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Epoxy-coated steel for the reinforcement of concrete

Armatures en acier pour béton armé avec revêtement époxy

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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 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 14654 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 16, *Steel for the reinforcement and prestressing of concrete.*

Annex A forms a normative part of this International Standard. Annexes B, C and D are for information only.

Epoxy-coated steel for the reinforcement of concrete

1 Scope

This International Standard specifies requirements for fusion-bonded epoxy-coated post-fabricated and pre-fabricated steel bar, wire and welded fabric for the reinforcement of concrete.

This International Standard permits the application of either flexible (type A) or nonflexible (type B) coatings. Steel reinforcing bar, wire and welded fabric coated with a nonflexible (type B) coating shall not be fabricated after coating.

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 document indicated below. For undated references, the latest edition of normative document referred to applies. Members of ISO and IEC maintain regiters of currently valid International Standards.

ISO 2808:1997, *Paints and varnishes — Determination of film thickness*.

ISO 4287:1997*, Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters.*

ISO 6935-1:1991, *Steel for the reinforcement of concrete — Part 1: Plain bars*.

ISO 6935-2:1991, *Steel for the reinforcement of concrete — Part 2: Ribbed bars*.

ISO 6935-3:1992, *Steel for the reinforcement of concrete — Part 3: Welded fabric.*

ISO 10544:1992, *Cold-reduced steel wire for the reinforcement of concrete and the manufacture of welded fabric*.

ISO 14656:—[1)], *Epoxy powder and sealing material for the coating of steel for the reinforcement of concrete*.

3 Terms and definitions

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

3.1
batch
production unit of epoxy powder

1) To be published.

3.2
bundle
two or more lengths properly bound together

3.3
coated bar
steel reinforcing bar which has been coated with a fusion-bonded epoxy coating

3.4
coated wire
straightened steel wire which has been coated with a fusion-bonded epoxy coating

3.5
coated welded fabric
sheet of steel welded fabric which has been coated with a fusion-bonded epoxy coating

3.6
coating line
strand (deprecated)
one length-coating process line in a multiple-line steel reinforcing bar coating plant

3.7
conversion coating
preparation of the blasted metal surface prior to coating application which is designed to pretreat the metal, promote coating adhesion, improve corrosion resistance and increase blister resistance

3.8
disbonding
loss of adhesion between the fusion-bonded epoxy coating and the steel reinforcing bar, wire or welded fabric

3.9
fabricator
any organization which cuts and/or bends coated steel reinforcing bar, wire or welded fabric

3.10
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

3.11
holiday
discontinuity in a coating which is not discernible to a person with normal or corrected vision

3.12
length
piece of nominally straight steel reinforcing bar cut to a specified length

3.13
longitudinal rib
uniform continuous rib parallel to the axis of the steel reinforcing bar

3.14
manufacturer
any organization which produces coated steel reinforcing bars, wire or welded fabric

3.15
post-fabricated reinforcement
steel reinforcing bar, wire or welded fabric that is fabricated after being coated with a fusion-bonded epoxy coating

3.16
pre-fabricated reinforcement
steel reinforcing bar, wire or welded fabric that is fabricated before being cleaned and coated with a fusion-bonded epoxy coating

3.17
sealing material
a coating system, formulated to be compatible with the fusion-bonded epoxy coating, used to repair damaged areas and cut ends

3.18
test unit
the quantity of coated reinforcing steel to be accepted or rejected together, on the basis of the tests to be carried out on sample products in accordance with the requirements of the product standard or order

NOTE Adapted from ISO 404:1992.

3.19
transverse rib
any rib on the surface of the steel reinforcing bar or wire other than a longitudinal rib

3.20
wetting agent
material that lowers the surface tension of water allowing it to penetrate more effectively into small discontinuities in the coating giving a more accurate indication of the holiday count

4 Materials

4.1 Steel reinforcing bars

Steel reinforcing bars to be coated shall be in accordance with ISO 6935-1 or ISO 6935-2 or any other product standard as specified by the purchaser, and shall be free of contaminants such as oil, grease or paint.

NOTE Prior to coating, the steel reinforcing bars should be inspected for their suitability for coating. Steel reinforcing bars with sharp edges on the ribs, rolled-in slivers or other surface imperfections are difficult to coat properly. The coating will tend to flow away from sharp edges on the ribs, rolled-in slivers or other surface imperfections, and could result in inadequate coating thickness at these points.

4.2 Steel wire or welded fabric

Steel wire or welded fabric to be coated shall be in accordance with ISO 10544 or ISO 6935-3 or any other product standard as specified by the purchaser, and shall be free of contaminants such as oil, grease or paint.

4.3 Epoxy powder

The epoxy powder upon application shall be in accordance with ISO 14656. Upon request, the purchaser shall be provided with test data for review.

The purchaser shall be furnished with a written certificate that properly identifies the batch designation of the epoxy powder used in the order, states quantity, date of manufacture, name and address of the powder manufacturer and a statement that the supplied epoxy powder is the same composition as that prequalified in accordance with ISO 14656. The manufacturer of the epoxy powder shall furnish an infrared trace and a differential scanning calorimetry trace of the powder batches used in preparing the coated steel reinforcing bars, wire and welded fabric as part of the certificate.

If specified in the order, a representative 0,2 kg sample of the epoxy powder shall be supplied to the purchaser from each batch. The sample shall be packaged in an airtight container and identified by batch designation.

The epoxy powder shall be maintained in a temperature-controlled environment following the written recommendations of the powder manufacturer until ready for use, at which point the epoxy powder will be given sufficient time to reach the approximate plant ambient temperature. The epoxy powder shall be used within the powder manufacturer's written recommended shelf life.

4.4 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 coatings at the manufacturer, fabricator or at the site, and shall be in accordance with ISO 14656.

When specified in the order, sealing material shall be supplied to the purchaser.

5 Surface preparation of steel reinforcing bar, wire and welded fabric

The surface of the steel reinforcing bar, wire and welded fabric shall be cleaned by abrasive blast steel grit. The amount of residual mill scale on the cleaned surface shall not exceed 5 % when tested in accordance with C.10.

Average blast profile roughness depth readings of 50 µm to 70 µm, defined as the arithmetic mean deviation of the assesed profile, R_a, in ISO 4287:1997, shall be considered suitable as an anchor pattern.

NOTE 1 The use of a "profilometer" type surface measurement instrument which measures the peak count as well as the maximum profile depth is recommended.

A steel grit of Rockwell hardness C 55 or higher, such as GL-25, shall be used. Preferably 100 % grit shall be used.

NOTE 2 Recycled steel grit abrasive should be maintained so as to minimize contaminants such as oil, salt and dust caused by the blasting operation.

Multidirectional, high-pressure dry air knives shall be used after blast cleaning to remove dust, grit and other foreign matter from the steel surface. The air knives shall not deposit oil on the steel reinforcing bars, wire and welded fabric.

NOTE 3 Steel reinforcing bar, wire and welded fabric found to be salt contaminated should be cleaned by acid washing or other suitable methods to remove contaminants from the surface prior to preheating. Washed surfaces should not be allowed to flash rust.

