
Standard Method of Test for

**Surface Resistivity Indication of
Concrete's Ability to Resist
Chloride Ion Penetration**

AASHTO Designation: T 358-22¹

Technically Revised: 2022

Editorially Revised: 2021

Technical Subcommittee: 3c, Hardened Concrete



**American Association of State Highway and Transportation Officials
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1. SCOPE

- 1.1. This test method covers the determination of the electrical resistivity of water-saturated concrete to provide a rapid indication of its resistance to the penetration of chloride ions. This test method is applicable to types of concrete where correlations have been established between this test procedure and long-term chloride diffusion procedures such as those described in ASTM C1556. Examples of such correlations are discussed in the reference shown in Hamilton et al. (2007).
- 1.2. The values stated in SI units are to be regarded as the 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 and health practices and determine the applicability of regulatory limitations prior to use.*
- 1.4. *The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
- M 201, Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
 - M 339M/M 339, Thermometers Used in the Testing of Construction Materials
 - R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
 - R 39, Making and Curing Concrete Test Specimens in the Laboratory
 - R 100, Making and Curing Concrete Test Specimens in the Field
 - R 101, Developing Performance Engineered Concrete Pavement Mixtures
 - T 24M/T24 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
 - T 277, Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

- < TP 119, Standard Method of Test for Electrical Resistivity of a Concrete Cylinder Tested in a Uniaxial Resistance Test

2.2.

ASTM Standards:

- < C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- < C1202, Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration
- < C1556, Standard Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion
- < E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
- < E230/E230M, Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples
- < E2877, Standard Guide for Digital Contact Thermometers

2.3.

International Electrotechnical Commission Standard:

- < IEC 60584-1:2013, Thermocouples - Part 1: EMF Specifications and Tolerances

2.4.

Other Documents:

- < Chini, A. R., L. C. Muszynski, and J. Hicks. *Determination of Acceptance Permeability Characteristics for Performance-Related Specifications for Portland Cement Concrete*. Final Report (Contract No. BC 354-41) submitted to Florida Department of Transportation, Tallahassee, FL, July 2003.
- < Hamilton, H. R., A. J. Boyd, and E. A. Vivas. *Permeability of Concrete—Comparison of Conductive and Diffusion Methods*. Final Report (Contract No. BD 536) submitted to Florida Department of Transportation, Tallahassee, FL, June 2007.
- < Kessler, R. J., R. G. Powers, and M. A. Paredes. Resistivity Measurements of Water Saturated Concrete as an Indicator of Permeability. Paper 05261. *Corrosion 2005*, Houston, TX, sponsored by NACE International, April 3–7, 2005.
- < Kessler, R. J., R. G. Powers, E. A. Vivas, M. A. Paredes, and Y. P. Virmani. Surface Resistivity as an Indicator of Concrete Chloride Penetration Resistance. 2008 Concrete Bridge Conference.
- < Morris, W., E. I. Moreno, and A. A. Sagüés. Practical Evaluation of Resistivity of Concrete in Test Cylinders Using a Wenner Array Probe. *Cement and Concrete Research*, Vol. 26, No. 12, 1996, ScienceDirect, Elsevier, Amsterdam, The Netherlands, December 1996, pp. 1779–1787.
- < Paredes, M., N. M. Jackson, A. El Safty, J. Dryden, J. Joson, H. Lerma, and J. Hersey. Precision Statements for the Surface Resistivity of Water Cured Concrete Cylinders in the Laboratory. *Advances in Civil Engineering Materials*, Vol. 9, No. 4, PAPER ID ACEM104268, 2012. Available from www.astm.org.
- < Spragg, R. P., S. Jones, Yiwen Bu, Yang Lu, D. P. Bentz, K. A. Snyder, and W. J. Weiss. Leaching of Conductive Species: Implications to Measurements of Electrical Resistivity. *Cement and Concrete Composites*, Vol. 79, February 2017. Available from <https://doi.org/10.1016/j.cemconcomp.2017.02.003>.
- < Spragg, R. P., Yiwen Bu, K. A. Snyder, D. P. Bentz, and W. J. Weiss. *Electrical Testing of Cement-Based Materials: Role of Testing Techniques, Sample Conditioning, and Accelerated Curing*. FHWA/IN/JTRP-2013/28. Joint Transportation Research Program, Indiana Department of Transportation, and Purdue University, West Lafayette, IN, 2013. Available from <https://doi.org/10.5703/1288284315230>.
- < Weiss, W. J., K. A. Snyder, J. W. Bullard, and D. P. Bentz. Using a Saturation Function to Interpret the Electrical Properties of Partially Saturated Concrete. *Journal of Materials in Civil*

3. TERMINOLOGY

3.1. Definitions:

- 3.1.1. *apparent surface resistivity*—a value correlated to surface resistivity that is dependent on the specimen size and geometry of the testing configuration. Apparent surface resistivity does not account for the effect of the finite size of the specimen with respect to the probe spacing.

