinized wire anode is used, the end of the wire submerged in the solution must be completely sealed with silicone to prevent damage to the copper core.) Place the tip of the anode within 10 mm of the drilled hole in the coating. Connect the shunt resistor (5.2.1.3) to the anode and the positive lead from the power supply in series.

5.2.2.6 Insert the calomel reference electrode (5.2.1.4) in the electrolyte. Place the porous tip within 10 mm of the drilled hole in the coating. Connect the positive lead of the voltmeter (5.2.1.2) to the calomel electrode and the negative lead to the bar.

5.2.2.7 Turn on the power supply. Adjust the power supply until the polarized potential is stabilized at – 1 500 mV ± 20 mV with respect to the calomel electrode. Measure the voltage drop across the shunt resistor using the voltmeter and calculate the current flow. Record the time as the start time.

5.2.2.8 The bar shall remain in the electrolyte, which shall be maintained at a temperature of 23 °C ± 2 °C, for a period of 168 h ± 2 h. At 2 h intervals, record the potential readings and adjust the voltage to correct any drift from – 1 500 mV ± 20 mV during the first 8 h. Check the potential again at 24 h and at least twice every 12 h thereafter. Measure the voltage drop across the shunt resistor at each potential measurement and calculate the current flow.

5.2.2.9 The calomel electrode shall be removed after each potential measurement to avoid the danger of contamination of the electrode. The calibration of the electrode shall be verified after each cathodic disbondment test.

5.2.2.10 Remove the bar from the beaker and store it in air at 23 °C ± 2 °C for 1 h before preparing it for adhesion testing.

5.2.2.11 Using a new blade in the utility knife (5.2.1.9), make four cuts through the coating at the intentionally drilled hole, extending outward from the site at 0°, 90°, 180°, and 270°, providing four sections of coating for adhesion testing. Ensure that the cuts extend through the coating such that the metal is visible. Replace the knife blade if it becomes dull or damaged. The length of each cut shall not be less than 5 mm or the distance between adjacent ribs.

5.2.2.12 Insert the tip of the utility knife under the coating at a section. Use a levering action to remove the coating. Continue until the coating resists the levering action. Measure the radius of the disbonded area from the edge of the original 3 mm circle (formed in the coating by drilling the hole) to the coating exhibiting firm adhesion.

5.2.2.13 Repeat the procedure for all four sections of coating and average the values. (It may be easier to measure the diameter of the resulting circle at the 0° and 180° positions and 90° and 270° positions, average these values, subtract the original 3 mm hole, and divide by two.)

5.2.3 Acceptance criteria

The average coating disbondment radius of three coated steel reinforcing bars shall not exceed 2 mm when measured from the edge of the intentional coating defect.

5.3 Salt spray resistance

The coating's ability to resist loss of adhesion in a corrosive, hot and humid environment shall be evaluated by this 800 h test.

5.3.1 Equipment

5.3.1.1 **Salt spray cabinet.**

5.3.1.2 **Salt solution,** NaCl, 5 % (*m*/*m*) dissolved in distilled water.

5.3.1.3 **Utility knife,** with a sharp blade.

5.3.1.4 Coated steel reinforcing bars, each 200 mm long; both ends of each bar shall be completely sealed with sealing material.

5.3.2 Procedure

5.3.2.1 On each test bar (5.3.1.4), drill six 3 mm diameter holes, three on one side of the bar and three on the other. The first hole on each side shall be drilled at least three transverse ribs from one end of the bar. The hole shall be centered between ribs and just deep enough to expose the steel. The second hole shall be drilled at least three transverse ribs from the other end of the bar and the third hole drilled approximately half way between. These holes shall also be centered between ribs.

5.3.2.2 Place the bars with the damage sites facing to the side (90°), in the salt spray cabinet (5.3.1.1) for 800 h ± 20 h at 35 °C ± 2 °C.

5.3.2.3 After 800 h 6 20 h, remove the bars and wash them in distilled water. Store the bars in air at 23 °C ± 2 °C for 24 h ± 2 h before preparing them for adhesion testing.