It shall be permissible for a chemical wash and/or conversion coating of the steel reinforcing bar, wire and welded fabric surface to be used to enhance coating adhesion.

NOTE 4 Some powder coatings may require pretreatment of the steel in accordance with the powder manufacturer's instructions.

The pretreatment shall be applied after abrasive cleaning and before coating, in accordance with the written application instructions specified by the pretreatment manufacturer.

Alternative surface preparation criteria to the foregoing may be applied provided:

a) they can be shown to give a good or better performance with respect to clause 7 and C.8 to C.11;

b) the preparation procedures and critical measures are documented, including tolerance limits which can be shown not to compromise overall quality;

c) the product is produced under a quality assurance scheme which validates a) and b) above.

6 Application of powder

The epoxy powder shall be applied to the cleaned and pretreated (if applicable) surface as soon as possible after surface treatments have been completed, and before any visible (to a person with normal or corrected vision) surface rusting occurs. The maximum time to application of coating shall be based on the relative humidity (RH) in the coating plant according to Table 1:

Table 1 — Maximum time between surface treatment and application of powder

Relative humidity RH	Maximum time min
RH $\leqslant$ 55 %	180
55 % < RH $\leqslant$ 65 %	90
65 % < RH $\leqslant$ 75 %	60
75 % < RH $\leqslant$ 85 %	30

If the relative humidity is in excess of 85 %, coating application shall cease, except where the surface preparation, heating and coating process is a continuous operation.

The powder shall be applied in accordance with the written recommendations of the manufacturer of the powder in the case of initial steel surface temperature range and post application cure requirements. During continuous operations, the temperature of the surface immediately prior to coating shall be measured using infrared guns and/or temperature-indicating crayons at least once every 30 min.

NOTE 1 The use of infrared guns and temperature-indicating crayon measurement of the coated steel reinforcing bar, wire or welded fabric is recommended.

NOTE 2 Periodic checks of the coating's cure by differential scanning calorimetry is recommended.

NOTE 3 When twin wire types of welded fabric are to be coated, an appropriate method of coating application should be considered.

7 Requirements for coated steel reinforcing bar, wire and welded fabric

7.1 General

Nonflexible (type B) coatings shall be required to meet the performance requirements of flexible (type A) coatings with the exception of the requirements for coating flexibility (7.4).

NOTE Some national standards include a qualification test to determine the relative bond strength of ribbed steel reinforcing bars in concrete. In the USA, for example, relative bond strength is determined with beam-end test specimens in accordance with ASTM A 944. In the qualification testing, the relative bond strength of the coated bars is required to be at least 85 % of the relative bond strength of the uncoated bars. For more information see ASTM A 944.

When specifying epoxy coated reinforcing steel according to this International Standard, the need for a bond strength specification should also be considered.

7.2 Coating thickness

The coating thickness after curing shall be 170 µm to 300 µm. The upper thickness limit does not apply to repaired areas of damaged coating.

7.3 Coating continuity

There shall not be more than four holidays per linear metre of the coated steel reinforcing bar or coated wire (spool and individual lengths). For coated bars or wires less than 300 mm in length, the maximum shall be one holiday.

In welded fabric, the number of holidays shall not exceed the values given in Table 2.

Table 2 — Coating continuity in welded fabric

Wire spacing [a]	Number of intersections [b] to be checked	Maximum number of holidays
b_L and $b_c \leqslant 100$ mm	10	20 holidays/m^2
b_L or $b_c > 100$ mm	5	10 holidays/m^2

[a] b_L is the spacing of longitudinal wires; b_c is the spacing of transverse wires.

[b] One intersection is a welding point including 13 mm wire in each direction.

Damage at cut ends shall not be counted.

7.4 Coating flexibility

No cracking or disbonding of the coating shall be visible to a person with normal or corrected vision on the outside radius of the bent test piece.

7.5 Coating adhesion

The coating adhesion shall be evaluated by cathodic disbondment and salt spray testing in accordance with procedures descibed in ISO 14656.

The manufacturer shall be able to demonstrate a disbondment radius on cathodic disbondment testing of less than 2 mm on greater than 95 % of the samples tested on a three-month rolling average.

The manufacturer shall be able to demonstrate a disbondment radius on salt spray testing of less than 3 mm on greater than 95 % of the samples tested on a three-month rolling average.

8 Permissible coating damage and repair of damaged coating

Coating damage discernible to a person with normal or corrected vision shall be repaired with sealing material meeting the requirements of 4.4 in accordance with the written recommendations of the sealing material manufacturer. Any rust shall be removed by suitable means before application of the sealing material.

The total damaged surface area, prior to repair with sealing material, shall not exceed 0,5 % of the surface area in any one metre length of the bar or wire. This limit on repaired damage does not include sheared or cut ends that are coated with sealing material.

When coated steel reinforcing bars, wire and welded fabric are sheared, saw-cut, or cut by other means during the fabrication process, the cut ends shall be sealed with the same sealant that is used for the repair of damaged coating.

The coating at repaired areas shall have a minimum thickness of 180 µm.

NOTE 1 These requirements apply to the coated product before the coated steel is accepted from the supplier by the purchaser and are not site acceptance criteria, see annex B.

NOTE 2 Process limitations on straight-bar coating lines can result in inadequate coating for approximately 200 mm at each end of the steel reinforcing bar. It is recommended that these ends be either removed or repaired during subsequent fabrication.

NOTE 3 If the coating damage in any one metre length of the bar or wire exceeds 0,5 % of the surface area, that section should be removed from the coated bar or wire and discarded. In repairing coating damage, care should be taken not to apply the sealing material to an excessive amount of intact coating during the repair process.

9 Manufacturer's certificate

The manufacturer shall make available, when requested by the purchaser, a certificate of testing stating:

a) that the material supplied complies with the requirements of this International Standard;

b) the address at which the record of test results is available for inspection;

c) the identification symbol of the certification body, where applicable.

10 Handling, storage and identification

Coated steel reinforcing bars, wire and welded fabric shall be transported and handled with care. All systems for handling coated bars, wire and welded fabric shall have padded contact areas. All bundling bands shall be padded or suitable banding shall be used to prevent damage to the coating. All bundles of coated reinforcement shall be lifted in such a way as to prevent bar-to-bar abrasion from sags in the bundles. The coated reinforcement shall not be dropped or dragged.

If circumstances require that coated steel reinforcing bars, wire and welded fabric be stored outdoors for more than two months, protective storage measures shall be implemented to protect the material from sunlight, salt spray and weather exposure. Coated reinforcement stored in corrosive environments shall require protection sooner. If the coated reinforcements are stored outdoors without cover, the date on which the coated reinforcements are placed outdoors shall be recorded on the identification tag on the bundled steel. Coated reinforcement shall be covered with opaque polyethylene sheeting or other suitable opque protective material. For stacked bundles, the protective covering shall be draped around the perimeter of the stack. The covering shall be secured adequately, and allowance for air circulation around the coated reinforcement be made in orders to minimize condensation under the covering.

