Designation: C 457 – 98

Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete[1]

This standard is issued under the fixed designation C 457; 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 (**1**).[2] Two procedures are described:

1.1.1 *Procedure A,* the linear-traverse method (**2, 3**).

1.1.2 *Procedure B,* the modified point-count method (**3, 4, 5, 6**).

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 SI units are to be regarded as the standard. The values in parentheses are provided for information purposes only.

1.5 *This standard does not purport to address all of the safety concerns 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.* For specific hazard statements see Note 3 and Note 6.

2. Referenced Documents

2.1 *ASTM Standards:*

C 42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete[3]

C 138 Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete[3]

C 173 Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method[3]

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method[3]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[3]

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions[3]

C 856 Practice for Petrographic Examination of Hardened Concrete[3]

D 92 Test Method for Flash and Fire Points by Cleveland Open Cup[4]

2.2 *American Concrete Institute Standards:*

201.2R Guide to Durable Concrete[5]

211.1 Recommended Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *air content (A)*—The proportion of the total volume of the concrete that is air voids; expressed as percentage by volume.

3.1.2 *air void*—A space enclosed by the cement paste and that was filled with air or other gas prior to the setting of the paste.

3.1.2.1 *Discussion*—This term does not refer to voids of submicroscopical dimensions, such as the porosity inherent to the hardened-cement paste. Air voids are usually larger than a few micrometers in diameter. The term includes both entrapped and entrained voids.

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

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

[1] This practice is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.65 on Petrography.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this test method.

[3] *Annual Book of ASTM Standards,* Vol 04.02.

[4] *Annual Book of ASTM Standards,* Vol 05.01.

[5] American Concrete Institute of Concrete Practice, issued annually, available from ACI, 38800 Country Club Drive, Farmington Hills, MI 48331.

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

3.1.5.1 *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 mineral admixtures present **(7, 8)**.

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

3.1.7 *specific surface* (α)—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.

3.1.8 *void frequency* , *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.

3.1.8.1 *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).

3.1.9 *water void*—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 sample. 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 sample. 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 *Paste-Air Ratio Modification*—In some instances the sample 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 samples from the finished surface region, for both of which the examined sample 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 5.7).

5. Significance and Use

5.1 The parameters of the air-void system of hardened concrete determined by the procedures described in this test method are related to the susceptibility of the cement paste portion of the concrete to damage by freezing and thawing. Hence, this test method can be used to develop data to estimate the likelihood of frost damage to concrete or to explain why it has occurred. The test method can also be used as an adjunct to the development of products or procedures intended to enhance the frost resistance of concrete **(1)**.

5.2 Values for parameters of the air-void system can be obtained by either of the procedures described in this test method.

5.3 No provision is made for distinguishing among entrapped air voids, entrained air voids, and water voids. Any such distinction is arbitrary, because the various types of voids intergrade in size, shape, and other characteristics. Reports that do make such a distinction typically define entrapped air voids as being larger than 1 mm in at least one dimension being irregular in shape, or both. The honey-combing that is a consequence of the failure to compact the concrete properly is one type of entrapped air void **(9, 10)**.

5.4 Water voids are cavities that were filled with water at the time of setting of the concrete. They are significant only in mixtures that contained excessive mixing water or in which pronounced bleeding and settlement occurred. They are most common beneath horizontal reinforcing bars, pieces of coarse aggregate and as channelways along their sides. They occur also immediately below surfaces that were compacted by finishing operations before the completion of bleeding.

5.5 For air-entrained concrete designed in accordance with ACI 201.2R and ACI 211.1, the paste-air ratio *(p/A)* is usually in the range 4 to 10, the specific surface (α) is usually in the range 24 to 43 mm^{-1}(600 to 1100 $in.^{-1}$), and the spacing factor ($\bar{L}$) is usually in the range 0.1 to 0.2 mm (0.004 to 0.008 in.).

5.6 The air-void content determined in accordance with this test method usually agrees closely with the value determined on the fresh concrete in accordance with Test Methods C 138, C 173, or C 231 **(11)**. However, significant differences may be observed if the sample of fresh concrete is consolidated to a different degree than the sample later examined microscopically. For concrete with a relatively high air content (usually over 7.5 %), the value determined microscopically may be higher by one or more percentage points than that determined by Test Method C 231.

5.7 Application of the paste-air ratio procedure is necessary when the concrete includes large nominal maximum size aggregate, such as 50 mm (2 in.) or more. Prepared sections of such concrete should include a maximum of the mortar fraction, so as to increase the number of counts on air voids or traverse across them. The ratio of the volume of aggregate to the volume of paste in the original mix must be accurately known or estimated to permit the calculation of the air-void systems parameters from the microscopically determined paste-air ratio.