5.3.2.4 At each damage site and its adjacent area, scrape the surface gently with the front side of the utility knife (5.3.1.3) to remove corrosion products which have loosely deposited on the surface. Do not apply such force as to damage the coating.

5.3.2.5 Using a new blade for each specimen, using the utility knife make four cuts through the coating at each damage site, extending outward from the site at 0°, 90°, 180° and 270°, providing four sections of coating for adhesion testing. Ensure that the cuts extend through the coating such that the metal is visible. Replace the knife blade if it becomes dull or damaged. The length of each cut shall not be less than 5 mm or the distance between adjacent ribs.

5.3.2.6 Insert the tip of the utility knife under the coating at a section. Use a levering action to remove the coating. Continue until the coating resists the levering action. Repeat for all four sections.

5.3.2.7 Measure the diameter of the disbonded area from the 0° to 180° coating edges and the 90° to 270° coating edges and average the two values. Subtract the original 3 mm circle (formed in the coating by drilling the hole) from this average and divide by two to obtain the test value.

5.3.2.8 Repeat steps 5.3.2.6 and 5.3.2.7 for each test site.

5.3.3 Acceptance criteria

The average coating disbondment radius of six test sites on three coated steel reinforcing bars shall not exceed 3 mm when measured from the edge of the intentional coating defect.

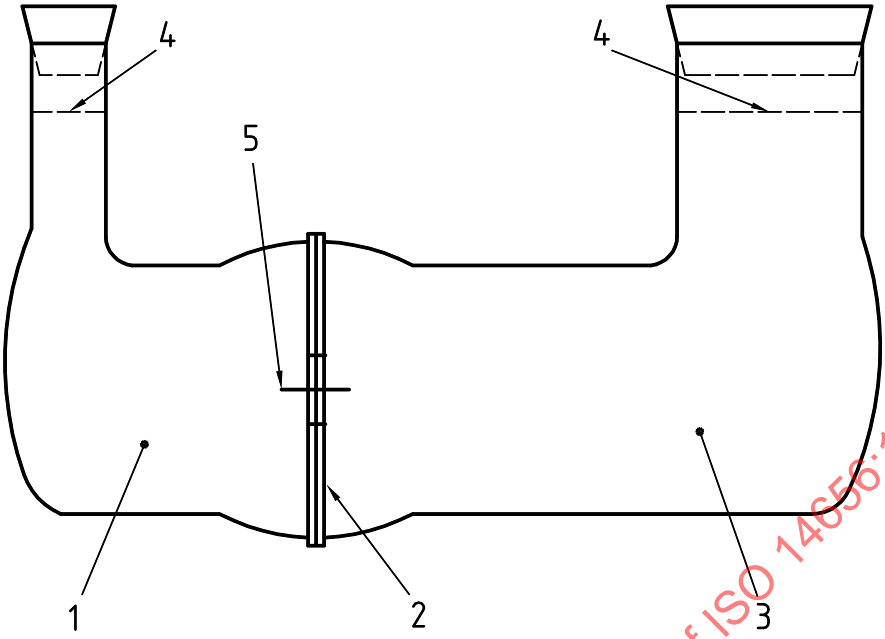
5.4 Chloride permeability

The coating's performance as a chloride barrier shall be evaluated by this 45 d test.

5.4.1 Equipment

5.4.1.1 Two-compartment glass cell, as shown in Figure 2

Where the compartments are separated by two glass plates, each having centered, 24 mm diameter holes. The test specimen shall be sandwiched between the two glass plates, forming a membrane in the opening. The level in both compartments shall be equal when the liquid volumes are 115 ml and 175 ml in compartments 1 and 3 respectively. The opening shall then be completely immersed.



Key

1 115 ml compartment for distilled water
2 Epoxy film between two glass plates each having a centered 24 mm hole
3 175 ml compartment for 3 mol/l NaCl
4 Level mark
5 25 mm hole, centered

Figure 2 — Permeability cell (example)

5.4.1.2 Equipment capable of determining chloride concentrations down to 0,000 1 mol/l

Activity measurements shall be converted into concentration values of moles per liter with a conversion diagram, constructed by plotting measured chloride ion activities versus known chloride ion concentrations.