All coated reinforcement shall be stored off the ground on protective bearers.

Quality assurance codes shall be placed on all identification tags of the coated steel reinforcing bars, wire and welded fabric. These codes shall certify compliance to this International Standard and include references to the date of fabrication, the date of coating, the powder lot designation and the quality assurance testing performed. The identification of all steel reinforcing bars, wire and welded fabric shall be maintained throughout the coating and fabrication processes up to the point of shipment.

Annex A
(normative)

Test methods and frequency of tests, and retests

A.1 Test methods and frequency of tests

A.1.1 Coating thickness

A.1.1.1 Test method

For acceptance purposes, at least 95 % of all recorded coating thickness measurements shall be within the specified range. Thickness measurements less than 130 µm shall be considered cause for rejection.

A single recorded coating thickness measurement is the average of three individual readings obtained between three consecutive transverse ribs of the steel reinforcing bar, or between three consecutive indentations or ribs of the wire or welded fabric wires. A minimum of five recorded measurements shall be obtained approximately evenly-spaced along each side of the test specimen (a minimum of ten recorded measurements per specimen).

Measurements shall be made in accordance with method No. 6 of ISO 2808:1997 following the instructions for calibration and use issued by the thickness gauge manufacturer. Pull-off and fixed probe gauges may be utilized. "Pencil-type" pull-off gauges that require the operator to observe the readings at the instant the magnet is pulled from the surface shall not be used.

For ribbed bars and ribbed or indented wire, the thickness of the coating shall be measured on the body of a straight length of bar or wire between the transverse ribs or indentations.

Measurements of coating thickness for plain bars and plain wire shall follow the preceding procedure for ribbed bars and ribbed or indented wire, except for the location of the three individual readings. The three individual readings, the average of which is a single recorded coating thickness measurement, shall be obtained at three consecutive points. The spacing between the three consecutive points shall be approximately equal to the nominal diameter of the bar or wire.

A.1.1.2 Frequency of tests

For steel reinforcing bars, tests for coating thickness shall be made on a minimum of two bars of each size from each production hour.

For wire and welded fabric, tests shall be made on a minimum of 0,3 m length of each size wire or welded fabric coated during each production hour.

A.1.2 Coating continuity

A.1.2.1 Test method

Holiday checks to determine the acceptability of the coated steel reinforcing bars prior to shipment shall be made at the manufacturer's plant with a hand-held 67,5 V, 80 000 Ω, wet-sponge type, direct-current holiday detector or equivalent method. The testing voltage shall be fixed and the detector designed so that an external instrument can indicate that it is correct. The detector shall be equipped with indicators such as a lamp and/or a buzzer for indicating discontinuities. The probe shall be capable of covering all surfaces of the coated bars, wire and welded fabric of the shapes and dimensions being tested.

The sponge shall be soaked in tap water to which a wetting agent has been added.

NOTE 1 In-line holiday detection is recommended. Hand-held holiday detector checks should be performed regularly to verify the accuracy of the in-line system.

NOTE 2 To obtain an accurate holiday count, care should be taken to ensure that contact of the sponge along the entire steel surface being tested is maintained.

A.1.2.2 Frequency of tests

For steel reinforcing bars, tests for coating continuity shall be conducted on a minimum of two bars of each size from each production hour. For wire and welded fabric, tests shall be made on a minimum of 0,3 m length of each wire size or welded fabric coated during each production hour.

A.1.3 Coating flexibility

A.1.3.1 Test method

For steel reinforcing bars, the coating flexibility shall be evaluated by bending production-coated steel reinforcing bars 180° (after rebound) around a mandrel having a diameter of 4 d for $d \leqslant 20$ mm and 6 d for $d > 20$ mm, where d is the nominal diameter of the bar. For bars with $d > 36$ mm, the bend angle shall be 90°. The bend test shall be made at a uniform angular velocity of at least 8 rad/min. Where present, 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 23 °C ± 5 °C.

For wire and welded fabric, the coating flexibility shall be evaluated by bending production-coated wire and welded fabric at a uniform rate 180° (after rebound) around a mandrel having a diameter three times the nominal diameter of the wire. The wire or welded fabric shall be placed in a plane perpendicular to the mandrel radius. The temperature of the test specimens shall be 23 °C ± 5 °C.

Fracture or partial failure of the steel reinforcing bar, wire or welded fabric, or cracking or disbonding caused by imperfections in the bar or wire surface visible after performing the bend test, shall not be considered as a coating flexibility failure. Two additional specimens shall be tested and evaluated against this requirement.

A.1.3.2 Frequency of tests

For steel reinforcing bars, tests for coating flexibility shall be made on a minimum of one bar of each bar size from each production hour. For wire and welded fabric, tests for coating flexibility shall be conducted on at least one wire of each size or type of fabric from each production hour.

A.1.4 Coating adhesion

A.1.4.1 Test methods

The coating adhesion shall be tested by cathodic disbondment and salt spray resistance in accordance with ISO 14656.

A.1.4.2 Frequency of tests

Tests for coating adhesion using cathodic disbondment testing shall be made on one bar of each size of bar produced from each 8 h of production. The sampling shall be rotated through each coating line.

Tests for coating adhesion using salt spray testing shall be made on one bar for every 24 h of production. After each seven days, at least one sample representative of each bar size produced shall be tested.

For pre-fabricated coated steel reinforcing bars, one-half of the pieces tested shall be straight bar pieces and one-half shall be bent bar pieces. Testing on the bent bar pieces shall be alternated between the inside and outside radius. If there are no bent bars being coated during the production period, straight bar pieces shall be substituted for the test.

A.2 Retests

A.2.1 If any test specimen for coating thickness, continuity, or flexibility fails to meet the specified requirements, it shall be discarded.

A.2.1.1 For coated steel reinforcing bars, two further bars from the same bundle shall be subjected to the test or tests in which the original bar failed. If both additional coated bars pass the retest, the bundle from which they were taken shall be deemed to comply with this International Standard. If either of them fails, the bundle shall be deemed not to comply with this International Standard.

A.2.1.2 For coated wire or welded fabric, two further samples from the same test unit shall be subjected to the test or tests in which the original sample failed. If both additional coated samples pass the retest, the test unit from which they were taken shall be deemed to meet the requirements of this International Standard. If either of them fails, the test unit shall be deemed not to comply with this International Standard.

A.2.2 For coated steel reinforcing bars, if the bundle does not comply with this International Standard, two bars shall be selected from the bundle immediately preceding and also from the untested bundle immediately following the non-compliant bundle and then subjected to the test or tests in which the original bars failed. If all bars pass the retests then the bundles shall be deemed to comply with this International Standard. If any bar fails a retest, the bundle from which it originated shall be deemed not to comply with this International Standard.

For pre-fabricated coated steel reinforcing bar, wire and welded fabric, if the test unit does not comply with this Internatioinal Standard, two samples shall be selected from the test unit immediately preceding and from the test unit immediately following the non-compliant test unit and subjected to the test or tests in which the original samples failed. If all samples pass the retests, then the test units shall be deemed to comply with this International Standard. If any sample fails a retest, the test unit from which it originated shall be deemed not to comply with this International Standard.

