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Standard Guide for Microbially Induced Corrosion of Concrete Products[1]

This standard is issued under the fixed designation C1894; 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 guide discusses microbially induced corrosion (MIC) of concrete products and laboratory test methods for determining the resistance of concrete to MIC. Although the guide is intended for concrete products, it also covers cementitious mortar and paste that are used in specialized applications or laboratory investigations.

1.2 While this guide discusses concrete materials and admixtures, the document is not intended to specifically address field exposure conditions or sewage pipe, concrete tank, or concrete riser network design.

1.3 This guide does not cover live trial tests where concrete coupons or other specimens are monitored in sewers.

1.4 This guide does not cover concrete deterioration due to chemical sulfate attack, which is caused by the reaction of sulfate compounds that exist in wastewater with the hydration products of cement. Test methods for assessing sulfate attack are provided by Test Methods C452 and C1012/C1012M.

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

1.6 The text of this guide references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.7 *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.*

1.8 *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
C33/C33M Specification for Concrete Aggregates
C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C125 Terminology Relating to Concrete and Concrete Aggregates
C150/C150M Specification for Portland Cement
C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C260/C260M Specification for Air-Entraining Admixtures for Concrete
C294 Descriptive Nomenclature for Constituents of Concrete Aggregates
C452 Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate
C494/C494M Specification for Chemical Admixtures for Concrete
C497 Test Methods for Concrete Pipe, Concrete Box Sections, Manhole Sections, or Tile
C595/C595M Specification for Blended Hydraulic Cements
C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
C822 Terminology Relating to Concrete Pipe and Related Products
C989/C989M Specification for Slag Cement for Use in Concrete and Mortars
C1012/C1012M Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution
C1017/C1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete (Withdrawn 2022)[3]
C1240 Specification for Silica Fume Used in Cementitious Mixtures
C1600/C1600M Specification for Rapid Hardening Hydraulic Cement

[1] This test method is under the jurisdiction of ASTM Committee C13 on Concrete Pipe and is the direct responsibility of Subcommittee C13.03 on Determining the Effects of Biogenic Sulfuric Acid on Concrete Pipe and Structures.

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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] The last approved version of this historical standard is referenced on www.astm.org.

C1898 Test Methods for Determining the Chemical Resistance of Concrete Products to Acid Attack
C1904 Test Methods for Determination of the Effects of Biogenic Acidification on Concrete Antimicrobial Additives and/or Concrete Products
D4262 Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces
D4783 Test Methods for Resistance of Adhesive Preparations in Container to Attack by Bacteria, Yeast, and Fungi
G21 Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi

2.2 *Other Standards:*[4]

ISO 22196 Measurement of antibacterial activity on plastics and other non-porous surfaces

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, refer to Terminology standards C125 and C822.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *antimicrobial admixture, n*—EPA registered chemical admixture that is intended to inhibit microorganism growth (-static effect) or kill microorganisms (-cidal effect). Antimicrobial admixtures are registered according to the organisms they are effective against and typically, due to their chemical nature for industrial use, have broad spectrum effectiveness against many organism types, including bacteria, fungi and algae.

3.2.2 *aerobic bacteria, n*—bacteria that have a metabolic requirement for the presence of available oxygen to grow and thrive.

3.2.3 *anaerobic bacteria, n*—bacteria that do not live or grow when oxygen is present.

3.2.4 *biofilm, n*—a complex mixture of established microorganisms, microorganism components (extra-cellular matrix) and environmental detritus.

3.2.5 *biogenic (biotic) acidification, n*—process of production of mixture of inorganic and organic acids from respiring organisms resulting in acidification of the microbial environment.

3.2.6 *chemical (abiotic) acidification, n*—when compounds like ammonia, nitrogen oxides and sulphur dioxides are converted in a chemical reaction into acidic substances.

3.2.7 *Desulfovibrio desulfuricans, n*—anaerobic dissimilatory sulfate-reducing bacterium.

3.2.8 *dissolved oxygen (DO) content, n*—oxygen (O_2) molecules available for respiration to aquatic organisms.

3.2.9 *hydrogen sulfide (H_2S), n*—a colorless poisonous gas made by the action of acids on sulfides. At low concentrations, H_2S has the odor of rotten eggs, but at higher, lethal concentrations, it is odorless.

3.2.10 *microbially induced corrosion (MIC) of concrete, n*—a multi-stage deterioration process influenced by the presence and activities of bacteria within wastewater collection, storage and treatment infrastructure. Also referred to as biogenic sulfuric acid (BSA) corrosion, and biological corrosion of concrete, hydrogen sulfide corrosion, microbial corrosion of concrete.

3.2.11 *chemical oxidation, n*—chemical reaction in which the atoms in a molecule lose electrons and the net valence of the molecule is correspondingly increased, commonly associated with addition of molecular oxygen to the chemical composition of an 'oxidized' material.

3.2.12 *sulfate oxidizing bacteria (SOB), n*—bacteria that can convert hydrogen sulfide (H_2S) into elemental sulfur (S) by partial oxidation, or sulfate (SO_4^{2-}).

3.2.13 *sulfate reducing bacteria (SRB), n*—bacteria that can obtain energy by oxidizing organic compounds or molecular hydrogen while reducing sulfate to hydrogen sulfide. Most sulfate reducing bacteria can also reduce other oxidized inorganic sulfur compounds, such as sulfite, thiosulfate/elemental sulfur. A common mechanism for anaerobic bacterial for respiration in the absence of oxygen.

3.2.14 *Thiobacillus species (for example, Thiobacillus thioparus, Starkeya novella, Halothiobacillus neapolitanus, Thiomonas intermedia and Acidithiobacillus thiooxidans.), n*—a genus of gram negative bacteria, known for using sulfur and sulfur compounds as part of their respiration cycle (sulfur a.k.a. thio-).

3.2.15 *turbulence, n*—violent or unsteady movement of air or water, or of some other fluid.

4. Microbially Induced Corrosion (MIC) of Concrete

4.1 The MIC of concrete is considered to be a three-stage process (**1-3**)[5] with the reduction in pH (Stage I) (for example, 12.5 > pH > 9-10) (**4, 5**), the establishment of biofilms which further lowers the pH (Stage II) (for example, 9-10 > pH > 4-6) (**1, 4, 6, 7**) and eventual deterioration due to biogenic acid exposure (Stage III) (for example, < ~4 pH) (**7-11**). Fig. 1 illustrates these stages that have been observed in laboratory testing. Testing procedures are described that simulate all three stages or individual stages. This document clarifies the stages where each test applies.

4.2 This section provides a brief summary of the commonly accepted chain of events that lead to the initiation and propagation of MIC in wastewater collection networks. Additional details are provided in 4.3.

4.2.1 Abiotic lowering of the concrete surface pH takes place before colonization by bacteria can occur. Carbonation, the process by which atmospheric carbon dioxide reacts with calcium hydroxide and water within the cement microstructure, is typically credited with the initial reduction in surface pH of the concrete. Leaching of calcium hydroxide through contact with wastewater may also lead to a reduction in pH near the concrete surface (**12, 13**). It is also claimed that H_2S undergoes inorganic chemical reaction to lower the initial pH of concrete

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] The boldface numbers in parentheses refer to a list of references at the end of this standard.