5.4.1.3 Test specimens

100 mm × 100 mm cured epoxy film without substrate. The thickness of the film shall be the minimum coating thickness to be applied on the reinforcing steel.

NOTE For epoxy-coated steel in accordance with ISO 14654, the minimum thickness is 170 μm.

Prior to installation in the cell the test specimen shall be handled carefully and examined for any defects.

5.4.2 Procedure

The test specimen (5.4.1.3) is placed between the two glass plates in the cell (5.4.1.1), with its centre in the plates' openings. The larger compartment is filled with 175 ml of 3 mol/l NaCl in water. The smaller one is filled with 115 ml of distilled water. After 45 d at (23 ± 2) °C, the chloride concentration in the smaller compartment is determined.

5.4.3 Acceptance criteria

The chloride concentration in the smaller compartment shall be less than 0,000 1 mol/l.

5.5 Coating flexibility

The flexibility requirements apply to type A coatings only.

The coating flexibility shall be evaluated by bending three coated steel reinforcing bars 180° (after rebound) around a mandrel having a diameter of 6 d, where d is the nominal diameter of the bar. The bend test shall be made at a uniform angular velocity of at least 8 rad/min. The two longitudinal ribs of the coated steel reinforcing bar shall be placed in a plane perpendicular to the mandrel radius. The temperature of the test specimens shall be between 17 °C and 30 °C. No cracking of the coating on the outside radius of any of the three bent bars shall be discernible to a person with normal or corrected vision.

A partial failure or cracking of the steel shall not be considered as failure of the coating. Two additional coated bars shall be tested.

5.6 Abrasion resistance

The resistance of the coating on each of three steel panels to abrasion by a Taber abraser (see ISO 9352) or its equivalent, using CS-10 wheels and a 1 kg load per wheel, shall be such that the mass loss shall not exceed 50 mg after 1 000 cycles.

5.7 Impact test

The resistance of the coating to mechanical damage shall be assessed by the falling weight test. A test apparatus similar to that described in ISO 6272 shall be used along with a 1,8 kg tup having a nose diameter of 16 mm. Impact shall occur on the low-lying areas of the coated bars, i.e., between transverse ribs. The test shall be performed at 23 °C ± 2 °C. With an impact of 10 N·m for type A coatings and 4,5 N·m for type B coatings, no shattering, cracking, or bond loss of the coating shall occur except at the impact area, i.e., the area permanently deformed by the tup.

6 Sealing material requirements

6.1 Chemical resistance

The ability of the sealing material to resist blistering and corrosion in a solution that simulates potential exposure environments shall be evaluated by immersing three coated, flat steel panels, with intentional defects repaired using the sealing material, in an aqueous solution containing 0,3 N KOH and 0,05 N NaOH at 55 °C ± 2 °C for 28 d.

Each intentional defect shall be an area 12 mm × 25 mm removed from the centre of one side of the coated panel using a grinding wheel or other suitable method. Dust and loose material shall be removed from the intentional defect site with a clean cloth after the coating's removal. The sealing material shall be prepared for application in accordance with the written instructions of the sealing material manufacturer. The sealing material shall be applied, using a new paint brush, to the intentional defect to form a sealed area 25 mm × 37 mm fully covering the intentional defect. The coated panel shall be lying flat on a table during the sealing material application and shall remain in such a position until the coating has cured in accordance with the manufacturer's instructions. The sealing operation and the sealed panels shall be maintained at a temperature of 23 °C ± 2 °C. The sealed area coating thickness shall be measured and reported.

Upon examination after completion of the test, the sealed areas on each of the three coated panels shall not be found to have formed blisters or have developed areas of rust from holes in the sealed area itself or from the sealing material interface with the coated panel.

6.2 Salt spray resistance

The resistance of the sealing material to a hot, wet corrosive environment shall be evaluated by this 400 h test. Three coated, flat steel panels, with intentional defects repaired using the sealing material, shall be exposed to 35 °C ± 2 °C salt spray composed of 5 % (m/m) NaCl dissolved in distilled water for 400 h ± 10 h.