A.2.3 For coated steel reinforcing bars, in the case of a second non-compliant bundle, the untested bundle immediately next to it, which may be preceding or following, shall be subjected to retest. This procedure shall be repeated until a compliant bundle is tested.

For pre-fabricated coated steel reinforcing bar, wire and welded fabric, in the case of a second non-compliant test unit, the untested test unit immediately next to it, which may be preceding or following, shall be subjected to retest. This procedure shall be repeated until a compliant test unit is tested.

A.2.4 A certain number of coated reinforcing steel specimens will have been produced since the last acceptance test was performed and accepted. The reinforcing steel that has been coated since that last test shall be divided into four equal time period groups according to when they were produced. Each test unit should be defined as the coated reinforcing steel that has been produced in a given time period since the last accepted test.

Annex B
(informative)

Guidelines for site practice

This International Standard is a product standard. Its requirements cease when the purchaser accepts the coated steel reinforcing bars, wire and welded fabric from the supplier. A product standard does not delineate requirements for subsequent practices at the site.

The project specifications should prescribe requirements for the coated steel reinforcing bars, wire and welded fabric from the time the purchaser accepts the coated bars, wire and welded fabric from the supplier, and subsequent practices at the site. In the absence of such requirements in the project specifications, the following guidelines for site practices are recommended.

a) Exercise care when handling coated steel reinforcing bars, wire and welded fabric; avoid bundle-to-bundle abrasion, or bar-to-bar abrasion resulting from sagging bundles.

b) Equipment for handling coated steel reinforcing bars, wire and welded fabric should have protected contact areas.

c) Coated steel reinforcing bars, wire and welded fabric should be off-loaded as close as possible to their fixing area to minimize rehandling.

d) Coated steel reinforcing bars, wire and welded fabric should be stored off the ground on protective bearers, and timbers placed between bundles when stacking is necessary. Supports should be spaced sufficiently close to prevent sags in the bundles.

e) Coated and uncoated steel reinforcing bars, wire and welded fabric should be stored separately.

f) Long-term storage should be minimized and call-offs phased to suit construction progress.

g) If circumstances require outdoor storing of coated steel reinforcing bars, wire and welded fabric for an accumulated period of more than two months, protective storage measures should be implemented to protect the material from sunlight, salt spray and weather exposure. Coated reinforcement stored in corrosive environments may require protection sooner. If the coated reinforcements are stored outdoors without cover, the date on which the coated reinforcements are placed outdoors shall be recorded on the identification tag on the bundled steel.

   Coated reinforcement should be covered with opaque polyethylene sheeting or other suitable protective material. For stacked bundles, the protective covering should be draped around the perimeter of the stack. The covering should be secured adequately, and allow for air circulation around the coated reinforcement to minimize condensation under the covering.

h) Fabrication of coated reinforcement on site is not recommended. If circumstances make site fabrication necessary, care should be exercised when fabricating coated reinforcement. Bending pins and other components which will be in contact with coated reinforcement should be equipped with nylon collars. Epoxy tends to become brittle at lower temperatures, e.g. below + 5 °C; therefore, additional care should be exercised when fabrication is performed during cold weather. Alternatively the work should be postponed until warmer weather occurs. Cut ends of coated reinforcement should be sealed with sealing material. Damaged coating due to fabrication should be repaired with sealing material.

i) When the extent of the coating damage exceeds 1 % of the surface area in any one metre length of the coated steel reinforcing bar, or of each coated steel wire, the coated bar or wire or welded fabric should be discarded.

j) When the extent of the coating damage does not exceed 1 % of the surface area in any one metre length of the coated bar, or of each coated wire, all damaged coating discernible to a person with normal or corrected vision should be repaired with sealing material.

k) Sealing material should be applied in strict accordance with the written instructions furnished by the sealing material manufacturer. Prior to application of the sealing material, rust should be removed from the damaged areas by suitable means. The sealing material should be allowed to cure before placing concrete over the coated steel reinforcing bars, wire and welded fabric.

l) When fixing coated steel reinforcing bars, wire and welded fabric, all wire bar supports and spacers, and tying wire should be coated with dielectric material, e.g. epoxy-coated or plastic-coated material compatible with concrete.

m) Fixed coated steel reinforcing bars, wire or welded fabric should be inspected for coating damage prior to placing concrete. Particular attention should be paid to sheared ends of coated bars. Where damage exists, it should be repaired with a sealing material in accordance with ISO 14656.

n) After fixing, walking on coated steel reinforcing bars, wire and welded fabric should be minimized. The placement of mobile equipment should be planned to avoid damage to coated reinforcement.

o) Coating damage can result from concreting operations. When immersion-type vibrators are used to consolidate concrete around epoxy-coated steel reinforcing bars, wire and welded fabric, the vibrators should be equipped with non-metallic heads.

Annex C
(informative)

Quality assurance and test procedures during the production of epoxy-coated steel reinforcement

C.1 Scope

This annex includes the recommended provisions for the procedures to be included as part of a manufacturer's quality assurance programme for fusion-bonded epoxy coating of reinforcing steels.

Furthermore, it gives recommendations for tests to evaluate the accuracy of the manufacturing process in the framework programme.

C.2 Quality system

The organization and procedural requirements of this scheme are contained in ISO 9002. This schedule covers the specific quality control and operational aspects to be applied to ensure consistency of quality in the product.

C.3 Quality and operational control

C.3.1 Records

Records should be retained for a minimum period of ten years from the date of delivery of the final part of the steel cast. The records should ensure traceability of each batch of epoxy-coated reinforcing steel to its parent cast and coating materials, and each batch of coated reinforcing steel to a specific order. Any concession granted by the purchaser, should be traceable to a specific order.

C.3.2 Reinforcing steel

C.3.2.1 There should be a prescribed system for ordering reinforcing steel from steel manufacturers. This procedure should include all aspects of the material specification which are important in ensuring satisfactory material quality and identity. The reinforcing steel should satisfy the requirements of ISO 6935-1, ISO 6935-2, ISO 10544 or ISO 6935-3, or any other product standard as specified by the purchaser. Supplies should be purchased from certification agency-approved sources only.

C.3.2.2 There should be a designated procedure for the receipt of reinforcing steel from supplying mills which should include inspection and correlation of advice notes and test certificates. No materials should be released for production or sale until verification of conformity to specified requirements has been received subject to 4.10.2.1 of ISO 9002:1994.

C.3.2.3 There should be a prescribed system for the recording and identification of all materials held in stock and subsequently processed. This system should enable the identification of such materials to the original cast information in a manner that reflects the requirements of C.3.1, and should prove objectively that only materials from approved steel mills are being used. Traceability should extend through the coating process to the final product.

C.3.3 Coating materials

C.3.3.1 There should be a prescribed procedure for ordering coating materials. Epoxy powder manufacturers should be approved by an acceptable third party certification body. In the absence of such an approval, powder should be subject to batch checks to ensure compliance with the requirements of ISO 14656. Such checks should be performed at an independent laboratory acceptable to the certification agency.

