



Designation: C457/C457M – 23a

Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete¹

This standard is issued under the fixed designation C457/C457M; 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 describes procedures for microscopical determinations of the air content of hardened concrete and of the specific surface, void frequency, spacing factor, and paste-air ratio of the air-void system in hardened concrete. Three procedures are described:

- 1.1.1 *Procedure A*—Linear-traverse method.
- 1.1.2 *Procedure B*—Modified point-count method.
- 1.1.3 *Procedure C*—Contrast enhanced method.

1.2 This test method is based on prescribed procedures that are applied to sawed and lapped sections of specimens of concrete from the field or laboratory.

1.3 It is intended to outline the principles of this test method and to establish standards for its adequate performance but not to describe in detail all the possible variations that might be used to accomplish the objectives of this test method.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.5 *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.* For specific hazard statements see [Note 9](#) and [Note 12](#).

1.6 *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.*

¹ This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.65 on Petrography.

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2. Referenced Documents

2.1 ASTM Standards:²

- C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
- C125 Terminology Relating to Concrete and Concrete Aggregates
- C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
- C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
- C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
- C231/C231M Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
- C666/C666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing
- C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- C672/C672M Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals (Withdrawn 2021)³
- C823/C823M Practice for Examination and Sampling of Hardened Concrete in Constructions
- C856 Practice for Petrographic Examination of Hardened Concrete
- D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
- E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 American Concrete Institute Standards:⁴

- 201.2R Guide to Durable Concrete
- 211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete

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.

⁴ Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, <http://www.aci-int.org>.

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

3. Terminology

3.1 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 *average chord length* ($\bar{l}$), n —the average length of the chords formed by the transection of the voids by the line of traverse; the unit is a length.

3.2.2 *binary image*, n —formed by segmenting an image using only one threshold with the resulting image having only areas of black or white.

3.2.3 *digital image*, n —an image captured using a computer-based storage method where the information presented in the image can be seen visually, like a traditional photographic image, but can also be extracted in a numeric form that can be used for additional analysis.

3.2.4 *paste-air ratio* (p/A), n —the ratio of the volume of hardened cement paste to the volume of the air voids in the concrete.

3.2.5 *paste content* (p), n —the proportion of the total volume of the concrete that is hardened cement paste expressed as percentage by volume.

3.2.5.1 *Discussion*—When this parameter is calculated, it is the sum of the proportional volumes of the cement, the net mixing water (including the liquid portions of any chemical admixtures), and any supplementary cementitious materials present.

3.2.6 *pixel*, n —the smallest definable point of a digital image that has an assigned value representing the brightness of that component in an image.

3.2.6.1 *Discussion*—Typically a pixel will have the same aspect ratio as the overall image and will have an assigned integer value occurring in the range 0-255. Multiple pixels are arranged contiguously in two-dimensional arrays to form a digital image.

3.2.7 *segment*, v —the process of placing image pixels into classes or like-groupings using any number of thresholds.

3.2.8 *spacing factor* ($\bar{L}$), n —a parameter related to the maximum distance in the cement paste from the periphery of an air void, the unit is a length.

3.2.9 *specific surface* (α), n —the surface area of the air voids divided by their volume, expressed in compatible units so that the unit of specific surface is a reciprocal length.

3.2.10 *threshold*, n —a value used to discriminate pixels into more than one class or like grouping.

3.2.11 *void frequency* (n), n —voids per unit length of traverse; the number of air voids intercepted by a traverse line divided by the length of that line; the unit is a reciprocal length.

3.2.11.1 *Discussion*—The value for void frequency (n) cannot be directly determined by the paste-air ratio method as this value refers to the voids per unit measure of traverse in the total concrete (including aggregate).

3.2.12 *water void*, n —a space enclosed by the cement paste that was occupied by water at the time of setting and frequently found under an aggregate particle or reinforcing bar. A water-

void is usually identified by its irregular shape or evidence that a channel or cavity has been created by bleed water trapped in the concrete at the time it hardened.

4. Summary of Test Method

4.1 *Procedure A, Linear-Traverse Method*—This procedure consists of the determination of the volumetric composition of the concrete by summing the distances traversed across a given component along a series of regularly spaced lines in one or more planes intersecting the specimen. The data gathered are the total length traversed (T_t), the length traversed through air voids (T_a), the length traversed through paste (T_p), and the number of air voids intersected by the traverse line (N). These data are used to calculate the air content and various parameters of the air-void system. If only the air content is desired, only T_a and T_t need be determined.

4.2 *Procedure B, Modified Point-Count Method*—This procedure consists of the determination of the volumetric composition of the concrete by observation of the frequency with which areas of a given component coincide with a regular grid system of points at which stops are made to enable the determinations of composition. These points may be in one or more planes intersecting the specimen. The data gathered are the linear distance between stops along the traverse (I), the total number of stops (S_t), the number of stops in air voids (S_a), the number of stops in paste (S_p), and the number of air voids (N) intersected by the line of traverse over which the component data is gathered. From these data the air content and various parameters of the air-void system are calculated. If only the air content is desired, only S_a and S_t need be determined.

4.3 *Procedure C, Contrast Enhanced Method*—This procedure consists of the determination of the volumetric composition of the concrete by summing distances measured in digital images of a prepared concrete surface using a series of regularly spaced lines in one or more digital images obtained from one or more planes intersecting the specimen. The specimen is prepared exactly as described for Procedures A and B with the additional steps of darkening the specimen surface and filling the air voids with a fine particle size white powder. The data gathered are the total length measured (T_t), the length measured through air voids (T_a), and the number of air voids intersected by the measurement lines (N). These data are used to calculate the air content and various parameters of the air-void system, except the paste-air ratio and spacing factor that require determination of the paste content (T_p) as described in 16.1. If only the air content is desired, only T_a and T_t need be determined.

4.4 *Paste-Air Ratio Modification*—In some instances the specimen is not representative of the concrete as a whole, so T_t and S_t lose their significance and cannot be used as a basis for calculations. The most common examples are concrete with large coarse aggregate and specimens from the finished surface region, for both of which the examined specimen consists of a disproportionately large amount of the mortar fraction. In such instances the usual procedure must be changed, and the paste-air ratio modification must be used (see 5.5).