Designation: C1556 – 22

Standard Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion[1]

This standard is issued under the fixed designation C1556; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the laboratory determination of the apparent chloride diffusion coefficient for hardened cementitious mixtures.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C125 Terminology Relating to Concrete and Concrete Aggregates

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C1152/C1152M Test Method for Acid-Soluble Chloride in Mortar and Concrete

C1202 Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

2.2 *NORDTEST Standards:*

NT BUILD 443 Approved 1995-11, Concrete, Hardened: Accelerated Chloride Penetration (in English)[3]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *apparent chloride diffusion coefficient, D_a, n*—a chloride transport parameter calculated from acid-soluble chloride profile data obtained from saturated specimens exposed to chloride solutions, without correction for chloride binding, that provides an indication of the ease of chloride penetration into cementitious mixtures.

3.2.2 *chloride binding, v*—the chemical process by which chloride ion is removed from solution and incorporated into cementitious binder hydration products.

3.2.2.1 *Discussion*—Chloride binding is primarily associated with hydration products formed by the aluminate phase of cement and mixtures containing ground granulated blast furnace slag.

3.2.3 *chloride penetration, v*—the ingress of chloride ions due to exposure to external sources.

3.2.4 *exposure liquid, n*—the sodium chloride solution in which test specimens are stored prior to obtaining a chloride profile.

3.2.5 *exposure time, n*—the time that the test specimen is stored in the solution containing chloride ion.

3.2.6 *initial chloride-ion content, C_i , n*—the ratio of the mass of chloride ion to the mass of concrete for a test specimen that has not been exposed to external chloride sources.

3.2.7 *profile grinding, v*—the process of grinding off and collecting a powder sample in thin successive layers from a test specimen using a dry process.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.66 on Concrete's Resistance to Fluid Penetration.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Published by NORDTEST, P.O. Box 116 FIN-02151 ESPOO Finland, Project 1154-94, e-mail: nordtest @vtt.fi, website: http://www.vtt.fi/nordtest

***A Summary of Changes section appears at the end of this standard**

3.2.8 *surface chloride content, C_s, n*—the theoretical ratio of the mass of chloride ion to the mass of concrete at the interface between the exposure liquid and the test specimen.

4. Summary of Test Method

4.1 Obtain a representative sample of the cementitious mixture prior to exposure to chloride ion. Separate each sample into a test specimen and an initial chloride-ion content specimen. Crush the initial chloride-ion content specimen and determine the initial acid-soluble chloride-ion content. Seal all sides of the test specimen, except the test surface, with a suitable barrier coating. Saturate the sealed specimen in a calcium hydroxide solution, rinse with tap water, and then place in a sodium chloride solution. After a specified exposure time, the test specimen is removed from the sodium chloride solution and thin layers are ground off parallel to the exposed face of the specimen. The acid-soluble chloride content of each layer is determined. The apparent chloride diffusion coefficient and the projected surface chloride-ion concentration are then calculated using the initial chloride-ion content, and at least six related values for chloride-ion content and depth below the exposed surface.

5. Significance and Use

5.1 This test method is applicable to cementitious mixtures that have not been exposed to external chloride ions, other than the negligible quantity of chloride ion exposure from sample preparation using potable water, prior to the test.

5.2 The calculation procedure described in this test method is applicable only to laboratory test specimens exposed to a sodium chloride solution as described in this test method. This calculation procedure is not applicable to specimens exposed to chloride ions during cyclic wetting and drying.

NOTE 1—The diffusion of ionic species in concrete occurs within the fluid-filled pores, cracks and void spaces. The concentration and valence of other ionic species in the pore fluid also influence the rate of chloride diffusion, and therefore, the apparent diffusion coefficient as determined by this test procedure.

5.3 In most cases, the value of the apparent chloride diffusion coefficient for cementitious mixtures changes over time (see Note 2). Therefore, apparent diffusion coefficients obtained at early ages may not be representative of performance in service.

NOTE 2—The rate of change of the apparent diffusion coefficient for cementitious mixtures containing pozzolans or blast-furnace slag is typically different than that for mixtures containing only portland cement.

5.4 The apparent chloride diffusion coefficient is used in Fick's second law of diffusion to estimate chloride penetration into cementitious mixtures that are in a saturated condition.

5.5 The apparent chloride diffusion coefficient is commonly used in chloride ingress models based on Fick's second law of diffusion. The apparent diffusion coefficient determined by this method includes bound chloride, so proper use of the apparent chloride diffusion coefficient to predict chloride ingress requires consideration of chloride binding.

5.6 The resistance to chloride penetration is affected by such factors as the environment, finishing, mixture composition, workmanship, curing, and age.

6. Apparatus

6.1 *Balance,* accurate to at least ±0.01 g.

6.2 *Thermometer,* accurate to at least ±1.0 °C.

6.3 *Controlled Temperature Laboratory or Chamber.* The laboratory or chamber shall maintain the temperature of a water bath at 23 °C ± 2 °C.

6.4 *Plastic Container,* with tight-fitting lid. Select a container size in accordance with provisions in 9.1.2.

6.5 Equipment for grinding off and collecting powder from concrete, mortar, or grout specimens in layers of approximately 2 mm thickness. Refer to Figs. 1 and 2 for examples of satisfactory equipment (see Note 3).

NOTE 3—A lathe or milling machine equipped with a short-barrel carbide-tipped, or diamond-tipped, core drill bit has been found satisfactory for profile grinding.

6.6 *Resealable Polyethylene Bags,* 200 mm to 300 mm wide by 250 mm to 300 mm long, and sheet thickness not less than 0.1 mm.

6.7 Equipment for crushing concrete, mortar or grout. Suitable equipment is described in Test Method C1152/C1152M.

6.8 Equipment for chloride analysis as described in Test Method C1152/C1152M.

6.9 *Slide Caliper,* accurate to at least ± 0.1 mm.

7. Reagents and Materials

7.1 *Distilled or De-ionized Water.*

7.2 *Calcium Hydroxide [$Ca(OH)_2$],* technical grade.

7.3 *Calcium Hydroxide Solution,* saturated, (approx. 3 g/L).

7.4 *Sodium Chloride [NaCl],* technical grade.

7.5 *Exposure Liquid*—An aqueous NaCl solution prepared with a concentration of 165 g ± 1 g NaCl per L of solution.

7.6 *Two-component Polyurethane or Epoxy-resin Based Paint,* capable of forming a barrier membrane that is resistant to chloride ion diffusion.

8. Test Specimens

8.1 Drilled cores, molded cylinders, or molded cubes are acceptable test specimens. One sample consists of at least two test specimens representative of the cementitious mixture under test. Specimens must be free of defects such as voids or cracks visible to the unaided eye (see Note 5). The minimum dimension across the exposed surface of each test specimen must be at least 75 mm, but not less than three times the nominal maximum aggregate particle size. The specimen depth must be at least 75 mm.

NOTE 4—Specimens with voids deeper than the profile layer thickness can increase the apparent rate of chloride penetration, and increases test variability.

NOTE 5—The quality of the concrete between the exposed surface and the outermost layer of reinforcement can deviate from that in the rest of the system, as this region is often affected by construction practices.

8.2 Unless otherwise specified, provide 28 days of laboratory standard moist curing in accordance with Practice C31/C31M or C192/C192M prior to sample preparation for immersion in the exposure liquid.