C.3.3.2 There should be a designated procedure for receipt of coating materials which shall include inspection and correlation of advice notes with written certificates of conformity. No materials should be released for process purposes until verification of conformity to specified requirements has been received.

C.3.3.3 There should be a designated procedure for the recording and identification of all coating materials held in stock and subsequently used in the coating process.

C.3.4 Product during manufacture

C.3.4.1 There should be a prescribed procedure to ensure that reinforcing steel is free from oil, grease or other contaminants before grit blasting.

C.3.4.2 Surface preparation should be achieved by a prescribed grit blasting system and include the method by which the grit is applied, the grit specification, and the bar surface topography requirements.

C.3.4.3 Any pretreatment practice should be fully described, and should include the pretreatment medium, method of application and control of pretreatment material.

C.3.4.4 There should be a prescribed practice for pre-heating the steel prior to coating, which will include a designated system for dealing with the treatment of reinforcing steel held in the furnace during delays of any significant duration. The system should include, where appropriate, combustion conditions and pre-heat temperature. The method of temperature determination should be specified.

C.3.4.5 There should be a prescribed practice for coating application, which will include a system of monitoring and recording coating thickness and imperfections.

C.3.4.6 The curing and cooling practice should be prescribed and should comply with the requirements specified by the powder manufacturer with regard to steel temperature, curing and quenching.

C.3.4.7 There should be a prescribed practice for modification of plant operating conditions when changing from one bar or wire size to another.

C.3.4.8 Testing, inspection and despatch should be in accordance with the appropriate product and/or customer standards. Where appropriate for further processing there should be a prescribed system for transmitting requisite test information to customers.

C.3.5 Product post manufacture

C.3.5.1 There should be a prescribed system for handling steel after epoxy coating which will include procedures for cutting, bending (if type A), bundling, packaging and transportation, in order to minimize damage to the coating.

C.3.5.2 Repair of defects in the epoxy coating or finished steel should be prescribed and will include treatment of bar and wire ends. This procedure should conform to the requirements specified by the manufacturer of the repair medium.

C.3.6 Process control

All process control equipment and testing equipment should be regularly maintained in accordance with a prescribed maintenance programme. Calibration of process control equipment and instruments should be in accordance with ISO 10012-1 as appropriate.

C.3.7 Corrective action

Corrective action procedures should provide for dealing with customer complaints relating to material subject to the certification agency scheme. Record of all complaints received and action taken should be retained. Action, where appropriate, should include recall of suspect material.

C.3.8 Technical service

There should be a system for providing technical advice to customers with regard to processing and application of the products which are subject to this schedule.

C.4 Recommended tests

The procedures recommended by this annex are as follows.

a) The blast media and steel reinforcing bar surface should be evaluated based on:

- screen analysis of blasting abrasive (C.6);
- steel reinforcing bar surface profile measurement (C.7);
- steel reinforcing bar surface residue (C.8);
- detection of salt contamination (C.9);
- detection of mill scale contamination (C.10).

b) The epoxy coating should be evaluated based on the porosity rating and interfacial contamination (C.11).

C.5 Minimum test frequency

a) The blast media and steel reinforcing bar surface evaluation frequencies are as follows:

- screen analysis of blasting abrasive: once per production shift;
- steel reinforcing bar surface profile measurement: three times per production shift and whenever the bar size changes;
- steel reinforcing bar surface residue: three times per production shift and whenever the bar size changes;
- detection of salt contamination: three times per production shift and whenever the bar size or steel source changes;
- detection of mill scale contamination: three times per production shift and whenever the bar size changes.

b) The epoxy coating porosity rating and interfacial contamination should be evaluated a minimum of once per production shift.

C.6 Screen analysis of blasting abrasive

C.6.1 Scope

This test describes a procedure for measuring the particle size distribution of the abrasive.

C.6.2 Equipment

C.6.2.1 Standard sieves, 850 µm, 600 µm, 425 µm, 300 µm, 212 µm, a catch pan and lid (additional pans may be included).

C.6.2.2 **Scale** or **graduated cylinder,** 100 ml.

C.6.2.3 **Funnel.**

C.6.3 Procedure

C.6.3.1 Obtain a representative sample of abrasive from the air wash curtain.

C.6.3.2 Stack the sieves (C.6.2.1) from top to bottom from the coarsest to finest mesh with the pan at the bottom.

C.6.3.3 Place approximately 0,45 kg (or 100 ml) of the sample on the top sieve.

C.6.3.4 Place the lid on the top sieve and shake by hand or mechanically for three minutes.

C.6.3.5 Measure the mass (volume) of material on each sieve and in the pan. Convert these values to percentages.

C.6.4 Criteria

Greater than 80 % of the abrasive should be contained on the 850 µm , 650 µm and 425 µm screens. Less than 3 g of abrasive should be found in the catch pan. If these particle size distribution requirements are not met, the production line should be shut down and the blaster checked. The test should then be repeated.

C.7 Steel reinforcing bar surface profile measurement

C.7.1 Scope

This test measures the surface profile of abrasive blast-cleaned steel reinforcing bars.

C.7.2 Equipment

C.7.2.1 **Spring-loaded dial micrometer.**

C.7.2.2 **Replica tape,** consisting of compressible film containing microscopic bubbles attached to a polyester film 50 µm thick.

C.7.2.3 **Burnishing tool.**

C.7.3 Procedure

C.7.3.1 Obtain an uncoated length of at least 1 m of steel reinforcing bar that has been freshly blast cleaned on the production line.

C.7.3.2 Locate a representative surface site.

C.7.3.3 Peel the wax paper backing from the replica tape (C.7.2.2) and apply it to the blasted surface.

C.7.3.4 Rub the burnishing tool (C.7.2.3.) over the round cut-out portion of the tape until the entire circular area has uniformly darkened.

C.7.3.5 Remove the replica tape from the bar and place it between the anvils of the spring micrometer (C.7.2.1). Subtract 50 µm from the gauge reading to compensate for the thickness of the plastic film. The gauge reading is the average peak-to-valley height of the blasted surface.

C.7.3.6 Perform the procedure on two other areas of the test bar.

Instead of replica tape, a "profilometer" type surface measurement may be used to measure the surface profile.

C.7.4 Criteria

The suitable average blast profile roughness depth range is specified in clause 5. If this anchor profile range is not found, the production line should be shut down and the blaster checked. The test should then be repeated.

C.8 Steel reinforcing bar surface residue

C.8.1 Scope

This test measures the amount of visible residue left on the steel reinforcing bar surface by the blast cleaning process.

C.8.2 Equipment

C.8.2.1 **White adhesive tape,** 6 mm wide (3M #471 plastic tape or equivalent).

C.8.2.2 **Visual contamination charts** (see Figure C.1).

C.8.2.3 **Microscope,** magnification × 30.