Note 1—On many commercial units, the apparent surface resistivity is automatically calculated and displayed on the screen, but offer no indication this correction is applied nor is it often clearly identified that the value displayed is apparent surface resistivity.

- 3.1.2. *electrical resistance*—the measure of the opposition to the flow of electric current, that is dependent of the size and shape of the specimen and the geometry of how it is measured.

Note 2—Some suppliers of testing units will utilize the term Impedance instead of resistance. Impedance is analogous to resistance, and for most moist-cured concretes the terms are considered equivalent.

- 3.1.3. *electrical resistivity*—a measure of the opposition to the flow of electric current, that is independent of the size and shape of the specimen and the geometry of how it is measured.

- 3.1.4. *geometric correction*—corrections to measured values to determine intrinsic material properties. The corrections are typically a function of electrode configuration, specimen size, and specimen shape.

- 3.1.5. *surface resistivity*—the electrical resistivity when tested on the surface of a specimen, most often on the circumference of cast or cored cylinder. It requires the application of a unitless geometric correction to the apparent surface resistivity to account for the non-infinite geometry. Surface resistivity is analogous to a material's electrical resistivity, with surface indicating it was measured using a surface test.

- 3.1.6. *uniaxial resistivity or bulk resistivity*—the electrical resistivity when tested along the longest axis of a specimen with uniform cross-section (e.g., prism or cylinder). It requires the application of a geometric correction to the measured resistance. Uniaxial resistivity is analogous to a material's electrical resistivity, with uniaxial indicating it was measured using a uniaxial test. The two terms (uniaxial resistivity or bulk resistivity) can be used interchangeably.

- 3.1.7. *Wenner array probe*—an equally spaced, four-probe device, that applies an alternating current between the outer probes and measures the voltage between the inner probes. The ratio of voltage and current is multiplied by a factor of $2\pi a$, where a is the spacing between the probes, to determine the apparent surface resistivity.

Note 3—The Wenner probe was originally developed for an infinite half-space geometry.

3.2. Units and Unit Conversions:

- 3.2.1. Resistance is measured in units of ohms (Ω), with the use of SI prefixes.

- 3.2.2. Resistivity is measured in units of ohm meter ($\Omega \cdot \text{m}$), with SI prefixes often being used. Another common unit of resistivity is kilohm centimeter ($\text{k}\Omega \cdot \text{cm}$), which has a conversion of $10\Omega \cdot \text{m} = 1\text{k}\Omega \cdot \text{cm}$.

Note 4—Both apparent surface resistivity and surface resistivity are measured in units of ohm meter, which complicates properly differentiating between these two types of measurements.

4. SUMMARY OF TEST METHOD

- 4.1. This test method consists of measuring the resistivity of 100-mm (4-in.) nominal diameter by 200 mm (8 in.) nominal length or 150-mm (6 in.) nominal diameter by 300-mm (12 in.) nominal length cylinders or cores by use of a 4-pin Wenner probe array. An alternating current (AC) potential difference is applied by the surface resistivity apparatus at the outer pins of the Wenner array generating current flow in the concrete. The resultant potential difference between the two inner pins is measured. The current used and resultant potential along with the affected sample area are used to calculate the resistivity of the concrete. The resistivity, in kilohm centimeter ($k\Omega \cdot \text{cm}$), has been found to be related to the resistance of the specimen to chloride ion penetration.

5. SIGNIFICANCE AND USE

- 5.1. This test method covers the laboratory evaluation of the electrical resistivity of concrete samples to provide a rapid indication of their resistance to chloride ion penetration. Wenner probe measurements have shown good correlations with other electrical indication tests such as the T 277 and the ASTM C1202 tests. In most cases, the electrical resistivity results have shown good correlation with chloride exposure tests, such as ASTM C1556, on companion cylinders cast from the same concrete mixtures (Hamilton et al., 2007 and Kessler et al., 2005 and 2008).
- 5.2. This test method is suitable for evaluation of the potential resistance of concrete mixtures using different materials and mixture proportions to chloride ion penetration and for quality control and acceptance during projects, as well as for research and development.
- 5.3. Appendix X1 offers guidance on estimating chloride ion penetration using the results of this method.
- 5.4. The surface resistivity can be calculated from the apparent surface resistivity using the geometric correction outlined in Appendix X2. Surface resistivity can be used in life cycle estimation tools outlined in R 101. The test method applies to 100 mm (4 in.) and 150 mm (6 in.) nominal diameter specimens in determination of their apparent surface resistivity. Other specimen diameters may be tested with appropriate changes to the geometric correction outlined in Appendix X2. (See Appendix X2 and the reference in Morris et al. (1996) and Paredes et al. (2012).
- 5.5. Other factors that are known to affect resistivity as well as chloride ion penetration include water/cement ratio; use of pozzolans or slag cement; the presence of polymeric admixtures; air-void system; aggregate type; and degree of consolidation, paste volume, curing time, and curing method.

Note 5—Preliminary results indicate exposing concretes to extremely low temperatures at early ages (between casting and demolding) can significantly reduce resistivity values measured at later ages.