C.8.2.4 **Marker pen.**

C.8.2.5 **Utility knife.**

C.8.2.6 **Burnishing tool.**

C.8.3 Procedure

C.8.3.1 Obtain an uncoated length of at least 1 m of steel reinforcing bar that has been freshly blast cleaned on the production line.

C.8.3.2 Approximately 300 mm from one end of the bar, place a mark between the transverse ribs using the marker pen (C.8.2.4). Between the next set of transverse ribs, apply a piece of the adhesive tape. Pass over the next two valleys and place a second piece of adhesive tape between the next set of transverse ribs. In the next valley, place a second mark with the marker pen.

C.8.3.3 Rub the tapes (C.8.2.1) lightly with the burnishing tool (C.8.2.6).

C.8.3.4 Remove the tapes.

C.8.3.5 Examine the darkest area on the tapes using the 30 × magnifying glass or microscope (C.8.2.3) and compare them to the visual contamination charts (C.8.2.2) in order to determine the percentage of backside contamination.

C.8.3.6 Approximately 300 mm from the other end of the bar, and on the other side from the first test site, apply another piece of the adhesive tape. Repeat steps C.8.3.3 to C.8.3.5.

C.8.3.7 Bend the bar 180° around a 6 d mandrel with the marked area on the outside radius of the bend. Care should be taken not to contaminate the marked area before and after the bend.

C.8.3.8 In the marked area, apply a fresh piece of the adhesive tape between the set of transverse ribs next to the first mark. Skip the next two valleys and place a second piece of adhesive tape between the next set of transverse ribs. The next valley should contain the second mark from the marker pen. The new tapes should be located in the same positions as the first set of tapes applied before bending.

C.8.3.9 Repeat steps C.8.3.3 to C.8.3.5.

C.8.4 Criteria

Contamination on the straight and bent bar samples should not exceed 30 %. If the percent contamination is in excess of this value, the production line should be shut down and the blaster checked. The test should then be repeated.

C.9 Detection of salt contamination

C.9.1 Scope

This test is used to detect chloride that may be present on the steel reinforcing bar surface after blast cleaning and also in the abrasive media.

C.9.2 Equipment

C.9.2.1 **Potassium ferricyanide-coated paper strips.**

C.9.2.2 **Distilled water.**

C.9.2.3 **Plastic bags.**

C.9.2.4 **Plastic spray bottle.**

C.9.2.5 **Rubber gloves.**

C.9.2.6 **Tweezers.**

C.9.2.7 **Chloride charts** (see Figure C.2).

C.9.3 Procedure

C.9.3.1 Upon receipt, store the potassium ferricyanide-coated strips (C.9.2.1) in a sealed plastic bag (C.9.2.3). Protect the strips from exposure to light. The test paper should have a yellow colour (no blue colour should be observed). Even with proper care, the test strips deteriorate over time.

C.9.3.2 Obtain an uncoated length of at least 1 m of steel reinforcing bar that has been freshly blast cleaned on the production line.

C.9.3.3 Wet the test paper with distilled water (C.9.2.2) until the paper is saturated. Allow any excess water to drip off.

C.9.3.4 Lightly press the test paper on to the reinforcing steel surface and maintain contact for 30 s. Remove the paper, turn it over and observe for colour change. The presence of soluble ferrous chloride will be indicated by a blue colour.

C.9.3.5 When testing the abrasive media, sprinkle the abrasive on the wet test paper until it is covered. Leave the abrasive on the paper for 30 s.

C.9.3.6 Avoid contact of the test paper with the fingers.

C.9.3.7 Compare the test strip to the chloride charts (C.9.2.7) in oreder to estimate the chloride concentration on the steel.

C.9.3.8 Perform the procedure on two other areas of the test bar.

C.9.4 Criteria

If chloride is found to be present on the blasted steel reinforcing bar or in the abrasive media, repeat the test. If chloride is still observed in the new sample, shut the production line down until the source of the contamination is found and corrected. The test should then be repeated.

C.10 Detection of mill scale contamination

C.10.1 Scope

This test is used to determine the cleanliness of the blasted steel reinforcing bar surface when examined for mill scale.

C.10.2 Equipment

C.10.2.1 **Copper sulfate,** anhydrous.

C.10.2.2 **Distilled water.**

C.10.2.3 **Eye dropper** and **clean bottle,** for mixing the solution.

C.10.2.4 **Microscope,** magnification × 30.

C.10.2.5 **Mill scale contamination charts** (see Figure C.3).

C.10.3 Procedure

C.10.3.1 Dissolve 5 % (m/m) copper sulfate (C.10.2.1) in distilled water (C.10.2.2).

C.10.3.2 Obtain an uncoated length of at least 1 m of steel reinforcing bar that has been freshly blast cleaned on the production line. This test piece shall not be wiped or cleaned in any way.

C.10.3.3 Apply a few drops of copper sulfate solution to the blasted surface and allow it to sit for 1 min.

C.10.3.4 All clean steel will react with copper sulfate with the surface iron replacing the copper in solution thus plating out the copper. The copper sulfate will not react with mill scale, dirt or rubber.

C.10.3.5 Use a 30 × magnifying glass or microscope (C.10.2.4) in order to estimate the amount of mill scale and other non-reactive contaminants by comparing the surface to the mill scale contamination charts (C.10.2.5).

C.10.3.6 As a minimum, this test should be conducted once on opposite sides of the bar (a minimum of two tests per bar).

C.10.4 Criteria

If mill scale is found to be in excess of 5 % of the steel surface, the production line should be shut down and the blaster checked. The test should then be repeated.

C.11 Porosity rating and interfacial contamination

C.11.1 Scope

This porosity rating method provides a numerical value for the level of porosity in a coating. The interfacial contamination test also provides an indication of the amount of visible residue left on the substrate from the abrasive cleaning process. These procedures are combined as they utilize the same test specimens. Type A coatings require the use of liquid nitrogen to produce chip samples.

C.11.2 Equipment

C.11.2.1 **Microscope,** magnification × 30.

C.11.2.2 **Bend equipment.**

C.11.2.3 **Freezer** or **dry ice.**

C.11.2.4 **Copper sulfate solution,** 5 % (*m*/*m*).

C.11.2.5 **Porosity charts A and B** (see Figure C.4).

C.11.2.6 **Interfacial contamination comparison charts** (Figure C.1 can be used).

C.11.3 Procedure

C.11.3.1 Obtain a coated length of at least 1 m of steel reinforcing bar that has been freshly coated on the production line.

C.11.3.2 Chill the sample with dry ice or a suitable freezer (C.11.2.3) to –40 °C or below) for a minimum of 30 min. Bend the specimen approximately 30° over a 13 mm bar pin radius mandrel (C.11.2.2) in order to crack the coating. A large enough chip sample should be removed to give a good representation of the steel surface (at least 100 mm^2).

C.11.3.3 Examine the cross-section of the coating at a magnification of × 30 and determine the porosity level based on porosity chart A. If the cross-sectional porosity rating is 2 or less, no interfacial test is required.

C.11.3.4 If the rating is 3 or greater, or if the bulk of the void areas are within 20 % of the coating nearest the substrate, a sharp razor blade should be used to remove a thin layer from the underside of the coating thus exposing its degree of porosity. The interfacial porosity can then be estimated using porosity chart B (C.11.2.5).

C.11.3.5 To determine the interfacial contamination rating observe the backside (the side originally against the steel surface) of the coating at a magnification of × 30 and estimate the amount of non-coating material as a percentage of total viewed area using the interfacial contamination comparison chart (C.11.2.6). Figure C.1 can be used. Record this value as "% contaminated area".

C.11.3.6 Dip the coating sample into copper sulfate solution (C.11.2.4) for 10 s and again observe the backside of the coating under magnification. The contamination which is primarily steel will change to a copper colour. Record this value as "% contaminated area which is steel".

C.11.4 Criteria

If a rating of 3 or greater is determined on the interfacial porosity measurement or the non-steel contamination level is greater than 30 % on the interfacial contamination test, the production line should be shut down until the source of the porosity/contamination is found and corrected. The test should then be repeated.

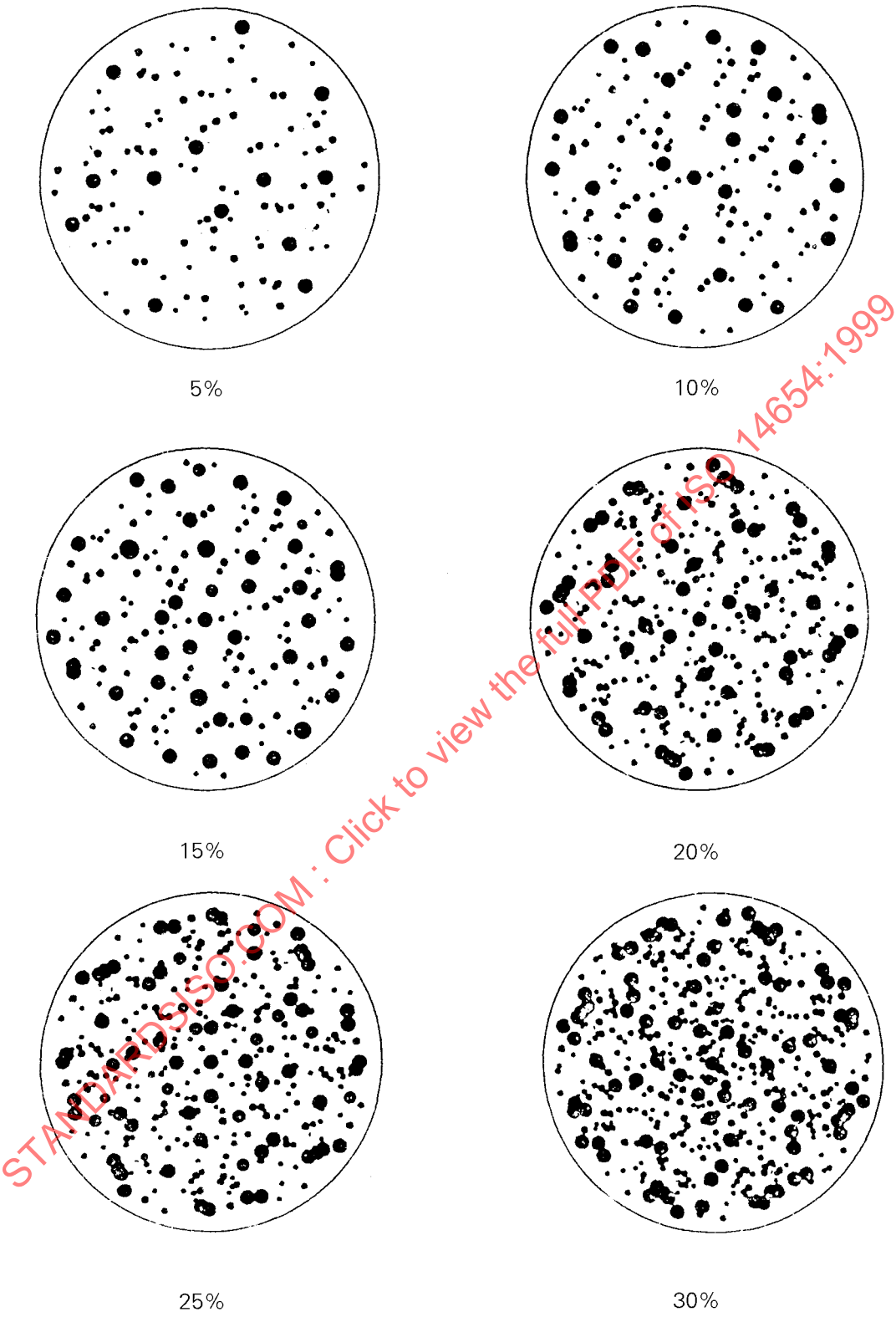


Figure C.1 — Backside contamination charts

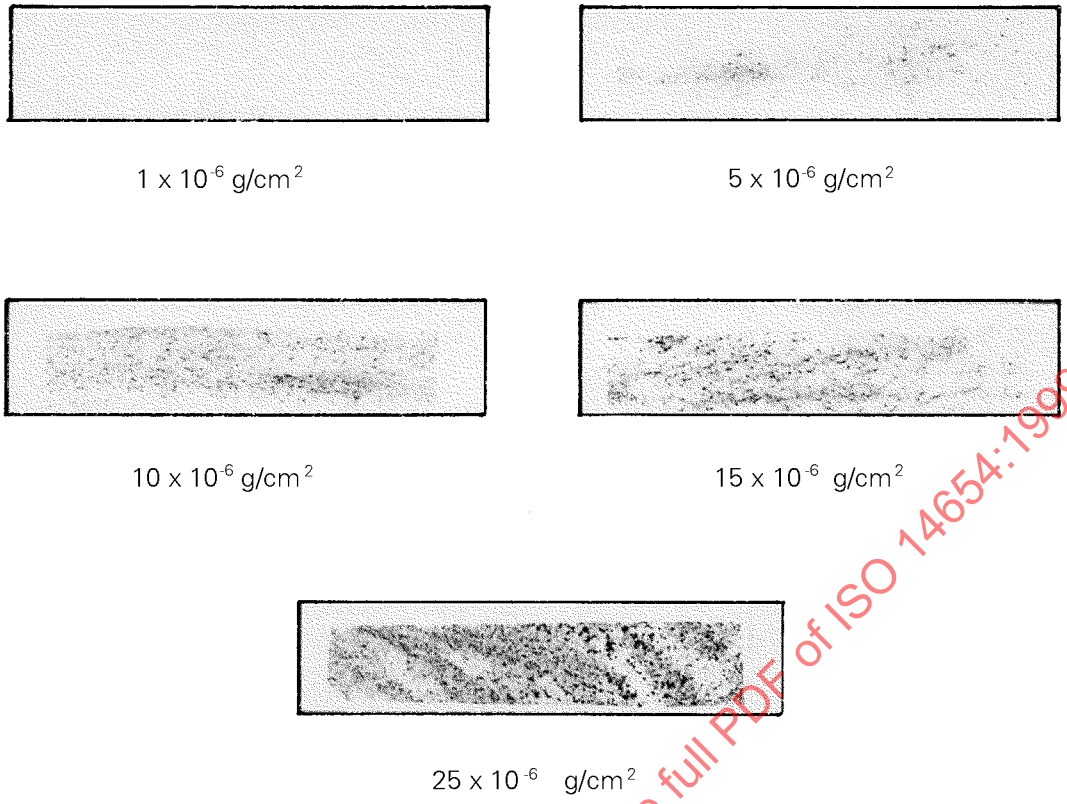


Figure C.2 — Chloride charts

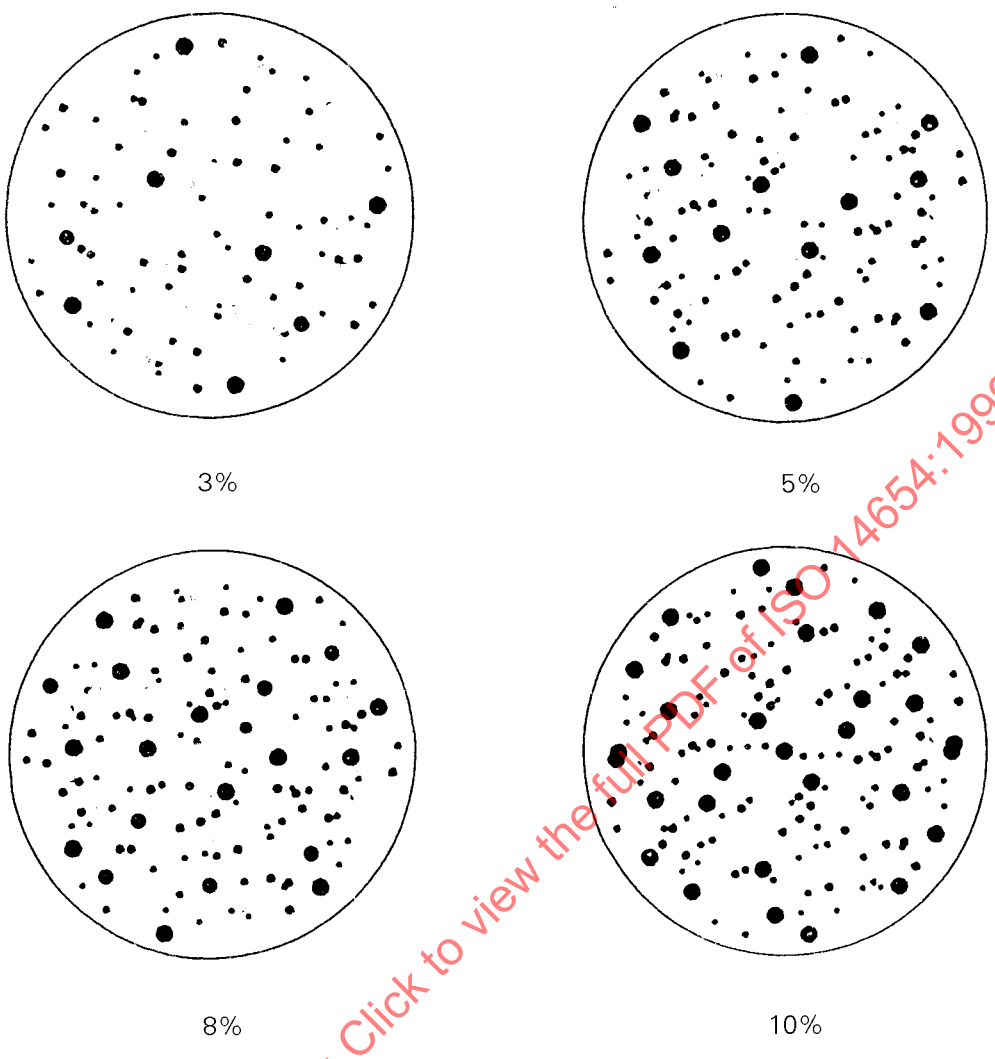
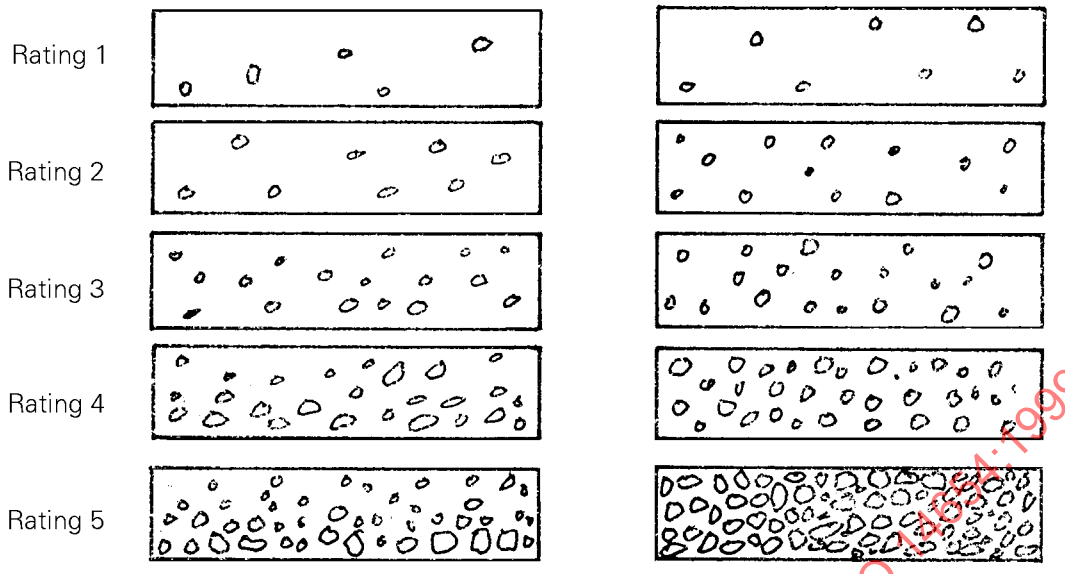
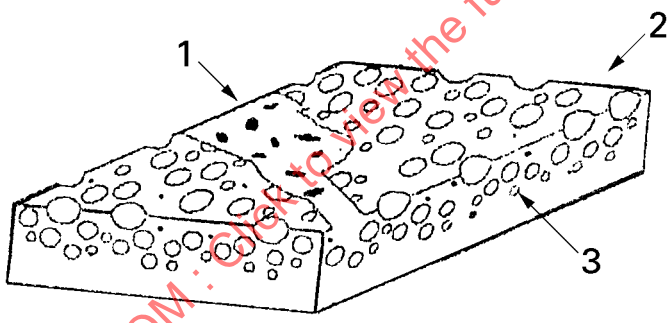


Figure C.3 — Mill scale contamination charts



Example of coating chip:



Key

1 Check backside contamination in these areas
2 Check interfacial porosity in these areasa
3 Check cross sectional porosity in these areas

Figure C.4 — Porosity charts A and B